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RESPONSE TO COMMENTS

for

Draft Order No. R8-2014-0002
NPDES Permit No. CAS618030

Orange County Flood Control District, the County of Orange
And
The Incorporated Cities therein within the Santa Ana Region

Area-wide Urban Storm Water Runoff

December 22, 2014

Response No.	Comment Date	Commenter	Comment Summary	Response
1.1	5/19/2014	Jane Webb, Owner/Inspector for F.A.S.T. Fire Pro	Recommends incorporation of CalFire "Watershed Based Fire Protection System Discharge Best Management Practices Manual" into the 2014 OC MS4 Permit.	If the recommendation is implemented, the scope of the Permit would limit the requirements to discharges caused by the Co-permittees. This would create an uneven regulatory field relative to persons not subject to the Permit. Although Regional Board staff agrees that the recommendation would be beneficial, it would be most appropriate to incorporate into the *De Minimis* Permit (Order No. R8-2009-0003).
2.1	5/18/2014	Association of California Cities	Was it the intention of Regional Board staff to add a requirement in Section III.B.3. that Co-permittees submit reports of waste discharge for De Minimis discharges?	The addition of the requirement to submit a report of waste discharge for *de minimis* discharges was intentional. However, this requirement exceeds the Regional Board's resources to effectively implement. Therefore, the requirement is not included in the revised draft Permit.
2.2	5/18/2014	Association of California Cities	Section XII.A. appears to require Co-permittees to add "specific water quality regulations and mitigation measures" as part of General Plan updates or Specific Plans.	The requirements of Section XII.A. have been removed. See Response 16.32. Section XII.A. required that the Co-permittees adopt measurable and verifiable objectives to implement the goals in Section XII.A.1. that they adopt. The adoption of goals and objectives may require updates to municipal codes and similar governing documents and include the methods suggested by the commenter. However, this was not expressly required in the Draft Permit. The most effective methods to execute adopted goals and objectives may be specific to a Co-permittee. Consequently, the methods had been left to the Co-permittees' discretion.
2.3	5/18/2014	Association of California Cities	Section XII.C. requires WQMPs to be recorded in public records. These documents are lengthy. What would be a reasonable time frame for updating the records.	After further discussion with County staff, the language of Section XII.A. has been amended to replace "recorded in public records" with "maintained in public records". This removes the unintended implication that project WQMPs must be recorded with the County Clerk-Recorder and allows the Co-permittees greater latitude in how project WQMPs will be stored and made available to interested persons. The language of the Permit is intentionally silent on the time frames. Therefore, the discretion has been left to the Co-permittees. Records maintenance is not a new requirement or unique to WQMPs (e.g. CC&Rs). Regional Board staff expects that the Co-permittees already have established policies and procedures. Therefore, there is no need to establish a standard or make a recommendation as requested by the commenter.
2.4	5/18/2014	Association of California Cities	Section XII.D.10. requires Co-permittees to secure the authority to "enter into private property to inspect and maintain the property". Property and privacy rights are implicated. Is the Regional Board requiring individuals to waive these rights if a WQMP is associated with their property?	Persons responsible for implementing WQMPs are not directly regulated and are not being required by the draft Permit to waive rights. These persons are also not expected to waive their rights in the face of the Co-permittees' authorities. More specifically, Provision XII.D.10. requires Co-permittees to secure the authority to enter onto a property to "perform maintenance or take other remedial action on structural treatment control BMPs in the event that the responsible party fails to adequately operate or maintain the facility". Admittedly, the Provision is inappropriately worded and, for other reasons, it will be removed (See Response 16.49). But Regional Board staff believes that this provision could have been met in a similar manner as the Co-permittees' abatement of public nuisances and other matters already regulated under their municipal ordinances, including addressing the recovery of costs.

2.5	5/18/2014	Association of California Cities	What is the rationale for requiring an electronic database to include records for WQMPs back to 2009?	In part, this is a continuation of Provision XII.I.3. in the current (2009) Permit, which already requires a database. Storm water programs are expected to be continuous endeavors under the ongoing NPDES permitting program. Therefore, it is logical that many activities will be continued across iterations of the MS4 Permit in an evolutionary manner consistent with the "iterative process". Provision XII.B.10.b. requires records for WQMPs approved prior to May 22, 2009. This is the date of adoption of the current MS4 Permit. However, WQMPs have been required earlier in Order No. R8-2002-0010. The draft Section improves the existing requirement through the addition of records for these earlier WQMPs to the database opportunistically, as they are discovered through the inspection program. This is intended to make the database more complete and facilitate compliance with existing inspection requirements related to approved WQMPs.
2.6	5/18/2014	Association of California Cities	Does the Regional Board expect each Co-permittee to achieve 10 million public education impressions and other measureable objectives? Or is this the responsibility of the Principal Permittee?	The language of Section XIII of the draft Permit refers to the Co-permittees collectively. However,the Co-permittees included will vary depending on the scale of the "high-priority urban runoff pollution issues" or of the requirement. For example, if the Co-permittees choose an issue at the watershed scale, the collective responsibilities will be shared by those Co-permittees in that watershed. Likewise, if a requirement is at the Permit Area scale, the responsibility is shared by all of the Co-permittees. The draft Permit also explains in Section II, that the Principal Permittee has certain obligations to coordinate, monitor, and report the execution of necessary common activities or activities of mutual interest. The collective assignment of the public education requirements makes them of mutual interest to the Co-permittees and triggers the Principal Permittee's obligations in Section II. This rationale applies elsewhere in the Permit where requirements are a collective responsibility and has been the traditional practice in earlier iterations of the Permit. The apportionment of collective responsibilities is generally left to the discretion of the Co-permittees.
3.1	5/18/2014	Gene Estrada, City of Orange	Is it the Board's intention to expand Section XIV to include inspection and cleaning of closed storm water conveyances such as underground pipes?	This was not Regional Board staff's intent. The revised draft Permit has been amended to clarify this.
3.2	5/18/2014	Amanda Carr, City of Irvine	The language of Section VII.E. suggests that the Executive Officer's approval is needed to carry out day-to-day operations and maintenance of certain trash and debris control BMPs. For example, approval would be needed to remove an inlet device to remedy flooding.	Section VII.E. is not intended to micro-manage the day-to-day operation of the trash and debris control BMP program. Instead, changes at the program level must be approved by the Executive Officer. The revised draft Permit has been amended to clarify this.
4.1	5/18/2014	Building Industry Association of Southern California, Inc.	With respect to the Receiving Waters Limitation and TMDL Sections, is it the Board's intention to "ensure that permittees will not be subject to third-party enforcement if they are diligently implementing an iterative process?"	The purpose of the proposed Receiving Waters Limitation language is to cause the Co-permittees to achieve Water Quality Standards and Waste Load Allocations through compliance with the Permit's requirements, including implementation of the "iterative process".
4.2	5/18/2014	Building Industry Association of Southern California, Inc.	Will the Board provide additional evidence that the application of the 1.5 sizing factor for biotreatment LID BMPs is appropriate for Orange County?	The evidence supporting the 1.5 sizing factor is provided in the draft Technical Report and is the best available information. Regional Board staff is open to considering additional information that may become available prior to the adoption of the Permit. This factor is included at the recommendation of USEPA staff. USEPA staff has reviewed the comments on this matter and provided their remarks in an e-mail to Regional Board staff on October 8, 2014. Those remarks are included in Attachment 1 of these responses.

4.3	5/18/2014	Building Industry Association of Southern California, Inc.	Findings 10 and 16 of the draft Permit appear to contradict the apparent intent to allow certain types of off-site LID BMPs.	The Regional Board supports the use of regional or subregional structural treatment controls within certain limits. Findings 10 and 16 and the provisions in Section XII.K. define these limits; they are not contradictions or anomalies.
4.4	5/18/2014	Building Industry Association of Southern California, Inc.	Section XII appears to change an effective program for the application of LID BMPs. It appears to create "a new structure and selection hierarchy". Please explain the technical underpinnings and the necessity of these changes.	Section XII establishes a more precise terminology to describe the selection hierarchy for structural treatment controls but does not change it. In comparison, the terminology does not differ materially from that used in Section 7.II of the 2011 Model WQMP. The hierarchy in the 2011 Model WQMP identifies "retention" and "biotreatment" as subcategories of "LID BMPs". Section XII of the draft Permit describes these as "retention LID BMPs" and "biotreatment control BMPs" with no difference in the meaning of the terms. Section XII further subdivides retention LID BMPs into "infiltration LID BMPs" and "harvest and use LID BMPs" in a similar manner as WQMP Section 7.II. also with no change to the meaning of the terms. Section 4.7 of the Technical Guidance Document references the term "treatment control BMPs". However, this is an overly-broad term that may include LID BMPs. Therefore, for precision, Section XII.H. uses the terms "all other structural treatment control BMPS", qualified as "non-LID BMPs". Section XII does take a different approach to the location of structural treatment controls BMPs with respect to being either on-site or off-site. Section XII states a default requirement of on-site as opposed to a 'preference' in the current permit. A qualified off-site facility may be used without the need to prove on-site feasibility under circumstances specified in the Draft Permit.
4.5	5/18/2014	Building Industry Association of Southern California, Inc.	The watershed planning requirements have been essentially removed from the Permit.	The draft Permit provides the Co-permittees with increased editorial freedom for planning and has a greater focus on the "iterative process". The draft Permit does not expressly dictate the scale of planning. Rather, the draft Permit allows circumstances to dictate. For example, TMDL-related BMPs and certain public education high-priority issues will logically require planning on the watershed scale. Additionally, a single planning document may operate on multiple scales; dictating a single scale for a plan may be inefficient.
4.6	5/18/2014	Building Industry Association of Southern California, Inc.	Requirements pertaining to hydrologic conditions of concern have changed, particularly those for peak flow matching. Please provide the rationale.	The peak flow rate omission was unintentional and is included in the revised draft Permit. Further technical changes have been made to eliminate unintended changes and align the hydrologic conditions of concern requirements with the Technical Guidance Document. An intentional correction has been made for the 'increased' time of concentration requirement; this had been administratively corrected to address decreased time of concentration in the approved Technical Guidance Document.

5.1	6/18/2014	NAIOP, Commercial Real Estate Development Association	"In light of the extensive resources…poured into essentially completing [Provision XII.B.16], why are we being asked to do this again?"	Provision XII.B.16. requires each Co-permittee to have guidelines that provide for site design and structural treatment controls to be readily inspectable and maintainable, aethetically pleasing where applicable, and generally of a quality that is satisfactory to the Co-permittee. This provision is designed to compel the Co-permittees to adopt their own design criteria that address issues related to the sustainability of their programs, community acceptance of BMPs, public safety, conflicts or harmonization with community goals, and other non-technical design issues that still fall within the scope of "maximum extent practicable". In doing so, the Provision is intended to protect the substantial investment in site design and structural treatment controls. For example, basin-type structural controls may include features that serve multiple community goals for open space, walkable communities, and non-motorized traffic circulation. Consolidating the achievement of all of these goals into that space, according to the required guidelines, may add value which makes that facility a vital part of the community, and may facilitate its long-term operation. The 2011 Model WQMP and Technical Guidance Document focus on the technical aspects of treating storm water runoff. These documents may not adequately address these important non-technical issues. The scope and depth of the required guidelines are not dictated by the Provision. They may vary substantially depending on local experience, community goals and sensitivity, and other matters. The guidelines may begin simply as paraphrasing Provision XII.B.16. itself or they may evolve into greater complexity with local experience. This Provision is intended to supplement the 2011 Model WQMP and Technical Guidance Document; it does not duplicate the effort.
5.2	6/18/2014	NAIOP, Commercial Real Estate Development Association	Please provide data that shows that the 1.5 sizing factor for biotreatment control BMPs is applicable to hydrologic and soil conditions in Orange County.	The Ventura County study cited in the Technical Report provides adequate justification for the use of a sizing factor for biotreatment control BMPs to perform more similarly to retention LID BMPs. The factor of 1.5 comes from a best available source, is recommended by USEPA staff, and is consequently incorporated into the draft Permit. Regional Board staff is open to considering other additional sources of information.
5.3	6/18/2014	NAIOP, Commercial Real Estate Development Association	A portion of the commenter's remarks are similar to the comment in Response 2.4. In addition, the commenter asks: Is the Regional Board planning to place any limitations on the requirement to inspect structural treatment controls? No one reasonably expects that an inspector will be coming into your bathroom, kitchen, or in this case, backyard, if that is where a BMP is located, in perpetuity. It places the Co-permittees in a bad position for several reasons.	Some of the Co-permittees already have, for example, "the right to enter the private establishment…for the purpose of making reasonable inspections of animals and the premises where animals are kept" (City of Anaheim Municipal Code Chapter 8.08.070.025). Section XII.D.10. required Co-permittees to extend their inspection authority to addressing compliance with approved WQMPs. Certainly, it is understandable that a Co-permittee may want to minimize the invasiveness of such inspections. Nonetheless, on further consideration, the requirement appears unnecessary and has been deleted from the revised draft Permit.

5.4	6/18/2014	NAIOP, Commercial Real Estate Development Association	Why does Regional Board staff believe that they have the authority to decide how and when cities should be disciplining its staff pursuant to Provision XII.E.5. This is "highly inappropriate and serves as an example of how this Regional Board staff is straying far from its charge to protect water quality."	Provision XII.E.5. does not exist. Regional Board staff believes that the commenter is referring to Provision XIV.E.5., which states that the field activities and fixed facilities program "include disciplinary procedures or policies for Co-permittees' staff that unnecessarily deviate from standard operating procedures". The Provision does not dictate the content of the standard operating procedures or, as alleged by the commenter, whether, how or when cities discipline their staff when unnecessary deviations occur. However, the commenter raises a valid point on the nexus between plans, policies, and procedures and the actions of Co-permittees' staff; they clearly cannot be successful if Co-permittees' staff do not carry them out. The requirements for written standard operating procedures and supporting disciplinary policies and procedures are designed principally to facilitate internal enforcement. Disciplinary policies and procedures are a widely-accepted best management practice to provide that employees carry out their duties. After further consideration however, the absence of written supporting disciplinary policies and procedures is best regarded as a contributing factor to a related violation and not a violation in of itself. Consequently, the requirements for supporting disciplinary policies and procedures have been removed. However, their absence or failure to employ may lend gravity for enforcement actions where they are found to be a contributing factor to a violation.
6.1	6/19/2014	Orange County Business Council	The Section XII.A. requirement to create and report measurable and verifiable items in their General and Specific Plans, including specific treatment controls and design features is irregular, inappropriate, and unnecessary. Has Regional Board staff reviewed the likely impacts this would cause to Co-permittees from a legal and planning perspective?	See Response 16.32.
6.2	6/19/2014	Orange County Business Council	Why did Regional Board staff eliminate provisions in Section XII allowing the Co-permittees to "create urban runoff funds and water quality credit systems to increase the flexibility of regional treatment programs"?	The referenced Provisions from the current Permit were eliminated in favor of remaining silent. Although the mechanisms identified by the commenter are not discussed, they are not prohibited either. This omission does not signal a lack of support for "regional treatment systems" or the elimination of credit systems, runoff funds, impact fees, area drainage plans, service districts or any other funding mechanisms the Co-permittees may choose to develop this infrastructure. Instead, the omission represents the recognition that "runoff funds" and "water quality credit systems" are vague regulatory constructs and that there are also other long-established, proven funding mechanisms that may be employed at the discretion of the Co-permittees.
6.3	6/19/2014	Orange County Business Council	Why is it not necessary for the Regional Board to perform a more detailed economic analysis?	From a regulatory perspective, the Technical Report provides adequate justification for not performing the requested analysis. The Technical Report also explains that there is insufficient reliable or complete cost or benefit information to perform a meaningful detailed economic analysis.
7.1	6/20/2014	City of Orange	It is nearly impossible to condense the Model WQMP, Technical Guidance Document, and other program plans into a new Permit. "In the course of distilling those documents, certain information is bound to be missed."	It is not Regional Board staffs' intent to condense the Co-permittees' program plans into a Permit. The intent is to identify elements of those plans and synthesize them into the Permit; essentially to summarize the programs in a manner that they can be enforced. In addition, certain requirements were incorporated to address program deficiencies discovered during program audits. The commenter has a valid concern that certain information is bound to be missed. Certain information is intentionally omitted in the interest of providing flexibility. Certain information that may be important to program enforcement may also be unintentionally omitted. If certain omissions are discovered, we hope that the Co-permittees (or other stakeholders) would point them out, even at the risk of creating liability for themselves in the new Permit. Regional Board staff believes that the risk of unintentional omissions is outweighed by the benefits to the permittees and to the regulatory program gained by providing flexibility.

7.2	6/20/2014	City of Orange	Section XII omits the reduction of peak design flow rates to existing flow rates as a means to comply with requirements for hydraulic conditions of concern.	Regional Board staff has revised Section XII.N. in the draft Permit to incorporate peak design flow rate restrictions consistent with the existing Permit.
7.3	6/20/2014	City of Orange	Section XII establishes 48-hours as a static drawdown period for retention LID BMPs. This standard is excessively rigid.	Regional Board staff has revised Provision XII.D.3. in the draft Permit to conform to Section I.2. of the Technical Guidance Document.
7.4	6/20/2014	City of Orange	There are too many other examples of conflicts between the draft Permit and the 2011 Model WQMP and Technical Guidance Document to list.	Section XII of the draft Permit spans 19 pages. The commenter points out that the 2011 Model WQMP and Technical Guidance Document are over 400 pages. Regional Board staff spent over 200 staff hours in reviewing the 2011 Model WQMP and Technical Guidance Document prior to their approval and produced approximately 1,000 comments on the documents. Regional Board staff appreciates the resources that the Co-permittees and the Regional Board placed in the development of these documents. The commenter notes that there are too many other examples of conflicts to list; Regional Board staff presumes that those conflicts have been in fact identified and that this statement is not conjecture. Regional Board staff has met with County staff and the principal authors of the 2011 Model WQMP and Technical Guidance Document to address conflicts that they have identified in a process that took less than 3 hours. The resulting changes are in the revised draft Permit. If the commenter identifies further conflicts, Regional Board staff is committed to resolving those as well.
7.5	6/20/2014	City of Orange	Section XII omits alternative compliance programs such as water quality credits and in lieu fee programs that were previously permitted.	The alternative compliance programs in the current 2009 permit were intended to support LID. LID is defined in the current 2009 Permit as "an approach to land development (or redevelopment) that works with nature to manage storm water as close to its source as possible using structural and nonstructural best management practices to reduce environmental impacts" (footnote 20). USEPA defines LID to also include land use strategies. Therefore, practicing LID may include altering land use patterns and mitigating the hydrologic impacts of land development. Towards these ends, the Regional Board approved a system in the 2011 Model WQMP that provides discounts on the design capture volume for certain land use types that are generally regarded as LID. Development patterns are influenced by the preferences of residents, physical and institutional infrastructure constraints, regional distribution of housing needs, compatibility with other land uses in the vicinity, seismic and geotechnical issues, and many other factors. To be effective, the discounts would have to influence a project proponent to change a non-LID project to a LID project, possibly in conflict with one or more of these factors. Regional Board staff is unaware of any evidence that those discounts have been effective at motivating the Co-permittees or the development community to alter development patterns in Orange County. The Draft Permit does not mention credit systems, *in lieu* fee programs, or other funding mechanisms for regional or sub-regional facilities. Instead, the draft Permit allows the use of regional or sub-regional facilities where they exist or are planned regardless of the planning or funding mechanisms employed. This approach focuses on the *outcome* of the mechanisms, instead of the mechanisms themselves. Based on comments from other stakeholders, the draft Permit has been amended to include a credit system to allow trading of 'excess' design capture volume treatment between projects in the same receiving water body's watershed.

7.6	6/20/2014	City of Orange	The requirement that Co-permittees not accept development applications as complete unless a report of waste discharge for discharges of dredge or fill has been submitted should not interfere with the Co-permittees' land application process. The timing of these applications is very different from the submittal of an initial land development application.	Regional Board staff agrees and Provision XII.A.6. has been removed. See also Response 16.36.
7.7	6/20/2014	City of Orange	The requirement for non-priority project plans captures too many projects and is impracticable and unreasonable. The provision would require projects such as reroofs, patio covers, and others to prepare WQMPs and impose unreasonable costs to hire a licensed professional for their preparation.	Based on the commenter's explanation of the nature of projects that would be affected by Provision XII.M.1., Regional Board staff concurs that the scope of affected projects is overly-inclusive and would yield limited water quality benefits relative to the cost of compliance. Regional Board staff is proposing language that would establish the goal of requiring site design and source control BMPs for non-priority projects where there are opportunities for their application. Because Co-permittees' permitting programs vary significantly in scope, the Co-permittees would be individually tasked to develop methods to identifying these projects by type, permit, or other practical methods and then report their methods. Subsection XII.M. does not require non-priority projects to prepare WQMPs as alleged. It would require non-priority project plans; but these do not require a licensed professional for their preparation under the draft language. As such, the detail required in these plans would be commensurate with the nature and complexity of the project, and is left to the Co-permittees' discretion.
7.8	6/20/2014	City of Orange	The draft Permit requires the Executive Officer to affirmatively approve waivers of structural treatment controls for priority projects. "Unless, there is substantial evidence that waivers are being issued indiscriminately by Co-permittees, the language in the existing permit should remain or require action within 30-days."	The commenter is referring to Provision XII.L.1.d. of the draft Permit. This Provision was included at the urging of USEPA to combat potential abuses of the waiver process. During the term of the current Permit, there have been no notices of waivers provided to the Executive Officer. Regional Board staff concurs with the commenter and has amended the draft Permit to specify that waiver notices be deemed approved if no action is taken by the Executive Officer within 30-days. This approach is more in keeping with the observed risk of abuse.
7.9	6/20/2014	City of Orange	The draft Permit requires a registered engineer or licensed landscape architect prepare and sign non-priority project plans. This makes no sense where other persons would also be qualified.	There is no requirement that non-priority project plans be prepared by such persons. There is a requirement that they be *approved* by a registered civil engineer or licensed landscape architect on behalf of the Co-permittee.
7.10	6/20/2014	City of Orange	Requiring inspections of storm drains is problematic and expensive. Consider replacing "storm water conveyance" with "drainage facilities" and define these as catch basins, storm drain inlets, and open channels.	The commenter is referring to Subsections XIV.B., C., and D. Regional Board staff has no objections to the recommendation and has amended the revised draft Permit to narrow the scope of the inspection program.
8.1	6/20/2014	Orange County Coastkeeper	Section IV.A. creates an illegal "safe harbor" that violates federal anti-backsliding requirements.	The revised draft Permit language has been modified to more closely conform with State Water Resources Control Board Resolution WQ 99-05. It is Regional Board staff's understanding that the State Board is considering revising the language in Resolution WQ 99-05. Given the timing of the anticipated adoption of the new Permit, it is likely that the receiving waters limitations language will undergo further modifications prior to or shortly after its adoption.

8.2	6/20/2014	Orange County Coastkeeper	The inclusion of numeric action levels will lead to improved triggers for implementation of the "iterative process".	Regional Board staff agrees in concept with the commenter. Although not expressly identified as such, the draft Permit includes numeric action levels in Section IV (Receiving Waters Limitations) in the form of water quality standards; and in Section XVII (TMDLs) in the form of waste load allocations. Exceedances of water quality standards and waste load allocations trigger the development or modification of compliance plans. The draft Permit improves upon these two processes in the current Permit by requiring a more robust process for discovering exceedances of water quality standards and waste load allocations as part of requirements for a new Water Quality Monitoring Plan. This process for discovering exceedances recognizes that the Co-permittees' capability to detect exceedances can outpace their ability to implement BMPs and then detect improvements in water quality. The process requires a cycle of monitoring, analysis, and reporting that is more in pace with their capabilities, but must comply with compliance deadlines established in adopted TMDLs. The cycle should provide frequent performance feedback, but not at a frequency that it does not generate new or useful information. Further, the draft Permit includes additional numeric action levels in Section VII. In these instances, exceedances trigger source investigations as part of the illicit discharge/connection detection program. These numeric action levels are established based on objective statistical flow and parameter thresholds (e.g. control charts), along with subjective criteria (e.g. odors), as opposed to storm water benchmark values. As described in more detail in the Technical Report, the objective approach is based on long-standing statistical quality control theories that recognize that the causes of variations can be divided into Special Causes and General Causes. Effective remedies for either group of causes are not likely to be the same. In the case of Section VII, source investigations may not always be effective, particularly for General Causes, but can be used to inform other BMPs such as public education campaigns that may be more effective. It is important to recognize also that numeric action levels fall within the meaning of performance metrics or measures, which as a whole drive the "iterative process" in the draft Permit. Consequently, the Co-permittees may develop performance metrics or measures that may serve as additional action levels designed to improve the effectiveness of their programs.
8.3	6/20/2014	Orange County Coastkeeper	Commenter requests that the following additional attributes be required in the database described in Subsection X.2. of the Draft Permit: "pollutants potentially generated by the site/source"; "whether the site is tributary to 303(d) water body segment and whether the facility generated pollutants for which the water body segment is impaired"; and a "narrative description including SIC codes which best reflects the principal products or services provided by each facility". Commenter asserts that "Requiring more complete information...will allow for a more efficient municipal inspection program".	Regional Board staff agrees in concept that a collection of complete information may promote efficiency. Regional Board staff shares common experiences with the Co-permittees in managing inspection programs. Based on these experiences, the costs of collecting and maintaining complete information must be balanced against the incremental value of each piece of information. In addition, the benefits of a complete set of information may not be fully realized if there are limited resources in other parts of the inspection program process to capitalize on the information. The commenter has not explained how the added information supports the existing program process, including the prioritization process. With these considerations in mind, the commenter's general assertion is not sufficient to justify the requested change. Instead, the Co-permittees have the discretion to include additional attributes for which they have the resources to manage and utilize.

8.4	6/20/2014	Orange County Coastkeeper	Subsection X.3. of the Draft Permit should include "automobile (or other vehicle) parking lots and storage facilities; cement mixing or cutting; equipment repair, maintenance, fueling or cleaning; mobile auto or other vehicle washing; mobile drape, carpet or furniture cleaning; power washing services; and retail or wholesale fueling".	Subsection X.3. is not designed for implementation of an inspection program of mobile businesses in large part due to the inherent difficulty of completing inspections in a methodical way. Because of this, it would not be reasonable to require the Co-permittees to meet specific inspection schedules and expect them to develop reliable methods to perform inspections in a similar manner as fixed businesses. Mobile businesses are instead addressed through the ID/IC and Public Education program elements. 'Automobile storage facilities' and "machinery and equipment repair, maintenance, fueling, or cleaning" are already included in the language of the draft Permit; retail and wholesale fueling are a subset of "machinery and equipment repair, maintenance, fueling or cleaning". "Cement mixing or cutting" are more appropriately included in the construction and industrial inventories and are also effectively included. Parking lots are common features of numerous businesses; their inclusion would undermine the prioritization approach that underlies the categories in the Draft Permit by treating nearly all businesses equally. Therefore, Regional Board staff does not agree that parking lots should be included.
8.5	6/20/2014	Orange County Coastkeeper	Section XIV.A.1. should include public golf courses, public swimming pools, special event venues, and landscape maintenance on municipal property consistent with the San Diego Regional Water Quality Control Board's MS4 permits.	The inventory of "fixed facilities" in Subsection XIV.A. is not limited to those facility types listed. This is indicated by the use of "must include" preceding the list. Landscape maintenance on municipal property is included in the meaning of "field activities" and is addressed in Subsection XIV.E. Public golf courses, swimming pools, and special event venues typically are part of parks. If not, they also fall within the meaning of "fixed facilities". However, for the sake of clarity, golf courses, swimming pools, and special event venues have been expressly added.
8.6	6/20/2014	Orange County Coastkeeper	Section XIV.A.1. should include fuel storage areas, and other facilities at which chemicals or materials have a high potential to be discharged at "high priority" sites for inspection.	The list is already designed to address such facilities.
8.7	6/20/2014	Orange County Coastkeeper	Section XIV.F. of the Draft Permit should specifically include herbicide.	Herbicide is a subcategory of and within the meaning of "pesticide". A footnote has been added for clarity.
8.8	6/20/2014	Orange County Coastkeeper	The Regional Board should stress non-chemical integrated pest management solutions.	Integrated Pest Management ("IPM") already stresses non-chemical solutions; chemical solutions are the method of last resort in the practice of IPM. By emphasizing IPM, the Draft Permit already addresses the commenter's suggestion.
9.1	6/20/2014	Contech Engineered Solutions LLC	Commenter recommends referencing pre-treatment criteria for infiltration LID BMPs established by the Washington State Department of Ecology.	Regional Board staff appreciates the need for pre-treatment for infiltration LID BMPs and addresses this with Provision XII.I.5., which requires structural treatment control BMPs to pretreat. This Provision does not establish performance criteria; the criteria are established in Subsection XII.H. and "must be based on the best available objective evidence". Furthermore, "The evidence must include field performance test data specific to the BMP". Although not specified, the Co-permittees may utilize the Department of Ecology's criteria to comply. However, other similar criteria may also be employed. Without specific evidence of superiority, Regional Board staff does not believe it is appropriate to specify the use of any particular criteria as recommended by the commenter.

9.2	6/20/2014	Contech Engineered Solutions LLC	Commenter recommends "Requiring that high-rate biotreatment systems…be sized per their [Department of] Ecology use level designations."	To clarify, pursuant to the draft Permit, proprietary biotreatment systems would be given "Secondary Consideration" if they "maximize the infiltration of the design capture volume or flow" according to Provision XII.G.6. Some proprietary systems do not allow infiltration and would not comply with this Provision without some additional design features or modifications. In these cases, such systems would be given "Third Priority Consideration" (previously "Tertiary Consideration") as non-LID BMPs because they do not meet the definition of a Biotreatment Control BMP in that they do not permit incidental infiltration. The Draft Permit describes a method for establishing the performance of these non-LID BMPs in Subsection XII.H. The Co-permittees' use of the Department of Ecology use-level designations may be part the method in the Draft Permit. As indicated in Response 9.1, Regional Board staff will not specify it, or any other specific method. The Draft Permit does not require the "highest performing systems". Greater flexibility is appropriately provided because other factors, in addition to expected effluent quality, may influence BMP selection.
9.3	6/20/2014	Contech Engineered Solutions LLC	Commenter recommends allowing the use of harvest and use cisterns in conjunction with infiltration in landscape areas. The irrigation application rate may exceed the agronomic demand.	The Draft Permit does not disallow this approach, but it may involve the use of plants tolerant of saturated soils that conflicts with xeric landscaping guidelines (This conflict may be avoided by using un-vegetated landscaping.). The commenter points out one of several possible approaches that would be allowable under both the current and Draft Permits.
9.4	6/20/2014	Contech Engineered Solutions LLC	Please clarify that rainwater harvesting systems may retain water for longer than 48 hours as adequate volume is recovered.	The language of Provision XII.D.3. has been amended to provide greater flexibility consistent with the Technical Guidance Document.
9.5	6/20/2014	Contech Engineered Solutions LLC	Please clarify that manufactured treatment devices "must be designed and constructed in substantial conformance with published and generally accepted engineering design criteria". Adhering to established performance evaluation programs (e.g. Technology Acceptance Protocol - Ecology) would be a more protective alternative to standard guidance to "refer to manufacturers recommendations".	The requirement for "substantial conformance" as indicated by the commenter appears in Provision XII.D.14. The language applies to all structural treatment control BMPs but is more targeted at non-proprietary facilities. This is intended to apply design standards that allow for a reasonable presumption that the proposed facility will perform in a similar manner as other tested designs. Proprietary structural treatment controls are presumed to be sound facilities because the manufacturer is presumed to be concerned with product liability. But since the design is generally not in the public domain, the performance testing is often unique to the product. Subsection XII.H. is specifically included in the Draft Permit to evaluate performance testing with respect to effluent quality. The Co-permittees may use established performance evaluation programs described by the commenter to comply with these requirements.
9.6	6/20/2014	Contech Engineered Solutions LLC	Please clarify that the rating of "high", "medium" and "low" levels of pollutant removal should be relative to LID BMP performance.	The language of Subsection XII.H.1. does not specify a method for establishing cutoffs between the performance categories other than to state they must be distinguished by fixed numeric thresholds. The commenter's suggested method is one possible approach, but Regional Board staff recognizes that other methods may be equally valid. Consequently, Regional Board staff is not proposing to require any particular approach in the draft Permit.
9.7	6/20/2014	Contech Engineered Solutions LLC	Please require "General Use Level Designation for Basic Treatment" by the Washington State Department of Ecology as a minimum qualification for manufactured BMP use along with consistent sizing for the use level.	Regional Board staff does not believe it is appropriate to specify any particular BMP assessment program for rating the performance of structural treatment controls absent evidence of its relative superiority to other methods. However, Regional Board staff believes that additionally requiring that the performance data be collected according to recognized protocols would be an improvement to the language of the Permit. Subsection XII.H. has been amended accordingly. See also Responses 9.1 and 9.2.

9.8	6/20/2014	Contech Engineered Solutions LLC	At a minimum, pretreatment BMPs discharging to regional or subregional BMPs should have a General Use Level Designation for "Pre-Treatment" from the Washington State Department of Ecology.	Pre-treatment structural treatment controls are subject to the same requirements as other structural treatment controls in the Draft Permit. As noted earlier, Regional Board staff will not include in the draft Permit any particular method for evaluating the performance of structural treatment controls. However, we believe that the language of Subsection XII.H. can be improved as described in Responses 9.1, 9.2, and 9.7.
9.9	6/20/2014	Contech Engineered Solutions LLC	Please require pretreatment BMPs upstream of infiltration BMPs.	Pre-treatment structural treatment controls are already required in the Draft Permit in Provision XII.I.6.
9.10	6/20/2014	Contech Engineered Solutions LLC	Please clarify that retention LID BMPs containing more than the design capture volume do not need to be drawn down within 48 hours.	The language of Provision XII.J.1. has been amended to provide greater flexibility with respect to the drawdown time consistent with the Technical Guidance Document.
9.11	6/20/2014	Contech Engineered Solutions LLC	The reference to Provision XII.J.1.b. in Provision XII.K.2.c.ii. may be incorrect.	The commenter is correct. The correct reference is Provision XII.K.1.b.; the Provision has been amended accordingly.
10.1	6/20/2014	Natural Resources Defense Council	The commenter provides detailed information indicating that 'stormwater runoff is a leading source of water pollution in the Orange County Region' and the legal background of the Permit.	The comment is informational and noted.
10.2	6/20/2014	Natural Resources Defense Council	The approach taken in the Draft Permit creates illegal safe harbor in violation of federal anti-backsliding and antidegradation requirements.	Subsection IV.A. has been amended to be more in conformance with State Water Resources Control Board Resolution WQ 99-05. See Response 8.1.
10.3	6/20/2014	Natural Resources Defense Council	The commenter supports the requirements for on-site retention of at least the 85th percentile storm.	The comment is noted.
10.4	6/20/2014	Natural Resources Defense Council	The commenter is opposed to treatment of the design capture volume of a hydraulically-disconnected off-site area in lieu of treating the runoff volume from the project site.	Regional Board staff generally agrees. Subsections XII.I. and XII. allow the Co-permittees to approve WQMPs where all or a portion of the project design capture volume may be treated off-site at another project location or by retro-fitting an already-developed site. However, either site must be located in the same watershed of the nearest receiving water body. These requirements are intended to ensure that the original project and the off-site location are hydraulically related. They also are intended to promote future development of regional or sub-regional facilities in the watershed by keeping treatment obligations and interests within the same watershed.

10.5	6/20/2014	Natural Resources Defense Council	The Draft Permit must require a determination that it is technically infeasible to retain the design capture volume on site before biotreatment is authorized.	Regional Board staff has determined that the language in the Draft Permit which would allow the consideration of biotreatment control BMPs is inconsistent with the current 2009 Permit. The language has been modified so that retention LID BMPs must be disproven as opposed to proven. Regional Board staff disagrees that BMPs always must be on-site. The use of an off-site facility essentially requires, in part, that it has been a planned and approved facility. In such circumstances, the Co-permittee would have limited capability to additionally require on-site BMPs. In addition, excluding a project that lies within the service area of a regional BMP would be a failure to implement the plan and could compromise its funding. The language of the Draft Permit recognizes the practical aspects of funding the construction and maintenance of off-site facilities.
11.1	5/27/2014	The Irvine Company	The commenter recommends specific technical changes to the language of Subsection XII.N., including the reintroduction of peak flow rates and more precise definitions of the design storm events.	Regional Board staff agrees that the recommended changes are more consistent with the Technical Guidance Document. The recommended changes have been incorporated into the revised draft Permit.
12.1	6/23/2014	Orange County Water District	"Please make clear whether the provisions of Section IV, Receiving Water Limitations, apply to both surface water and groundwater." "The permit needs to contain provisions that are protective of both surface and groundwater quality."	Within the broader context of the Porter-Cologne Water Quality Control Act, the term "receiving waters" applies to both surface and groundwater. The term holds the same meaning in the Draft Permit. However, the scope of the Draft Permit is narrower and is intended to protect surface waters that are waters of the U.S. The Draft Permit does include provisions intended to protect groundwater quality but, because of the narrower scope, the reader should not expect the Draft Permit to represent a comprehensive program to accomplish this.
12.2	6/23/2014	Orange County Water District	The commenter recommends that a pilot study to monitor the impact of infiltration systems on the quality of groundwater be continued in the 5th term permit to ensure that on-site LID infiltration practices within Orange County are protective of groundwater quality.	Provision XII.B.5.g. of the current Permit required that such a pilot study be performed. The commenter states that "One study alone cannot come close to characterizing the impact of on-site LID style groundwater infiltration systems within an area as large and diverse as Orange County". Regional Board staff agrees. Regional Board staff has included language in the revised draft Permit that has been separately provided by the County based on a mutually-agreeable solution.
12.3	6/23/2014	Orange County Water District	The commenter recommends specific language requiring consultation with OCWD for all WQMPs involving the use of infiltration LID BMPs.	Regional Board staff has no objections to the concept and has amended the revised draft Permit accordingly.
12.4	6/23/2014	Orange County Water District	From a water supply perspective, it would be more effective to locate infiltration LID BMPs in areas where they would replenish aquifers more heavily used for water supply. This approach should be allowed whether the facility is located on or off of a project site. The commenter urges the Regional Board to continue to encourage development of regional and sub-regional facilities.	Comment noted. The emphasis of this Permit is the protection of receiving water quality from pollutants in storm water. But Regional Board staff believes that it is important to support facilities that provide multiple water quality benefits, inclusive, but not limited to groundwater replenishment. Harvest and use BMPs also have incidental water supply benefits and are equally deserving of support. The language of the draft Permit makes a greater effort to achieve multiple objectives by allowing greater flexibility to use off-site or on-site facilities.
12.5	6/23/2014	Orange County Water District	OCWD is concerned that small-scale infiltration facilities will not be maintained properly and their performance will suffer over the long term.	Comment noted. The Draft Permit includes new requirements pertaining to the accessibility, inspectability, and maintainability of structural treatment controls to address these concerns.

12.6	6/23/2014	Orange County Water District	"There is an exception from [the 10-foot separation with groundwater] for cases where groundwater does not support or have the potential to support beneficial uses. Please note that the entire Orange County Groundwater Basin supports or has the potential to support beneficial uses, therefore, this exception language is unnecessary."	The boundaries of the Orange County Groundwater Basin do not match those of the Permit Area. While the commenter's assertion is generally correct, it does not apply to areas outside of the OCWD's Basin boundaries. For example, the exception may also be appropriate for coastal cities whose MS4s discharge to and infiltrate at the beaches where the underlying groundwater is shallow and brackish. It is appropriate that the exception remain.
12.7	6/23/2014	Orange County Water District	The commenter provides specific recommendations for language changes in support of their comments.	Regional Board staff has considered the recommended changes and made revisions to the draft Permit where appropriate. In some cases, the recommended changes were rejected because they over-emphasize the protection of groundwater in a permit intended to protect surface waters. In other cases, the recommended changes were rejected because they reference actions that are 'protective of groundwater quality' in an overly-ambiguous way. In other instances, the recommendation inappropriately suggests the application of numeric ground water quality objectives in a permit intended to protect surface waters.
13.1	6/20/2014	U.S. Environmental Protection Agency, Region 9	Basing TMDL compliance on plans limits enforceability and makes it difficult to confirm that the TMDL water quality targets are being maintained.	Regional Board staff does not agree with this general statement. Regional Board staff recognizes that “plans” may contain ambiguity that can be capitalized on to postpone or avoid compliance. However, the associated problems may be avoided by establishing clear guidelines on the acceptable content of plans and by including specific and enforceable due dates. These are effective methods to provide that TMDL requirements are met and have been included in the draft Permit.
13.2	6/20/2014	U.S. Environmental Protection Agency, Region 9	It's important that the draft permit include a "more rigorous analysis", including how specifically-identified BMPs will result in the achievement of waste load allocations.	Provision XVIII.C.2.e. requires "an objective analysis which provides a reasonable assurance that the new or modified BMPs can be expected to cause discharges to comply with the applicable WLA(s)". This language satisfies the commenter's request for defined relationship between BMPs and the achievement of waste load allocations. The analysis is subject to public review and approval according to Provisions XVIII.C.3. and XVIII.C.4.; these provisions are intended to control the quality of the analysis and provide sufficient demonstration of the efficacy of the proposed actions.
13.3	6/20/2014	U.S. Environmental Protection Agency, Region 9	It's important that the draft permit include interim milestones to track progress towards achieving WLAs.	Milestones are a type of performance measure and can take various forms. Performance measures are required in Section I.A.2. Provision XVIII.C.2.d. requires a schedule for the implementation of BMP. This schedule will include a type of milestone. Provision XVIII.C.2.f. requires "a monitoring program and periodic review to characterize the affective discharge(s) and to objectively assess the effectiveness of BMPs employed to address the exceedance(s)." Achieving a decreasing pollutant trend may also be a valid and necessary interim milestone to satisfy this requirement; particularly if the rate of change in pollutant loading cannot be reasonably predicted to establish a fixed value as an interim milestone. Regional Board staff does not believe that it is appropriate to specify interim pollutant concentrations or loads as milestones outside of the TMDL process. This may effectively make them enforceable as numeric effluent limits even though their development may lack scientific rigor.
13.4	6/20/2014	U.S. Environmental Protection Agency, Region 9	"Contrary to the draft permit, [a planning-based compliance approach] should only be available upon approval of the plans following opportunity for public comment by the Executive Officer."	Provision XVIII.C.4. states "The Executive Officer will provide a 30-day public review period prior to approving the draft plan." Provision XVIII.C.3. states, in part, "The draft plan is subject to review and approval by the Executive Officer." The review and approval process sought by the commenter is in the Draft Permit.

13.5	6/20/2014	U.S. Environmental Protection Agency, Region 9	The permit language "must be modified in several places to accurately describe that Permittee's [*sic*] discharges must comply with water quality-based effluent limits (WQBELs)."	The terms "water quality-based effluent limit" and "WQBEL" were purposefully omitted from the provisions of the draft Permit because they are technical regulatory jargon and are not necessary for the intended audience to understand the Permit requirements. The terms were omitted in the draft Permit in keeping with the State's "plain language" requirement but used in the Technical Report. However, at the urging of the commenter, Regional Board staff has amended the draft Permit to sparingly increase the use of the term.
13.6	6/20/2014	U.S. Environmental Protection Agency, Region 9	The commenter recommends that "the permit either include the monitoring frequency [needed to determine WLA compliance determinations]…or direct the Permittee to a specific document where it could be found."	Regional Board staff has amended the Monitoring and Reporting Program to direct the reader to Chapter 5 of the Basin Plan.
13.7	6/20/2014	U.S. Environmental Protection Agency, Region 9	The permit should be revised "to include action levels as part of the permits [sic] monitoring and reporting program and, if appropriate, the Permittees' water quality improvement plans."	"Action levels" are effectively required in Provision VII.D.6. as part of the ID/IC program. These "action levels" are subjective or objective and their exceedance triggers "source investigations". Generally, objective action levels should be established so that the signal triggers an effective response. To achieve this, objective "action levels" are purposefully set at several standard deviations from a regularly-adjusted mean parameter concentration because of the low signal-to-noise ratio, or high variance, in the collected monitoring data. Essentially, the high variance may cause the data to produce relatively few useful signals that can be resolved using source investigations. “Action levels” also fall within the meaning of performance metrics; these are required for all BMPs or groups of BMPs. Performance metrics may also take the form of "interim milestones" in compliance plans. WLAs are also performance metrics.
13.8	6/20/2014	U.S. Environmental Protection Agency, Region 9	Provision XVIII.B.4. of the Draft Permit would allow exceedances of a WLA at a frequency that is less than or equal to a site-specific exceedance frequency found in the "Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List". The Policy's frequencies do not affect the applicability of WLAs and do not justify the proposed exceedances. Absent justification, the commenter recommends this Provision be removed.	Section XVIII has been re-written and no longer includes the method described by the commenter.
13.9	6/20/2014	U.S. Environmental Protection Agency, Region 9	The commenter recommends including a provision that would require the development and submittal of a plan to comply with a TMDL which may be approved during the term of the Permit.	Section XXII has been amended to address the commenter’s recommendation.
13.10	6/20/2014	U.S. Environmental Protection Agency, Region 9	The commenter requests specific modifications of the second paragraph in Appendix G.	Regional Board staff has deleted erroneous references to State approvals of the Toxic Pollutants TMDL.

13.11	6/20/2014	U.S. Environmental Protection Agency, Region 9	Subsection XII.A.7. falls short of the retrofit provisions in the San Diego Regional Board's Regional MS4 Permit. This MS4 Permit requires each Co-permittee to identify candidate areas for retrofitting existing development. The San Diego Permit also requires a strategy to "facilitate implementation of projects identified as potential candidates for retrofits".	Provision XIV.10. of the current 2009 Permit required a similar analysis on publicly-owned property. In practice, the strategy has been the use of local and grant funding for public improvements to improve water quality; Regional Board staff and USEPA staff have been participants in the implementation of this strategy. The strategy for private property is already established in Section XII of both the current and Draft Permits: to install site design, source control, and in certain cases, structural treatment control BMPs as part of redevelopment. The Draft Permit furthers Provision XIV.10 of the current Permit with its Provision XII.A.7. by expanding the scope of publicly-owned property to be analyzed and requiring an update of the previous analysis. The retrofit analysis is being continued in the Draft Permit. After further discussions, Section XII.I. has been amended to allow off-site retrofits on private property subject to certain restrictions.
13.12	6/20/2014	U.S. Environmental Protection Agency, Region 9	"It is necessary that water quality protections are in place at the site of the triggering development/redevelopment project" even when an off-site structural treatment control is used. Provision VI.D.7.c.iii(7) of the Los Angeles County MS4 Permit is recommended.	Provision XII.C.1. requires that priority projects use source control and site design BMPs on-site regardless of the location of structural treatment control BMPs. Where structural treatment control BMPs are offsite, this Provision is reinforced by Provisions XII.K.2.a.iv., K.2.b.i. and ii., K.2.c.i., and K.2.d.i. and ii. Regional Board staff believes that these Provisions are comparable to the Los Angeles County MS4 Permit provision.
13.13	6/20/2014	U.S. Environmental Protection Agency, Region 9	It is not clear whether regional or sub-regional biotreatment facilities would be required to treat 1.5 times the design capture volume as would be required if the facility were on-site.	This will depend on the requirements in effect at the time of the design and approval of the off-site facility. If design and approval generally occurs during the term of this Permit, then the 1.5 factor for the design capture volume is applicable.
13.14	6/20/2014	U.S. Environmental Protection Agency, Region 9	The draft permit does not require "off-site mitigation when on-site LID is determined to be infeasible and regional or sub-regional facilities are not being used."	Before the situation described by the commenter occurs, the project would also have to give third priority consideration to non-LID BMPs according to Subsection XII.H. Non-LID BMPs are generally proprietary devices of which only those providing "high" or "medium" performance would be permissible to employ. In the event that this step fails to produce acceptable structural treatment controls, a waiver would be required according to Subsection XII.L. Regional Board staff is unaware of a single instance where a waiver notice has been provided to the Executive Officer during the term of the current Permit. We believe that this is evidence of the comprehensive approach of the selection process. Although a process similar to the commenter's recommendation had been envisioned in the current Permit, no practical system has emerged or has been approved. Nonetheless, at the urging of the commenter and others, Regional Board staff has formulated a requirement as part of the conditions of granting a waiver in Subsection XII.L. A waiver would not be necessary for those portions of projects that will employ structural treatment controls over the vast majority of the site but inevitably miss some extreme areas, such as public sidewalks and driveway approaches; Regional Board staff regards such untreated volumes to be minimal.
13.15	6/20/2014	U.S. Environmental Protection Agency, Region 9	The commenter prefers the same receiving waters limitations language as found in the current Permit. There is one alternative in the draft version of the San Diego Regional Board's Regional MS4 Permit that they could support. The alternative uses detailed "Water Quality Improvement Plans to demonstrate measureable progress to achieving [receiving waters limitations]". "The Los Angeles MS4 permit also lays out a thorough, rigorous planning process". However they opposed this approach because compliance would be achieved before the plans were approved.	Regional Board staff has modified the receiving waters limitations language to be more consistent with State Water Resources Control Board Resolution WQ 99-05. In addition, Regional Board staff has included language addressing the point in the planning process where compliance is achieved only after the plan is approved by the Executive Officer after public consideration and is being fully implemented. See Response 8.1.

13.16	6/20/2014	U.S. Environmental Protection Agency, Region 9	The "plan-based compliance approach" to achieving receiving water limitations in the draft permit is deficient because it lacks measureable interim milestones and modeling to support assurances that BMPs will achieve compliance.	Regional Board staff has modified the language to require an objective analysis that provides a reasonable assurance that the proposed BMPs will address exceedances of water quality standards. Although not specifically identified, Subsection IV.D.3. does require milestones. Provision IV.D.3.d. requires, in part, a schedule for the implementation of proposed BMPs. This schedule constitutes milestones for planning actions. In addition, Provision IV.D.3.e. requires a monitoring program and periodic review to characterize exceedances and to objectively assess the effectiveness of BMPs. This monitoring and review requirement establishes a process to track the effort. The tracking process is based, in part, on measurements of water quality rather than the completion of tasks and is a more direct measure of progress. See also Response 13.2.
13.17	6/20/2014	U.S. Environmental Protection Agency, Region 9	Subsection II.F.3. of the Monitoring and Reporting Program requires the performance of toxicity tests using dilutions. The rationale behind these dilutions should be explained in the Technical Report.	The dilutions were carried over from the existing monitoring program as part of Regional Board staff's effort to incorporate the program into the Permit (as opposed to incorporation by reference) and to provide continuity in the program across iterations of the Permit. The dilutions are performed in order to estimate the magnitude of toxicity if it is detected. Along with water chemistry from testing of other parameters, the dilution may also help determine the cause of toxicity. With the introduction of the Test for Significant Toxicity, the dilutions have been removed from the revised draft Permit.
13.18	6/20/2014	U.S. Environmental Protection Agency, Region 9	The commenter recommends that the list of organophosphate pesticides tested for in urban runoff be expanded to include pyrethroids and neonicotinoides.	The Co-permittees are already testing for organophosphate pesticides. Regional Board staff agrees that pyrethroids and fibronils monitoring should continue to be part of the monitoring program since they have been detected. As pointed out by the commenter in separate communications, neonicotinoids are the first new class of insecticides to be developed in the last 50 years and that the neonicotinoid, imidacloprid, is currently the most widely used insecticide in the world. The Monitoring and Reporting Program has therefore been amended to include neonicotinoids.
13.19	6/20/2014	U.S. Environmental Protection Agency, Region 9	The commenter request that the language of the Permit clarify that representative sampling locations must be selected to allow compliance determinations with applicable waste load allocations.	Subsection II.B.2. of the Monitoring and Reporting Program requires a process for determining compliance with each of the waste load allocations and requirements in Appendices B through H. The process must include cycles of monitoring, analysis, and reporting. For some of the TMDLs, parts of the process, including sampling locations, have already been prescribed in the Basin Plan. In addition, Provision II.D. requires that outfall monitoring be representative. Provision II.C.1. requires that the sampling method and practice must minimize bias, of which non-representative sampling is a form of.
13.20	6/20/2014	U.S. Environmental Protection Agency, Region 9	The Regional Board should ensure that the County clearly understands its responsibility to compare sample results against criteria in the California Toxics Rule.	In Footnote 1, the "Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California" states, in part, "This Policy does not apply to regulation of storm water discharges." Footnote 1 goes on to indicate specific resolutions and waste discharge requirements that address storm water discharges. State Board Resolution WQ 99-05 is among those indicated in Footnote 1; the Resolution establishes that the exceedance of water quality standards drive the "iterative process". Therefore, Footnote 1 does not prohibit the use of water quality standards in the California Toxics Rule from being used to drive the "iterative process". In support of this, Subsection II.C.1. of the Monitoring and Reporting Program requires that the Co-permittees "Determine if discharges of urban runoff exceed water quality standards". Those standards include the criteria in the California Toxics Rule.

13.21	6/20/2014	U.S. Environmental Protection Agency, Region 9	Provision II.I.1.c. of the Monitoring and Reporting Program does not allow samples to be collected on days where rainfall has occurred. The basis for this condition should be explained in the Fact Sheet.	The language in Section II of the Monitoring and Reporting Program is based largely on Exhibit 11.II, Santa Ana Region Water Quality Monitoring Program, in the DAMP. Regional Board staff was unable to locate the origin of Provision II.I.1.c. The Provision has been removed from the revised draft Permit.
13.22	6/20/2014	U.S. Environmental Protection Agency, Region 9	The commenter recommends that the public be provided with the opportunity to comment on the initial submittal of the Water Quality Monitoring Plan. The public is provided the opportunity for subsequent changes.	The Monitoring and Reporting Program has been amended to allow public review.
14.1	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City of Lake Forest supports the County's comment letter and joins in its submission.	Comment noted.
14.2	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City request that the Draft Permit be revised to remove requirements that force the City to address issues that are outside of its physical and legal jurisdiction.	See Response 14.4 below.
14.3	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	"The voluntary watershed approach of Water Code Section 16100 *et seq*. allows permittees to *elect* to pursue a watershed approach and *offers* the permittee a compliance option as an incentive to move from a jurisdictional approach to a watershed approach. Porter-Cologne does not <u>require</u> a Co-permittee to expend resources to address discharges beyond its jurisdiction."	California Water Code Section 16100 was adopted as part of the California Watershed Improvement Act of 2009 and is not part of the Porter-Cologne Water Quality Control Act found in CWC Section 13000 *et seq*. See Response 14.4 below.
14.4	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	State and Federal law do not permit the Draft Permit's creation of joint and severable liability. For example waste load allocations have been assigned to collections of Co-permittees. The City "would be unable to establish compliance with its WLAs unless it is complying with its own WLAs and it can show that all other dischargers are also in full compliance...If only one Co-permittee fails to implement BMPs to achieve WLAs, all Co-permittees may be held liable for a resulting water quality exceedance".	Regional Board staff does not agree with the commenter. All persons who discharge any pollutant to waters of the U.S. must obtain an NPDES permit. (See 40 CFR 122.21) In this case, 28 entities are subject to the NPDES permit and discharge to a common conveyance system and receiving waters. The Permit implements the requirements of the Clean Water Act, which require the dischargers to meet water quality standards to the "maximum extent practicable"; to comply with "such other provisions as the Administrator or the State determines appropriate for the control of such discharges; and to effectively prohibit unpermitted discharges of non-storm water to the MS4, with certain conditional exemptions. Co-permittees are responsible for complying with the permit (See 40CFR 122.41(a) ["Any permit noncompliance constitutes a violation of the Clean Water Act and is grounds for enforcement action."]) The permit covers a large geographic area. Co-permittees that discharge to a common outfall where the discharges comingle in the receiving water may be responsible for violations of the receiving water limitations. Once the Regional Board determines that there is a violation of the receiving water limitations, or other conditions of the permit based on monitoring reports and/or other information, it is up to the co-permittees to demonstrate that they are not responsible for the specific violation. The permit sets forth methods for a discharger to demonstrate that they are not responsible. This is consistent with the Clean Water Act, which imposes strict liability and requires discharger so establish and maintain records, samples and monitor discharges, and report the results to the Water Boards. (See *e.q.*, 33 USC 1318(a): 40 CFR 122.41(i); 122.48; and 123.5.) This system of self-reporting is critical to the NPDES program which "fundamentally relies" upon it (see *U.S. v. Brittain* (10th Cir. 1991) 931 F.2d1413, 1416.) In addition, the federal

				regulations contemplate that co-permittees will be responsible for developing management programs and controls involving inter-governmental coordination to reduce the discharge of pollutants (40 CFR 122.26(d)92)(vii)); and must have legal authority and agreement with other dischargers to control contributions of pollutants from portion of the MS4 to another (40 CFR 122.26(d)(2)(iv)(B)(3) [application for permit must show how permittees will investigate any part of their system with a reasonable potential for contributing pollutants into the system from other sources].). The Clean Water Act and applicable regulations set up a system that is consistent with the application of joint and several liability in nuisance actions. It is initially up to the harmed party to provide proof of the harm. Where a party asserts that they are not responsible for the harm, or it can be apportioned, the party must provide proof of the apportionment of the harm. (See e.g. Restatement (Second) of Torts § 433B. 433A.) In addition, the Restatement states that damages for harm are to be apportioned among two or more causes where there are distinct harms or there is a reasonable basis for determining the contribution of each cause to a single harm. (See e.g. Restatement (Second) of Torts § 433A.) Regional Board staff agrees, however, that Co-permittees need only comply with permit conditions relating to discharges from the MS4 for which they are operators. So, for example, one Co-permittee is not required to implement or correct best management practices employed by another Co-permittee. (See 40 CFR 122.26(a)(3)(vi).)

14.5	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City seeks clarification incorporated into the Draft Permit that the Regional Board does not intend to hold the City liable or responsible for permit conditions that do not relate to a discharge for which it is operator.	See Response 14.4. No further clarification will be provided.
14.6	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	There is no reason that the New Development and Significant Redevelopment requirements should be changed and no evidence has been provided to justify the changes. The City requests that the existing program continue.	As described in the Technical Report, the re-write of the subject section, Section XII, was based on the 2011 Model WQMP and Technical Guidance Document. Significant changes were made to better accommodate the development and use of off-site structural treatment controls. Additionally, some minor changes were made, such as the application of record-protection practices for WQMPs; but no wholesale process changes were intended. Regional Board staff has worked with the Principal Permittee to identify and correct unintended changes.
14.7	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City objects to the New Development and Significant Redevelopment requirements on the grounds that they improperly regulate the discharge of storm water as a surrogate for the regulation of pollutants. They should be removed or be modified to incorporate existing requirements.	Finding 2 states, in part, "This Order regulates the discharge of pollutants from anthropogenic sources in urban runoff from MS4s". With the exception of imposing numeric effluent limits, Regional Board staff is unable to see another way to separate the pollutants from the storm water except to impose requirements to remove pollutants using methods that achieve the maximum extent practicable standard. Those methods involve treating volumes of storm water that have been correlated to the removal of pollutants in objective studies (the use of untested structural treatment controls is effectively disallowed by the Draft Permit). The design capture volume is not a simple surrogate. The Draft Permit requires preferential consideration of structural treatment controls for the design capture volume that reduces runoff but does not mandate specific controls to the exclusion of alternatives. The design capture volume may be discharged after retention LID BMPs are determined to be infeasible.
14.8	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The Draft Permit regulates storm water as a surrogate for pollutants. Storm water on a priority project site does not qualify as "urban runoff" because it has not entered a storm water conveyance system; it is also not a "pollutant" under the Clean Water Act or a "waste" under Porter-Cologne. The intent of Section XII of the Draft Permit appears to be the regulation of storm water runoff and authorized non-storm water discharges from priority project sites as a surrogate for the regulation of pollutants.	Storm water retained on a site is not urban runoff, a waste, or a pollutant as noted by the commenter. The design capture volume prescribed by the Draft Permit has been correlated to the removal of pollutants and is part of "controls to reduce the discharge of pollutants to the maximum extent practicable" according to Clean Water Act Section 102(p)(3)(B)(iii); it is not a simple surrogate. Such controls are to support the design of structural treatment controls to reduce the discharge of pollutants from the MS4 that "receive discharges from areas of new development and significant development", including post-construction discharges in accordance with 40 CFR 122.26(d)(2)(iv)(A)(2). Furthermore, the concept of regulating storm water as a surrogate for the pollutants contained in the storm water makes little sense, either legally or practically. Storm water itself, aside from whatever pollutants it may contain, can have adverse water quality impacts on receiving waters through hydro-modification. In addition, the Clean Water Act and its implementing regulations clearly require that NPDES permits regulate the discharge of storm water.
14.9	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	Regulation of storm water alone rather than pollutants or waste in storm water exceeds the Regional Board's authority. The commenter describes a TMDL for Accotink Creek in Virginia where USEPA regulated flow as a surrogate for sediment; this approach was rejected by the Court.	Commenter's citation to *Virginia Department of Transportation v. EPA* (E.D. Va. Jan. 3, 2013) is unavailing. That case involved the adequacy of a TMDL which expressly used storm water as a surrogate for the pollutant of concern, sediment. This Permit is a storm water permit itself, which is designed to regulate and control the impacts of storm water to receiving waters. These are not the same thing.

14.10	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	Storm water itself is not a Waste, though it may contain Waste. The Clean Water Act only authorizes the regulation of pollutants. Porter-Cologne only authorizes the regulation of Waste. By mandating the elimination of pollutants through the control of storm water and authorized non-storm water, the Draft Permit treats storm water as a surrogate for all, unspecified pollutants in the same way that USEPA treated storm water as a surrogate for sediment. The Regional Board therefore has no authority to regulate discharges without specifically identifying a particular pollutant of concern.	See Responses 14.8 and 14.9 above. Storm water that is a waste becomes a pollutant when it alters the quality of the waters of the state to a degree which unreasonably affects beneficial uses, such as through hydro-modification. Provision XII.N.3. of the Draft Permit requires the control of storm water runoff where it has the potential to adversely affect sensitive stream habitat. Under these circumstances, it is within the Regional Board's authority for storm water to be regulated (See CWA § 402(p).).
14.11	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City request changes to the Draft Permit to provide clarity that the intent of Section XII is to control pollutants directly caused by a project. Forcing the City to require mitigation in excess of a project's impacts exposes the City to potential liability for takings claims.	The Co-permittees may require mitigation from projects for their cumulative and indirect impacts; not just the direct impacts. In addition, the requirements of Section XII on a project would not violate limitations on mitigation under CEQA because the requirements would not be imposed as the result of a CEQA analysis. The Clean Water Act's implementing regulations mandate that certain requirements be included in MS4 permits in order to achieve the Act's requirements. The state is required to select controls necessary to meet the requirements of the Clean Water Act and its implementing regulations. (See *NRDC v. USEPA* (9th Cir. 1992) 996 F .2d 1292, 1308; *City of Rancho Cucamonga v. Regional Water Quality Control Bd., Santa Ana Region* (2006) 135 Cal. App. 4th 1377, 1389-90.). Federal NPDES regulation 40 CFR 22.26(d)(2)(iv)(A)(2) requires permit applicants to develop and implement a program to include "A description of planning procedures including a comprehensive master plan to develop, implement and enforce controls to reduce the discharge of pollutants from municipal separate storm sewers which received discharges from areas of new development and significant redevelopment. Such plans shall address controls to reduce pollutants in discharges from municipal separate storm sewers after construction is completed."
14.12	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The Draft Permit's hydro-modification and LID requirements exceed the scope of the City's and the Regional Board's authority under State and Federal law. For example, in areas where redevelopment results in the addition or replacement of more than 50% of the impervious surfaces of an existing development site, Section XII will generally require a project to retain all storm water runoff on site, or mitigate off-site even where the runoff is not caused or increased by the redevelopment. California law prohibits exaction on a project in excess of a project's impact.	The commenter's reliance on *Nollan/Dolan* is misplaced. The authority to issue this Permit derives from the federal Clean Water Act. Accordingly, the takings challenge implied by the reliance on *Nollan/Dolan* misses the mark because the hydro-modification and LID requirements are not impact or *in lieu* fees that the Regional Board is somehow exacting as a condition for development of the property. Rather, these requirements are designed to mitigate the environmental impacts of operating an under-sized structural treatment control. Accordingly, the appropriate standard is not the *Nollan/Dolan* test, but rather whether these provisions, and the permit as a whole, meet the federal standard set forth in the Clean Water section 402(p) and its implementing regulations. Reliance on the State of California's Mitigation Fee Act is similarly misguided.
14.13	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The Draft Permit's requirements for source and site design control BMPs for non-priority projects would apply to projects that do not create any additional runoff or change the type of pollutants, such as roof-top solar panel installations. This may cause the City to impose mitigation and/or exactions for impacts that are not a result of the project itself.	Regional Board staff has modified the language of Provision XII.M.1. to narrow the scope of non-priority project plans.

14.14	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	There is no evidence in the record demonstrating that implementing LID requirements in every priority and non-priority project improves water quality. There is no evidence in the record demonstrating that a change to the existing program is necessary or would benefit the environment.	Regional Board staff has modified the Draft Permit to include additional evidence. The commenter alleges that changes have been made to the existing program but does not provide specifics. Wholesale changes to Section XII were not intended but certain changes where. Specifically, changes were made to the consideration of off-site facilities and certain changes intended to improve the program were also made (i.e. the record protection requirement). To the extent that unintended changes were made, Regional Board staff will correct them where they are identified.
14.15	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City requests that the Receiving Waters Limitations language in Section IV be removed because they impose a substantial burden and they are not required by federal law. Additionally, the language is inconsistent with the State Water Resources Control Board's Water Quality Order 2001-15.	Under the Clean Water Act, an NPDES permit must implement applicable water quality control plans which include water quality standards. The receiving waters limitations language in Section IV is necessary to be consistent with this requirement. Regional Board staff has modified the receiving waters limitations language to be more consistent with State Board Order No. WQ 99-05 (and thereby State Board Order 2001-15). See Response 8.1.
14.16	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City requests that the Draft Permit's TMDL requirements be revised to clarify that compliance is to be attained through the implementation of BMPs and that the waste load allocations do not constitute numeric effluent limits. If there are numeric effluent limits, the Regional Board must find that there is reasonable potential that the discharge of the pollutant may cause or contribute to an excursion above a narrative or numeric criteria within a water quality standard. The Clean Water Act does not require TMDLs to be incorporated into the Draft Permit.	As stated in Provision XVIII.B. the waste load allocations in Appendices B through H must be achieved by the compliance date specified. If no compliance date is specified, then compliance must be on the effective date of the Order unless the responsible Co-permittees initiate the development of plans to comply or a time schedule order is adopted. If there is no compliance date specified and the Co-permittees do not develop the plans, then a waste load allocation will become a numeric effluent limit. Plan development is voluntary; however, Regional Board staff expects that the Co-permittees are motivated to develop and implement WQBEL compliance plans in order to avoid the application of numeric effluent limits. As noted in other Responses, federal regulations clearly require the inclusion of effluent limits in an NPDES permit that are consistent with the assumptions of any waste load allocation. This is not conditioned on the performance of a reasonable potential analysis. Moreover, requiring a reasonable potential analysis prior to incorporating waste load allocations is duplicative within the context of the Clean Water Act's regulatory scheme regarding TMDLs. A TMDL is only performed when a water body is impaired; waste load allocations are set at a level necessary to bring the water body into compliance with the applicable standard. As a practical matter, an analysis has already been conducted as part of the TMDL process itself, to determine that effluent limits implanting the waste load allocation are necessary to meet applicable standards and to protect beneficial uses.
14.17	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	Where a TMDL provides for the development and implementation of a compliance plan, the Draft Permit should provide a provision accordingly. Implementation of BMPs and other requirements consistent with compliance plans should be sufficient for permit compliance.	To incorporate the TMDLs, Provision XVIII.B. provides that the Co-permittees may develop a compliance plan consistent with adopted TMDLs as suggested by the commenter. The Co-permittees execution of an approved compliance plan pursuant to the Permit's requirements serves as an alternative to immediate compliance with waste load allocations.

14.18	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City requests that Provision XII.B.1. be modified to more appropriately designate the dates after which project applicants and Co-permittee projects must comply with Section XII. The requested dates are those received 12 months after the adoption of the Order and Co-permittee projects approved after 12 months after the adoption of the Order.	Regional Board staff agrees that the language of Provision XII.B.1. could be improved but disagrees that the requirements of Section XII should be postponed for almost 12 months as requested. Considering that the Draft Order does not change the BMP selection criteria that is identified in the current 2009 Permit; or, with the exception of the 1.5 sizing factor for biotreatment control BMP, makes no changes to the sizing or the design criteria; and the need for the Co-permittees to develop criteria for non-priority projects to develop non-priority project plans, Regional Board staff believes that 90-days postponement (from a practical standpoint,140 days including the 50-day period between Permit adoption and it's effective date) is sufficient.
14.19	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	Section VII.F. is unnecessarily duplicative of alternative permit requirements and should be deleted. The City is not the operator of a sanitary sewer system and is not subject to State Board Order No. 2006-0003-DWQ; another entity has this responsibility. "Requiring the City to establish and meet 'SSO response time targets, training targets, and spill recovery targest' over which it has no control exceeds the Regional Board's authority...The City should not be required to enter into an agreement with that entity to assume a portion of that entity's legal responsibilities." SSOs from private facilities are already addressed under Subsections VII.A, B, C, and D; Subsection F is duplicative and the additional obligations are not supported by evidence showing that they will improve water quality.	Section VII.F. is modeled after the County's SSO program described in the 2003 DAMP. This program was incorporated by reference as a permit requirement in the current 2009 Permit. With the exception of the performance metrics, the requirements are not new. The performance metrics are prescribed but numeric targets are not established in the Draft Permit; they are to be established by the Co-permittees. Consequently, the City is not required to meet the performance metrics as alleged. The City is not required to enter into an agreement to assume the responsibilities of the entity subject to State Board Order No. 2006-0003-DWQ. The agreement should complement the entity's capabilities; the exact nature of this agreement is not prescribed but will be driven by the iterative process. The agreement may be a mutual aid and assistance agreement where, for example, the City will agree to provide public education assistance, train certain staff to detect SSOs and, if capabilities exist, to assist in the response.
14.20	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The Regional Board has failed to comply with California Water Code Sections 13000, 13263, and 13241.	California Water Code Section 13000 is the Legislative findings. It includes a description of the factors considered by the Legislature to administer efforts to protect water quality on a regional basis; it places no particular compliance obligations on the Regional Board. Section 13263 includes factors that the Regional Board is to consider in issuing waste discharge requirements including factors in Section 13241. As noted by the commenter, the Regional Board is to consider these factors, including "'economic' impacts...on the dischargers themselves", "to the extent NPDES Permit requirements are not compelled by federal law". The Technical Report explains how each Section of the Draft Permit is supported by requirements of federal law. Neither Regional Board staff nor the commenter has identified requirements that are not compelled by federal law that would necessitate consideration of those factors. This Permit does not exceed the requirements of federal law; therefore, compliance with Sections 13263 and 13241 is legally unnecessary.

14.21	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City raises objections to the economic analysis provided in the Technical Report on the basis that it: relies on partial, outdated and irrelevant data; excludes the performance of a cost-benefit analysis or other formal analysis; and calculation of costs and benefits on a 'per household' basis are meaningless in terms of a Co-permittee's funding methods.	The Technical Report opines on the lack of complete and reliable data that would be necessary to perform a formal economic analysis such as a cost-benefit analysis. As is common for economic analyses, the analysis that is performed relies on the best available information. The methods used in the underlying studies are sound and generally accepted. The data from those studies is time-sensitive and dated; Regional Board staff resolved this by bringing the values into 2013 dollars in order to adjust for inflation using the Consumer Price Index. This method is also sound and generally accepted. Methods of economic analysis are not intended to be used for accounting purposes. They are not typically compared to funding methods as suggested by the commenter's remarks. Costs do not take into account the funding methods: an analyst does not typically distinguish a dollar of cost from other dollars because of the account each comes from as an accounting approach does. They are all treated equally as costs, in this case, as social costs. Accounting methods do not always monetize all social costs or benefits either (e.g. transaction costs, opportunity costs, intangible benefits, etc.). Costs are compared to benefits and must be normalized. In this case the underlying studies were normalized on a per household basis. This is also a sound and generally accepted method. Furthermore, there is no requirement to conduct an economic analysis because, as the Clean Water Act makes clear, the benefits of clean water and the protection of beneficial uses cannot be simply reduced to a cost/benefit equation. That said, costs have been considered in the drafting of this Permit, to the extent that the information is available, as reflected above and in the Technical Report.
14.22	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The economic analysis tells the public nothing at all about the relationship between the cost of any particular BMP and its pollution control benefits. This approach allows extremely costly BMPs relative to the pollution control benefits to be justified as long as the overall program costs are within an acceptable range. The Technical Report's generalized economic analysis is improper and a more individualized assessment of cost is required.	The economic analysis performed in the Technical Report is intended to evaluate the overall program costs with respect to their cumulative water quality benefit. It is not intended to evaluate the cost-effectiveness of any particular BMP; this is a different kind of analysis. It is notable that the Co-permittees have been the principal architects of the storm water programs through the development of the DAMPs. Regional Board staff reasonably assumes that the Co-permittees have access to the data necessary to evaluate and have, at least at some subjective, cursory level, already evaluated cost-effectiveness as part of the development of the BMPs in the DAMPs and related planning documents. It is also notable that, during the near 25-year duration of the storm water program, the iterations of the MS4 Permit have never prohibited the kinds of analysis suggested by the commenter. Both the current and draft Permit encourage the Co-permittees to perform these types of analyses as part of the goals in the Monitoring and Reporting Programs. Subsection VII.E. of the draft Permit, for example, is a virtual directive to honestly and objectively examine the cost-effectiveness of trash and debris controls.
14.23	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The City points to a March 2014 report from the Public Policy Institute of California, "Paying for Water in California, Technical Appendix E". The City notes that one of the conclusions in that report is that "the total annual costs of meeting urban storm water permit requirements are currently in the range of $1 billion to $1.5 billion, with costs likely to continue to rise as new permit requirements come due". The report goes on to state that public agencies "are likely to have stable funding for no more than half that amount, leaving a gap of $500 million to $800 million per year, or $40 to $65 per household."	The PPIC extrapolated their cost estimate based on annual revenues from a storm water utility assessment in Contra Costa County. They also estimated funding needs for additional costs likely to be incurred in the implementation of their regional storm water permit, and a similar analysis of an unidentified Bay Area agency. Although illuminating, these per household cost figures are likely to vary widely across the state due to differences in demographics and permit requirements. It is unclear how representative they are of the Co-permittees' situation. It is unlikely that these figures are sufficiently reliable to be used by the Co-permittees to make budgeting decisions and it is unclear whether the data is any less or more valid than the studies relied on in the Technical Report. Nonetheless, the $60 per household cost increase, when added to the estimated program costs in the Technical Report, certainly makes the cost-effectiveness of the program less attractive, but it does not show that the estimated costs exceed the estimated benefits. It is notable that the PPIC also concludes that the funding gap could be even higher "unless regulatory and management approaches are employed that help contain costs". The draft Permit attempts to address this issue. The draft Permit increases flexibility in the program's management by reducing reliance on 'incorporation by reference' of the Co-permittees' program plans and introduces the "iterative process" as a performance improvement method that, if implemented properly, will serve to contain costs.

14.24	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	Federal law does not require TMDLs to be included in MS4 permits. Therefore the Regional Board is required to consider the factors in California Water Code sections 13000, 13263, and 13241 before including the TMDLs in the Draft Permit.	Federal law, namely 40 CFR 122.44(d)(1)(vii)(B), requires that NPDES permits contain water quality-based effluent limits consistent with the assumptions and requirements of all available waste load allocations. Because this effectively requires that "TMDLs be included in MS4 permits", the Regional Board is not required to consider the factors identified by the commenter. See Response 14.20.
14.25	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The practical effect of the Draft Permit's establishment of joint and several liability among the Co-permittees will reduce coordination among them. If the City were to be liable for another Co-permittee's failure to implement TMDL requirements, for example, the City is unlikely to participate in developing or implementing a compliance plan. This scheme discourages coordination and is unnecessary to attain water quality objectives. This scheme should be removed or explicitly denounced.	The language of the Draft Permit does not explicitly require that multiple responsible Co-permittees develop compliance plans jointly. Regional Board staff believes that this is unnecessary as it will often be in the Co-permittees' interests to do so anyhow. Simply because multiple Co-permittees jointly prepare a compliance plan does not in and of itself establish joint and several liability. It is well within the Co-permittees' ability to structure compliance plans to avoid this by clearly assigning responsibilities among the participants.
14.26	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	The state mandates analysis in Finding 32 and Technical Report consider improper factors and is not supported by evidence. Because the Commission on State Mandates is the authority to determine whether the Draft Permit's requirements are State mandates and because the state mandates analysis is improper, the analysis should be removed.	Regional Board staff disagrees. Clearly, the Regional Board is aware that the Commission on State Mandates holds ultimate authority when determining whether this Permit contains provisions that constitute a reimbursable state mandate. Nonetheless, it is entirely appropriate for the Regional Board to set forth the legal and factual basis for why this Permit does not constitute a reimbursable state mandate.
14.27	6/20/2014	Best Best & Krieger on behalf of the City of Lake Forest	Findings 10, 13, Section V of the Technical Report, and the glossary improperly classify natural waters as part of the MS4. The definition of an MS4 is specifically limited to man-made channels and systems and does not encompass natural water bodies. Discharging into or improving natural water bodies does not make them part of an MS4. Municipalities do not generally own, control, or operate natural rivers.	The definition of an MS4 at 40CFR122.26.(b)(8) describes MS4s as a conveyance or system of conveyances that include man-made drainage facilities but does not exclude "natural" waters. "Natural" waters are conveyances that may be owned or operated by a public body and are designed and used for collecting storm water. To the extent that such "natural" waters are not a combined sewers or part of a publicly owned treatment works, they are MS4s. The definition of waters of the U.S. is not predicated on whether or not the water body is an MS4. Therefore, these terms are not mutually exclusive. Regional Board staff notes that the definitions of "discharge" and "outfall" in the federal regulations are of similar interest to the commenter and pose constraints to the regulation of parts of an MS4. See Response 16.16.
15.1	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City of Santa Ana supports the County's comment letter and joins in its submission.	Comment noted.

15.2	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City requests that the Co-permittees have the flexibility to undertake activities required in the Draft Permit to be performed by the Principal Permittee.	Regional Board staff is not opposed to this, but the circumstances of each activity assigned to the Principal Permittee needs to be taken into consideration. In some circumstances, it seems that the Principal Permittee is best suited to undertake activities of mutual interest to the Co-permittees and is appropriately identified in the draft Permit. But Regional Board staff agrees that this is not the case for Provision XIV.C.4. and we have modified the language accordingly. If there are other instances, they will be considered. The City should consider that they are not prohibited from undertaking certain activities assigned to the Principal Permittee.
15.3	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City request that the Draft Permit be revised to remove requirements that force the City to address issues that are outside of its physical and legal jurisdiction.	See Response 14.2.
15.4	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	State and Federal law do not permit the Draft Permit's creation of joint and severable liability. For example waste load allocations have been assigned to collections of Co-permittees. The City "would be unable to establish compliance with its WLAs unless it is complying with its own WLAs and it can show that all other dischargers are also in full compliance...If only one Co-permittee fails to implement BMPs to achieve WLAs, all Co-permittees may be held liable for a resulting water quality exceedance".	See Responses 14.4 and 14.25.
15.5	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City seeks clarification incorporated into the Draft Permit that the Regional Board does not intend to hold the City liable or responsible for permit conditions that do not relate to a discharge for which it is operator.	See Response 14.5
15.6	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	There is no reason that the New Development and Significant Redevelopment requirements should be changed and no evidence has been provided to justify the changes. The City requests that the existing program continue.	See Response 14.6
15.7	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City objects to the New Development and Significant Redevelopment requirements on the grounds that they improperly regulate the discharge of storm water as a surrogate for the regulation of pollutants. They should be removed or be modified to incorporate existing requirements.	See Response 14.7

15.8	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The Draft Permit regulates storm water as a surrogate for pollutants. Storm water on a priority project site does not qualify as "urban runoff" because it has not entered a storm water conveyance system; it is also not a "pollutant" under the Clean Water Act or a "waste" under Porter-Cologne. The intent of Section XII of the Draft Permit appears to be the regulation of storm water runoff and authorized non-storm water discharges from priority project sites as a surrogate for the regulation of pollutants.	See Response 14.8
15.9	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	Regulation of storm water alone rather than pollutants or waste in storm water exceeds the Regional Board's authority. The commenter describes a TMDL for Accotink Creek in Virginia where USEPA regulated flow as a surrogate for sediment; this approach was rejected by the Court.	See Response 14.9
15.10	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	Storm water itself is not a Waste, though it may contain Waste. The Clean Water Act only authorizes the regulation of pollutants. Porter-Cologne only authorizes the regulation of Waste. By mandating the elimination of pollutants through the control of storm water and authorized non-storm water, the Draft Permit treats storm water as a surrogate for all, unspecified pollutants in the same way that USEPA treated storm water as a surrogate for sediment. The Regional Board therefore has no authority to regulate discharges without specifically identifying a particular pollutant of concern.	See Response 14.10
15.11	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City request changes to the Draft Permit to provide clarity that th eintent of Section XII is to control pollutants directly caused by a project. Forcing the City to require mitigation in excess of a project's impacts exposes the City to potential liability for takings claims.	See Response 14.11

15.12	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The Draft Permit's hydro-modification and LID requirements exceed the scope of the City's and the Regional Board's authority under State and Federal law. For example, in areas where redevelopment results in the addition or replacement of more than 50% of the impervious surfaces of an existing development site, Section XII will generally require a project to retain all storm water runoff on site, or mitigate off-site even where the runoff is not caused or increased by the redevelopment. California law prohibits exaction on a project in excess of a project's impact.	See Response 14.12
15.13	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The Draft Permit's requirements for source and site design control BMPs for non-priority projects would apply to projects that do not create any additional runoff or change the type of pollutants, such as roof-top solar panel installations. This may cause the City to impose mitigation and/or exactions for impacts that are not a result of the project itself.	See Responses 7.7 and 14.13
15.14	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	There is no evidence in the record demonstrating that implementing LID requirements in every priority and non-priority project improves water quality. There is no evidence in the record demonstrating that a change to the existing program is necessary or would benefit the environment.	See Response 14.14
15.15	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City requests that the Receiving Waters Limitations language in Section IV be removed because they impose a substantial burden and they are not required by federal law. Additionally, the language is inconsistent with the State Water Resources Control Board's Water Quality Order 2001-15.	See Response 14.15
15.16	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City requests that the Draft Permit's TMDL requirements be revised to clarify that compliance is to be attained through the implementation of BMPs and that the waste load allocations do not constitute numeric effluent limits. If there are numeric effluent limits, the Regional Board must find that there is reasonable potential that the discharge of the pollutant may cause or contribute to an excursion above a narrative or numeric criteria within a water quality standard. The Clean Water Act does not require TMDLs to be incorporated into the Draft Permit.	See Response 14.16

15.17	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	Where a TMDL provides for the development and implementation of a compliance plan, the Draft Permit should provide a provision accordingly. Implementation of BMPs and other requirements consistent with compliance plans should be sufficient for permit compliance.	See Response 14.17
15.18	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City requests that Provision XII.B.1. be modified to more appropriately designate the dates after which project applicants and Co-permittee projects must comply with Section XII. The requested dates are those received 12 months after the adoption of the Order and Co-permittee projects approved after 12 months after the adoption of the Order.	See Response 14.18.
15.19	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The Regional Board has failed to comply with California Water Code Sections 13000, 13263, and 13241.	See Response 14.20
15.20	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City raises objections to the economic analysis provided in the Technical Report on the basis that it: relies on partial, outdated and irrelevant data; excludes the performance of a cost-benefit analysis or other formal analysis; and calculation of costs and benefits on a 'per household' basis are meaningless in terms of a Co-permittee's funding methods.	See Response 14.21
15.21	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The City points to a March 2014 report from the Public Policy Institute of California, "Paying for Water in California, Technical Appendix E". The City notes that one of the conclusions in that report is that "the total annual costs of meeting urban storm water permit requirements are currently in the range of $1 billion to $1.5 billion, with costs likely to continue to rise as new permit requirements come due". The report goes on to state that public agencies "are likely to have stable funding for no more than half that amount, leaving a gap of $500 million to $800 million per year, or $40 to $65 per household."	See Response 14.22

15.22	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The economic analysis tells the public nothing at all about the relationship between the cost of any particular BMP and its pollution control benefits. This approach allows extremely costly BMPs relative to the pollution control benefits to be justified as long as the overall program costs are within an acceptable range. The Technical Report's generalized economic analysis is improper and a more individualized assessment of cost is required.	See Response 14.23
15.23	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	Federal law does not require TMDLs to be included in MS4 permits. Therefore the Regional Board is required to consider the factors in California Water Code sections 13000, 13263, and 13241 before including the TMDLs in the Draft Permit.	See Response 14.24
15.24	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The practical effect of the Draft Permit's establishment of joint and several liability among the Co-permittees will reduce coordination among them. If the City were to be liable for another Co-permittee's failure to implement TMDL requirements, for example, the City is unlikely to participate in developing or implementing a compliance plan. This scheme discourages coordination and is unnecessary to attain water quality objectives. This scheme should be removed or explicitly denounced.	See Response 14.25
15.25	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	The state mandates analysis in Finding 32 and Technical Report consider improper factors and is not supported by evidence. Because the Commission on State Mandates is the authority to determine whether the Draft Permit's requirements are State mandates and because the state mandates analysis is improper, the analysis should be removed.	See Response 14.26
15.26	6/20/2014	Best Best & Krieger on behalf of the City of Santa Ana	Findings 10, 13, Section V of the Technical Report, and the glossary improperly classify natural waters as part of the MS4. The definition of an MS4 is specifically limited to man-made channels and systems and does not encompass natural water bodies. Discharging into or improving natural water bodies does not make them part of an MS4. Municipalities do not generally own, control, or operate natural rivers.	See Response 14.27

16.1	6/20/2014	County of Orange	The commenter provides an index of summarized comments.	Regional Board staff appreciates the organization provided by the commenter. Responses to comments are structured around the detailed comments in order to avoid repetition.
16.2	6/20/2014	County of Orange	The Draft Order does not recognize the Report of Waste Discharge or the significant water quality outcomes that have been achieved in Orange County. It therefore lacks substantial evidence to support new or modified program requirements. The Draft Order needs to include the key findings from the Report of Waste Discharge and use this information as the basis for the Draft Order's requirements.	The principal bases for the requirements of the Draft Order are the requirements of the Clean Water Act and its implementing regulations. The mechanisms for fulfilling those requirements are currently the Drainage Area Management Plan, Local Implementation Plans, 2011 Water Quality Management Plan, the Technical Guidance Document, and other planning documents authored by the Co-permittees. Many of the draft Permit requirements are based on the programs described in these planning documents as part of the effort to have the fifth term Permit minimize reliance on their incorporation by reference. The Report of Waste Discharge has been considered in the preparation of the Draft Permit. While the Report of Waste Discharge does demonstrate certain water quality improvements, it does not correlate those improvements to the Co-permittees' storm water program in a reliable way. The Report of Waste Discharge does not recognize other equally-important water quality efforts that have also contributed to the improvements, such as the Industrial and Construction Storm Water Programs, waste discharge requirements for nurseries, and the State Board's Sanitary Sewer Overflow Program. Other events have also influenced water quality including water conservation efforts, land use changes, and the drought. It would be inappropriate for the Regional Board to arbitrarily determine that the water quality improvements documented in the Report of Waste Discharge were caused solely by the Co-permittees' efforts. Furthermore, the implied argument in the Report of Waste Discharge that, because a program appears to be working to improve water quality, it should be scaled back (e.g. the inspections programs) is illogical. Indeed, of those programs are effective at improving water quality, they should be expanded or, at a minimum, be continued under the current structure.
16.3	6/20/2014	County of Orange	The Draft Permit seeks to make 19 significant changes to Section XII that will necessitate a comprehensive revision of the Model WQMP and Technical Guidance Document without substantial evidence for justification. The Draft Order should be modified to incorporate the existing Model WQMP and Technical Guidance Document.	Regional Board staff appreciates the opportunity to review the 19 significant changes. We have considered the merits of each of the changes individually. Changes that were unintended or unjustifiable, have been removed or amended. Additional changes have been made at County staffs' request during a meeting on July 23, 2014. Most of these amendments are intended to improve the clarity of the language. Where the significant changes were left, Regional Board staff will provide a better explanation in the Technical Report.
16.4	6/20/2014	County of Orange	The commenter appreciates the equivalent consideration between on-site and off-site structural treatment controls.	The commenter's support is noted.
16.5	6/20/2014	County of Orange	The commenter is supportive of the "iterative process" as described in the receiving waters limitations in the Draft Permit.	The commenter's support is noted. See Response 8.1.

16.6	6/20/2014	County of Orange	The Draft Permit should allow for a watershed management-based alternative compliance pathway. The commenter provides a detailed narrative on trends towards watershed-based solutions. The Draft Permit should be revised to allow for a watershed-based approach.	The Draft Permit is purposefully silent on the spatial scale of Copermittees' planning documents necessary to carry out the requirements of the Permit. The language instead allows the circumstances to dictate the scale. See also Response 14.3.
16.7	6/20/2014	County of Orange	The Draft Permit includes certain overly-prescriptive provisions. The commenter provides examples for which more detailed comments are provided elsewhere in their letter.	Regional Board staff has evaluated the merits of each of the provisions of concern individually and has made changes to the revised draft Permit accordingly.
16.8	6/20/2014	County of Orange	The Fact Sheet inappropriately includes directive language. The commenter notes an apparent contradiction on Page 63 of the Fact Sheet regarding TMDLs. The commenter asserts that "Where a Permittee fails to comply with the development and implementation of a plan, other compliance options are available". TMDLs contain attainment schedules and the only instance in which compliance would be immediate and enforcement action possible is if the schedule has passed and/or no schedule has been established and the WLAs have not been met.	The commenter raises several distinct issues. Directive language may be necessary in the Fact Sheet in order to reinforce the requirements of the Permit. It may also be necessary to provide instruction to different readers, including Regional Board staff and Co-permittees. Directive language in the Technical Report is not equivalent to a provision in the Permit and cannot be enforced. Regional Board staff concurs that contradictory language will need to be corrected where it is found. The commenter's issue with the TMDL language warrants further discussion in the Technical Report to explain the relationship between the related Basin Plan language and the Permit. In summary, the Basin Plan language is generally not enforceable unless it is incorporated into waste discharge requirements, clean-up and abatement order, cease and desist order, or other regulatory mechanism. The Draft Permit incorporates the Basin Plan language in a generic way by requiring immediate compliance with waste load allocations by a specified date, or allowing compliance with a plan or a time schedule order. This is the same general approach employed in the Basin Plan language and is essentially consistent with the commenter's remarks. The allowed compliance plans and related monitoring should be consistent with the Basin Plan language for the TMDL.
16.9	6/20/2014	County of Orange	Many of the new or modified requirements in the Draft Permit do not have adequate findings of fact and/or technical justification. The commenter provides several examples. The Fact sheet should be modified accordingly.	Regional Board staff has evaluated the specific instances individually and amended the Fact Sheet as appropriate.
16.10	6/20/2014	County of Orange	The Fact Sheet omits the City of Laguna Hills in Section IV from the list of regulated entities.	The omission is an error that has been corrected.
16.11	6/20/2014	County of Orange	The requirement to submit an Annual Progress Report should be waived if Permit adoption occurs in the middle of the reporting period.	Regional Board staff recognizes the inconvenience that the commenter's scenario poses on the Co-permittees. However, a waiver is inappropriate. Instead, Regional Board staff has inserted into the revised draft Permit language so that the Executive Officer is allowed to accept a late submittal under certain circumstances.

16.12	6/20/2014	County of Orange	Findings 4 and 35 of the Draft Permit are inconsistent with the language of Clean Water Act Section 402(p)(3)(B) by implying that "other measures" may exceed the "maximum extent practicable" standard.	These findings are not inconsistent with Clean Water Act section 402(p)(3)(B). Section 403(p)(3)(B) articulates two separate permit requirements: 1) require controls to reduce the discharge of pollutants to the maximum extent practicable; and 2) include such other provisions as the Administrator or the State determines appropriate for the control of such pollutants.
16.13	6/20/2014	County of Orange	In Finding 8, the Co-permittees should not be required to submit reports of waste discharge or obtain separate coverage for de minimis discharges outside of the Newport Bay Watershed.	See Response 2.1.
16.14	6/20/2014	County of Orange	In Finding 9, the Draft Permit should continue to recognize the limits of the Co-permittees' ability to control discharges of pollutants. Finding 9 in the Draft should be replaced with Finding 10 in the fourth-term Permit.	The language of Finding 10 was modified from the current 2009 Permit because it implied that that the Co-permittees have no capability to control pollutants from state and federal facilities, utilities, and other similar entities. This is not known to be true. It is more accurate to state, as Finding 9 does, that the capability may not exist or is limited. Wherever the boundary of the Co-permittees' authority lies, it must be exercised to the maximum extent practicable. Finding 9 cannot create authority where it does not exist, and thus, cannot create a new liability as suggested by the commenter.
16.15	6/20/2014	County of Orange	Finding 10 will preclude the use of Regional BMPs. Finding 10 should be modified to allow for stream restoration and rehabilitation, constructed wetlands and regional BMPs and related maintenance.	Finding 10 applies to the use of waters of the U.S. as structural treatment controls. It does not preclude BMPs such as restoration or rehabilitation projects. In practical terms, if a water of the U.S. were proposed to be converted to a structural treatment control, then it could no longer be considered waters of the U.S. and the loss of beneficial uses would have to be compensated for. Finding 10 has been modified for clarity.
16.16	6/20/2014	County of Orange	In Finding 13, discharges to receiving natural waters cannot be legally be classified as part of the MS4. A waterbody cannot be classified as both an MS4 and a receiving water.	The definitions of waters of the U.S. and MS4 are not mutually exclusive. See Response 14.27. Additionally, it should be noted that the commenter partially misstates the definition of an MS4. An MS4 does not need to be “owned and operated” by a public entity; rather it can be “owned or operated” by a municipality for purposes of collecting or conveying storm water.

16.17	6/20/2014	County of Orange	The County request that their findings regarding new development be incorporated into the Draft Permit. Proposed finding 18 summarizes the genesis of the 2011 Model WQMP and Technical Guidance Document; declares a "comprehensive and innovative approach", "significant progress", and a "robust and successful program"; and describes their relationship to the requirements of Section XII of the draft Permit. Proposed Finding 19 similarly describes the purposes and genesis of the 2011 Model WQMP and Technical Guidance Document and repeats the relationship with Section XII in Proposed Finding 18. Finding 20 remarks on the challenges in complying with Section XII and makes generalizations regarding the infeasibility of infiltration and the challenging competition between recycled water and harvested storm water. Finding 21 declares regional BMPs to be a "critical tool" that provide "invaluable treatment" and summarizes their practical benefits.	Proposed Finding 18 contains conclusory statements on the quality of the program that are not supported by an audit or other evaluation by Regional Board staff. The Technical Report already makes the relationship clear between the 2011 Model WQMP and Technical Guidance Document and the language of Section XII of the draft Permit. This relationship is a technical matter and suitable for discussion in the Technical Report. Therefore, proposed Findings 18 and 19 are unnecessary. Proposed Finding 20 is decidedly negative in its tone and seems to contradict the positive statements in proposed Finding 18. Proposed Finding 20 invites generalizations that discourage structural treatment controls which the draft Permit is attempting to encourage. Regional Board staff recognizes that projects will universally face constraints. But these constraints should be evaluated on a case-by-case basis and not on broad generalizations. Regional Board staff welcomes the commenter's summary in proposed Finding 21 but believes that it is appropriate for inclusion in the Technical Report. For balance, Regional Board staff has included a discussion on the benefits of on-site structural treatment controls.
16.18	6/20/2014	County of Orange	The Draft Order contains limitations that are more stringent than federal law and therefore requires an economic analysis. The economic analysis in the Technical Report is inadequate.	The commenter asserts that "a number of provisions of the Draft Order are more stringent than federal law" but only cites one example of this: volumetric flow limitations to address hydro-modification. Regional Board staff will address specific instances where they are brought to our attention. Therefore, in the cited instance, Regional Board staff generally developed numeric design standards for BMPs meant to address hydro-modification. As explained in Response 14.10, storm water runoff that is the result of human habitation is a waste and may become a pollutant where it may adversely affect beneficial uses. The Co-permittees have been required to identify channels or channel segments where this may occur and employ BMPs to prevent it. State Board Order No. WQ 2000-11 established that numeric design standards for BMPs are not separate BMPs or water quality standards (see also WQ 2001-15). They are a more detailed description of the maximum extent practicable standard as allowed by Clean Water Act Section 402(p)(3)(B). As a result, an economic analysis is not required. The commenter's remarks on the economic analysis are addressed in Responses 14.21 and 14.23. In addition, Regional Board staff cannot present costs or benefits in 2014 dollars as requested by the commenter; the year is not complete and an annual Consumer Price Index is not yet available.
16.19	6/20/2014	County of Orange	The Regional Board has no legal ability to determine whether a particular Permit requirement is an "unfunded mandate" as described in Finding 32 and the discussion in Section VI.E. of the Technical Report.	Regional Board staff recognizes the authority of the Commission on State Mandates and the commenter's right to disagree with the arguments in Finding 32. However, neither of these preempts the Regional Board from making those arguments. See also Response 14.26.
16.20	6/20/2014	County of Orange	The Co-permittees should not be required to submit reports of waste discharge or obtain separate coverage for *de minimis* discharges outside of the Newport Bay Watershed.	See Responses 2.1 and 16.13.

16.21	6/20/2014	County of Orange	The requirement in Subsection VII.E. for the Co-permittees to obtain approval from the Executive Officer for modifications to indivual drain inlet screens is overly burdensome and limits the Co-permittees' ability to adaptively manage their program.	See Response 3.2.
16.22	6/20/2014	County of Orange	The Co-permittees have been implementing the Countywide Area Spill Control Program in collaboration with the Orange County Sanititation District for over 10 years. Subsection VII.F. should be modified to recognize this established program and be consistent with it.	Subsection VII.F. was modeled after the Countywide Area Spill Control Program as described in the 2003 DAMP. If the description in the 2003 DAMP is inaccurate or Subsection VII.F. is inconsistent, Regional Board staff is open to making appropriate modifications to the Subsection. Regional Board staff agrees that recognition of the Program is appropriate in the Technical Report, but is opposed to its incorporation by reference as suggested by the commenter.
16.23	6/20/2014	County of Orange	The Draft Order should not require inventory of construction projects with a duration that is less than 2 weeks. The commenter indicates that this is consistent with other sections.	The other sections cited by the commenter do not exist in this Draft Permit. Regional Board staff's understanding is that the Co-permittees use their project permitting systems to generate their inspection inventory. Whether or not a site is in the inspection inventory, it will be in "an inventory" as the result and is therefore in compliance with Provision VIII.A. Both the larger inventory and the inspection inventory will need to be monitored to track projects whose duration exceeds 2-weeks and consequently become part of the inspection inventory. As the result, including the limit as requested could impair the Co-permittees' ability to comply but omitting the limit would not cause the Co-permittees to be in noncompliance.
16.24	6/20/2014	County of Orange	The inventory of construction sites should be updated on a bi-annual basis. The frequency of once-per-month is unreasonably burdensome and does not provide a benefit to water quality.	The commenter's request could have the effect of having projects with durations of less than 6-months not being inspected. It is unclear how this is a benefit to water quality. During program audits, Regional Board staff learned that Co-permittees were able to perform updates more frequently than the Draft Permit requires using existing data from their permitting information systems. The data existed in near-real time but needed to be compiled and transferred between departments. The higher update frequency was facilitated by cooperative relationships between departments. The commenter has not identified the source of the burden (i.e. data collection, compilation, extraction). But if the burden is caused by uncooperative departments or lack of coordination, the Co-permittee has an obligation under Provision I.A.5. to attempt to resolve it before seeking Permit relief.
16.25	6/20/2014	County of Orange	The inspection of high-priority construction sites should only be required 3 times during the wet season.	Regional Board staff concurs. After consultation with Regional Board staff with extensive experience in construction site inspection, we have concluded that our experience is consistent with the Co-permittees'. The revised draft Permit has been amended accordingly.
16.26	6/20/2014	County of Orange	The Draft Permit requires that "all industrial sites" unconditionally be within their inspection inventory. This is a departure from the current Permit which is not supported by the Fact Sheet.	Regional Board staff concurs. The language of Section IX will be modified to limit the industrial site inventory to those "with the potential to discharge pollutants to the MS4" consistent with the current Permit.

16.27	6/20/2014	County of Orange	The requirements for the industrial program should be consistent with the approach proposed in the Report of Waste Discharge.	Regional Board staff disagrees. The basis for the requested changes, as presented in the Report of Waste Discharge, is biased. Although the basis is principally due to a 'high degree of compliance', inspectors do not reliably detect compliance. Inspectors are more reliable in detecting non-compliance. The Co-permittees' reported inspection outcomes are more properly described as a 'low rate of detection of non-compliance'. Further rationale is detailed in the Technical Report.
16.28	6/20/2014	County of Orange	The Draft Permit requirements for the commercial site inspection program should be consistent with the proposals in the Report of Waste Discharge. Based on the Co-permittees' calculations, proposed Option 1 reduces the inspection burden 12 to 88%. Option 2 reduced the inspection burden by 41%. The Draft Permit reduces the inspection burden by 16%.	Regional Board staff has identified the error in Table TR-2: the average number of inspections for medium-priority sites is 2.5 per 5-year permit term and not 2. The commenter's proposed amended value of 16% is correct. The comparison provided by the Co-permittees shows that Option 1 and Option 2 will reduce the number of inspections that the Co-permittees perform. But it does not communicate how the reduced number of inspections translates into a "focus on those facilities that pose the greatest risk to water quality". Logically, any reduction in the number of inspections can provide this focus. But the Co-permittees have not explained how their proposed magnitude of the reduction relates to this stated goal or how it would reflect improvements in water quality. The basis provided by the Co-permittees - a 'high degree of compliance' - is also biased. Further rationale is detailed in the Technical Report.
16.29	6/20/2014	County of Orange	The Draft Permit does not reflect all of the technical details in the 2011 Model WQMP and Technical Guidance Document. The result is that the permit makes significant changes to the OC Land Development Program. The Draft Permit would trigger significant revisions to the 2011 Model WQMP, Technical Guidance Document and associated program documents, computer systems, and training programs. The changes would potentially disrupt an extensive investment in the program. To avoid these significant unintended changes, the 2011 Model WQMP and Technical Guidance Document should be expressly referenced in the Draft Permit.	The Draft Permit is not intended to reflect all of the technical details in the 2011 Model WQMP and Technical Guidance Document. See Responses 7.1 and 7.4.
16.30	6/20/2014	County of Orange	The lexicon describing categories of structural treatment control BMPs should be consistent with the 2011 Model WQMP and Technical Guidance Document.	Regional Board staff has examined the lexicon in the 2011 Model WQMP and Technical Guidance Document and concluded that there are differences but these differences are highly unlikely to cause confusion. See Response 4.4.

16.31	6/20/2014	County of Orange	Certain land development requirements in the Draft Order appear to disregard the Permittees' ability to apply CEQA by prescribing alternative processes, thereby preempting certain parts of the CEQA process. Public Resources Code Section 21081.6(c) does not allow compliance or non-compliance by a responsible agency or agency having jurisdiction over natural resource to limit the authority of the Lead Agency to approve, condition, or deny projects. Section 21081.1 states that the Lead Agency's determination "shall be final and conclusive on all persons, including responsible agencies, unless challenged". Section XII and the Fact Sheet should be modified to state that the Order include a limitation that includes the statutory and categorical exemptions from CEQA documentation.	The specific reference to CEQA in this comment has been removed. See Response 14.11.
16.32	6/20/2014	County of Orange	The Regional Board has no authority to require Co-permittees to amend their General and Specific Plans and cannot mandate the goals, policies, and procedures that comprise those plans. Only the Legislature may impose general plan and specific plan requirements on municipalities; the Regional Board has no express delegation from the Legislature. The California Constitution mandates a separation of powers between the legislative, executive, and judicial branches of State government. The Regional Board cannot order the amendment of a general plan or dictate the substance of that plan. The Regional Board may not be the arbiter of the validity of general or specific plans.	Subsection XII.A. has been removed. The principal purpose of Subsection XII.A. was to cause the Co-permittees to use existing mechanisms to communicate that water quality-related community goals are a shared responsibility among its departments. This communication would help to cause different departments to act in strategic alignment with those goals and promote inter-departmental cooperation and minimize departments working at cross-purposes. This would help to prevent narrow compartmentalization of NPDES responsibilities within one or a few departments. The secondary purpose was to establish related objectives for the achievement of water quality-related community goals in various implementing documents. Instead making this a permit requirement, as part of program audits and investigations into violations, Regional Board staff will examine if negative inter-departmental relations were contributing factors to violations and use the information as gravity to support resulting enforcement action(s).
16.33	6/20/2014	County of Orange	If a Co-permittee adopts goals identified in Subsection XII.A., they should specifically apply to new development and redevelopment.	See Response 16.32.
16.34	6/20/2014	County of Orange	The goals listed in Subsection XII.A. should recognize that infiltration should not be encouraged in areas that would cause or exacerbate a known groundwater quality issue.	Regional Board staff has no expectation that Co-permittees would adopt goals that result in unmitigatable environmental hazards in general. See Response 16.32.
16.35	6/20/2014	County of Orange	The Draft Order should not require the development of objectives with the adoption of goals for a General or Specific Plan. Specifically, such objectives would be redundant with the requirements of the Model WQMP and Technical Guidance Document.	Subsection XII.A. does not require that objectives reside in any General Plan or any particular implementing documents. In the specific case raised by the commenter, if the objectives stated in the 2011 Model WQMP and Technical Guidance Document are sufficient and there is a goal in the General or Specific Plan that is supported by those goals, then it would be redundant to develop another set of objectives. See Response 16.32.

16.36	6/20/2014	County of Orange	The Co-permittees should not be required to verify that a report of waste discharge for discharges of dredge or fill to waters of the U.S. has been submitted to the Regional Board. The Regional Board does not have the authority to dictate how permitting applications should be processed. The requirement improperly places the burden of determining when a report of waste discharge is required on the Co-permittee.	After further consideration, Provision XII.A.6. has been removed.
16.37	6/20/2014	County of Orange	The effective date of Subsection XII.B. should be postponed to 12 months following the adoption of the final Permit. This will allow time for the Co-permittees to update the 2011 Model WQMP and Technical Guidance Document and other documents.	See Response 14.18.
16.38	6/20/2014	County of Orange	The applicability of Section XII.B. for municipal priority and non-priority projects should be based on project approvals and not on funding.	Regional Board staff agrees that the language of Provision XII.B.1. should be improved. Based on the commenter's remarks, the triggering event has been changed to the date of project approval.
16.39	6/20/2014	County of Orange	The criteria for priority projects and non-priority projects should be consistent with the 2011 Model WQMP and Technical Guidance Document. The requirement for non-priority project plans for certain non-priority projects is too inclusive and will cause unwarranted project delays and costs for projects such as patio covers, block walls, and reroofs.	See Responses 7.7, 7.9 and 14.12.
16.40	6/20/2014	County of Orange	Single and multi-family dwelling units should not be priority projects. Provision XII.B.5.b. adds these types of developments where they were not previously included in the current permit. The Draft Permit provides no justification for this change.	Regional Board staff partly disagrees. Under the existing Permit, single and multi-family dwelling units that do not involve a subdivision of land would require project WQMPs if they fell into categories (a), triggered in part by the addition or replacement of 5,000 square feet or more of impervious surface; (e), triggered in part by 2,500 square feet or more on certain hillsides; or (f), triggered in part by 2,500 square feet or more in the vicinity of environmentally-sensitive areas. The current 2009 Permit includes "single family home subdivisions and multi-family home subdivisions" that "create 10,000 square feet or more of impervious surfaces (collectively over the entire project site)". The Draft Permit substitutes this phrasing with "single and multi-family dwelling units" that "create a total of 10,000 square feet or more of impervious surfaces". Regional Board staff recognizes that the phrasing is significantly different in that the current Permit would also have to involve subdivision of land. The term "subdivisions" has been added to category (b) to correct this omission. Consequently, the revised draft Permit does not change how single and multi-family dwelling units are treated.

16.41	6/20/2014	County of Orange	Section XII.B.5.c. identifies that "new or expanded' automotive repair shops are identified as priority projects. No practical threshold is given to define "expanded". Additions to such facilities should fall into category (a) for redevelopment.	The existing language in the current Permit for automotive repair shops is equally problematic because it is remarkably vague. It contains no explanation as to what about such facilities would trigger the need for a WQMP. It could be read to include the addition of new services that trigger an approval by a Co-permittee. The commenter is correct to note that "expanded" automotive repair shops would fall under category (a). Regional Board staff agrees that the thresholds in category (a) and elsewhere are sufficiently protective and has removed the term "expanded".
16.42	6/20/2014	County of Orange	Routine maintenance should include maintenance on the entire roadway structure, not just the surface course of pavement.	Category (h) of Subsection XII.B. triggers a project WQMP in the event that work affects 5,000 square feet or more of paved surface. If the work does not affect paved surfaces at all, even if it exceeds 5,000 square feet, a project WQMP is not required. Regional Board staff does not see the need for the requested amendment.
16.43	6/20/2014	County of Orange	Precise grading or final construction work should not proceed until a final project WQMP is approved as per the current Permit. The Draft Permit allows no construction work at all. No justification is provided for this change. This new requirement would prohibit investigative work such as potholing and geotechnical investigations, creating an unwarranted burden with no water quality benefit.	Regional Board staff concurs. Provision XII.B.10. of the Draft Permit has been amended to be consistent with Provision XII.A.3. of the current Permit.
16.44	6/20/2014	County of Orange	The type of mechanisms required in Provision XII.C.6. may be redundant or not applicable for all of the Co-permittees. An efficient program does not require each and every mechanism identified. Each Co-permittee should have the discretion to identify mechanisms that work best for their program.	Regional Board staff concurs. Provision XII.C.6. has been amended to afford greater flexibility in selecting mechanisms.
16.45	6/20/2014	County of Orange	The recordation of final project WQMPs should be left to the discretion of the Co-permittees.	Regional Board staff concurs. The use of the term "public records" in Provisions XII.C.10. and 11. should be read to have broad meaning. In this way, the language affords the discretion requested by the commenter. To avoid implying that documents must be filed with the County Recorder, the term "recorded" has been substituted with "maintained".
16.46	6/20/2014	County of Orange	Provision XII.D.3. requires that infiltration LID BMPs loss of the design capture volume occur over a period not to exceed 48 hours. This requirement is overly rigid and inconsistent with the specification in the 2011 Model WQMP and Technical Guidance Document.	Regional Board staff concurs. See also Response 7.2.
16.47	6/20/2014	County of Orange	Provision XII.D.6. requires that structural treatment control BMPs be sized and designed by, or under the direction of, a registered civil engineer. This is already part of the Technical Guidance Document and is redundant.	The Draft Permit does not incorporate the requirements of the 2011 Model WQMP or Technical Guidance Document by reference. Therefore, a requirement in these documents is not a requirement in the Draft Permit. The Provision is not redundant for enforcement purposes.

16.48	6/20/2014	County of Orange	If a structural treatment control BMP satisfies the requirements of the Order then the requirements are met and no cost analysis should be performed according to Provision XII.D.8. of the Draft Permit. Impacts must be identified for the lawful requirement of mitigating impact.	An undersized structural treatment control BMP may experience premature failure, entrainment and by-pass of its captured pollutants, and may cause flooding. Some types of controls may experience abnormal vector problems or present a drowning hazard. Efforts to mitigate these potential environmental impacts may be manageable in some cases. But in others, mitigation may impose excessive and unsustainable burdens on future responsible parties. The threshold between manageable and unmanageable is unknown and specific to the situation. But the purpose of the cost analysis is to disclose at least part of that burden to potentially-affected parties and, as such, to deter project proponents from proposing structural controls that serve their own short-term interests at the expense of future responsible parties, including the Co-permittees. Regional Board staff has substituted the performance of a cost analysis with a simpler disclosure requirement.
16.49	6/20/2014	County of Orange	Permittees should not be required to secure the legal authority to enter private property. Both the Co-permittees and the Regional Board have Constitutional limits on their ability to enter private property, so it is difficult to understand why Co-permittees would be expected to compel inspections without consent, when the Regional Board itself does not possess this authority. Furthermore, the requirement in Provision XII.D.10. to perform maintenance runs afoul of the constitutional prohibition on gifts of public funds and certain local prohibitions on the use of public funds or the performance of work on private property. Provision XII.D.10. should be deleted.	See Response 5.3.
16.50	6/20/2014	County of Orange	Provision XII.E.1. prohibits Co-permittees from approving structural treatment control BMPs that do not substantially conform to published and generally-accepted engineering design criteria. There are many structural treatment control BMPs that can improve water quality but are not in published design manuals. Co-permittees should have the discretion to approve BMPs that have field-scale performance date but not in a published design manual.	Provision XII.E.1. does not adequately consider the structural treatment control BMPs discussed by the commenter. The Provision holds well for non-proprietary structural treatment controls, mainly LID BMPs, but not for proprietary controls which are less likely to be found in design manuals. Regional Board staff has amended the revised draft to allow more flexibility.
16.51	6/20/2014	County of Orange	The Draft Order should recognize the technical feasibility criteria in the 2011 Model WQMP and Technical Guidance Document.	The Draft Order indirectly refers to the criteria in the 2011 Model WQMP and Technical Guidance Document in Provision XII.C.2. This Provision requires that WQMPs be prepared "in substantial conformance with uniform written technical guidance". This indirect reference is intended to avoid incorporating the requirements of the Co-permittees' documents by reference and to provide the Co-permittees with flexibility to amend and improve those documents. The commenter is correct to note that the relationship of this technical guidance to the technical feasibility criteria for selecting structural treatment control BMPs is not strong. Regional Board staff has added various language to the revised draft Permit that strengthens this relationship, but Regional Board staff are opposed to directly referencing the 2011 Model WQMP and Technical Guidance Document as specific Permit requirements.

16.52	6/20/2014	County of Orange	Mitigation of the environmental and public health hazards of retention LID BMPs should be consistent with the requirements of the Technical Guidance Document.	Similar to Response 16.51, Regional Board staff has amended the language that strengthens the relationship between the methods to accomplishing this mitigation with those in the "uniform written technical guidance".
16.51	6/20/2014	County of Orange	Section XII.G.1.d. requires that volume-based bio-treatment control BMPs be sized to 1.5 times the design capture volume. This is an increase from the current Permit. There is no factual support for this sizing factor. The study cited in the Technical Report is location-specific. The commenter provides alternative evidence.	The reports provided by the commenter raise important points regarding the importance of drawdown time for retention LID BMPs in order to prevent overflow. In comparison, the Ventura Study compares the pollutant load reductions that may be achieved by treating different volumes of storm water runoff in biotreatment control BMPs. The critiques of the Ventura Study in the commenter's cited reports are not applicable because the mechanisms of treatment are different. Where retention LID BMPs rely on the loss of the design capture volume and its pollutants, biotreatment control BMPs discharge a portion of the design capture volume and additionally rely on biological transformations and other mechanisms to remove pollutants from discharges. The methods used in the studies for estimating the effectiveness of these BMPs are different and do not invalidate the Ventura Study. Regional Board staff acknowledges that the 1.5 factor derived in the Ventura Study is based on data specific to Ventura County and represents the best available information at this time. The validity of the factor could be improved by using data specific to Orange County and Regional Board staff encourages the Co-permittees to evaluate site-specific conditions. But it is unclear if there are site-specific differences which would result in a significantly different sizing factor. Regional Board staff is open to considering additional information. See also Responses 4.2 and 5.2.
16.54	6/20/2014	County of Orange	The system for rating the performance of non-LID structural BMPs should be consistent with the Technical Guidance Document. The requirement for bi-annual review of these performance ratings is not necessary given the low priority of non-LID BMPs in the hierarchy.	The system described in Section XII.H. reflects the system in the Technical Guidance Document. The bi-annual frequency is based more on the expected rate of change in technology and performance information than how often non-LID structural BMPs have been used. Their low-ranking in the hierarchy does not mean that they are rarely used. Regional Board staff notes that since the 2008-2009 annual reporting period, the Co-permittees have stopped reporting the types of structural treatment control BMPs that are approved. Therefore, no information has been provided by the Co-permittees to estimate the occurrence of the different categories of BMPs or to evaluate the effectiveness of the hierarchy since the approval of the 2011 Model WQMP and Technical Guidance Document.
16.55	6/20/2014	County of Orange	The vertical separation from the bottom of an infiltration facility to the seasonal high groundwater should be consistent with the Technical Guidance Document.	Section XII.I.2. has been modified to be consistent with the Technical Guidance Document.
16.56	6/20/2014	County of Orange	The compliance requirement for Class IV injection wells is too general. Local permitting agencies may have more stringent requirements.	Section XII.I.5. has been modified to address additional standards.
16.57	6/20/2014	County of Orange	Indoor use of harvested storm water should only be considered where the plumbing code allows.	True. But the commenter implies that the plumbing code does not allow plumbing for storm water. The indoor plumbing code allows plumbing for hazardous materials; many industrial operations would not be possible without it. The commenter provides no citations to support the implication. Without this support, the language would suggest prohibitions that may not exist.

16.58	6/20/2014	County of Orange	Demand rate calculations for harvest and use of storm water should not be included in the Draft Order. This information is already contained in the Technical Guidance Document.	Regional Board staff concurs that the calculations in the draft Permit are out of place. The calculations have been removed from the revised draft Permit.
16.59	6/20/2014	County of Orange	"Offsite structural BMPs should be on the same level in the BMP hierarcy as onsite BMPs." The commenter goes on to explain why but appears to shift their concern more specifically to retention LID BMPs that may have been designed and constructed under Order No. R8-2002-0010.	If the commenter is asserting that retention LID BMPs should be supported whether they are located on site or off, Regional Board staff agrees. In a situation where a retention LID BMP is planned or constructed by any entity, according to a WQMP prepared under older versions of the Permit, Subsection XII.K.2.a. would allow that facility to be used without requiring a demonstration of on-site infeasibility. This provides the equal consideration the commenter requests. Subsections XII.K.2.b. and c. apply to retention LID BMPs and biotreatment control BMPs respectively planned by Co-permittees or another public agency. These subsections presume that a private entity would plan such facilities on their own only as part of a WQMP. Public entities, on the other hand, may plan these facilities on their own or under a private-public partnership using any mechanism they choose, including a WQMP. But whatever the planning mechanism, LID BMPs would also be given the equal consideration the commenter requests. The commenter particularly objects to Subsection XII.K.2.d. This subsection is essentially a catch-all for scenarios not already considered in Subsections XII.K.2.a., b., or c. In the Subsection XII.K.2.d. scenario, the origin of the off-site LID BMP is not known. One possible scenario would be coordination between two or more private entities to use an existing older facility where: there is no WQMP for the facility or the WQMP cannot be located; the design standards used for the facility are unknown; and/or the facility is defective (e.g. the facility cannot be identified, it is undersized, etc.) and may require improvements. Regional Board staff believes that scenarios under Subsection XII.K.2.d. will be exceptionally rare. Because of the uncertainties surrounding this type of facility, the Provisions under Subsection XII.K.2.d. are intended to be protective.
16.60	6/20/2014	County of Orange	The requirements for non-priority projects should be clear and consistent with the 2011 Model WQMP. The definition of a non-priority project should be consistent with the 2011 Model WQMP and Technical Guidance Document. The language of Section XII.M.1. regarding source control, site design, and structural treatment controls is ambiguous. Section XII.M.3.b. confuses source controls and site design with structural treatment controls and should be deleted. The commenter contends that the qualifications of the approving personnel for non-priority projects will add thousands of dollars of unnecessary costs but later suggests that the increase in costs is due to the required qualifications of the preparer.	The commenter raises several distinct issues. The definition of a non-priority project should be consistent with the term as applied in the current permit: a project that is not a priority project. As part of the preparation of the 2011 Model WQMP and Technical Guidance Document, the Co-permittees narrowed down the number of non-priority projects requiring a plan by re-defining a non-priority project. Regional board staff did not object to this because we recognized that the term "non-priority" project was exceptionally inclusive. Since then, Regional Board staff has realized that the Co-permittees' approach is overly-narrow and leaves out projects that could apply source control and site design BMPs, in conflict with the maximum extent practicable standard. See also Responses 7.7 and 14.13. The commenter's remarks about the ambiguity in Provision XII.M.1. regarding source control, site design, and structural treatment controls is accompanied by a strike-out of the statement indicating that structural treatment controls for non-priority projects are not presumed to be infeasible. The concept of structural treatment controls for non-priority projects is carried over from the current Permit where, in Provision XII.B.7. non-priority projects "may or may not include treatment control BMPs". It is appropriate that the Draft Permit continue to contain language regarding structural treatment control BMPs for non-priority projects. However, Regional Board staff declines to establish further criteria for what needs to be required for non-priority projects, and instead, leaves the matter to the Co-permittees' discretion as is done in the current Permit. Regional Board staff agrees that the language of Provision XII.M.3.b. is confusing and we have revised this provision. Provision XII.M.5. allows persons "under the supervision of a registered civil engineer or licensed landscape architect" to approve non-priority project plans. See also Response 7.9.

16.61	6/20/2014	County of Orange	All engineered channels should be exempt from hydro-modification requirements. The word "hardened" should be removed from Provisions XII.N.1.b. and XII.N.3.	An engineered channel is not necessarily stable under current design guidelines. This may occur when a channel was originally constructed under older design standards. Conversely, a channel that is un-hardened also is not necessarily unstable. Therefore, limiting the exemption to "hardened" channels is inappropriate. Regional Board staff concurs that "hardened" should be removed.
16.62	6/20/2014	County of Orange	The hydro-modification criteria in Subsection XII.N.2. should be consistent with the current Permit and the 2011 Model WQMP and Technical Guidance Document.	Regional Board staff concurs and has amended the draft Permit.
16.63	6/20/2014	County of Orange	The "alternative compliance program" described in the 2011 Model WQMP and Technical Guidance Document should be continued in the Draft Permit.	See Responses 7.5 and 10.4.
16.64	6/20/2014	County of Orange	Section XIII.b.5. requires the Co-permittees to develop educational content with the "most" potential to appeal to audiences. This cannot be demonstrated and should be deleted. The rationale in the written plan required by Provision XIII.b.5. should be deemed to meet this requirement.	The commenter appears to be remarking on Provision XIII.b.4. The phrasing is intended to be instructive by setting a goal for the educational content. It is not intended to serve as an objective way of determining compliance. The initial selection of the content is expected to occur in a subjective way, with public input. However, the effectiveness of the content is to be assessed based on measurable objectives. The measurable objectives will be established by the Co-permittees as part of the written plan according to Provision XIII.b.6. If the content is not effective, the Co-permittees must adapt the content. This general "iterative" approach is required in Section I of the Draft Permit and applies across all storm water program elements.
16.65	6/20/2014	County of Orange	Completion of three campaigns to address high-priority urban runoff pollution issues within the permit term is infeasible. The Draft Permit language requires the campaigns to be initiated but it is infeasible to complete the campaigns within a permit term.	A water quality issue is not necessarily the same as a public education campaign. A public education campaign may focus on changing one behavior in order to address several water quality issues. Likewise, one water quality issue may be addressed by focusing on multiple behaviors. The draft Permit does not require that a campaign be completed within the term of the permit; to do so is arbitrary and may undermine the effectiveness of a campaign by ending it too soon or too late. Regional Board staff has amended the revised draft Permit to clarify this matter.
16.66	6/20/2014	County of Orange	The approach for drainage facility management was modified from the current Permit without technical justification. Subsection XIV.C. expands the inspection program to "flood management and storm water conveyance systems" where the Draft Permit now includes underground facilities. The phrase "unusually large quantities" of pollutants is new terminology and has no technical basis.	See Response 7.10. See also Response 15.2. regarding the assignment of responsibility. The phrase "unusually large quantities" is not a technical term. The purpose of the requirement is to allow Co-permittees to prioritize their cleaning frequency. The Co-permittees are tasked with establishing a technical rationale for determining its practical meaning. "Accumulated pollutants" means pollutants that have accumulated; it is also not a technical term. This certainly would not include mobile pollutants such as suspended pathogens and dissolved wastes. Subsection XIV.C. assumes that an "accumulated pollutant" is also a removable pollutant. For clarity, Regional Board staff will indicate that the pollutants will be detected based on visual observation and cleaning will be performed mechanically or physically.

16.67	6/20/2014	County of Orange	The approach described in Subsection XIV.E. is overly prescriptive. It one case, it requires "disciplinary procedures". This requirement goes well beyond the manner of compliance prohibition in Water Code Section 13360 and does not demonstrate a direct effect on water quality. The Regional Board has no authority to mandate requirements that affect the labor and employment practices of the Co-permittees.	See Response 5.4.
16.68	6/20/2014	County of Orange	The requirement for program effectiveness assessments do not link to known guidance materials. There is very little guidance developed by the State or USEPA. The California Stormwater Quality Association (CASQA) has documents that provide clear guidance to storm water managers. This document should be referenced in the Draft Permit.	The development and use of performance metrics is a well-studied practice in business, education, and medical care. There are other resources available that are widely accepted and used and which may be adapted to storm water quality management. Nevertheless, the Co-permittees have the discretion to use whatever resources they believe are most useful.
16.69	6/20/2014	County of Orange	The commenter requests various changes to Section XVIII and Appendices B through G and eslewhere to provide clarity and ensure that the provisions reflect the intent of the Regional Board. The commenter provides specific changes that reflect their own intentions.	Regional Board staff has made various changes in Appendices B through H to improve their clarity as appropriate. Requirements to develop methods to determine compliance with the water quality-based effluent limits in Appendices B through H have been moved to the Monitoring and Reporting Program. There is a statement in each of the Appendices that compliance with the water quality-based effluent limitations in those Appendices will be determined pursuant to the methods required in Section XVIII.
16.70	6/20/2014	County of Orange	The process in Section XVIII presents time schedules for developing compliance plans for waste load allocations that are inconsistent with schedules in the related Basin Plan amendments. The commenters recommend changes that would create two categories of plans based on whether or not the Basin Plan amendment requires the plans.	Regional Board staff has considered the recommended changes to Section XVIII and rejected many of them. The creation of two categories of plans for compliance is unnecessarily complicated. Although some of the TMDLs do not require plans, this does not preclude the Order from having such requirements. Regional Board staff has made changes that relate compliance with the water quality-based effluent limitations in Appendices B through H to Section XVIII. to clarify that the effluent limitations are not stand-alone provisions.
16.71	6/20/2014	County of Orange	The commenter requests that changes be made in the Draft Permit that expressly recognizes that plans that are being developed, or have been approved, for the purpose of complying with waste load allocations, are sufficient for BMP-based compliance purposes.	Regional Board staff has reviewed the related Basin Plan amendments and found that all of the plans are past their due dates. It is appropriate then that, where plans have not been submitted and approved, new due dates be established as part of the Permit. Where a plan has been approved, it should be implemented until and unless a monitoring, analysis, and reporting period elapses and waste load allocations are not met.
16.72	6/20/2014	County of Orange	The commenter requests that 18 months be provided to allow the development of compliance plans for waste load allocations. This request is based on practical experience and would apply only to new plans or plans currently required in the related Basin Plan amendments.	Section XVIII has been re-written. If the Co-permittees elect to develop a WQBEL compliance plan, they will have either 180-days from the effective date of the Order to submit a notice of their intent, plus an additional 6-months to submit a draft plan. Another 60-days is provided to make required amendments. With the additional 50-days to the effective date of the Order, this will provide over 15-months for the Co-permittees to develop the compliance plans.

16.73	6/20/2014	County of Orange	The commenter requests two methods to provide consistency between the monitoring and reporting requirements of the Draft Permit and requirements for each of the adopted TMDLs.	Regional Board staff concurs and has amended the draft Permit to require consistency with the TMDLs' monitoring and reporting requirements.
16.74	6/20/2014	County of Orange	The commender points out specific inconsistencies between the waste load allocations and requirements in Appendices B through H and the related Basin Plan amendments.	Regional Board staff has reviewed the recommended changes in the Appendices. Many of the changes appear to be based on different preferences on how to present the water quality-based effluent limits. Generally, those recommended changes did not provide new information or improve how the water quality-based effluent limitations are communicated; nevertheless, the changes were generally accommodated. In some cases, the changes involved the addition of relevant information and so changes have been made accordingly.
16.75	6/20/2014	County of Orange	The Draft Permit is not the appropriate mechanism to implement the load allocation in the Sediment TMDL. Federal regulation 40CFR122.44(d)(1)(vii)(B) specifies that effluent limits must be consistent with "any available wasteload allocation", not load allocation.	The allocations in the Basin Plan were inadvertently misidentified as load allocations. The load allocations apply to point-source discharges from MS4s and are therefore waste load allocations. The requirements shown in the draft Permit come from the Basin Plan amendments which are assigned to certain Co-permittees. The requirements are intended to achieve the load allocations which, as the commenter notes elsewhere, are measured at San Diego Creek at Campus Drive. This location is a point source discharge from the responsible Co-permittees' MS4s (which are also point source discharges). In addition, the Sediment TMDL was incorporated by reference into the Nutrient TMDL, which expressly applies to point source discharges and contains waste load allocations.
16.76	6/20/2014	County of Orange	Language is needed in the Draft Permit to link the waste load allocations and requirements in Appendices B through H to specific mechanisms for compliance. Otherwise, the Appendices may be viewed as stand-alone provisions.	Regional Board staff agrees in concept. See Response 16.68.
16.77	6/20/2014	County of Orange	The Basin Plan amendments for the TMDLs include waste load allocations in tabular format. These tables include key information in important footnotes that are part of the waste load allocations. The Draft Permit restates the tables in the Basin Plan amendments and further segregated the text into separate sections within each appendix. This approach introduces language that is contrary to the Basin Plan amendments and is confusing.	The waste load allocations have been presented in tabular format. Key information is presented in notes that appear directly under the tables rather than the page footers. Key information should not be relegated to footers.

16.78	6/20/2014	County of Orange	The TMDL provisions in Appendices A though H have inconsistencies with the relevant Basin Plan Amendments. Sediment load allocations are improperly included. The Resolution cited for the Organophosphate Pesticide TMDL does not apply to the Toxics TMDL and was not adopted by the Regional Board. Certain aspects of the Organophosphate Pesticide TMDL have been superceded by Basin Plan amendments. The Regional Board did not adopt a Basin Plan amendment for organochlorines for the Rhine Channel in 2003. The compliance date for the organochlorines TMDL should be December 31, 2020 pursuant to the Basin Plan Amendment. The schedule and actions in the implementation schedule for the Metals TMDL for Coyote Creek are not included in Appendix H. Finally, the text explanation for the Nutrient TMDL is unclear and lacks implementation dates for each waste load allocation. The general use of text to describe waste load allocations instead of tables, introduces inconsistencies with the related Basin Plan amendments.	See Responses 16.74, 16.73, 16.76. and 13.10. Regional Board staff has corrected the compliance date for the organochlorines TMDL.
16.79	6/20/2014	County of Orange	The Permittees should have flexibility in how they develop the Water Quality Monitoring Plan in Section II of the Monitoring and Reporting Program ("MRP"). The purpose of Subsection II.B.2. of the MRP is to integrate TMDL monitoring with the outfall monitoring, receiving water monitoring, toxicity testing and other types of monitoring required. This is difficult. Certain monitoring activities are dynamic and monitoring and analysis and related conclusions are out of phase with the August 1 deadline proposed in Provision II.B.6. of the MRP. The Co-permittees should be allowed to submit additional changes after the August 1 deadline.	The purpose of Subsection II.B.2. is on its face: to describe processes for determining compliance with waste load allocations and requirement in Appendices B though H. The extent to which the Co-permittees integrate various monitoring efforts and achieve efficiencies is up the the Co-permittees' discretion and capabilities. The August 1 deadline does not prohibit the Co-permittees from submitting proposed changes before or afterwards. Regional Board staff has made changes to provide the flexibility desired by the commenter.
16.80	6/20/2014	County of Orange	The commenter recommends specific technical changes to the monitoring requirements in Subsection II.D. of the MRP.	Regional Board staff has made the recommended changes.
16.81	6/20/2014	County of Orange	Table 1 in the MRP is incorrectly referenced by Provision II.E.3. and Subsection II.E.4. The correct reference is Table 2.	Regional Board staff has made the correction.

16.82	6/20/2014	County of Orange	The Test of Significant Toxicity Approach required in Subsection II.F. of the MRP is too unreliable to base regulatory matters. The rate of false failures is between 5 and 40%. Even at the lowest rate of 5% this guarantees at least one false numeric effluent limit "violation" over a 5-year permit term. The TST approach is a guidance document and not a rule and there is no justification in the Technical Report for its use. As such, toxicity testing requirements should remain the same as the previous permit.	Based on the reports listed below, Regional Board staff has concluded that the TST is the more transparent and superior statistical approach for analyzing Whole Effluent Toxicity test data compared to the statistical approaches used under the current Permit. The “false failure” rate alleged by the commenter is based on an overly-broad definition of false failure that is not supported by actual effluent and ambient water toxicity data generated by thousands of toxicity tests in California (Diamond et al, 2013). The “Test Drive” in California demonstrated that more than 90% of the samples tested for toxicity would be categorized the same regardless of whether or not the TST approach or the current approach had been used (California SWRCB, 2011). Both the “Test Drive” report and Diamond et al (2013) show that the TST classified toxic and nontoxic samples more correctly than the current NOEC-LOEC approach. Neither report supports the commenter’s claim that the TST results in a false positive rate that is up to three times higher than the current approach. The SWRCB has already addressed the claim that the false positive rate of the TST is greater than USEPAs’ 1999 “Blank” Study when it concluded, for example, that, based on a detailed review of individual toxicity test results, the alleged higher false positive rate related to *C. dubia* was incorrect and overblown. Even if two of the 27 blank tests were indeed false positives, 7.4% is well within the population error rate of 5% for such a small sample size (n=27). The commenter’s complaint that false failures could place the Co-permittees in jeopardy of noncompliance is addressed by the statistical approach. The false positive rate of the current approach and the false negative rate of the TST are set at 5% or less in the sense of long-run frequency. Both approaches have the same probability that samples will be declared toxic when they are truly nontoxic. It is theoretically possible that a Co-permittee could be subject to enforcement action based on a single WET limit exceedance. However, USEPA and the SWRCB do not recommend enforcement action for a single exceedance causing no known harm. Furthermore, single, wholly past exceedances of WET limits do not provide standing for citizen plaintiffs. References: California State Water Resources Control Board, December 2011. Effluent, Stormwater, and Ambient Toxicity Test Drive Analysis of the Test of Significant Toxicity (TST). Diamond, JM; Denton DL; Roberts JW Jr.; Zheng, L . 2013. Evaluation of the test of significant toxicity for determining the toxicity of effluents and ambient water samples, *Environmental Toxicology & Chemistry* 2013 April; 32(5): 1101-8. USEPA, July 2011. Whole Effluent Toxicity Test Drive Analysis of the Test of Significant Toxicity
16.83	6/20/2014	County of Orange	Whole Effluent Toxicity ("WET") testing was developed to test effluent from publicly-owned treatment works and other similar dischargers. Using WET testing directly on receiving waters is not necessarily applicable.	In the interest of providing the Co-permittees with flexibility, the method of toxicity testing will be omitted.
16.84	6/20/2014	County of Orange	The toxicity testing required in Section II.F.2. needs to specify whether samples are to be collected from outfalls or in receiving waters; it appears that these should be receiving waters.	Regional Board staff has made the correction.

16.85	6/20/2014	County of Orange	The commenter recommends the use of sea urchin fertilization toxicity testing over sea urchin embryo development toxicity testing required in Provisions II.F.2 and 5.	Regional Board staff has made the recommended change.
16.86	6/20/2014	County of Orange	Provision II.E.2. and II.F.7. will require quarterly sediment toxicity testing versus the current annual testing.	The change in frequency is an error and has been corrected.
16.87	6/20/2014	County of Orange	Provisions II.F.1., 2., 4., and 5. identify toxicity monitoring frequencies for dry and wet aquatic and sediment testing. These frequencies should be related to the frequencies for outfall monitoring and receiving water monitoring in Subsections II.D. and II.E. respectively.	Regional Board staff has made the recommended changes.
16.88	6/20/2014	County of Orange	The language of Subsection II.B. of the MRP needs to be clarified that this is a monitoring program for the harbors and estuaries sites and should be sampled on an annual basis concurrent with the monitoring sites selected each even or odd year under the receiving waters monitoring program.	Regional Board staff has made the recommended changes.
16.89	6/20/2014	County of Orange	Language on the illicit discharge/illicit connections program in Provisions VII.D.5. through 9. is more appropriately located in the MRP. "Dry season", as used in Provision II.H.1. needs to be defined.	Regional Board staff agrees and has relocated and amended the language.
16.90	6/20/2014	County of Orange	Provision II.H.2. does not accurately represent the methods used to select illicit discharge/illicit connection monitoring locations. These locations are selected each spring for sampling the following year.	Regional Board staff has made changes accordingly.
16.91	6/20/2014	County of Orange	The language of Subsection II.J. is not sufficiently flexible to allow the Co-permittees to revise their approach if the Stormwater Monitoring Coalition monitoring program is modified.	Regional Board staff has modified the language to improve flexibility.

16.92	6/20/2014	County of Orange	The requirement in Section II.J. of the MRP to perform Causal Assessments if premature. The specific process for conducting and interpreting Causal Assessements is still being evaluated by the State Water Resources Control Board. There are unresolved issues on how Causal Assessments will be applied to "modified" channels.	After further consideration, Regional Board staff believes that performing Causal Assessments annually may be overly ambitious until the process becomes more streamlined. The language of the draft Permit has been modified to require the performance of one Causal Assessment during the Permit term. Regional Board staff disagrees that the performance of Causal Assessments is premature. By performing a Causal Assessment the Co-permittees will be advancing approaches and techniques for regional assessments and advancing our collective knowledge of stressors on receiving waters. That there are unresolved issues on the application of Causal Assessments to modified channels is not a convincing reason to not perform them. Causal Assessments are a process to determine what stressors have led to low bioassessment scores. The process will allow users to identify controllable and uncontrollable factors contributing to degraded biological integrity. Uncertainty regarding the application of this knowledge is a separate matter that should not preclude performance of Causal Assessments.
16.93	6/20/2014	County of Orange	The requirement for a work plan under Section II.L.2. of the MRP should be consolidated with the requirement for the revised Water Quality Monitoring Plan in Section II.B.6.	Regional Board staff has no preference on the mechanism for providing the required annual work plan and we have no objection to its consolidation with other annual reports. The language of Section L. has been modified to provide flexibility in the mechanism used to submit the work plan.
17.1	6/20/2014	Disneyland Resort	The commenter requests that an "alternative compliance and in lieu program" be continued in the Draft Permit for projects where structural treatment control BMPs are not feasible. Specific language is recommended.	See Responses 7.5 and 10.4.
18.1	6/20/2014	Construction Industry Coalition on Water Quality	The broad requirements on non-priority projects will create a new bureaucratic process and project review layer, and impose additional compliance costs for projects that pose little or no threat to water quality.	See Responses 7.7 and 14.13.
18.2	6/20/2014	Construction Industry Coalition on Water Quality	The General and Specific Plan requirements in Subsection XII.A. seem unnecessary and the commenter suggests deleting them from the Draft Permit.	See Response 16.32.
18.3	6/20/2014	Construction Industry Coalition on Water Quality	The commenter sees no justification in any Draft Permit Finding for changing the existing process for project WQMP approval. The draft Permit language creates inflexibility and stifles innovation rather than fostering it. The Model WQMP and the Technical Guidance Document provide the necessary engineering guidance and design criteria; these documents can be changed as new information is gathered, whereas the Permit is generally fixed.	The justification for reducing the draft Permit's reliance on 'incorporation by reference' is explained in the Technical Report, which is incorporated by Finding 40. The requirements of Section XII regarding project WQMPs establish certain requirements that are based on key elements of the 2011 Model WQMP and the Technical Guidance Document. These elements are fundamental and unlikely to change over the term of the Permit; as such, they have been fixed within the Permit language. However, the draft Permit language is not intended to provide all of the detail needed to prepare a project WQMP. This is left to the "uniform written technical guidance" described in Provision XII.C.2. The flexibility and innovation desired by the commenter may be achieved through the uniform technical guidance, necessarily within the bounds of the Permit requirements. The commenter has not provided specific instances of language in the draft Permit that is overly-restrictive. The Co-permittees have identified specific instances and Regional Board staff has made various changes to the revised draft Permit accordingly. See Responses 16.50 through 16.63.

18.4	6/20/2014	Construction Industry Coalition on Water Quality	The commenter is concerned about the loss of compensatory programs for new development projects that cannot reliably retain the design capture volume and do not have an off-site BMP option available. This will discourage advancements in the storm water program by reducing available options.	Since the Regional Board's approval of the 2011 Model WQMP and Technical Guidance Document, the Co-permittees have never reported information that suggests a need for the compensatory programs. During the term of the current Permit, there have also been no applications for waivers reported by the Co-permittees. In some instances, the alternative compliance programs may do more harm over the long term. Credit programs may provide more options for an individual project, but they may also discourage the development of regional or sub-regional facilities that may provide much broader benefits. This may occur because a project that receives a credit generated in another watershed may have no incentive to participate with other property/project owners in the development of a facility in its own watershed. A short-term "advancement" for one project can become a long-term impediment for others. In such a situation, granting a waiver may be preferred over foreclosing on a future opportunity for other projects in that watershed. Regional Board staff questions the need for the alternative compliance programs except in very narrow situations. But in consideration of these narrow situations, alternative compliance programs have been reintroduced in the revised draft Permit with conditions. See Responses 7.5 and 10.4.
18.5	6/20/2014	Construction Industry Coalition on Water Quality	The commenter is unconvinced that the 1.5 sizing factor for biotreatment control BMPs is adequately supported by technical evidence.	See Response 16.53.
18.6	6/20/2014	Construction Industry Coalition on Water Quality	The commenter supports amendments proposed by The Irvine Company.	See Response 11.1.
19.1	6/20/2014	City of Irvine	"The City is very concerned that some of the prescriptive requirements of the Draft Order…may actually cause increased pollutant loading (and loading in more bio-available forms) in the Newport Bay Watershed, while at the same creating a disincentive for Co-Permittees, and the developers they regulate, to undertake regional projects that produce large scale pollutant removal and improvements in watershed health."	The comment contains broad generalizations that the commenter supports with more detailed remarks elsewhere in their comment letter. The comment will be addressed through responses to the commenter's more detailed remarks.
19.2	6/20/2014	City of Irvine	"Much of the pollutant loading within natural and man-made drainages within the City results from non-point source pollution, selenium and other non-anthropogenic substances that passively discharge into the MS4 from numerous seeps, springs, and weep holes in areas throughout the City with a historical presence of high groundwater."	The commenter has provided a selective description of the causes of the pollutant loading. The pollutant loading into Newport Bay is caused by changes to the watershed's hydrology which occurred to facilitate development. These changes include the construction of flood control channels to drain wetlands and lower the water table and the subsequent and ongoing disposal of the drained water to the Bay. Prior to the construction of the flood control channels, the hydrological connection to Newport Bay was intermittent or highly limited. While the development was not the source of the pollutants, the drainage infrastructure that supports the development is the ultimate conveyance of pollutants contributing to the impairment of Newport Bay. This drainage infrastructure includes outfalls that now add pollutants to the Bay. Consequently, the discharge from the MS4 is a point source discharge.

19.3	6/20/2014	City of Irvine	Because of the diffuse nature, conventional treatment approaches can be difficult or impossible to implement within the City. The best prevention of pollutant loading within the City is generally to keep the rising groundwater in the ground and to utilize natural treatment systems such as treatment wetlands to remove pollutants - an approach that appears to be disfavored in the draft Permit.	The approach of "keeping rising groundwater in the ground" runs counter to the purpose of much of the City's drainage infrastructure. The rising groundwater must be collected and disposed of before it creates soil conditions that threaten structures built in low-lying areas (e.g. hydrostatic pressure) or even causes flooding in low-lying areas: this is a function of the weep hole-channel design. The commenter's perception that the use of natural treatment systems is in disfavor is a matter of regulatory nuance. The term "natural treatment system" has no regulatory definition and Regional Board staff is not aware of a published definition from the entity coining the term, Irvine Ranch Water District. Nearly all water bodies have the ability to attenuate pollution (although it may not be sufficient to protect its beneficial uses). The plain meaning of the term "natural treatment system" would include natural channels and water bodies. Therefore, the term is too inclusive to use in the draft Permit. Instead, the draft Permit uses the terms "structural treatment control BMP" or "structural treatment control". Regional Board staff has no objection to “natural treatment systems” per se,
19.4	6/20/2014	City of Irvine	Retention-based LID BMPs "should not be treated as an end unto itself" in the absence of a showing that they remove pollutants from storm water to the maximum extent practicable within the Newport Bay Watershed. It is difficult to see how the Regional Board could "make a finding of MEP pollutant removal within the Newport Bay Watershed for retention based LID BMPs" given the evidence provided by the City and in numerous prior Regional Board documents, that the implementation of retention/infiltration based BMPs in the City is likely to result in greater discharge of pollutant loading to receiving waters than would occur without.	The Regional Board has made no such finding pertaining to the City and the Newport Bay Watershed in the draft Permit. The term "retention LID BMP" includes harvest and use and other methods that do not rely on infiltration. Retention LID BMPs are not an "end unto itself" as alleged by the City. They serve the legitimate purpose of removing pollutants from storm water runoff. Retention LID BMPs are not mandated in the draft Permit to the exclusion of other less-preferred solutions. The City has options to avoid unmitigatable environmental hazards such as "greater discharge of pollutant loading" where they may occur based on substantial evidence.
19.5	6/20/2014	City of Irvine	Section IV and XII of the draft Order should be harmonized to allow for selection of "non-retention based BMPs", without penalty or increased BMP sizing, where infiltration can be reasonably anticipated to cause exceedances of groundwater objectives.	Not all retention LID BMPs require infiltration; retention LID BMPs do not all pose the same hazards. The "penalty" or "increased sizing" are intended to improve the performance of biotreatment LID BMPs so that their expected performance is comparable to retention LID BMPs, not to punish the Co-permittees or the project proponent. The draft Permit language allows selection of "non-retention based BMPs" based on certain considerations; the language does not require "special permission".
19.6	6/20/2014	City of Irvine	Section XII of the draft Permit should be revised to provide that "retention based LID BMPs" are not required to receive primary consideration in any location where there are documented high groundwater levels containing pollutants of concern or where their use is likely to interfere with the attainment and maintenance of beneficial uses of groundwater.	Not all retention LID BMPs require infiltration and pose hazards to groundwater quality. To do as the commenter requests would preclude other types of retention LID BMPs based on issues that are not relevant.
19.7	6/20/2014	City of Irvine	The 1.5 sizing factor for biotreatment control BMPs places an undue burden on Irvine projects without sufficient technical justification and is mandated in contravention of the MEP standard.	See Responses 4.2, 5.2, and 16.53.

19.8	6/20/2014	City of Irvine	As proposed, the use of regional treatment options is only available if those BMPs infiltrate a portion of the design capture volume. This makes regional treatment infeasible within the City due to hazards related to groundwater quality. This also appears to make the NTS regional treatment locations also ineligible to provide treatment for redevelopment projects within their drainage boundaries.	Not all NTS designs are the same. Consequently, not all NTS designs will be ineligible for use as regional or subregional structural treatment controls based on whether or not they permit or promote infiltration. Some will be ineligible due to their inability to meet sizing or design standards. Others will be ineligible because they are not intended to, or cannot satisfy the requirements of the MS4 Permit for new development. The circumstances need to be evaluated on a case-by-case basis. If an infiltration LID BMP is infeasible due to unmitigatable hazards to groundwater quality, the City may allow a project proponent to choose other retention LID BMPs. An off-site biotreatment control BMP is also permissible under Subsection XII.K.2.c. An NTS is allowable if it meets the requirements in Subsection XII.K.
19.9	6/20/2014	City of Irvine	No matter how rigorous a program that the City implements and no matter how much money it spends, it is unlikely that the Co-permittees will ever be able to guarantee compliance throughout the Newport Bay Watershed at least with the current CTR criteria for selenium. CWA does not require MS4s to strictly comply with water quality standards under Section 301.	The draft Permit does not require that the Co-permittees guarantee compliance or to strictly comply with water quality standards. The draft Permit, in large part, describes an iterative process towards achieving water quality standards in conformance with federal regulations.
19.10	6/20/2014	City of Irvine	The City objects to the rapid expansion of non-priority projects subject to non-priority project plans.	See Responses 7.7 and 14.13.

ATTACHMENT 1

USEPA Staff Remarks on Comments Regarding the Proposed 1.5 Sizing Factor for Biotreatment Control BMPs

From an electronic message from USEPA staff to Regional Board staff dated October 8, 2014

We understand that Orange County has objected to the requirement in the draft MS4 permit for Orange County that the design storm for biotreatment facilities be 1.5 times that for retention facilities (comment #52 in the County's letter of June 20, 2014). For reasons discussed below, we continue to support the 1.5 factor. Orange County's objection is based on claims that:

1) The 1.5 factor was obtained from an analysis specific to Ventura County and would not be applicable in Orange County

2) The harvest/reuse retention option can actually result in discharges of pollutants larger than biotreatment

Regarding the first claim, many of the factors going into the derivation of the 1.5 factor in the Ventura County Guidance Manual (Appendix D) are not unique to Ventura County and would be just as applicable to Orange County as they are to Ventura County. Further, factors that are unique to Ventura County have a very minor effect on the value of the factor which is derived.

For example, the BMP effectiveness data for biotreatment facilities were obtained from literature data such as the international BMP database and are not specific to Ventura County. The incidental infiltration estimates for biotreatment facilities are also based on literature data rather than Ventura County data. As such, we believe it would reasonable to use this information to derive the factor in question in both counties.

One factor used in the Ventura County analysis that is specific to Ventura County is the % capture volume for retention facilities found in a 2003 CASQA manual for 48-hour drawdown at the Oxnard Gauge. However, similar data in the CASQA manual for Orange County show that the % capture volume would be slightly higher in Orange County – and following the procedures used to derive the 1.5 factor, this would ultimately lead to a factor for Orange County slightly higher than 1.5.

Similarly, if a lower incidental infiltration factor for biotreatment facilities were assumed for Orange County (due to poor infiltration conditions as sometimes alleged by the County) than was assumed for Ventura County, this would also lead to a factor higher than 1.5 for Orange County. However, given the wide range in incidental infiltration rates that have been noted in literature data, we believe further refinement of the 1.5 factor based on this consideration would be questionable.

Regarding the second claim concerning harvesting/reuse, it should be noted that this is just one of several retention options available. The draft permit requires LID controls consisting of harvest/reuse, evaporation/transpiration, infiltration or any combination thereof. The paper cited by the County in its comments (Water Report Issue 65) notes that harvesting/reuse is much less common than infiltration. As such, we believe it's more appropriate to base the factor on the relative performance of the more common BMPs of biotreatment and retention. Moreover, the analysis cited by the County only considers toilet flushing and irrigation as potential uses for the water; the County's 2011 Technical Guidance Document notes other potential uses such as vehicle washing, evaporative cooling and industrial processes. In applications where other uses such as these would be available, the conclusions in the analysis cited by the County would not be valid.

There are also other reasons to favor retention over biotreatment. One is replenishment of groundwater supplies given that biotreatment facilities will discharge much of influent water. There is also a wide range in the pollutant removal performance for biotreatment facilities leading to uncertainties in the degree of receiving water protection that is provided. We note that both the Los Angeles County and San Diego Regional MS4 permits include the 1.5 factor and we recommend it be retained in the Orange County permit.

Finally, if the 1.5 factor is no longer used, we'd recommend that biotreatment controls be considered the same as other non-LID treatment control BMPs. That is, if retention BMPs (not "retention or biotreatment BMPs") are not feasible, the permit should require the implementation of on-site treatment control BMPs AND the implementation of off-site mitigation projects for any portion of the design capture volume for which retention is determined to be infeasible.

Eugene Bromley
NPDES Permits Office (WTR-5)
EPA Region 9

ASSOCIATION OF CALIFORNIA CITIES
ORANGE COUNTY

May 18, 2014

Mr. Kurt Berchtold, Executive Officer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501

BY ELECTRONIC MAIL ONLY TO KBERCHTOLD@WATERBOARDS.CA.GOV

Re: North Orange County MS4 Permit Workshop

Dear Mr. Berchtold:

The Association of California Cities – Orange County (ACC-OC) is our region's leading advocate for local control and municipal governments. We represent the interests of all 34 Orange County Cities are a governed by a 23-member Board of Directors, composed of elected officials, industry leaders and city staff.

We are in receipt of your Notice of the upcoming workshop to discuss the draft MS4 Permit ("Permit") for North Orange County on May 19. As the capacity of the venue, as well as time available for comments and questions, is unknown, I would ask that you or your staff provide justification for the following provisions in the Permit to better help us understand their aim.

2.1 **(Section III.B.3)** This appears to add a requirement for Permittees to submit Report of Waste Discharge for de minimus discharges. What is the Regional Board's intent to add this new requirement?

2.2 **(Section XII.A)** This section appears to require cities add specific water quality regulations and mitigation measures as part of updates to General or Specific plans. Please explain this new requirement and its intended outcome.

2.3 **(Section XII.C)** Requires WQMPs to be "recorded in public records with County and/or the relevant City." As these documents are often hundreds – if not thousands – of pages long and are updated frequently, does the Regional Board expect that each city record

2.3 the WQMPs with the County Clerk-Recorder as well as onsite at city halls? If so, what would the Regional Board believe to be a reasonable time frame for updating the records (e.g. every year, six months, etc.)?

2.4 **(Section XII.D.10)** This section of the Permit requires the cities to "security the authority" to enter into private property to inspect and maintain the property. We are interested to know what limitations the Regional Board intends on placing on this requirement as it seems there are property and privacy rights implicated by this element of the Permit, especially as it relates to individuals' homes and businesses. Is the Regional Board requiring individuals to waive these rights if they have a water quality management plan associated with their property?

2.5 **(Section XII.C.12)** Provides new requirement for electronic database of WQMP data, requiring that all WQMP's back to 2009 be included. What is the Regional Board's rationale for requiring five years of WQMPs, approved under a previous Permit, as part of this electronic database?

2.6 **(Section XIII.B)** Specifies that "Co-permittees must" endeavor on an extensive public education efforts that, among other requirements, must achieve "a minimum of 10 million impressions" using a number of measures. Does the Regional Board expect each co-permittee to meet such requirements or is the intent to ensure the Principal Permittee achieves these measurable objectives?

Thank you for your kind attention to this matter and we will look forward to discussion of these items. Please contact me at (714) 953-1300 or lkelly@accoc.org with any questions.

Sincerely,

Lacy Kelly

Lacy Kelly
Chief Executive Officer
Association of California Cities – Orange County

From:	Shanda Beltran
To:	Berchtold, Kurt@Waterboards
Cc:	Fischer, Adam@Waterboards
Subject:	Letter for consideration at 5/19 Workshop
Date:	Sunday, May 18, 2014 9:20:42 PM
Attachments:	Letter to RWQCB on North OC MS4 Permit Workshop 5_18_14 Signed.pdf

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Please see the attached letter for consideration at the workshop on the North OC MS4 Permit tomorrow, May 19th, 2014.

Regards,

Shanda Beltran

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May 18, 2014

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Mr. Kurt Berchtold, Executive Officer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501

By Electronic Mail Only To: kberchtold@waterboards.ca.gov

Re: North Orange County MS4 Permit Workshop

Dear Mr. Berchtold:

On behalf of the Building Industry Association of Southern California, Inc. ("BIASC") we write to you today regarding the workshop to discuss the draft municipal separate storm sewer system ("MS$ Permit" or "Permit") for North Orange County (Order No. R8-2014-0002) on May 19, 2014. BIASC is a nonprofit trade association representing over 1,000 member companies involved in planning and building Southern California's communities. Our members are involved in all aspects of construction and green building—from architecture to roofing to landscape design.

We recognize that the workshop on May 19th only allows for 90 people to attend, and it is not clear whether we will be allowed to speak. Accordingly, please have your staff describe, at the time of workshop, the rationale for the following requirements in the Permit, so that we may understand the intent:

4.1

1. We thank the Santa Ana Regional Water Quality Control Board ("Board") staff for including provisions in the Receiving Waters Limitation section (§ IV.D) and the Total Maximum Daily Load ("TMDL") Implementation (§XVIII.B.1) section of the Permit that provide an iterative process as the method of compliance for permittees that may need to avail themselves of such processes in order to meet TMDL requirements or receiving water limitations. We are interested if the intent of the Board is to ensure that permittees will not be subject to third-party enforcement if they are diligently implementing an iterative process?"

4.2

2. With regard to the Biotreatment BMP requirements discussed in Section XII.G.1 of the Permit, would the Board cite or provide additional evidence, in addition to the report cited in the draft Technical Report (Appendix D, BMP Performance Guidance, to the Ventura County Technical Guidance Manual for Storm Water Quality Control Measures-Manual Update 2011) that the application of the 1.5 times sizing factor for biotreatment low impact design ("LID") Best Management Practices ("BMPs") is appropriate for Orange County?

4.3

3. Regarding the requirements for LID retention BMPs, the Permit appears to allow on-site LID BMP retention or certain types off-site LID BMP retention options, which is a welcome development. However, Finding No. 10 and No. 16 of the Permit appear to contradict that intent. We request that the Board staff explain this anomaly.

4.4

4. We have been informed by the lead permittee, the County of Orange, that more than 10,000 acres of projects have been conditioned with LID BMPs since the 2010 permit was adopted—a program we feel satisfies the Maximum Extent Practicable ("MEP") standard by any objective measure. Section XII of the Permit appears to change what has been shown to be an effective program for the application of LID

4.4 BMP principles at all priority development projects in Orange County through the Water Quality Management Plan preparation process. Namely, the Permit appears to create a new structure and selection hierarchy. We would request that Board staff explain the technical underpinning of these changes and why they are necessary given the current successes of the permittee's programs for new development and redevelopment.

4.5 5. We noticed that watershed planning requirements have been essentially removed from the Permit. We would request the Board staff explain why this removal taken place and what purpose the removal might serve.

4.6 6. Section XII.N—Hydrologic Conditions of Concern—of the Permit has been changed significantly from the 2009 Permit. We are curious as to the scientific and engineering rationale for these changes. We would like the Board staff to provide insight into these changes. Also, we note that an important compliance metric, peak flow matching, has been eliminated, and again, we would ask why such a metric was removed from the current draft Permit.

While we reserve our right to make additional comments on the Permit in the future, we thank you for your kind attention to this matter, and we will look forward to discussion of these items.

Sincerely,

Shanda M. Beltran, Esq.
Executive VP & General Counsel

Mark Grey, PhD
Director of Environmental Affairs

cc: adam.fischer@waterboards.ca.gov

Construction Industry Coalition on Water Quality

June 20, 2014

Mr. Adam Fischer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501

Via Email: adam.fischer@waterboards.ca.gov

RE: Comments on Draft Orange County Municipal Separate Storm Sewer System ("MS4") Permit, NPDES Permit No. CAS61080

Dear Mr. Fischer:

The Construction Industry Coalition on Water Quality (CICWQ) is submitting comments concerning the Draft Orange County Municipal Separate Storm Sewer System ("MS4") Permit, NPDES Permit No. CAS61080 (herein referred to as Draft Permit). We are submitting this letter on behalf of the CICWQ membership, which is described below.

CICWQ is an advocacy, education, and research 501(c)(6) non-profit group of trade associations representing builders and trade contractors, home builders, labor unions, landowners, and project developers. The CICWQ membership is comprised of members of four construction and building industry trade associations in southern California: The Associated General Contractors of California, Building Industry Association of Southern California, Engineering Contractors Association, and Southern California Contractors Association, as well as the United Contractors located in San Ramon. Collectively, members of these associations build a significant portion of the transportation, public and private infrastructure, and commercial and residential land development projects in California.

In preparing this comment letter, we draw from many years of our members collective experience working both on public infrastructure and facilities, and private commercial, industrial, and residential development projects in Orange County that are governed by NPDES permits issued by the Santa Ana Regional Water Quality Control Board (Regional Board).

Our review of the Draft Permit notes some helpful clarifications to the permit requirements generally, such as the Regional Board's affirmation of the iterative approach to meet MS4 stormwater discharge compliance obligations. Conversely, we note significant changes to the permit requirements for Section XII. New Development (Including Significant Redevelopment), and find that some proposed changes are not technically supported, or are unjustified at the current time given the evolution, documented accomplishments, and management approach of the Orange County stormwater program. We support these assertions with evidence, and offer suggested improvements to the permit below.

18.1

I. Regional Board staff indicated in a presentation to the Regional Board members on June 13, 2014, that it "concurs that scope of non-priority projects needs to be narrowed" and that "alternative language is being developed" (See Draft Permit, Section XII.M). CICWQ agrees that the applicability requirements of non-priority projects should be closely evaluated, and believes that additional examination will show that applicability requirements are overly broad. And in fact, given input provided by the principal and co-permittees at the Draft Permit Workshop on May 19, 2014, and at the June 13, 2014, Regional Board meeting, such broad project applicability requirements will create a new bureaucratic process and project review layer, and impose additional compliance costs for projects that pose little or no threat to water quality.

18.2

II. Section XII.A of the Draft Permit requires the cities to create and report on specific "measurable and verifiable" items in their General and Specific Plans including specific treatment controls and design features. As the Regional Board knows, the General Plan is an expression of a particular community's development goals and objectives in a broad context. It seems highly irregular and inappropriate to impose precise regulatory requirements in the General Plan which applies to all actions a City may take. The General and Specific Plan requirements of Section XII.A seem unnecessary, and we suggest deleting them from the Draft Permit.

III. Throughout Section XII, we find examples where the Regional Board has extracted Model WQMP and supporting Technical Guidance Document (TGD) guidance information and inserted it into the Draft Permit language in an attempt to reduce "incorporation by reference." In addition, Regional Board staff has indicated that the language drawn from the Model WQMP and TGD in the Draft Permit "reflects a change in how enforcement will occur." At this point in time and given the current state of the Orange County stormwater program, which is using the Model WQMP and TGD process that has been in place since 2011, we see no justification in any Draft Permit Finding for changing the existing process for preparing a WQMP. We know the principal and co-permittees share this viewpoint as well.

18.3

Specific instances of overly prescriptive requirements and process appear throughout Section XII, Subsections D through J, and primarily address LID BMP evaluation and use at priority project sites. For example, Section XII.J is highly prescriptive in requiring harvested water demand calculations that are currently addressed in the TDG in sufficient detail and with sufficient flexibility for different project conditions. The evaluation and use of stormwater harvest and use systems is best addressed comprehensively using the existing Model WQMP LID BMP hierarchy and evaluation process and TGD tools for guidance and direction. Moreover, our concerns about the overly prescriptive language are amplified by the very short time period (including time relative to cycles of development in Orange County) the existing Model WQMP process has been required of project proponents—less than three years. It is unclear to the building and construction industry the findings of "audits" of municipal programs implementing the Model WQMP program enacted in 2011, and the allegation these "audits" demonstrate

a lack of enforcement that would precipitate a course correction of such magnitude as proposed in Section XII.D-J of the Draft Permit.

18.3 While the Regional Board cites the need to provide clarity and create consistency in eliminating "incorporation by reference," the Draft Permit language in effect creates inflexibility and stifles innovation rather than fostering it. The Model WQMP and the TGD provide the necessary engineering guidance and design criteria, as well as the flexibility to adapt to project site conditions; and these documents are adaptive and can be changed as new information is gathered, whereas the permit is generally fixed with respect to adaptation. And, we know from presentations by the principal and co-permittees that they have spent more than $1 million in resources to develop the Model WQMP and TGD. Changing course now is unwarranted, and threatens to undermine the current, positive program momentum.

We understand the staff at the Regional Board has agreed to meet with the principal and co-permittees and their engineering support team to discuss these issues in detail, and we hope that much of the unnecessary prescriptive permit language can be removed in favor of reliance on the existing Model WQMP and TGD processes.

IV. We appreciate the positive development toward providing clear, approvable pathways for the responsible and appropriate use of sub-regional and regional opportunities for managing stormwater runoff from a priority project (Section XII.K. Off-site Structural Treatment Control BMPs: Regional and Sub-Regional Facilities). However, we note that the 2009 MS4 permit's in-lieu or alternative compliance provisions have been eliminated in favor of those requirements defined in Section XII.K a-d and in Section XII.L. Waiver of Structural Treatment Control.

18.4 We are concerned about the loss of such compensatory programs and the loss of options to enact such programs for projects that cannot reliably retain the 85th percentile, 24-hour storm and do not have an off-site BMP option available. Without these compensatory options (such as a BMP retrofit program to create "credits" for a fee in lieu fund), the only option would be to seek a waiver from the Executive Officer. This will discourage advancements in the Orange County stormwater program by reducing available options. Moreover, the option for using an off-site LID BMP that is not publically-owned as described in Section XII.K.d is confusing and relies on an equally confusing footnote (Footnote 9, page 51) for implementation. We ask the Regional Board to clarify the intent and process described here, and to provide alternative compliance options including potential use of in-lieu or credit trading programs.

V. 18.5 We note that the Regional Board is proposing to require that project proponents use a 1.5 times the on-site design capture volume sizing factor when designing biotreatment BMPs. It appears these biotreatment sizing criteria are being copied from MS4 permit to MS4 permit since they first appeared in the Ventura MS4 permit in 2010. We remain unconvinced these criteria are supported with

18.5 technical evidence beyond “modeling” done as part of the Ventura County permit development process, and again ask the Regional Board to cite or provide evidence as to the justification for using these criteria in Orange County.

18.6 VI. The performance standard for hydromodification has been changed in this Draft Permit compared to what is contained in the current 2009 MS4 Permit. It is our understanding that the Regional Board intended to maintain the current standard, but inadvertently omitted key compliance pathways for projects that cannot reliably retain the 2-year storm event. We also understand that the Regional Board staff has indicated agreement with addressing this issue in a manner consistent with redlines previously submitted by Dean Kirk of the Irvine Company on May 27, 2014. We support these proposed redlines.

CICWQ’s membership is in the forefront of water quality regulation, providing to water quality regulators practical ideas and solutions that are implementable and that have as their goal clean water outcomes. If you have any questions or would like to discuss the content of our comment letter, please feel free to contact me at (951) 781-7310, ext. 210, (909) 525-0623, cell phone, or mgrey@biasc.org.

Respectfully submitted,

Mark Grey, Ph.D.
Technical Director
Construction Industry Coalition on Water Quality

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June 20, 2014

Santa Ana Regional Water Quality Control Board
Email: santaana@waterboards.ca.gov

Subject: City of Irvine Comments on Santa Ana Regional Water Quality Control Board Proposed Order No. R8-2014-0002

Dear Chairman Ruh and Members of the Board:

On behalf of the City of Irvine ("City"), please accept the following comments on Draft Order No R8-2014-0002 dated May 2, 2014 ("Draft Order") and Fact Sheet/Technical Report ("Fact Sheet") that accompanies the Draft Order. These comments are submitted by the City with the intent that they supplement, and where appropriate, expand upon, the comprehensive comment letter developed by the County of Orange ("County") on behalf of the Northern Orange County Municipal Stormwater Co-Permittees (hereinafter "Co-Permittees"), which comments the City joins and herein incorporates by reference.

Like the County, the City of Irvine takes its stormwater responsibilities very seriously. This commitment is evidenced by the City's implementation of a robust stormwater compliance and inspection program, the City's substantial effort in developing a network of regional treatment wetlands in cooperation with Irvine Ranch Water District and property owners that provide significant pollutant removal while also facilitating wildlife habitat in the midst of an urban environment, and the City's development with other Co-Permittee funding partners of the 8.7 million dollar Peters Canyon Wash Channel Capture and Reuse Project that will remove large amounts of selenium from the local ecosystem, notwithstanding that the City's point source contribution to total selenium loadings are very small. Indeed, the City often steps forward to help develop watershed based solutions—even where the source of pollution originates from non-point sources that the City has no authority to regulate. It is part of the City's ethos of being part of the solution when it comes to problem solving on a watershed basis.

19.1

However, notwithstanding the progress made to date in addressing sources of pollutant loading to surface waters within the City, there continue to be unique water quality compliance challenges that arise from the reality of the City's hydrogeology. The City is very concerned that some of the prescriptive requirements of the Draft Order, while well intended, may actually cause increased pollutant loading (and loading in more bio-available forms) in the Newport Bay Watershed, while at the same creating a

19.1 disincentive for Co-Permittees, and the developers they regulate, to undertake regional projects that produce large scale pollutant removal and improvements in watershed health.

Mandates to Implement Retention LID BMPs

19.2 As Regional Board staff is aware, much of the pollutant loading within natural and man-made drainages within the City results from non-point source pollution, selenium and other non-anthropogenic substances that passively discharge into the MS4 from numerous seeps, springs, and weep holes in areas throughout the City with a historical presence of high groundwater. (*See* Exhibit 1[1]). Generally speaking, the higher the water table in the City, the greater the daylighting of shallow groundwater that may contain pollutants such as selenium, a pollutant derived from natural sources—marine sediments, and the more the consequent pollutant loading with the potential to make its way into City drainages through no fault of the City. Because of the diffuse nature of the non-point source loading, conventional stormwater treatment approaches can be difficult or impossible to implement within the City—as is discussed in detail in Exhibit 1 hereto. The best prevention of pollutant loading within the City, therefore, is generally to keep the rising groundwater in the ground, and to utilize natural treatment systems

19.3 ("NTS"), such as treatment wetlands, on the surface to remove pollutants—an approach that appears to be disfavored in the Draft Order.

19.4 Retention/infiltration based BMPs can be valuable tools in addressing pollutant loading.[2] Some soils do act as a natural filtration media and keep surface waters from receiving the "first flush" that can contain many pollutants associated with the urban environment. That stated, retention based LID should not be treated as an end unto itself—which is what the Draft Order appears to do—in the absence of a showing, based on substantial

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[1] Exhibit 1 is a technical memorandum prepared by the City's Water Quality Administrator, Amanda Carr, describing the severe challenges—from a technical and economic perspective–associated with any requirement to strictly meet the California Toxics Rule (CTR) criteria for selenium in the water column in the Newport Bay Watershed.

[2] Several of the retention based LID BMPs appear difficult to implement because of the lack of state health and safety standards that would allow for wide-spread implementation in the City. There is currently no state standard for the harvest and reuse of captured stormwater in domestic applications, and captured stormwater may contain a variety of pathogens and contaminants that would make any type of domestic use a public health risk without treatment. At the same time there is no state plumbing code that would facilitate introduction of captured stormwater into indoor water fixtures, such as for flushing toilets. While such "retained" water can be used for outdoor irrigation—the window to achieve such use is generally fairly short and seasonal storage is a challenge. It is also possible to export captured stormwater out of a watershed entirely, but this raises the issue of whether the exportation of native water from its watershed of origin is likely to cause damage to the existing riparian ecosystem that has come to rely upon the existing hydrologic regime. So, in many cases, the only retention based LID BMP that is implementable is infiltration—and infiltration carries all of the difficulties previously referenced within the City of Irvine. On the positive side, state standards for recycled water under Title 22 are well understood, and Irvine Ranch Water District has extensive experience in managing recycled water safety and distributes large amounts of recycled water within the City—to include indoor applications, such as toilet flushing for non-residential buildings.

evidence in the record, that retention based LID BMPs remove pollutants from stormwater to the maximum extent practicable ("MEP") within the Newport Bay Watershed. Indeed, it is difficult to see how the Regional Board could make a finding of MEP pollutant removal within the Newport Bay Watershed for retention based LID BMPs given the evidence, summarized in Exhibit 1, and in numerous prior Regional Board documents, that the implementation of retention/infiltration based BMPs in the City is likely to result in a greater discharge of pollutant loading to receiving waters than would occur without retention based LID.

19.4

Concerns regarding Groundwater Degradation: The City also shares the concerns raised by Orange County Water District ("OCWD") at the June 13 Workshop regarding the risk of transforming a surface water quality problem into exacerbated groundwater quality problems within the City via the blanket implementation of retention based LID BMPs. While the North Orange County MS4 Permit is admittedly more focused on removing pollutants from surface water, state law also requires the Regional Board to protect beneficial uses in the groundwater from degradation. (State Water Resources Control Board 68-16 [Anti-Degradation Policy]; *AGUA v. Central Valley Regional Water Quality Control Board* (2012) 210 Cal. App. 4th 1255.) The Draft Order in Section XII appears to gloss over protection of groundwater beneficial uses in favor of mandating a one size fits all policy that penalizes Co-Permittees for not utilizing retention based LID BMPs in new construction and significant redevelopment activities. Ironically, the Draft Order, in Section IV, still mandates stormwater discharges not cause exceedances of groundwater quality objectives, but then gives the Co-Permittees little ability to avoid such exceedances. Section IV and Section XII of the Draft Order should be harmonized to allow for selection of non-retention based BMPs, without penalty or increased BMP sizing, where infiltration can be reasonably anticipated to cause exceedances of groundwater objectives.

19.5

Along these same lines, the City relies on pumped groundwater from the basin underlying the City, a basin managed by OCWD, for most of its water supply requirements. Per OCWD's comment at the June 13 Workshop, the Draft Order should allow the Co-Permittees, after consulting with OCWD and local water suppliers, to consider anticipated impacts to groundwater supply in determining whether to implement retention based LID BMPs. Where retention based LID BMPs would risk mobilizing existing volatile organic compounds ("VOCs") associated with legacy military operations and industrial activities (a legitimate concern in Northern Orange County), or would otherwise threaten to degrade groundwater quality, the City should have the option to utilize non-retention based LID BMPs without having to obtain special permission.

Specific Revisions Requested:

19.6

Section XII of the Draft Order should be revised to provide that retention based LID BMPs are not required to receive primary consideration in any location where there are documented high groundwater levels containing pollutants of concern, or where the use

19.6 of retention based LID BMPs is likely to cause interfere with the attainment and maintenance of beneficial uses in the groundwater. Indeed, simply maintaining the current New Development and Significant Redevelopment Program outlined in the existing Model WQMP and Technical Guidance Document would be a simple way of addressing the City's concerns.

Specific Recommendations if the program in the current MS4 Permit is not maintained:

19.7 • Section XII.G. Secondary Consideration of Biotreatment Control BMPs in WQMPs. As currently drafted in this section, the use of biotreatment is only able to be considered by the City when infiltration is shown to be infeasible, and then penalizes the City and future developers by requiring non retention based LID BMPs to treat 1.5 times the volume of stormwater that is required to be captured by retention. In the current permit, new development program biotreatment BMPs, and retention based BMPs, have the same volume treatment requirements. As most priority projects within the City of Irvine will, by necessity, have to rely on Biotreatment Control BMPs due to the infeasibility of onsite retention and infiltration, this new requirement places an undue burden on Irvine projects without sufficient technical justification and is, the City asserts, mandated in contravention of the MEP standard.

Requested Revision:

This requirement should be removed and Biotreatment controls sizing requirements should be revised to match the design capture volume equivalent to retention LID BMPs.

19.8 • Section XII.K. Off-site Structural Treatment Control BMPs: Regional and Sub-Regional Facilities: As proposed, the use of regional treatment options is only available if those regional treatment BMPs infiltrate a portion of the design capture volume. This requirement essentially makes regional treatment infeasible within the City due the reasons discussed above, and also appears to make the existing NTS regional treatment locations, which were the subject of large capital investment by multiple parties, and which were designed to accept additional volume and treatment capacity, ineligible to provide treatment for redevelopment sites within their drainage boundaries. The requirement to forego use of this existing NTS facilities, which were intentionally designed to address the impacts of future new development and redevelopment within the City, may ultimately discourage willingness of the Co-Permittees and development interests to invest in future large-scale regional treatment BMPs for fear that the rules will change every five years—rendering regional investments obsolete. If regional treatment BMPs become obsolete with every permit renewal, stakeholders will be reluctant to fund future projects, and ironically, these significant problems arise because of the preference unilaterally afforded retention based LID BMPs under circumstances where such BMPs will cause more pollutant loading to surface waters than the continued use of NTS.

Requested Revision:

19.8 (a) Section XII.K should be revised to allow for off-site regional and sub-regional treatment facilities to utilize biotreatment and NTS when infiltration is shown to be infeasible or detrimental to ground or surface water quality.

The Requirement to Meet Numeric Water Quality Objectives

Section IV of the Draft Order prohibits Co-Permittees from causing or contributing to a violation of a water quality objective or beneficial uses through their stormwater discharges. With the Prohibition, the Board also spells out a proposed iterative process whereby the Co-Permittees would be deemed in compliance, notwithstanding an exceedance of a numeric water quality objective, where: 1) the Co-Permittee is removing pollutants to the Maximum Extent Practicable ("MEP") through its program; 2) the Co-Permittee submits a draft plan, within 6 months, specifying how it intends to achieve future compliance with water quality objectives—numeric or otherwise.

19.9 While this process is a step in the right direction, no amount of planning is going to change the fundamental challenge for the Co-Permittees in the Newport Bay Watershed—the fact that the most difficult pollutant to control, selenium, is primarily the result of non-point source loading and therefore outside of the City's control. As a result, as Exhibit 1 aptly illustrates, no matter how rigorous a program the City implements, and no matter how much money it spends, it is unlikely that the Co-Permittees will ever be able to guarantee compliance—throughout the Newport Bay Watershed—at least with the current CTR criteria for selenium.[3] (*See* Exhibit 1 and references cited therein.)

And the law does not require the Regional Board to mandate the impossible—only that the Co-Permittees comply with the MEP standard—as Section 402 (p) of the Clean Water Act[4] prescribes. (*See Hughey v. JMS Develpment Corp.* (11th Cir. 1996) 78 F.3d 1523, 1527, 1530; see also *In re State Water Quality Order No. 2001-15* at page 8 [confirming iterative approach via MEP BMP implementation, and stating "we will generally not require 'strict adherence' with water quality standards through numeric effluent limitations."].) Indeed, the Ninth Circuit Court of Appeals explicitly held that the CWA does not require MS4s to strictly comply with water quality standards under Section 301 of the CWA where the MS4 is otherwise controlling pollutants to the MEP. (*Defenders of Wildlife v. Browner* (9th Cir. 1999) 191 F.3d 1159, 1165; *see also BIA of San Diego County v. State Board* (2004) 124 Cal.App.4th 866, 874.) *Defenders of Wildlife*, which was not overruled by the Ninth Circuit's recent *NRDC* decision, held that

[3] As previously noted, the City has participated for years, at substantial cost, in efforts to remove selenium from the Newport Bay Watershed. It intends to continue doing so as part of the collaborative watershed based management approaches, heartily endorsed by the Regional Board in the last iteration of the permit, *see* Order No. R8-2009-0030, Section XVIII. B.8., that have resulted in significant pollutant loading reduction in the Newport Bay Watershed. However, fundamentally, loading derived from rising groundwater is not a source that the City can control, nor one that it should be asked to control—since the City is not the cause of the non-point source derived impairment.

[4] 33 U.S.C. § 1342(p)(3)(B)

the proper statutory requirements for a municipal MS4 Permit are set forth in CWA section 402(p), the source of the MEP standard, and that CWA section 301(b)(1)(C) should not be strictly applied in the municipal stormwater context—since municipal stormwater purveyors cannot go out of business (as an industrial discharger could), cannot control when it rains, and have limited ability to control private activities on private property. (*Id.*) Regional Boards can choose to require compliance with water quality requirements above and beyond the requirements of federal law, *City of Burbank v. State Water Resources Control Board* (2005) 35 Ca1.4th 613, but where they do so, they must do so in accordance with other provisions of the Water Code and state law, to include consideration of the factors enumerated in Water Codes Section 13241 and state prohibitions against unfunded mandates.

19.9

Requested Revision:

In this regard, the City asks the Regional Board to consider, as part of showing compliance with the "iterative process" described in Section IV, amending the Draft Order to allow Co-Permittees to demonstrate compliance with the CWA and Porter Cologne where the Co-Permittee shows that: 1) meeting a numeric standard would be technically or economically infeasible (*see, e.g.,* Exhibit 1); or 2) the discharges of the Co-Permittee are now, or will otherwise be within the permit term, in full compliance with the requirements of a TMDL; or 3) the source of pollution causing the exceedance is non-anthropogenic or resulting from activities not within the jurisdiction or control of the Co-Permittee; or 4) it is in full compliance with BMP Strategic Plan for the Santa Ana Delhi and San Diego Creek sub-watersheds in the Newport Bay watershed.[5]

<u>Changes Regarding Regulation of Non-Priority Projects</u>:

Finally, the City wants to echo comments made by the County regarding proposed changes on Non-Priority Projects. Rapid expansion of the Non-priority Project category will create a significant administrative and applicant burden, yet produce negligible water quality benefits within the City. Currently, Non-priority projects are limited to projects that do not meet Priority Project thresholds, and require either a non-residential plumbing permit or a discretionary permit from the City. In the last three years, the City has had only a very small number of projects that triggered the requirement for preparation of a non-priority project plan. Under the newly revised non-priority project category in the Draft Order, based on permit applications from 2013, the City anticipates it will need to process over 1900 applications beyond what it processed last year for projects such as:

19.10

[5] The current MS4 Permit, Order No. R8-2009-0030, Section XVIII. B.8, provides: "[a]s long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay." The addition of similar language in the Draft Order would go a long way towards alleviating some of the City's concerns vis-a-vis selenium and would incentivize robust participation in future regional project development.

- Residential and commercial solar permits,
- Residential and commercial re-roof permits,
- Residential Patio Covers, Remodels and Additions, including Walls/Fences and Retaining Walls,
- Small residential exterior projects such as fire pits and fireplaces, fountains, sinks and underground electrical conduits,
- All residential and commercial swimming pools, and
- Miscellaneous commercial projects like platforms for rooftop HVAC units, walls/fences, retaining walls, high piled storage racks, and commercial trellises.

19.10

The impact of having to process a large influx of new applications would be felt at our permit counter, and also by city residents who would now have to prepare a complex plan, approved by an engineer knowledgeable in water quality, for what would otherwise be a simple ministerial approval of minor renovations. It would also place a large burden on the City's Building and Safety staff with a new requirement to review 1,900 individual plans, and inspect 1,900 sites to ensure that plans are implemented at each site. For most, if not all, of the projects that would fall into this category, it is not clear what site design or source control BMPs could actually be incorporated into these projects that would improve stormwater quality. Thus, as currently drafted, the new requirements for non-priority projects would create significant burdens and costs for the Co-Permittees and the public they serve, while providing little to no benefit in terms of reduced pollutant loading.

Requested Revision:

The City requests that the definition of Non-priority Project remain consistent with the current New Development and Significant Redevelopment Program outlined in the Model WQMP and Technical Guidance Document—as this approach has reduced pollutant loadings for projects where additional City review can make a big difference.

In closing, I thank you for considering our comments, and the City looks forward to working with Board staff in addressing the concerns raised herein.

Sincerely,

Eric M. Tolles

Eric M. Tolles, S.E.
Director of Community Development

cc(via email): Kurt Berchtold, California Regional Water Quality Control Board
Hope Smythe, California Regional Water Quality Control Board
Michelle Beckwith, California Regional Water Quality Control Board
Jennifer Shook, County of Orange

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Joseph Kirkpatrick, Chief Building Official
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Amanda Carr, Water Quality Administrator

Technical Justification of Infeasibility of California Toxic Rule Selenium Standard in the Newport Bay Watershed

By: Amanda Carr, Water Quality Administrator
June 17, 2014

In my role as the Water Quality Administrator for the City of Irvine for the last three years, and my previous role as the Chief of Water Quality Planning for the County of Orange from 2004 through 2011, I have been involved in the development of many of the technical documents produced by the Nitrogen and Selenium Management Program cited below and have gained a thorough understanding of selenium water quality as it pertains to the Newport Bay Watershed and the City of Irvine. In this capacity, I believe meeting the California Toxics Rule selenium standard of 5 µg/l is not technically nor economically feasible in the Newport Bay Watershed.

The City of Irvine and its partners in the Nitrogen and Selenium Management Program (NSMP) have been investigating and pilot testing potential technologies to remove selenium since 2004. The work plan required by Santa Ana Regional Water Quality Control Board (Regional Board) Order No. R8-2004-0021 to detail work needed to address issues related to groundwater-related discharges of nitrates and selenium in the Newport Bay Watershed included Task 2: Develop and Evaluate BMPs and Treatment Technologies, to ensure a thorough investigation of possible treatment technologies. Task 2 included the following sub-tasks to develop and evaluate effective treatment approaches, emphasizing the use of pilot and demonstration projects:

- Task 2.2 Survey Current Selenium and Nitrogen Treatment Methods
- Task 2.3 Develop Simple Treatment-Related Model
- Task 2.4 Select and Pilot Test Candidate BMPs and Treatment Technologies
- Task 2.5 Develop BMP and Treatment Technology Implementation Plan
    - Task 2.5.1 Determine optimal selection of BMPs and treatment technologies
    - Task 2.5.2 Develop BMP and treatment technology implementation plan

This research effort resulted in the following reports which were submitted to the Regional Board in accordance with Order No. R8-2004-0021:

- Task 2.2 - Identification/Assessment of Selenium and Nitrogen BMPs/Treatment Technologies, March 31, 2006.
- Task 2.2: Identification and Assessment of Selenium and Nitrogen Treatment Technologies and Best Management Practices, March 30, 2007
- Quick Start BMP Evaluation, September 20, 2005
- Volume Reducing BMP Fact Sheets
- Task 2.3: Simple Treatment-Related Model Final Report, June 8, 2007

Exhibit 1

- Task 2.4: BMP Selection and Pilot-Scale Testing Considerations Interim Report, November 28, 2006
- Task 2.4: Pilot Test Report for Nitrogen and Selenium Removal Technologies Newport Bay Watershed FINAL REPORT, March 21, 2008
- Task 2.5: BMP Strategic Plan Framework, November 6, 2008

In January 2011, the County of Orange and cities of Costa Mesa, Irvine, Laguna Hills, Laguna Woods, Lake Forest, Newport Beach, Orange, Santa Ana and Tustin, and the Irvine Ranch Water District, Irvine Company and Lennar submitted the Time Schedule Order R8-2009-0069 BMP Strategic Plan to the Regional Board. The plan included a cost estimate of watershed-wide BMP implementation to achieve compliance with the CTR 5 µg/l selenium standard based on output from the Simple Treatment Model. The Simple Treatment Model is a pollutant mass balance calculator that divides the Newport Bay Watershed into concentration points and predicts seasonal pollutant concentrations as flow weighted averages of sources that contribute to selenium. Model predictions of total selenium concentrations at several locations throughout the watershed were within an acceptable level of accuracy for this type of simple model, and were typically within five to 15 percent of observed seasonal values. However, the groundwater exfiltration flow rates used in the model had not been quantified with the same level of accuracy as surface flows throughout the watershed and it is likely that this data gap contributes to errors in water quality predictions, particularly in the Peter's Canyon Wash subwatershed. Using this best available data, depending on the suite of potential BMPs implemented, the total estimated cost to meet the California Toxic Rule (CTR) standard ranged from $52,092,000 to $84,797,000 and this expenditure would not guarantee attainment of CTR criteria because of the diffuse nature of exfiltrating groundwater in the watershed. In any event, this level of investment is economically infeasible for the municipalities and dischargers within the watershed, particularly where this expenditure will not assure compliance throughout the watershed.

Subsequently, in October 2013, work to characterize the hydrogeology of the central watershed and evaluate water sources and sinks over representative water years 2005 to 2011 was completed by Daniel B. Stephens and Associates and submitted to the Regional Board. This report found that groundwater flows from upgradient areas of the Newport Bay Watershed and recharges the shallow aquifer within the central watershed. Additionally, the historical presence of the Swamp of Frogs and regional topography depicts a regional convergence of groundwater in this area. Groundwater flows into surface water channels in the central watershed through direct discharge from dewatering projects, and diffuse, passive discharge through weeps, seeps, springs, and channel/creek bottoms. The final estimated passive groundwater discharge to surface channels, taken from a calibrated groundwater balance approach, range from 9,027 to 20,780 ac-ft/yr, with an average of 12,157 ac-ft/yr. Given the diffuse nature of groundwater inputs to surface waters and the high volume of groundwater discharged annually, it is infeasible to construct treatment technologies sufficient to ensure

achievement of selenium water quality standards consistently throughout the watershed.

Based on the findings of the NSMP Work Plan and subsequent reports, at the time the General Discharge Permit for Discharges to Surface Waters of Groundwater Resulting from Groundwater Dewatering Operations and/or Groundwater Cleanup Activities at Sites Within the San Diego Creek/Newport Bay Watershed Polluted by Petroleum Hydrocarbons, Solvents, Metals and/or Salts (R8-2007-0041) was adopted, the Regional Board acknowledged the lack of a readily available, practicable treatment technology that could assure compliance with the selenium discharge limitations in the Permit (R8-2007-0041 fact sheet §IV-F at pg. F-18-19). This finding was reaffirmed when Time Schedule Order R8-2009-0069 for Dischargers Enrolled in Order No. R8-2007-0041 was adopted in December 2009, "...there is currently no readily available, conventional treatment technology that can be implemented in a reasonably practicable manner for point source discharges." (R8-2009-0069 at Finding 16 page 4 of 12), and therefore, "...compliance with the final numeric selenium limitations in Order No. R8-2007-0041 remains infeasible for many dischargers." (Staff Report for R8-2009-0069, December 10, 2009 at page 5 of 6).

Based on the findings of the reports and plans referenced above and on the Regional Board staff reports and findings for the Order Numbers R8-2007-0041 and R8-2009-0069 meeting the California Toxics Rule selenium standard of 5 µg/l is not technically, nor economically feasible in the Newport Bay Watershed.

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June 20, 2014

VIA EMAIL (santaana@waterboards.ca.gov)

Kurt Berchtold
Executive Officer
C/O Adam Fischer
Environmental Scientist
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
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Re: Comments on Draft Orange County MS4 Permit, Tentative Order No. R8-2014-0002

Dear Mr. Fischer:

14.1 Best Best & Krieger represents City of Lake Forest ("City"). The City submits the following comments on the Draft Orange County Municipal Separate Storm Sewer System ("MS4") Permit, Order No. R8-2014-0002 ("Draft Permit"). The City is committed to improving and sustaining water quality in the Santa Ana and San Diego Creek Watersheds and has undertaken extensive efforts to further these goals. The City is aware that the County of Orange has prepared and submitted comments on the Draft Permit. The City would like to express its support for the County's comment letter and to join with the County in the submission of those comments. The comments in this letter supplement the County's letter and are intended to allow the City and other Co-permittees to continue working toward the common goal of improving water quality in the region.

1. THE CITY REQUESTS THAT THE DRAFT PERMIT BE REVISED TO REMOVE REQUIREMENTS THAT FORCE THE CITY TO ADDRESS ISSUES THAT ARE OUTSIDE OF ITS PHYSICAL AND LEGAL JURISDICTION.

A. A Co-permittee cannot be liable or responsible for permit conditions for which it is not the operator

14.2 The City objects to the Draft Permit to the extent it creates or impliedly relies on a system of joint and several liability that contradicts the Clean Water Act and Porter-Cologne. Both the Clean Water Act and Porter-Cologne hold dischargers responsible only for those pollutants that discharge from their point sources. (33 U.S.C. §§ 1311, 1319, 1342, subd. (p)(3)(B) and 1362,

subd. (12); Water Code §§ 13350, subd. (a), 13263, subd. (f) and 13376.)[1] The Clean Water Act's definition of "Co-permittee" is a permittee who "is only responsible for permit conditions relating to the discharge for which it is operator." (40 C.F.R. § 122.26, subd. (b)(1).) Although storm water permits may be issued on a system – or jurisdiction – wide basis, a Co-permittee need only comply with permit conditions relating to discharges from the MS4 which it is operating. (33 U.S.C. § 1342(p)(3)(B)(i); 40 C.F.R. § 122.26(a)(3)(vi); *So. Fla. Water Mgmt. Dist. v. Miccosukee Tribe of Indians* (2004) 541. U.S. 95, 105; *Jones v. E.R. Shell Contractor, Inc.* (N.D. Ga. 2004) 333 F.Supp.2d 1344; *In re City of Irving, Texas, Mun. Separate Storm Sewer Sys.* (EPA July 16, 2001) 10 E.A.D. 11; 40 C.F.R. §§ 122.26, subd. (a)(3)(vi).)

14.2

Porter-Cologne has a similar focus on individual discharges. (Water Code, § 13260.) For example, Porter-Cologne makes watershed planning an option that Co-permittees may pursue, not a mandatory requirement with which Co-permittees must comply. (Water Code, §§ 16101, subd. (a), 13263, 13350, subd. (a).) The purpose of such voluntary watershed planning is to allow permittees to implement existing and future water quality requirements and regulations on a watershed rather than a jurisdictional level. (*Id.*) If the Regional Board incorporates watershed planning into the waste discharge requirements issued to a permittee, the implementation of the plan by the permittee may represent compliance with waste discharge requirements. (Water Code, § 16102 subd. (d) and (c).) Thus, the voluntary watershed approach of Water Code section 16100 *et seq.* allows permittees to *elect* the pursue a watershed approach and *offers* the permittee a compliance option as an incentive to move from a jurisdictional approach to a watershed approach. Porter-Cologne does not <u>require</u> a Co-permittee to expend resources to address discharges beyond its jurisdiction. (40 C.F.R. § 122.26, subd. (b)(1).)

14.3

B. State and Federal Law do not permit the Draft Permit's creation of joint and several liability

Mandatory watershed requirements which are not linked directly to pollutants discharged to or from a Co-permittee's MS4 are contrary to the plain meaning of the Clean Water Act. Such requirements are also beyond the responsibility of that Co-permittee and should be removed from the Draft Permit. The Draft Permit's Receiving Waters Limitations, Total Maximum Daily

14.4

[1] The City acknowledges that EPA and others believe that the watershed approach would result in better water quality results. (*See, e.g.,* EPA's Watershed-Based NPDES Permitting Policy Statement dated January 7, 2003 and the conclusions of the National Research Council's 2009 Report on Urban Stormwater Management in the United States [concluding that the "course of action most likely to check and reverse degradation of the nation's aquatic resources would be to base all stormwater and other wastewater discharge permits on watershed boundaries instead of political boundaries."].) However, structural changes in the Clean Water Act and the laws of authorized states are required to implement such a watershed permitting approach. (*See, e.g.,* National Research Council Report, p 524 [noting that the "national watershed-based approach to stormwater is likely to require legislative amendments . . . ."].) In the absence of such structural changes, the Clean Water Act must be applied as currently written, and as currently written, its focus is on jurisdictional boundaries.

Load ("TMDL") Implementation requirements, and Monitoring and Reporting Program ("MRP") include multiple requirements for joint efforts by the City, without regard to the City's jurisdictional boundaries. (Draft Permit, § IV, XIII, MRP.) For example, the Draft Permit creates a system of joint and several liability by requiring "Co-permittees [to] implement BMPs to achieve the Waste Load Allocations ("WLAs") specified in Appendices B through H of this Order."[2] (Draft Permit, § XVIII.A.) Under this provision, the City would be unable to establish compliance with its WLAs unless it is complying with its own WLAs and it can show that all other dischargers are also in full compliance with their WLAs. If only one Co-permittee fails to implement BMPs to achieve WLAs, all Co-permittees may be held liable for a resulting water quality exceedance contrary to the Clean Water Act and Porter-Cologne.

14.4

Co-permittees may develop and implement a plan to comply with WLAs and where an execcedance is measured, revise the TMDL WLA compliance plan. (Draft Permit, § XVIII.C.5.) Under this draft requirement, any time an exceedance is measured in a receiving water, the Co-permittees must participate in revising the compliance plan, even if all Co-permittees have complied with their WLAs and with the approved TMDL WLA compliance plan. (Draft Permit, § XVIII.C.5.) If a Co-permittee other than the City violates the TMDL WLA compliance plan and causes an exceedance, and that Co-permittee refuses to act, the City would not be able to comply with the Draft Permit's TMDL requirements. In that instance, the City could be held liable for failure to amend, revise, or comply with a TMDL WLA compliance plan, as required in the Draft Permit, even though the City fully complied with requirements applicable to the City. Such a result is unjust and contrary to the Clean Water Act and Porter-Cologne.

The Regional Board has no authority to impose such liability on the City. (40 C.F.R. § 122.26, subd. (b)(1); *City of Modesto Redevelopment Agency v. Superior Court* (2004) 119 Cal.App.4th 28; *In re Alvin Bacharach and Barbara Borsuk* (Order No. WQ 91-07, SWRCB 1991.) Any permit conditions that impose responsibility or liability for discharges or other Draft Permit violations that are not caused by the Co-permittee being held responsible or liable exceed the Regional Board's authority and must be removed from the permit. The City also seeks clarification incorporated into the Draft Permit that the Draft Permit does not intend to hold the City liable or responsible for permit conditions which do not relate to a discharge for which it is operator.

14.5

[2] Other Permit sections impose joint liability, including: MRP sections II.A.2; II.B.3; II.C.1.a; II.C.5; II.D.1; II.H; II.I; II.J.

2. THE CITY REQUESTS THAT DRAFT PERMIT SECTION XII'S NEW DEVELOPMENT AND REDEVELOPMENT REQUIREMENTS BE REVISED TO INCORPORATE THE CITY'S EXISTING PROGRAM

A. Co-permittees' existing new and redevelopment program adequately regulates pollutants in storm water and the Draft Permit should not require any changes to the program.

14.6 The City and the other Co-permittees have expended great resources to develop a program for implementing new and redevelopment standards consistent with the current MS4 Permit. There is no reason that this program should be changed. The Draft Permit and its Technical Report do not include any evidence demonstrating that a change to the existing program is necessary or better for the environment. For this reason, the City requests that the Permit be revised to allow the existing program to continue.

14.7 Additionally, the City objects to the New Development and Redevelopment regulations in the Draft Permit on the grounds that they improperly regulate the discharge of storm water as a surrogate for the regulation of pollutants. (Draft Permit, § XII.) For this reason, the new development and redevelopment standards should be removed from the Draft Permit or be modified to incorporate the City's existing requirements.

B. The Draft Permit regulates storm water as a surrogate for pollutants

14.8 While stating that Co-permittees "must require priority projects to use source control, site design, and structural treatment control BMPs to remove pollutants in urban runoff[,]" the Draft Permit actually regulates storm water flows rather than pollutants. Draft Permit sections XII.A.1.c and XII.D mandate the methods by which Co-Permittees must minimize the quantity of "urban runoff" draining directly to impermeable surfaces and MS4s by establishing, in part, BMP requirements for all priority projects as defined in the Draft Permit. Priority projects include areas of new development and redevelopment. (Draft Permit, § XII.B.5.) The primary methods for attaining these goals is through the use of infiltration, evaporation, evapotranspiration, rainwater harvesting and use, green or brown roofs, and other low impact development ("LID") methods. (Draft Permit, §§ XII.A.1.c, e.) Urban runoff is defined as:

> [A]ll flows in a storm water conveyance system from urban areas which include residential, commercial, industrial, and construction areas. Urban runoff consists of the following components: (1) storm water runoff and (2) authorized non-storm water discharges (See Section III of this Order). Urban runoff does not include

> runoff from undeveloped open space, feedlots, dairies, farms, and agricultural fields. (Draft Permit, Glossary.)

14.8 Storm water on a priority project site does not qualify as "urban runoff" because it has not entered a storm water conveyance system. Further, storm water on a priority project site is not a "pollutant" under the Clean Water Act or a "Waste" under Porter-Cologne. The intent of section XII's New Development requirements appears to be the regulation of storm water runoff from priority project sites and authorized non-storm water discharges from priority project sites as a surrogate for the regulation of pollutants.

C. Regulation of storm water as a surrogate for pollutants is contrary to the Clean Water Act and Porter-Cologne

Contrary to the requirements of the Clean Water Act and Porter-Cologne, the Draft Permit regulates the discharge of storm water as a pollutant, rather than the pollutants in the storm water. (*Virginia Department of Transportation v. EPA* (E.D. Va., Jan. 3, 2013) 2013 U.S. Dist. Lexis 981, 43 ELR. 20002 ("*VDOT*").)

Regulation of storm water alone rather than pollutants or waste in storm water exceeds the Regional Board's authority under both the Clean Water Act and Porter-Cologne. (*Ibid.*) In *VDOT*, the US EPA had established a TMDL for Accotink Creek to limit the flow of storm water into the creek. The purpose of the TMDL was to regulate the amount of sediment into Accotink, based on EPA's belief that the sediment was the primary cause of its impairment. The parties to the case and the court agreed that sediment is a "pollutant" under the Clean Water Act, and that storm water is not a pollutant. In an attempt to justify the storm water flow TMDL, the EPA claimed that the storm water flow rate was a "surrogate" for sediment. The Court, however, held that EPA had no authority under the CWA to regulate the flow of storm water into the creek, stating:

14.9

> The language of § 1313(d)(1)(C) is clear. EPA is authorized to set TMDLs to regulate pollutants, and pollutants are carefully defined. Stormwater runoff is not a pollutant, so EPA is not authorized to regulate it via TMDL. Claiming that the stormwater maximum load is a surrogate for sediment, which is a pollutant and therefore regulatable, does not bring stormwater within the ambit of EPA's TMDL authority. Whatever reason EPA has for thinking that a stormwater flow rate TMDL is a better way of limiting sediment load than a sediment load TMDL, EPA cannot be allowed to exceed its limited statutory authority. (*Id.* at pp. 14-15.)

By mandating the elimination of pollutants through the control of storm water and authorized non-storm water, the Draft Permit treats storm water as a surrogate for all, unspecified pollutants in the same way that the EPA treated storm water as a surrogate for sediment. Accordingly, the Regional Board in this case has no authority under the Clean Water Act to regulate discharges from completed project sites without specifically identifying a particular pollutant of concern.

14.9 Similar restrictions exist in State law. Porter-Cologne prohibits the discharge of "Waste" without a permit. (Water Code, §§ 13260; 12363; 13264.) Waste is defined as:

> sewage and any and all other waste substances, liquid, solid, gaseous, or radioactive, associated with human habitation, or of human or animal origin, or from any producing, manufacturing, or processing operation, including waste placed within containers of whatever nature prior to, and for purposes of, disposal. (Water Code, § 13050, subd. (d).)

Storm water itself is not Waste, though it may contain Waste. The Clean Water Act only authorizes the regulation of pollutants. Porter-Cologne only authorizes the regulation of Waste. Draft Permit terms, such as section XII's New Development regulations, which seek to regulate storm water flows without identifying specific pollutants in such flows are beyond the authority
14.10 of the Regional Board and must be removed from the Draft Permit. In the event such requirements are modified to regulate only pollutants and Waste, the Draft Permit should also be revised to permit Co-permittees' current program to satisfy the section XII's revised requirements.

3. THE CITY REQUESTS THAT DRAFT PERMIT SECTION XII BE REVISED TO REMOVE REQUIREMENTS THAT THE CITY IMPOSE MITIGATION ON PROJECTS IN EXCESS OF THE PROJECT'S IMPACTS.

The City objects to the Draft Permit's LID provisions to the extent they require
14.11 mitigation of pollutants in storm water which are not caused by a project. (Draft Permit, §§ XII.D, E, G, H, K [requiring treatment of runoff from tributary areas], B.5.iv ["numeric sizing requirements must be applied to runoff from the entire development"].) The City requests these changes to the Draft Permit to provide clarity that the intent of section XII is to control pollutants directly caused by a project. Forcing the City to require mitigation in excess of a project's impacts exposes the City to potential liability for takings claims.

A. The Draft Permit requires exactions on projects which exceed a project's scope.

14.12

As applied to redevelopment priority projects and nonpriority projects, the Draft Permit's hydromodification and LID requirements exceed the scope of both the City's and the Regional Board's authority regarding exactions under State and Federal law. For example, in areas where redevelopment results in the addition or replacement of more than 50% of the impervious surfaces of an existing developed site, compliance with Section XII will generally require a redevelopment project proponent to retain all storm water runoff on site or mitigate off-site, even where the runoff is not caused or increased by the redevelopment project. (Draft Permit, § B.5.a.iv.) In this way, the Draft Permit requires the City to impose mitigation and/or exactions for impacts that are not a result of the redevelopment project itself.

14.13

Similarly, the Draft Permit requires a Non-Priority Project Plan, source control and site design BMPs for all non-priority projects that modify, improve or affect areas exposed to storm water. (Draft Permit, § XII.M.) This requirement would apply to projects that do not create any additional run-off or change the type of pollutants in existing run-off, such as roof-top solar panel installations and patio covers. By requiring a Non-Priority Project Plan, source control and site design BMPs to address run-off that is not changed, caused, or affected by a project, the Draft Permit requires the City to impose mitigation and/or exactions for impacts that are not a result of the non-priority project itself.

B. California law prohibits exactions on a project in excess of a project's impact.

14.12

When imposing a condition on a development permit, a local government is required under the federal and state constitutions to impose only those conditions bearing a reasonable relationship to the impacts of the project. (*Building Indus. Assn v. City of Patterson* (2009) 171 Cal. App. 4th 886, 898.) This rule applies to legislatively enacted requirements and impact fees or exactions. (*Ibid.*) Fees imposed on a discretionary ad hoc basis are subject to heightened scrutiny under a two-part test. (*Nollan v. California Coastal Comm'n.* (1987) 483 U.S. 825, 837 ("*Nollan*").) First, local governments must show that there is a substantial relationship between the burden created by the impact of development and any fee or exaction. (*Ibid.*) Second, a project's impacts must bear a "rough proportionality" to any development fee or exaction. (*Dolan v. City of Tigard* (1994) 512 U.S. 374, 391 ("*Dolan*").)

Under California law, the *Nollan/Dolan* heightened scrutiny test also applies to in-lieu fees. (*Ehrlich v. City of Culver City* (1996) 12 Cal.4th 854, 876.) The Legislature has memorialized these requirements in the Mitigation Fee Act which establishes procedures that local governments must follow to impose impact fees. (Gov. Code, §§ 66000-66025.) By requiring certain redevelopment priority projects to retain all storm water on-site, the City would be requiring a project developer to make changes to the project site that are not related to the

project's impacts. Imposing such requirements would exceed the City's (and the State's) authority under *Nollan, supra,* 483 U.S. at p. 837 and *Dolan, supra,* 512 U.S. at p. 391.

14.12 Draft Permit conditions requiring mitigation of pollutants in storm water which are not caused by a project violate the *Nollan/Dolan* limitations. For this reason, Draft Permit section XII must be revised to reflect the limitations of the City's and State's authority. Without requesting the inclusion of new and redevelopment standards or waiving the objections set forth herein, if the new and redevelopment standards are modified in such a way as to require exactions commensurate with a project's scope, the City and Co-permittees' existing program should be recognized as satisfying all such Draft Permit requirements.

4. SECTION XII'S LID REQUIREMENTS ARE NOT SUPPORTED BY EVIDENCE AND NEED TO BE REMOVED.

The City objects to the Draft Permit's new LID requirements on the grounds that there is no evidence in the record demonstrating that a universal requirement to implement LID requirements in every development and redevelopment priority and non-priority project improves water quality. (Draft Permit, § XII.) As described above, the City and other Co-permittees have expended great resources to develop a program for implementing LID requirement consistent with the current MS4 Permit. There is no evidence in the record demonstrating that a change to the existing program is necessary or would benefit the environment.

14.14 The Regional Board admits that the LID requirements are based on "a *presumption* that carrying out the actions prescribed in the permit . . . will improve water quality." (Draft Permit, Technical Report, at p. 18 [emphasis added].) Instead of relying on substantial evidence, the Regional Board appears to base all New and Significant Redevelopment Draft Permit requirements on the findings of Appendix D, to the Ventura County Technical Guidance Manual for Storm Water Quality Control Measures (Manual Update 2011). This document itself contains no evidence that LID requirements and their resulting reduction in flows of storm water to receiving waters results in water quality benefits. (*Ibid.*)

For these reasons, the hydromodification and LID requirements lack substantial evidence and are arbitrary and capricious under the California Administrative Procedure Act and violate the Clean Water Act in that the requirements do not, on their face, demonstrate water quality benefits. These requirements should be removed from the Draft Permit or modified to the extent that substantial evidence demonstrates: (1) the LID requirements control pollutants rather than storm water; and (2) an improvement to receiving water quality from reduced storm water flows.

5. THE PERMIT'S RECEIVING WATERS LIMITATIONS DISCHARGE PROHIBITIONS EXCEED THE REQUIREMENTS OF FEDERAL LAW

The City greatly appreciates the Regional Board's efforts to find a middle ground by incorporating an iterative compliance path for the Draft Permit's RWL requirements. However, because the Clean Water Act does not require receiving waters limitations to be incorporated into the Draft Permit, the City requests that the receiving waters limitations requirements in the Draft Permit simply be removed.

The City would like to highlight the fact that it views the current RWL requirements in the Draft Permit as a preferred alternative to the approaches taken by the San Diego and Los Angeles Regional Water Quality Control Boards. Nonetheless, the proposed requirements will impose a substantial burden on the City. If the Regional Board is going to look to other approaches on this issue, the City requests that the Regional Board adopt the approach taken by the Colorado Basin Regional Water Quality Control Board which provides a BMP-based, iterative compliance path. In all cases, it is the City's preference that the Regional Board simply remove the RWL prohibitions from the Draft Permit, as they are not required by Federal law.

A. *Federal Law does not require receiving waters limitations to be incorporated into the Draft Permit.*

14.15

The Clean Water Act does not require direct incorporation of water quality standards into municipal storm water permits. (*Defenders of Wildlife v. Browner* (9th Cir. 1999) 191 F.3d 1159 ("*Defenders of Wildlife*").) When adopting Section 402, Congress chose "not to include a similar provision [i.e., strict compliance with state water quality standards] for municipal storm-sewer discharges." (*Id.* at p. 1165.) Although the Clean Water Act does not require incorporation of receiving waters limitations into the permit, the Draft Permit requires compliance with water quality standards until a draft plan for compliance is submitted to the Regional Board.

Under Provision IV.D, a draft plan must be submitted *after* a determination has been made "that a discharge is causing or contributing to the exceedance of an applicable water quality standard." (Draft Permit, § IV.D.) Thus, compliance with water quality standards is mandatory, and only *after* non-compliance may a Co-permittee develop and submit a compliance plan. In this manner, the Draft Permit exceeds federal law by directly incorporating water quality standards and prevents compliance with receiving waters limitations through the iterative process until after an exceedance is demonstrated. Inclusion of the receiving waters limitations provision exceeds the Clean Water Act without the inclusion of an immediate compliance option and may function to impair water quality by: (1) preventing the development of a compliance plan until after an exceedance is detected, and (2) disregarding compliance plans developed in a

manner other than the manner provided in Draft Permit Provision IV.D, such as TMDL compliance plans.

The Draft Permit should be revised to remove the mandatory receiving waters limitations language, or alternatively and in accordance with Comment 5B, below, to allow Co-permittees to comply with Provision IV by implementing plans developed in a manner other than the manner provided in Draft Permit Provisions IV.D, such as TMDL compliance plans.

B. Inclusion of the receiving waters limitations provisions under Porter-Cologne is inconsistent with precedential state Board Orders

14.15 Inclusion of the Receiving Waters Limitations requirements in the Draft Permit pursuant to Porter-Cologne must comply with precedential Water Resources Control Board ("State Board") orders. (Gov. Code, § 11425.60; State Board Order WQ 2001-15; State Board Order WR 96-1, footnote 11 ["the [State Board] designates all decisions or orders adopted by the [State Board] at a public meeting to be precedent decisions"].) State Board Order WQ 2001-15 states that compliance with water quality standards is to be achieved over time, through an iterative approach requiring improved BMPs. Compliance with precedential State Board orders is mandatory. (See *California Assn of Sanitation Agencies v. State Water Resources Control Board* (2012) 208 Cal.App.4th 1438, 1461, fn. 20.)

By mandating immediate compliance with the Draft Permit's Receiving Waters Limitations requirements, the Draft Permit violates the State Board's precedential order. As demonstrated in State Board Order WQ 2001-15, compliance with receiving waters limitations must be achieved through the iterative process. The Draft Permit should recognize plans already developed for the purpose of attaining reductions in pollutant loads as satisfying the compliance plan provision under Draft Permit section IV.A. The Draft Permit cannot prevent compliance through the iterative process until after an exceedance occurs. Draft Permit Provision IV needs to be revised to align the language with the State Board's precedential orders.

6. THE CITY REQUESTS THAT THE DRAFT PERMIT'S TMDL REQUIREMENTS BE REVISED TO CLARIFY THAT COMPLIANCE IS TO BE ATTAINED THROUGH THE IMPLEMENTATION OF BMPS.

14.16 The Clean Water Act does not require TMDLs to be incorporated into the Draft Permit. (Draft Permit, § XVIII.) The City seeks clarification on the following points: (1) that the Permit does not require immediate compliance with all WLAs; (2) that the WLAs do not constitute numeric effluent limitations; and (3) that implementation of BMPs on an iterative basis constitutes compliance with the Permit.

A. *Federal Law does not require TMDLs to be incorporated into the Draft Permit.*

The Clean Water Act does not require a TMDL to be incorporated into the Draft Permit. (*Defenders of Wildlife, supra,* 191 F.3d 1159.) Unlike industrial dischargers, who must comply strictly with state water quality standards, municipal storm sewer discharges are not required to comply strictly with water quality standards. (*Id.* at p. 1165.)

Because any inclusion of TMDLs in the Draft Permit is not required under the Clean Water Act, any such inclusion in the Draft Permit is a function of State law at the discretion of the Regional Board. As explained more fully below, the manner in which the Regional Board included the nutrient, fecal coliform, organochlorine compounds, diazinon, chlorpyrifos, toxics, and sediment TMDLs for San Diego Creek and Newport Bay Watershed, and the Coyote Creek Metals TMDL for the San Gabriel River into the Draft Permit represents an abuse of discretion, and the Draft Permit must be revised.

B. *To the extent that any TMDL is incorporated as an effluent limit, the Regional Board is required to follow Federal Regulations.*

14.16

The City requests that the Regional Board clarify that the Draft Permit's TMDL requirements are not effluent limits.

Federal law does not require the inclusion of TMDLs in municipal storm water permits, when issuing NPDES permits, the Regional Board is required to follow federal regulations regarding such inclusion. (See 40 C.F.R. § 122.44, subd. (d); 23 Cal. Code Regs., § 2235.2 ["Waste discharge requirements for discharge from point sources to navigable waters shall be issued and administered in accordance with the currently applicable federal regulations for the National Pollutant Discharge Elimination System (NPDES) program"].) Before it can incorporate any TMDL Waste Load Allocations ("WLAs") into the Draft Permit as effluent limits, the Regional Board must first find that there is a "reasonable potential" that the discharge of the pollutant to be regulated "has the reasonable potential to cause, or contributes to an in-stream excursion above a narrative or numeric criteria within a State water quality standard." (40 C.F.R. § 122.44, subd. (d)(1)(iii).)[3]

To determine whether a permitted discharge "causes, has the reasonable potential to cause, or contributes to an in-stream excursion above the allowable ambient concentration of a State numeric criteria within a State water quality standard[,]" the Regional Board must:

[3] Pursuant to the *Defenders of Wildlife* decision, 40 C.F.R. § 122.44(d) does not require incorporation of TMDLs or WQBELs into municipal storm water permits. When incorporated, however, Section 122.44(d) requires implementation of WQBELs to attain water quality standards.

> use procedures which account for existing controls on point and nonpoint sources of pollution, the variability of the pollutant or pollutant parameter in the effluent, the sensitivity of the species to toxicity testing (when evaluating whole effluent toxicity), and where appropriate, the dilution of the effluent in the receiving water. (40 C.F.R. § 122.44, subd. (d)(1)(ii).)

There are two generally accepted approaches to conducting reasonable potential analysis: "A permit writer can conduct a reasonable potential analysis using effluent and receiving water data and modeling techniques, or using a non-quantitative approach." (NPDES Permit Writers' Manual, September 2010, pages 6-23.)

14.16

The first approach requires end of pipe monitoring data to be evaluated against in-stream generated ambient (dry weather) data. There is no evidence in the Draft Permit or the Draft Technical Report that the Regional Board based the Draft Permit's requirements on any such data. (Draft Technical Report, pages 63-67.) Nor is there any information regarding the performance of the second approach, a non-quantitative analysis based on recommended criteria described in the EPA guidance. Neither the Draft Permit nor the Draft Technical Report contain any evidence that a reasonable potential analysis has been performed in accordance with 40 C.F.R. section 122.44(d).

If the TMDL requirements are being imposed as effluent limits, the Regional Board must comply with requirements for developing those limits instead of passing those on to the Co-permittees.

C. *The Draft Permit's TMDL requirements need to be consistent with applicable implementation plans developed for each TMDL.*

Consistent with TMDL requirements, Co-permittees have developed and implemented or are in the process of developing and implementing compliance plans for several TMDLs in the Newport Bay watershed. The Executive Officer has reviewed and approved some of these plans, and the Co-permittees are implementing the plans. Where a TMDL provides for the development and implementation of a compliance plan, the Draft Permit should reflect such a provision. Implementation of BMPs and other requirements consistent with these plans should be sufficient for permit compliance.

14.17

7. SECTION XII.B.1 SHOULD BE REVISED TO EXEMPT CO-PERMITTEE PROJECTS FROM COMPLYING WITH NEW REQUIREMENTS ONCE A PROJECT IS FUNDED

Section XII.B.1 of the Draft Permit requires Co-permittee-initiated "projects for which funding is approved on the date of the adoption of this Order" to comply with the new and redevelopment standards set out in the Draft Permit. The intent of this provision appears to be to exempt projects for which funding is approved on the date of the adoption of the Draft Permit from complying with the standards. The language, however, accomplishes the opposite and requires such projects to comply with the Permit requirements. If the Draft Permit's intent is the require such compliance, all projects which have been approved, funded, or are partially constructed on the date of the Draft Permit's adoption must cease all construction activity, be redesigned, deconstructed, and reconstructed to comply with the new requirements. Such interference with City projects may result in an unconstitutional impairment of contracts in violation of the contract clauses of the United States and California Constitutions. (U.S. Const. art. I, § 10; Cal. Const. art. I, § 9.)

14.18

The City offers the following revised language:

> The requirements of Section XII.B., and subsequent sub-sections of Section XII., apply to initial project applications received by the Co-Permittees 12 months after adoption of this Order. For projects initiated by the Co-permittees, the requirements of Section XII. do not apply to projects that have been approved within 12 months after the date of the adoption of this Order. In the interim, the relevant requirements of Order No. R8-2009-0030 shall apply.

8. SECTION VII.F IS UNNECESSARILY DUPLICATIVE OF ALTERNATIVE PERMIT REQUIREMENTS AND SHOULD BE DELETED

The City objects to the addition of Section VII.F of the Draft Permit on the grounds that it is duplicative of other permit provisions. Because the City is not subject to the requirements of Order No. 2006-0003-DWQ, Section VII.F requires the City to implement an effective program to detect and mitigate sanitary sewer overflows ("SSO"), including entering into an agreement establishing financial and jurisdictional responsibilities and objective performance metrics. (Draft Permit, § XII.F.1.)

14.19

A sanitary sewer system is comprised of two main elements: publicly owned facilities and privately owned facilities. An SSO from publicly owned facilities within the City's geographic jurisdiction is already regulated under Order No. 2006-0003-DWQ. A separate, legal

entity has authority and regulatory responsibility for such SSOs. The City does not own, maintain or otherwise control these public facilities or SSOs from these facilities. Requiring the City to establish and meet "SSO response time targets, training targets, and spill recovery targets" over which it has no control exceeds the Regional Board's authority. The entity responsible for such spills is already regulated by a separate order and is responsible for responding to such spills in accordance with that order. The City should not be required to enter into an agreement with that entity to assume a portion of that entity's legal responsibilities.

14.19

An SSO from privately owned facilities within the City's geographic jurisdiction is already regulated under Sections VII.A, B, C, and D of the Draft Permit. The City has already implemented an effective program to detect illicit discharges, including SSOs, and to respond to such spills in a timely manner. Section VII.F creates duplicative requirements and the additional obligations are not supported by any evidence showing that these additional actions will improve water quality. For these reasons, Section XII.F should be deleted from the Draft Permit.

9. THE REGIONAL BOARD HAS FAILED TO COMPLY WITH WATER CODE SECTIONS 13000, 13263, AND 13241

Under the California Supreme Court's holding in *Burbank v. State Board* (2005) 35 Cal.4th 613 ("*Burbank*"), a regional board must consider the factors set forth in sections 13263, 13241 and 13000 when adopting an NPDES Permit, unless consideration of those factors "would justify including restrictions that do not comply with federal law." (*Id.* at 627.) Section 13263 directs regional boards, when issuing waste discharge requirements, to take into account various factors including those set forth in Section 13241." (*Id.* at 625, emphasis added.) Specifically, the Court held that to the extent NPDES Permit requirements are not compelled by federal law, the regional boards are required to consider, among other factors, the "economic" impacts of such requirements on the dischargers themselves; such a requirement means that the boards must analyze the "discharger's cost of compliance." (*Id.* at 618.)

14.20

A. Finding 31 and Technical Report section X do not adequately consider economic impacts of complying with the state mandated requirements.

To the extent the Draft Permit provisions are not compelled by federal law, a regional board must consider the factors set forth in sections 13263, 13241 and 13000 when adopting an NPDES Permit, unless consideration of those factors "would justify including restrictions that do not comply with federal law." (*Burbank*, *supra*, 35 Cal.4th 6 at p. 627.) Specifically, regional boards are required to consider the "economic" impacts of Draft Permit requirements on Co-permittees, with the Court finding that such a requirement means that the boards must analyze the "discharger's cost of compliance." (*Id.* at 618.)

14.20 The Draft Permit does not undertake a complete analysis of the Co-permittees' costs of complying with the Draft Permit's requirements which exceed the federal minimum. According to the Draft Permit, a lack of comprehensive or reliable economic data on the costs and benefits makes performing a formal economic analysis impractical at this time. (Draft Permit, Draft Technical Report, at p. 31.) After asserting that such an analysis is impractical and not required, the Draft Permit then considers economic factors. (*Id.* at pp. 30-31.) The Draft Permit relies on the partial, outdated and irrelevant data provided by the US EPA, State Water Resources Control Board and regional boards, as well as a Willingness to Pay and Travel Cost Analysis to conclude that the "benefits of protecting beneficial uses . . . considerably exceed the annual per-household costs of the MS4 programs summarized in [the studies]." (*Id.* at p. 33.) Despite concluding that the benefits exceed the costs, the economic considerations set out in the Draft Permit expressly excludes "a Cost-Benefit analysis or other formal economic analyses." (*Id.* at p. 31.)

Section 13241 is not satisfied by relying on partial and unreliable data or its irrelevant "per household" consideration of an informal cost-benefit analysis. As a result, the Draft Permit's economic consideration is arbitrary and capricious and must be reconsidered to include data relevant to the Co-permittees and to the Draft Permit's specific requirements. Nothing in the Draft Technical Report links the permits studied by the US EPA and the state and regional boards generally with any of the specific requirements of the Draft Permit. Therefore, the studies tell the public nothing about the costs to implement the Draft Permit.

14.21 The data included in the Technical Report are outdated, ranging from 9 to 17 years old. The costs and benefits are also calculated on a meaningless basis in terms of a Co-permittee's funding of the Draft Permit's costs: a per household basis. Co-permittees do not incur costs or collect revenues to implement Draft Permit requirements on a per household basis. Indeed, Co-permittees cannot collect revenues on such a basis unless the public approves such a method in an election. (Cal. Const. arts. XIIIC, XIIID.) Since 1995, only 67% of such water-specific storm water measures have been approved by voters. (Public Policy Institute of California, Paying For Water in California, Technical Appendix E (Mar. 2014), p. 11 ("PPIC Report").) Not only are the data in the PPIC Report nearly a decade more recent than the data in the Draft Permit, the PPIC Report considered Draft Permit requirements which did not exist when the studies cited in the Draft Permit were conducted. The PPIC Report concludes that, even using state wide household cost estimates, "the total annual costs of meeting urban storm water permit requirements are currently in the range of $1 billion to $1.5 billion, with costs likely to continue to rise as new permit requirements come due." (*Ibid.*) Public agencies, such as the City, "are likely to have stable funding for no more than half that amount, leaving a gap of $500 million to $800 million per year, or $40 to $65 per household." (*Ibid.*) Not only is the annual funding gap identified by the most recent data twice as much as the Draft Permit estimates as the total per-household cost to comply with the Draft Permit, the City currently has no authority to address the funding gap on a per-household basis. (Cal. Const. arts. XIIIC, XIIID.)

14.22

In addition to relying on outdated and inapplicable data, the Regional Board's cost analysis is fundamentally flawed because it tells the public nothing at all about the relationship between the cost of any particular BMP and the pollution control benefits to be achieved by implementing that BMP. Under this "generalized" approach, extremely costly requirements that bear little or even no relationship (or even a negative relationship) to the pollution control benefits to be achieved could be "justified" as long as the "overall" program costs are within what the Regional Board deems to be an acceptable range.

14.22 A generalized approach to economic considerations is not a proper way to assess the cost of complying with the Draft Permit's particular requirements. A more individualized assessment of cost is required. Otherwise, dischargers may be required to implement very costly controls that have no relationship to pollution control benefits, a result inconsistent with MEP. This analytical flaw in the Technical Report is compounded by the approach taken to assess the benefits of the Draft Permit. The Draft Permit relies on the Willingness to Pay and Travel Cost Analysis to calculate the benefit of the Draft Permit requirements at $180 per household (2005 dollars). (Draft Permit, Technical Report, at p. 33.) Here again, the assessment approach misses the mark because it tells the public nothing about the pollution control benefits to be achieved by implementation of the controls in the Draft Permit and ignores the Co-permittees' inability to collect such funds on a per-household basis without an affirmative vote of such households. All the Technical Report indicates, in essence, is that people like clean water and, in theory, may be willing to pay for it. The PPIC Report demonstrates that, for as much as people like clean water, only 67% of the time are they willing to actually pay for it. (2014 PPIC Report, Appendix E, at
14.23 p. 11.) The Draft Permit's analysis sheds no light on the relationship between the actual cost of complying with the Draft Permit and the pollution control benefits to be achieved by implementing the Draft Permit's requirements and must be reconsidered using current and relevant data.

B. Section XVIII does not adequately consider economic or non-economic factors required by Water Code sections 13000, 13263, and 13241.

As described above, Federal Law does not require TMDLs to be included in municipal storm water permits. (*Defenders of Wildlife*, *supra*, 191 F.3d at p. 1165; 40 C.F.R. § 122.44,
14.24 subd. (d).) Consequently, the Regional Board is required to consider the factors listed in Water Code sections 13000, 13263 and 13241 before including the TMDL in the Draft Permit. (*Burbank, supra,* 35 Cal.4th 613.)

Water Code sections 13000, 13263, and 13241 require much more than an economic analysis. They require an analysis, in part, of the following elements:

(a) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto;

(b) Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area;

(c) The need for developing housing within the region;

14.24 (d) The need to develop and use recycled water;

(e) An analysis of whether the proposed Permit terms are "reasonable, considering all demands being made and to be made on [receiving] waters[;]" and

(f) whether specific Permit requirements are necessary, given "the beneficial uses to be protected, the water quality objectives reasonably required for that purpose, other waste discharges." (Water Code, §§ 13000, 13241, subds. (b)-(f), 13263, subd. (a).)

The Draft Permit ignores the environmental characteristics of the watershed. (Water Code, § 13241, subd. (b).) Co-permittees have undertaken extensive programs to improve water quality and have prepared a thorough report on the quality of waters in the watershed. The Draft Permit disregards these efforts and the present state of the waters and increases Co-permittees obligations under the Draft Permit without any reference to the water quality conditions that could reasonably be achieved through the Draft Permit's additional requirements. The Draft Permit should be based on the state of the environment and only impose requirements on Co-permittees designed to address specific environmental problems.

The Draft Permit likewise ignores the present state of the law and the scheme of joint and several liability established by the Draft Permit in facilitating coordination among Co-permittees. (Water Code, § 13241, subd. (c).) The practical effect of the Draft Permit's scheme and the Ninth Circuit's decision in *Natural Resources Defense Council v. County of Los Angeles* (9th Cir. 2013) 725 F.3d 1194 will be to reduce coordination among Co-permittees. Where the City may be liable for another Co-permittee's failure to implement TMDL requirements, for example, 14.25 the City is unlikely to participate with other Co-permittees in developing or implementing a TMDL compliance plan. (See Draft Permit, § XVIII.C.) A scheme of joint and several liability that discourages coordination is also unnecessary to protect beneficial uses and attain water quality objectives. (Water Code, § 13263, subd. (a).) Because the Draft Permit does not identify how a scheme of joint and several liability promotes coordination and is necessary to protect beneficial uses, such a scheme should be removed or explicitly denounced in the Draft Permit.

Finally, the Draft Permit does not address how its requirements affect the need for developing housing within the region (Water Code, § 13241, subd. (e)); the need to develop and use recycled water (Water Code, § 13241, subd. (f)); or whether the proposed Draft Permit terms are "reasonable, considering all demands being made and to be made on [receiving] waters" (Water Code, § 13000).

14.24 The inclusion of the TMDL in the Draft Permit violates sections 13263, 13241 and 13000, as well as the California Supreme Court's decision in *Topanga Association for a Scenic Community v. County of Los Angeles* (1974) 11 Cal.3d 506. For these reasons, the TMDL requirements should be removed from the Draft Permit or modified to address the concerns raised in this letter.

10. THE STATE MANDATES ANALYSIS IN FINDING 32 AND TECHNICAL REPORT SECTION VI.E CONSIDER IMPROPER FACTORS AND IS NOT SUPPORTED BY THE EVIDENCE.

The only agency charged with determining whether a mandate is imposed by the state is the Commission on State Mandates ("Commission"). (Gov. Code, § 17552.) The Draft Permit, however, concludes that the Draft Permit's requirements are federal mandates. (Draft Permit, 14.26 Finding 32; Draft Permit, Technical Report, VI.E.) This conclusion is based on improper factors, such as a comparison of the Co-permittee's obligations with the obligations imposed on non-governmental and new dischargers. (Draft Permit, Finding 32.b.) The proper analysis for determining whether a requirement is a state mandate is to compare the express requirements of federal law with the requirements of the state action. (See *San Diego Unified School District v. Commission on State Mandates* (23004) 33 Cal.4th 859, 868.) Because the Commission has authority to determine whether the Draft Permit's requirements are State mandates and because the analysis set forth in the Draft Permit does not apply a proper state mandates analysis, the Draft Permit should be revised to remove all state mandates analyses.

11. FINDINGS 10, 31, TECHNICAL REPORT SECTION V, AND THE GLOSSARY IMPROPERLY CLASSIFY NATURAL WATERS AS PART OF THE MS4.

Natural waters cannot be both receiving waters and part of the MS4. (40 C.F.R. § 122.26, subd. (b)(8); (*Los Angeles County v. NRDC* (2013) 133 S.Ct. 710.) The Draft Permit states that development often makes use of natural drainage patterns and features as conveyances 14.27 for runoff. (Draft Permit, Finding 13.) Finding 13 goes on to state that rivers, streams and creeks in developed areas used in this manner and under the ownership and control of the Co-permittees are part of an MS4, whether the river, stream or creek is natural, anthropogenic or partially modified. It further states that these natural water bodies are both an MS4 and a receiving water.

Finding 13 is expressly contradicted by the Federal Regulation defining an MS4 and by recent United States Supreme Court case law. Federal Regulations define a municipal separate storm sewer system as:

> a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains):
>
> i. Owned or operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) ... including special districts under state law such as a sewer district sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act that discharges into waters of the United States;
>
> ii. Designed or used for collecting or conveying stormwater;
>
> iii. Which is not a combined sewer; and
>
> iv. Which is not part of a publicly owned treatment works (POTW) as defined at 40 C.F.R. 122.2. (40 C.F.R. § 122.26, subd. (b)(8).)

14.27

The definition of a municipal separate storm sewer system is specifically limited to *man-made* channels and systems and does not encompass natural water bodies. Discharging to a natural water body does not transform a natural water body into an MS4. A discharge makes a natural water body a "receiving water." Similarly, improving natural rivers, streams and creeks does not make them MS4s, or part of an MS4. They simply become improved waters of the United States. The US Supreme Court recently confirmed this conclusion when it determined that the flow of water from an improved portion of a navigable flood control channel into an unimproved portion of the same waterway is not a "discharge of a pollutant" under the Clean Water Act. (*Los Angeles County v. NRDC* (2013) 133 S.Ct. 710.)

14.27

Lastly, municipalities do not generally own, control or operate natural rivers, streams and creeks. Such water bodies are often administrated by the State of California in the public trust for the right of the people to use such waters for certain purposes or are privately owned. The Legislature, acting within the confines of the common law public trust doctrine, is the ultimate administrator of the trust and may often be the final arbiter of permissible uses of trust lands. Such waters are not therefore, part of the City's MS4. For these reasons, Finding 13 and Technical Report section V, and reference to "natural drainage features or channels" and "modified natural channels" in the Glossary's definition of Municipal Separate Storm Sewer System should be deleted.

CONCLUSION

The City appreciates this opportunity to comment on the Draft Permit. The City believes that the Regional Board has a genuine interest in working with all interested parties to develop a permit that protects the waters in the Santa Ana and Newport Bay/San Diego Creek Watersheds while at the same time giving dischargers such as the City the ability to comply with the permit's requirements.

Thank you for considering the City's comments and feel free to contact me if you have any questions.

Sincerely,

J. G. Andre Monette
Best Best & Krieger LLP

From:	Peter Herzog
To:	Berchtold, Kurt@Waterboards
Cc:	Fischer, Adam@Waterboards
Subject:	Comment Letter - North County MS4 Permit
Date:	Wednesday, June 18, 2014 1:34:56 PM
Attachments:	6-18SARWQCBlettMS4.pdf

Mr. Berchtold:

Attached is our comment letter on the draft MS4 permit for North Orange County. Thank you for also providing this to the Board Members for their consideration.

Peter Herzog, Assistant Director of Legislative Affairs
NAIOP SoCal
Commercial Real Estate Development Association
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Laguna Hills, California 92653

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Please visit the SoCal Legislative Update at www.naiopsocal.org

The NAIOP SoCal Chapter represents commercial real estate professionals in Orange and Los Angeles Counties.

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NAIOP
COMMERCIAL REAL ESTATE DEVELOPMENT ASSOCIATION
SoCAL CHAPTER

June 18, 2014

Kurt Berchtold, Executive Officer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, California 92501

Sent via Email

Re: Comments on the Draft North Orange County MS4 Permit

Dear Mr. Berchtold:

Since 1967, NAIOP, the Commercial Real Estate Development Association, has become the leading organization for developers, owners and investors of office, industrial, retail and mixed-use real estate. NAIOP comprises 15,000+ members and provides strong advocacy, education and business opportunities through a powerful North American network. The NAIOP SoCal Chapter covers Orange and Los Angeles Counties. Please accept these comments to the draft MS4 Permit ("Permit") for North Orange County.

1. WQMP Guidelines: Section XII.B.16 of the Permit requires that each Co-Permittee "develop, publish, and apply guidelines" for site design and structural treatment controls that are "readily inspected and maintainable, aesthetically pleasing, and of a quality that is satisfactory to the Co-permittee."

5.1 Guidelines that fulfill these requirements are already present in the County of Orange's Model Water Quality Management Plan and Technical Guidance Document. Our cities and the development community spent substantial resources (several million dollars) and a year of stakeholder meetings creating and editing these guidelines along with the Regional Board. Further CASQA and others agencies publish engineered and peer reviewed criteria for the site design and structural treatment controls. *In light of the extensive resources the taxpayers and the development community have already poured into essentially completing this specific element of the NPDES program, why are we being asked to do this again?*

2. Biotreatment BMP Sizing: Section XII.G.1 of the Permit requires that biotreatment BMPs should be sized to treat 1.5 times the site's design capture volume when it is used in lieu of a retention LID BMP.

5.2 It seems the Technical Report provided with the Permit, indicates this requirement was based on the results of a Ventura County study that focuses on their local hydrologic and soil conditions. *Please provide the data which shows the sizing criteria that is applicable to hydrologic and soil conditions in Orange County.*

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3. WQMP Inspection Authority: Section XII.D.10 of the Permit requires the cities to "secure the authority" to enter into private property to inspect and maintain the property.

5.3 Is the Regional Board requiring individuals to waive their property and privacy rights if they have a water quality management plan associated with their property? Every element of every home and building that is approved is subject to inspection at the time of development, but no one reasonably expects that an inspector will be coming into your bathroom, kitchen, or in this case, backyard if that is where a BMP is located, in perpetuity. *We would like to know if the Regional Board is planning to place any limitations on this inspection requirement. It certainly puts the Cities in a bad position for several reasons.*

4. Staff Discipline: Section XII.E.5 of the Permit requires that the copermittees "include disciplinary procedures or policies for Co-permittees' staff that unnecessarily deviate from standard operating procedures."

5.4 Each city and private organization has defined labor and employment requirements which are defined by statutory and common law parameters. We would be most interested to understand why you believe Regional Board staff has the authority to decide how and when cities should be disciplining its staff. *This seems highly inappropriate and serves as an example of how this Regional Board staff is straying far from its charge to protect water quality.*

NAIOP SoCal is committed to treating water quality as a high priority for the County of Orange, but we have concerns regarding the requirements of the Permit not efficiently utilizing public resources.

We appreciate your attention to our comments and look forward to further dialogue regarding the Permit.

Sincerely,

Peter Herzog
Assistant Director of Legislative Affairs

Cc: Adam Fischer

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June 20, 2014

Adam Fischer, MESM
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500,
Riverside, CA 92501

RE: ORDER NO. R4-2012-0175

Dear Mr. Fischer,

Thank you for the opportunity to review and comment on the draft Orange County stormwater permit. My comments are focused on Section XII which contains New Development requirements. Attached to this letter is a list of specific changes requested to make this permit more clear and effective. In addition, some of the main comments are elaborated on below.

Infiltration System Pretreatment

9.1 Pretreatment requirements for infiltration systems need to be strengthened to prevent spills from contaminating native soils and groundwater and to ensure that the infiltrative capacity of native soils is sustained for the life of the project. Unfortunately in many cases, we see that pretreatment to remove oil and grease, sediment and gross pollutants is given only token consideration and may even be eliminated in a short-term effort to reduce infrastructure costs. However, the cost of restoring systems that fail due to native soil occlusion by fine sediment and the risk to groundwater from not providing adequate spill protection in high risk areas is a long-term problem. This permit presents an opportunity to set a minimum pretreatment performance standard for high risk infiltration systems. Specifically, a reference to the Washington State Department of Ecology Pretreatment[1] criteria is suggested to ensure that a basic level of protection is provided.

Biotreatment BMP Design

9.2 Under the current permit, a wide variety of biotreatment system configurations have been specified for use where retention BMPs are infeasible. Conventional slow rate systems utilizing a combination of sand and organic media are common in the region and throughout the Western United States. Although precise gradation and composition specifications have been established for biomedia, recent research suggests that export of key pollutants including phosphorus, nitrogen and dissolved copper is common during establishment of the system meeting those specifications and may continue for a year or more[2]. These performance questions, combined with construction sequencing and quality control challenges, and the relatively large area required for slow rate systems has led to innovation in compact biofiltration systems. These systems use engineered media that has been optimized and standardized to provide high infiltration rates, comparable pollutant removal to slow rate systems and to support robust vegetative growth. These systems are often designed at up to the equivalent of a 100 inch-per-hour infiltration rate and are commonly used in ultra-urban applications.

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[1] Washington Department of Ecology. Program information available at: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html

[2] Herrera Environmental Consultants, Inc. March 6th, 2014. "185th Avenue NE Bioretention Stormwater Treatment System Performance Monitoring". Prepared for City of Redmond, WA

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9.2 These optimized systems should be allowed for use in Orange County only if their performance is similar or better than their slow-rate conventional counterparts. To ensure that only highly effective biotreatment systems are allowed, this permit should reference the Washington State Department of Ecology (Ecology) program for the evaluation of emerging technologies, "Technology Acceptance Protocol - Ecology" (TAPE)[3]. This program requires robust field- testing following a peer reviewed testing protocol during which performance on par with conventional biotreatment systems must be demonstrated. Where adequate sediment removal is demonstrated, a General Use Level Designation for Basic Treatment is awarded. Additional use level designations are available for phosphorus removal and dissolved zinc and copper removal. Requiring that high-rate biotreatment systems used in Orange County be sized per their Ecology use level designations would ensure that only the highest performing systems are allowed.

Rainwater Harvesting Feasibility

9.3 California is in a drought. While we are hopeful that this is a temporary condition, it is likely that pressure on our water supply will be increasing in the long term as the global climate slowly warms. Rainwater harvesting and infiltration to a usable aquifer are stormwater strategies that also have water supply benefits and are justifiably prioritized. A simple change that could make rainwater harvesting feasible on more sites in Orange County would be to allow a cistern to drain to a landscaped area at the maximum rate that would not produce runoff. Depending on the soil type, this may be far in excess of the agronomic demand as it would be dictated by the infiltration rate of the native soils. Essentially the landscape area would be operating at its full retention capacity during and within 48 hours of a storm event.

Thank you for considering these suggestions as well as the attached comments as you update the draft permit. Please let me know if you have any questions.

Sincerely,

Vaikko P. Allen II, CPSWQ, LEED-AP
Director - Stormwater Regulatory Management

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[3] Washington Department of Ecology. Program information available at: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html

Suggested Changes
Draft NPDES NO. CAS 618030
Orange County MS4 Permit

Submitted by Vaikko Allen, CPSWQ, Director - Regional Regulatory Management
CONTECH Engineered Solutions, LLC
Phone: 310-850-1736, e-mail: vallenv@conteches.com
Address:2550 Bonmark Drive, Ojai, CA 93023

Section	Proposed Change or Comment	Justification
XII.D.3 9.4	Please clarify that rainwater harvesting systems may retain water for longer than 48 hours as long as adequate volume is recovered in the cistern to retain the DCV within 48 hours. Alternatively, real time controls may be designed to release cistern water to permeable landscaping in excess of irrigation demand based on precipitation forecasting and in proportion to the expected runoff volume.	Integration of smart controls that are linked to weather forecasting can minimize potable water demand by holding and judiciously using treated runoff during dry periods. When rain is forecast, cistern volume can be recovered by discharging stored water to permeable landscape areas without generating runoff.
XII.D.14 9.5	Please provide clarity on the requirement that BMPs "must be designed and constructed in substantial conformance with published and generally accepted engineering design criteria" for manufactured treatment devices.	The Washington State Department of Ecology program for the evaluation of emerging technologies, ("Technology Acceptance Protocol - Ecology" (TAPE)) and the New Jersey Department of Environmental Protection certification program for manufactured treatment devices are the two leading evaluation programs. Each program requires testing in the laboratory and/or field following a peer reviewed protocol. Performance results are also peer reviewed and based on these results specific design conditions are established for each BMP to ensure reliable performance. Adhering to these design and sizing conditions would be a more protective alternative to the standard guidance to "refer to manufacturers recommendations". At this time there is no comparable reference in California that provides the technology specific information needed by project proponents.

Section	Proposed Change or Comment	Justification
XII.H.1.b 9.6	Please clarify that the rating of "high", "medium" and "low" levels of removal should be relative to approved LID BMP performance.	Several current and past Phase I stormwater permits in California require selection of BMPs with at least medium effectiveness for pollutants of concern. Since LID BMPs are approved as providing adequate treatment in sections F and G, alternative non-LID BMPs should provide similar water quality benefit. Any rating of BMPs should reflect the fact that some pollutants are more easily removed than others. For example, trash and debris removal targets should be much more stringent than targets for bacteria and nitrates. Also, BMP ratings and selection criteria must recognize the fact that optimum removal of all pollutants may not be possible simultaneously within a single BMP. For example, increasing organic content of filter media can improve removal of heavy metals and reduce toxicity but may reduce nitrogen and phosphorus removal.
XII.H.1.c 9.7	Please require General Use Level Designation for Basic Treatment by the Washington State Department of Ecology as a minimum qualification for manufactured BMP use. Furthermore, sizing should be consistent with Ecology use level designation such that the approved hydraulic loading rate is not exceeded during the design storm.	The Washington State Department of Ecology administers the Technology Acceptance Protocol - Ecology (TAPE) program in order to assess the performance capabilities and operation and maintenance demands of emerging technologies. A General Use Level Designation for Basic Treatment is only awarded for those technologies that achieve at least 80% TSS removal or less than 20 mg/L effluent TSS concentration in peer reviewed field studies. Additional use level designations may be granted for phosphorus removal or dissolved copper and zinc removal. Referencing Basic Treatment at a minimum would ensure that BMPs are reasonably sized and have demonstrated operational feasibility at the approved hydraulic loading rate. Simply requiring field data without specifying that it must be collected following a recognized protocol opens the door for the use of unreliable or incomplete field studies. Data collected under other peer reviewed field monitoring protocols for example the TARP Tier II protocol, Caltrans field monitoring protocol or the Sacramento stormwater quality partnership protocol would also produce reliable data.
XII.H.5 9.8	At a minimum, BMPs selected for pretreatment prior to discharge to a regional or sub-regional BMP should have a General Use Level Designation for "Pre-Treatment" from the Washington State Department of Ecology.	Where no LID BMPs are proposed on site, a minimum level of treatment must be provided on-site to prevent exposure to pollutants as runoff travels to the regional facility. For example, trash and debris can be noxious as it decomposes and can be transported by wind and wildlife as it comes to rest in a conveyance system.

Section	Proposed Change or Comment	Justification
XII.I 9.9	Please add a requirement that pretreatment BMPs be required upstream of infiltration BMPs to protect groundwater quality. For example, BMPs with spill capture capability should be required at sites at risk for spills including sites with average daily traffic counts greater than 25,000, gas stations, light industrial facilities, restaurants etc.	As currently written this section only requires pretreatment as necessary to maintain the performance of the facility. The performance of the facility could be reasonably interpreted as its ability to efficiently convey stormwater to subsurface soils. This requirement needs to be strengthened to protect groundwater from mobile pollutants. This can include nutrients, pesticides and other pollutants associated with conventional landscaping practices.
XII.J.1 9.10	Please make it clear in this section that cistern volume in excess of the design capture volume does not need to be drawn down within 48 hours.	The intent of the draw down requirement is to provide adequate cistern volume to store the design capture within 48 hours of a storm. Additional volume may be stored for longer term potable water demand offset.
XII.K.2.c.ii	Reference to Section XII.J.1.b may be incorrect.	

9.11

OC Public Works
Integrity, Accountability, Service, Trust
Shane L. Silsby, Director

June 20, 2014

By E-Mail Kurt

Mr. Kurt Berchtold, Executive Officer.
California Regional Water Quality Control Board, Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Comment – Draft Order No. R8-2014-0002, NPDES Permit No. CAS618030

Dear Mr. Berchtold:

The County of Orange, as Principal Permittee of the Orange County Stormwater Program, appreciates the opportunity to provide comments on *Draft Order No. R8-2014-0002, NPDES Permit No. CAS618030 National Pollutant Discharge Elimination System (NPDES) Permit and Waste Discharge Requirements*. The north Orange County Permittees (Permittees) were involved in the development of these comments and the Cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fullerton, Garden Grove, Huntington Beach, Irvine, La Habra, La Palma, Laguna Hills, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda have directed that they be recognized as concurring entities on this letter.

16.1 We understand the key interest of your staff in creating a self-contained Order that eliminates permitting by reference to other documents such as the Drainage Area Management Plan and Model Water Quality Management Plan. In addition, the Permittees appreciate the re-affirmation of an adaptive management approach as the fundamental basis of permit compliance in a manner that is consistent with Board Order 99-05. This permitting approach is unequivocally the most appropriate approach for a nonpoint source problem in a point source regulatory framework. Nonetheless, the further development of a permit for surface water quality protection that does not consider the current state of the surface water environment in Orange County as described in detail in the Report of Waste Discharge, and accomplishments of the Orange County Stormwater Program, is a concern. The Permittees are also concerned by the many new requirements that that are presented by the Draft Order in the absence of justification.

Should Regional Board staff modify the Draft Order in response to comments, we request that an additional written comment period be provided prior to submittal to the Regional Board for adoption. We also reserve the right to respond to other commenters at a hearing and present evidence for the record.

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Our comments on the Draft Order are organized and submitted as follows:

16.1

- Attachment A presents our general observations and detailed comments on the entire permit.
- Attachment B presents a redline/strikeout version of recommended changes to the Tentative Order.

Thank you for your attention to our comments. Please contact each of the undersigned directly if you have any questions. For technical questions, please also contact Chris Crompton at (714) 955-0630 or Richard Boon at (714) 955-0670 as appropriate.

Sincerely,

Mary Anne Skorpanich, Deputy Director
OC Environmental Resources

Ryan Baron, Senior Deputy County Counsel
Office of the County Counsel

Attachments: A – Detailed Comments
B – Redline Version of the Tentative Order

Cc: (Electronic copies only)

North Orange County Permittees
Orange County Technical Advisory Committee
Jason Uhley, Riverside County Flood Control and Water Conservation District
Marc Rodabaugh, San Bernardino County Flood Control District

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Attachment A

County of Orange Detailed Comments
Draft Order No. R8-2014-0002

ATTACHMENT A
COUNTY OF ORANGE COMMENTS ON
CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
SANTA ANA REGION
DRAFT ORDER NO. R8-2014-0002
NPDES NO. CAS618030

This document, **Attachment A**, contains the detailed technical and legal comments ("Comments") of the County of Orange and the Orange County Flood Control District (collectively, "County") on Draft Order No. R8-2014-0002 dated May 2, 2014 ("Draft Order") and the Fact Sheet/Technical Report ("Fact Sheet"). These Comments are divided into three sections (*General Comments*, *Findings*, and *Permit Provisions*) and address issues relating to specific parts of the Draft Order. At times, the issues and concerns raised will pertain to more than one section of the Draft Order. **Attachment B** identifies the recommended changes to the Draft Order to address the Comments raised in Attachment A as well as general edits in order to provide additional clarification where necessary.

The County of Orange, as the Principal Permittee, the Orange County Flood Control District, and the cities of Anaheim, Brea, Buena Park, Costa Mesa, Cypress, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, Irvine, Laguna Hills, Laguna Woods, La Habra, La Palma, Lake Forest, Los Alamitos, Newport Beach, Orange, Placentia, Santa Ana, Seal Beach, Stanton, Tustin, Villa Park, Westminster, and Yorba Linda collectively refer to themselves as "Santa Ana Region Permittees" or "Permittees." The Draft Order refers to the County, Orange County Flood Control District, and incorporated cities of north Orange County as the "Co-Permittees." However, the Comments below use the term "Permittees" to be consistent with the terminology used by cities and the County.

GENERAL COMMENTS

1. THE DRAFT ORDER DOES NOT RECOGNIZE THE REPORT OF WASTE DISCHARGE OR THE SIGNIFICANT WATER QUALITY OUTCOMES THAT HAVE BEEN ACHIEVED IN ORANGE COUNTY AND, THEREFORE, LACKS SUBSTANTIAL EVIDENCE TO SUPPORT NEW OR MODIFIED PROGRAM REQUIREMENTS.

16.2

The Permittees submitted a Report of Waste Discharge (ROWD) to the Santa Ana Regional Water Quality Control Board ("Regional Board") on October 3, 2013. Pursuant to federal law, the Permittees' ROWD is an application to discharge pollutants from a point source to waters of the United States and be covered by a fifth term municipal separate storm sewer system (MS4) National Pollutant Discharge Elimination System (NPDES) Permit.[1] The ROWD evaluates the fourth term MS4 Permit activities and discusses the accomplishments of the Orange County Stormwater Program. Based on the ROWD's assessment and findings, the application identifies the activities that are proposed for the fifth term MS4 Permit, including additional pollutant control initiatives. The ROWD is also the technical

[1] 40 CFR § 122.21

basis or substantial evidence for what regulations and activities will be required in the fifth term MS4 permit.

The Permittees' application for a fifth term MS4 permit is predicated on the assessment of the "State of the Environment" (ROWD Section 2). This assessment describes the results of the long-term monitoring and special studies that are used to examine the condition of the surface water environment in Orange County with an emphasis on recreation and aquatic ecosystem health. The analyses point to bacteria, nutrients, and toxicity as the water quality priorities and identify needed improvements in water quality as well as recommendations for the fifth term MS4 permit intended to ensure further improvements in surface water quality.

16.2 Formulating the fifth term MS4 permit needs to follow the iterative process, that is: assess what measures have been implemented and how the environment has responded. Despite the detailed activities and accomplishments described in the ROWD, there is no discussion in the Draft Order regarding the "State of the Environment." In fact, the Draft Order Findings and Fact Sheet do not reference the Permittees' application or cite specific areas in the ROWD to provide a basis for or justify particular fifth term stormwater program modifications. Section B of the Findings (Discharge Characteristics and Runoff Management) only contains generic statements about water quality and excludes the key findings presented in the ROWD. Although the Findings within Section B of the Draft Order may have been the general factual basis for the Permittees' first and second term MS4 Permits, they are not appropriate for a fifth term MS4 Permit and a Stormwater program as advanced as in north Orange County.

The absence of any recognition of the significant water quality outcomes that have been achieved in Orange County (e.g. coastal water quality) creates a false case, in many instances, for regulatory change. Without support from specific findings and other evidence, the requirements of the Draft Order, in many instances, lack substantial evidence and are arbitrary and capricious, and therefore, cannot be lawfully adopted.[2]

In addition, the Draft Order does not recognize the development of or relationships between the Drainage Area Management Plan (DAMP) and jurisdictional Local Implementation Plans (LIPs).

Action: The Draft Order needs to include the key findings from the Report of Waste Discharge (including the State of the Environment) and use this information as the basis for the Draft Order's requirements.

2. THE DRAFT ORDER SEEKS TO MAKE SIGNIFICANT CHANGES TO THE MODEL WATER QUALITY MANAGEMENT PLAN (WQMP). AFTER ONLY TWO YEARS OF IMPLEMENTATION, IT IS SIMPLY TOO EARLY TO REQUIRE CHANGES TO THE MODEL WQMP AND TECHNICAL GUIDANCE DOCUMENT (TGD), AND THERE IS NO SUBSTANTIAL EVIDENCE TO SUPPORT DOING SO.

16.3 The 2011 Model Water Quality Management Plan ("Model WQMP" or "WQMP") and accompanying Technical Guidance Document ("TGD") were developed during the last

[2] *City of Rancho Cucamonga v. Regional Water Quality Control Bd.*, 135 Cal.App.4th 1377, 1384–1385 (2006); Code Civ. Proc., § 1094.5(b).

permit term through a collaborative stakeholder process inclusive of Regional Board staff, U.S. EPA, Permittees, environmental nongovernmental organizations (NGOs), the land development community, technical consultants, and other interested parties. The Model WQMP Technical Advisory Group (TAG) met for a total of six meetings over twenty-four months and the Planning Advisory Group (PAG) met ten times over 18 months to develop this comprehensive program. A Planning Advisory Committee (PAC) was also formed.[3] The total cost of developing the revised Land Development Program was in excess of $1.5 million. In addition to being developed through an extensive and collaborative stakeholder process, the Model WQMP and TGD were subject to a public comment period and two presentations before the Regional Board. Following approval of the Model WQMP and TGD by the Executive Officer, the Orange County Stormwater Program conducted numerous training events, and maintains a help desk to provide technical support for implementation of the new land development requirements, which has addressed approximately 100 inquires since August of 2011.

Despite this investment and relatively short period of Model WQMP implementation, the Draft Order seeks to affect nineteen significant changes to the new development provisions that would necessarily require a comprehensive revision of the Model WQMP and TGD. This impact to the Model WQMP is contrary to the Draft Fact Sheet which states that Section XII has been expanded to incorporate synthesized elements of the Model WQMP and TGD.

16.3 The effect of these changes is that, not only will the Model WQMP and TGD need to be updated, but protocols at each of the Cities and the County will need to be updated and new training will need to be developed and provided to County and City Staff as well as the developers and the construction industry. In the absence of any technical justification that these changes will have a measurable improvement to water quality, the time, effort and cost to update the Land Development Program is simply not warranted. Given that the Model WQMP has only been in place for two years and lacks implementation experience and evaluation, making material changes to this program simply does not make sense.

The Draft Order also requires all development projects to be defined either as "priority" or "non-priority" projects. The provisions in the Draft Order would require projects such as reroofs, patio covers, solar panel roof installations, block walls, swimming pools and spas and other projects typically issued permits by building departments to prepare Non-Priority Project Plans. This requirement will cause significant project delays and will add potentially thousands of dollars to insignificant projects because applicants will now have to hire a licensed professional (civil engineer or landscape architect) per Section XII.M.5 to prepare their Non-Priority Project Plans. Without technical justification or a linkage to water quality impacts that these types of projects would have, expanding the universe of "non-priority" projects is not warranted.

[3] The Planning Advisory Committee (PAC) was created in February 2009 at the request of the City Engineers' Technical Advisory Committee (TAC) and the City Managers' Water Quality Committee to serve as a focus for increasingly complex land development and redevelopment requirements in the municipal NPDES stormwater permits. The PAC has delegated authority for private projects. The City Engineers' TAC will continue to have delegated authority for public projects. The PAC, when convened, meets with the TAC.

16.3 *Action: The Draft Order should be modified to incorporate the existing Model WQMP and TGD that have been approved by the Executive Officer.*

3. REGIONAL BMPS

The restoration of the equivalency of Regional BMPs is particularly welcomed in the Fifth Term MS4 Permit. Currently, the use of "Regional BMPs" in the Model WQMP as a subordinate choice to on-site mitigation is not supportive of water quality, water supply, and restorative goals that could be realized and optimized at the watershed level. This LID hierarchy is increasingly being viewed as obstructive, as California adapts to increasing uncertainty regarding the resilience of its water supply infrastructure by seeking to better retain stormwater in the landscape for local water supply augmentation. Since Regional BMPs are seen to be a key part of this adaptive effort (see Southern California Water Committee www.socalwater.org/), the re-establishment by the Draft Order of the equivalency of Regional BMPs is both very welcome and timely. Indeed, Regional BMP solutions are integral to the Integrated Water Resource Management (IRWM) approaches being encouraged by the California Water Action Plan (State of California, 2014) as the means of solving the challenges of increasingly stringent water quality regulations and the water supply demands of a growing population.

16.4 The proposed equivalency of Regional BMPs revisits the recurring debate about the merits of centralized versus de-centralized approaches, or on-site versus regional controls, to creating a stormwater management infrastructure. While the Fourth Term MS4 Permits have required on-site BMPs to be constructed unless they can be determined to be infeasible, the Third Term MS4 Permit encouraged examination of regional approaches. The Regional BMP emphasis is supported by technical guidance (see WEF/ASCE, 1998) that contemplates stormwater quality being managed across the landscape in a drainage system retrofitted with basins and under the direct management of a special district. This guidance concludes that constructing fewer Regional BMPs will ultimately be both less expensive than a large number of on-site controls and more effective in the longer term since they could additionally capture the street runoff that would be missed by on-site controls. Such basins would also be large enough to offer opportunities for compatible uses such as recreation and ecological habitat. With the new imperative to have IWRM inform approaches to stormwater management, the permitting framework clearly needs to allow for on-site and off-site BMP "equivalency."

Action: Promote on-site and off-site BMP equivalency throughout the Draft Order.

4. THE DRAFT ORDER'S RECEIVING WATER LIMITATIONS LANGUAGE PROVIDES THE PERMITTEES WITH FLEXIBILITY

16.5 The Draft Order's receiving water limitations language provides the Permittees with the flexibility to achieve compliance with receiving water quality standards. The Orange County stormwater program is a robust and mature program that has made tremendous progress in improving water quality.[4] The Orange County Permittees have spent a collective total of approximately $1.16 billion since 1995. However, in certain instances, receiving waters limitations are not able to be met. As further discussed in these Comments,

[4] *See* ROWD, State of the Environment.

the Permittees do not have control over every aspect of the environment, and despite investigations and source control efforts, have no control over certain pollutants that end up in their channels.[5] And, in some instances, it is technically and/or economically infeasible to meet a numeric standard.[6]

The Permittees need for a NPDES permit is based on their legal obligations to protect life and property from flooding.[7] This mission is sometimes at odds with achieving water quality standards, which is why the Clean Water Act contains a maximum extent practicable standard ("MEP"). Much of Orange County lies within a large flood plain where billions of dollars have been expended constructing and maintaining the Santa Ana River Project, which has channel, dam and other improvements as far out as San Bernardino County. Likewise, city storm drain systems are designed to protect life and ensure that residential, commercial and industrial properties do not suffer economic damage. In some cases, the terms of the Draft Order conflicts with the Legislature's delegation of flood control authority to the Permittees. And in this highly urbanized environment, much of which predates the Clean Water Act and Porter-Cologne, it is difficult if not infeasible to retrofit prior land and flood control development.

16.5

The Orange County Permittees are committed to the concepts of the Clean Water Act and restoring and maintaining the chemical, physical and biological integrity of the nation's (and State's) waters.[8] The Orange County program is one of the most well recognized in the U.S., and it will continue to strive to meet the water quality standards in the Draft Order. However, the Draft Order needs to and does contain an iterative process that allows the Permittees the opportunity to achieve compliance over successive permit terms. This is not a "safe harbor" or "get out of jail free card." It is a recognition that diligently implementing a BMP-based plan takes time, and is in accordance with the MEP standard. It is also a recognition that in certain instances it may be technically and economically infeasible to meet numeric standards.

Although some commenters may contend that the iterative process is unlawful due to anti-backsliding and other reasons, this is simply not the case. The iterative process has been implemented by the State Water Board and supported by EPA in California and other

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[5] *See e.g.*, SB 346 (Kehoe 2010) (allowing manufacturers to deplete their inventory of brake pads containing certain unlawful constituents until 2023).

[6] *See* Comments of the City of Irvine, Draft Order R-8-2014-0002 (June 20, 2014) (describing the technical and economic infeasibility of addressing selenium in rising groundwater). The County concurs and joins in the City of Irvine's comments as well as the other Permittees that have submitted comments on the Draft Order.

[7] *See e.g.*, Orange County Flood Control Act of 1927, Chapter 723 of the State of California Statutes of 1927 (uncodified). *See also*, *S.D. Warren Co. v. Me. Bd. of Envtl. Prot.*, 547 U.S. 370 (2006) (holding that state and regional boards have no authority to impose NPDES conditions that impact volumetric flows); *PUD No.] v. Washington Dep't of Ecology*, 511 U.S. 700 (1994); *Arreola v. County of Monterey*, 99 Cal.App.4th 722 (2002) (holding that residents have a right to rely on flood control standards).

[8] CWA § 101(a).

16.5

NPDES permits nationwide.[9] The lack of an iterative process for receiving water limitations and other numeric standards would render the permit unlawful and not in accordance with Congress' or the State Board's intent for MEP.[10] At least one Regional Water Board has acknowledged that without an iterative process, Permittees are out of compliance with their permit on Day One. That approach effectively turns the stormwater sections of the CWA and Porter Cologne into a strict liability regime, much like products liability or oil spills, where MS4s are legally liable for exceedances regardless of culpability or their efforts in attaining standards. Neither Congress nor the Legislature nor the State Water Board intended that the law, let alone MEP, be defined in this way.[11]

Action: The Draft Order should support the iterative process in the receiving water limitations as is currently drafted.

5. THE DRAFT ORDER SHOULD ALLOW FOR A WATERSHED MANAGEMENT-BASED ALTERNATE COMPLIANCE PATHWAY.

16.6

Consideration needs to be given to including an alternative compliance pathway based upon a watershed planning approach. A watershed-based approach would enable compliance activities to be directed toward addressing specific pollutant-waterbody combinations and allow for explicit recognition of watershed-specific constraints, such as the significance of shallow groundwater exfiltration in the Newport Bay Watershed. There is broad support for and many benefits related to a watershed-based approach:

- Nationally, there is a permitting approach shift from the traditional stormwater program (six to eight core program elements) to a more watershed/pollutant-based approach (developing the program to address high priority water quality issues).

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[9] *See* State Water Resources Control Board, WQ 2001-15 at 7 (Nov. 15, 2001). The State Water Board stated that the precedential receiving water limitations language in WQ 1999-05, which is substantially similar to the language in the Draft Order, does not require strict compliance with water quality standards:

> "[The receiving water limitations language] does not require strict compliance with water quality standards. Our language requires that storm water management plans be designed to achieve compliance with water quality standards. Compliance is to be achieved over time, through an iterative approach requiring improved BMPs . . .[T]he iterative approach is consistent with U.S. EPA's general approach to storm water, which relies on BMPs instead of numeric effluent limitations."

[10] *See e.g.*, *Hughey v. JMS Development Corp.*, 78 F.3d 1523, 1530 (11th Cir. 1996).

[11] *Defenders of Wildlife v. Browner*, 191 F.3d 1159, 1165 (9th Cir. 1999); *Divers Environmental Conservation Organization v. State Water Quality Resources Board*, Cal. App. 4th 246, 256 (2006); *Bldg. Indus. Ass'n v. State Water Resources Control Board*, 124 Cal.App.866, 889 -(2004); Betsy Jennings, State Board Memorandum, *Definition of Maximum Extent Practicable* (1993). *See also* State Board Order No. 99-05; State Board Order 2001-15. In WQ 2001-15 at page 8, the State Board affirmed the iterative approach stating that "we will generally not require 'strict adherence' with water quality standards through numeric effluent limitations and we continue to follow an iterative approach." Most recently on September 7, 2012, State Board found that "[i]t is not feasible at this time to set enforceable numeric effluent criteria for municipal BMPs and in particular urban discharges." See also Fact Sheet for NPDES Permit and Waste Discharges Requirements for State of California Department Transportation, NPDES Permit No. CAS000003, Order No. 2012 -XX - DWG.

- The shift is occurring at both the regulatory agency and local levels, as many communities are beginning to develop comprehensive water resources strategic plans to address multiple water-related programs and/or the various Total Maximum Daily Loads (TMDLs) in the relevant watershed.
- Although the concept has not been fully acted upon, the current stormwater permit recognizes the benefits of this type of approach (Finding 29).

  "The Regional Board and the permittees recognize the importance of integrated watershed management initiatives and regional planning and coordination in the development and implementation of programs and policies related to water quality protection. A number of such efforts are underway in which the permittees are active participants (e.g., Orange County Flood Control Master Plan, Irvine Ranch Water District Natural Treatment System Master Plan, Orange County Watershed Plans, Nutrient and Selenium Management Program, etc.). As recommended in the 2008 National Academy of Sciences Report on Urban Stormwater Management, this order provides an option for the permittees to develop and implement watershed master plans integrating water quality, hydromodification, water supply and habitat protection issues. The Regional Board recognizes that a watershed master plan should integrate all other related programs, including the stormwater program and TMDL processes."

16.6

- EPA has developed Watershed-based NPDES Permitting Implementation Guidance (2003),[12] and has conducted three pilot projects to identify the constraints and opportunities with watershed-based permitting, as well as the range of options available.
- TMDLs are being incorporated into permits and are being addressed more and more by watershed-based plans.
  - This type of approach is supported within the current stormwater permit for compliance with the selenium and nutrient TMDLs:[13]

    "A collaborative watershed approach to implement the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay is expected."

    "As long as the stakeholders are participating in and implementing the approved Cooperative Watershed Program, they will not be in violation of this order with respect to the nitrogen and selenium TMDLs for San Diego Creek and Newport Bay."
- Watershed-based approaches may encourage collaboration among Permittees to implement regional integrated water resources approaches such as stormwater capture and re-use to achieve multiple benefits.

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[12] Watershed Based NPDES Permitting, EPA, *Available at:* http://cfpub.epa.gov/npdes/wqbasedpermitting/wspermitting.cfm

[13] Order No. R8-2009-0030, Section XVII.B.8

16.6 *Action: The Draft Order should be revised to allow for a watershed-based approach. The Permittees offer to meet with Regional Board staff to assist in identifying what modifications would be necessary.*

6. THE DRAFT ORDER INCORPORATES HIGHLY PRESCRIPTIVE PROVISIONS, AND THEREBY, LIMITS THE ABILITY OF THE PERMITTEES TO ADAPTIVELY MANAGE THEIR PROGRAMS.

Although the Draft Order provides some flexibility to the Permittees, in many cases, the provisions prescribe the method and manner of compliance and level of activity that must be maintained. Such prescription is contrary to the prohibition on dictating the manner and compliance contained at Water Code § 13360. Instead, the Order need only establish the goals and objectives of program elements. Examples of prescription include the following:

- The new requirement for Executive Officer approval of any modifications to the trash and debris control measures (Section VII.E.3.a & b);
- 16.7 The need to address three high-priority urban runoff pollution issues as a part of the Public Education and Outreach Program (Section XIII b.2);
- The partitioning of all development into Priority and Non-Priority Projects (Section XII.B.2);
- The basis for specific tools to be used in the evaluation of Project WQMPs (Section XII.C.6);
- The requirement to update inspection inventories on a quarterly basis (Section IX.A.1); and
- The continued inability of the Permittees to reduce the inspection burden associated with oversight of industrial and commercial facilities (Section IX.B.1).

Action: The above permit Sections should be modified in order to provide the necessary flexibility that the Permittees need in order to adaptively manage their stormwater programs.

7. THE FACT SHEET INAPPROPRIATELY INCLUDES DIRECTIVE LANGUAGE.

The purpose of the Fact Sheet is to provide factual support for the requirements of the Draft Order. The Fact Sheet, however, goes beyond factual explanation by including language that appears to constitute additional permit requirements. Further, this language does not support the Permit provisions, and, in some places, contradicts the provisions it is trying to explain. For example:

- On Page 63 of the Fact Sheet, Section O addresses the provisions of the Draft Order Section XVIII: Total Maximum Daily Load Implementation. The Fact Sheet states that where Permittees fail to comply with development and implementation of a plan to comply with WLAs, immediate attainment with the WLA will be required by default.
- 16.8 The Fact Sheet states that Permittees will be subject to enforcement action whether or not the discharges are known to exceed WLAs.

These statements are factually contradictory to the provisions in Section XVIII. Where a Permittee fails to comply with the development and implementation of a plan, other compliance options are available to the Permittees and compliance is not necessarily

required immediately. TMDLs contain attainment schedules and the only instance in which compliance would be immediate, and enforcement actions possible, is if the compliance schedule has passed and/or no compliance schedule has been established and the Permittees have failed to meet WLAs.

16.8

Action: The Fact Sheet should be universally modified to remove language that goes beyond explanatory and supporting text for the provisions of the Draft Order and all contradictory language removed.

8. MANY OF THE NEW OR MODIFIED REQUIREMENTS WITHIN THE DRAFT ORDER DO NOT HAVE ADEQUATE FINDINGS OF FACT AND/OR TECHNICAL JUSTIFICATION.

In many instances, the Findings and/or Fact Sheet provide little or no justification for the new or modified requirements of the Draft Order. Although Finding 40 states that the Fact Sheet "contains background information, regulatory and legal citations, references and additional explanatory information and data in support of the requirements of this Order," many of the new or modified requirements within the Draft Order do not have adequate findings of fact and/or technical justification. In addition, they do not identify the "program deficiency" that warrants the modification. The Comments provided herein identify many of the areas where new or modified provisions of the Draft Order lack factual or technical support in the Findings and/or Fact Sheet. Examples of this include, but are not limited to; the following (see also Comment 2):

16.9

- Lack of a basis for requiring the Permittees to obtain coverage under the General *De Minimus* Permit for Discharges to Surface Waters (Order No. R8-2009-0003, Section III.B.3); and
- Lack of a basis for including a requirement that the municipal facilities/activities "program must include disciplinary procedures or policies for Permittees' staff that unnecessarily deviate from standard operating procedures (Section XIV.E.5).

Action: The Fact Sheet should be universally modified to provide the technical justification and basis for these provisions.

9. THE FACT SHEET OMITS THE CITY OF LAGUNA HILLS IN THE LIST OF PERMITTEES WHO ARE REGULATED BY THE DRAFT ORDER.

16.10

The Fact Sheet does not include the City of Laguna Hills in the list of Permitted Entities (Section IV., page 4 of 74).

Action: Revise the Fact Sheet to include the City of Laguna Hills.

10. THE REQUIREMENT TO SUBMIT AN ANNUAL PROGRESS REPORT SHOULD BE WAIVED IF PERMIT ADOPTION OCCURS IN THE MIDDLE OF THE REPORTING PERIOD.

If the fifth term MS4 permit is adopted, as expected according to the Regional Board adoption schedule, in the middle of the 2014-15 reporting period, the requirement to submit an annual progress report in 2015 should be waived as the Permittees would have to reconcile two different permit requirements.

16.11

Action: Include a waiver of the requirement to submit an annual progress report in 2015 should permit adoption occur in the middle of the 2014-15 reporting period.

FINDINGS

16.12

11. FINDING 4 (CWA NPDES PERMIT CONDITIONS): FINDING 4 IS NOT CONSISTENT WITH THE LANGUAGE FROM THE CLEAN WATER ACT.

The language in Finding 4 deviates from CWA Section 402(p)(3)(B) in that it separates the MEP clause from the "other measures" clause as two separate statements, potentially implying that "other measures" are not subject to the MEP standard. Finding 4 states:

> "This Order requires controls to reduce the discharge of pollutants in urban runoff from the MS4s to the MEP. This Order also includes other provisions that the Regional Board has determined are appropriate to control pollutants."

However, the actual language from CWA Section 402(p)(3)(B) states the following:

> (B) Municipal discharge permits for discharges from municipal storm sewers -
>
> (i) may be issued on a system- or jurisdiction-wide basis;
>
> (ii) shall include a requirement to effectively prohibit non-stormwater discharges into the storm sewers; and
>
> (iii) shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants.

Action: Finding 4 and Finding 35 should be modified to include the actual language from the CWA.

16.13

12. FINDING 8 (NON-STORMWATER AND STORMWATER DISCHARGES): THE PERMITTEES SHOULD NOT BE REQUIRED TO SUBMIT ROWDS OR OBTAIN SEPARATE COVERAGE FOR DE MINIMUS DISCHARGES OUTSIDE OF THE NEWPORT BAY WATERSHED.

See Comment 19

16.14

13. FINDING 9 (LIMITS OF PERMITTEES' JURISDICTION OVER URBAN RUNOFF): THE DRAFT ORDER SHOULD CONTINUE TO RECOGNIZE THE LIMITS OF THE PERMITTEES' ABILITY TO CONTROL DISCHARGES OF POLLUTANTS.

The Finding appears to create a new regulatory obligation that is inconsistent with the Clean Water Act.

Action: Finding 9 should be replaced with Finding 10 in the fourth term MS4 Permit.

16.15

14. FINDING 10 (IN-STREAM TREATMENT CONTROL SYSTEMS): THE IN-STREAM TREATMENT CONTROL SYSTEMS FINDING WILL PRECLUDE THE USE OF REGIONAL BMPS.

Due to the highly urbanized nature of Orange County's principal watersheds, the Permittees need to be afforded maximum regulatory flexibility to pursue creative solutions for pollutant control and realization of the restorative goals of the Federal Clean Water Act. This Finding should not be the basis for preventing both the implementation of stream restoration and rehabilitation projects and their maintenance.

16.15 *Action: Finding 10 should be modified to allow for the implementation of stream restoration or stream rehabilitation projects and constructed wetlands, or maintenance of reconstruction of existing stream restoration or rehabilitation projects, constructed wetlands, and Regional BMPs.*

15. FINDING 13: RUNOFF DISCHARGES TO RECEIVING NATURAL WATERS CANNOT LEGALLY BE CLASSIFIED AS PART OF THE MS4, AND CANNOT BE CLASSIFIED AS BOTH A MS4 AND RECEIVING WATER.

Rivers, streams, creeks and other natural waterbodies cannot be legally classified as a MS4. The definition of a *municipal separate storm sewer* means "a conveyance or system of conveyances including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains" "owned and operated" by a municipality.[14]

In California, natural waterbodies are not "owned" by the municipality through which they flow. Such water bodies are generally administered by the State of California in the public trust for the right of the people to use such waters for certain purposes.[15] The Legislature, acting within the confines of the common law public trust doctrine, is the ultimate administrator of the trust and may often be the final arbiter of permissible uses of trust lands.

16.16 A "receiving water" cannot also be an MS4, as is plain from the CWA regulations. An MS4 is itself defined as discharging to waters of the United States.[16] An MS4 cannot, in essence, discharge to itself. Moreover, an "outfall" from an MS4 (the point at which the discharge enters a receiving water) does not, pursuant to 40 C.F.R §122.26 (b)(9), include conveyances connecting "segments of the same stream or other waters of the United States and are used to convey waters of the United States."

In EPA's Preamble to the initial version of the MS4 regulations, the agency expressly determined that "streams, wetlands and other water bodies that are waters of the United States are not storm sewers for the purposes of this rule" and that "stream channelization, and stream bed stabilization, which occur in waters of the United States" were not subject to National Pollutant Discharge Elimination System ("NPDES") permits under Section 402 of the CWA.[17] In further support of the point that a MS4 is an artificial, not natural, watercourse, the types of "conveyances" identified in the regulation ("roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains") all refer to anthropogenic structures, not natural streams.[18]

Lastly in *South Florida Water Management District v. Miccosukee Tribe of Indians*, the U.S. Supreme Court opined on the issue of whether a NPDES permit was needed when water from a channelized canal was pumped across a levee into a reservoir. The Court held that if

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[14] 40 CFR 122.26(b)(8).

[15] *Marks v. Whitney* (1971) 6 Cal. 3d 251, 259, 260.

[16] 40 C.F.R. §122.26(b)(8)

[17] 53 Fed. Reg. 49416, 49442 (Dec. 7, 1988)

[18] 40 CFR § 122.26(b)(8)

the two waterbodies were meaningfully distinct, no permit was needed.[19] Likewise, the Court held in *L.A. County Flood Control District v. NRDC* that the flow of water from an improved portion of a navigable flood control channel into an unimproved portion of the same waterway is not a "discharge of a pollutant" under the CWA.[20] Based on these two holdings, there is no discharge of pollutants under the CWA if a waterbody like a flood control channel is both classified as a MS4 and receiving water.

16.16

Action: Finding 13 should be deleted.

16. FINDINGS 18, 19, 20 AND 21: THE DRAFT ORDER NEEDS ADDITIONAL FINDINGS REGARDING NEW DEVELOPMENT.

The Draft Order is in need of additional Findings regarding new development. As such, several Findings have been proposed in Attachment B:

- Finding 18 recognizes the significant progress that has been made through development and implementation of the Model WQMP and TGD.
- Finding 19 identifies the importance of the key technical feasibility considerations identified in the TGD developed through comprehensive analysis, extensive BMP and LID implementation experience, and review and comment by the Model WQMP and TGD TAG. Finding 19 also identifies the importance of having technical feasibility alternatives that result in long term effective BMPs, as well as that the intent of provisions in Section XII is to build off of the established technical feasibility criteria within the Model WQMP and TGD.
- Finding 20 identifies the significant challenges to meeting the requirements for redevelopment in Section XII of the Order.
- Finding 21 identifies the value of Regional BMPs and the benefit of integrating redevelopment goals with water quality improvement of existing developed areas with use of Regional BMPs.

16.17

Action: Incorporate the new Findings that have been provided in Attachment B.

17. FINDING 31 (ECONOMIC CONSIDERATIONS): THE DRAFT ORDER CONTAINS POLLUTANT RESTRICTIONS THAT ARE MORE STRINGENT THAN FEDERAL LAW REQUIRING AN ECONOMIC ANALYSIS. IN ADDITION, THE ECONOMIC ANALYSIS IN THE FACT SHEET IS INADEQUATE.

16.18

As discussed herein, a number of provisions of the Draft Order are more stringent than federal law, for example conditions that impact volumetric flows such as hydromodification, requiring an economic analysis conducted pursuant to Water Code §

[19] 541 U.S. 95, 109-112 (2004) (remanding the case to the Florida District Court to determine the hydrological connection between the two waterbodies). After the case was remanded to the Florida District Court, the EPA created an exemption for water transfers based on the Supreme Court's ruling in *Miccosukee Tribe* (*i.e.*, unitary waters theory), which was subsequently upheld by the 11th Circuit Court of Appeals. 40 C.F.R. § 122.3(i). *Friends of the Everglades v. South Fla. Water Management Dist.*, 570 F.3d 1210 (11th Cir. 2009), *cert. denied*, 131 S. Ct. 643 (2010).

[20] *L.A. County Flood Control District v. National Resources Defense Council*, 133 S.Ct. 710 (Jan. 8, 2013). .

13241.[21] Finding 31 states that pollutant restrictions are not more stringent than federal law, yet a section 13241 economic analysis is conducted anyway. Despite this assertion, provisions of the Draft Order are indeed more stringent than federal law, and the economic analysis in the Fact Sheet is inadequate.

There has not been a full consideration of the section 13241 factors. Section 13241 requires an analysis of requirements that must include, but are "not necessarily limit to," all of the following: Past, present and probable future beneficial uses of water; environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto; water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area; economic considerations; the need for developing housing within the region; and, the need to develop and use recycled water. This would also include an analysis of the economic impacts that would result from compliance with the existing stormwater permit compared to the costs of complying with the proposed Draft Order (*i.e.*, the costs of complying with the new requirements). Instead, the Draft Order's analysis begins by stating that a formal economic analysis is not practical at this time due to the limited amount of economic information and/or the large variability in reported costs.[22]

16.18 The Fact Sheet also fails to cite any recent cost benefit numbers, but relies on inapplicable cost data such as a 1999 EPA study on household costs.

The analysis of costs contained in the Fact Sheet is deficient in two additional ways. First, the approach to compliance costs is fundamentally deficient because it tells the public nothing at all about the relationship between the cost of any particular control and the pollution control benefits to be achieved by implementing that control. Under this "generalized" approach, extremely costly requirements that bear little or even no relationship (or even a negative relationship) to the pollution control benefits could be "justified" as long as the "overall" program costs are within what the Regional Board deems to be an acceptable range. This is not a proper way to determine whether a control reduces the discharge of pollutants from the MS4 to the MEP. A more individualized assessment of cost is required. Otherwise, dischargers may be required to implement very costly controls that have no relationship to pollution control benefits, a result inconsistent with MEP.

This analytical flaw in the Fact Sheet is compounded by the approach taken to assess the benefits of the Draft Order. Here again, the assessment approach misses the mark because it tells the public nothing about the pollution control benefits to be achieved by implementation of the controls in the Draft Order. All the Fact Sheet says, in essence, is that people like clean water and in theory may be willing to pay for it, that urban stormwater may contribute to beach closures and that such beach closures have an economic impact. This analysis sheds no light on the relationship between a BMP's costs and the pollution control benefits to be achieved by implementing that BMP.

Second, the Fact Sheet contains faulty assumptions and relies upon outdated or inapplicable data. The California State University, Sacramento (CSUS) Cost Survey assessed program

[21] *See also City of Burbank v. State Water Resources Control Bd.*, 35 Cal. 4th 613, 618, 626-627 (2005).

[22] Fact Sheet, pp. 29-33.

costs for Phase I cities. Nothing in the Fact Sheet links any of the actual conditions of the Phase I permits of the Phase I cities studied by CSUS with any of the requirements of the Draft Order. Therefore, the study tells the public nothing about the costs to implement the Draft Order. The data included in the Fact Sheet is almost a decade old. The Fact Sheet uses old data from Phase I programs that have no linkage to any conditions of the Draft Order. The full costs of implementing the entire program required by the Draft Order in 2014 dollars must be assessed.

16.18

Lastly, stormwater agencies cannot readily establish or raise fees to help pay for the BMPs necessary to comply with either the California Toxics Rule (CTR) criteria or proposed Site Specific Objectives (SSOs) due to the requirements of Proposition 218, Proposition 26 and the Mitigation Fee Act. For instance, Proposition 218 requires that property-related fees be put to a vote, so cities cannot assess fees without the consent of a super-majority (two-thirds) of property owners. Therefore, the costs associated with the implementation and maintenance of the BMPs is more likely to be covered through a municipality's General Funds.

Action: An economic analysis should be conducted that pertains to the Draft Order and that considers the 13241 factors.

18. FINDING 32 (UNFUNDED MANDATES): THE REGIONAL BOARD HAS NO LEGAL ABILITY TO DETERMINE WHETHER A PARTICULAR MANDATE IS UNFUNDED.

Finding 32 and the supporting arguments in the Fact Sheet are an attempt to address whether the requirements of the Draft Order Permit constitute an unfunded state mandate. That attempt, however, is beyond the scope of the Regional Board's powers as the *only* agency charged by the Legislature with determining the presence of a state mandate, and whether that mandate is unfunded, is the Commission on State Mandates.[23]

16.19

The Regional Board has no jurisdiction to make a legal finding or discuss in the Fact Sheet that the Draft Order, in whole or in part, does not constitute an unfunded state mandate. Fact sheets are only required under CWA regulations to provide the legal authority and reasons for each substantive permit provision.[24] Finding 32 and the discussion in Section 6.E of the Fact Sheet does not relate to any provision of the Draft Order, and does not provide legal authority or justification for the Draft Order's adoption. As such, Finding 32 and the Fact Sheet discussion should be deleted.

In addition, the County disagrees with each of the arguments set forth in Finding 32 and the Fact Sheet as to why the Draft Order does not constitute an unfunded state mandate. Nevertheless, because the exclusive arena for such disagreements is the Commission on State Mandates, whose jurisdiction does not commence unless and until a test claim is filed before the Commission, the County need not and will not address those arguments.

Action: Finding 32 and its accompanying Fact Sheet discussion in section 6.E should be deleted.

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[23] Govt. Code § 17552; *Kinlaw v. State of California* 54 Cal.3d 326, 333 (1991).

[24] 40 CFR § 124.8(a)(4); 40 CFR § 124.56(a). *See also City of Rancho Cucamonga v. Regional Water Quality Control Board-Santa Ana Region* (2006), 135 Cal.App.4th 1377, 1382 (stating that fact sheets contains "the legal and factual grounds for the Water Board's recommendation to adopt the… permit").

PERMIT PROVISIONS

III. DISCHARGE PROHIBITIONS AND LIMITATIONS & IV. RECEIVING WATER LIMITATIONS

19. THE PERMITTEES SHOULD NOT BE REQUIRED TO SUBMIT ROWDS OR OBTAIN SEPARATE COVERAGE FOR DE MINIMUS DISCHARGES OUTSIDE OF THE NEWPORT BAY WATERSHED.

Section III.B.3 requires that non-stormwater discharges occurring outside of the Newport Bay Watershed from Permittee owned or operated facilities or Permittee activities be in compliance with the conditions and provisions of the General "*De Minimus*" Permit for Discharges to Surface Waters (Order No. R8-2009-0003). This includes the need to submit a ROWD.

However, it is unclear and unexplained within the Fact Sheet why the regulatory approach for these types of discharges changed from the fourth term MS4 permit to the Draft Order and why it appears to be inconsistent with the Findings in Order No R8-2009-0003. Pursuant to the fourth term MS4 Permit, these types of discharges must be in compliance with the *De Minimus* Permit. Separate permit coverage is not required.

16.20

In fact, Order No. R8-2009-0003 states "However, as discussed in the Fact Sheet (Attachment F), certain types of municipal separate storm sewer system (MS4) Permittee discharge activities will no longer be regulated under this Order but will be regulated under the area-wide MS4 permits when these permits are updated appropriately and renewed during the early part of 2009."[25] The types of Permittee discharges that would no longer require coverage under a MS4 Permit include:

- Construction dewatering wastes; (except stormwater dewatering at construction sites);
- Dewatering wastes from subterranean seepage, except for discharges from utility vaults;
- Discharges from fire hydrant testing or flushing;
- Air conditioning condensate;
- Swimming pool discharge; and
- Discharges resulting from diverted stream flows.

Given that these discharges are in fact *de minimus*, the Permittees are already regulated under an MS4 Phase I Permit, and the *De Minimus* Permit recognizes that the Permittees should be regulated pursuant to the area-wide permit, this provision should continue the current regulatory approach (see Finding 68, Order No R8-2009-0003).

Action: Modify Finding 8 and Section III.B.3 to continue the current language from Order No R8-2009-0003.

[25] Provision I.B.1 and Fact Sheet page F-6

VII. ILLICIT DISCHARGES, ILLICIT CONNECTIONS, AND ILLEGAL DUMPING; LITTER DEBRIS AND TRASH CONTROL

20. THE REQUIREMENT FOR THE PERMITTEES TO OBTAIN EXECUTIVE OFFICER APPROVAL OF INDIVIDUAL DRAIN INLET SCREEN MODIFICATIONS IS OVERLY BURDENSOME AND LIMITS THE ABILITY OF THE PERMITTEES TO ADAPTIVELY MANAGE THEIR PROGRAM.

16.21

Section VII.E.1 and E.2 requires the Permittees to implement an effective program to reduce and/or eliminate the discharge of trash and debris to waters of the U.S. Although this provision allows for the annual review and reporting on the effectiveness of the program, Section VII.E.1 and E.2 further require that any changes to the control measures be approved by the Executive Officer of the Regional Board.[26] It is unclear why this level of review and approval is necessary for this control measure as factual justification has not been provided in the Fact Sheet. Unless this provision is targeting a large regional trash control BMP that is being replaced with another BMP, it is unrealistic to assume that Executive Officer approval is required to replace a catch basin screen with another BMP. It is also not realistic to require Executive Office approval to discontinue the use of catch basin screens in favor of other more favorable or effective technologies. Some BMPs may also cause unforeseen consequences and the best solution is to remove the BMP. Requiring Executive Officer approval when faced with this scenario unnecessarily delays corrective action. Adhering to this provision would simply add an administrative burden that is costly, time consuming, delays implementation of newer technologies. This will ultimately limit the ability of the Permittees to adaptively manage their program in a cost efficient manner and result in delays to the program.

Action: Section VII.E.1 and E.2 should be modified to allow the Permittees to identify modifications to the control measures as a part of the Annual Progress Report.

21. THE ILLICIT DISCHARGES AND ILLICIT CONNECTIONS PROGRAM DOES NOT RECOGNIZE THE EXISTING SANITARY SEWER OVERFLOW RESPONSE PROGRAM.

16.22

Section VII.F requires the Permittees to either comply with the Statewide General Waste Discharge Requirements for Wastewater Collection Agencies or implement an effective program to detect and mitigate SSOs. However, unlike the current permit, the Draft Order does not recognize the fact that the Permittees have been developing and implementing the Countywide Area Spill Control (CASC) Program in collaboration with the Orange County Sanitation District for over 10 years. This permit Section should be modified to recognize the establishment of and be consistent with the CASC program.

Action: Modify Section VII.F to include information about the Countywide Area Spill Control Program and delete Sections VII.F.1.d and F.1.e.

VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

22. THE DRAFT ORDER SHOULD NOT REQUIRE INVENTORY OF CONSTRUCTION PROJECTS OF LESS THAN 2 WEEKS IN DURATION.

16.23

Section VIII.A requires each Permittee to maintain an inventory of all construction sites within its jurisdiction; however, this section does not exclude from the inventory

[26] Section VII.E.3, pg. 39.

16.23

construction sites with an expected or actual duration of less than two weeks, as does Section VII.B.1.. Section VIII.A should also contain this exclusion.

Action: Section VIII.A should be modified consistent with Attachment B so that construction projects less than two weeks in duration are not required to be included in the inventory of construction sites.

23. INVENTORY OF CONSTRUCTION SITES SHOULD BE UPDATED ON A BIANNUAL BASIS.

16.24

Section VIII.A.3 requires a Permittee to update the inventory of all construction sites within its jurisdiction once per month. The frequency of once per month is unreasonably burdensome to the Permittees and does not provide a benefit to water quality. The time allocated to update the inventory monthly would better be served by performing construction site inspections that do have an impact on water quality. An update to the inventory should be carried out only on a biannual basis, once in September prior to the wet season and once in May of each year.

Action: Modify Section VIII.A.3 to be consistent with Attachment B so that the inventory of construction sites only needs to be updated biannually.

24. INSPECTION OF HIGH-PRIORITY CONSTRUCTION SITES SHOULD ONLY BE REQUIRED THREE TIMES DURING THE WET SEASON.

16.25

Section VIII.B.1.b.i requires that high priority construction sites be inspected once per month for the entirety of the construction period. This frequency is not warranted as the majority of construction sites complete recommended corrections during the first inspection and continue to implement BMPs effectively. Staff time spent on repeat inspections each month could better be spent on recalcitrant construction sites that do not take corrective actions and are a threat to water quality.

Action: Modify Section VIII.B.1.b.i to be consistent with Attachment B so that the inspection of construction sites is required at a frequency of three times per year.

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL SITES

25. THE DRAFT ORDER REQUIRES OVERSIGHT OF "ALL" INDUSTRIAL SITES, THEREBY INCREASING THE ADMINISTRATIVE BURDEN FOR THE PERMITTEES.

16.26

Section IX.A requires a Permittee to maintain an inventory of "all" industrial sites within its jurisdiction, regardless of whether the site is subject to the Statewide Industrial General Permit or other individual NPDES permit. This is a departure from the fourth term MS4 permit and will likely result in the need to add industrial sites that may not pose a threat to water quality. In fact, if "all" sites have to be added in the inventory, the Permittees could end up tracking and inspecting sites that have been deemed not to be a threat pursuant to the State Industrial General Permit (*i.e.*, facilities that file a valid Notice of Non-applicability). In addition, the Fact Sheet does not justify why the modification from the fourth term MS4 permit is necessary.

Action: The Draft Order should be modified so that it remains consistent with the fourth term MS4 permit.

26. The Recommended Inspection Approach Described in the ROWD Was Not Included in the Draft Order. Instead, the Prioritization of the Sites and Inspection Frequencies are Similar to the Existing Program.

The ROWD contained an analysis of the industrial inspection program and concluded that the prescriptive nature of the prioritization criteria limited the ability to adaptively manage the program and did not correlate well with changes in behavior (i.*e.*, facilities that are in compliance versus those that are not). The fundamental point raised by the Permittees within the ROWD was that, due to the high rate of compliance that has been seen by the inspectors, it is reasonable that the inspection frequency could be modified to reduce the burden of the program. This would allow the Permittees to better focus their resources on those facilities that posed the greatest risk to water quality. In order to reduce the inspection burden and simultaneously allow for an inspection program that would be focused on the high threat facilities (based on past performance), a revised approach was recommended. The approach included two options for the Permittees:

16.27

- Option 1 – A targeted approach with inspection frequencies based on a prioritization scheme (based on past performance of the facility).
- Option 2 – A synoptic approach with no fluctuation in the inspection frequency from year to year (inspect 20% of the sites each year; with 100% inspected by the end of the 5 year permit term).

By allowing two options, the Permittees could tailor the inspections to best fit their individual stormwater programs while still implementing an effective industrial inspection program.

Although the ROWD proposed these two options, the Draft Order incorporates an industrial inspection program that is very similar to the fourth term MS4 permit. While the Draft Order states that it provides some inspection relief, the level of that relief is unclear. In fact, Table TR-2 in the Fact Sheet (page 50 of 74) identifies "no change" between the level of effort during the previous permit term and that which would be required pursuant to the Draft Order.

Given the fact that a significant number of industrial facilities are already regulated pursuant to the Industrial General Permit, the Permittees' have identified a high rate of compliance in the industrial facilities inspected by the Permittees. It would be a better expenditure of the Permittees' resources to focus on those facilities that pose the greatest risk to water quality by allowing a revised approach.

Action: The requirements for the industrial program should be consistent with the approach proposed in the ROWD. Section IX of the Draft Order should be modified to be consistent with Attachment B.

X. MUNICIPAL INSPECTIONS OF COMMERCIAL SITES

27. THE RECOMMENDED APPROACH OUTLINED IN THE ROWD WAS NOT INCLUDED IN THE DRAFT ORDER. INSTEAD, THE PRIORITIZATION OF THE SITES AND INSPECTION FREQUENCIES ARE SIMILAR TO THE EXISTING PROGRAM.

The ROWD contained an analysis of the commercial inspection program and concluded that the prescriptive nature of the prioritization criteria limited the ability of the Permittees' to adaptively manage the program and did not correlate well with high priority pollutants of concern and/or issues within a watershed. The fundamental point raised by the Permittees within the ROWD is that the resources expended on the commercial inspection program should be focused on those facilities that pose the greatest risk to water quality and those that are not in compliance. In order to reduce the inspection burden and simultaneously allow for an inspection program that would be focused on the high threat facilities (based on the high priority pollutants of concern and/or past performance), a revised approach was recommended. The approach included two options for the Permittees:

- Option 1 – A targeted approach with inspection frequencies based on a prioritization scheme (based on watershed pollutants of concern and past performance of the facility)

16.28

- Option 2 – A synoptic approach with no fluctuation in the inspection frequency from year to year (inspect 20% of the sites each year; with 100% inspected by the end of the 5 year permit term)

By allowing two options, the Permittees could tailor the inspections to best fit their individual stormwater programs while still implementing an effective commercial inspection program.

Although the ROWD proposed these two options, the Draft Order incorporates a commercial inspection program that is very similar to the fourth term MS4 permit. While the Draft Order states that it provides some inspection relief, the level of that relief is unclear. In fact, Table TR-2 in the Fact Sheet (page 50 of 74) has errors that have been identified. Given the difficulty in being able to understand how the values were derived in Table TR-2 in the Fact Sheet, the County has developed a supplemental Table TR-2 (below) that clearly corrects these errors with revised values in red text (back up data and calculations can be provided upon request). The key observations include the following:

- Although there would be a reduction in the number of inspections from the current permit to the Draft Order (from 22,810 to 19,120 – 16%), it is not as large of a decrease as stated within the Fact Sheet due to an error that was in Fact Sheet Table TR-2 (stated as from 22,810 to 18,114 – 21%).
- The determination of the actual reductions achieved through the various options for the commercial inspection program should be compared against the number of facilities that would be subject to the inspection program pursuant to the current permit (22,810 – not 25,622 or 30,882).
- Depending on the high priority pollutants of concern and the number of commercial facilities that would present the highest risk to water quality (assumptions made can

be provided upon request), Option 1, as proposed in the ROWD, would result in a decrease of 12-88% for the inspection program.

  - Facilities under this Option that are not inspected would continue to receive outreach information twice during the permit term.

- Option 2 would result in a 41% decrease for the inspection program.

16.28

Revised Fact Sheet Table TR-2: Comparison of the Number of Commercial Inspections

Reported inspections over 5-years (2008-2013)	Expected inspections over 5-years (per previous permit's requirements)	Expected inspections over 5-years (per this Order's requirements	Expected inspections over 5 years (Option 1)	Expected inspections over 5 years (Option 2)
25,622	22,810	18,114 (26% decrease) 19,120 (16% decrease)	15,251 (51% decrease) 2,684 – 20,126 (12-88% decrease)	13,418 (57% decrease) 13,418 (41% decrease)

Given the fact that there are limited resources within the stormwater program and that they should be focused on the highest water quality issues, it would be a better expenditure of the Permittees' resources to focus on those facilities that pose the greatest risk to water quality. As such, the Permittees' believe that a revised approach for the commercial program should be considered.

Action: The requirements for the commercial program should be consistent with the approach proposed in the ROWD. Section X of the Draft Order should be modified to be consistent with Attachment B.

XII. NEW DEVELOPMENT

16.29

Section XII of the Draft Order has been wholly revised and restructured in comparison to the 2009 MS4 Permit (Order No R8-2009-0030). The Permittees recognize that the intent of these revisions was to improve clarity and to reinforce the existing land development program that is currently being implemented by the Permittees. However, as a byproduct of these revisions, the Draft Order would trigger significant revisions to the Model WQMP, TGD, and associated program documents, computer systems, and training programs. These revisions would not necessarily improve the effectiveness of the technical documentation; however, they could potentially result in a significant disruption to ongoing program implementation and jeopardize the significant investment in program development and training. Therefore, it is requested that the Draft Order be revised to be consistent with and reinforce the existing program that was approved by the Executive Officer.

In response to the 2009 MS4 Permit, the Permittees made an extensive investment in the development of the Model WQMP and TGD, as well as templates, checklists, training modules, and Local Implementation Plan revisions to facilitate consistent implementation. This suite of program documents represents a strong technical foundation for an effective program. However, this program has been in effect for less than three years and, due to the economy, a

limited number of projects with approved Project WQMPs have been constructed to date. Therefore, there remains relatively limited practical experience upon which to base an opinion about necessary improvements to the program and the technical guidance. The changes proposed in the Draft Order, and their resulting "ripple effect" through the existing program documents and training materials, will result in an overall setback for program implementation at this time rather than an improvement.

It is recommended that the Draft Order be revised in a manner that reinforces the existing program and allows the effectiveness of the program to be evaluated through a longer period of time before revisions are made. The Permittees firmly believe in a process for ongoing improvement in Project WQMP development, implementation, and enforcement. However, this process should be based on actual project experience from a representative period of program implementation and should be expressed in terms of regular technical updates to program documents that are led by the results of the effectiveness evaluation, not driven by unnecessary increased prescriptiveness in the MS4 Permit. The Draft Fact Sheet that accompanies the Draft Order does not present a clear basis for why these technical revisions are necessary. The following Comments regarding Section XII are suggested.

28. THE MODEL WQMP AND TGD SHOULD BE REFERENCED THROUGHOUT SECTION XII. OF THE DRAFT ORDER, CONSISTENT WITH ATTACHMENT B.

16.29

The Model WQMP and TGD were developed during the last permit term through a collaborative process inclusive of Regional Board staff, U.S. EPA, Permittees, NGOs, the land development community, technical consultants, and other interested people. The result of this process is the Model WQMP and TGD that together are a comprehensive and innovative stormwater quality approach to new and redevelopment that integrates the principles of Low Impact Development (LID). The OC Land Development program is recognized as one of the most robust and successful programs in the State of California. There are references in Sections XII.C2, XII.E.1.f, and XII.I.8 to "uniform written technical guidance" or "uniform protocol" throughout Section XII, however, the existing technical guidance is the Model WQMP and TGD that were developed by the Permittees during the fourth permit term through the collaborative process mentioned above. The Draft Order should explicitly recognize the Model WQMP and TGD as the "uniform written technical guidance." Implementation of the Model WQMP and TGD in the Land Development program in Orange County has started to make progress toward improving the quality of runoff from new and redevelopment projects. The Draft Fact Sheet states that "Section XII has been expanded to incorporate synthesized elements of the 2011 Model Water Quality Management Plan and its accompanying Technical Guidance Document;" however, the concern is that the synthesis changes and/or leaves out many technical details of the Model WQMP and TGD. The Permittees understand the desire of Regional Board Staff to have a "stand alone" document, but the Permit does adequately reflect all the technical details identified in the Model WQMP and TGD. The result is that the permit makes significant changes to the OC Land Development Program. To avoid these significant unintended changes to the Program, it is most appropriate that the Model WQMP and TGD be referenced to throughout Section XII.

Action: Modify Section XII consistent with Attachment B to expressly reference the Model WQMP and TGD.

29. The BMP Lexicon in the Draft Order Should Be Consistent with the Model WQMP and TGD.

16.30

Throughout Section XII, the BMP lexicon is inconsistent with the Model WQMP and TGD. If left unmodified, the new BMP lexicon will require considerable updates to the Model WQMP and TGD, as well as to the associated Model WQMP Template and DAMP sections, which would be a significant burden to modify. Furthermore, the changes in terminology in the Draft Order would introduce unnecessary confusion. The Draft Fact Sheet identifies that "Section XII has been expanded to incorporate synthesized elements of the 2011 Model Water Quality Management Plan and its accompanying Technical Guidance Document," but the BMP lexicon in the Draft Order conflicts with the lexicon in the Model WQMP and TGD.

Action: Modify Section XII consistent with Attachment B so the BMP lexicon is consistent with the Model WQMP and TGD.

30. The Draft Order Should Recognize the Statutory and Categorical Exemptions from CEQA.

16.31

On Page 54 of the Draft Fact Sheet, the first paragraph states that the "Order is intended to provide the Permittees with a method to address the water quality impacts of new development consistent with the requirements of CEQA. These requirements are intended to address projects that may have an impact on water quality." It should be noted that certain development provisions in the Draft Order, such as the hydromodification management plan and LID, are designed to address potential adverse impacts on water quality that may occur from a new development project. Such an analysis, however, is already required to be conducted by the Permittees under CEQA. CEQA imposes numerous requirements with which municipalities must comply when considering projects within their respective jurisdictions, and requires that they consider and mitigate potentially significant adverse environmental impacts.

CEQA does not allow a local government discretionary approval to require over-mitigation of a project. The CEQA Guidelines provide that "a lead agency for a project has the authority to require feasible changes in any or all activities involved in the project in order to substantially lessen or avoid significant effects on the environmental, consistent with applicable constitutional requirements such as the 'nexus' and 'rough proportionality' standards established by case law."[27] Should it be demonstrated that a project will not have a significant adverse impact on water quality or that the mitigation measure does not have a nexus to the project, CEQA prohibits such measure from being implemented.

CEQA allows local agencies the discretion to adopt a Statement of Overriding Considerations if the agency finds that "specific overriding economic, legal, social, technological, or other benefits of the project outweigh the significant effects on the environment."[28] And, CEQA allows local agencies the ability to utilize statutory and categorical exemptions for those projects that will not have a potential impact on the environment. Certain land development requirements in the Draft Order appear to

[27] Cal. Code Regs. Tit. 14, § 15041 (citing *Nollan*, 483 U.S. at 825 and *Dolan*, 512 U.S. at 374.

[28] Pub. Res Code § 21081.

disregard the Permittees ability to apply CEQA by prescribing alternative processes, thereby preempting certain parts of the CEQA process. It should be noted that under Public Resources Code section 21081.6(c), a responsible agency – such as the Regional Board – cannot direct how a lead agency – such as Permittee – is to comply with CEQA's terms. "Compliance or non-compliance by a responsible agency or agency having jurisdiction over natural resources affected by a project with that requirement shall not limit . . . the authority of the lead agency to approve, condition, or deny projects as provided by this division or any other provision of law."[29] Furthermore, section 21081.1 states that the lead agency's determination "shall be final and conclusive on all persons, including responsible agencies, unless challenged as provided in Section 21167."[30]

16.31

Action: Modify Section XII and the Fact Sheet to state that the Order include a limitation that include the statutory and categorical exemptions from CEQA documentation.

31. THE REGIONAL BOARD HAS NO AUTHORITY TO REQUIRE PERMITTEES TO AMEND THEIR GENERAL AND SPECIFIC PLANS, AND CANNOT MANDATE THE GOALS, POLICIES AND PROCEDURES THAT COMPRISE THOSE PLANS.

The Regional Board has no authority to impose general plan and specific plan requirements. The general plan is the basic land use charter that embodies fundamental land use and planning decisions for a municipality.[31] The California Supreme Court has held that the general plan is the "constitution for all future development."[32] A specific plan is one step below the general plan in the land use hierarchy. It establishes a link between implementing policies of the general plan and individual development proposals in a defined geographic area.[33]

16.32

The general plan and individual specific plans are constitutional enactments, and therefore, their adoption and amendment is a legislative act.[34] Only the Legislature may impose general plan and specific plan requirements on municipalities. The Regional Board has no express delegation from the Legislature. In limited cases, the Legislature has delegated authority to the executive branch to develop guidelines for the elements of a general plan as

[29] *Id.* at § 21081.6(c).

[30] *See also* Pub. Res. § 21083.1. "It is the intent of the Legislature that courts, consistent with generally accepted rules of statutory interpretation, shall not interpret this division or the state guidelines adopted pursuant to Section 21083 in a manner which imposes procedural or substantive requirements beyond those explicitly stated in this division on in the state guidelines."

[31] *City of Santa Ana v. City of Garden Grove*, 100 Cal. App. 3d 521, 532 (1979); *DeVita v. County of Napa*, 9 Cal. 4th 763, 812 fn. 8 (1995); Gov't Code § 65300 *et seq.*

[32] *Lesher Communications, Inc. v. City of Walnut Creek*, 52 Cal. 3d 531, 540 (1990); *see also Citizens of Goleta Valley v. Board of Supervisors*, 52 Cal. 3d 553, 570-571 (1990).

[33] Gov't Code § 65450.

[34] *Yost v. Thomas*, 36 Cal. 3d 561, 570 (1984); *Midway Orchards v. County of Butte*, 220 Cal. App. 3d 765, 780 (1990); Gov't Code §§ 65350 *et seq.* and 65453.

well as review general plans for compliance with regional housing needs.[35] However, no such delegation has been given to the State and Regional Water Boards.

More particularly, Article 3, Section 3 of the California Constitution mandates a separation of powers between the legislative, executive, and judicial branches of State government.[36] Administrative agencies like the State and Regional Water Boards often possess the powers of all three branches of government, and are limited by this separation depending on the type of power they are exercising. When adopting a regulation or policy, the State or Regional Board is exercising a legislative function.

16.32

When adopting a NPDES permit and waste discharge requirements, the Regional Board sits as a judicial body.[37] Therefore, when adopting the Draft Order, the Regional Board is essentially sitting as a judge or fact-finder. It cannot then in a judicial capacity require the Permittees to perform a legislative act, such as an affirmative requirement to amend a general plan, without violating constitutional separation of powers.[38] It is akin to a judge telling Congress what law to pass. The Regional Board can generally require the Permittees develop certain programs to improve water quality when there's substantial evidence to do so, but it cannot order the amendment of a general plan or dictate the substance of that plan.

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[35] Gov't Code § 65040.2 (delegating authority to the Office of Planning and Research); Gov't Code § 65585(a) (delegating authority to the State Housing and Community Development agency to adopt housing element guidelines that are advisory only).

[36] "The powers of state government are legislative, executive, and judicial. Persons charged with the exercise of one power may not exercise either of the others except as permitted by this Constitution."

[37] *City of Rancho Cucamonga v. Reg'l Water Quality Control Bd.-Santa Ana Region*, 135 Cal.App.4th 1377, 1385 (2006). *Sommerfield v. Helmick*, 57 Cal.App.4th 315, 320 (1997) ("The exercise of discretion to grant or deny a license, permit or other type of application is a quasi-judicial function."); *City of Santee v. Superior Court*, 228 Cal.App.3d 713, 718 (1991).

[38] "[T]he courts may not order the Legislature or its members to enact or not to enact, or the Governor to sign or not to sign, specific legislation.' [Citation.] '... [B]y virtue of the separation of powers doctrine courts lack the power to order the Legislature to pass a prescribed legislative act.' [Citation.] ... Were it otherwise, courts would be involved in 'an attempt to exercise legislative functions, which ... is expressly forbidden....' [Citations.]" (*Id.* at p. 624, 230 Cal.Rptr. 42; see also *Mandel v. Myers* (1981) 29 Cal.3d 531, 551, fn. 9, 174 Cal.Rptr. 841, 629 P.2d 935; *Serrano v. Priest* (1976) 18 Cal.3d 728, 751, 135 Cal.Rptr. 345, 557 P.2d 929; *Hicks v. Board of Supervisors* (1977) 69 Cal.App.3d 228, 235, 138 Cal.Rptr. 101.) Separation of Powers applies to counties and cities when they act in a legislative capacity. "These corollaries of the separation of powers doctrine regarding legislative acts apply to local government bodies, including boards of supervisors, when they act in a legislative capacity." *Steiner v. Superior Court*, 50 Cal. App. 4th 1771, 1785 (1996); *see also County of Los Angeles v. Superior Court,* 13 Cal.3d at p. 726, [legislative motivation]; *City Council of Santa Barbara v. Superior Court* (1960) 179 Cal.App.2d 389, 395–396 [legislative inaction]; *Cinevision Corporation v. City of Burbank,* 745 F.2d at p. 577. For instance, judicial review of the adoption or amendment of a general plan is limited to its vertical and horizontal consistency, procedural deficiencies and whether the general plan was arbitrary, capricious or entirely lacking in evidentiary support. Code of Civ. Proc § 1085; *Mitchell v County of Orange*, 165 Cal. App. 3d 1185, 1191-92 (1985); *Environmental Council v. Board of Supervisors*, 135 Cal. App. 3d 428, 436 (1982).

16.32 Furthermore, the Regional Board is requiring the Permittees to amend their general plans to a) identify specific, enforceable and measureable metrics, and b) report to the Regional Board on their "progress." This is inappropriate for planning documents, which are intended to provide more generalized objectives and goals framing the direction of the city or county. It also puts the Regional Board in the position of being the arbiter of the validity of general and specific plans, despite that there is State law that squarely addresses the requirements of these documents.

Measurable and specific water quality outcomes are appropriately placed in individual permits, but not in general and specific Plans.

Action: All general plan and specific plan requirements should be stricken from the Draft Order.

32. General Plan and Specific Plan Updates to Include Goals Identified in the Draft Order Should Specifically Reference Applying to New Development and Redevelopment.

16.33 Although the Regional Board lacks authority to require general and specific plan amendments and mandate the substance of those plans, Comments 33 and 34 are made regarding the merits of those requirements.

Section XII.A.1 requires the adoption of an effective set of goals, policies, and procedures consistent with goals identified in the section when updating the General Plan or adoption or update of specific plans. Update of General and Specific Plans with the identified goals should be identified to pertain to new development and significant redevelopment as defined in the Draft Order to clarify that the goals, policies and procedures to be developed only apply to new development and significant redevelopment.

Action: Modify Section XII.A.1 consistent with the Attachment B so there is no confusion that the goals, policies and procedures to be developed only apply to new development and significant redevelopment.

33. The Goals Identified in the Draft Order for Update of General Plans and Specific Plans Should Recognize that Infiltration Should Not be Encouraged in Areas that Would Cause or Exacerbate a Known Groundwater Quality Issue.

16.34 Section XII.A.1.e identifies one of the goals for updating General Plans and Specific Plans should be to encourage use of infiltration, however infiltration should not be encouraged in areas that would cause or exacerbate a known groundwater quality issue. In north Orange County there is shallow groundwater with elevated levels of selenium due to the natural geology of the Monterrey formation as well as brownfield sites that have contaminated groundwater such as the former El Toro United States Marine Corps Base. It should be recognized in the Draft Order that infiltration should not be encouraged everywhere.

Action: Modify Section XII.A.1 consistent with Attachment B to recognize that infiltration should be encouraged except in areas that would cause or exacerbate a known groundwater quality issue.

34. THE DRAFT ORDER SHOULD NOT REQUIRE THE DEVELOPMENT OF OBJECTIVES WITH THE ADOPTION OF GOALS FOR A GENERAL PLAN OR SPECIFIC PLAN.

16.35

Section XII.A.3 requires that when a Permittee adopts goals within a General Plan or Specific Plan that measurable and verifiable objectives should also be adopted. The Permittees encourage the adoption of goals with in a specific plan or General Plan, however, the development of measurable objectives would be redundant to the requirements of the Model WQMP and TGD. Development projects are subject to the requirements Model WQMP and TGD which already include objectives and specific criteria associated with the goals identified in Section XII.A.1. The requirement to develop specific objectives associated with the goals identified for General and Specific Plans creates an additional burden on the Permittees which is unnecessary and provides no water quality benefit as the Model WQMP and TGD already accomplish the intent of this provision.

Action: Delete Section XII.A.3 from the Draft Order.

35. THE DRAFT ORDER SHOULD NOT REQUIRE THAT THE PERMITTEES VERIFY IF A REPORT OF WASTE DISCHARGE FOR DISCHARGES OF DREDGE AND FILL TO WATERS OF THE U.S. HAS BEEN SUBMITTED TO THE REGIONAL BOARD.

Section XII.A.6. requires that a Permittee not deem a development application complete without evidence that a report of waste discharge has been submitted to the Regional Board for any discharges of dredge or fill to waters of the U.S. It is not clear why this requirement is being imposed on the Permittees. It is also unclear as to whether the provision relates to the Permit Streamlining Act.[39]

16.36

First, the Regional Board lacks authority to require how permitting applications should be processed and when a particular application is complete or not. This is an unlawful intrusion into the Permittees constitutional police powers for land use decisions, which are often dictated by ordinance and are therefore a legislative act. There is also no express authority granted to the Regional Board by the Legislature.[40]

Secondly, it is the applicant's responsibility and the responsibility of the Regional Board to verify compliance with report of waste discharge requirements. The Draft Order shifts the burden of Regional Board staff to determine if and when a ROWD is required to the Permittees. Permittees can impose conditions or restrictions on projects to meet state and local regulations. However, the discharge of dredge or fill material to waters of the U.S. requires submittal of applications to federal and state agencies (404 permit and 401 certification) where Permittees do not have any jurisdiction. The timing of these applications is also very different from the submittal of an initial land development application (months or years), and this requirement would greatly interfere and delay a Permittees obligation to accept land development applications under the 30-day window of the Permit Streamlining Act.

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[39] Gov't Code § 65920 *et seq.*

[40] In addition to the 10th Amendment and State Constitutional prohibition, Water Code § 13360 prohibits dictating the manner of compliance.

16.36 Lastly, there has been no demonstration that this requirement would provide additional water quality benefit, and appears to simply command the nuances of the permitting process.

Action: Delete Section XII.A.6 from the Draft Order.

36. THE EFFECTIVE DATE FOR SECTION XII.B SHOULD BE 12 MONTHS FOLLOWING ADOPTION OF THE DRAFT ORDER.

16.37 Section XII.B.1 identifies that the requirements of Section XII.B and subsequent sub-sections of Section XII apply to all initial applications 50 days after the adoption of the Order. With the new elements and change in lexicon identified in Section XII.B, the Permittees will need time to update the Model WQMP and TGD and implement the changes in municipal protocols and the timeframe of 50 days to complete this is unrealistic. As previously stated updates to the OC Land Development Program are not necessary as the program has been in place less than 3 years. The current program as discussed previously was developed over a period of 24 months with periodic meetings of the Technical Advisory Group (TAG). To effectively update the Model WQMP and TGD and with the substantial changes need based on the current Draft Order at least 12 months is needed. Since the requirements of the Model WQMP and TGD are in place, there would be no impact to water quality if the implementation of the new permit is deferred to allow the appropriate time to ensure orderly and effective implementation of the updated program.

Action: Modify Section XII.B.1 consistent with the Attachment B to provide 12 months after adoption of the order for the effective date of Section XII.B.1 of the Draft Order.

37. APPLICABILITY OF SECTION XII.B FOR MUNICIPAL PRIORITY AND NON-PRIORITY PROJECTS SHOULD BE BASED ON PROJECT APPROVALS AND NOT ON FUNDING

16.38 Section XII.B.1 identifies that the requirements of Section XII.B apply to municipal projects for which funding is approved on the date of the adoption of the Order. The wording of this sentence can be interpreted that all municipal projects that have funding approved are required to meet the requirements of Section XII.B, which would potentially mean that some municipal projects would need to be re-designed to meet the new requirements. It appears the intent of the sentence is that all projects where funding is approved moving forward from the date of the adoption of the permit would be subject to the requirements of Section XII.B, and that projects that having funding approved prior to adoption of the permit would not be subject to the requirements of Section XII.B, however the wording of the sentence is not clear. The sentence should be reworded for clarity. Additionally funding is not the correct mechanism for a trigger for applicability, but rather approval of projects is the more appropriate trigger. Finally, with the new elements identified in Section XII.B., the Permittees will need time to implement the changes in the municipal projects that are in the pipeline and requiring that this happen on the day of adoption of the permit is unrealistic. The Order should provide an effective date for this provision of 12 months after the effective date of the Order.

Action: Modify Section XII.B.1 consistent with the Attachment B to modify the applicability of Section XII.B for municipal projects to be based on project approvals and provide 12 months after adoption of the order for the effective date of Section XII.B for municipal projects.

38. The Criteria for "Priority Projects" and "Non-priority Projects" Should be Consistent With the Model WQMP and TGD.

Section XII.B.2 requires that all development projects be classified as "priority projects" or "non-priority projects." This proposed change in the program would have a significant impact in the project approval process and would impose significant and unwarranted costs on both the project applicant and the Permittees and cause extended delays in project approvals. The provision in this paragraph along with the definition provided in paragraph M.1 for Non-Priority Projects to include projects exposed to stormwater or are sources of urban runoff is broad and will result in Permittee expenditure of resources and costs that are unnecessary. An unambiguous reading of these provisions would require projects such as reroofs, patio covers, solar panel roof installations, block walls, swimming pools and spas and other projects typically issued by building departments over the counter to prepare Non-Priority Project Water Quality Plans. This will not only cause project delays but will also prove costly adding potentially thousands of dollars to projects because applicants must now hire a licensed professional (civil engineer, landscape architect, Section M.5) to prepare the Non-Priority Project Water Quality Plans. This requirement is clearly impracticable and unreasonable.

16.39 For illustrative purposes, the City of Orange conducted a review of the number of building permits issued between July 1, 2013 and April 30, 2014. In those ten months 1,927 permits were issued. Of those permits, 579 permits (200 reroof, 250 solar panel installations, 40 patio covers, 89 other such as residential additions, block walls, etc.) about 30% could be subject to Non-Priority Project Water Quality Plans since they would be exposed to stormwater. As a basis for comparison, the City has reported the approval of 23 Non-Priority Projects during the last four years in its annual NPDES reports. That is an average of six Non-Priority Projects approved per year compared to 579 that would require Non-Priority Project Water Quality Plans in one year.

Clearly, this is not a reasonable requirement nor does it make sense. Implementation of these provisions will bring issuance of over the counter permits to a halt and have significant economic consequences for each project and would require cities to add a significant number of personnel to review and process the Non-Priority Project Water Quality Plans.

Additionally, proponents of these small projects would be required to develop a Non-Priority Project Water Quality Plan where there is little or no potential for water quality impacts from their project. Impacts from development must be identified for the lawful requirement of mitigation of impacts.

The Permittees are concerned that implementing these requirements, and overly broad hydromodification and LID requirements, would subject them to liability under the Takings Clause of the U.S. and California Constitutions and the Mitigation Fee Act because of the questionable nexus between a Non-Priority Project's impacts on water quality and the project's management measures specified in the Draft Order. When imposing a condition of a development permit, a local government is required under federal and state law to establish that the condition bears a reasonable relationship to the impacts of the project.

This rule applies even to legislatively enacted requirements and impact fees and exactions.[41] Moreover, fees imposed on a discretionary ad hoc basis are subject to heightened scrutiny under a two-part test. First, local governments must show there is a substantial relationship between the burden created by the impact of development and any fee or exaction.[42] Second, a project's impacts must bear a "rough proportionality" to any development fee or exaction.[43] Under California law, the *Nollan/Dolan* heightened scrutiny test also applies to in-lieu fees.[44]

16.39

The Legislature has memorialized these requirements in the Mitigation Fee Act, which establishes procedures that local governments must follow to impose impact fees.[45] Irrespective of whether the non-priority project requirements are implemented by legislative act or on an ad-hoc basis, the Permittees' attempt to enforce them as proposed in the Draft Order would likely result in claims alleging unconstitutional takings or private property and violations of the Mitigation Fee Act. This is because a landowner, developer or other project applicant could argue that requiring Non-Priority Project Water Quality Plans where there isn't a water quality impact would not have a legally sufficient nexus to the impact of the development project. The criteria for "priority projects" and "non-priority projects" should be consistent with the Model WQMP and TGD.

Action: Modify Section XII.B.2 consistent with Attachment B to make the criteria for "priority projects" and "non-priority projects" consistent with the Model WQMP and TGD, and qualify that all Permittee approvals are subject to federal and state law limitations.

39. SINGLE AND MULTI-FAMILY DWELLING UNITS SHOULD NOT BE "PRIORITY PROJECTS."

Section XII. B.5.b adds single and multi-family dwelling units to the list of "priority projects," which is a change from single family home subdivisions and multi-family attached subdivisions in the 2009 permit. The Draft Order contains no technical justification in the Fact Sheet for this modification. In addition this would put a significant administrative burden as all individual single family and multi family unit projects that meet the impervious surface threshold would have to be reviewed and checked. Additionally single family and multi-family project proponents would be required to develop a Project WQMP where there has not been shown that these projects are a threat to water quality. Impacts from development must be identified for the lawful requirement of mitigation of impacts.

16.40

Such requirements could also constitute an unlawful taking under the *Nollan/Dolan* test and the Mitigation Fee Act as discussed above at Comment 38.

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[41] *Building Indus. Ass'n v. City of Patterson*, 171 Cal. App. 4th 886, 898 (2009).

[42] *Nollan v. California Coastal Comm'n*, 483 U.S. 825, 837 (1987).

[43] *Dolan v. City of Tigard*, 512 U.S. 374, 391 (1994).

[44] Erlich v. City of Culver City, 12 Cal. 4th 854, 876 (1996); *see also Koontz v. St. Johns River Water Management Dist.*, 133 S.Ct. 2586 (2013) (holding the *Nollan/Dolan* test applies to in-lieu fees as well as permits that are denied because the landowner rejects the provisions).

[45] Cal. Gov't Code §§ 66000-66025.

16.40 *Action: Modify Section XII.B.5.b consistent with Attachment B so that the definition of the category is consistent with the 2009 permit.*

40. EXPANSION OF AUTOMOTIVE REPAIR SHOPS SHOULD NOT BE PRIORITY PROJECTS.

16.41 Section XII.B.5.c identifies that new or expanded automotive repair shops are identified as "priority" projects. The term expanded means added to an existing facility, which by definition means redevelopment not new development. The redevelopment category requires the addition of 5000 square foot of impermeable surface to require a Priority WQMP. There is no threshold for what "expanded" means and this could simply be one square foot of surface, which is clearly impracticable. Additions to existing facilities should be subject to the requirements contained in the redevelopment category.

Action: Modify Section XII.B.5.c consistent with the Attachment B to remove the word "expanded" from the provision.

41. ROUTINE MAINTENANCE SHOULD INCLUDE MAINTENANCE ON THE ENTIRE ROADWAY STRUCTURE.

16.42 Section XII.5.h.i contains an exclusion for routine maintenance of roadways limited to maintenance of the surface course of pavement. However maintenance on roadways often includes maintenance on more than just the surface course that does not substantially change the surface type or line and grade of the roadway structure. The exclusion should allow this type of maintenance.

Action: Modify Section XII.B.h.i consistent with Attachment B to allow the exclusion to include maintenance on the full roadway structure.

42. PRECISE GRADING OR FINAL CONSTRUCTION WORK SHOULD NOT PROCEED UNTIL A FINAL PROJECT WQMP IS APPROVED.

Section XII.B.10 identifies that construction work cannot proceed on a project prior to approval of a final project WQMP or Non-Priority Project Water Quality Plan. The existing requirements of the 2009 Permit, though only apply to precise grading. The Regional Board has provided no technical justification for this change in the Draft Fact Sheet. This also puts a burden on the project proponent without any proven water quality benefit, and could 16.43 result in an unconstitutional taking. Additionally some construction work is appropriate such as potholing for utilities and geotechnical work such as infiltration tests to identify the best locations for retention BMPs. Because some construction work is appropriate precise grading is more appropriate trigger to ensure that a final approach to water quality is identified and approved prior to completion of the final grading of a site. The Permittees also recognize that some redevelopment projects will not include grading and so for these projects final construction work should not commence without an approved Final Project WQMP.

Action: Modify Section XII.B.10 consistent with Attachment B to require that precise grading for new development or final construction work should not proceed without approval of the Final Project WQMP or non-priority project plan.

43. THE TYPE OF MECHANISMS TO PROVIDE EFFICIENCY AND CONSISTENCY IN THE PROJECT WQMP APPROVAL PROCESS SHOULD BE AT THE DISCRETION OF THE PERMITTEE.

16.44 Section XII.C.6 requires that Permittees employ all the mechanisms listed in the provision to provide efficiency and consistency in their WQMP approval process. This list of mechanisms has redundancy and the entire list may not be applicable to each Permittee. A Permittee does not need to use each and every item in this list to have an effective program. Each Permittee should have the discretion to identify mechanisms that work best for their program.

Action: Modify Section XII.C.6 consistent with Attachment B to allow the Permittees the discretion to identify mechanisms provision to provide efficiency and consistency in their Project WQMP approval process.

44. RECORDATION OF PROJECT WQMPS SHOULD BE LEFT TO THE DISCRETION OF THE PERMITTEES.

16.45 Sections XII.C.10 and XII.C.11 requires that approved WQMPs and any covenants, conditions and restrictions associated with the WQMP are recorded in public records. The Permittees should have the discretion to identify an appropriate mechanism that works for their process so that the Project WQMP and associated appropriate easements and ownerships are adhered to and information is conveyed to all appropriate parties when there is a change in project or site ownership.

Action: Modify Sections XII.C.10 and XII.C.11 consistent with Attachment B to allow the Permittees the discretion to identify a mechanism so that the Project WQMP and associated appropriate easements and ownerships are adhered to and information is conveyed to all appropriate parties when there is a change in project or site ownership.

45. THE DRAFT ORDER SHOULD RECOGNIZE AND MAINTAIN THE ADEQUACY OF THE CURRENT BMP SIZING AND SELECTION APPROACHES IN THE MODEL WQMP AND TGD.

16.46 Section XII.D.3. identifies specific requirements for structural treatment control BMPs. These requirements should be consistent with the Model WQMP and TGD. Section XII.D.3. requires structural treatment control BMPs intended to retain the design capture volume to be designed to infiltrate, evaporate, evapotranspirate, or use the volume over a period not to exceed 48-hours. This requirement is inconsistent with the Model WQMP and TGD and the Draft Fact Sheet provides no technical justification for the change.

Action: Modify Section XII.D consistent with Attachment B to be consistent with the Model WQMP and TGD.

46. STRUCTURAL TREATMENT CONTROL BMPS BEING SIZED AND DESIGNED BY A REGISTERED CIVIL ENGINEER IS ALREADY A REQUIREMENT OF THE TGD.

16.47 Section XII.D.6 requires that structural treatment control BMPs be sized and designed by, or under the direction of, a registered civil engineer. The requirement that structural treatment control BMPs be sized and designed by, or under the direction of, a registered civil engineer is already a requirement of the TGD. With the proposed redline changes to Section XII.D.14,

16.47 which refers to the TGD, Section XII.D.6., becomes redundant and should be deleted from the Draft Order.

Action: Delete Section XII.D.6 from the Draft Order.

47. IF A STRUCTURAL TREATMENT CONTROL BMP SATISFIES THE REQUIREMENTS OF THIS ORDER BUT IS UNDERSIZED RELATIVE TO ITS TRIBUTARY AREA THERE SHOULD BE NO REQUIREMENT TO PERFORM A COST ANALYSIS.

16.48 Section XII.D.8. requires where a structural treatment control BMP satisfies the requirements of this Order but is undersized relative to its tributary area that a cost analysis be performed. If a structural treatment control BMP satisfies the requirements of the Order then the requirements are met and no further analysis should be required. Impacts from development must be identified for the lawful requirement of mitigation of impacts.

Such requirements could also constitute an unlawful taking under the Nollan/Dolan test and the Mitigation Fee Act as discussed above at Comment 38.

Action: Delete Section XII.D.8 from the Draft Order.

48. PERMITTEES SHOULD NOT BE REQUIRED TO SECURE THE LEGAL AUTHORITY TO ENTER PRIVATE PROPERTY.

Section XII.D.10 requires the Permittees to strictly supervise the use of, and potentially take over the operation of BMPs sited on private property. This requirement should be deleted in its entirety because it ignores state law and would violate federal constitutional protections, while exposing the Permittees to extensive liability for inverse condemnation.

16.49 The Permittees generally have the ability to enter private property within their respective jurisdictions for health and safety inspection purposes: 1) where the owner of the property has given consent, or 2) where there are demonstrated exigent circumstances showing immediate risk to public health or safety that precludes taking the time to obtain an inspection warrant pursuant to Code of Civil Procedure ("CCP") § 1822.50 *et seq.* However, absent consent or exigent circumstances, the Permittees cannot simply demand to enter private property—as doing so would potentially constitute a violation of the private property owner's Fourth Amendment rights. Accordingly, under many circumstances, access may only occur after application for, and receipt of, an inspection warrant, which is a burdensome and lengthy process.[46]

The Regional Board is similarly limited in its ability to demand access to private property,[47] so it is difficult for the Permittees to understand why they would be expected to compel BMP inspections on private property without consent, when the Regional Board itself does not possess such authority. Moreover, the process for obtaining an inspection warrant under CCP 1822.50 requires a neutral magistrate to find there is "cause" to believe that violation of the law or other health and safety issues have occurred on the property to be

[46] *See Griffith v. City of Santa Cruz*, 207 Cal. App. 4th 982, 993 (2012); *Currier v. City of Pasadena*, 48 Cal. App. 3d 810 (1975); *Tellis v. Municipal Court of Marin County*, 5 Cal. App. 3d 455 (1970).

[47] Water Code § 13267(c).

inspected.[48] Thus, there is no guarantee that the magistrate will issue a warrant allowing access, and even if the magistrate does authorize access, it can be for no more than 14 days without returning to the court to obtain another warrant.[49]

The apparent requirement for the Permittees to take over the operation of BMPs on private property, where the private property owner has failed to maintain them, is particularly problematic. Not only does it suffer from the 4th Amendment and statutory limitations addressed above, but the Permittees would incur extensive liability for inverse condemnation under the Fifth and Fourteenth Amendments to the U.S. Constitution. The fact that the a Permittee would only be required to occupy part of the Property on a non-permanent basis when "taking over" a BMP would not relieve it from liability for the taking of private property.[50]

16.49

The Permittees are further restricted from operating BMPs on private property pursuant to the constitutional prohibition on gifts of public funds.[51] A case-by-case analysis would need to be demonstrated that there is an overall public benefit to the taxpayers. This analysis could not be done for certain BMPs. In addition, certain Permittees have outright prohibitions that public employees cannot expend funds or perform work on private property.[52]

It is recognized that maintenance of approved structural BMPs is critical to ensure a project's pollutants are being minimized or eliminated. This measure is included in various water quality related documents (*e.g.*, conditions of approval, Model WQMP, Technical Guidance Document, DAMP), and Permittees make every effort to comply with these requirements. Permittees also make efforts to ensure approved structural BMPs are adequately maintained. In the event that it is discovered that a BMP is not being adequately maintained, Permittees work with the owner or responsible party to ensure appropriate measures are implemented to make the BMP operational and functional.

Action: Delete Section XII.D.10 from the Draft Order.

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[48] Code of Civil Procedure § 1822.51.

[49] *Id.* at § 1822.55.

[50] *First English Evangelical Lutheran Church v. Los Angeles County*, 482 U.S. 304 (1987) (holding that a temporary taking of property for environmental reasons still requires compensation to the property owner); *Loveladies Harbor v. United States*, 28 F.3d 1171 (1994) (holding that occupying only a discrete segment of overall property is nevertheless a compensable taking).

[51] California Constitution, Art. 16, Sec. 6; Gov't Code § 8314. "The Legislature shall have no power . . . to make any gift or authorize the making of any gift, of any public money or thing of value to any individual, municipal or other corporation whatever . . ." Various remedies and penalties are applicable with respect to the unauthorized expenditure of public funds. *See e.g.*, Code Civ. Proc. § 526a; Gov't Code § 8314; Pen. Code § 424; 83 Ops. Cal. Atty. Gen. 124, 128-131 (2000).

[52] *See e.g.*, County of Orange Policy and Procedure, *Emergency Work on Private Property* (adopted Nov. 8, 2011). This was a legislative act by the Orange County Board of Supervisors prohibiting work on private property and the expenditure of public funds absent exigent circumstances or a declaration of local emergency (that is only made pursuant to statutory findings in time of flood, fire and other hazards).

49. PERMITTEES SHOULD HAVE THE DISCRETION TO APPROVE BMPS THAT HAVE FIELD-SCALE PERFORMANCE DATA BUT ARE NOT IN A PUBLISHED DESIGN MANUAL.

16.50

Section XII.E.1 prohibits the Permittees from approving structural treatment control BMPs that do not substantially conform to published and generally-accepted engineering design criteria. This provision essentially restricts innovative BMPs without any technical justification. The Permittees should be given the discretion to approve BMPs that have field-scale performance data but are not in a published design manual. There are potentially many structural treatment control BMPs that can improve water quality and they should not be restricted just because they are not in published design manual. Field-scale performance data is sufficient to give the Permittees the flexibility to approve or deny use of a structural treatment control BMP.

Action: Modify Section XII.E.1 consistent with Attachment B to provide the discretion to approve BMPs that have field-scale performance data but are not in a published design manual.

50. THE DRAFT ORDER SHOULD RECOGNIZE THE MODEL WQMP AND TGD TECHNICAL FEASIBILITY CRITERIA.

16.51

Section XII.F.2 requires the Permittees to require retention LID BMPs for the design capture volume, or the maximum portion thereof, wherever, based on substantial evidence such controls are technically infeasible, economically infeasible, and where environmental and public health hazards can be mitigated to an acceptable level. The Draft Order should defer to the TGD for criteria related to evaluating the feasibility of retention and biotreatment and the associated burden of proof that must be met by project applicants as part of Project WQMP submittals. Furthermore, substantial evidence is an undefined term in the Draft Order and infeasibility for retention BMPs is already defined in the Model WQMP and TGD, which should be referenced as the definition of substantial evidence.

Action: Modify Section XII.F.2 consistent with Attachment B so that the Model WQMP and TGD are referred to for the description of "substantial evidence."

51. MITIGATION OF THE ENVIRONMENTAL AND PUBLIC HEALTH HAZARDS OF RETENTION LID BMPS SHOULD BE CONSISTENT WITH THE REQUIREMENTS OF THE TGD.

16.52

Sections XII.F.4.and XII.G.5 require mitigation of environmental and public health hazards of retention LID BMPs by the Permittees. The requirement for mitigation should be consistent with the requirements for hazard mitigation identified in the TGD.

Action: Modify Sections XII.F.4 and XII.G.5 consistent with Attachment B to be consistent with the requirements for hazard mitigation in the TGD.

52. BIOTREATMENT BMPS SHOULD BE SIZED FOR THE DESIGN CAPTURE VOLUME.

16.53

Section XII.G.1.d requires volume-based biotreatment control BMPs to be sized to 1.5 times the design capture volume, which is an increase from the 2009 permit. The technical justification identified in the Draft Fact Sheet is based on the findings of Appendix D, BMP Performance Guidance, to the Ventura County Technical Guidance Manual for Stormwater

Quality Control Measures (Manual Update 2011)[53]. The Draft Fact Sheet states that "[t]he Regional Board recognizes that the Ventura County study was based on local hydrologic and soil conditions." It is also the Permittees' understanding that EPA has recommended the 1.5 design capture standard in oral statements to Regional Board staff.

There is no factual support to require the 1.5 design capture standard. The standard has only been recommended in one study that was specific to the hydrologic and soil conditions of Ventura County. In fact, a study based on work conducted within Orange County by Geosyntec Consultants provides contrary support for the inclusion of a 1.5 factor which are attached to these comments as Appendix A-1 & Appendix A-2.[54]

16.53 The study assessed the costs and modeled the performance of harvest and use retention BMPs, and compared average annual total suspended solids (TSS) load removed and annual TSS concentrations with BMPs. In both scenarios presented, biotreatment provided superior TSS results to harvest and use.

A paper published in The Water Report Issue #65: Stormwater Retention on Site, An Analysis of Feasibility and Desirability[55] identified significant limitations for all retention BMPs stating that "There needs to be a more technical vetting of 'retain on site' and stormwater harvest and use before these approaches are made mandatory." The authors of that paper also cautioned that a "one size fits all" approach requiring retention may not be desirable and "in many cases would lead to undesirable results."

Based on the above information, the requirement to oversize volume-based biotreatment BMPs should be deleted from the Draft Order. Biotreatment should be considered equivalent to other retention BMPs and should remain a full part of the LID toolbox without penalization.

Action: Modify Section XII.G.1.d consistent with Attachment B deleting the requirement to oversize biotreatment BMPs.

53. Performance of Structural Treatment Control BMPs Should be Consistent with the TGD.

16.54 Section XII.H.1 requires the Permittees to maintain and employ a schedule that rates the expected performance of specific structural treatment control BMPs. This schedule should be consistent with the TGD. Section XII.H.1.d further requires biannual review of performance ratings however this level of review is not necessary given the low priority of structural treatment BMPs in the BMP hierarchy.

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[53] *Available at*: www.waterboards.ca.gov/losangeles/water_issues/programs/stormwater/municipal/ventura_ms4/VenturaTGM/ Ventura%20Stormwater%20TGM%20Final%207-13-11.pdf

[54] Eric Strecker, Geosyntech Consultants, Storage and Reuse Systems for Stormwater Management – Preliminary Cost and Performance Estimates for Residential Use in Irvine, CA, 2009 (presentation to Santa Ana Regional Board).

[55] Eric W. Strecker, PE, and Aaron Poresky, EIT, Geosyntec Consultants (Portland, OR), Stormwater Retention On Site, An Analysis of Feasibility and Desirability, The Water Report Issue #65, *available at* http://www.thewaterreport.com/Issues%2065%20to%2068.html

16.54 *Action: Modify Section XII.H.1.d consistent with Attachment B to reference the TGD and delete the requirement to perform a biannual assessment.*

54. VERTICAL SEPARATION FROM THE BOTTOM OF AN INFILTRATION FACILITY TO THE SEASONAL HIGH GROUNDWATER SHOULD BE CONSISTENT WITH THE TGD.

Section XII.I.2 requires the vertical separation from the bottom of the infiltration facility to the seasonal high groundwater to be distance of 10 feet. This requirement should be consistent with the technical guidance in the TGD that was developed by the Permittees in coordination with Orange County Water District (OCWD), which identifies:

16.55 "The separation between the infiltrating surface and the seasonally high mounded groundwater table shall not be less than 5 feet for all BMP types. BMPs for which 5-foot minimum separation applies include:

- Rain gardens and dispersion trenches (small, residential applications)
- Bioretention and planters
- Permeable Pavement
- Similar BMPs infiltrating over an extensive surface area and providing robust pretreatment or embedded treatment processes."

Action: Modify Section XII.I.2 consistent with Attachment B to reference the TGD.

55. THE COMPLIANCE REQUIREMENT FOR CLASS V INJECTION WELLS IS TOO GENERAL.

16.56 Section XII.I.5 only cites a compliance requirement for USEPA's Class V Rule, however, local permitting agencies may have more stringent requirements to ensure compliance with the California Well Standards or to maintain proper setbacks from active or closed industrial clean-up sites.

Action: Modify Section XII.I.5 to include additional language which requires compliance with all applicable county and municipal well construction/ destruction ordinances and standards.

56. INDOOR USE OF HARVESTED STORMWATER SHOULD ONLY BE CONSIDERED AS THE APPLICABLE PLUMBING CODE ALLOWS.

16.57 It is recommended that Section XII.J.1.a.iv be added to the Draft Order as indoor use of harvested stormwater can only be considered where the plumbing code allows.

Action: Add Section XII.J.1.a.iv consistent with Attachment B to identify that indoor use of harvested stormwater can only be considered where the plumbing code allows.

57. DEMAND RATE CALCULATIONS FOR HARVEST AND USE OF STORMWATER SHOULD NOT BE INCLUDED IN THE DRAFT ORDER.

16.58 Section XII.J.1.b identifies demand rate calculations for harvest and use of stormwater. It is not appropriate to include demand rate calculations for harvest and use of stormwater in an MS4 Permit. The TGD already contains information regarding harvest and use of stormwater.

Action: Delete Section XII.J.1.b from the Draft Order.

58. OFFSITE STRUCTURAL BMPS SHOULD BE ON THE SAME LEVEL IN THE BMP HIERARCHY AS ONSITE BMPS.

16.59

Section XII.K.2.a.iv references sites subject to R8-2002-0010 retaining a portion of the design capture volume (DCV) via source control and site design. If an offsite structural treatment has the ability to meet the requirements of the permit, no portion of the DCV should be required to be retained onsite. This provision does not consider infiltration constraints such as high groundwater, contaminated groundwater and/or soils, and soil type. Sections XII.K.2.d.i & ii require demonstration consideration of retention LID BMPs on site and maximization of retention of the DCV onsite. The use of offsite structural BMPs should not be constrained by requirements onsite because as long as the retention of the DCV is met offsite, the retention of the volume of stormwater and associated pollutants are achieved. The intent of having offsite structural BMPs be at the same level in the BMP Hierarchy as Onsite BMPs is to have the most flexibility with meeting the retention standard and provide opportunities to achieve an integrated water resource approach. If a project has the ability to convey its DCV to an offsite BMP for harvest and use but is required to infiltrate on site, the full benefits of using stormwater as a resource through the off-site BMP cannot be realized.

Action: Delete Section XII.K.2.a.iv and Sections XII.K.2.d.i& ii from the Draft Order to allow Offsite Structural BMPs to be on the same level in the BMP hierarchy as onsite BMPs.

59. THE REQUIREMENTS FOR NON-PRIORITY PROJECTS SHOULD BE CLEAR AND CONSISTENT WITH THE MODEL WQMP.

16.60

Section XII.M.1 defines Non-Priority Projects as exposed to stormwater or are sources of urban runoff, which is broad and will result in Permittee expenditure of resources and costs that are unnecessary. Per comment 38 the definition of Non-Priority Projects should be consistent with the TGD and Model WQMP. Section XII.M.1 also includes language about source controls, site designs and structural treatment controls that is ambiguous. This section should be modified for clarity and should be consistent with the Model WQMP. Section XII.M.3.b contains language that confuses source controls and site design with structural treatment controls and should be deleted.

Section XII.M.5 requires a plan to be approved under the supervision of a registered civil engineer which is appropriate for Project WQMPs that require technical knowledge, but not for Non-Priority Project Water Quality Plans. It will add thousands of dollars to a project's costs that are unnecessary. For example, a small restaurant outdoor patio dining expansion where only a canopy may be used could be prepared by someone other than a licensed professional through a simple plan.

Action: Modify Section XII.M.1 and Section XII.M.5 consistent with Attachment B and delete Section XII.M.3.b from the Draft Order for clarity and consistency with the Model WQMP.

60. ALL ENGINEERED CHANNELS SHOULD BE EXEMPT FROM HYDROMODIFICATION REQUIREMENTS.

16.61

Section XII.N.1.b states that all downstream conveyance channels that will receive runoff from the project and are engineered, hardened, and regularly maintained to accommodate the necessary design flow capacity are exempt from hydromodification requirements. The only change to this provision is that the word "hardened" should be removed, as

16.61 engineered and maintained conveyance systems are designed to accept and convey the range of storms that have been proven to cause hydromodification impacts. Since these systems were designed for this purpose development projects that discharge to these facilities will not cause hydromodification impacts. These systems do not need to be hardened but just engineered and maintained with the necessary design flow capacity. Similarly text in Section XII.N.3 should be revised to also remove the word "hardened."

Action: Modify Section XII.N.1.b and XII.N.3 consistent with Attachment B and delete the word "hardened" from these provisions.

61. THE HYDROMODIFICATION CRITERIA SHOULD BE CONSISTENT WITH THE 2009 ORDER AND THE MODEL WQMP AND TGD.

16.62 Section XII.N.2 describes certain hydromodification criteria, but the criteria do not include matching flow rates for the 2-year event within 10% which is currently in the 2009 permit and identified in the TGD for those projects that cannot infiltrate or capture and use the volume of the 2 year event. To be consistent with the 2009 permit and the Model WQMP and TGD projects that cannot modify runoff volumes and times of concentration from the project site conditions for the 2-year, 24-hour storm projects should be allowed match post-project peak runoff flow rates for the 2-year, 24-hour storm event within 10% compared to the pre-project peak flow rates for the 2-year, 24-hour storm event.

Action: Modify Section XII.N.2 consistent with Attachment B to be consistent with the 2009 Order and the Model WQMP and TGD.

62. THE DRAFT ORDER SHOULD MAINTAIN THE ALTERNATIVE COMPLIANCE PROGRAM IDENTIFIED IN THE MODEL WQMP AND TGD.

16.63 The Draft Order does not include the concept of alternative compliance which provides options for those projects that cannot meet the requirements of the order on the project site. The Model WQMP has developed a structure for alternative compliance which should be recognized and maintained in the Draft Order.

Action: Add Section XII.O consistent with Attachment B to be consistent with the 2009 Order and the Model WQMP.

XIII. PUBLIC EDUCATION AND OUTREACH

63. REQUIREMENT TO DEVELOP EDUCATIONAL CONTENT WITH THE "MOST" POTENTIAL TO APPEAL TO AUDIENCES SHOULD BE MET THROUGH THE DEVELOPMENT OF THE WRITTEN PLAN.

16.64 Section XIII.b.5 requires the Permittees to develop educational content for media with the "most" potential to appeal to audiences. This would be difficult, if not impossible, to demonstrate, and is therefore without merit. Prioritizing messages for materials and content using a rationale in the written plan though the process specified in Section XIII.b.5 should be deemed to meeting this requirement.

Action: The term "with the most potential to appeal to the audiences" should be deleted from XIII.b.5. The intent of this permit provision should also be clarified in Section XII.J of the Fact Sheet.

64. Completion of Three Campaigns to Address High-Priority Urban Runoff Pollution Issues within the Permit Term is Infeasible.

16.65

Section XIII.b.2 requires the Permittees to "identify goals and related measureable objectives that address a minimum of three high-priority urban runoff pollution issues over the term of this Order." Due to the time that it takes to develop and implement a public education campaign and then assess the results (1-2 years), it will not be possible to conduct three full rounds of "action campaigns" or targeted outreach programs based on high priority pollutants, re-examine and monitor for the high priority pollutants, solicit public feedback and assess results within the 5-year permit term (see also Comment #6).

In fact, the Fact Sheet (Section XII.J) states "this Order now requires that the Permittees *initiate* public education campaigns that address a minimum of three high-priority pollution issues…..other than to initiate campaigns on three issues, this Order does not specify any particular milestones or other performance metrics for those campaigns."[56] It should be made clear in the permit provisions that the requirement is to "initiate" the process for the three campaigns. As currently written, the language could be interpreted that the full process of development, implementation, and assessment would be required for three full campaigns during the permit term, which is infeasible and exceeds the methods that the Permittees developed as a part of the 2012 Orange County Stormwater Program Public Education & Outreach 5-Year Strategic Plan.

Action: Section XIII.b.2 should be modified consistent with Attachment B so that the Permittees can identify the high priority issues pursuant to the process that is outlined in the 2012 Orange County Stormwater Program Public Education & Outreach 5-Year Strategic Plan.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

65. The Approach for the Drainage Facility Maintenance was Modified From the Fourth Permit Term Without Technical Justification.

16.66

The Draft Order includes several new requirements for the maintenance of drainage facilities without providing the technical justification for the modifications. The new requirements include the following:

- Section XIV.C now requires inspection of "flood management and stormwater conveyance systems." while the previous requirement was for inspection of "drainage facilities," which was defined as *catch basins, storm drain inlets and open channels*. As a result, this provision appears to expand the inspections to include underground facilities. However, there is no basis provided for this change within the Fact Sheet.
- This Section also requires that the cleaning frequency be based on the accumulation of "unusually large quantities" of pollutants. The Principal Permittee is required to establish objective thresholds for "unusually large quantities" of pollutants. This is new terminology and no technical basis is provided for inclusion of the provision in Section K of the Fact Sheet.

[56] (emphasis added).

16.66

The two terms "unusually large quantities" and "accumulated pollutants" are used within the Municipal Facilities/Activities section of the Draft Order (Section XIV.C) in reference to the inspection and cleaning of the flood management and stormwater conveyance systems. Although the Permittees understand that the purpose of these provisions is to define when the systems need to be cleaned, these new terms add unnecessary complexity to this process. For example, as a result of the new terms, the Permittees will now be required to define a threshold for the term "unusually large quantities." In addition, it is unclear how inspectors would know if there are "accumulated pollutants" and if this term is just meant to reference trash and/or debris or a broad range of pollutants.

Action: Modify the following:

- *Clarify that Section XIV B and C only apply to the drainage facilities (catch basins, storm drain inlets, open channels) that are under the Permittees' control.*
- *Delete the term "unusually large quantities."*
- *Modify the term "accumulated pollutants" to "accumulated trash and debris."*

66. THE DESCRIPTION OF THE APPROACH FOR THE FIELD ACTIVITIES AND FIXED FACILITIES (XIV.E) IS OVERLY PRESCRIPTIVE.

16.67

Section XIV.E includes requirements for the implementation of the municipal facilities program. However, many of the requirements are overly prescriptive and, in one case, require that the program include "disciplinary procedures or policies for Permittees' staff that unnecessarily deviate from standard operating procedures." Such a requirement goes well beyond the manner of compliance prohibition in Water Code § 13360, and does not demonstrate a direct effect on water quality. In addition, the Regional Board has no authority to mandate requirements that affect the labor and employment practices of the Permittees. Employee relations are exclusively governed by the Meyers-Milias-Brown Act and collective bargaining contracts that the Regional Board has no authority with which to impair or otherwise interfere.[57]

Action: Modify this Section so that it is less prescriptive and does not dictate staff disciplinary procedures to the Permittees.

XIX. PROGRAM EFFECTIVENESS ASSESSMENT

67. THE PROGRAM EFFECTIVENESS ASSESSMENT REQUIREMENT DOES NOT LINK TO KNOWN PEA GUIDANCE MATERIALS.

16.68

This Provision requires the Permittees to develop a program effectiveness assessment approach and implement it in order to assess the effectiveness of their stormwater programs. However, there is very little guidance that has been developed by the State or EPA to identify how municipal program managers can assess their programs. Further, the Draft Order does not reference the documents that have been developed by the California Stormwater Quality Association (CASQA) that provide clear guidance to stormwater

[57] Gov't Code §§ 3500-3510.

16.68 managers. An updated version of this guidance is expected in the near future and the County has been participating in its Development.

Action: Provide a reference to the approach in the CASQA PEA Guidance, including the planned update, in order to provide a framework for this component.

XVIII. TOTAL MAXIMUM DAILY LOAD IMPLEMENTATION

68. THE METHOD FOR DETERMINING COMPLIANCE LACKS CLARITY AND NEEDS MODIFICATION TO ENSURE THE LANGUAGE PROVIDES THE COMPLIANCE OPTIONS THAT APPEAR TO BE INTENDED, PARTICULARLY THE BMP-BASED COMPLIANCE OPTION.

The Permittees support the inclusion of the BMP-based compliance option for TMDL wasteload allocations (WLAs). However, the language and structure of the Draft Order lacks clarity regarding how compliance will be determined. As TMDLs and MS4 permits have become more complex, the language pertaining to the method of determining compliance, and the explicit clarity of such language, has increased in importance to ensure that the permit language reflects the intention of the Regional Board. Therefore, extensive revisions have been provided in Attachment B to propose approaches that will clearly support and document the compliance options, including:

- Creating two parts of the provision – TMDL Provisions and Compliance Determination.
    - TMDL Provisions: This section is needed to clearly introduce the structure and intent of the provision. Language is included to (1) document the structure of the provisions and requirements, (2) provide justification for the selected approach of incorporating the WLAs into the Permit, including clearly stating that BMP-based compliance is an option, and (3) provide the linkage between the TMDL provisions and the Receiving Water Limitations provisions.
    - Compliance Determination: This section is needed to provide a very clear and explicit provision directly pertaining to compliance. The language provided is based upon two key aspects, (1) a provision that directly states compliance will be based upon demonstrating *any one* of the options (that subsequently follow) and (2) a provision that clearly details the components of the BMP-based compliance option. In addition, Attachment B provides clear language for instances where a Permittee either fails to, or opts not to, implement the BMP-based compliance option. This language is critical to ensure the process is clear and consistent with the TMDL Basin Plan Amendments (BPAs).

16.69

- Providing an explicit provision in each of the TMDL-related Appendices (Appendix B through G) that links directly back to the compliance provisions in Section XVIIII.B. This linkage is necessary to ensure that the requirements in the appendices are not viewed as stand-alone requirements lacking a compliance mechanism.

16.69 *Action: Modify Section XVIII, consistent with Attachment B, to provide clarity and ensure the provisions reflect the intent of the Regional Board. Specifically, see Section XVIII.1 and Appendices B through G, Section III.*

69. THE PROCESS FOR PLAN DEVELOPMENT AND IMPLEMENTATION CREATES REQUIREMENTS THAT ARE INCONSISTENT WITH MANY OF THE TMDL BPAS.

It appears that the BMP-based compliance option is the same process included under the Receiving Water Limitations provisions (Section IV). However, this process must be modified in order to be consistent with the assumptions and requirements of the respective TMDL Basin Plan Amendments. While the process itself may be different, the processes are equivalent in ensuring water quality objectives are attained in receiving waters.

a. Implementation actions and schedules are included in all State adopted TMDLs. Several TMDLs include requirements to develop and implement plans, as well as additional requirements regarding approvals, public review, etc. The Draft Order does not recognize these plans, timeframes, or the requirements of the TMDLs.

16.70 The Draft Order seems to create a structure whereby all plans must be submitted either at 6 months (where WLAs are not attained) or 18 months (where WLAs are attained). However, the TMDLs include implementation schedules and several explicitly include timeframes and processes for the development and submittal of these types of plans. In addition, TMDLs under development and anticipated to be effective during the permit term (e.g., selenium) rely extensively upon this approach. Therefore, a more appropriate structure is to divide the plans into the following two categories, (1) TMDLs where a plan is not specifically required in the BPA and (2) TMDLs where plans are explicitly required in the BPA. By grouping the plans in this manner, the Permit can explicitly allow plan development, content, and timeframe to be consistent with the applicable TMDL BPA, while also providing the process and timeline for TMDLs where no requirements are in place through the TMDL itself. To implement these requests, extensive revisions have been provided in Attachment B (see Section XVIII.B.2).

Action: Modify Section XVIII to be consistent with the language provided in Attachment B, specifically Section XVIII.B.2.a and c.

b. Permittees have developed and are implementing several plans, consistent with TMDL requirements. These plans should fulfill the requirements for plan development.

Permittees have developed and are implementing several plans to address multiple TMDLs in the Newport Bay Watershed. The Draft Order does not recognize these plans or consider the implementation of these plans in the BMP-based compliance option.
16.71 Certain plans have been reviewed and approved by the Executive Officer (Selenium BMP Strategic Plan, Bacteria Source Management Plan) and in some cases are well into implementation (Sediment Control Plan), or are currently under staff review (Toxicity Reduction and Investigation Program Workplan). These plans have been developed consistent with the applicable TMDL and should therefore be sufficient for BMP-based compliance purposes. Language in Attachment B has been provided which specifically allows for these plans to be deemed equivalent and satisfy the requirements of the BMP-based compliance option.

16.71 *Action: Modify Section XVIII to be consistent with the language provided in Attachment B, specifically Section XVIII.B.2.a.iii.*

70. THE SIX-MONTH TIMEFRAME FOR PLAN DEVELOPMENT IS INSUFFICIENT.

16.72 Based upon extensive experience by the Permittees, a plan that includes identification of BMPs and an analysis that demonstrates with reasonable assurance that WLAs will be attained will require more time than six months. In addition to the time necessary to collaboratively work together to identify solutions, as these plans will require a commitment to implement BMPs per a certain schedule, Permittees may need to seek approval from their respective boards/councils prior to finalizing and submitting a draft plan to the Executive Officer. Further, the Permittees historically have collaborated with Regional Board staff and environmental groups to develop these types of plans. This process ensures that the plan receives the benefit of collaboration and public review from the very beginning. Finally, the Permittees will need to secure funding commitments for these plans, historically through the adoption of cost-share agreements and budgeted appropriations. Therefore, 18 months is a more appropriate and realistic timeframe. Note that this requested timeframe only applies to new plans and does not apply to plans that are currently required in the applicable BPA or to plans that have already been developed (see Comment 69a and 69b).

Action: Modify Section XVIII to be consistent with the language provided in Attachment B, specifically Section XVIII.B.2.a.i.

71. MONITORING AND REPORTING REQUIREMENTS FOR EACH TMDL ARE UNCLEAR. GIVEN THAT EACH TMDL HAS SPECIFIC REQUIREMENTS, BOTH MONITORING AND REPORTING REQUIREMENTS SHOULD BE SPECIFIED.

16.73 The BPAs for each TMDL specify monitoring and reporting requirements. The Permit must be consistent with each TMDL and the current language in the Draft Order is unclear. Therefore, it is requested that specific requirements are included. The first preference, as reflected in Attachment B, includes specific provisions in each of the attachments. Alternatively, a provision could be added to Section XVIII that clearly states monitoring and reporting requirements shall be consistent with the applicable BPA.

Action: Make revisions to Appendix B through G, consistent with Attachment B, to provide clarity and ensure monitoring and reporting requirements are consistent with each BPA.

16.74 **72. THE TMDL PROVISIONS IN THE APPENDICES (APPENDIX B THROUGH H) HAVE INCONSISTENCIES WITH THE RELEVANT BASIN PLAN AMENDMENTS.**
SEE SPECIFIC COMMENTS UNDER APPENDICES A THROUGH H BELOW.

APPENDICES A – F (General Comments)

73. THE MS4 PERMIT IS NOT THE APPROPRIATE REGULATORY MECHANISM TO IMPLEMENT THE LOAD ALLOCATIONS OF THE SEDIMENT TMDL.

16.75

While many of the Newport Bay Watershed Permittees have implemented significant sediment control measures over the years, the Sediment TMDL does not establish WLAs for MS4 Permittees. The TMDL is based upon load allocations and control measures to be implemented through the Newport Bay Executive Committee. These actions have been very effective and have resulted in attainment of the load allocations and associated TMDL targets. However, absent wasteload allocations assigned to the MS4 Permittees, the MS4 Permit is not the appropriate regulatory mechanism for this TMDL.

40 CFR 122.44(d)(1)(vii)(B) states (emphasis added):

> When developing water quality based effluent limits under this paragraph the permitting authority shall ensure that: (B) Effluent limits developed to protect a narrative water quality criterion, a numeric water quality criterion, or both, are consistent with the assumptions and requirements ***of any available wasteload allocation*** for the discharge prepared by the State and approved by EPA pursuant to 40 CFR 130.7.

The County supports continued management actions to ensure sediment does not impair Newport Bay and proposes that continued monitoring efforts are instead included as part of Attachment A, Monitoring and Reporting Program.

Action: Revise Appendix A and delete Appendix D of the Draft Order to remove the Sediment TMDL. Revisions are proposed in Attachment B.

74. THE APPENDICES DO NOT INCLUDE LANGUAGE LINKING BACK TO THE COMPLIANCE LANGUAGE IN THE MAIN BODY OF THE PERMIT OR PROVIDE COMPLIANCE LANGUAGE IN THE INDIVIDUAL APPENDIX FOR EACH TMDL. THIS LANGUAGE MUST BE LINKED TO ENSURE THAT THE APPENDICES ARE NOT VIEWED AS STAND-ALONE PROVISIONS WITHOUT A SPECIFIED MECHANISM FOR COMPLIANCE.

16.76

While Section XVIII includes language for determining compliance with the TMDL WLAs, this language is not included in Appendix B through G where the WLAs are presented. As each provision of the permit could be read separately and construed as a standalone provision, exposing the Permittees to state and federal enforcement actions, as well as to third party actions under the federal Clean Water Act's citizen suit provisions.

Therefore, clear compliance language must also be included in each of the TMDL-related appendices to ensure that they are linked to Section XVIII to provide the intended compliance options.

Action: Modify Appendix B through G[58] (the TMDL-related appendices) to be consistent with the language provided in Attachment B, specifically through the inclusion of Section III for each TMDL-related appendix.

[58] References to the TMDL-related appendices include all appendices. As the Permittees have requested deletion of the Sediment TMDL, Attachment B reflects this deletion and the TMDL-related appendices are therefore A through G (with the first TMDL-specific appendix being Appendix B).

75. WLA Tables are Unnecessarily Converted into Text, Introducing Language that is Inconsistent with the Applicable BPAs.

The individual TMDL BPAs include WLAs in table format. These tables typically include key information, such as important footnotes, that are part of the WLAs. However, the Draft Order has converted these tables into text and further segregated the text into separate sections within each appendix. Such an approach introduces language that is contrary to the BPAs and creates an unnecessarily confusing structure.

16.77

For example, the phrase "urban runoff must not transport more than" is used consistently throughout the TMDL-related appendices to incorporate the applicable WLA. It is unclear what this phrase means, and, introduces inconsistencies with the intent of several TMDLs. For example, many TMDLs in the Newport Bay Watershed were designed to be assessed at San Diego Creek at Campus Drive (or other similar receiving water monitoring stations). Such TMDLs are assessed at that monitoring location, not throughout the watershed.

Therefore, to ensure consistency with the Basin Plan Amendments and to ensure the WLAs are clearly interpreted, each TMDL appendix has been revised to remove the text-based approach and to restore the WLAs tables.

Action: Modify Appendix B through G[59] (the TMDL-related appendices) to be consistent with the language provided in Attachment B, specifically through the utilizing the language presented as Section I (WLAs) in each of the TMDL-related appendices.

76. The TMDL Provisions in the Appendices (Appendix A through H) have Inconsistencies with the Relevant BPAs.

- Load allocations (for the Sediment TMDL in the Newport Bay Watershed) have been inappropriately incorporated into the Permit. Federal regulations specify that waste load allocations, not load allocations, are to be incorporated into the Permit (40 CFR 122.44(d)(1)(vii)(B)). See Comment 73.

16.78

- The Toxics TMDL for the Newport Bay Watershed contains factually incorrect information regarding the establishment of the TMDL. It references a Resolution for the Organophosphate Pesticide TMDL which does not apply to the Toxics TMDL, and states it was adopted by the Regional Board when it was promulgated by USEPA. Further, the language fails to mention that certain aspects of the TMDL have been superseded by Basin Plan Amendments adopted by the Regional Board.
- The Regional Board did not adopt a Basin Plan Amendment for organochlorines for Rhine Channel in 2003, as indicated in Appendix E.
- The Los Angeles Regional Board adopted an implementation schedule for the Metals TMDL for Coyote Creek. The implementation schedule and actions are not included in Appendix H.

[59] References to the TMDL-related appendices include all appendices. As the Permittees have requested deletion of the Sediment TMDL, Attachment B reflects this deletion and the TMDL-related appendices are therefore A through G (with the first TMDL-specific appendix being Appendix B).

- The compliance dates for the Organochlorines TMDL in Appendix E are incorrect (provisions state December 31, 2015 while the Basin Plan Amendment states December 31, 2020).

16.78

- The use of text to incorporate the WLAs for the Nutrient TMDL for the Newport Bay Watershed is unclear and lacks the implementation dates for each WLA. The use of text to describe the WLAs, rather than using a table format, introduces inconsistencies with the BPA.

Action: Modify the TMDL-related appendices[60] to be consistent with the modifications provided in Attachment B, to ensure the requirements are consistent with the applicable Basin Plan Amendments.

[60] References to the TMDL-related appendices include all appendices. As the Permittees have requested deletion of the Sediment TMDL, Attachment B reflects this deletion and the TMDL-related appendices are therefore A through G (with the first TMDL-specific appendix being Appendix B).

MONITORING AND REPORTING PROGRAM (MRP)

77. THE PERMITTEES SHOULD HAVE FLEXIBILITY IN HOW THEY DEVELOP THE WATER QUALITY MONITORING PLAN.

Section II.B.2, the Monitoring and Reporting Program (MRP), requires the Water Quality Monitoring Plan (Plan) to describe a process for determining compliance with each of the waste load allocations ("WLAs") and requirements in Appendices B through H of the Draft Order. In addition, the Plan must also include cycles of monitoring, analysis, and reporting for all of the WLAs.

The purpose of Section II.B.2 is to integrate TMDL monitoring with the other types of monitoring covered under the MRP (e.g., outfall monitoring, receiving water monitoring, toxicity testing). While this can be an effective way to gain efficiencies in monitoring, it can also be difficult to integrate the various monitoring, analysis, and reporting requirements from all of the TMDLs. In addition, the schedules for TMDL-related monitoring, analysis, and reporting are often variable due environmental conditions, logistical issues, and regulatory changes, among other unmitigatable factors.

Action: Modify Section II.B.2.a to be consistent with the modifications provided in Attachment B to provide flexibility in how the Monitoring Plan is developed.

16.79

Section II.B.6 requires the Permittees to submit proposed changes to the Plan or a written correspondence stating there are no proposed changes to the Executive Officer of the SARWQCB by August 1 of each year following the approval of the Plan. However, there may be certain monitoring activities covered under the Plan that are dynamic and/or iterative that will be difficult to document by the August 1 deadline. Two such monitoring activities include: (1) selecting dry weather monitoring sites; and (2) special studies.

- Typically, dry weather monitoring data is analyzed in the fall (October/November), once the May-September sampling period has ended and all laboratory results have been provided. Control charts are prepared to identify which sites experienced chronic and/or acute tolerance interval exceedances. Sites to be sampled the following dry season are then finalized in the spring (March/April), with reconnaissance performed as necessary. As such, it would be difficult to document the proposed monitoring sites for the following May-September dry weather season by the August 1 deadline, while the program is underway.
- In addition, the development and implementation of special studies is often an iterative process with frequent changes to the schedule(s). As such, it would be difficult to document the proposed special studies changes by the August 1 deadline each year.

Therefore, it would be beneficial to include language that would provide flexibility when submitting the proposed changes to these programs.

Action: Modify Section II.B.6 of the MRP to be consistent with the modifications provided in Attachment B to provide the necessary flexibility to the Permittees:

Certain changes to specific monitoring activities covered under the Plan that are inherently dynamic and/or iterative, which may occur after the August 1 deadline, may be submitted, in

16.79 *written form, after the August 1 deadline to the Executive Officer, as an addendum to any proposed changes to the Plan that were submitted by the August 1 deadline.*

78. THERE ARE SEVERAL INCONSISTENCIES WITHIN THE OUTFALL MONITORING REQUIREMENTS THAT SHOULD BE CLARIFIED.

Section II.D.1-7 requires monitoring of urban runoff from MS4 outfalls under storm and dry-weather conditions. Section II.D.2 states: "Each outfall monitoring location must be sampled every two years on an alternating basis; some sites may be sampled every odd year while the remainder will be sampled every even year. The nature, number and distribution of samples are described below in this Section." Section II.D.4 and II.D.5 contain the specific requirements for storm event and dry weather sampling, respectively. However, the language in Section II.D.4 and Section II.D.5 does not include the alternating year language that is included Section II.D.2 in that the sections do not specify which group of monitoring sites (even year or odd year) is required to be monitored. As such, clarifying language should be added to Section II.D.4 and Section II.D.5 so that they are consistent with Section II.D.2.

Action: Add clarifying language to MRP Section II.D.4.a.i, MRP Section II.D.4.b, and MRP Section II.D.5, to be consistent with the modifications provided in Attachment B. The language should state: "A sample must be collected at each outfall monitoring location during the applicable even or odd monitoring year."

16.80 In addition, there is a disconnect between the composite sampling requirements from the first storm event of the year and the subsequent storm events during the year. For the first storm event, Section II.D.4.a.ii states: "A second sample for this event must be collected after the storm's first hour; this sample must consist of a composite of discrete samples collected every two (2) hours during a 96-hour period or until flow is insufficient to allow sampling." For the storm events occurring after the first storm event, Section II.D.4.b.i states: "Each sample must consist of discrete samples collected hourly during a 24-hour period or until flow is insufficient to allow sampling."

Action: Modify Section II.D.4.b.i to require sampling every two (2) hours instead of hourly so that it is consistent with Section II.D.4.a.ii.

Section II.D.6, Section II.D.7, and Table 1 of the MRP identify the Outfall Monitoring constituents that must be monitored and the manner in which they are supposed to be collected. Language should be included in Section II.D.7 that allows the Permittees to remove any analyte that is not detected upon completion of annual monitoring. Removal of an analyte should be on a site-by-site basis and on a storm sampling/dry weather sampling basis.

Action: Modify Section II.D.6 and Section II.D.7 of the MRP to be consistent with the modifications provided in Attachment B to allow the Permittees to remove analytes if there are a series of non-detected values.

79. THE RECEIVING WATERS MONITORING PROVISION INCORRECTLY REFERENCED THE OUTFALL MONITORING PARAMETERS TABLE.

16.81

Section II.E.3 and Section II.E.4 of the MRP both reference Table 1. However, Table 1 is for Outfall Monitoring while Table 2 is for Receiving Water Monitoring. As such, the references in Section II.E.3 and Section II.E.4 of the MRP should be revised from Table 1 to Table 2.

Action: Modify the table references in MRP Section II.E.3 and Section II.E.4 to be consistent with the modifications provided in Attachment B from Table 1 to Table 2.

80. THE TOXICITY TESTING REQUIREMENTS SHOULD BE ALIGNED WITH THE CURRENT MONITORING PROGRAM.

The proposed toxicity testing requirements in Section II.F include an overarching statement that states: "The water quality monitoring program must include toxicity testing, analyzed using USEPA's Test of Significant Toxicity Approach." The Test of Significant Toxicity[61] (TST) approach differs from what is required for toxicity testing in the current permit. Review and analysis of the TST approach has yielded some issues with the reliability of the approach.

16.82

TST tests have been shown to have 5-40% false failures (failing the TST when there is no actual toxicity), placing their regulatory usefulness in question and raising constitutional due process issues in the context of strict liability for permit violations. The EPA has determined that "the accuracy of toxicity tests cannot be determined."[62] Even if there is only a 5% false failure level (as is set for the TST), this guarantees at least one numeric effluent limit "violation" in the five year permit term, even though there is no actual toxicity for those incidents. But this would still be a violation, while not subject to Mandatory Minimum Penalties (MMPs, Water Code section 13385(i)(1)(D)) if there are other toxic pollutant limits in the permit that is subject to citizen suit enforcement. No reason exists to put Permittees in such compliance jeopardy unnecessarily.

Reanalysis of actual Whole Effluent Toxicity (WET) test data, from a wide variety of real-world samples, demonstrates that the TST technique consistently "detects" the existence of toxicity more frequently than the No Observable Effect Concentration (NOEC) method, especially for tests with relatively small effect levels.[63]

It should not be assumed that greater statistical sensitivity equates with improved accuracy in WET testing. Reanalysis of data from EPA's inter-laboratory WET variability study indicates that the TST technique also "detects" toxicity in blank samples at a rate up to three

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[61] USEPA. 2010. *National Pollutant Discharge Elimination System Test of Significant Toxicity Implementation Document*. EPA 833-R-10-003. US Environmental Protection Agency, Office of Wastewater Management, Washington D.C.

[62] See *Short Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms*; EPA/600/4-91/002 at 139, 193, and 225 (July 1994).

[63] See State Water Resources Control Board. *Effluent, Stormwater and Ambient Toxicity Test Drive Analysis of the Test of Significant Toxicity (TST)* (Dec., 2011).

times higher than the NOEC.[64] Blank samples are comprised solely of laboratory dilution water that is known to be non-toxic before the test begins. Such inaccuracies demonstrate that the TST does not provide performance equivalent to that of the standard methods that were promulgated in 2002.

In addition, the TST document is only considered to be a guidance document as it has not been approved under 40 CFR Part 136. Although EPA often tries to regulate by guidance, courts have frowned upon this practice as aptly described in *Appalachian Power Co. v. EPA*[65]., The district court in the *Appalachian Power* case found fault in EPA's regulating by setting aside the guidance in its entirety.[66] "If an agency acts as if a document issued at headquarters is controlling in the field, if it treats the document in the same manner as it treats a legislative rule, if it bases enforcement actions on the policies or interpretations formulated in the document, if it leads private parties or State permitting authorities to believe that it will declare permits invalid unless they comply with the terms of the document, then the agency's document is for all practical purposes 'binding.'"[67]

16.82

More recent cases have reached the same conclusion in other instances when EPA tried to regulate through interpretive rules, such as the 2010 TST guidance. One case related to invalidating EPA guidance setting forth air quality attainment alternatives.[68] (Another related to "requirements" contained in letters related to water quality permitting prohibitions related to blending and mixing zones. In this case, the court found that EPA not only lacked the statutory authority to impose the guidance regulations on blending, but also violated the Administrative Procedures Act by implementing the guidance on both issues without first proceeding through the notice and comment procedures for agency rulemaking.[69] The case law is clear that EPA must regulate through rules and not through informal guidance.[70] Similar rules apply to the Water Boards, which also cannot regulate by guidance, particularly where that guidance is contrary to established regulations (*e.g.*, the CCW Toxicity TMDL) and statewide precedential orders as described in the next section.

Furthermore, the Fact Sheet for the Draft Order does not provide the background information necessary to determine why the use of the TST approach is necessary. Inclusion of the TST approach is inconsistent with existing policies and regulations. As such, toxicity testing requirements should remain the same as the previous permit since no change in law or regulations have occurred to authorize these modifications.

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[64] U.S. EPA. Final Report: Interlaboratory Variability Study of EPA Short-term Chronic and Acute Whole Effluent Toxicity Test Methods, Vol. 1; EPA-821-B-01-004 (Sept., 2001).

[65] 208 F.3d. 1015, 1020 (D.C. Cir. 2000).

[66] *Id.* at p. 1028.

[67] *Id.* at p. 1021 [*citations omitted*].

[68] *NRDC v. U.S. EPA*, 643 F.3d 311 (D.C.Cir. 2011).

[69] *Iowa League of Cities v. U.S. EPA*, 711 F.3d 844, 878 (8th Cir. 2013).

[70] *See also United States v. Mead Corp.*, 533 U.S. 218 (2001) (defining a two-part test for when agency guidance documents have the force and effect of law).

16.82 *Action: Delete the requirement to utilize the USEPA's TST approach from the MRP and allow toxicity testing be conducted utilizing current methods.*

16.83 Section II.F.1, 2, 4, and 5 requires the Permittees to perform WET testing. WET testing measures the observable toxic response of effluent to specific, chosen organisms, which intends to approximate the effluent's potential to affect organisms in receiving water. WET testing was developed to test effluent from publicly owned treatment works (POTWs) and effluent from other facilities regulated by waste discharge requirements (WDRs). As such, utilizing WET testing directly on receiving waters is not necessarily applicable. In addition, utilizing WET testing would differ from the current toxicity testing program implemented by the Permittees.

Action: Delete the Whole Effluent Toxicity (WET) testing requirements from Section II.F.1, 2, 4, and 5 and to be consistent with the modifications provided in Attachment B and replace it with the term toxicity matching the existing monitoring program.

16.84 Section II.F.2 requires toxicity testing to be performed twice per season on wet-weather samples, but it does not specify whether the samples should be collected from outfall locations or receiving water locations. Section II.F.1 requires wet-weather toxicity testing from outfall locations, so it is likely that Section II.F.2 relates to receiving water monitoring.

Action: Add language to Section II.F.2 to be consistent with the modifications provided in Attachment B indicating toxicity testing is to be performed on samples collected from receiving water locations.

16.85 Section II.F.2 and 5 require toxicity testing of sea urchin fertilization, sea urchin embryo development, and mysid survival and growth. However, historic toxicity testing data show that sea urchin fertilization toxicity testing is more sensitive to samples collected in Orange County than the sea urchin embryo development test. Due to this, it is not believed the sea urchin embryo test is necessary or beneficial and the County has discontinued its use in the current toxicity monitoring program.

Action: Delete the sea urchin embryo development toxicity testing requirement from Section II.F.2 and 5 to be consistent with the modifications provided in Attachment B.

16.86 Section II.F.7 requires toxicity testing to be performed on sediment samples collected pursuant to Section II.E.2 using 10-day amphipod survival test in solid-phase sediment and a 48-hour bivalve embryo development test at the sediment-water interface. Section II.E.2 requires quarterly dry weather sediment sampling at certain even and odd year sampling locations. Quarterly sampling is four times more frequent that what is currently conducted by and will require significant more monitoring effort than what is currently required. These tests should be conducted annually for certain even and odd year sampling locations for the Receiving Waters Monitoring Program.

Action: Delete the language referencing Section II.E.2 from Section II.F.7 and add language requiring sediment toxicity testing once annually at applicable even and odd year Receiving Water Monitoring Program sites.

16.87 Section II.F.1, 2, 4, 5, and 8 present toxicity monitoring frequencies for dry and wet aquatic and sediment testing. These frequencies should be related to the frequencies for outfall monitoring and receiving water monitoring as per Section II.D and Section II.E, respectively.

16.87 *Action: Include language in Section II.F.1, 2, 4, 5, and 8 to be consistent with the modifications provided in Attachment B indicating monitoring is to occur at the frequencies specified only during the applicable even or odd monitoring year to be consistent with Section II.D and Section II.E.*

81. BENTHIC INVERTEBRATE TAXONOMY REQUIRES CLARIFICATION.

16.88 Section II.G of the MRP requires the Permittees to identify the taxonomy of the benthic invertebrate communities on an annual basis from monitoring locations that are sampled that year. The permit language needs to be clarified that this is a monitoring program for the harbors and estuaries sites and should be sampled on an annual basis concurrent with the monitoring sites selected each even or odd year under the Receiving Waters Monitoring Program.

Action: Clarify the location of these samples and that the sites will be monitoring annually at even and odd year sample locations consistent with the Receiving Waters Monitoring Program provisions in Attachment B.

82. THE ILLICIT DISCHARGES AND ILLICIT CONNECTIONS PROVISIONS, INCLUDING THE MONITORING REQUIREMENTS, MONITORING SCHEDULE, AND MONITORING LOCATIONS, REQUIRE REVISIONS.

Section II.H of the MRP provides general requirements for monitoring illicit discharges and illicit connections. However, the Draft Order, in Section VII.D.5-9, prescribes more detailed monitoring requirements. The monitoring requirements in Section II.H of the MRP should incorporate the information from Section VII.D.5-9 (with a corresponding reference).

16.89 *Action: Modify Section VII.D.5-9 and MRP Section II.H to be consistent with the modifications provided in Attachment B by removing the monitoring language from Section VII.D.6-9 and incorporating it into MRP Section II.H. In addition, Section VII.D.5 should include a reference to MRP Section II.H*

Section II.H.1 requires monitoring to occur during the dry season. However, the dry season is not clearly defined. Language should be included in Section II.H.1 to define the dry season.

Action: Include the definition of the dry season in Section II.H.1 (May 1 through September 30), consistent with the modifications provided in Attachment B.

16.90 Section II.H.2 requires illicit discharge and illicit connection monitoring to occur at locations and frequencies specified in the Water Quality Monitoring Plan. However, illicit discharge and illicit connection monitoring sites are selected each spring for sampling to be conducted the following year. As such, language should be included in the Draft Order to allow for changes to illicit discharge and illicit connection monitoring.

Action: Include language in Section II.H.2 consistent with the modifications provided in Attachment B stating that any changes to monitoring locations and frequencies shall be provided annually in the revised Water Quality Monitoring Plan due August 1 (pursuant to Part II.B.6).

83. THE BIOASSESSMENT MONITORING NEEDS TO SUPPORT THE STORMWATER MONITORING COALITION (SMC) REGIONAL MONITORING PROGRAM AND NOT PREMATURELY REQUIRE CAUSAL ASSESSMENTS.

Although Section II.J requires the Permittees to conduct bioassessment monitoring in support of the SMC monitoring plan, the Draft Order does not allow the Permittees the flexibility to revise their approach if the SMC monitoring plan is modified.

Action: Modify the Draft Order so that flexibility is provided to the Permittees so that they can be consistent with the SMC monitoring plan.

In addition, Section II.J requires the Permittees to conduct a minimum of one Causal Assessment (CA) per year to identify the likely causes of the biological condition at the monitoring locations. This requirement is premature for several reasons:

- The State Water Resources Control Board is in the process of developing a Biological Integrity Policy that will be incorporated into the Inland Surface Waters Plan. Although CAs are a part of the overall Policy, the specific process for conducting and interpreting the CA is still be evaluated.
- This Policy will include guidance to the Regional Boards on a number of issues including when a CA should be conducted, how a CA should be conducted, how to interpret the results, and what the follow up actions should be. Until these decisions have been made, it would be difficult to implement this on a consistent basis.
- There is still significant debate about if and how the Policy should apply to "modified" channels. In addition, if the Policy does apply to "modified" channels, there may be a CA "lite" that is conducted to determine if a significant driver for the biological integrity of a site is habitat modification. If this is the case, then a full CA may not be necessary. Given that much of north Orange County is fully developed and the waterways significantly modified, the outcome of these discussions will be critically important.

Action: Delete Section II.J.3 and 4 to be consistent with the modifications provided in Attachment B.

84. MODIFICATIONS TO THE SPECIAL STUDIES SHOULD BE CONVEYED AS A PART OF THE REVISED WATER QUALITY MONITORING PLANS THAT ARE SUBMITTED ON AUGUST 1 EACH YEAR.

Section II.L.2 of the MRP requires the Permittees to provide a written work plan each year in the Annual Progress Report to describe the progress of ongoing special studies and special studies proposed to be initiated during the next reporting period. The work plan must include a schedule of proposed milestones, a description of work products, and the achievement of milestones. However, this requirement seems to be redundant with the August 1 submittal of the revised Water Quality Monitoring Plan that is required in Section II.B.6. As such, the work plan requirement should be replaced with a requirement to provide any updates to the special studies as a part of the revised Water Quality Monitoring Plan.

Action: Modify Section II.L.2 to be consistent with the modifications provided in Attachment B to require the Permittees to provide special study updates as a part of the revised Water Quality Monitoring Plan that is submitted on August 1 (pursuant to Section II.B.6).

Attachment B

Redline Version of the Draft Order

STATE OF CALIFORNIA
CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD SANTA ANA REGION

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ORDER NO. R8-2014-0002
NPDES PERMIT NO. CAS 618030

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM ("NPDES") PERMIT AND WASTE DISCHARGE REQUIREMENTS

Orange County Flood Control District, the County of Orange
And
The Incorporated Cities therein within the Santa Ana Region

Area-wide Urban Runoff, Santa Ana Region

The following Co-permittees, listed in Table 1, are subject to waste discharge requirements as set forth in this Order (or Permit):

Table 1: List of Entities Subject to the Requirements of this Order

County of Orange	City of La Habra
Orange County Flood Control District	City of La Palma
City of Anaheim	City of Lake Forest
City of Brea	City of Los Alamitos
City of Buena Park	City of Newport Beach
City of Costa Mesa	City of Orange
City of Cypress	City of Placentia
City of Fountain Valley	City of Santa Ana
City of Fullerton	City of Seal Beach
City of Garden Grove	City of Stanton
City of Huntington Beach	City of Tustin
City of Irvine	City of Villa Park
City of Laguna Hills	City of Westminster
City of Laguna Woods	City of Yorba Linda

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ADMINISTRATIVE INFORMATION

This Order was adopted by the Santa Ana Regional Water Quality Control Board ("Regional Board") on:	Month day, 2014
This Order shall become effective on:	Month day, 2014
This Order shall expire on:	Month day, 2019
The U.S. Environmental Protection Agency ("USEPA") and the Regional Board have classified the ~~is~~ discharges from the Co-Permittees' municipal separate storm sewer systems (MS4s) as a "large municipal separate storm sewer system" ("MS4") pursuant to 40 CFR 122.26(b)(4).	

IT IS HEREBY ORDERED that the Co-permittees[1] subject to this Permit, in order to meet the provisions contained in division 7 of the California Water Code (commencing with section 13000) and the provisions of the federal Clean Water Act ("CWA") and regulations and guidelines adopted thereunder, shall comply with the requirements of this Permit.

I, Kurt V. Berchtold, Executive Officer, do hereby certify that this Order with all attachments is a full, true, and correct copy of an Order adopted by the California Regional Water Quality Control Board, Santa Ana Region, on MONTH DAY, 2014.

Kurt V. Berchtold
Executive Officer

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[1] This Order refers to all of the Co-permittees collectively as "Co-Permittees", including the Principal Permittee.

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Appendix A: Applicability of TMDL requirements to Co-permittees

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FINDINGS

The California Regional Water Quality Control Board, Santa Ana Region (hereinafter Regional Board) finds that:

A. JURISDICTION

1. **MS4 Ownership or Operation**. Each of the Co-permittees owns or operates a municipal separate storm sewer system ("MS4), through which it discharges storm water and non-storm water (collectively "urban runoff") into waters of the U.S. within the Santa Ana Region. These MS4s fall into one or more of the following categories: (1) a medium or large MS4 that services a population of greater than 100,000 or 250,000 respectively; or (2) a small MS4 that is "interrelated" to a medium or large MS4; or (3) an MS4 which contributes to a violation of a water quality standard; or (4) an MS4 which is a significant contributor of pollutants to waters of the U.S.

2. **Regulated Sources and Activities**. This Order regulates the discharge of pollutants ~~from anthropogenic sources~~ in urban runoff from anthropogenic sources and/~~MS4s~~ or activities within the jurisdiction and control of the Co-permittees. ~~Except as noted in Finding 8 below, this~~~~t~~This Order authorizes discharges of urban runoff from MS4s subject to the conditions and provisions herein. This Order is not intended to obligate the Co-permittees to address background or naturally-occurring pollutants or flows ~~in receiving waters~~.

3. **Legal and Regulatory Authority**. This Order is issued pursuant to section 402 of the federal Clean Water Act ("CWA") and implementing regulations (Code of Federal Regulations [CFR] Title 40, Part 122 [40 CFR 122]) adopted by the United States Environmental Protection Agency ("USEPA"), and chapter 5.5, division 7 of the California Water Code ("CWC") (commencing with section13370). This Order serves as a National Pollutant Discharge Elimination System ("NPDES") permit for discharges of urban runoff from MS4s to waters of the U.S. This Order also serves as waste discharge requirements (WDRs) pursuant to article 4, chapter 4, division 7 of the CWC (commencing with section 13260).

   The Regional Board has the legal authority to issue a system- wide MS4 permit pursuant to its authority under CWA section 402(p)(3)(B) and 40 CFR122.26(a)(1)(v). The USEPA has established that the permitting authority, in this case the Regional Board, has the flexibility to establish system- or region-wide permits affecting multiple Co-permittees (40 CFR122.26(a)(3)(ii)). The system-wide nature of this Order will ensure consistency of regulation within watersheds and is expected to result in overall cost savings for the Co-permittees and Regional Board. The federal regulations make it clear that the Co-permittees need only comply with permit conditions relating to discharges from the MS4s for which they are operators (40 CFR

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122.26(a)(3)(vi)). This Order does not require the Co-permittees to manage storm water outside of their jurisdictional boundaries, but rather to work collectively to improve storm water management ~~within watersheds.~~originated from its jurisdiction.

4. **CWA NPDES Permit Conditions**. Pursuant to CWA section 402(p)(3)(B), NPDES permits for ~~storm water~~ discharges from MS4s must include requirements to effectively prohibit non-storm water discharges into MS4s; ~~-~~and require controls to reduce the discharge of pollutants to the maximum extent practicable ("MEP") including management practices, control techniques and system, design and engineering methods, and other such ~~;~~
~~and to require other~~ provisions as the Regional Board determines ~~are~~ appropriate for the ~~to~~ control of such pollutants. This Order prescribes conditions to comply with the CWA requirements for owners and operators of MS4s ~~to effectively prohibit non- storm water discharges into the MS4s. This Order requires controls to reduce the discharge of pollutants in urban runoff from the MS4s to the MEP. This Order~~
~~also includes other provisions that the Regional Board has determined are appropriate to control pollutants~~.

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5. **CWA and CWC Monitoring Requirements**. CWA section 308(a) and 40 CFR122.41(h),(j)-(l) and 122.48 require that NPDES permits specify monitoring and reporting requirements. Federal regulations applicable to large and medium MS4s also specify additional monitoring and reporting requirements in 40 CFR122.26(d)(1)(iv)(D), 122.26(d)(1)(v)(B), 122.26(d)(2)(i)(F), 122.26(d)(2)(iii)(D),122.26(d)(2)(iv)(B)(2) and 122.42(c). CWC section 13383 authorizes the Regional Board to establish monitoring, inspection, data entry, reporting and recordkeeping requirements. This Order establishes monitoring and reporting requirements to implement federal and State requirements.

6. **Total Maximum Daily Loads**. CWA section 303(d)(1)(A) requires that each state "shall identify those waters within its boundaries for which the effluent limitations…are not stringent enough to implement any water quality standard applicable to such waters." The CWA also requires states to establish a priority ranking of impaired water bodies known as Water Quality Limited Segments and to establish Total Maximum Daily Loads ("TMDLs") for such waters. This priority list of impaired water bodies is called the Clean Water Act Section 303(d) List of Water Quality Limited Segments, commonly referred to as the "303(d) List". The CWA requires the 303(d) List to be updated every two years.

   TMDLs are numerical calculations of the maximum amount of a pollutant that a water body can assimilate and still meet water quality standards. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point sources (waste load allocations or "WLAs") and non-point sources (load allocations or "LAs"), background contribution, plus a margin of safety. Discharges from MS4s are point source discharges.

   The federal regulations (40 CFR 22.44(d)(1)(vii)(B)) require that NPDES permits incorporate water quality based effluent limitations ("WQBELs") developed to protect a narrative water quality criterion, a numeric water quality criterion, or both, consistent with the assumptions and requirements of any available WLA for

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the discharge. This Order implements ~~TMDLs~~ WLAs that have been adopted by the Regional Board and approved by USEPA as of the time this Order is issued. This

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Order also implements TMDLs that have been promulgated by the USEPA. This Order establishes WQBELs consistent with the assumptions and requirements of TMDL implementation requirements and WLAs assigned to discharges from the Permittees' MS4s.

7. **Permit Modification.** In accordance with 40 CFR122.41(f), this Order may be modified, revoked or reissued prior to its expiration date for cause. This includes ~~for~~ the following reasons:
    a. To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this Order;
    b. To incorporate applicable requirements of state-wide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board, and, if necessary, by the Office of Administrative Law;
    c. To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this Order;
    d. Or to incorporate any requirements imposed upon the Co-permittees through the TMDL process.

8. **Non-Storm Water and Storm Water Discharges**. The discharge of pollutants from the MS4 is subject to the MEP standard and other provisions necessary to reduce pollutants whether the pollutants are transported by storm water or non-storm water.

This Order requires each Co-~~P~~permittee to effectively prohibit discharges of non-storm water into its MS4 ~~unless such discharges are authorized by an NPDES permit.~~ . The MS4s generally contain non-storm water flows such as irrigation runoff, runoff from non-commercial car washes, runoff from miscellaneous washing and cleaning operations, and other nuisance flows generally referred to as de-minimus discharges. Federal regulations, 40 CFR Part 122.26(d)(2)(i)(B), prohibit the discharge of non-storm water containing pollutants into the MS4s and to waters of the U.S. unless they are regulated under a separate NPDES permit, or are exempt, as indicated in Discharge Prohibitions, Section III of this Order.

Certain non-storm water discharges may be permitted under various NPDES permits adopted by the Regional Board and the State Water Resources Control Board. These permits include NPDES Permit No. CAG998001 (commonly known as the "*De Minimus*" Permit); NPDES Permit No. CAG990002, Discharges from Utility Vaults and Underground Structures to Surface Waters; and NPDES Permit No. CAG918002, for
discharges to surface waters of certain groundwater at sites within the San Diego Creek/Newport Bay watersheds. Non- storm water discharges permitted under these and other NPDES permits do not need to be prohibited by the Co-~~P~~permittees.

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This Order authorizes the discharge of urban runoff from the Co-permittees' MS4s. This ~~authorization~~ includes authorization for certain non-storm water discharges. The Regional Board adopted a number of NPDES permits to address de-minimus type of pollutant discharges. However, the permittees need not get coverage under the de-minimus permits for the types of discharges listed under Section III (Table 2), except for discharges to the Newport Bay watershed (where coverage under the Newport Bay watershed-specific de-minimus permit is required), as long as they are in compliance with the conditions specified under Section III of this order. ~~Authorized non-storm water discharges are subject to both the requirements herein and the requirements of the *"De Minimus"* Permit.~~ This Order does not authorize the Co-permittees' non-storm water discharges that are subject to NPDES Permit No. CAG918002. Authorization for such discharges must be obtained through the process described in NPDES Permit No. CAG918002.

Monitoring conducted by the Permittees, as well as the 303(d) List, have identified dry weather, non-storm water discharges from the MS4s as a source of pollutants causing or contributing to receiving water quality impairments in the Santa Ana Region. The federal regulations (40 CFR 122.26(d)(2)(iv)(B)(1)) require Co- permittees to have a program to prevent illicit discharges to the MS4. The federal regulations, however, allow specific categories of unpermitted non-storm water discharges or flows to be regarded as illicit discharges only where such discharges are identified as sources of pollutants to waters of the U.S. Such un- permitted non-storm water discharges are listed in this Order in Section III. However, this list of discharges is subject to modification during the term of this Order.

9. **Limits of Co-permittees' Jurisdiction over Urban Runoff.** The Co-permittees may lack or have limited legal jurisdiction~~, or that jurisdiction may be limited,~~ over urban runoff into their MS4s from some state and federal facilities, Native American tribal lands, utilities, special districts, and other entities. The Regional Board recognizes that the Co-permittees can only be held responsible for discharges of pollutants from such entities to the extent that the Co-permittees have the authority to eliminate or control the pollutants. Recognizing these limitations, the Co-permittees are expected to control pollutants in discharges into their MS4s from such entities to the MEP. Similarly, certain activities that generate pollutants present in urban runoff may be beyond the ability of the Co-permittees to eliminate. Examples of these include operation of internal combustion engines, atmospheric deposition, brake pad wear, tire wear, and leaching of naturally occurring minerals from local geography.

10. **In-Stream Treatment Control Systems**. Pursuant to federal regulations (40CFR 131.10(a)), in no case shall a state adopt waste transport or waste assimilation as a designated use for any waters of the U.S. Authorizing the construction of a structural treatment control BMP within a water of the U.S., or using the water body itself as a structural treatment control BMP or for conveyance to such a facility, would be tantamount to accepting waste assimilation as an appropriate use for that water body. Waters of the U.S. must not be converted into structural treatment control best management practices ("BMPs", a.k.a. storm water control measures or "SMCs"), however this

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exclusion does not prevent the implementation of stream restoration or stream rehabilitation projects and constructed wetlands, or maintenance of reconstruction of existing stream restoration or rehabilitation projects, constructed wetlands, and regional BMPs. Construction, operation, and maintenance of a structural treatment control facility in a water body can negatively impact the physical, chemical, and biological integrity, as well as the beneficial uses, of the water body.

B. DISCHARGE CHARACTERISTICS AND RUNOFF MANAGEMENT

11. **Potential Beneficial Use Impairment**. The discharge of pollutants from MS4s may cause or threaten to cause the concentration of pollutants in receiving waters to exceed applicable water quality ~~objectives~~standards. Discharges from MS4s may result in alterations to the hydrology of receiving waters that negatively impact their physical integrity. These conditions may impair or threaten to impair designated beneficial uses resulting in a condition of pollution, contamination, or nuisance.

12. **Pollutants Generated by Land Development**. Land development has created, and ~~continues~~ threatens to create, new sources of non-storm water discharges and pollutants in storm water discharges as human population density increases. This brings higher levels of car emissions, car maintenance wastes, municipal sewage, pesticides, household hazardous wastes, pet wastes, and trash. Development typically converts natural ground cover to impervious surfaces such as paved highways, streets, rooftops, and parking lots. Pollutants deposited on these surfaces are dumped or washed off the by non-storm water or storm water flows into and from the MS4s. As a result of the increased imperviousness in urban areas, less rain water can infiltrate through and flow over vegetated soil where physical, chemical, and biological processes can remove pollutants. Therefore, runoff leaving a developed area can contain greater pollutant loads and have significantly greater runoff volume, velocity, and peak flow rate than pre- development runoff conditions from the same area. Certain best management practices can minimize these impacts to water quality.

13. ~~**Runoff Discharges to Receiving Waters**. The MS4s discharge runoff into lakes, reservoirs, rivers, streams, creeks, bays, estuaries, coastal lagoons, the Pacific Ocean, and tributaries thereto within the Santa Ana Region. Development generally makes use of natural drainage patterns and features to convey runoff. Rivers, streams and creeks in developed areas used in this manner and under the ownership and control of the Permittees are part of MS4s regardless of whether they are natural, anthropogenic, or partially modified features. In these cases, the rivers, streams and creeks in the developed areas of the Permittees' jurisdictions are both an MS4 and receiving water.~~

14. **Pollutants in Urban Runoff**. The most common pollutants in urban runoff include total suspended solids, sediment, pathogens (e.g., bacteria, viruses, protozoa), heavy metals (e.g., cadmium, copper, lead, and zinc), petroleum products and polynuclear aromatic hydrocarbons, synthetic organics (e.g., pesticides,

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herbicides, and PCBs), nutrients (e.g., nitrogen and phosphorus), oxygen-demanding substances (e.g., decaying vegetation, animal waste), detergents, and trash. Pollutants in urban runoff are typically generated by persons or activities over which the Co-permittees have the authority to enact measures to control those pollutants. The Regional Board recognizes that the Co-permittees' authority is not equal for all persons or activities in their jurisdictions. The limits of the Co-permittees' authority over some persons, such as school districts, are not clear. Nonetheless, the Co-permittees are required to exercise their authority consistent with the requirements of the Clean Water Act and this Order.

15. **Human Health and Aquatic Life Impairment**. Pollutants in runoff discharged from the MS4s risk adversely affecting human health and aquatic organisms. Adverse human health effects include gastrointestinal diseases and infections. Adverse physiological responses to pollutants in runoff include impaired reproduction, growth anomalies and mortality in aquatic organisms. These responses may be the result of different mechanisms, including bioaccumulation of toxicants. During bioaccumulation, toxicants carry up the food chain and may affect both aquatic and non-aquatic organisms, including human health. Increased volume, velocity, rate, and duration of storm water runoff greatly accelerate the erosion of downstream natural channels. This alters stream channels and habitats and can adversely affect aquatic and terrestrial organisms.

16. **Best Management Practices**. Wastes which are deposited and accumulate in MS4 drainage structures will be discharged from these structures to waters of the U.S. unless they are removed. These discharges may cause or contribute to, or threaten to cause or contribute to, a condition of pollution in receiving waters. For this reason, pollutants in storm water discharges from the MS4s can be and must be effectively reduced in runoff by the application of a combination of pollution prevention, source control, and treatment control BMPs. Pollution prevention BMPs are practices that prevent or reduce the generation of potential pollutants, typically at their source. Pollution prevention is the "first line of defense". Source control BMPs (both structural and non-structural) eliminate or minimize the contact between potential pollutants and urban runoff, therefore preventing the transport of pollutants to receiving waters. Treatment control BMPs remove pollutants that have entered into urban runoff.

    Certain structural treatment control BMPs, such as constructed wetlands, are or will be waters of the state, and may support beneficial uses. The operation and maintenance of these BMPs may impact the beneficial uses of those waters. Section III of this Order contains ~~Provisions~~ provisions to minimize impacts to those beneficial uses as the result of operating and maintaining structural treatment control BMPs. However, it is not the intent of the Regional Board to regulate discharges *within* structural treatment control BMPs in a way that is counterproductive to their purpose of satisfying the MEP standard or to interfere with efforts to comply with the requirements of this Order.

17. **BMP Implementation**. To reduce the discharge of storm water pollutants, to effectively prohibit non-storm water discharges, and to protect receiving waters, the water quality impacts of development need to be addressed during the three

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major phases of planning, construction, and use. Development which is not guided by water quality planning policies and principles can result in increased pollutant load discharges, flow rates, and flow durations which can negatively affect receiving water beneficial uses. The County of Orange, Construction sites without adequate BMP implementation may result in sediment or runoff rates which greatly exceed natural erosion rates of undisturbed lands, causing siltation and potentially impairing the beneficial uses of receiving waters. In addition, existing development can generate substantial pollutant loads which are discharged in runoff to receiving waters. Retrofitting areas of existing development with storm water pollutant control and hydro-modification management BMPs is necessary to address discharges of urban runoff that may cause or contribute to a condition of pollution or a violation of water quality standards.

18. **Orange County Model WQMP and Technical Guidance Document (TGD).** The Orange County Model WQMP (Model WQMP) and TGD were developed during the last permit term through a collaborative process inclusive of Regional Board staff, Copermittees, environmental nongovernmental organizations (NGOs), the land development community, technical consultants, and other interested people. The result of this process is the Model WQMP and TGD that is a comprehensive an innovative stormwater quality approach to new and redevelopment that integrates the principles of Low Impact Development (LID). Through the development and implementation of the Model WQMP and TGD with comprehensive technical guidance, a robust training program, and development plan check procedures, the land development program in Orange County has made significant progress toward improving the quality of runoff from new and redevelopment projects and is recognized as one of the most robust and successful programs in the State of California. The intent of the new development and significant redevelopment provisions in Section XII is to build off of Model WQMP and TGD.

19. **OC Model WQMP and TGD Technical Feasibility Criteria**. The Model WQMP and TGD has developed critical technical feasibility criteria developed through comprehensive analysis, extensive BMP and LID implementation experience, and review and comment by the Model WQMP and TGD Technical Advisory Group. It is critically important to maintain the technical feasibility criteria identified in the Model WQMP and TGD as having technical feasibility alternatives will ensure that long-term effective BMPs can be maintained and do not contribute to risks to people, property, or the environment. The intent of provisions in Section XII is to build off of the established technical feasibility criteria with in the Model WQMP and TGD.

20. **Redevelopment Projects.** Redevelopment projects in North Orange County have significant challenges to meeting the requirements in Section XII. North Orange County is predominantly built out and with this there are challenges for redevelopment projects for implementing LID and retention based compliance for redevelopment. The primary challenge is infiltration capacity in North Orange County as there are limited opportunities for infiltration. This is due primarily to the natural geology with soil types that are not conducive to infiltration. This is also due to the soil compaction that has occurred with previous development

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where many areas are compacted to 90%. An additional constraint is the known presence of groundwater quality issues in large portions of North Orange County. In the Newport Bay Watershed there is shallow groundwater that has elevated levels of Selenium due to the natural geology of the Monterrey formation. Additionally there are also known brownfield sites that have contaminated groundwater and soils such as the old El Toro USMC Base. With infiltration not feasible in many parts of the County, other methods of retention need to be evaluated such as stormwater harvest and use. This presents other challenges including the availability of recycled water in a good portion of North Orange County which reduces or eliminates the demand for harvested stormwater. These challenges for redevelopment projects in North Orange County are reflected in the provision of Section XII.

21. **Regional BMPs.** Regional BMPs consist of a critical tool to help achieve improvement in stormwater quality and ultimately receiving waters. Regional BMPs can provide similar retention and treatment to onsite BMPs for development. One of the benefits of regional BMPs is that maintenance can be better monitored and most regional BMPs are maintained by a Copermitee or an HOA ensuring that maintenance is actually performed. Regional BMPs also provide a better opportunity for implementation of harvest and use of stormwater as more water demands and storage is available usually than onsite harvest and use systems. Additionally regional BMPs can be placed in areas where groundwater recharge is desired, where this resource can be used as a future water supply, as opposed to distributed infiltration, where this may not be able to be realized. Regional BMPs can also be increased in size to meet the redevelopment criteria to improve water quality from existing developed areas by treatment or retention. An example of this is the San Diego Creek Natural Treatment System Master Plan that has integrated these principles and serve as a complex system of constructed wetlands that provide invaluable treatment implemented to provide treatment for new development and redevelopment. Regional BMPs have been included in Section XII as a method to achieve compliance with the new and redevelopment provisions based in this understanding.

22~~18~~. **Water Quality Improvements**. Since 1990, the Permittees have been developing and implementing programs and BMPs intended to effectively prohibit non-storm water discharges to the MS4s and control pollutants in storm water discharges
from the MS4s. As a result, beach closures have been significantly reduced, public awareness of water quality issues has increased, and several water body / pollutant combinations are being considered for removal from the CWA Section

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303(d) List. The Permittees have been able to achieve improvements in water quality in some respects, but significant improvements to the quality of receiving waters and discharges from the MS4s are still necessary to meet the requirements and objectives of the CWA.

23~~19~~. **Long Term Planning and Implementation**. Federal regulations require municipal storm water permits to expire 5 years from adoption, after which the permit must
be renewed and reissued. The Regional Board recognizes that water quality degradation and impacts to beneficial uses in the Santa Ana Region occurred over several decades and will not be undone easily. The Regional Board subsequently recognizes that a decade or more may pass before water quality objectives are consistently achieved in the Santa Ana Region.

24~~0~~. "**Iterative Process"**. This Order is based on an iterative approach that, in summary, is comprised of planning, implementing, evaluating, and improving BMPs carried out as part of the Co-~~P~~permittees' storm water programs. Multiple iterations will occur during this permit term, and are likely to occur over multiple permit terms, to achieve water quality objectives. To fully ~~affect~~ effect the "iterative process", this Order includes ~~prescriptive~~ requirements for conducting program effectiveness assessments ("PEAs"). PEAs are a necessary component of the "iterative process". As part of the ~~performance of~~ PEAs, Co-permittees must compare the outcomes of program activities to the ~~objective~~ requirements of this Order and ~~to objective~~ performance standards developed by the Permittees. The purposes of conducting PEAs include:

a. assessing compliance with the requirements of this Order;
b. tracking progress towards meeting performance standards and/or water quality objectives;
c. justifying the Permittees' commitment of resources, including the cessation of ineffective management practices;
d. providing feedback to Permittees' program managers, in part, to identify the "best" or most effective management practices undertaken; and
e. assessing reductions in pollutant loads to receiving waters and any relationship to management practices.

It is not the intent of the Regional Board that ~~objective~~ performance standards ~~that~~ are developed exclusively by the Permittees as part of PEAs, or be used as the basis for enforcement action against any of the Permittees for failure to satisfy those standards. The intent of the Regional Board is that the Permittees constructively use those performance~~ose~~ standards, and the related monitoring, to iteratively improve the performance of their storm water programs in a timely way to remove pollutants in urban runoff to the maximum extent practicable. Permittees are also required to periodically evaluate the validity of their performance standards and methods of measurement and make modifications accordingly.

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C. WATER QUALITY STANDARDS

25~~1~~. **Basin Plan**. The Regional Board adopted the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) on January 24, 1995 that designates beneficial uses, establishes water quality objectives, and contains implementation programs and policies to achieve those objectives for receiving waters addressed through the plan. Subsequent revisions to the Basin Plan have also been adopted by the Regional Board and approved by the State Water Board, the Office of Administrative Law, and where appropriate, the USEPA. The requirements of this Order implement the Basin Plan.

The Basin Plan identifies the following existing and potential beneficial uses for surface waters in the Santa Ana Region: Municipal and Domestic Supply (MUN); Agricultural Supply (AGR); Industrial Process Supply (PROC); Industrial Service Supply (IND); Ground Water Recharge (GWR); Navigation (NAV); Hydropower Generation (POW); Water Contact Recreation (REC1); Non-contact Recreation (REC2); Commercial and Sport Fishing (COMM); Warm Freshwater Habitat (WARM); Limited Warm Freshwater Habitats (LWRM); Cold Freshwater Habitat (COLD); Preservation of Biological Habitats of Special Significance (BIOL); Wildlife Habitat (WILD); Rare, Threatened, or Endangered Species (RARE); Spawning, Reproduction, and Development (SPWN); Marine Habitat (MAR); Shellfish Harvesting (SHELL); and Estuarine Habitat (EST).

26~~2~~. **Ocean Plan**. The State Water Board adopted the Water Quality Control Plan for Ocean Waters of California, California Ocean Plan (Ocean Plan) in 1972 and amended it in 1978, 1983, 1988, 1990, 1997, 2000, 2005, and 2009. The State Water Board adopted the latest amendment on October 16, 2012 and it became effective on August 19, 2013. The Ocean Plan is applicable, in its entirety, to point source discharges to the ocean. The requirements of this Order implement the Ocean Plan. The Ocean Plan identifies the following beneficial uses of ocean waters of the state to be protected: Industrial water supply; water contact and non-contact recreation, including aesthetic enjoyment; navigation; commercial and sport fishing; mariculture; preservation and enhancement of designated Areas of Special Biological Significance; rare and endangered species; marine habitat; fish spawning and shellfish harvesting.

27~~3~~. **Sediment Quality Control Plan**. On September 16, 2008, the State Water Board adopted the Water Quality Control Plan for Enclosed Bays and Estuaries – Part 1
Sediment Quality (Sediment Quality Control Plan). The Sediment Quality Control Plan became effective on August 25, 2009. The Sediment Quality Control Plan establishes: 1) narrative sediment quality objectives for benthic community protection from exposure to contaminants in sediment and to protect human health, and 2) a program of implementation using a multiple lines of evidence approach to interpret the narrative sediment quality objectives. Requirements of this Order implement the Sediment Quality Control Plan.

28~~4~~. **National Toxics Rule and California Toxics Rule**. USEPA adopted the National

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Toxics Rule (NTR) on December 22, 1992, and later amended it on May 4, 1995 and November 9, 1999. About forty criteria in the NTR applied in California. On May 18, 2000, USEPA adopted the California Toxics Rule (CTR). The CTR promulgated new toxics criteria for California and, in addition, incorporated the previously adopted NTR criteria that were applicable in the state. The CTR was amended on February 13, 2001. The CTR and NTR contain water quality criteria for priority pollutants in discharges to surface water. However, the *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California* states that the Policy does not apply to regulation of storm water discharges. The Regional Board believes that compliance with Water Quality Standards through implementation of BMPs is appropriate for regulating urban runoff. The USEPA articulated this position on the use of BMPs in storm water permits in the policy memorandum entitled, "Interim Permitting Approach for Water Quality-Based Effluent Limitations in Storm Water Permits" (61 FR 43761, August 9, 1996). The USEPA also has articulated this position with respect to implementing TMDLs in their policy memorandum entitled "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on those WLAs", November 22, 2002.

29~~5~~. **Anti-degradation Policy**. Federal anti-degradation policy is applicable to all NPDES permits. 40 CFR 131.12 requires that State water quality standards include an anti-degradation policy consistent with the federal policy. The State Water Resources Control Board established California's anti-degradation policy in State Board Resolution No. 68-16. Resolution No. 68-16 incorporates the federal anti-degradation policy where the federal policy applies under federal law. Resolution No. 68-16 requires that existing quality of waters be maintained unless degradation is justified based on specific findings. The Santa Ana Water Board's Basin Plan implements, and incorporates by reference, both the State and federal anti-degradation policies. This Order requires the Co-permittees to implement programs and policies necessary to improve water quality; the Order does not allow any degradation of water quality. Therefore, this Order is consistent with the anti-degradation provisions of 40 CFR 131.12 and State Board Resolution No. 68-16.

30~~26~~. **Anti-Backsliding Requirements**. Section 402(o)(2) of the CWA and federal regulations at 40 CFR 122.44(l) prohibit backsliding in NPDES permits. These anti-backsliding provisions require effluent limitations in a reissued permit to be as stringent as those in the previous permit, with some exceptions where limitations may be relaxed. All effluent limitations in this Order are at least as stringent as effluent limitations in the previous permits.

D. CONSIDERATIONS UNDER FEDERAL AND STATE LAW

31~~27~~. **Coastal Zone Act Reauthorization Amendments**. Section 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) requires

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coastal states with approved coastal zone management programs to address non-point source pollution impacting or threatening coastal water quality. CZARA addresses five sources of non-point source pollution: agriculture, silviculture, urban, marinas, and hydro-modification. This Order addresses the management measures required by CZARA for the urban category, with the exception of septic systems. The programs developed pursuant to this Order fulfill the need for coastal cities to develop a runoff non-point source plan identified in the Non-Point Source Program Strategy and Implementation Plan. The Regional Board addresses septic systems through the administration of other programs.

32~~28~~. **Endangered Species Act**. This Order does not authorize any act that results in the taking of a threatened or endangered species or any act that is now prohibited, or becomes prohibited in the future, under either the California Endangered Species Act (Fish and Game Code sections 2050 to 2097) or the Federal Endangered Species Act (16 USC sections 1531 to 1544). This Order requires compliance with receiving water limits, and other requirements to protect the beneficial uses of waters of the State. The Permittees are responsible for meeting all requirements of the applicable Endangered Species Act.

33~~29~~. **Report of Waste Discharge Process**. The waste discharge requirements set forth in this Order are based upon the Report of Waste Discharge submitted by the Orange County Permittees prior to the expiration of Order No. R8-2009-0030 (NPDES No. CAS618030). The federal regulations (40 CFR 122.21(d)(2)) and CWC section 13376 impose a duty on the Permittees to reapply for continued coverage through submittal of a Report of Waste Discharge no later than 180 days prior to expiration of a currently effective permit. This requirement is set forth in Provision XXIII.1. of Order No. R8-2009-0030. Order No. R8-2009-0030 (NPDES No. CAS618030) expires on May 22, 2014. Once adopted and in effect, this Order supersedes Order No. R8-2009-0030, except for purposes of enforcement, and is subject to any necessary revisions to its requirements made after the Regional Board considers the Report of Waste Discharge through the public process provided in 40 CFR Part 124.

34~~0~~. **Integrated Report and Clean Water Act Section 303(d) List**. The Santa Ana Regional Water Quality Control Board and the State Water Resources Control Board submit an Integrated Report to USEPA to comply with the reporting requirements of CWA sections 303(d), 305(b) and 314, which lists the attainment status of water quality standards for water bodies in the Santa Ana Region. USEPA issued its Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act on July 29, 2005, which advocates the use of a five-category approach for classifying the attainment status of water quality standards for water bodies in the Integrated Report. Water bodies included in Category 5 in the Integrated Report indicate at least one beneficial use is not being supported or is threatened, and a TMDL is required. Water bodies included in Category 5 in the Integrated Report are placed on the 303(d) List. The most recent 303(d) List was issued in 2010.

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Surface water bodies may be included in Category 4 of the Integrated Report if a TMDL has been adopted and approved by the USEPA for all identified pollutants or impairments (Category 4a); if other pollution control requirements required by a local, state or federal authority are stringent enough to implement applicable water quality standards within a reasonable period of time (Category 4b); or, if the failure to meet an applicable water quality standard is not caused by a pollutant, but caused by other types of pollution (Category 4c). According to the 2010 Integrated Report, no water bodies in the Santa Ana Region are identified in Category 4.

Information acquired as part of implementing this Order may be used by the Regional Board to include surface waters impaired by discharges from the Permittees' MS4s in Category 4 in the Integrated Report. The inclusion of those waters will allow for their consideration during the next 303(d) List submittal by the State to USEPA.

35~~1~~. **Economic Considerations**. The California Supreme Court has ruled that, although CWC section 13263 requires the State and Regional Water Boards (collectively Water Boards) to consider factors set forth in CWC section 13241 when issuing an NPDES permit, the Water Board may not consider the factors to justify imposing pollutant restrictions that are less stringent than the applicable federal regulations require. (City of Burbank v. State Water Resources Control Bd. (2005) 35 Cal.4th 613, 618, 626-627.) However, when pollutant restrictions in an NPDES permit are more stringent than federal law requires, CWC section 13263 requires that the Water Boards consider the factors described in CWC section 13241 as they apply to those specific restrictions.

As noted in the following finding, the Regional Board finds that the requirements in this Order are not more stringent than the minimum federal requirements. The minimum federal requirements include the effective prohibition of ~~on the discharge of~~non-storm water discharges into the MS4; and ~~, for~~ controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, ~~in storm water to the MEP,~~ and such other provisions ~~that~~ as the Regional Board ~~has~~ determines~~d~~ appropriate for the ~~to~~ control of such pollutants. The minimum federal requirements also include requirements for limitations consistent with any applicable waste load allocation. Therefore, considerations pursuant to CW C section 13241 are not required. Notwithstanding the above, the Regional Board has taken into account economic considerations pertaining to the requirements in this Order. The economic consideration is described in the accompanying Technical Report.

36~~2~~. ~~**Unfunded Mandates**. This Order does not constitute an unfunded local government mandate subject to subvention under Article XIIIB, Section (6) of the California Constitution for several reasons, including, but not limited to, the~~

~~following:~~

~~a. This Order implements federally mandated requirements under CWA section~~

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~~402 (33 USC section 1342(p)(3)(B)).~~

~~b. The local agency Permittees' obligations under this Order are similar to, and in many respects less stringent than, the obligations of non-governmental and new dischargers who are issued NPDES permits for storm water and non-storm water discharges.~~

~~c. The local agency Permittees have the authority to levy service charges, fees, or assessments sufficient to pay for compliance with this Order.~~

~~d. The Permittees have requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in CWA section 301(a) (33 USC section 1311(a)) and in lieu of numeric restrictions on their MS4 discharges (i.e. effluent limitations).~~

~~e. The local agencies' responsibility for preventing discharges of waste that can create conditions of pollution or nuisance from conveyances that are within their ownership or control under State law predates the enactment of Article XIIIB, Section (6) of the California Constitution.~~

~~f. The provisions of this Order to implement TMDLs are federal mandates. The CWA requires TMDLs to be developed for water bodies that do not meet federal water quality standards (33 USC section 1313(d)). Once the USEPA or a state develops a TMDL, federal law requires that permits must contain water quality based effluent limitations consistent with the assumptions and requirements of any applicable waste load allocation (40CFR 122.44(d)(1)(vii)(B)).~~

37~~3~~. **California Environmental Quality Act**. The issuance of this NPDES permit for the discharge of runoff from MS4s to waters of the U.S. is exempt from the requirement for preparation of environmental documents under the California Environmental Quality Act (CEQA) (Public Resources Code, Division 13, Chapter 3, section 21000 et seq.) in accordance with CWC section 13389.

E. STATE WATER RESOURCES CONTROL BOARD DECISIONS

38~~4~~. **Compliance with Prohibitions and Limitations**. The receiving water limitation language specified in this Order is consistent with language recommended by the USEPA and established in State Water Board Order WQ 99-05 (amending WQ 98-01), Own Motion Review of the Petition of Environmental Health Coalition to Review Waste Discharge Requirements Order No. 96-03, NPDES Permit No. CAS0108740, adopted by the State Water Board on June 17, 1999. The receiving water limitation language in this Order requires storm water discharges from MS4s to comply with receiving water quality standards, through an "iterative approach". This requires the Co-permittees to implement a process of increasingly effective BMPs over time and that the process include objective performance standards to evaluate effectiveness. The "iterative approach" is necessary to ensure that storm water discharges from the MS4 will not ultimately cause or contribute to violations of water quality standards and will not create conditions of pollution, contamination, or nuisance.

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395. **Special Conditions for Areas of Special Biological Significance**. On March 20, 2012, the State Water Board approved Resolution No. 2012-0012 approving an exception to the Ocean Plan prohibition against discharges to Areas of Special Biological Significance ("ASBS") for certain nonpoint source discharges and NPDES permitted municipal storm water discharges. State Water Board Resolution No. 2012-0012 requires monitoring and testing of marine aquatic life and water quality in several ASBS to protect California's coastline during storms when rain water overflows into coastal waters. Specific terms, prohibitions, and special conditions were adopted to provide special protections for marine aquatic life and natural water quality in ASBS. The Special Protections contained in Attachment B to Resolution No. 2012-2012, applicable to discharges to ASBSs, are hereby incorporated into this Order as if fully set forth herein (See Provision IV.D.).

F. ADMINISTRATIVE FINDINGS

4038. **Executive Officer Delegation of Authority**. The Regional Board by prior resolution has delegated all matters that may legally be delegated to its Executive Officer to act on its behalf pursuant to CWC section 13223. Therefore, the Executive Officer is authorized to act on the Regional Board's behalf on any matter within this Order unless such delegation is unlawful under CWC section 13223 or this Order explicitly states otherwise.

4139. **Standard Provisions**. Standard Provisions, which apply to all NPDES permits in accordance with 40 CFR 122.41, and additional conditions applicable to specified categories of permits in accordance with 40 CFR 122.42, are provided in this Order.

420. **Fact Sheet/Technical Report**. The Technical Report for this Order contains background information, regulatory and legal citations, references and additional explanatory information and data in support of the requirements of this Order. The Technical Report serves as a fact sheet described in Parts 124.8 and 124.56 of the Code of Federal Regulations. The Technical Report is hereby incorporated into this Order and constitutes part of the Findings of this Order.

431. **Public Notice**. In accordance with State and federal laws and regulations, the Regional Board notified the Co-permittees, and interested agencies and persons of its intent to prescribe waste discharge requirements for the control of discharges into and from the MS4s to waters of the U.S. and has provided them with an opportunity to submit their written comments and recommendations. Details of notification are provided in the Technical Report.

442. **Public Hearing**. The Regional Board held a public hearing on MONTH(S), DATE(S) 2014, and heard and considered all comments pertaining to the terms and conditions of this Order. Details of the public hearing are provided in the Technical Report.

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45~~3~~. **Effective Date**. This Order serves as an NPDES permit pursuant to CWA section 402 or amendments thereto, and becomes effective fifty (50) days after the date of its adoption, provided that the Regional Administrator, USEPA, Region IX, does not object to this Order.

46~~4~~. **Review by the State Water Board**. Any person aggrieved by this action of the Regional Board may petition the State Water Board to review the action in accordance with CWC section 13320 and California Code of Regulations, title 23, sections 2050, et seq. The State Water Board must receive the petition by 5:00 p.m., 30 days after the Regional Board action, except that if the thirtieth day following the action falls on a Saturday, Sunday or State holiday, the petition must be received by the State Water Board by 5:00 p.m. on the next business day. Copies of the law and regulations applicable to filing petitions will be provided upon request or may be found on the Internet at:

http://www.waterboards.ca.gov/public_notices/petitions/water_quality

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PERMIT REQUIREMENTS

IT IS HEREBY ORDERED that the Co-permittees[2], in order to meet the provisions contained in Division 7 of the California Water Code and regulations adopted thereunder, and the provisions of the Clean Water Act, as amended, and regulations and guidelines adopted thereunder, must comply with the following:

I. GENERAL RESPONSIBILITIES OF THE CO-PERMITTEES

A. The Co-permittees (inclusive of the Principal Permittee), shall be responsible for the management of storm drain systems within their jurisdictions and, to carry out the requirements of this Order, must:
   1. Accurately document and effectively implement best management practices, including programs, policies, and procedures, within each of their respective jurisdictions.
   2. Develop and apply ~~objective~~ performance measures to track and assess the effectiveness of individual best management practices or systems of best management practices and execute timely program improvements necessary to improve the effectiveness of those practices.
   3. ~~Annually e~~Evaluate the validity of performance measures and the methods used to measure achievement of performance measures.
   4. Participate with one another in the development of necessary programs, plans, procedures, strategies, and reports that are of mutual interest.
   5. Coordinate the relevant plans, policies, procedures, and standards of their internal agencies, departments, and divisions.
   6. Develop and execute necessary interagency agreements.
   7. Establish and maintain adequate legal authority, as required by the Federal Storm Water Regulations.
   8. Maintain records and submit reports that are adequate to determine compliance with the requirements of this Order.
   9. Monitor and report the progress of any plans, projects, and programs implemented to control the discharge of pollutants in urban runoff to their MS4s. Reports must include comparisons of outcomes to objectives, performance measures, or milestones prescribed by this Order or developed by the Co-permittees.

II. GENERAL RESPONSIBILITIES OF THE PRINCIPAL PERMITTEE

A. In addition to the General Responsibilities in Section I above, the Principal Permittee (County of Orange) is responsible for the overall management of the storm water program and, to carry out the requirements of this Order, must:

[2] As described in the Glossary of this Order, the term "Co-permittees" includes the Principal Permittee.

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1. Coordinate the planning and execution of necessary common programs, plans, policies, procedures, and strategies among the Co-permittees.
2. Monitor and report the progress of any plans, projects, and programs of mutual interest to the Co-permittees.
3. Conduct chemical and biological water quality monitoring; and conduct any additional monitoring as directed by the Executive Officer and authorized by this Order.
4. Coordinate the preparation of written reports, programs, plans, and procedures, including the Annual Progress Report, and their submittal to the Executive Officer.

III. DISCHARGE PROHIBITIONS AND LIMITATIONS

A. Prohibitions

1. In accordance with the requirements of 40 CFR § 122.26(d)(2)(i)(B) and (F), the Co-permittees must effectively prohibit illicit/illegal discharges from entering into the municipal separate storm sewer system ("MS4") unless such discharges are authorized by an NPDES permit or not prohibited in accordance with Section III.A.2.
2. The non-storm water discharges in Table 2 ~~below~~ do not need to be prohibited by the Co-permittees unless such discharges are identified by the Co-permittee(s) or the Executive Officer as a significant source of pollutants.
3. Except for those discharges described in Table 2 ~~below~~, non-storm water discharges from Co-permittees' activities into waters of the U.S. are prohibited unless the discharge is authorized under an NPDES Permit.
4. With the recommendation of the Co-permittees or based on Substantial Evidence, the Executive Officer is authorized to add other types of discharges to Table 2 ~~below~~, by way of written notice to the Co-permittees and after providing a minimum of 30 days for public comment.
5. Discharges of urban runoff from MS4s owned or operated by the Co-Permittees must be in compliance with the applicable discharge prohibitions contained in Chapter 5 of the Basin Plan.
6. Except as provided for in Provision B.6, and IV, or as otherwise authorized by this Order, discharges of urban runoff into waters of the U.S. from MS4s owned or operated by the Co-permittees which cause or contribute, or which threaten to cause or contribute to a condition of pollution, contamination, or nuisance (see CWC Section 13050) are prohibited.
7. The discharge to waters of the U.S. of any substance(s) in concentrations that are toxic to animal or plant life is prohibited.
8. The discharge to waters of the U.S. of any radiological, chemical, or biological warfare agent, or high-level radiological waste, is prohibited.

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Table 2: Types of non-storm water discharges presumed to not be a significant source of pollutants

Discharges composed entirely of stormwater Air conditioning condensate
Irrigation water
Passive foundation or footing drains
Water from crawl space pumps
Individual residential car washing and charity car washing events conducted by non-profit 501(c)organizations
De-chlorinated water from swimming pools (except cleaning wastewater and filter backwash)
Diverted stream flow
Rising ground water and natural springs
Ground water infiltration (as defined in 40 CFR § 35.2005(20)
Uncontaminated pumped groundwater
Flow from riparian habitats and wetlands
Temporary non-storm water discharges authorized by USEPA pursuant to Sections 104(a) or 104(b) of the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA") [3]
Emergency firefighting flows necessary for the protection of life and property
Water not otherwise containing "waste", as defined in CW C Section 13050(d)

B. Limitations

1. The Co-permittees must implement an effective public education and outreach program for the purpose of reducing the volume of the anthropogenic non-storm water discharges included in Table 2 to the MS4s.
2. Each Co-permittee must implement an effective water conservation program to minimize irrigation runoff from facilities that they own or control.
3. For discharges outside the Newport Bay watershed the de minimus types of discharges listed in the Regional Board's General De Minimus Permit for Discharges to Surface Waters, Order No. R8-2009-0003, NPDES No. CAG 998001 (General De Minimus Permit), shall be in compliance with the terms and conditions of the General De Minimus Permit. Separate coverage under the General De Minimus Permit is not required. For discharges within the Newport Bay watershed, separate permit authorization for these de minimus discharges will be required when the discharges contain selenium, nitrogen or other pollutants at levels of concern.

~~Non-storm water discharges occurring outside of the Newport Bay watershed from Co-permittee-owned or operated facilities or Co-permittee activities must be in compliance with the conditions and provisions of the General "*De Minimus*" Permit for Discharges to Surface Waters, Order No. R8-2009-~~

[3] These discharges must comply with water quality standards as applicable or relevant and appropriate requirements ("ARARs") under Section 121(d)(2) of CERCLA; or must be subject to either a written waiver of ARARs by USEPA pursuant to Section 121(d)(4) of CERCLA, or a written determination by USEPA that compliance with ARARs is not practicable considering the exigencies of the situation pursuant to 40CFR300.415(j).

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~~0003, NPDES Permit No. CAG998001 ("General *De Minimus* Permit") or subsequent reauthorizations or amendments. This includes, but is not limited to, the need to submit a report of waste discharge.~~

4. Discharges to waters of the U.S. from swimming pools that are owned or operated by the Co-permittees must meet all of the following requirements:
    a. The discharge must not be composed of pool cleaning wastewater or filter backwash.
    b. The discharge must be de-chlorinated to a concentration of 0.1 ppm[1] or less.
    c. The discharge must have a pH between 6.5 and 8.5 for direct discharges to inland surface waters or between 7.0 and 8.6 for direct discharges to enclosed bays and estuaries.
    d. The discharge volume and velocity must be controlled to prevent causing hydrologic conditions of concern.

5. Discharges from potable water sources, including water line flushing, superchlorinated water line flushing, fire hydrant system flushing, and pipeline hudrostatic test water must meet the following conditions:
    a. The discharge must be dechlorinated to a concentration of 0.1 ppm or less[1];
    b. pH adjusted if necessary; and
    c. Volumetrically and velocity controlled to prevent causing hydrologic conditions of concern in receiving waters.

6~~5~~. Discharges from facilities owned or controlled by Co-permittees that extract, treat, and discharge water diverted from waters of the U.S. must meet the following requirements:
    a. The discharge to waters of the U.S. must not contain any pollutants added by the treatment process or contain pollutants in greater concentration(s) than the influent.
    b. The discharge must not cause or contribute to a condition of erosion or cause the suspension and discharge of pollutants already in the conveyance.
    c. The extraction and treatment must be in compliance with Section 404 of the Clean Water Act or with the conditions or provisions of any applicable permit, license, or CWA Section 401 Water Quality Standards Certification.

7~~6~~. For discharges associated with water body pollutant combinations addressed in a TMDL in the affected Permittees shall achieve compliance as outlined in XVIII:

IV. RECEIVING WATER LIMITATIONS

A. Discharges from the Co-permittees' MS4s must not cause or contribute to

[1] Total residual chlorine = 0.1 mg/L or parts per million (ppm). Compliance determination shall be made at a point before the discharge mixes with any receiving water.

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exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface or ground waters or cause of contribute to a condition of nuisance unless a draft plan, prepared pursuant to Provision IV.D. below, has been submitted or, if final, is being fully implemented.

B. Discharges of urban runoff from the Co-permittees' MS4s must comply with receiving water quality standards through timely implementation of storm water control measures and other actions to reduce pollutants in discharges according to the conditions and provisions of this Order.

C. For receiving water limitations associated with a water body pollutant combination addressed in a TMDL Order, the affected Copermittees shall achieve compliance as outlined in XVIII.

D. Determinations that discharges are causing or contributing to exceedances of water quality standards will be based, in part, on assessments of water quality data which are performed according to the schedule specified in attached Monitoring and Reporting Program No. R8-2014-0002 (Attachment A).

E~~D~~. Upon a determination by the Co-permittees or the Executive Officer that a discharge is causing or contributing to the exceedance of an applicable water quality standard, the responsible Co-permittee(s) must submit a draft plan to the Executive Officer describing actions that will be taken to achieve compliance. A plan, prepared according to Section XVIII of this Order, to achieve compliance with TMDL waste load allocations related to the exceeded water quality standard also satisfies this Provision.

1. The draft plan must be submitted to the Executive Officer within 6 months of the Co-permittees becoming aware that a discharge is causing or contributing to the exceedance.
2. Where a draft plan is requested in writing by the Executive Officer, the plan must be submitted within 90-days of the date of the request.
3. The plan must:
   a. describe the pollutant(s) that are known or suspected of causing or contributing to the exceedance(s);
   b. describe the persons or activities believed to cause or contribute to the pollutant(s);
   c. describe the BMPs that are being employed to control the pollutant(s);
   d. describe any proposed new BMPs, or modification of currently-employed BMPs, along with a schedule for their implementation to prevent or reduce the pollutant(s); AND
   e. include a monitoring program and periodic review to characterize the exceedance(s) and to objectively assess the effectiveness of BMPs employed to address them[4]; OR
   f. provide objective evidence, acceptable to the Executive Officer, that there is a trend indicating that relevant pollutant loads or concentrations are decreasing and that the applicable water quality standard(s) are expected to be satisfied without further intervention, or that the source of pollution is non-anthropogenic or from activities not within the jurisdiction of control of the Co-permittee.
4. The draft plan is subject to review by the Executive Officer. The Co-

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Permittees must make any such modifications to the plan within 60-days of written notification by the Executive Officer.

5. The draft plan becomes a final plan and must be fully implemented by the responsible Co-permittees upon approval by the Executive Officer.
6. The Executive Officer will provide a 30-day public review period prior to approving and finalizing the draft plan.
7. If, despite the implementation of the approved final plan described above in this Section, there are continuing or recurring exceedances of water quality standards caused or contributed to by discharges from the Co-permittees' MS4s, the Co-permittees must reinitiate the procedure in this Section. Successive iterations must include modifications to BMPs, additional BMPs, and changes to the monitoring program as appropriate.
8. The Co-permittees must make the final plan accessible to the public by posting the plan to the responsible Co-permittees' web sites, the Principal Permittee's web site, or another method acceptable to the Executive Officer.
9. Except for inconsequential grammatical or technical corrections, the final plan may be amended by the Co-permittees only with the approval of the Executive Officer.

F~~E~~. The Special Protections contained in Attachment B to Resolution No. 2012-~~2012~~0012, as amended or reauthorized by the State Water Resources Control Board, are hereby incorporated into this Order as if fully set forth herein. The Special Protections are specifically applicable to discharges from the City of Newport Beach to Newport Coast and Crystal Cove (ASBS 32 and ASBS 33, respectively) which are authorized by this Order. Where there are conflicts between this Order and the Special Protections, the most protective requirements, as determined by the Executive Officer, shall prevail. The Special Protections are accessible at:

http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2012/rs2012_0012.pdf

[4] Monitoring programs should not be designed to negate the prior monitoring results; such efforts will indicate deficiencies in the overall monitoring program and will require program improvements. Additional monitoring should be designed to characterize the severity and distribution of exceedances and inform the BMP improvement process.

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V. IMPLEMENTATION AGREEMENT

The Co-permittees must execute inter-agency and inter-Co-permittee agreements necessary to satisfy the requirements of this Order.

VI. LEGAL AUTHORITY/ENFORCEMENT

A. Each Co-permittee must secure and maintain legal authority adequate to control the discharge of pollutants in urban runoff to their MS4s pursuant to the requirements of this Order.
B. Each Co-permittee must track and evaluate challenges to their authority to control the discharge of pollutants in urban runoff to their MS4s.
   1. Where a formal or informal challenge indicates a weakness in the Co- Permittees' authority, the Co-permittee must act in good faith and in a timely manner to make their authority adequate.
   2. The Co-permittees must report any discovered weaknesses in their legal authority in their Program Effectiveness Assessment. The report must include a plan, with a schedule of action(s), to make their authority adequate.
C. Each Co-permittee must secure and maintain legal authority, to the extent allowed by State and Federal Law, and subject to limitations on municipal action under the constitutions of the state of California and the United States, that is adequate to enter, inspect, and gather evidence (including pictures, video, samples, statements, and documents) from industrial, construction, and commercial establishments to determine compliance with ordinances, permits, conditions, and other requirements of the Co-permittees related to the control of discharges of pollutants to their MS4s.
D. Each Co-permittee must maintain adequate legal authority to impose a series of effective, progressive sanctions to compel compliance with their regulatory requirements related to the control of discharges of pollutants to their MS4s.
   1. Sanctions ~~must~~ may include monetary and/or non-monetary penalties; bonding requirements; and permit denial, revocation, or stays for non-compliance.
   2. Co-permittees must provide for civil and/or criminal penalties for violations and to provide abatement of violations that constitute a nuisance.
   3. Where a Co-permittee finds that a sanction has not affected compliance, the Co-permittee must impose the next progressive sanction.
   4. Within 90-days of the adoption of this Order, each Co-permittee must develop a formal, written program, which describes supporting policies and procedures that effectively promote the consistent and decisive use of their sanctions, and describes performance measures to track and objectively evaluate the sanctions' effectiveness.

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VII. ILLICIT DISCHARGES, ILLICIT CONNECTIONS, AND ILLEGAL DUMPING; LITTER DEBRIS AND TRASH CONTROL

A. Each Co-permittee must effectively prohibit illicit discharges and illicit connections to their respective MS4s through their ordinances and other appropriate mechanisms.

B. Each Co-permittee must employ an effective mechanism for the public to report known or suspected illicit discharges, illicit connections, and illegal dumping. The reporting mechanism must be continuously advertised to the public by each Co- Permittee using a minimum of two media outlets (i.e. newsprint, internet, telephone directory, etc.).

C. Each Co-permittee must ~~make available and~~ advertise, for residential purposes, the availability of ~~legitimate mechanisms to dispose of~~ waste disposal ~~s~~ that has~~ve~~ the potential to be illicitly discharged to their MS4s.

D. The Co-permittees must implement an effective program to detect illicit discharges and illicit connections; to abate illegal dumping that has the potential to result in a discharge of pollutants to their MS4s; to trace the source of illicit discharges and connections; and to eliminate or permit such discharges and connections. The Co-permittees' program must be fully described in written processes and procedures. Sanitary Sewer Overflows shall be treated as a sub- class of illicit discharges subject to additional requirements of Subsection VII.F.

1. Co-permittees must provide mutual assistance to one another in detecting known or suspected illicit discharges, illicit connections, and illegal dumping.
2. Each Co-permittee must maintain an electronic database that tracks instances of known or suspected illicit discharges, illicit connections, and illegal dumping within their respective jurisdictions.
   a. The database must be designed and used to track compliance with the requirements of this Section (Subsection VII.D.) and Section VI.
   b. The database must be designed and used to guide the Co-Permittees' most effective use of resources towards satisfying the requirements of this Section.
3. Each Co-permittee must identify the personnel or staff positions that are responsible for satisfying the requirements of Subsection VII.D. of this Order in their written program.
4. The Co-permittees must maintain maps of their respective MS4s that contain information of sufficient detail and quality to trace the source of suspected illicit discharges in a timely manner.
   a. The maps must be distributed in a format that is readily available to personnel responsible for satisfying the requirements of Subsection VII.D. of this Order.
   b. The maps must be reviewed and updated annually.
5. The Co-permittees must monitor illicit discharges/ illicit connections ~~a minimum of 30 monitoring stations during the dry season~~according to Part II.H of Attachment A of this Draft Order.
6. ~~For each monitoring station, the Co-permittees must characterize the base-line hydrology of the dry-weather discharges, and the parameters of the~~

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~~discharge (e.g. pH, TSS, etc.). Based on this information, the Co-Permittees must employ statistical flow and parameter thresholds that indicate when an illicit discharge may have occurred or when an illicit connection may exist (e.g. control charts or Shewhart charts). The Co-Permittees must also utilize odor, color, clarity, unusual wildlife morbidity or mortality, sheen, staining, corrosion, unnatural deposits, and other subjective indicators to identify suspected illicit discharges or illicit connections.~~

~~7. The Co-permittee that is the local jurisdiction must initiate (or cause to be initiated) an investigation to trace the source of the suspected illicit discharge or illicit connection (source investigation) where indicators developed pursuant to Provision VII.D.6. are found.~~

~~8. The Co-permittee that is the local jurisdiction must initiate (or cause to be initiated) a source investigation where bacterial monitoring (see Monitoring and Reporting Program No. R8-2014-0002) indicates AB411 receiving water standards are exceeded in ocean outfalls/tributaries and in the nearby surf zone.~~

~~9. A source investigation must occur in substantial conformance with a common set of written techniques and procedures developed by the Permittees as part of the written program described in Provision VII.D.~~

~~a. Except as provided for in Section XVII, indications of a potential illicit discharge or connection must be investigated within three (3) business days of the Co-permittee (including the Principal Permittee) becoming aware of it.~~

~~b. A source investigation may only be regarded as concluded after the cause(s) of the illicit discharge has been identified or continued additional monitoring fails to detect a subsequent exceedance of the same parameter(s) after 180 days. In the interim, the Co-permittee that is the local jurisdiction must put forth a good faith effort to identify the source of an identified illicit discharge or illicit connection.~~

~~c. When the source of an illicit discharge or illicit connection is discovered, the Co-permittee(s) must take immediate action to eliminate the discharge or connection within 120 calendar days of discovery.~~

E. Each Co-permittees must implement an effective program to reduce and/or eliminate the discharge of trash and debris to waters of the U.S.

1. Measures employed for the control of trash and debris must be reported and reviewed annually by the Co-permittees to objectively evaluate the measures' effectiveness and/or the effectiveness of the overall trash and debris program. The results of the first review must be provided in the Annual Progress Report.
2. The principle Co-permittee must demonstrate that the Co-permittees have formally evaluated new technologies, as needed, for the control of trash and debris and report the findings in the Annual Progress Report.
3. Co-permittees may discontinue control measures for trash and debris that they deem to be a health and/or safety issue or ineffective provided that the measure is replaced by a more- effective measure.
   a. Any substitution must be identified in the Annual Progress

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Report ~~approved by the Executive Officer~~ and ~~must be~~ supported by substantial objective evidence.

~~4. .~~

~~b. Co-permittees must satisfy any conditions imposed by the Executive Officer as part of the approval of any substitution.~~

F. For those Co-permittees that own or operate sanitary sewer systems over one mile in length, the State Board has established minimum requirements to prevent and mitigate sanitary sewer overflows ("SSOs") in Order No. 2006-0003-DWQ, "Statewide General Waste Discharge Requirements for Wastewater Collection Agencies". The Co-permittees that are not subject to the requirements of Order No. 2006-0003-DWQ, or subsequent renewals, must implement an effective program to detect and mitigate SSOs such as the Countywide Area Spill Control Program ("CASC") and collaborate with the Orange County Sanitation District and Irvine Ranch Water District. The SSO program should include the ~~as~~ following~~s~~:

1. The Co-permittees' SSO program(s) must be comprised of the following elements:
   a. Procedures for responding to SSOs.
   b. A hands-on field training program for Co-permittees' staff responsible for responding to SSOs.
   c. An awareness-level training program for Co-permittees' field staff most likely to initially detect SSOs.
   ~~d. If necessary, executed Memorandum/Memoranda of Understanding ("MOU") for delineating jurisdictional and financial responsibilities for the program.~~
   ~~e. Objective program performance measures comprised, at a minimum, of SSO response time targets, training targets, and spill recovery targets.~~
2. Co-permittees must respond to SSOs according to the formal written response procedures ~~and MOU~~ unless there is cause to believe that such a response would not be most effective under the circumstances.
3. Co-permittees must maintain records adequate to demonstrate that they implemented the SSO program and its elements; records must be maintained for a minimum of five (5) years.
4. The Principal Permittee is responsible for developing a model SSO program and its elements; and for documenting and reporting the program(s') outcomes in the Annual Progress Report.

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VIII. MUNICIPAL INSPECTIONS OF CONSTRUCTION SITES

A. Each Co-permittee must maintain an inventory of all construction sites, except for construction projects that are less than two weeks in duration, within its jurisdiction.
   1. The construction sites inventory must include sites where building or grading permits are applicable and where activities at the site include the following:
      a. Soil movement;
      b. Uncovered storage of materials or wastes, such as dirt, sand, fertilizer, or landscaping materials; OR
      c. Exterior mixing of cementitious products (i.e. concrete, mortar, or stucco).
   2. All construction sites shall be included in the Co-permittees' inventory regardless of whether the site is subject to the Statewide General Construction Permit or an individual NPDES permit.
   3. The inventory of construction sites must be updated ~~once per month,~~ at a minimum on a biannual basis, once in September and the second update in May.
   4. Each Co-permittees' inventory of construction sites must be maintained in an electronic-format database. The database records must include information on site/project ownership, project area, General Construction Permits WDID (if any), and location (latitude/longitude in decimal-degrees or NAD83/WGS84 format).

B. Each Co-permittee must inspect construction sites in their inventory, subject to limitations on municipal action under the constitutions of the State of California and the United States. Each Co-permittee must have written policies and procedures that describe how inspections and related enforcement actions are carried out. Inspections and related enforcement actions must be carried out in a manner that enforces compliance with applicable ordinance(s), plans, permits, or other requirements related to the control of discharges of pollutants to their MS4s.
   1. Co-permittees must categorize all construction sites in their inventory as either "high-priority", "medium-priority", or "low-priority". Construction sites with an expected or actual duration of more than two weeks must be inspected according to the following schedule:
      a. May 1st through September 30th of each year (dry season): all construction sites must be inspected at a frequency where sediment and other pollutants are properly controlled and that unauthorized, non-storm water discharges are prevented.
      b. October 1st through April 30th of each year (wet season):
         i. High-priority sites must be inspected ~~once per month in their entirety~~three times during the wet season.
         ii. Medium-priority sites must be inspected twice during the wet season.
         iii. Low-priority sites must be inspected once during the wet season.
      c. Where a Co-permittee determines that BMPs or their maintenance are inadequate or out of compliance, the site must be inspected

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weekly until the deficiency is corrected.

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2. A construction site must be considered "high priority" if it meets any of the following minimum criteria:
    a. The site is 20-acres or larger;
    b. The site is over one acre and tributary to a water body listed according to Clean Water Act Section 303(d), as being impaired by sediment or turbidity; OR
    c. The site is tributary to, and within 500-feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance ("ASBS").
3. A construction site must be considered "medium-priority" if it consists of between 5 and 20 acres of disturbed soil and is not otherwise a high-priority site. All other sites may be considered "low-priority".
4. Co-permittees must exercise good judgment and consider other factors or circumstances that could cause a construction site to fall into a higher priority. These factors include, but are not limited to, soil erosion potential, site slope, proximity to a receiving water, and the sensitivity of the receiving water to potential pollutants from the site.
5. Co-permittees must inspect construction sites according to a checklist. The checklist must document, at a minimum, that the inspector:
    a. Verified that the site has been covered by the General Construction Permit, if applicable, during the initial inspection;
    b. Reviewed an Erosion and Sediment Control Plan, to verify that the BMPs on the site are appropriate for the phase of construction;
    c. Identified, through visual observation, any non-storm water discharges and potential pollutant sources;
    d. Assessed the effectiveness of BMPs implemented at the site; and
    e. Identified and communicated to the site representative non-compliance with requirements related to the control of discharges of pollutants to the Permittee's MS4s.
6. Co-permittees must address non-compliance with relevant requirements with a series of effective, progressive sanctions in order to compel compliance.
7. Completed inspections must be recorded in an electronic-format database. The database must be organized in a manner that is adequate to determine compliance with the requirements of this Order. Inspection records must be maintained a minimum of three (3) years from the date of the project's completion.
8. Construction site inspectors must be trained according to Section XVI of this Order; inspectors must undergo training once per year.
9. The Executive Officer must be notified of any known, suspected, or threatened violation of applicable waste discharge requirements (i.e. State-wide General Construction Permit, etc.), discovered during inspections of construction sites according to Section XVII.C. of this Order. Such violations include, but are not limited to:
    a. Failure to obtain coverage under the applicable waste discharge requirements.
    b. Observed or threatened unauthorized discharges.

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10. Except as provided for in Section XVII of this Order, Co-permittees must investigate complaints regarding construction sites, received by internal departments or divisions, external agencies, or the public, within three (3) business days of the complaint being brought to their attention.

IX. and X. INSPECTIONS OF INDUSTRIAL AND COMMERCIAL SITES

The industrial and commercial site inspection program is outlined in the table below. Additional detail is provided in Sections IX. and X.

Task	Option 1		Option 2	Mobile
	Industrial	Commercial	Industrial/Commercial	
Inventory (Section IX. A and X.A)	See Section IX.A.	See Section X.A	See Section IX.A and X.A	- Automobile Detailers - Carpet Cleaners - Pet Services
Prioritization (Section IX.B and X.B)	Based on past performance	Based on pollutants of concern and past performance	None	None
Inspections (Section IX.B and X.B)	- On site - individual - Drive by + Outreach - Outreach only	- On site – individual - On site – property based - Drive by + Outreach - Outreach only	- On site - individual	As Needed
Frequency (Section IX.B and X.B)	- High priority – Annual - Medium/Low priority – As needed	- High priority – Annual on site - Medium – Annual drive by + outreach - Low priority – 2x per permit term outreach	- 20% of inventory per year - 100% of inventory over permit term	As needed
Follow Up (Section IX.B and X.B)	As needed	As needed	As needed	As needed
Minimum (Section IX.B and X.B)	20% of high priority per year	None	20% per year 100% over permit term	Address within permit term

IX. MUNICIPAL INSPECTIONS OF INDUSTRIAL SITES

A. Inventory: Each Co-permittee must continue to maintain an inventory of ~~all~~ industrial sites within its jurisdiction.

1. All industrial sites that have the potential to discharge pollutants to the MS4 shall be included in the Co-permittees' inventory regardless of whether the site is subject to the Statewide Industrial General Permit or other individual NPDES permit.
2. The inventory of industrial sites must be updated annually~~once every three months~~, or more frequently, as needed.
3. Each Co-permittees' inventory of industrial sites must be maintained in an electronic-format database. The database records must include information on site/project ownership, project area, Industrial General Permits WDID (if any), and location (latitude/longitude in decimal-degrees

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or NAD83/WGS84 format).

B. Prioritization and Inspections: There are two options for the prioritizations and inspections of the industrial sites:

- Option 1 – A targeted approach, with inspection frequencies based on the prioritization scheme;
- Option 2 - A synoptic approach, with no fluctuation in the inspection frequency from year to year.

Each option is outlined below.

No matter which option is utilized, each Co-permittee must inspect industrial sites in their inventory, subject to limitations on municipal action under the constitutions of the State of California and the United States. Each Co-permittee must have written policies and procedures that describe how inspections and related enforcement actions are carried out. Inspections and related enforcement actions must be carried in a manner that consistently enforces compliance with applicable ordinance(s), plans, permits, or other requirements related to the control of discharges of pollutants to their MS4s.

Either option listed below may be used by the Permittees for the facilities listed within their industrial inventory.

1. Option 1 – Targeted approach for industrial site prioritizations and inspections.

a. The Permittees shall develop a prioritization process for the facilities that is based on the past performance of that facility. The Permittees will identify the high, medium, and low priority facilities based on this approach.

b. At a minimum, 20% of the high priority facilities would be inspected each year.
The Permittees will conduct one of the following types of inspections:
(a) On-site individual inspections; or
(b) Drive by inspections.
Where a business does not receive a formal inspection, outreach should be provided periodically.

c. The medium and low priority facilities shall be inspected on an as needed basis. Each site that is not inspected should receive outreach information, including BMP Fact Sheets twice per permit term.

d. An inspection of an industrial site that is covered by the General Industrial Permit by Regional Board staff may be substituted for any one of the above-required inspections for the same site.

e. Where a Co-permittee determines that a site is out of compliance with requirements, the industrial site must be inspected, at a minimum, once per month until the site is in compliance.

2. Option 2 – Synoptic approach for industrial site prioritizations and inspections.

a. The Permittees shall annually inspect 20% of the facility inventory, with 100% of the inventory inspected over the permit term.

b. The Permittees will conduct on site-individual inspections.

c~~1. Co-permittees must categorize all industrial sites in their inventory as either "high-priority", "medium-priority", or "low-priority". Industrial sites must be inspected according to the following schedule:~~

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~~a. High-priority sites must be inspected once per year in their entirety.~~
~~b. Medium-priority sites must be inspected once every two years.~~
~~c. Low-priority sites must be inspected once every five years.~~

~~d~~. An inspection of an industrial site that is covered by the General Industrial Permit by Regional Board staff may be substituted for any one of the above-required inspections for the same site.

d~~e~~. Where a Co-permittee determines that a site is out of compliance with requirements, the industrial site must be inspected, at a minimum, once per month until the site is in compliance.

~~2. An industrial site must be prioritized as high priority if the site meets any of the following criteria:~~
~~a. The site is subject to Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 ("SARA");~~
~~b. The site requires coverage under the General Industrial Permit;~~
~~c. The site has a history of unauthorized non-storm water discharges;~~

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4. Co-permittees must conduct inspections of industrial sites according to a checklist. The checklist must document, at a minimum, that:
    a. During the initial inspection, the inspector verified that the site has been covered by the General Industrial Permit, if applicable;
    b. The inspector identified, through visual observation, any non-storm water discharges and potential pollutant sources;
    c. The inspector assessed the effectiveness of BMPs implemented at the site;
    d. The inspector documents evidence of non-compliance or threatened non-compliance with requirements related to the control of discharges of pollutants to the Co-permittee's MS4s.
5. Industrial site inspections must be recorded in an electronic-format database in a manner that is adequate to determine compliance with the requirements of this Order. Inspection records for a facility operator must be maintained for a minimum of three years following termination of business at the site.
6. Co-permittees must address instances of non-compliance with a series of effective, progressive sanctions to ultimately compel compliance.
7. Industrial site inspectors must be trained according to Provision XVI of this Order; inspectors must undergo training once per year.
8. The Executive Officer must be notified of any known, suspected, or threatened violation of applicable waste discharge requirements (i.e. State-wide General Industrial or Construction Permits, etc.), discovered during inspections of industrial sites according to Provision XVII.C. of this Order. Such violations include, but are not limited to:
    a. Failure to obtain coverage under the applicable waste discharge requirements.
    b. Observed or threatened unauthorized discharges.
9. Except as provided for in Provision XVII of this Order, Co-permittees must investigate complaints regarding industrial sites, received by internal staff, external public agency staff, or the public, within three (3) business days of the complaint being brought to their attention.

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X. MUNICIPAL INSPECTIONS OF COMMERCIAL SITES

A. Inventory: Each Co-permittee must maintain an inventory of all fixed commercial sites within its jurisdiction.
   1. The inventory of commercial sites must be updated annually or more frequently, as needed.~~once every three months, at a minimum.~~
   2. Each Co-permittees' inventory of commercial sites must be maintained in an electronic-format database. The database records must include information on the following attributes:
      a. site/business ownership;
      b. site area;
      c. any related approved Water Quality Management Plans and associated structural treatment control BMPs; AND
      d. location (latitude/longitude in decimal-degrees or NAD83/WGS84 format).
   3. Commercial facilities include, but are not limited to those engaged in the following:
      a. Aircraft maintenance, fueling, or cleaning;
      b. Animal care facilities such as petting zoos and boarding and training facilities;
      c. Automobile and other motor vehicle body repair or painting;
      d. Automobile impound and storage facilities;
      e. Automobile mechanical repair, maintenance, fueling, or cleaning;
      f. Botanical or zoological gardens;
      g. Building material retail and storage facilities;
      Cement mixing, cutting, masonry;
      h. Cemetaries;
      i. Eating or drinking establishments, including food markets and restaurants;
      j. Golf courses, parks, and other recreational areas or facilities (those not owned/operated by the Co-permittees);
      k. Landscape and hardscape installation;
      l. Machinery and equipment repair, maintenance, fueling, or cleaning;
      m. Marina operations;
      n. Nurseries and greenhouses;
      o. Painting and coating;
      p. Pest control service facilities;
      q. Pool, lake and fountain cleaning;
      r. Portable sanitary service facilities;
      Retail or wholesale fueling;
      s. Transportation services for passengers, parcels or freight;
      ~~t. Watercraft maintenance, fueling, or cleaning;~~
      u. Any commercial sites that is tributary to, and within 500-feet of, an area defined by the Ocean Plan as an Area of Special Biological Significance; AND
      v. Other commercial sites that the Co-permittee determines may be a significant contributor of pollutants to the MS4.

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B. Prioritizations and Inspections: There are two options for the prioritizations and inspections of the commercial sites:

- Option 1 – A targeted approach, with inspection frequencies based on the prioritization scheme;
- Option 2 - a synoptic approach, with no fluctuation in the inspection frequency from year to year.

Each option is outlined below.

No matter which option it utilized, ~~B. E~~each Co-permittee must inspect commercial sites in their inventory, subject to limitations on municipal action under the constitutions of the State of California and the United States. Inspections must occur according to written processes and procedures, and in a manner to enforce compliance with ordinance(s), plans, permits, WQMPs, or other requirements related to the control of discharges of pollutants to their MS4s.

Either option listed below may be used by the Co-permittees for the facilities listed within their commercial inventory, with the exception of the food facilities, which is addressed within Section X.X below.

3. Option 1 – Targeted approach for commercial site inspections.

a. The Permittees shall develop a prioritization process for the commercial facilities that is based on the watershed pollutants of concern and the past performance of that facility. The Permittees will identify the high, medium, and low priority facilities based on this approach.

b. At a minimum, 20% of the high and medium priority facilities would be inspected each year.

The Permittees will conduct one of the following types of inspections:

(a) On-site individual inspections;
(b) On-site property-based inspections; or
(c) Drive by inspections.

Where a business does not receive a formal inspection, outreach should be provided periodically.

c. The commercial inspection program under this option would be structured as illustrated in the Orange County ROWD Table 3.6.2.

d~~b~~. Where a Co-permittee determines that BMPs or their maintenance is inadequate or out of compliance, the commercial site must be re- inspected monthly until BMPs and their maintenance is adequate and in compliance.

e~~c~~. If Regional Board staff inspects a commercial site, the Co-permittee may substitute Regional Board staff's inspection for an inspection required under this Order for the same site.

4. Option 2 – Synoptic approach for commercial site inspections.

a. The Permittees shall annually inspect 20% of the commercial facility inventory, with 100% of the inventory inspected over the permit term.

~~1. Co-permittees must prioritize all commercial sites (except for eating or~~

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~~drinking establishments, see Section X.C. below) in their inventory as either "high-priority" or "low-priority".~~

~~2. Each Co-permittee must categorize a minimum of 10% of their inventoried commercial sites as "high-priority" and a minimum of 20% of their inventoried commercial sites as "medium-priority".~~

~~3. Prioritized commercial sites must be inspected according to the following schedule:~~

~~a. High-priority sites must be inspected once per year in their entirety.~~

~~b. Medium-priority sites must be inspected once every two years.~~

~~c. Low-priority sites must be inspected once every five (5) years.~~

~~4. Any Co-permittee may propose an alternative priority category distribution of their commercial sites and implement the related inspection schedule subject to the written approval of the Executive Officer.~~

~~a. The approved alternative distribution and schedule must be implemented in lieu of the distribution and inspection schedule prescribed in this Section.~~

~~b. The Executive Officer may rescind that approval for cause with written notification to the Co-permittee(s).~~

~~5~~b. Where a Co-permittee determines that BMPs or their maintenance is inadequate or out of compliance, the commercial site must be re-inspected ~~within two weeks~~monthly until BMPs and their maintenance is adequate and~~or~~ in compliance.

. c. If Regional Board staff inspects a commercial site, the Co-permittee may substitute Regional Board staff's inspection for an inspection required under this Order for the same site.

~~7. Co-permittees must exercise their discretion and consider site-specific factors that could cause a commercial site to be categorized into a higher priority. These factors include, but are not limited to, soil erosion potential, site slope, proximity to a receiving water, and the sensitivity of the receiving water to potential pollutants from the site.~~

5~~8~~. Co-permittees must conduct inspections of commercial sites according to a checklist. The Co-permittees must use the checklist to document, at a minimum, that:

a. The inspector identified, through visual observation, any non-storm water discharges, evidence of non-storm water discharges, and potential pollutant sources;
b. The inspector assessed the effectiveness of BMPs implemented at the site;
c. The inspector documented evidence of non-compliance or threatened non-compliance;
d. If the inspector identifies non-compliance or a threat of non-

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compliance with relevant requirements, or determines that BMPs are ineffective; the inspector notified the site operator and provided the applicable BMP Fact Sheet(s) and any other relevant published educational materials.

9. Commercial site inspections must be recorded in an electronic-format database in a manner that is adequate to determine compliance with the requirements of this Order. Inspection records for a site operator must be maintained for a minimum of three (3) years following the termination of business at the site.
10. Co-permittees must address non-compliance with a series of effective, progressive sanctions to ultimately compel compliance.
11. Commercial site inspectors must be trained according to Provision XVI of this Order; inspectors must undergo training once per year.
12. The Executive Officer must be notified of any known, suspected, or threatened violation of applicable waste discharge requirements (i.e. State-wide Construction Permit, etc.), discovered during inspections of commercial sites according to Provision XVII of this Order.
13. Except as provided for in Provision XVII of this Order, Co-permittees must investigate complaints regarding commercial sites, received by internal departments or divisions, external agencies, or the public, within three (3) business days of the complaint being brought to their attention.

C. The Co-permittees must inspect eating or drinking establishments annually or cause such inspections to occur on their behalf by another party. These third-party inspections are anticipated to occur as part of the Orange County Health Care Agency ("HCA") restaurant inspection program.
   1. The inspections must occur, in part, to enforce the local Co-permittee's requirements related to the control of discharges of pollutants to their MS4s (See Section III).
   2. Where the inspecting agency staff observes known or suspected violations of a local Co-permittee's requirements related to the control of discharges of pollutants to their MS4s, the known or suspected violation must be referred to the Co-permittee within two (2) business days.
   3. Co-permittees must respond to referrals from the HCA or other third-party within three (3) business days of the matter being brought to their attention.

D. Mobile Businesses: the Co-permittees must implement an enforcement and outreach program for the following mobile businesses operating in the permit area: automobile wash/detail services, carpet cleaners, and pet services. The purpose of the program must be to identify potential dischargers and eliminate illicit non-storm water discharges into the MS4.

XI. RESIDENTIAL PROGRAM (INCORPORATED INTO PUBLIC EDUCATION)

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XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT REDEVELOPMENT)

A. Planning Requirements

1. During the course of updating their respective General Plans; or the adoption or update of a Specific Plan and where the related change in the environment may impact surface water quality; the Co-permittees must, except as described in Section XII.A.2. below, adopt an effective set of goals, policies, and procedures for new development including significant redevelopment as defined in this Order consistent with the following goals:
    a. Limit disturbance of natural water bodies and drainage systems; conserve natural areas; protect slopes and channels; and minimize the impacts of urban runoff on the biological integrity of natural drainage systems and water bodies.
    b. Minimize changes in hydrology and pollutant loading; require incorporation of controls on hydrology and pollutants, including structural and non-structural best management practices; prevent post-development runoff rates and velocities from a site from having a significant direct, indirect, or cumulative adverse impact on downstream erosion or causing degradation of stream habitat.
    c. Minimize the quantity of urban runoff draining directly to impermeable surfaces and MS4s; maximize the use of permeable surfaces to percolate storm water into the ground.
    d. Preserve wetlands, riparian corridors and buffer zones, and establish reasonable limits on the clearing of vegetation from project sites.
    e. Encourage the use of infiltration except in areas that would cause or exacerbate a known groundwater quality issue, rainwater harvest and use, green or brown roofs, and other low-impact development methods where those methods are likely to be effective, feasible, and consistent with the Co-permittees' water conservation, open space, healthy communities, waste diversion, or other sustainability-related goals or objectives[5].
2. A Co-permittee may reject any of the above-listed goals in whole or part. Where a Co-permittee rejects any of the above-listed goals in whole or part, the Co- Permittee must include findings explaining the basis of the rejection in their decision-making or supporting documents for the adoption of the new or updated General Plan or Specific Plan.
3. ~~Where a Co-permittee adopts goals within their General Plan or Specific Plan consistent with the above-listed goals, the Co-permittee must also adopt supporting objectives that are measurable and verifiable within 12 months of the adoption of the General Plan or Specific Plan. Those adopted objectives may be developed as part of subsequent updates to the Co-permittee's municipal code, development standards, conditions of approval, or similar governing documents necessary to implement the~~

[5] For example, the incorporation of ground tire rubber into permeable asphalt pavement may help a Co-

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Permittee achieve water conservation, waste diversion, and ambient noise goals in addition to reducing pollutants in runoff from a site

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~~General Plan or Specific Plan.~~

3~~4~~. Each Co-permittee must adopt policies and procedures that are effective at integrating source control, site design and structural treatment control BMPs as early in the land-use planning and development process as practicable.

4~~5~~. The Executive Officer or his designee, must be given the appropriate notices where a Co-permittee initiates an amendment or update of their General Plan which may directly, indirectly, or cumulatively impact beneficial uses, consistent with the requirements of Government Code Section 65350 *et seq*. This requirement does not diminish any other obligations of the Co-permittees' to provide notice to the Regional Board as a Responsible Agency pursuant to CEQA.

~~6. Co-permittees must not accept a development application as being complete without evidence that a report of waste discharge has been submitted to the Regional Board for any discharges of dredge or fill to waters of the U.S. associated with the project.~~

5~~7~~. Within 12-months of the adoption of this Order, the Principal Permittee must review, update and submit to the Executive Officer any studies performed to examine feasible opportunities to retrofit existing storm water conveyance systems, parks, and other recreational areas with regional or sub-regional structural treatment control BMPs. The update shall expand the scope of the examination to include areas owned or controlled by the Co-permittees. If necessary, work necessary to complete only the expanded scope may be phased, but all phases must be completed no later than 36-months from the adoption of this Order.

B. Classifying and Processing Priority and Non-priority Projects[2]

1. The requirements of Section XII.B., and subsequent sub-sections of Section XII., apply to initial project applications received by the Co-Permittees ~~on the effective date of this Order (50-days~~ 12 months following adoption of this Order~~)~~. For projects initiated by the Co-permittees, the requirements of Section XII.B., and subsequent sub-sections of Section XII., apply to projects ~~for which funding is~~that have been approved within 12 months after ~~on~~ the date of the adoption of this Order. In the interim, the relevant requirements of Order No. R8-2009-0030 shall apply.
2. Each Co-permittee must classify development and redevelopment projects over which they have approval authority as "priority projects" (see Subsection XII.B.5. below) or "non-priority projects"~~.~~ as defined in the

[2] For the purpose of Section XII of this Order, the terms "Development Project" and "Redevelopment Project" refer to projects that include the addition or replacement of impervious surfaces and could reasonably cause water quality or hydrologic impacts. Site improvements or maintenance activities that do not include the addition or replacement of impervious surfaces are exempt from the requirements of Section XII of this Order. Examples of exempted site activities include interior building improvements, roof or siding replacements, sign installations, retaining wall installation, irrigation system installations, routine maintenance activities, and other activities, including those specifically exempted in Section XII.B.

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Orange County Model Water Quality Management Plan ~~as projects that do not fall under one of the Priority Project Categories but meet the following conditions;~~

~~a. Require discretionary action that will include a precise plan of development, except for those projects exempted by the Permittee Water Quality Ordinance (as applicable); or~~

~~b. Require issuance of a non-residential plumbing permit for pipelines conveying hazardous materials (e.g. gasoline) as defined in the Permittee Water Quality /Stormwater Ordinance.~~

3. Each Co-permittee must employ a standardized form, checklist, or similar mechanism to document the basis for classifying a project as a priority project, ~~or a~~ non-priority project, or an exempt activity (see Footnote below)..
   a. Each Co-permittee is responsible for ensuring the accuracy of information relied on in support of the Co-permittee's classification.
   b. The Co-permittees must maintain records of the basis for classification for a minimum of five years following the completion of the project.
4. Co-permittees must consider the whole of the project, consistent with the requirements of CEQA, in classifying a project; the Co-permittees must not piecemeal a project.
5. Each Co-permittee must regard projects that fit any of the following categories of projects as priority projects~~; all other projects may be regarded as non-priority projects~~:
   a. Significant redevelopment projects that include the addition or replacement of 5,000 square feet or more of impervious surfaces on a developed site.
      i. Redevelopment projects do not include routine maintenance activities, or activities that are conducted to maintain the original line and grade, hydraulic capacity, or original purpose of a facility.
      ii. Redevelopment projects do not include the replacement, upgrade, or installation of dry utilities (e.g. gas, electric, and telecommunications), sanitary sewer, or water distribution lines in existing transportation rights of way.
      iii. Where a redevelopment project results in the addition or replacement of less than 50% of the impervious surfaces of an existing developed site, and the existing development was not subjected to a properly-implemented and properly-approved WQMP, the numeric sizing requirements for structural treatment control BMPs apply only to runoff from the impervious areas added or replaced and not from the entire developed site.
      iv. Where a redevelopment project results in the addition or replacement of more than 50% of the impervious surfaces of an existing developed site, the numeric sizing requirements must be applied to runoff from the entire development.
   b. New developments that create a total of 10,000 square feet or more

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of impervious surfaces, including commercial, industrial, and mixed-use developments; public and private capital improvement projects; and residential housing subdivisions (i.e., detached single family home subdivisions, multi-family attached subdivisions (town homes), condominiums, apartments, etc.)~~single and multi-family dwelling units~~. This category includes public or private land development projects subject to the planning and building authorities of the Co-permittees.

c. New ~~or expanded~~ automotive repair shops that engage in activities described by Standard Industrial Classification ("SIC") codes 5013, 5014, 5541, 7532 through 7534, and 7536 through 7539.
d. Restaurants where the area of land development is 5,000 square feet or more.
e. Hillside developments affecting 5,000 square feet or more, in areas with known erosive soil conditions or where the natural slope is 25% or more.
f. Development that includes the construction of 2,500 square feet or more of impervious surface that is located within 200 feet of, or which discharges the site's runoff into, an environmentally sensitive area where the discharge is not commingled with discharges from other sites.
g. Parking lots, or other land areas or facilities for the temporary storage of motor vehicles, that includes the construction of 5,000 square feet or more of impervious surface exposed to storm water.
h. Street, road, highway and freeway improvement or construction projects affecting 5,000 square feet or more of paved surface used for the transportation of vehicles.
   i. This category excludes routine maintenance to restore or preserve ~~only the surface course of pavement~~the pavement structure such that the surface type, line and grade is not substantially changed and the activities have no net effect on water quality.
   ii. Project WQMPs for this category must be consistent with the USEPA's "Managing Wet Weather with Green Infrastructure Municipal Handbook: Green Streets"[6].
i. New retail gasoline outlets of 5,000 square feet or more and with a projected average daily traffic of 100 or more vehicles per day.

6. Each Co-permittee must require a preliminary WQMP or a Non-Priority Project Water Quality Plan~~non-priority project plan~~ as part of an ~~complete~~ application for a project, for those projects that qualify as "priority projects" and "non-priority projects" respectively~~in conformance with the Permit Streamlining Act~~. Both the preliminary WQMP and non- priority project plan must be subject to the Co-permittee's approval. A preliminary WQMP must be approved prior to the project's approval by the Co-permittee's decision-making body (e.g. city council, Board of Supervisors, etc.).
7. A WQMP or Non-Priority Project Water Quality Plan ~~Non-Priority Project Plan~~ is not required for a project which, in its entirety, is necessary to mitigate an emergency.
8. The Co-permittees' staff, contractors, or vendors responsible for preparing,

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reviewing or approving Water Quality Management Plans or Non-Priority Project Water Quality Plans~~non-priority project plans~~ or for enforcing their implementation must be trained according to Section XVI of this Order.

9. Each Co-permittee must employ an effective mechanism to inform potential project applicants of the need for a preliminary WQMP or a non- priority project plan as part of a complete application prior to the submittal of an application.
10. A Co-permittee must not allow ~~construction work~~precise grading for new development or final construction work for re-development projects to proceed on the subject phase of a project prior to approval of a final P~~p~~roject WQMP or Non-Priority Project Water Quality Plan~~non-priority project plan~~ for the respective phase.
11. Each Co-permittee must have an effective process that enforces substantial conformance between relevant project plans (i.e. grading plans, drainage plans, landscaping plans, etc.) and the approved preliminary and final P~~p~~roject WQMP or Non-Priority Project Water Quality Plans~~non-priority project plans~~.
12. Each project WQMP or Non-Priority Project Water Quality Plan~~non-priority project plan~~ approved by the Co- Permittees must contain sufficient information to demonstrate that the final Project WQMP or Non-Priority Project Water Quality Plan~~non-priority project plan~~ was approved according to the requirements of this Order.
13. Each Co-permittee must have effective standard processes to ensure that the final project WQMP and Non-Priority Project Water Quality Plan~~non-priority project plan~~ is internally consistent and free of material contradictions.
14. As part of the project approval process, each Co-permittee must apply standard conditions of approval, or some other equally-effective measure(s), that requires the proper operation and maintenance of all source control, site design, and structural treatment control BMPs by the project applicant, their successors and assigns over the life of the project.
15. Each Co-permittee must have an effective inspection program to identify and correct missing, damaged, or deficient source control, site design, and structural treatment control BMPs during the construction or development of priority and non-priority projects.
16. In addition to using published and generally-accepted engineering design criteria (see Subsection D below), each Co-permittee must utilize the guidelines in the Orange County ~~Technical Guidance Document~~TGD for site design and structural treatment controls to be readily inspected and maintainable, and generally of a quality that is satisfactory to the Co-permittee.
17. Co-permittees are prohibited from permitting final occupancy or otherwise effectively issuing final approval of a priority ~~or non-priority project~~ site until all source control, site design, and structural treatment control BMPs are constructed, serviceable, and satisfactory to the Co-permittee or otherwise certified as such by a licensed professional engineer on behalf of the project applicant.
    a. Serviceable facilities must operate as intended; where the Co-Permittee is unable to conclusively determine that a facility is serviceable, the Co-permittee must require that the project

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applicant conduct a satisfactory field demonstration.

b. Where deficiencies exist, the Co-permittee may permit final occupancy or issue final approval only if written enforcement action is taken and a time schedule to bring the site into compliance with its Project WQMP ~~or non-priority project plan~~ has been approved by the Co- permittee.

c. Co-permittees must require that certifications by the licensed professional engineer be affixed with said engineer's stamp and maintained as part of the WQMP ~~or non-priority project plan~~.

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[6] Lukes, Robb and Kloss, Christopher, "Managing Wet Weather with Green Infrastructure Municipal Handbook: Green Streets", USEPA, Low Impact Development Center, EPA-833-F-08-009, December 2008. Available at: http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_munichandbook_green_streets.pdf

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18. Each Co-permittee must have effective standard processes that provide the following:
    a. Approved final P~~p~~roject WQMPs and Non-Priority Project Water Quality Plans~~non-priority project plans~~ are retained using a system that allows for their ready retrieval for the life of the project.
    b. The Co-permittee is able to validate the authenticity of approved final P~~p~~roject WQMPs and Non-Priority Project Water Quality Plans~~non-priority project plans~~.
    c. Approved final Project WQMPs and Non-Priority Project Water Quality Plans ~~non-priority project plans~~ are protected by the Co-permittee's standard record protection practices in the event of fire, information system failure or attack, or other loss or damage.

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C. General Requirements for Priority Projects

1. The Co-permittees must require priority projects to use source control, site design, and Low Impact Development (LID) BMPs or structural treatment control BMPs[3] to remove pollutants in urban runoff.
2. Project Water Quality Management Plans must be prepared in substantial conformance with the Orange County Model WQMP and TGD~~uniform written technical guidance~~.which assists in the implementation of ~~The technical guidance must implement~~ the requirements of this Order for the benefit of persons responsible for preparing, reviewing and approving, enforcing, and implementing Project WQMPs[4].
3. Project Water Quality Management Plans must be prepared by or under the supervision of a registered civil engineer ~~or licensed landscape architect~~ (See Provision XII.D.6. below).
4. Final project Water Quality Management Plans must be approved by or under the supervision of a registered civil engineer acting on behalf, and with the expressed permission, of the Co-permittee.
5. LID BMPs and s~~S~~tructural treatment control BMPs must be identified using standard nomenclature and must be sized and designed in substantial conformance with standards and methods found in published and generally-accepted engineering design manuals or as identified in the Orange County TGD; unnecessary deviations from those standards and methods are prohibited. Where those manuals conflict with the requirements of this Order, this Order shall prevail. Where Co- Permittees allow deviations, justification(s) for their necessity must be documented in the final project WQMP.
6. Each Co-permittee must employ effective, uniform mechanisms to provide efficiency and consistency in their WQMP-approval process. Such mechanisms must include~~, at a minimum,~~ the following as applicable:
   a. Use of written standard instructions, processes, procedures, and/or methods.
   b. Use of standardized paper forms, checklists, and/or worksheets.
   c. Use of model language for project WQMPs or categories of P~~p~~roject WQMPs.
   d. Use of standardized models, electronic spreadsheets, web-based tools, and/or other software, as needed.
   e. Prepared maps, tables and/or other sources of information necessary for preparers and reviewers to evaluate the feasibility of LID BMPs and structural treatment control BMPs.
7. The mechanisms must be subject to a bi~~n~~-annual review by the Co-Permittees for the purpose of promoting the mechanisms' continual

[3] Structural treatment control BMPs refers to "low impact development" (LID) BMPs (i.e., BMPs that provide retention and biotreatment), as well as standard treatment control BMPs that provide flow-through treatment.

[4] The Co-Permittee's Model Water Quality Management Plan (Model WQMP) and Technical Guidance Document (TGD), and subsequent updates in response to this Order, constitute what is intended as uniform written technical guidance.

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improvement.

8. The Co-permittees must provide and promote a mechanism for stakeholder input in the continual improvement process at regular intervals for the preparation, review, enforcement, and implementation of WQMPs.
9. The Co-permittees must require project proponents to demonstrate in each approved Pproject WQMP that there is a source of funding available and a party responsible for the long-term performance, operation, and maintenance of source control, site design, and on-

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site or off-site structural treatment control BMPs over the life of the project.

10. The Co-permittees must provide that approved WQMPs and associated appropriate easements and ownerships are adhered to ~~recorded in public records~~through an appropriate mechanism and the information is conveyed to all appropriate parties when there is a change in project or site ownership. ~~in a manner that allows for their discovery by interested parties and the transfer of responsibility in the event of the sale, lease, or other transfer of ownership or control of the affected site.~~

~~11. The Co-permittees must provide that any covenants, conditions, and restrictions, easements or other similar mechanisms necessary for the implementation of an approved WQMP are properly recorded in public records with the County and/or the relevant city~~.

12~~11~~~~12~~. The Co-permittees must maintain an electronic database adequate to identify sites affected by an approved WQMP.

a. The database must be established within 6-months of the adoption of this Order. The database must include records identifying all LID BMPs and structural treatment control BMPs installed after May 22, 2009 and their following attributes:
   i. Type of LID BMPs and structural treatment control. If a 'type' does not comply with Provision XII.C.5., the facility must be identified as "undetermined".
   ii. Standards applied to the design of the facility.
   iii. Location by watershed and by a scale sufficient for location in the field.
   iv. Date of construction or date first placed in service.
   v. Party responsible for maintenance and their contact information, including emergency contact information.
   vi. Source of funding for operation and maintenance.
   vii. Actual or alleged performance, maintenance, or nuisance problems identified during any site inspections by the Co-Permittees or brought to their attention.
b. Each Co-permittee must provide that information regarding Project WQMPs that were approved prior to May 22, 2009 populates the database on an opportunistic basis.
c. Sites that are part of the Co-permittees' industrial and commercial inspection program inventories and which are subject to any approved WQMPs must have their information populated in the database no later than 60 months from the date of adoption of this Order.

13~~12~~~~13~~. The Co-permittees must refer nuisance problems associated with LID BMPs and structural treatment control BMPs to the Orange County Vector Control District within 5 business days of the problem becoming known. The Co- Permittees must cooperate in good faith with the Orange County Vector Control District to remedy any confirmed nuisance problems.

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D. General Requirements for Structural Treatment Control BMPs

1. Structural treatment control BMPs shall be sized to infiltrate, filter, or remove pollutants from the design capture volume or design capture flow from their respective tributary area as defined in Section XII.D.3 and XII.D.4 of this Order.
2. The selection of structural treatment control BMPs shall conform to the requirements of Section XII.E through XII.K of this Order and accompanying uniform written technical guidance developed by the Co-Permittees, as applicable.

3~~1~~. A singular or set of LID BMPs and structural treatment control BMPs that are volume- based must be sized to infiltrate, filter, or remove pollutants from any of the following design capture volumes from their tributary area:

a. The volume of runoff produced by a 24-hour, 85th percentile storm event. The volume must be calculated using the County of Orange's 85th Percentile Precipitation Isopluvial map.
b. The volume of annual runoff produced by the 85th percentile, 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/American Society of Civil Engineers Manual of Practice No. 87 (1998).
c~~b~~. 80% or more of the annual runoff volume, based on published ~~, based on unit basin storage volume, using the~~ methods (e.g., ~~recommended in~~ California Stormwater Best Management Practices Handbook – Industrial/Commercial or the ~~identified in the~~ Orange County TGD) or project specific continuous simulation analysis.
d~~c~~. The volume of runoff, as determined from the local historical rainfall record, that achieves approximately the same reduction in pollutant loads and flows as would be achieved by treatment of the volume of runoff produced by an 85th percentile, 24-hour rain event.

4~~2~~. A singular or set of ~~-~~LID BMPs and structural treatment control BMPs that are flow- based must be sized to infiltrate, filter, or remove pollutants from
any of the following design flows from their tributary area:

a. The maximum flow rate of runoff produced from a rainfall intensity of 0.2 inch of rainfall per hour, for each hour of a storm event.
b. The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two.

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c. The maximum flow rate of runoff, as determined from the local historical rainfall record, which achieves approximately the same reduction in pollutant loads and flows as would be achieved by treatment of the flow produced by the 85th percentile hourly rainfall intensity multiplied by a factor of two.

5~~3~~. ~~Structural treatment control~~LID BMPs intended to retain the design capture volume must be designed to infiltrate, evaporate, ~~evapotranspirate~~evapotranspire, or use the volume over a period not to exceed 48-hours or another alternative maximum drawdown time consistent with the sizing and design approaches described ~~allowed~~ in the Orange County TGD[5]. Any remaining volume must be passed on to another LID BMP or structural treatment control BMP.

6~~4~~. The design capture volume or flow may be treated by routing the runoff through multiple LID BMPs or structural treatment control BMPs organized in series or parallel. Co-permittees must require that the design capture volume or flow be calculated for each area tributary to a LID BMP or structural treatment control or group of LID BMPs or structural treatment control BMPs.

5. Co-permittees must require that practical and durable mechanisms are provided to indicate the need for maintenance of LID BMPs and structural treatment control BMPs for the benefit of the party responsible for long-term maintenance. The mechanism must be readily identifiable and located on, within, or in close proximity to LID BMPs and structural treatment control BMPs; such mechanisms must be documented in the related approved P~~p~~roject WQMP.

7~~6~~. ~~LID BMPs and sStructural treatment control BMPs must be sized and designed by, or under the direction of, a registered civil engineer.~~

8~~7~~. LID BMPs and s~~S~~tructural treatment control BMPs must incorporate design features to minimize the entrainment and bypass of captured pollutants in the course of routine maintenance, normal operation, or overflow.

~~8. Where a structural treatment control BMP satisfies the requirements of this Order but is undersized relative to its tributary area, Co-permittees must require that a cost analysis be performed.~~

~~a. The analysis must disclose any costs which exceed the expected costs of operating a properly-sized facility according to manufacturer's recommendations or published and generally-accepted standards and any uncertainties and assumptions forming the basis of the calculations.~~

~~b. The Co-permittees must require that the maintenance cost analysis be made part of the final approved WQMP and part of any disclosures associated with conveyance of the property to subsequent owners, operators, or other interested parties (e.g. lenders, insurers, etc.).~~

9~~8~~~~9~~. The Co-permittees must conduct inspections of all approved LID BMPs

[5] Alternative drawdown times may be used if BMPs are adequately sized to provide the same level of long term capture as a BMP sized for the design capture volume that drains in 48 hours. Alternative drawdown times must not result in vector issues or other nuisance issues, and must not compromise treatment performance.

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and structural treatment control BMPs according to the following schedule:

a. All privately-owned or operated LID BMPs and structural treatment control BMPs, must be inspected a minimum of once every 5 years[57].

b. All Co-permittee-owned or operated LID BMPs and structural treatment control BMPs must be inspected annually prior to the wet season (October 1st).

~~10. Co-permittees must secure the authority to enter onto a property that is subject to an approved WQMP and to perform maintenance or take other remedial action on structural treatment control BMPs in the event that the responsible party fails to adequately operate or maintain the facility.~~

10~~1~~. LID BMPs and s~~S~~tructural treatment control BMPs must not cause a condition of nuisance or pollution, as defined in CWC Section 13050.

11~~2~~. LID BMPs and s~~S~~tructural treatment control BMPs must not cause or contribute to an exceedance of groundwater quality objectives.

12~~3~~. LID BMPs and s~~S~~tructural treatment control BMPs must not be approved in a final Project WQMP if they are located within waters of the U.S. unless the related discharges have been authorized pursuant to a Clean Water Act Section 401 Water Quality Standards Certification or waste discharge requirements.

13~~4~~. Except as permitted by Subsection E, below, LID BMPs and structural treatment control BMPs must be designed and constructed in substantial conformance with the Orange County TGD or other published and generally-accepted engineering design criteria~~.~~. Unnecessary, non-substantial deviations from such criteria are prohibited.

E. Nonconforming Structural Treatment Control BMPs: Demonstration Facilities

1. The Co-permittees are prohibited from approving or allowing to be placed into service structural treatment control BMPs which do not substantially conform to published and generally-accepted engineering design criteria or have substantiated field verification of acceptable performance (nonconforming structural treatment control) unless the nonconforming structural treatment control BMP has developed and provided field-scale performance data through an application that has been reviewed and accepted by the Co-permittee in the jurisdiction where the nonconforming structural treatment control BMP will be implemented. ~~the following requirements are satisfied:~~

~~a. The planned construction of the nonconforming structural treatment control BMP~~has developed field-scale performance data. ~~is disclosed in the project's CEQA documentation.~~

~~b. The design of the nonconforming structural treatment control BMP is based on sound principles of operation and pollutant removal mechanisms exhibited by similar conforming structural treatment control BMPs.~~

~~c. The tributary area of any single nonconforming structural treatment control BMP is three (3) acres or less.~~

~~d. The nonconforming structural treatment control BMP is subject to~~

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~~an objective and statistically valid performance monitoring plan and program with the purpose of comparing the actual performance of the nonconforming structural treatment control BMP with the expected performance of the most similar conforming structural treatment control BMP.~~

~~e. A plan is established to decommission or render a facility inoperable in the event it is found to be a significant contributor of pollutants known to cause or contribute to the impairment to a water body that is listed pursuant to CWA Section 303(d) or subject to a TMDL.~~

~~f. The Co-permittees must develop and employ written uniform procedures, which is approved by the Executive Officer, for the preparation, design, and implementation of a performance monitoring plan; the procedures must also provide objective standards and conditions for approving nonconforming structural treatment control BMPs for wider use.~~

~~g. The Co-permittees approve no more than three (3) such similar nonconforming structural treatment control BMPs in total until and unless the results of the performance monitoring plan demonstrate that the nonconforming structural treatment control performs in a similar or better manner as compared to the most similar conforming structural treatment control.~~

~~h. The nonconforming structural treatment control BMP is subject to all other requirements of this Order.~~

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[7]Structural treatment controls that are part of sites in the Co-permittees' industrial and commercial inventories are required to be inspected as part of the requirements of Sections IX and X of this Order. This requirement does not supersede the inspection schedules in those Sections.

2. ~~A~~ Co-permittees must report both the application for approval and approval or denial of any nonconforming structural treatment control BMPs within their jurisdiction to the Principal Permittee.
3. The Principal Permittee is responsible for coordinating the Co-permittees in complying with the requirements of this Subsection.

F. Priority Consideration of Retention LID BMPs in WQMPs

1. The Co-permittees must require that ~~low impact development ("LID") controls~~LID BMPs that employ harvest and use, evaporation/transpiration, infiltration (collectively "retention LID BMPs") , or any combination thereof, of the entire design capture volume be given preference and first consideration in all WQMPs. That consideration must be demonstrated in the approved final Project WQMP.
2. The Co-permittees must require retention LID BMPs for the design capture volume, or the maximum portion thereof; biotreatment LID BMPs may only be used in a manner consistent with the criteria identified in Section XII.G.1 of this Order.~~, wherever, based on Substantial Evidence,~~

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~~as identified in the Orange County Technical Guidance Document,, such controls are:~~

~~a. technically feasible,including not causing or exacerbating a known groundwater quality issue;~~

~~b. economically feasible; AND~~

~~c. where environmental and public health hazards can be mitigated to an acceptable level, consistent with the Orange County Technical Guidance Document~~.

3. Where retention LID BMPs ~~cannot meet~~are not provided for, the full design capture volume, ~~above general criteria,~~ the ~~Co- permittees must document the~~ specific basis for this decision shall be documented based on Substantial Evidence[6] in ~~their rejection in~~ the approved final Project WQMP.

~~The rejection of retention LID BMPs must be supported with Substantial Evidence as identified in the Orange County Technical Guidance Document~~.

4. The Co-permittees must require project applicants to mitigate the environmental and public health hazards of retention LID BMPs to an acceptable level where the absence of such mitigation would, by itself, make the use of retention LID BMPs infeasible. Mitigation is limited to activities within the project site that could be reasonably undertaken as part of the development of the project site and are within the regulatory authority of the Co-permittees to mandate. Mitigation is not necessary if the costs disproportionately outweigh the pollution control benefits; any such finding must be documented in the final WQMP and be supported with Substantial Evidence. The approval of development projects shall not be delayed as a result of the schedule of ongoing or future cleanup activities outside of the control of the project applicant.

G. Secondary Consideration of Biotreatment ~~Control~~ LID BMPs in WQMPs

1. ~~Structural treatment control~~LID BMPs that employ biological uptake, transformation, or degradation of pollutants ("biotreatment ~~control~~ LID BMPs") must be given secondary consideration in the project final WQMP, when, based on Substantial Evidence, as identified in the Orange County TGD,~~,~~ any of the following conditions exist:
   a. Retention LID BMPs have been demonstrated to be technically or economically infeasible;
   ~~b. The hazards of using retention LID BMPs cannot be mitigated to an acceptable level;~~
   b~~c~~. A retention LID BMP is proposed but cannot be sized to treat the tributary area's entire design capture volume and a complementing biotreatment ~~control~~ LID BMP can be designed to treat the remainder of the design capture ~~remaining~~ volume or a portion thereof; OR

[6] [6] "Substantial evidence" is defined in Section 15384 of the CEQA Guidelines (http://resources.ca.gov/ceqa/guidelines/). The Orange County Technical Guidance Document provides feasibility criteria that are based on this definition.

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c~~d~~. A volume-based biotreatment ~~control~~ LID BMP, used as an alternative for the same tributary area, will treat the design capture volume ~~that is 1.5 times that~~ of the retention LID BMP that it replaces.

2. The Co-permittees must ensure that the final approved project WQMP demonstrates preferential consideration of biotreatment control BMPs over non- LID BMPs.
3. When retention LID BMPs are demonstrated to be infeasible according to Section XII.G.1. above, the Co-permittees must require biotreatment ~~control~~ LID BMPs wherever these are:
   a. technically feasible;
   b. economically feasible; ~~AND~~
   ~~c. where the environmental and public health hazards can be mitigated to an acceptable level.~~
4. Where biotreatment ~~control~~ LID BMPs ~~cannot meet~~ are not provided for the ~~above criteria~~entire remainder of ~~, the Co- Permittees must document~~ the design capture volume that was not retained, specific basis for this decision shall be documented ~~their rejection in the approved final WQMP. The rejection of biotreatment control BMPs must be~~ based on Substantial Evidence in the approved final Project WQMP.
5. ~~to an acceptable level where the absence of such mitigation would, by itself, make the use of biotreatment control BMPs infeasible. Mitigation is not necessary if the costs disproportionately outweigh the pollution control benefits; any such finding must be documented in the final WQMP and be supported with Substantial Evidence.~~
5~~6~~. Biotreatment ~~control~~ LID BMPs must be designed to maximize the infiltration of the design capture volume or flow unless they would cause or exacerbate a known groundwater quality issue.

H. Tertiary Consideration of ~~All Other~~ Structural Treatment Control BMPs: Non-LID BMPs

1. The Co-permittees must maintain and employ ~~a common~~ the schedule which rates the expected performance of specific structural treatment control BMPs included in the Orange County TGD~~, or categories of structural treatment control BMPs~~.
   a. Any category of structural treatment control BMPs must include only those controls that employ the same principal of operation; use similar treatment mechanisms, and which can reasonably be expected to exhibit generally similar performance in the removal of pollutants.
   b. The performance of structural treatment control BMPs must be rated based on the reasonably-expected level of removal of categories of pollutants. The performance ratings must be classified as “high”, “medium”, and “low” level of removal. These ratings must be distinguished by fixed numeric thresholds.
   c. The Co-permittees’ assignment of the expected level of performance for the structural treatment control BMPs must be based on the best available objective evidence (i.e. International BMP Database). The

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evidence must include field performance test data specific to the BMP.

~~d. The categorizations of structural treatment control BMPs and their performance ratings must be reviewed bi-annually so that they are supported by the best available information~~.

2. Structural treatment control BMPs, which are not LID BMPs ("non-LID BMPs") may be necessary to complement LID BMPs. Non-LID BMPs must not be accepted in an approved Project WQMP in lieu of LID BMPs unless LID BMPs cannot be employed pursuant to Sections XII.F. and XII.G. above.

3. The Co-permittees must maintain and employ a common schedule of project types and a corresponding common list of pollutants which can reasonably be expected to be found in urban runoff from those project types.

4. If ~~non-LID~~structural BMPs are the only type of ~~structural treatment control~~ BMP employed to treat runoff from a tributary area of a project, the Co-Permittees must only accept the use of ~~non-LID~~ structural BMPs that provide either a "medium" or "high" level of treatment for the expected pollutants.
   a. The Co-permittees must use the performance rating schedule in Provision XII.H.1. above and the project category schedule in Provision XII.H.3. above to identify acceptable ~~non-LID BMPs~~structural treatment control BMps for a project.
   b. Approved WQMPs must reflect the use of this prescribed methodology.

5. If a project does not propose to use any LID BMPs on-site and a regional or sub-regional off-site LID BMP, that meets the requirements in Section XII.K. below, is planned to serve the project, the Co-permittees may require the use of the regional or sub-regional facility. The Co-permittees must require any BMPs that are needed to satisfy pre-treatment requirements for that facility where applicable.

I. Specific Requirements for Infiltration LID BMPs

1. The requirements of this Section apply to retention LID BMPs that are intended to infiltrate the entire design capture volume or a portion thereof (infiltration LID BMPs). The requirements of this Section are not intended to apply to ~~bio-treatment control~~biotreatment LID BMPs or ~~other~~ structural treatment control BMPs
that incidentally infiltrate a portion of the design capture volume or flow.

2. The vertical separation from the bottom of the infiltration facility to the seasonal high groundwater must be a distance of 10-feet or more unless the LID BMP is determined to have a low contamination potential and an embedded pre-treatment layer in which case the vertical separation may be reduced to 5 feet using the evaluation criteria in Appendix VIII of the Orange County TGD.. Where the groundwater does not support, or does not have the potential to support, beneficial uses, the Co-permittee may approve infiltration facilities with less vertical separation provided that groundwater quality is maintained and that other potential hazards

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presented by such facilities can be mitigated to an acceptable level.

3. Infiltration facilities must be located a minimum horizontal distance of 100-feet from any water supply wells.
4. Infiltration facilities must incorporate one or more practical mechanisms to allow verification of the loss rate of the design capture volume. The mechanisms must be durable and useful over the life of the project and designed for the benefit of the party responsible for the operation of the facility.
5. Infiltration facilities which constitute Class V Injection Wells must comply with USEPA's Class V Rule, or as amended or revised[8]. In addition, these wells must also comply with all applicable County and municipal well construction/destruction ordinances and standards.
6. Structural treatment control BMPs must be provided to pre-treat and remove pollutants that could unreasonably diminish the performance of the infiltration facility for the duration of the project unless pre-treatment mechanisms are incorporated in the infiltration facility design itself (e.g., amended soil media).
7. The Co-permittees must develop, utilize the Orange County TGD for ~~publish, and employ a~~ common factor(s) of safety that must be used to size infiltration facilities. The factor(s) of safety must be based on those recommended in published and generally- accepted engineering design manuals.
8. The Co-permittees must utilize the Orange County TGDt for the ~~develop, publish, and employ a uniform~~ protocol for estimating the loss or draw-down rate used for designing LID BMPs that infiltrate.
    a. The protocol must be consistent with those used in published and generally-accepted engineering design manuals.
    b. The protocol must employ the best available information for estimating the loss rate.
    c. The Co-permittees must require that the following categories of projects use relevant site-specific methods to estimate soil infiltration rates:
        i. Residential projects affecting more than 10-acres or greater than 30 dwelling units.
        ii. Commercial or institutional projects affecting more than 5-acres or greater than 50,000 square feet of floor space.
        iii. Industrial projects affecting more than 2-acres or greater than 20,000 square feet of floor space.
9. Infiltration facilities must not be used in areas where there are known groundwater quality issues

J. Specific Requirements for Harvest and Use LID BMPs

1. The Co-permittees must not accept insufficient demand for harvested storm water as the sole basis for rejecting harvest and use LID BMPs unless the basis is supported by water demand calculations. Calculated estimates must demonstrate that the expected wet season water demand is insufficient to use the harvested design capture volume within a 48-hour period according to the following:

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a. The Co-permittees must publish and employ tables of daily average wet-season (October 1st through April 30th) demand rates and objective project characteristics necessary to provide sufficient demand for harvested storm water. The demand rates must be used for estimating anticipated non-potable uses of harvested storm water.

i. The rates and thresholds must be based on published and generally accepted rates or methods for calculating average daily demand of harvested storm water for non-potable uses such as toilet and urinal flushing, landscape irrigation, industrial process supply, evaporative cooling, and vehicle washing.

ii. The rates and thresholds must account for the off-setting effects of rainfall, reclaimed water, water conservation or the inconsistent nature of demand.

iii. Reclaimed water supplies must be based on available supplies, not speculative supplies.

iv. Indoor use of harvested stormwater shall only be considered as the applicable plumbing code allows~~b. Where demand rates are dependent upon variable site occupancy, average daily occupancy during the wet season must be used. For example: Assuming that a school site has zero occupancy on weekends and holidays, if a school site is occupied by 300 people daily, five days a week, 30 out of 34 weeks of the season (to account for four vacation weeks), then the average daily occupancy is approximately 189 people per day. With a *per capita* toilet and urinal flush use rate of 33 gallons per day, the school site would provide average daily demand for up to 12,479 gallons.~~

K. Off-Site Structural Treatment Control BMPs: Regional and Sub-Regional Facilities

1. Where a planned or existing off-site LID BMP is ~~available~~ used to treat runoff from a priority ~~or non-priority~~ project, the project WQMP ~~and non-priority project plan~~ must demonstrate that the ~~priority consideration for~~ use of the off-site facility is consistent with the provisions of this Section (XII.K).
2. Co-permittees must require that structural treatment control BMPs be located on the project site except under the following conditions:
   a. A regional or sub-regional structural treatment control BMP has been planned as part of a Project WQMP for a Specific Plan, parcel map, master tract map, master plan of drainage, or similar larger plan of development that was approved prior to the adoption of this Order and all of the following requirements will be met:
      i. The project and the regional or sub-regional structural treatment control BMP are both located within the approved Specific Plan, parcel map, or similar larger plan of development.

[8] USEPA, Office of Water, "Revisions to the Underground Injection Control Regulations for Class V Wells", 64 FR 68545-68573, December 7, 1999 (or as amended or revised)

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ii. The Project WQMP for the larger plan of development has been prepared and approved according to the requirements of this Order, Order No. R8-2009-0030 or Order No. R8-2002-0010, whichever was in force at the time.

iii. The Project WQMP for the project complies with all other requirements of this Order to the extent that those requirements do not conflict with this Subsection (Subsection XII.K.).

~~iv. Where Order No. R8-2002-0010 was in force at the time of the facility's approval, the project site must employ source and site design BMPs that infiltrate a portion of the design capture volume.~~

vi~~v~~. The regional or sub-regional facility is constructed, serviceable, and satisfactory to the Co-permittee prior to final occupancy or use of the project site(s) in its tributary area.

vi~~i~~. The larger plan of development was approved according to the requirements of CEQA.

b. A regional or sub-regional retention LID BMP has been planned by the Co-permittees, ~~or~~ another public agency, or another legal entity and the following requirements will be met:

i. Site design and source control BMPs have been provided in the project WQMP.

ii. Any structural treatment control BMPs deemed necessary by the party responsible for the facility's performance ("Operator") to pre-treat and remove pollutants that could unreasonably diminish the performance of the facility or cause or contribute to a condition of nuisance over its service life have been provided in the P~~p~~roject WQMP.

iii. An Operator will maintain ownership or control over the facility over the life of projects located within the facility's tributary area.

iv. The facility complies with, and/or is subject to, the requirements in Section XII.D. and, if an infiltration facility, Section XII.I. above.

v. The regional or sub-regional facility is constructed, serviceable, and satisfactory to the Co-permittee prior to final occupancy of the project site(s) in its tributary area.

vi. Approvals related to the facility occur according to the requirements of CEQA.

vii. The project WQMP is otherwise prepared according to the requirements of this Order.

c. A regional or sub-regional biotreatment ~~control~~ LID BMP has been planned by the Co-permittees, ~~or~~ another public agency, or another legal entity, and the following requirements will be

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met:

i. Retention of the design capture volume has been maximized on the project site using site design and source control BMPs.

ii. The requirements in Section XII.J.1.b. (for regional or sub-regional retention LID BMPs above) have been or will be met as appropriate.

d. There is a LID BMP located offsite for which the Co-permittees' approval for use would not otherwise cause the Co-permittee to violate any provision of this Order[9]. This includes, but is not limited to, the requirements to:

~~i. demonstrate consideration of retention LID BMPs on-site;~~

~~ii. maximize retention of the site's design capture volume on-site;~~

iii. demonstrate the capacity of the off-site facility to serve the project;

iv. demonstrate adequate funding for the off-site facility's construction, and/or operation and maintenance for the life of the project; AND

v. place the facility in service prior to final occupancy or use of the project site.

L. Waiver of Structural Treatment Control BMPs

1. Co-permittees are authorized to waive their requirement to provide structural treatment control BMPs (see Provision XII.C.1 above) to remove pollutants and subsequently approve a Project WQMP if all of the following conditions are met:

a. The cost of employing structural treatment control BMPs has been demonstrated in the project WQMP to disproportionately outweigh the pollution control benefits.

b. Source and site design BMPs have been incorporated to maximize the infiltration of urban runoff.

c. The Executive Officer has been provided written notice of the Co-Permittee's intent to issue the waiver, along with adequate supporting documentation, at least 30-days prior to issuance by the Co-permittee.

d. The Executive Officer approves the proposed waiver or takes no action within 30 days.

M. Requirements for Non-Priority Projects

1. Where a non-priority project, as defined in the Orange County Model WQMP, includes modifications or improvements that are, or affect areas that are exposed to storm water or which may be sources of urban runoff, Co-permittees must require non-priority projects (see Section XII.B.) to implement source control and site design BMPs to remove pollutants in urban runoff. ~~This requirement must not be construed to mean that structural treatment control BMPs are not required for non- priority~~

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~~projects; only that there is no presumption requiring rebuttal, that treatment control BMPs are economically or technically feasible.~~

2. ~~2.~~ Source control and site design BMPs must be documented in a Non-Priority Project Water Quality Plan~~Non-Priority Project Plan~~. The Non- Priority Project Plan must include a summary rationale for BMP selection.
3. ~~Non-priority projects may employ source and site design BMPs that rely on~~

[9] In other words, the Co-permittee is faced with the choice of approving a WQMP where either a retention LID control could be located on-site or off-site, or where an eligible biotreatment control could be located on- site or off-site. Except for the facility's location, the approval would not violate the requirements of this Order

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~~the same or similar set of treatment mechanisms used by structural treatment control BMPs or LID BMPs, such as infiltration and harvest and use. In many cases, such controls may resemble structural treatment control BMPs but be substantially deficient relative to sizing and design criteria. These deficiencies may be the only characteristic which distinguishes source and site design BMPs from structural treatment control BMPs. and LID BMPs.~~

~~a. Where substantial deficiencies occur in meeting published and generally accepted engineering design criteria, the Co-permittee must not accept that facility as a structural treatment control.~~

~~b. When practical, Co-permittees must pursue opportunities in good faith to have proposed source control and site design BMPs for non-priority projects modified such that they meet the relevant sizing requirements of this Order (see SectionXII.D. above); substantially conform to published and generally accepted engineering design criteria; and become acceptable structural treatment control BMPs.~~

4. Source and site design BMPs must generally conform to ~~published and generally accepted designs or methods~~the requirements of the Orange County Model WQMP and TGD.
5. ~~Non-priority project plans, that include structural BMPs, must be approved by or under the supervision of a registered civil engineer or licensed landscape architect acting on behalf of, and with the expressed permission of, the applicable Co- permittee.~~

N. Hydrologic Conditions of Concern

1. Co-permittees must address the changes in a priority project site's hydrology in the project WQMP according to the requirements of this Section except under any of the following conditions:
   a. The runoff volume and time of concentration for the two-year frequency, 24-hour storm event are not significantly affected by the project. A significant effect must be deemed to occur only where:
      i. The calculated runoff volume from the site increases by 5% or more over the pre-project condition, and/or
      ii. The calculated time of concentration for runoff from the site decreases by 5% or more over the pre-project condition.
   b. All downstream conveyance channels that will receive runoff from the project are engineered[7]~~, hardened,~~ and regularly maintained to accommodate the necessary design flow capacity as dictated by the latest version of the Orange County Hydrology Manual, and no sensitive stream habitat areas have the potential to be

[7] Engineered channels may include hardened channels and/or channels with engineered grade control structures or similar features designed to provide the necessary flow capacity and to be geomorphically stable under discrete and expected cumulative changes in hydrology.

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adversely affected by discrete or cumulative changes in hydrology.

c. The project has the demonstrated capacity to infiltrate, harvest and use, evaporate, or ~~evapotranspirate~~ evapotranspire the volume of runoff produced by a two-year storm event within a 48-hour period.

d. The Executive Officer grants an individual or general variance in writing to the Permittee(s).

   i. The granting of such variances must be supported by

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objective and relevant studies.

ii. The Co-permittees must comply with any conditions placed on the issuance of the variance by the Executive Officer.

iii. The Executive Officer and the requesting Co-permittee(s) must provide the public an opportunity to comment on the proposed variance for a period of not less than 30-days prior to its issuance.

2. For those priority projects that do not meet the conditions in Subsection XII.N.1. above, the Co-permittees must apply the following conditions:

a. The project WQMP must include a hydrology study that quantifies the pre- and post-project runoff volumes, peak flow rates, and times of concentration for a 2-year storm event.

b. ~~The~~Except as provided in section XII.N.2.c, the project WQMP must provide BMPs that modify runoff ~~flow rates,~~ volumes and times of concentration ~~to pre-~~ from the project site ~~conditions~~ for the~~a~~ 2-year, 24-hour storm such that:

i. Post-project runoff volumes for the 2-year, 24-hour storm event ~~or to within~~do not increase by more than 10% ~~thereof~~compared to the pre-project runoff volumes for the 2-year, 24-hour storm event, and

ii. Post project times of concentration for the 2-year, 24-hour storm event do not decrease by more than 10% compared to the pre-project times of concentration for the 2-year, 24-hour storm event.

c. The provisions of section XII.N.2.b shall apply ~~event or to within 10% thereof~~ unless any of the following have~~s~~ occurred:

i. A Clean Water Act Section 401 Water Quality Standards Certification has been issued authorizing discharges of fill associated with channel modifications that would accommodate the project's changes in hydrology while protecting beneficial uses.

ii. Site design and/or structural treatment control BMPs proposed for the site to reduce pollutants in urban runoff already effectively modify runoff volumes and times of concentration such that they satisfy Provision XII.N.2.b., above.

iii. The Project WQMP has demonstrated that it is infeasible to satisfy the criteria of XII.N.2.b, above, through the use of infiltration and/or harvest and use, and the project has provided site design, structural treatment control, and/or flow control BMPs such that the post-project peak runoff flow rates for the 2-year, 24-hour storm event are not increased by more 10% compared to the pre-project peak flow rates for the 2-year, 24-hour storm event.

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3. Co-permittees must prepare a set of watershed maps that identify management areas tributary to drainages that have not been engineered~~, hardened,~~ and regularly maintained to accommodate the design flow capacity, as dictated by the latest version of the Orange County Hydrology Manual, and where sensitive stream habitat areas have the potential to be adversely affected by discrete or cumulative changes in hydrology (see Provision XII.N.1.b. above).
    a. The Co-permittees must submit the watershed maps in draft form to the Executive Officer for approval no later than 6 months following the adoption of this Order.
    b. The Co-permittees must make changes requested by the Executive Officer within 30-days of receipt of the request. The Executive Officer is authorized to approve the watershed maps conditioned upon completion of the changes.
    c. Upon approval by the Executive Officer, the Co-permittees must consistently use the applicable maps to identify projects that will be subject to the limitations on changes in runoff volumes, ~~and~~ times of concentration, and peak flow rates provided in this Section (Section XII.N.).

O. Alternative Compliance

At the discretion of each Copermittee, Priority Projects may be allowed to participate in an alternative compliance program if implementation of Structural Treatment Control BMPs: Non-LID BMPs identified in Section VII.H. are deemed technically infeasible and there is no Off-Site Structural Treatment Control BMPs identified in Section VII.K available to treat runoff from the project. Alternative Compliance Programs shall be consistent with the elements for alternative compliance identified in the Orange County Model WQMP.

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XIII. PUBLIC EDUCATION AND OUTREACH

a. The Co-permittees must implement an effective public education program that both raises awareness of pollution prevention best practices and causes changes the audiencebehavior of target audiences take action to reduce pollution of urban runoff. The program must include a general audience, consisting of residents of school age and older and commercial and industrial establishments, and a target audience selected from the general audience to address high- priority urban runoff pollution issues identified by the Co-permittees.

b. The public education program must be described in a written plan. The Co-Permittees must:

1. Make a minimum of 10 Million annual impressions on the general audience using educational content in multiple media to raise awareness of pollution in urban runoff;
2. Identify goals and related measurable objectives that address a minimum of three high-priority urban runoff pollution issues over the term of this Order. Issues must be identified for the entire permit area, for each watershed, or for each city;
3. Identify and analyze target behaviors and target audiences for specific behavior-based outreach to address believed to have the greatest influence on the selected high-priority urban runoff pollution issues;
4. Create specific messages that are appropriate to the target audiences and to identified sub-groups within the general audience, where appropriate;
5. Develop educational content for media with the most potential to appeal to the audiences as defined by the Co-permittees in a written plan;
6. Determine the methods and processes of distributing the educational content;
7. Objectively evaluate the effectiveness of the program; AND
8. Provide opportunities for public input, and demonstrate consideration of that input, in the development of the programoutreach campaigns addressing high-priority urban runoff pollution issues identified in written plans.

c. The Co-permittees must provide a rationale in atheir written plan to justify the selected high-priority urban runoff issues and related target audiences.

d. During the term of this Order, the Co-permittees must distribute the educational content, using one or more of the selected methods and procedures determined most appropriate by the Co-permittees. The content must be distributed in a manner that is designed to communicate the program's messages to the general and target audiences annually, beginning with the next full monitoring and reporting period after the adoption of this Order.

e. The Co-permittees must implement an effective program to measure the achievement of the objectives and requirements in Section XIII.

1. The program must include an annual assessment of progress towards meeting the goals and objectives of the education program.
2. The Co-permittees must adapt their educational program in response to

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any shortcomings found as a result of the annual assessment.

3. The program must include a statistically valid survey to measure:
   a. the general audiences' knowledge regarding the sources of urban runoff pollution;
   b. the general audiences' knowledge of the impacts of the pollutant(s) on the environment; awareness of what the general audience can do to help prevent urban runoff pollution; AND
   c. specific changes in the general audiences' behavior(s) to prevent urban runoff pollution.
4. The survey must be completed no later than 60 months from the date of the adoption of this Order.
5. The survey results must be made available to the public through a press-release, web site, or similar method acceptable to the Executive Officer.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

A. Each Permittee shall continue to implement the Model Municipal Activities Program developed by the Permittes for fixed facilities, field operations and drainage facilities to ensure that public agency facilities and activities do not adversely impact water quality.

A. Each Co-permittee must maintain an inventory of fixed facilities, owned or controlled by the Co-permittee, that have the potential to discharge pollutants in urban runoff.
   1. The inventory must include the following:
      a. ~~Flood management and open storm water conveyance systems~~Drainage facilities;
      b. Municipal landfills;
      c. Waste incinerators;
      d. Solid waste transfer facilities;
      e. Land application sites;
      f. Sewage collection and treatment facilities;
      g. Hazardous waste treatment, disposal, and recovery facilities;
      h. Corporation, maintenance, and storage yards;
      i. Airfields;
      j. Parks and cemeteries;
      k. Public buildings (police and fire stations and training facilities, libraries, etc.)
      l. Stadiums;
      m. Equestrian facilities;
      n. Animal shelters and kennels;
      o. Boat yards and marinas;
      p. Public parking facilities; and
      q. Areas or facilities that discharge directly to lagoons, the ocean, or environmentally sensitive areas.

B. The Principal Permittee may propose a schedule for the prioritization, inspection and cleaning of ~~flood management and storm water conveyance~~drainage facilities ~~systems~~ under the Co- Permittees' control. The proposed schedule is subject to the approval of the Executive Officer. If

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approved, the schedule will serve as an alternative to the schedule prescribed by Subsection XIV.C. below.

C. Each Co-permittee must inspect a minimum of 80% of the drainage facilities (catch basins, storm drain inlets, open channels) ~~flood management and storm water conveyance systems~~ under their control annually. 100% of the ~~systems~~ facilities must be inspected every two years. Each Co-permittee must prepare a written inspection and maintenance schedule for each facility subject to this requirement.

1. Accumulated ~~pollutants~~ trash and debris must be removed from ~~below-ground portions of~~ the ~~systems~~ facilities in a timely manner when found.
2. Where other agencies' authorization is required to remove ~~pollutants~~ trash and debris from the ~~systems~~ facilities (i.e. CWA Section 404 permit), the Co-permittee must make a good faith effort to secure the necessary authorizations and remove the accumulated ~~pollutants~~ trash and debris in a timely manner.
3. Co-permittees must exercise their discretion and increase the inspection and cleaning frequency as necessary for those ~~portions of the systems~~facilities which tend to accumulate ~~"unusually large quantities" of pollutants~~trash and debris.
6. Each Co-permittee must have a program ~~n effective management system~~ in place to detect and eliminate or minimize the seepage of wastewater from sanitary sewers to the storm drain system.

D. Except for ~~flood management and storm water conveyance systems~~drainage facilities, each Co- Permittee must categorize fixed facilities that they own or control into "high- priority", "medium-priority", and "low-priority" sites.

1. The Co-permittee must inspect each fixed facility according to the following schedule:
   a. High-priority sites must be inspected once per year.
   b. Medium-priority sites must be inspected once every two years.
   c. Low-priority sites must be inspected once every five years.
2. The following fixed facilities must be categorized as "high-priority" sites:
   a. Municipal landfills
   b. Publicly-owned treatment works
   c. Waste incinerators
   d. Solid waste transfer facilities
   e. Land application sites
   f. Corporation, maintenance, and storage yards
   g. Hazardous waste treatment, disposal , and recovery facilities
   h. Land-side areas of airfields
   i. Facilities that are located adjacent or within an environmentally sensitive area or that discharge directly to an environmentally sensitive area.
3. Co-permittees must categorize all other fixed facilities according to a uniform objective ranking system developed by the Principal Permittee. The ranking system must be based on the following factors:
   a. The degree to which potentially polluting activities occur in areas exposed to storm water.
   b. The quantity of potentially polluting materials used or stored at the facility.

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c. Whether or not the activities at a site could produce pollutants that cause or contribute to the impairment of a water body listed according to CWA Section 303(d).
d. The risk of a release of a pollutant.
e. The occurrence of known or suspected non-storm water discharges.
f. ~~and the number of employees assigned to the~~

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~~facility~~.

4. Co-permittees must carry out inspections of fixed facilities to: identify and correct observed violations of the municipal code or ordinance related to protecting water quality; identify and correct unnecessary deviations from standard operating procedures (see Section XIV.E. below); internally enforce relevant discharge requirements; and identify and eliminate or minimize known or suspected non-storm water discharges.

E. Co-permittees must implement an effective program to prevent the discharge of pollutants from Co-permittees' field activities and fixed facilities.

1. ~~The program must include the imposition of written standard requirements on the person(s) performing field activities on behalf of Co-permittees. The requirements must direct the person(s) to effectively employ BMPs that are specific and relevant to the activity to prevent the discharge of pollutants to storm water.~~
2. The program must include written standard operating procedures for Co-Permittees' staff that engage in field activities and activities at fixed facilities that have the potential to discharge pollutants in urban runoff.

a. The standard operating procedures must incorporate BMPs to prevent or minimize such discharges of pollutants.

b~~. The standard operating procedures must be subject to an annual review to verify their relevance and effectiveness. Each standard operating procedure must display the date of the last review, the identity of the reviewing personnel, and the due date for the next review.~~

~~3~~. The program must include a training program to provide Co-permittees' staff with an awareness of the responsibilities described in standard operating procedures relevant to their duties (See Section XVI below).

4. The program must include an inspection program for field activities ~~to: identify and correct observed violations of the municipal code or ordinance related to protecting water quality; identify and correct unnecessary deviations from standard operating procedures; internally enforce compliance with relevant waste discharge requirements; and identify and eliminate or minimize known or suspected non-storm water discharges~~.
5. ~~The program must include disciplinary procedures or policies for Co-permittees' staff that unnecessarily deviate from standard operating procedures.~~

F. Each Co-permittee must implement an effective program: to reduce the use of unwarranted or excessive applications of pesticide and fertilizer at facilities that they own or control; to ensure that pests are controlled using the best available methods while protecting water quality; and to ensure that pesticides are used in accordance with Federal, State, and local laws and regulations.

1. Each Co-permittee must develop and implement Integrated Pest Management, Pesticide and Fertilizer Guidelines.
2. Each Co-permittee must review pesticide applications of ~~conduct annual integrated pest management audits for~~ chemicals known or suspected of impairing water quality to enforce the use Integrated Pest Management Strategies that reduce their potential entry into MS4s.

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3. Each Co-permittee must review ~~conduct~~ annual fertilizer use ~~audits~~ to verify that application rates do not exceed those recommended by University of California Integrated Pest Management Research, or similarly qualified organizations, and to enforce fertilizer application methods that eliminate or minimize fertilizer entry into MS4s.

XV. MUNICIPAL CONSTRUCTION PROJECTS AND ACTIVITIES

A. This Order authorizes the discharge of storm water runoff from construction projects that are under the ownership or direct responsibility of any of the Co-Permittees and that may result in land disturbance of one acre or more; or less than one acre if the project is part of a larger common plan of development or sale which is one acre or more.

B. All construction activities must be in compliance with the conditions and provision of the latest version of the State Board's General Permit for Storm Water Discharges Associated with Construction and Land Disturbance Activities (NPDES Permit No. CAS000002) with the following exceptions:
   1. A Notice of Intent does not need to be submitted to the State Board. However, an alternate report of waste discharge, acceptable to the Executive Officer, must be provided.
   2. A Notice of Termination does not need to be submitted. However, an alternative notice, acceptable to the Executive Officer, must be provided upon completion of the project.
   3. The conditions and provisions in this Order pertaining to post-construction BMPs prevail.

XVI. TRAINING PROGRAMS

A. Each Co-permittee must have an effective training program for their staff, contractors and vendors whose duties or responsibilities directly or indirectly affect the Co-permittee's capacity to satisfy the requirements of this Order (collectively, "personnel").
   1. Those personnel include, but are not limited to, the following:
      a. Storm water program managers;
      b. CEQA practitioners;
      c. Inspectors;
      d. Maintenance personnel;
      e. Plan checkers;
      f. Planners;
      g. The division heads of all of the above staff;
      h. Contractors and vendors who perform duties similar to the above staff.
   ~~2. Each Co-permittee must maintain a roster of personnel or staff positions whose duties or responsibilities directly or indirectly affect the Co-Permittee's capacity to satisfy the requirements of this Order.~~

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3. Except for industrial, commercial, and construction site inspectors, personnel must undergo training a minimum of once every two years. New hires must receive their initial training within 6 months of their initial hire date.
4. The training program must be subjected to an annual review, for the purpose of achieving continual improvement of its effectiveness, and must be updated accordingly.
5. Training materials must be written in plain, straightforward language, avoiding technical terms as much as possible, and using a coherent and easily readable style. ~~Training materials must not exceed a 13th grade reading level. The materials' readability must be measured using published and generally accepted methods (e.g. Flesch Kincaid Grade Level, Automated Readability Index, etc).~~
6. The Co-permittees must employ a method that objectively demonstrates that personnel individually have the necessary level of expertise and competence commensurate with their duties and responsibilities.
7. The Co-permittees must maintain records demonstrating that personnel have satisfied the requirements of the training program; records must be maintained for a minimum of three (3) years.
8. Training records must be maintained for ~~as part of~~ staff, ~~personnel records and~~ contractors, and vendors ~~records,~~ as part of a region-wide training registry, or through another mechanism acceptable to the Executive Officer.

B. The Principal Permittee must establish a written training curriculum for use by the Co-permittees. The contents of the curriculum must be commensurate with the duties and responsibilities of the affected personnel.
1. ~~At a minimum,~~ The Co-permittees should consider training all affected personnel ~~must be trained~~ in the following subject matter:
    a. An overview of Federal, state and local water quality laws and regulations pertaining to urban runoff.
    b. The potential direct and indirect impacts of urban runoff on receiving waters.
    c. Current water quality impairments.
    d. The potential sources of pollutants in urban runoff.
    e. Specific actions that personnel are obligated to take to reduce pollutants in urban runoff.
2. The Co-permittees should consider training~~At a minimum,~~ personnel who are responsible for inspecting construction sites ~~must be trained~~ in the following subject matter:
    a. Federal, state and local water quality laws and regulations pertaining to construction and grading activities.
    b. The potential effects of construction and grading activities and urbanization on water quality.
    c. The proper application and use of erosion and sediment control BMPs.
    d. The Co-permittee's enforcement tools and procedures.
3. The Co-permittees should consider training ~~At a minimum,~~ personnel responsible for inspecting commercial and industrial sites ~~must be~~

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~~trained~~ in the following subject matter:

a. Federal, state and local water quality laws and regulations

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pertaining to commercial and industrial activities.
   b. The potential effects of commercial and industrial activities and urbanization on water quality.
   c. The proper application and use of non-structural and structural treatment control BMPs.
   d. The Co-permittee's enforcement tools and procedures.
4. The Co-permittees should consider training~~At a minimum,~~ personnel responsible for inspecting restaurants ~~must be trained~~ in the following subject matter:
   a. Proper oil and grease disposal.
   b. Proper housekeeping of trash bins and trash bin enclosures.
   c. Proper cleaning of floor mats, mops, filters, and garbage containers and proper disposal of related waste water.
   d. Proper methods of cleaning parking lot areas.
   b. Proper spill clean-up methods.
   c. Proper operation and maintenance of devices designed to separate fat, oil, and grease from wastewater.
   d. The Co-permittee's enforcement tools and procedures.
5. The Co-permittees should consider training ~~At a minimum,~~ personnel responsible for investigating, eliminating or permitting illicit discharges and illicit connections ~~must be trained~~ in the following subject matter:
   a. The potential effects of illicit discharges and illicit connections on water quality.
   b. SSO and general spill response and coordination procedures.
   c. Investigation techniques and procedures.
   b. The Co-permittee's enforcement tools and procedures.
6. The Co-permittees should consider training ~~At a minimum,~~ personnel responsible for preparing, reviewing or approving Water Quality Management Plans or Non-Priority Project Water Quality Plans ~~non-priority project plans~~ or for ensuring their implementation ~~must be trained~~ in the following subject matter:
   a. The requirements found in Section XII of this Order.
   b. The related written processes, procedures, and methods for selecting, sizing, and designing source control, site design, and structural treatment control BMPs.
   c. Investigation techniques and procedures.
   d. The Co-permittee's enforcement tools and procedures.

XVII. NOTIFICATION REQUIREMENTS

A. When Co-permittees become aware of a site or incident within their jurisdiction that poses an imminent threat to human health or the environment, the Co-Permittee(s) must take the following actions:
   1. Provide oral or electronic mail notification to Regional Board staff of the imminent threat within 24 hours of becoming aware.
   2. Submit a written report within five (5) business days following the initial notification to Regional Board staff. The report must provide the following

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information:

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a. Details of the location, nature and circumstances of the threat to human health or the environment.
b. Details of any corrective action(s) taken or planned to mitigate the threat and prevent its reoccurrence.
c. Identity of the responsible parties.
d. Describe any enforcement actions taken or planned by the Co-Permittee.

3. Record incidences and the related report in the applicable construction, industrial or commercial site database.

B. For the purposes of this Section, sewage spills in excess of 1,000 gallons and all reportable quantities of hazardous waste spills, as per 40 CFR § 117 and 40CFR § 302, constitute imminent threats to human health or the environment.

C. If, during the course of a site inspection or complaint investigation, Co-permittees or their representatives become aware of a known, suspected, or threatened violation of applicable waste discharge requirements (i.e. State-wide General Industrial or Construction Permits, etc.), the Permittee must provide written notice to the Executive Officer.

1. Where circumstances do not pose an imminent threat to human health or the environment, the written notice must be provided on a quarterly basis. For the purposes of this Provision, each quarter of the monitoring and reporting period constitutes a reporting period, with the notice due within 30-days of the end of each period.
2. The notice must include the location, nature and circumstance of the known, suspected, or threatened violation(s); prior history of any relevant violations of state and local requirements; and action(s) taken or planned by the Co-permittee(s) to bring the site operator into compliance.

XVIII. TOTAL MAXIMUM DAILY LOAD IMPLEMENTATION

A. TMDL Provisions

1. The responsible Co-permittees must implement BMPs to achieve the Waste Load Allocations ("WLAs") specified in Appendices B through H of this Order[10]. The responsible Co-permittees must comply with all other requirements in those Appendices.

2. Effluent limitations are generally expressed in numerical form. However, USEPA guidance[8,9] provides discretion for how TMDLs should be incorporated into

[8] USEPA, 2002. Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. P. 4.

[9] USEPA, 2010. Revisions to the November 22, 2002 Memorandum "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on

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permits for NPDES-regulated municipal and small construction stormwater discharges, including expressing effluent limitations as BMPs or other similar requirements rather than as numeric effluent limitations.

3. Consistent with USEPA's recommendation, this section implements TMDLs through an iterative BMP approach capable of achieving the WLAs in accordance with the associated compliance schedule (e.g,. BMP-based compliance). The Permit includes numeric WLA as a performance standard and not as an effluent limitation. The WLA can be used to assess if additional BMPs are needed.

4. The provisions of this Part I implement and are consistent with the assumptions and requirements of all waste load allocations (WLAs) established in TMDLs for which some or all of the Permittees in this Order are assigned.

   a. TMDL-specific provisions are grouped by watershed in Appendix A.

   b. The Permittees subject to each TMDL are identified in Appendix A.

   c. The Permittees shall implement BMPs to achieve the applicable TMDL provisions contained in Appendix B through H, consistent with the assumptions and requirements of the WLAs established in the TMDLs, including implementation plans and schedules, where provided for in the State adoption and approval of the TMDL (40 CFR§122.44(d)(1)(vii)(B); Cal. Wat. Code §13263(a)). Where an implementation plan and schedule is not provided for a particular TMDL in Appendix B through H (e.g., TMDLs promulgated by USEPA), Permittees shall either demonstrate the applicable WLA has been achieved by the effective date of this Order, or, demonstrate compliance through any one of the means identified in Provision XVIII.B.

   d. A Permittee may comply with the applicable TMDL provisions in Appendix B through H using any lawful means, including the compliance mechanisms identified in Provision XVIII.B.

   e. Compliance with the requirements of Provision XVIII.B ~~the TMDL requirements for a pollutant(s) in Subsections XVIII.A. through XVIII.C. satisfies Subsections~~the requirements for the relevant water quality standard(s) in Provisions IV.A. through IV.C. ~~above for the relevant water quality standard(s).~~

~~A.~~B. Compliance Determination

1. By the final compliance date applicable to the relevant TMDL (specified in Appendices B through G), a Permittee shall be considered in compliance with an applicable TMDL if any one of the following is demonstrated:

   a. The Permittee, or group of Permittees, has notified the Executive Officer, through written notice, of the intent to develop a plan to achieve the applicable WLAs. Upon approval from the Executive Officer, the Permittee(s) must fully implement the plan.

Those WLAs."

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i. To be considered fully implementing an approved plan, a Permittee must be implementing all actions consistent with the approved plan and applicable schedules.

ii. A Permittee that does not implement the plan in accordance with the milestones and compliance schedules shall demonstrate compliance with the TMDL provisions pursuant to Provision XVIII.B.1.b – e.;

iii. This option applies to all TMDLs, including TMDLs where the implementation schedule has not yet passed, TMDLs where no implementation schedule has been specified (e.g., EPA promulgated TMDLs), or where the implementation schedule has passed.

iv. Plans must be developed according to the requirements specified in Provision XVIII.B.2.; **OR**

b. There are no exceedances of WLA(s) in the receiving water at the monitoring location(s) designated by the applicable TMDL to assess achievement of the WLA(s); **OR**

c. There are no exceedances of WLA(s) at the Permittee's applicable MS4 outfall(s). The monitoring location(s) must be designated pursuant to the requirements of MRP R8-2014-0002; **OR**

d. There is no discharge from the Co-permittees' MS4 to the receiving water during the time period subject to the WLA; **OR**

e. Exceedances of a WLA occur at a frequency that is less than or equal to the frequency specified in the "Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List" (September 2004) as amended or revised[11].

2. If a Permittee, or group of Permittees, elects to prepare a plan to comply with the applicable TMDL provisions pursuant to Provision XVIII.B.1.a, the plan must be comply with the following requirements:

a. Draft plans must be submitted per the following timeline:

i. For TMDLs where a plan is not a required element of the implementation plan section of the Basin Plan Amendment (e.g., EPA promulgated TMDLs), the draft plan must be submitted within 18 months of the written notice of intent for plan development.

ii. For TMDLs where a plan is a required element of the implementation plan section of the Basin Plan Amendment, the draft plan must be submitted consistent with the schedule of the Basin Plan Amendment.

iii. For TMDLs where a plan has already been developed and is currently being implemented, Permittees may request in their written notification that the Executive Officer approve the plan as equivalent to the requirements of this Provision XVIII.B.2. Upon

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approval, the plan will satisfy the requirement of this Provision XVIII.B.2.

b. A plan can be developed separately for an individual TMDL, or, several TMDLs can be combined and addressed in one plan.

c. For TMDLs where a plan is a required element of the Basin Plan Amendment, the development and implementation of the plan, including any associated schedules, review periods, and modifications, must be consistent with the requirements of the Basin Plan Amendment.

d. For TMDLs where a plan is not a required element of the Basin Plan Amendment, plans must:

i. Characterize water quality in the receiving waters, as it pertains to the relevant TMDL(s);

ii. Characterize contributions of MS4 discharges to exceedances in receiving waters

iii. Describe BMPs that are currently employed to control the pollutant(s)

iv. Describe any proposed new BMPs, or modification of currently employed BMPs, necessary to achieve the WLAs.

v. Include an analysis that provides reasonable assurance that the identified BMPs will achieve the WLAs. Such analysis can include trend analysis, acceptable to the Executive Officer, that demonstrates no additional BMPs are necessary to achieve the WLA(s).

vi. Identify an adaptive management process that evaluates the effectiveness of the BMPs and provides for modifications of the plan as necessary to achieve the WLAs

vii. Identify a schedule that includes key milestones and specific dates for the implementation of the BMPs.

viii. Draft plans are subject to review and approval by the Executive Officer. Permittees must modify the plan within 60-days of written notification by the Executive Officer. Upon approval by the Executive Officer, the plan is considered final and must be fully implemented by the Permittee(s).

ix. Prior to Executive Officer approval, each plan will be subject to a 30-day public review period.

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e. All final plans must be made available to the public and posted to the Permittee(s) website(s), the Principal Permittee's website, or another method acceptable to the Executive Officer.

~~B~~E ~~Discharges from the Co-permittees' MS4s must comply with the applicable WLAby the compliance date specified in Appendices B through H of this Order, or where no compliance date is specified, upon the effective date of this Order unless:~~

~~1. The responsible Co-permittee, or group of Co-permittees has notified the Executive Officer in writing of their intent to develop a plan to achieve compliance with one or more relevant WLAs in lieu of immediate compliance with those WLAs according to Subsection XVIII.C. below; and other requirements described in Subsection~~

[10] WLAs and other requirements are subject to change through the Basin Plan Amendment process during the term of this Order. When and if WLAs are modified through a Basin Plan Amendment, ~~T~~this Order may be modified, revoked or reissued prior to its expiration date to incorporate any requirements imposed upon the Co-permittees through the ~~TMDL process~~relevant Basin Plan Amendment. See Provision XXII.A.4.

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~~XVIII.C. below are complied with; OR~~

~~2. There are no exceedances of WLA(s) at the designated monitoring location(s) for an outfall or receiving water body. The monitoring location must be designated pursuant to the requirements of MRP R8-2014-0002; OR~~

~~3. There is no discharge from the Co-permittees' MS4 to the receiving water during the time period subject to the WLA; OR~~

~~4. Exceedances of a WLA occur at a frequency that is less than or equal to a site-specific exceedance frequency specified in the "Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List" (September 2004) as amended or revised[11].~~

~~C. If a responsible Co-permittee, or group of Co-permittees elects to prepare and implement a plan to comply with WLA(s) and related requirements in Appendices B through H, they must notify the Executive Officer in writing of their intent. The plan must be prepared according to the following requirements:~~

~~1. Unless discharges are not in compliance with WLAs, an initial draft plan must be submitted within 18 months of the date of the responsible Co-permittee's submittal of a written notice to the Executive Officer of the intent to prepare and implement a plan. If discharges are not in compliance with WLA(s), an initial draft plan must be submitted to the Executive Officer within 6 months of the Co-permittee's submittal of their written notice.~~

~~2. The draft and final plan must:~~

~~a. describe the pollutant(s) that are known or suspected of causing or contributing to actual or potential exceedance(s);~~

~~b. describe the persons or activities believed to cause or contribute to the pollutant(s);~~

~~c. describe the BMPs that are being employed to control the pollutant(s);~~

~~d. describe any proposed new BMPs, or modification of currently-employed BMPs, along with a schedule for their implementation to comply with the applicable WLA(s);~~

~~e. include an objective analysis which provides a reasonable assurance that the new or modified BMPs can be expected to cause discharges to comply with the applicable WLA(s); AND~~

~~f. include a monitoring program and periodic review to characterize the affective discharge(s) and to objectively assess the effectiveness of BMPs employed to address the exceedance(s)[12]; OR~~

~~g. provide objective evidence, acceptable to the Executive Officer,~~

[11] Available at: www.waterboards.ca.gov/water_issues/programs/tmdl/docs/ffed_303d_listingpolicy093004.pdf

[12] ~~Monitoring programs should not be designed to negate the prior monitoring results; such efforts will indicate deficiencies in the overall monitoring program and will require program improvements. Additional monitoring should be designed to characterize the severity and distribution of exceedances and inform the BMP improvement process.~~

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~~that there is a trend indicating that relevant pollutant loads or concentrations are decreasing and that the applicable WLA(s) may be satisfied without further intervention.~~

~~3. The draft plan is subject to review and approval by the Executive Officer. The Co-permittees must make any such modifications to the plan within 60-days of written notification by the Executive Officer.~~

~~4. The Executive Officer will provide a 30-day public review period prior to approving the draft plan.~~

~~5. If, following the approval and implementation of a final plan, subsequent monitoring demonstrates that discharges continue to exceed the WLA(s), the responsible Co-permittees must revise or amend the plan according to the requirements of this Section.~~

~~6. The Co-permittees must make a final plan accessible to the public by posting the plan to the responsible Co-permittees' web sites, the Principal Permittee's web site, or another method acceptable to the Executive Officer.~~

~~7. Except for inconsequential grammatical or technical corrections, the final plan may be amended by the Co-permittees only with the approval of the Executive Officer.~~

~~D. The draft plan becomes a final plan and must be fully implemented upon approval by the Executive Officer.~~

E. ~~Compliance with the TMDL requirements for a pollutant(s) in Subsections XVIII.A. through XVIII.C. satisfies Subsections IV.A. through IV.C. above for the relevant water quality standard(s).~~

XIX. PROGRAM EFFECTIVENESS ASSESSMENTS

A. Each Co-permittee must have a program in place to ~~objectively~~ assess the effectiveness of best management practices and/or the overall stormwater program~~employed in each of the elements of their storm water program~~. The program must be documented in writing.

B. The Principal Permittee must develop a model program effectiveness assessment. The model assessment must address storm water program elements that are common to all or a majority of the Co-permittees and that are necessary to compile information on the overall performance of the Co-Permittees' collective efforts.

C. Each Co-permittees' programs must be comprised of the following elements:

~~1. Conceptual generalized model(s) of how each pollutant, or functionally similar group of pollutants, are released to the environment and transported to the receiving water(s) (pollution process).~~

~~2. A list of each of the best management practices (interventions) in the pollution process and where in the process they are intended to be applied.~~

3. A system to ~~objectively~~ measure the performance of each ~~intervention~~ BMP or group of ~~interventions~~BMPs. The system must include valid performance metrics (or measures), the method(s) to measure and analyze the metrics, and a method to track and document outcomes.

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4. Annual evaluation of the ~~validity of the~~stormwater program; how effective the ~~interventions~~ BMPs are in achieving the desired outcomes; if the performance metrics and the method(s) for measuring outcomes are valid; and any changes found necessary to improve the effectiveness of the ~~interventions~~ BMPs or the overall ~~process~~stormwater program.

D. Each Co-permittee must perform assessments of their best management practices and/or overall stormwater program annually. The results must be included in the Annual Progress Report (see Monitoring and Reporting Program No. R8-2014-0002). Reported outcomes must be expressly compared to the ~~objective~~ requirements of this Order (prescribed performance standards) where they are provided. The Principal Permittee is responsible for compiling and analyzing information where necessary to demonstrate compliance with the requirements of this Order.

E. Each Co-permittee must have an effective mechanism that solicits input from stakeholders in the development and implementation of the program effectiveness assessments.

XX. FISCAL ANALYSIS

D. The Co-permittees must prepare and submit a unified fiscal analysis to the Executive Officer of the Regional Board. The analysis must conform to fiscal reporting guidance issued by USEPA when available. The analysis must be submitted with the Annual Progress Report (see Monitoring and Reporting Program No. R8-2014-0002) and, at a minimum, include:

1. An accounting of each Co-permittee's expenditures for the previous fiscal year;
2. An accounting of each Co-permittee's budget for the current fiscal year;
3. A description of the source of funds; AND
4. Each Co-permittee's estimated budget for the next fiscal year.

XXI. PROVISIONS

A. All reports that are submitted by the Co-permittees according to the requirements of this Order and which are subject to the approval of the Executive Officer will be publicly-noticed and made available at the Regional Board's web site or through other means. Noticed reports will be subject to public review and comment. The Executive Officer will consider all comments received prior to approval of the reports. Any unresolved, significant issues will be scheduled for a public hearing at a Regional Board meeting prior to approval by the Executive Officer.

B. The Co-permittees must comply with the requirements of Monitoring and Reporting Program No. R8-2014-0002 ("MRP"), as amended or revised during the term of this Order. The MRP is hereby made a part of this Order. The requirements of the MRP are subject to revision under the direction of the Executive Officer.

1. Any proposed revisions to the MRP must be submitted in writing to the

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Executive Officer for approval.

2. The Principal Permittee must provide public notice of any proposed revisions. The public notice must include direct notice given to potential and known interested stakeholders.
3. The Executive Officer must provide a minimum of 20-days to interested parties to comment before approving any revisions.
2. The Co-permittees must make available to the public the results of field and laboratory analyses performed on all samples collected pursuant to the MRP.

C. The NPDES program requirements contained in 40CFR§122.21(a), (b), (d)(2), (f), (p), (h), (i), (j), (k), and (l); and 40CFR§122.42(c) are incorporated into this order by reference.

D. The Co-permittees must report to the Executive Officer of the Regional Board any known discharges of storm water or non-storm water which may have an impact on human health or the environment.

E. The Co-permittees must report to the Executive Officer any suspected or known activities on federal, state, or other entity's land or facilities where the Co-Permittees do not have jurisdiction, where the activities may be contributing pollutants to waters of the U.S.

XXII. PERMIT MODIFICATION

A. In accordance with 40CFR§122.41(f), this Order may be modified, revoked or reissued prior to its expiration date for the following reasons:

1. To address significant changes in conditions identified in the technical reports required by the Regional Board which were unknown at the time of the issuance of this Order;
2. To incorporate applicable requirements of state-wide water quality control plans adopted by the State Water Resources Control Board or any amendments to the Basin Plan approved by the Regional Board, the State Board, and, if necessary, by the Office of Administrative Law;
3. To comply with any applicable requirements, guidelines, or regulations issued or approved under the Clean Water Act, if the requirements, guidelines, or regulations contain different conditions or additional requirements than those included in this Order; OR
4. To incorporate any requirements imposed upon the Co-permittees through the TMDL process.

B. The filing of a request by the Co-permittees for modification, revocation, and reissuance or termination or a notification of planned changes or anticipated noncompliance does not stay any conditions of this Order.

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XXIII. PERMIT EXPIRATION AND RENEWAL

A. This Order will expire on MONTH DAY, 2019. The Co-permittees must file a report of waste discharge (permit application) no later than 180 days in advance of the expiration of this Order after which this Order may be administratively extended (40 CFR §122.6). The submittal of a report of waste discharge will constitute an application for issuance of new waste discharge requirements (40 CFR § 122.41(b)).
B. All permit applications (reports of waste discharge), Annual Progress Reports, and other information submitted under this Order must be signed by either a principal executive officer or a ranking elected official (40 CFR § 122.22(a)(3)) or a duly-authorized representative as per 40 CFR § 122.22(b).
C. This Order shall serve as a National Pollutant Discharge Elimination System (NPDES) Permit pursuant to Section 402(p) of the Clean Water Act, or amendments thereto. This Order shall become effective fifty (50) days after the date of its adoption, provided that the Regional Administrator of the USEPA has no objections. If the Regional Administrator objects to its issuance, this Order shall not become effective until such objection is withdrawn.
D. Except for enforcement purposes, Order No. R8-2009-0030 is hereby withdrawn upon the effective date of this Order.

XXIV. STANDARD PROVISIONS

A. Duty to Comply
   1. The Co-permittee(s) must comply with all of the conditions and provisions of this Order. Any noncompliance with the requirements of this Order constitutes a violation of the CWA and the CWC. Noncompliance is grounds for enforcement action and/or removal from Permit coverage.
   2. Any failure to take appropriate corrective action(s) as specified in this Order or as directed by the Executive Officer is also a violation of this Order.
   3. The Co-permittee(s) must comply with effluent standards or prohibitions established under section 307(a) of the CWA for toxic pollutants. Compliance must be achieved within the time provided in the regulations that establish these standards or prohibitions, even if this Permit has not yet been modified to incorporate the requirement.
B. General Permit Actions

   If any toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is promulgated under section 307(a) of the CWA for a toxic pollutant which is present in the discharge and that standards or prohibition is more stringent than any limitation on the pollutant in this Permit, this Permit shall be

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modified or revoked and reissued to conform to the toxic effluent standard or prohibition and the Co-permittees so notified.

C. Need to Halt or Reduce Activity Not a Defense

It shall not be a defense for a Co-permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this Permit.

D. Duty to Mitigate

The Co-permittee(s) must take all responsible steps to minimize or prevent any discharge which has a reasonable likelihood of adversely affecting human health or the environment.

E. Proper Operation and Maintenance

The Co-permittees must at all times properly operate and maintain any facilities and systems of treatment and control (and related equipment and apparatuses) which are installed or used by the Co-permittee to achieve compliance with the conditions of this Permit. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. Proper operation and maintenance may require the operation of back-up or auxiliary facilities or similar systems installed by a Co-permittee when necessary to achieve compliance with the conditions of this Permit.

F. Property Rights

This Permit does not convey any property rights or any sort of exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor does it authorize any infringement of Federal, State, or local laws or regulations.

G. Duty to Provide Information

The Co-permittees must provide to the Regional Board, State Board, or USEPA, within a reasonable time, any requested information to determine compliance with this Permit. The Co-permittees must also furnish, upon request, copies of records that are required to be kept by this Permit.

H. Inspection and Entry

1. The Co-permittees must allow Regional Board staff, State Board staff USEPA staff, or an authorized representative of the municipal operator of the MS4 receiving the discharge, upon the presentation of credentials and other documents as may be required by law, to:
    a. Enter upon the Co-permittees premises at reasonable times where a regulated activity is being conducted or where records must be kept under the conditions of this Permit;
    b. Access and copy at reasonable times any records that must be kept under the conditions of this Permit.
    c. Inspect at reasonable times the facility; AND
    d. Take pictures, collect samples, collect evidence, or monitor at

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reasonable times for the purpose of ensuring Permit compliance.

I. Monitoring and Records
   1. Samples and measurements taken for the purpose of monitoring must be representative of the monitored activity.
   2. Records of monitoring must include:
      a. The date, exact place, and time of sampling or measurements;
      b. The date(s) analyses were performed;
      c. The individual(s) who performed the analyses;
      d. The analytical techniques or methods used; AND
      e. The results of such analysis.
   3. The Co-permittees must maintain a paper or electronic copy of all storm water monitoring information, copies of all reports (including the Annual Progress Reports), SWPPPS, and all other required records, including a copy of this Permit, for a period of at least five (5) years from the date generated or date submitted, whichever is later.

J. Electronic Signature and Certification Requirements

All Annual Progress Reports or other information required by this Permit or requested by the Regional Board, State Board, USEPA, or local storm water management agency must be certified and submitted by the Legally Responsible Person ("LRP") or the LRP's Approved Signatory.

K. Certification

Any person signing documents under Section XXIV.J. above, must make the following certification:

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for information submitted is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

L. Anticipated Noncompliance

The Co-permittee(s) must give notice to the Regional Board and local storm water management agency of any planned changes in any municipal activity which may result in noncompliance with this Permit's requirements.

M. Penalties for Falsification of Reports

Section 309(4) of the CWA provides that any person who knowingly makes a false material statement, representation, or certification in any record or other document submitted or required to be maintained under this Permit, including reports of compliance or noncompliance shall, upon

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conviction, be punished by a fine of not more than $10,000 or by imprisonment for not more than two years, or by both.

N. Oil and Hazardous Substance Liability

Nothing in this Permit shall be construed to preclude the institution of any legal action or relieve the Co-permittee(s) from any responsibilities, liabilities, or penalties to which the Co-permittee(s) is or may be subject to under Section 311 of the CWA.

O. Severability

The provisions of this Permit are severable; and, if any provision of this Permit or the application of any provision of this Permit to any circumstance is held invalid, the application of such provision to other circumstances and the remainder of this Permit shall not be affected thereby.

P. Penalties for Violations of Permit Conditions

Section 309 of the CWA provided significant penalties for any person who violated a permit condition the implements Sections 301, 302, 306, 307, 308, 318, or 405 of the CWA or any permit condition or limitation implementing any such section in a permit issued under section 401. Any person who violated any permit condition of this Permit is subject to civil penalty not to exceed $37,500 per calendar day of such violation, as well as any other appropriate sanction provided by Section 309 of the CWA. The Porter-Cologne Water Quality Control Act also provides for civil and criminal penalties, which in some cases are greater than those under the CWA

Q. Transfers (not applicable)

R. Continuation of Expired Permit

1. This Permit continues in full force and effect until a new Permit is issued or the Regional Board rescinds this Permit.
2. Only those Co-permittees authorized to discharge under the expiring Permit are covered by the continued Permit.

S. Other Federal Requirements

All other requirements of 40 CFR § 122.41 and 40 CFR § 122.42 are incorporated into this Permit by reference.

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ACRONYMS

ASBS Areas of Special Biological Significance

BMPs Best Management Practices

CCC Criterion Continuous Concentration

CCR California Code of Regulations (State Water Board regulations are in Title 23)

CEQA California Environmental Quality Act

CFR Code of Federal Regulations

CMC Criterion Maximum Concentration

CTR California Toxics Rule

CWA Clean Water Act

CWC California Water Code

DAMP Drainage Area Management Plan

DDT Dichlorodiphenyltrichloroethane

HCA Health Care Agency

LA Load Allocation

LID Low Impact Development

LIP Local Implementation Plan

LRP Legally Responsible Person

MOU Memorandum of Understanding

MPN Most Probable Number

MRP Monitoring and Reporting Program, R8-2014-0002

MS4 Municipal Separate Storm Sewer System

NPDES National Pollutant Discharge Elimination System

PCB Polychlorinated Biphenyl

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PEA Program Effectiveness Assessment

POTW Publicly-Owned Treatment Works

SARA Superfund Amendments and Reauthorization Act of 1986

SIC Standard Industrial Classification

SIP State Implementation Plan or, more formally, Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California

SSO Sanitary Sewer Overflow

SWAMP Surface Water Ambient Monitoring Program

SWRCB State Water Resources Control Board

TDS Total Dissolved Solids

TMDL Total Maximum Daily Load

USEPA United States Environmental Protection Agency

~~**WEF** Water Environment Federation~~

WDID Waste Discharger Identification

WDR Waste Discharge Requirements

WLA Waste Load Allocation

WQMP Water Quality Management Plan

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GLOSSARY

This Glossary has been prepared for the convenience of the reader. This Glossary is not an exhaustive catalog of terminology used in this Order. Additional terminology is defined in the Clean Water Act, USEPA regulations, and the California Water Code; all such terms not appearing below are incorporated into this Permit by reference.

Approved Signatory – A natural person who has been authorized by the Legally Responsible Person (see definition below) to sign, certify, and electronically submit Permit Registration Documents, Notices of Termination, and any other documents, reports, or information required by a Permit, the State or Regional Water Board, or U.S. EPA. The Approved Signatory must be one of the following:

1. For a corporation or limited liability company: a responsible corporate officer. For the purpose of this section, a responsible corporate officer means:
    a. a president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy or decision-making functions for the corporation or limited liability company; OR
    b. the manager of the facility if authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures;
2. For a partnership or sole proprietorship: a general partner or the proprietor, respectively;
3. For a municipality, State, Federal, or other public agency: a principal executive officer, ranking elected official, city manager, council president, or other public employee with managerial responsibility over the industrial facility (including, but not limited to, project manager, project superintendent, or resident engineer);
4. For the military: any military officer or Department of Defense civilian, acting in an equivalent capacity, who has been designated;
5. For a public university: an authorized university official;
6. For an individual: the individual, because the individual acts as both the Legally Responsible Person and the Approved Signatory.
7. For any type of entity not listed above: an authorized person with managerial authority over the industrial facility.

Authorized non-Storm Water Discharges – Non-storm water discharges authorized pursuant to an NPDES permit. Authorized non-storm water includes:

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uncontaminated condensate from air conditioners, coolers, and compressors and from the outside storage of refrigerated gases or liquids; flows from riparian habitats and wetlands; passive footing and foundation drains or crawlspace pumps; non-commercial vehicle washing; de-chlorinated water from swimming pools; diverted stream flows; uncontaminated groundwater or spring water; landscape watering, provided that all pesticides, herbicides, and fertilizers have been applied according to the approved labeling; discharges from emergency fire-fighting activities; irrigation water/drainage; and waters otherwise not containing waste.

Basin Plan – The Water Quality Control Plan for the Santa Ana River Basin (1995) and subsequent amendments.

Beneficial Uses – The uses of water necessary for the survival or well-being of man, plants, and wildlife. These uses of water serve to promote the tangible and intangible economic, social, and environmental goals. "Beneficial Uses" that may be protected against include, but are not limited to: domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves. Existing beneficial uses are uses that were attained in the surface or groundwater on or after November 28, 1975; and potential beneficial uses are uses that would probably develop in future years through the implementation of various control measures. "Beneficial Uses" are equivalent to "Designated Uses" under federal law (California Water Code Section 13050(f). Beneficial Uses for the Receiving Waters are identified in the Basin Plan.

Best Management Practices ("BMPs") – Also known as storm water control measures. Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMPs also include treatment requirements, operating procedures and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage (40 CFR § 122.2).

Bioaccumulate – The progressive accumulation of contaminants in the tissues of organisms to a higher concentration than in the surrounding environment. Bioaccumulation may occur through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, pore water, or dredged material. Bioaccumulation occurs with exposure and is independent of the trophic level of the organism.

Bioassessment – The use of biological community information to evaluate the

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biological integrity of a water body and its watershed. With respect to aquatic ecosystems, bio-assessment is the collection and analysis of samples of the benthic macro invertebrate community together with physical/habitat quality measurements associated with the sampling site and the watershed to evaluate the biological condition (i.e. biological integrity) of a water body.

Biological Integrity – Defined in Karr J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55-68 as: "A balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region." Also referred to as 'ecosystem health'.

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

California Toxics Rule – Numeric water quality criteria for certain Priority Toxic Pollutants and other water quality standards provisions promulgated by the USEPA for waters in the state of California. The California Toxics Rule is found in 40 CFR § 131.

Clean Water Act Section 402(p) – The federal statute, codified at 33 USC 1342(p), requiring municipal and industrial Co-permittees to obtain NPDES permits for their discharges of storm water.

Clean Water Act Section 303(d)-Listed Water Body – An impaired water body; a water body in which water quality does not meet applicable water quality standards and/or is not expected to meet water quality standards, even after the application of technology-based pollution controls required by the CWA.

Construction Site – Any project, including projects requiring coverage under the General Construction Permit, that involves soil disturbing activities including, but not limited to, clearing, grading, disturbances to ground such as stockpiling, and excavation.

Contamination – An impairment of the quality of waters of the State by waste to a degree which creates a hazard to the public health through poisoning or through the spread of disease. "Contamination" includes any equivalent effect resulting from the disposal of waste whether or not waters of the State (inclusive of waters of the U.S.) are

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affected. (California Water Code Section 13050(k))

Co-permittee(s) – Entities regulated under Order No. R8-2014-0002, inclusive of the Principle Co-permittee.

Criteria – The numeric values and the narrative standards that represent contaminant concentrations that are not to be exceeded in the receiving environmental media (surface water, groundwater, sediment) to protect beneficial uses.

Debris – Debris is defined as the remains of anything destroyed or broken, or accumulated loose fragments of rock.

Design Capture Flow – The calculated flow rate of storm water runoff, typically expressed as cubic feet per second ("cfs"), that must be treated in one or more structural treatment control BMPs according to the requirements of this Order.

Design Capture Volume – The calculated volume of storm water runoff, typically expressed in gallons or cubic feet, that must be treated in one or more structural treatment control BMPs according to the requirements of this Order.

Dry Weather – Weather in which there is no precipitation.

Effluent – Any discharge of water either to the receiving water or beyond the property boundary controlled by the discharger.

Effluent Limit/Limitation – Means any restriction on quantities, discharge rates, and concentrations of pollutants which are discharged from point sources into Waters of the United States, waters of the "contiguous zone," or the ocean. (40 CFR §122.2)

Emergency – A sudden, unexpected occurrence, involving a clear and imminent danger, demanding immediate action to prevent or mitigate loss of, or damage to, life, health, property, or essential public services (Public Resources Code Section 21060.3).

Environmentally Sensitive Area ("ESA") – An area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which would be easily disturbed or degraded by human activities and developments (Public Resources Code Section 30107.5). These areas include, but are not limited to: water bodies designated with the RARE beneficial use in the Basin Plan (Water Quality Control Plan for the Santa Ana River Basin [1995] and amendments); an area designated in the Ocean Plan as an Area of Special

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Biological Significance; a water body listed as being impaired pursuant to CWA Section 303(d); areas designated as preserves or their equivalent under the Natural Communities Conservation Program (Multiple Species Habitat Conservation Plan, "MSHCP") within the Cities and Counties of Orange, Riverside and San Bernardino; or any area designated as such by a public agency with designation powers.

Erosion – The process whereby material (such as sediment) is detached and entrained in water or air and can be transported to a different location. Chemical erosion involves materials that are dissolved and removed and transported.

Executive Officer – The Executive Officer of the Santa Ana Regional Water Quality Control Board or delegated staff.

Grading – The cutting and/or filling of the land surface to a desired slope or elevation.

Harvest and Use Low-Impact Development Best Management Practice ("Harvest and Use LID BMP") – A sub-category of retention LID BMPs that uses harvest and use of the design capture volume or quantified portion thereof. The captured volume is typically used for non-potable uses such as toilet-flushing, industrial process supply, and landscape irrigation.

Hazardous Substance – Any substance that poses a threat to human health or the environment due to its toxicity, corrosiveness, ignitability, explosive nature or chemical reactivity; any substance designated under 40 CFR §116 pursuant to Section 311(b)(2) of the Clean Water Act (40 CFR § 122.2).

Hydrologic Condition of Concern ("HCOC") – A condition of a stream or channel, or some reach thereof; or a condition of some other water body (e.g. a vernal pool), where its hydrology is, or is proposed to be, altered by past or future development such that there has been, or could be, cumulatively significant adverse impacts to the physical or biological integrity of the water body. A condition where a proposed development site discharges directly or indirectly to a water body where such conditions are known or suspected to exist based on Substantial Evidence.

Illicit Discharge – Any discharge to a municipal separate storm sewer that is not composed entirely of storm water. This does not include discharges that occur pursuant to an NPDES permit, other than the MS4 Permit, and discharges resulting from fire-fighting activities (40 CFR § 122.26(b)(2)).

Impaired Water Body – Section 303(b) of the CWA requires each of California's Regional Water Quality Control Boards to routinely monitor and assess the quality of waters of their respective regions. If this assessment indicates that Beneficial Uses are not met, then that water body must be listed under Section 303(d) of the CWA as an Impaired Water Body.

Impervious Surface – That part of a developed parcel that has been modified to reduce

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the land's natural ability to absorb and hold rainfall. It includes hard surfaces which cause water to run off the surface in greater quantities or at an increased rate of flow from the flow that existed under natural conditions prior to development. For example, common impervious surfaces include, but are not limited to, rooftops, walkways, patios, courtyards, driveways, parking lots, storage areas, concrete or asphalt paving, gravel roads, or any cleared, graded, graveled, paved, or compacted surfaces, or other surfaces which similarly impede the natural infiltration of surface water into the soil.

Infiltration – The flow of water into the soil by crossing the soil surface.

Infiltration Low-Impact Development Best Management Practice ("Infiltration LID BMP") – A type of retention LID BMP that employs infiltration at the principal mechanism for the loss of the design capture volume or quantified portion thereof.

Isopluvia – A line on a map drawn through geographical points having the same pluvial (rain, precipitation) index.

Land Disturbance – The clearing, grading, excavation, stockpiling, or other construction activity that results in the possible mobilization of soils or other pollutants into the MS4. This specifically does not include routine maintenance activity to maintain the original line and grade, hydraulic capacity, or original purpose of the facility. This also does not include emergency construction activities required to protect public health and safety.

Legally Responsible Person – A person, company, agency, or other entity that is the operator of the facility(ies) covered by this Permit.

Load Allocations ("LA") – Distribution or assignment of TMDL pollutant loads to entities or sources for existing and future nonpoint sources, including background loads.

Low-Impact Development ("LID") – A storm water management and land development strategy that combines a hydrologically functional site design with pollution prevention measures to compensate for land development impacts on hydrology and water quality. LID techniques mimic the site predevelopment site hydrology by using site design techniques that store, infiltrate, evapotranspirate, bio-filter or detain runoff close to its source.

Maximum Extent Practicable ("MEP") - refers to a standard for implementation of storm water management programs. Section 402(p)(3)(B)(iii) of the Clean Water Act requires that municipal storm water permits "shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques, and system design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants."

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In practice, compliance with the MEP standard is evaluated by how well the Co-Permittees implement the "minimum measures" identified by EPA, including: (1) Public education and outreach on storm water impacts; (2) Public involvement/participation; (3) Illicit discharge detection and elimination; (4) Construction site storm water runoff control; (5) Post-construction storm water management in new development and redevelopment; and (6) Pollution prevention/good housekeeping for municipal operations. Collectively, these minimum measures are often referred to as "Best Management Practices" or BMPs. The MEP standard does not require Co-permittees to reduce pollutant concentrations below natural background levels, nor does it require further reductions where pollutant concentrations in the receiving water already meet water quality objectives.

MEP is a technology-based standard established by Congress in CWA section 402(p)(3)(B)(iii) that operators of MS4s must meet. Technology-based standards establish the level of pollutant reductions that dischargers must achieve, typically by treatment or by a combination of source control and treatment control BMPs. MEP generally emphasizes pollution prevention and source control BMPs primarily (as the first line of defense) in combination with treatment methods serving as a backup (additional line of defense). MEP considers economics and is generally, but not necessarily, less stringent than BAT.

A definition for MEP is not provided either in the statute or in the regulations. Instead the definition of MEP is dynamic and will be defined by the following process over time: municipalities propose their definition of MEP by way of their urban runoff management programs. Their total collective and individual activities conducted pursuant to the urban runoff management programs becomes their proposal for MEP as it applies both to their overall effort, as well as to specific activities (e.g., MEP for street sweeping, or MEP for MS4 maintenance). In the absence of a proposal acceptable to the Regional Board, the Regional Board defines MEP.

In a memo dated February 11, 1993, entitled "Definition of Maximum Extent Practicable," Elizabeth Jennings, Senior Staff Counsel, SWRCB addressed the achievement of the MEP standard as follows:

> "To achieve the MEP standard, municipalities must employ whatever Best management Practices (BMPs) are technically feasible (i.e., are likely to be effective) and are not cost prohibitive. The major emphasis is on technical feasibility. Reducing pollutants to the MEP means choosing effective BMPs, and rejecting applicable BMPS only where other effective BMPS will serve the same purpose or the BMPS would not be technically feasible, or the cost would be prohibitive. In selecting BMPS to achieve the MEP standard, the following factors may be useful to consider:
>
> a. Effectiveness: Will the BMPS address a pollutant (or pollutant source) of concern?

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b. Regulatory Compliance: Is the BMP in compliance with storm water regulations as well as other environmental regulations?
c. Public Acceptance: Does the BMP have public support?
d. Cost: Will the cost of implementing the BMP have a reasonable relationship to the pollution control benefits to be achieved?
e. Technical Feasibility: Is the BMP technically feasible considering soils, geography, water resources, etc?

The final determination regarding whether a municipality has reduced pollutants to the maximum extent practicable can only be made by the Regional or State Water Boards, and not by the municipal discharger. If a municipality reviews a lengthy menu of BMPS and chooses to select only a few of the least expensive, it is likely that MEP has not been met. On the other hand, if a municipal discharger employs all applicable BMPS except those where it can show that they are not technically feasible in the locality, or whose cost would exceed any benefit derived, it would have met the standard. Where a choice may be made between two BMPS that should provide generally comparable effectiveness, the discharger may choose the least expensive alternative and exclude the more expensive BMP. However, it would not be acceptable either to reject all BMPS that would address a pollutant source, or to pick a BMP based solely on cost, which would be clearly less effective. In selecting BMPS the municipality must make a serious attempt to comply and practical solutions may not be lightly rejected. In any case, the burden would be on the municipal discharger to show compliance with its permit. After selecting a menu of BMPS, it is the responsibility of the discharger to ensure that all BMPS are implemented."

Monitoring and Reporting Period – For purposes of this Order, the monitoring and reporting period is July 1 to June 30 with a reporting deadline of the following November 15th of each year for Annual Progress Reports.

Municipal Storm Water Conveyance System – (See Municipal Separate Storm Sewer System or MS4).

Municipal Separate Storm Sewer System ("MS4") – A conveyance or system of conveyances designed to collect and/or transport urban runoff (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, natural drainage features or channels, modified natural channels, man-made channels, or storm drains): (i) Owned or operated by a State, city town, borough, county, parish, district, association, or other public body (created by or pursuant to State law) having jurisdiction over disposal of sewage, industrial wastes, storm water, or other wastes; (ii) Designated

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or used for collecting of conveying storm water; (iii) Which is not a combined sewer; (iv) Which is not part of the Publicly Owned Treatment Works (POTW) as defined at 40 CFR § 122.2 (40 CFR § 126.26(b)(8)).

Most Probable Number ("MPN") – The most probable number (MPN) of coliform or fecal coliform bacteria per unit volume of a sample. It is expressed as the number of organisms which are most likely to have produced the laboratory results noted in a particular test.

National Pollutant Discharge Elimination System ("NPDES") Permit – A national program under section 402 of the Clean Water Act for regulation of discharges of pollutants from point sources to waters of the United States. Discharges of pollutants are prohibited unless specifically exempted or authorized by an NPDES permit.

Non-Storm Water – Non-storm water consists of all discharges to and from a storm water conveyance system that do not originate from precipitation events (i.e., all discharges from a conveyance system other than storm water). Non-storm water includes illicit discharges, prohibited discharges, and NPDES permitted discharges.

Nuisance – anything which meets all of the following requirements: 1) Is injurious to health, or is indecent, or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property. 2) Affects at the same time an entire community or neighborhood, or any considerable number of persons, although the extent of the annoyance or damage inflicted upon individuals may be unequal. 3) Occurs during, or as a result of, the treatment or disposal of wastes (CWC Section 13050(m)).

Party – Defined as an individual, association, partnership, corporation, municipality, state or federal agency, or an agent or employee thereof (40 CFR § 122.2).

Permit Area – Areas that are under the jurisdiction of the Santa Ana Regional Water Quality Control Board. These include north and northwestern portions of Orange County, north and western portions of Riverside County and western portions of San Bernardino County. See the Basin Plan for a detailed description of the Regional Board boundaries.

Permit Registration Documents ("PRDs") – Include the Notice of Intent, Storm Water Pollution Prevention Plan, Site Map and the appropriate filing fee necessary to authorize a discharge under general waste discharge requirements.

Person – A person is defined as an individual, association, partnership, corporation, municipality, State or Federal agency, or an agent or employee thereof (40 CFR § 122.2).

pH - An indicator of the acidity or alkalinity of water.

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Point Source – Any discernible, confined, and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, runoff from concentrated animal feeding operations, landfill leachate collection systems, vessel, or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural storm water runoff.

Pollutant – Any agent that may cause or contribute to the degradation of water quality such that a condition of pollution or contamination is created or aggravated. It includes any type of industrial, municipal, and agricultural waste discharged into water. The term "pollutant" is defined in section 502(6) of the Clean Water Act as follows: "The term 'pollutant' means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water." It has also been interpreted to include water characteristics such as toxicity or acidity.

Pollution – The alteration of the quality of the Waters of the U.S. by waste, to a degree that unreasonably affects either of the following: 1) The waters for beneficial uses; or 2) Facilities that serve these beneficial uses. Pollution may include contamination (CWC Section 13050(l).

Pollution Prevention – Practices and processes that reduce or eliminate the generation of pollutants, in contrast to source control, treatment, or disposal.

Principal Permittee – The County of Orange

Priority Toxic Pollutant – A pollutant identified in the California Toxics Rule.

Receiving Waters – Waters of the United States within the Permit area.

Receiving Water Limitations – Waste discharge requirements issued by the Regional Board typically include both: (1) "Effluent Limitations" (or "Discharge Limitations") that specify the technology-based or water-quality-based effluent limitations; and (2) "Receiving Water Limitations" that specify the water quality objectives in the Basin Plan as well as any other limitations necessary to attain those objectives. In summary, the "Receiving Water Limitations" provision is the provision used to implement the requirement of CWA SECTION 301(b)(1)(C) that NPDES permits must include any more stringent limitations necessary to meet water quality standards.

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Retention Low-Impact Development Best Management Practice ("Retention LID BMP") – A sub-category of structural treatment control BMPs that employ retention of the design capture volume or a quantified portion thereof. The retained volume is infiltrated, evaporated, evapotranspirated, or used (typically for non-potable uses).

Sediment – Soil, sand, and minerals washed from land into water. Sediment resulting from anthropogenic sources (i.e. human-induced land disturbance activities) is considered a pollutant. This Order regulates only the discharges of sediment from anthropogenic sources and does not regulate naturally-occurring sources of sediment. Sediment can destroy fish-nesting areas, clog animal habitats, and cloud waters so that sunlight does not reach aquatic plants.

Standard Industrial Classification ("SIC") Code – Four digit industry code, as defined by the US Department of Labor, Occupational Safety and Health Administration. The SIC Code is used to identify if a facility requires coverage under the Industrial Activities
Storm Water Permits.

State Implementation Plan ("SIP") – Formally known as the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California. The SIP implements the California Toxics Rule.

Source Control and Site Design BMPs – In general, activities or programs to educate the public or provide low-cost non-physical solutions, as well as facility design or practices aimed to limit the contact between pollutant sources and storm water or authorized non-storm water. Examples include: activity schedules, prohibitions of practices, industrial area sweeping, facility maintenance, detection and elimination of illegal and unauthorized discharges, and other non-structural measures. Facility design (structural) examples include providing attached lids to trash containers, canopies for fueling islands, secondary containment, or roof or awning over material and trash storage areas to prevent direct contact between storm water and pollutants

~~**State Board** – California State Water Resources Control Board~~

Storm Water – Storm water runoff, snowmelt runoff and surface runoff and drainage (40 CFR § 122.26(b)(13)).

Storm Water General Permits – General Permit-Industrial (State Board Order No. 97-03 DWQ, NPDES No. CAS000001), and General Permit-Construction (State Board

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Order No. 2009-0009-DWQ, NPDES No. CAS000002).

Structural treatment control BMPs – Any system designed and constructed according to published and generally-accepted engineering criteria to remove pollutants from urban runoff. Pollutants are removed by simple gravity settling of particulate pollutants, filtration, biological uptake, media adsorption or any other physical, biological, or chemical process. In this Order, structural treatment control BMPs are classified as LID BMPs and non-LID BMPs. LID BMPs are further sub-classified into Retention LID BMPs and Biotreatment Control BMPs. All of these classes of structural treatment control BMPs are subject to general and specific requirements in this Order.

Substantial Evidence – Facts, reasonable assumptions predicated on facts, or expert opinion supported by facts. Substantial Evidence does not include argument, speculation, unsubstantiated opinion or narrative, or evidence which is clearly erroneous or inaccurate (Public Resources Code Section 21080(e)).

Storm Water Pollution Prevention Plan ("SWPPP") – A plan developed to minimize and control the discharge of pollutants from the industrial site to storm water conveyance systems. The plan shall identify pollutant sources, control measures for each pollutant source, good housekeeping practices and employee training programs.

Total Dissolved Solids ("TDS") – A measure of the total dissolved minerals in the water; the total dissolved (filterable) solids as determined by use of the method specified in 40 CFR § 136 (40 CFR § 122.2)

Total Maximum Daily Load ("TMDL") – The maximum amount of a pollutant that can be discharged into a water body from all sources (point and non-point) and still maintain water quality standards. Under Clean Water Act § 303(d), TMDLs must be developed for all water bodies that do not meet water quality standards after application of technology-based controls.

TMDL Implementation Plan – Component of a TMDL that describes actions, including monitoring, needed to reduce pollutant loadings and a timeline for implementation. TMDL implementation plans can include a monitoring or modeling plan and milestones for measuring progress, plans for revising the TMDL if progress toward cleaning up the waters is not made, and the date by which water quality standards will be met (USEPA Final TMDL Rule: Fulfilling the Goals of the CWA, EPA 841-F-00-008, July 2000).

Toxicity – Adverse responses of organisms to chemicals or physical agents ranging from mortality to physiological responses such as impaired reproduction or growth anomalies.

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Turbidity – The cloudiness of water quantified by the degree to which light traveling through a water column is scattered by the suspended organic and inorganic particles it contains. The turbidity test is reported in Nephelometric Turbidity Units (NTU) or Jackson Turbidity Units (JTU)

Uncontaminated Groundwater – Groundwater that is not impaired by waste to a degree which creates a hazard to the public health through poisoning or through the spread of disease

Urban Runoff – Urban runoff is defined as all flows in a storm water conveyance system from urban areas which include residential, commercial, industrial, and construction areas. Urban runoff consists of the following components: (1) storm water runoff and (2) authorized non-storm water discharges (See Section III of this Order). Urban runoff does not include runoff from undeveloped open space, feedlots, dairies, farms, and agricultural fields.

Waste – Waste includes sewage and any and all other waste substances, liquid, solid, gaseous, or radioactive, associated with human habitation, or of human or animal origin, or from any producing, manufacturing, or processing operation, including waste placed within containers of whatever nature prior to, and for purposes of, disposal (CWC Section 13050(d)). Article 2 of California Code of Regulations (CCR) Title 23, Chapter 15 (Chapter 15) contains a waste classification system which applies to solid and semi-solid waste which cannot
be discharged directly or indirectly to water of the state and which therefore must be discharged to land for treatment, storage, or disposal in accordance with Chapter 15. There are four classifications of waste (listed in order of highest to lowest threat to water quality): hazardous waste, designated waste, nonhazardous solid waste, and inert waste.

Waste Discharge Requirements ("WDR") – As defined in section 13374 of the California Water Code, the term "Waste Discharge Requirements" is the equivalent of the term "permits" as used in the Federal Water Pollution Control Act, as amended. The Regional Board usually uses the terms "permit" and "Order" to refer to Waste Discharge Requirements for discharges to Waters of the U.S.

Waste Load Allocations ("WLA") – WLA is the distribution or assignment of pollutant loads to entities or sources for existing and future point sources according to a TMDL; the maximum quantity of pollutants a discharger is allowed to release into a particular waterway, as set by a regulatory authority. Discharge limits usually are required for each specific water quality criterion being, or expected to be, violated.

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Water Quality Assessment – An assessment conducted to evaluate the condition of water bodies which receive process wastewater, storm water and non-storm water discharges.

Water Quality Objective – The limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area [California Water Code Section 13050(h)).

Water Quality Standards – Consist of beneficial uses, water quality objectives to protect those uses, an anti-degradation policy, and policies for implementation. Water quality standards are found in Regional Water Quality Control Plans and statewide water quality control plans. The USEPA has also adopted water quality criteria (the same as objectives) for California in the National Toxics Rule and California Toxics Rule.

Waters of the State – Any surface water or groundwater, including saline waters, within the boundaries of the State (California Water Code Section 13050(e)). Waters of the State includes waters of the United States.

Waters of the United States – Waters of the United States can be broadly defined as navigable surface waters and tributaries thereto. Groundwater is not considered to be Waters of the United States. As defined in 40 CFR § 122.2, the Waters of the U.S. are defined as: (a) All waters, which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide; (b) All interstate waters, including interstate "wetlands;" (c) All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sand flats, "wetlands," sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds the use, degradation or destruction of which would affect or could affect interstate or foreign commerce including any such waters: (1) Which are or could be used by interstate or foreign travelers for recreational or other purposes; (2) From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or (3) Which are used or could be used for industrial purposes by industries in interstate commerce; (d) All impoundments of waters otherwise defined as waters of the United States under this definition: (e) Tributaries of waters identified in paragraphs (a) through (d) of this definition; (f) The territorial seas; and (g) "Wetlands" adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs (a) through (f) of this definition. Waters of the United States do not include prior converted cropland. Notwithstanding the determination of an area's status as prior converted cropland by any other federal agency, for the purposes of the Clean Water Act, the final authority regarding Clean Water Act jurisdiction remains with the EPA

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Watershed – That geographical area which drains to a specified point on a water course, usually a confluence of streams or rivers; a drainage area, catchment, or river basin.

Wet Season – The period of October 1st through May 31st of each year, except where specifically defined otherwise in an approved TMDL Implementation Plan.

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Westminster; these Co-permittees do not discharge to waters for which there is an adopted TMDL.
[2] Only if the City of Yorba Linda discharges into Coyote Creek. See the Technical Report for further information.

Appendix A

Table A-1: Applicability of TMDL requirements to Co-permittees[1]

	San Diego Creek and Newport Bay Watershed TMDLs						San Gabriel River TMDL
Co-permittee	Nutrient TMDL	Fecal Coliform TMDL	Organochlorine Compounds TMDL	Diazinon & Chlorpyrifos TMDL	Toxics TMDL	Sediment TMDL	Coyote Creek Metals TMDL
County of Orange	X	X	X	X	X	X	X
Orange County Flood Control District	X	X	X	X	X	X	X
City of Anaheim							X
City of Brea							X
City of Buena Park							X
City of Costa Mesa	X	X	X	X	X	X	
City of Cypress							X
City of Fountain Valley							
City of Fullerton							X
City of Garden Grove							X
City of Irvine	X	X	X	X	X	X	
City of Laguna Hills	X		X	X	X		
City of Laguna Woods	X		X	X	X		
City of La Habra							X
City of La Palma							X
City of Lake Forest	X	X	X	X	X	X	
City of Los Alamitos							X
City of Newport Beach	X	X	X	X	X	X	
City of Orange	X	X	X	X	X		
City of Placentia							X
City of Santa Ana	X	X	X	X	X	X	
City of Seal Beach							X
City of Stanton							X
City of Tustin	X	X	X	X	X	X	
City of Yorba Linda							X[2]

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[1] Table A-1 excludes the cities of Fountain Valley, Garden Grove, Huntington Beach, Villa Park, and Westminster; these Co-permittees do not discharge to waters for which there is an adopted TMDL.

[2] Only if the City of Yorba Linda discharges into Coyote Creek. See the Technical Report for further information.

-	San Diego Creek and Newport Bay Watershed TMDLs						San Gabriel River TMDL
Co-permittee	Nutrient TMDL	Fecal Coliform TMDL	Organochlorine Compounds TMDL	Diazinon & Chlorpyrifos TMDL	Toxics TMDL	Sediment TMDL	Coyote Creek Metals TMDL
County of Orange	X	X	X	X	X	X	X
Orange County Flood Control District	X	X	X	X	X	X	X
City of Anaheim	-	-	-	-	-	-	X
City of Brea	-	-	-	-	-	-	X
City of Buena Park	-	-	-	-	-	-	X
City of Costa Mesa	X	X	X	X	X	X	-
City of Cypress	-	-	-	-	-	-	X
City of Fountain Valley	-	-	-	-	-	-	-
City of Fullerton	-	-	-	-	-	-	X
City of Garden Grove	-	-	-	-	-	-	X
City of Irvine	X	X	X	X	X	X	-
City of Laguna Hills	X	-	X	X	X	-	-
City of Laguna Woods	X	-	X	X	X	-	-
City of La Habra	-	-	-	-	-	-	X
City of La Palma	-	-	-	-	-	-	X
City of Lake Forest	X	X	X	X	X	X	-
City of Los Alamitos	-	-	-	-	-	-	X
City of Newport Beach	X	X	X	X	X	X	-
City of Orange	X	X	X	X	X	-	-
City of Placentia	-	-	-	-	-	-	X
City of Santa Ana	X	X	X	X	X	X	-
City of Seal Beach	-	-	-	-	-	-	X
City of Stanton	-	-	-	-	-	-	X
City of Tustin	X	X	X	X	X	X	-
City of Yorba Linda	-	-	-	-	-	-	X[2]

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	~~San Diego Creek and~~ Newport Bay Watershed TMDLs					San Gabriel River TMDLs
Responsible Permittee	Nutrient TMDL	Fecal Coliform TMDL	OC Compounds TMDL	Diazinon & Chlorpyrifos TMDL	Toxics TMDL	Coyote Creek Metals TMDL
County of Orange	√	√	√	√	√	√
Orange County FCD	√	√	√	√	√	√
City of Costa Mesa	√	√	√	√	√	
City of Irvine	√	√	√	√	√	
City of Laguna Hills	√		√	√	√	
City of Laguna Woods	√		√	√	√	
City of Lake Forest	√	√	√	√	√	
City of Newport Beach	√	√	√	√	√	
City of Orange	√	√	√	√	√	
City of Santa Ana	√	√	√	√	√	
City of Tustin	√	√	√	√	√	
City of Anaheim						√
City of Brea						√
City of Buena Park						√
City of Cypress						√
City of Fullerton						√
City of Garden Grove						√
City of La Habra						√
City of La Palma						√
City of Los Alamitos						√
City of Placentia						√
City of Seal Beach						√
City of Yorba Linda						√

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Appendix B

Total Maximum Daily Load for Nutrients in San Diego Creek and Newport Bay

(Resolution No. 98-9, as amended by Resolution No. 98-100)

~~Waste Load Allocations for Nutrients in Newport Bay~~

~~The following waste load allocations ("WLAs") apply to discharges of urban runoff from MS4s owned or controlled by those Co-permitees discharging into Newport Bay.~~

~~The WLAs in this~~ Appendix B ~~are based on~~ incorporates ~~presents~~the waste load allocations ("WLAs") assigned to urban runoff as identified in the Total Maximum Daily Load for Nutrients in San Diego Creek and Newport Bay (Nutrient TMDL). ~~.~~ Responsible Co-Permittees are identified in Appendix A.

The Nutrient TMDL ~~has been~~was approved by the Santa Ana Regional Water Quality Control Board, the State Water Resources Control Board, the Office of Administrative Law ("OAL") and USEPA as follows:

- Regional Board Adoption: April 17, 1998; amendment adopted October 9, 1998
- State Board Approval: May 13, 1998
- OAL Approval: TBD[10]
- USEPA Approval: TBD[10~~7~~]

~~. The Nutrient TMDL was adopted by the Santa Ana Regional Water Quality Control Board in Resolution No. 98-9 (amended by Resolution No. 98-100). The TMDL was approved by the Office of Administrative Law on February 10, 1999 and April 16, 1999.~~

I. WLAs for Nitrogen, Total[1] and Phosphorus, Total

a. Responsible Permittees shall implement BMPs to achieve the following WLAs by the specified dates for Reach 1 of San Diego Creek:

[10] TMDL adoption, approval, and effective dates are included to the extent these dates are readily available on the Regional Board's website. Permittees request that the Regional Board work with Permittees to identify any missing dates for these TMDLs.

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Nutrient TMDL	2002 Summer Allocation (Apr-Sept)	2007 Summer Allocation (Apr-Sept)	2012 Winter Allocation (Oct-Mar) [2],[3]	2002 Annual Allocation	2007 Annual Allocation
Urban Runoff WLA Lbs/season TN[1]	20,785	16,628	55,442	Not Applicable	Not Applicable
Urban Runoff WLA Lbs/year TP	Not Applicable	Not Applicable	Not Applicable	4,102	2,960

[1] TIN = (NO3 + NH3); TN = (TIN + organic N)

[2] Total Nitrogen winter loading limit applies between October 1 and March 31 when the mean daily flow rate in San Diego Creek at Campus Drive is less than 50 cubic feet per second (cfs), and when the mean daily flow rate in San Diego Creek at Campus drive is more than 50 cubic feet per second (cfs), but not as the result of precipitation.

[3] Assumes 67 non-storm days

b. The Responsible Permittees shall implement BMPs to achieve the following WLAs by the specified date for San Diego Creek, Reach 2 during non-storm conditions:

Nutrient TMDL	2012 Allocation[1]
Urban Runoff WLA	5.5 lbs/day TN

[1] Total nitrogen loading limit applies when the mean daily flow rate at San Diego Creek at Culver Drive is below 25 cfs, and when the mean daily flow rate in San Diego Creek at Culver Drive is above 25 cfs, but not as the result of precipitation.

II. Compliance Determination

a. Compliance with final requirements for this TMDL shall be determined pursuant to Provision XVIII.

b. Attainment of the WLAs was achieved prior to the final compliance dates identified in this Appendix B, Part I. Responsible Permittees shall continue to verify attainment of the WLAs through the monitoring and reporting program.

III. Monitoring and Reporting Requirements

a. Monitoring

i. Responsible Permittees shall conduct monitoring consistent with the requirements of the TMDL. Such monitoring can be integrated into the overall monitoring requirements specified in Attachment A, Monitoring and Reporting Program.

b. Reporting

i. Responsible Permittees shall submit reports consistent with the requirements of the TMDL.

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A. ~~Discharges of urban runoff in Reach 2 of San Diego Creek (above Jeffrey Road) must not transport more than 5.5 pounds of total nitrogen per day.~~

~~1. This WLA only applies to mean daily flow rate of less than 25 cfs and mean daily those flows above 25 cfs that are not the result of precipitation.~~

~~2. Flow must be measured in San Diego Creek at Culver Drive.~~

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~~B. Discharges of urban runoff in San Diego Creek at Campus Drive must not transport more than 55,442 pounds of total nitrogen into Newport Bay each "wet season".~~

~~C. Discharges of urban runoff in San Diego Creek at Campus Drive must not transport more than 16,628 pounds of total nitrogen into Newport Bay each "dry season".~~

~~1. For the purposes of both of these Waste Load Allocations for total nitrogen, "wet season" shall mean the period from October 1 to March 31 of each year. "Dry season" shall mean the period from April 1 to September 31 of each year.~~

~~2. The wet season Waste Load Allocation applies to discharges where the mean daily flow rate in San Diego Creek is less than 50 cubic feet per second ("cfs") and to mean daily flow rates in excess of 50 cfs that are not caused by precipitation.~~

~~II. Phosphorous, Total~~

~~Discharges of urban runoff must not transport into Newport Bay more than 2,960 pounds of total phosphorous per year.~~

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[1] ~~Total nitrogen WLAs are based on 67 non-storm days per wet season.~~

Appendix C

~~Waste Load Allocations for Fecal Coliform in Newport Bay~~
Total Maximum Daily Loads for Fecal Coliform in Newport Bay (Resolution No. 99-100)

~~The following waste load allocations ("WLAs") apply to discharges of urban runoff from MS4s owned or controlled by those Co-permitees discharging into Newport Bay.~~

~~The WLAs in this~~ Appendix C ~~are based on~~incorporates the waste load allocations (~~"~~WLAs~~"~~) assigned to urban runoff as identified in the ~~the Fecal Coliform TMDL~~Total Maximum Daily Loads for Fecal Coliform in Newport Bay (Fecal Coliform TMDL). Responsible Co-Permittees are identified in Appendix A.

The Fecal Coliform TMDL ~~has been~~was approved by Santa Ana Regional Water Quality Control Board, the State Water Resources Control Board, the Office of Administrative Law ("OAL") and USEPA as follows:

- Regional Board Adoption: April 9, 1999
- State Board Adoption: TBD[11]
- OAL Approval: February 28, 2000
- USEPA Approval: TBD[11~~9~~]

~~. The Fecal Coliform TMDL was adopted by the Santa Ana Regional Water Quality Control Board in Attachment Resolution No. 99-10. The TMDL was approved by OAL on December 24, 1999 and February 28, 2000.~~

I. WLAs for Fecal Coliform

a. Responsible Permittees shall implement BMPs to achieve the following WLAs for water contact recreation:

Fecal Coliform TMDL	**As soon as possible, but no later than December 30, 2014**
Urban Runoff Waste Load Allocation for Fecal Coliform (REC-1)	5-Sample/30-day Geometric Mean less than 200 organisms/100mL, and not more than 10% of the samples exceed 400 organisms/100mL for any 30-day period.

b. Responsible Permittees shall implement BMPs to achieve the following WLAs for shell fish harvesting standards:

[11] TMDL adoption, approval, and effective dates are included to the extent these dates are readily available on the Regional Board's website. Permittees request that the Regional Board work with Permittees to identify any missing dates for these TMDLs.

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Fecal Coliform TMDL	**As soon as possible, but no later than December 30, 2019**
Urban Runoff Waste Load Allocation for Fecal Coliform	Monthly Median less than 14 MPN/ 100mL, and not more than 10% of the samples exceed 43 MPN/ 100mL.

II. Compliance Determination

a. Compliance with the final requirements for the Fecal Coliform TMDL shall be determined pursuant to Provision XVIII.B.

b. The Responsible Permittees shall implement BMPs to achieve the final WLAs for water contact recreation standards by December 30, 2014 and with shell fish standards no later than December 30, 2019.

III. Monitoring and Reporting Requirements

a. Monitoring

i. Responsible Permittees shall conduct monitoring consistent with the requirements of the TMDL. Such monitoring can be integrated into the overall monitoring requirements specified in Attachment A, Monitoring and Reporting Program.

b. Reporting

i. Responsible Permittees shall submit reports consistent with the requirements of the TMDL.

I. ~~Fecal Coliform~~

~~A. The geometric mean for the following must be calculated based on a minimum of 5 representative samples of urban runoff taken over a 30- day period.~~

~~B. As soon as possible, but no later than December 30,2014:~~

~~1. The geometric mean[12] must be less than 200 organisms/100mL; and~~

~~2. Of the representative samples taken, not more than 10% can exceed 400 organisms/100mL for any 30-day period.~~

~~C. As soon as possible, but no later than December 30, 2019:~~

~~1. The monthly median of representative samples of urban runoff must be less than 14 most probable number ("MPN")/100 mL; and~~

~~2. Of the representative samples taken, not more than 10% can exceed 43 MPN/100 mL.~~

~~[12] The geometric mean for the following must be calculated based on a minimum of 5 representative samples of urban runoff taken over a 30- day period.~~

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~~Appendix D~~

~~Load Allocations and requirements for Sediment in Upper Newport Bay~~

~~The following load allocations ("LAs") and requirements apply to discharges of urban runoff from MS4s owned or controlled by those Co-permitees discharging into Upper Newport Bay.~~

~~The LAs and requirements in this Appendix are based on the Sediment TMDL. The Sediment TMDL has been approved by Santa Ana Regional Water Quality Control Board, the State Water Resources Control Board, the Office of Administrative Law ("OAL") and USEPA. The Sediment TMDL was adopted by the Santa Ana Regional Water Quality Control Board in Resolution No. 98-101. The TMDL was approved by OAL on February 2, 1999 and April 16, 1999.~~

I. ~~Sediment in discharges of urban runoff must not alter the distribution of habitat types in the 700-acre Upper Newport Bay Ecological Reserve, in Table D-1 below or as revised by the Department of Fish and Wildlife, by more than 1%.~~

~~Table D-1: Baseline Distribution of Habitat Types in the Upper Newport Bay Ecological Reserve~~

~~Habitat Type~~	~~Acres~~	~~Permissible Change (acres)~~
~~Marine aquatic~~	~~210~~	~~2.1~~
~~Mudflat~~	~~214~~	~~2.1~~
~~Salt marsh~~	~~277~~	~~2.8~~
~~Riparian~~	~~31~~	~~3.1~~

II. ~~The depths of the Unit 1 and 2 Sediment Basins (a.k.a. Unit I/III and Unit II) must be maintained at a minimum of 7 feet below mean sea level.~~

III. ~~Bathymetric and vegetation surveys must be performed no less than once every three years, or as agreed to by the Executive Officer, in a manner to determine compliance with the above requirements for sediment.~~

1. ~~Bathymetric and vegetation surveys must be performed within one year following any monitoring period in which monitoring at San Diego Creek at Campus Drive (Site ID: SDMF05) shows that more than 250,000 tons of sediment were discharged into Newport Bay.~~

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~~2. Bathymetric and vegetation surveys must be conducted by July 1of each year that they are performed, and must be submitted by December 31 of the same year.~~

~~IV. Sediment control measures must be effectively implemented by the Co-permitees such that Upper Newport Bay, including In-Bay Sediment Basins 1 and 2, do not need to be dredged more frequently than once every 10 years. The Executive Officer is authorized to grant exceptions to this requirement on the basis of extreme rainfall conditions.~~

~~V. All in-channel and foothill sediment control basins tributary to Newport Bay must have an available sediment capacity that is 50% or more of each facilities' design capacity prior to November 15th of each year.~~

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Appendix
~~E~~D

~~Waste Load Allocations~~Total Maximum Daily Loads for Organochlorine Compounds in the ~~Newport Bay~~ San Diego Creek and ~~San Diego Creek~~Newport Bay Watersheds (Resolution No. R8-2011-0037)

~~The following waste load allocations ("WLAs") apply to discharges of urban runoff from MS4s owned or controlled by those Co-permitees discharging into Newport Bay, Rhine Channel and San Diego Creek as indicated.~~

~~The WLAs in this~~ Appendix D ~~are based on~~ incorporates the waste load allocations (~~"~~WLAs~~"~~) assigned to urban runoff as identified in the Total Maximum Daily Loads for Organochlorine Compounds in the San Diego Creek and Newport Bay Watersheds ~~Organochlorine~~ (OC Compounds TMDL). Responsible Co-Permittees are identified in Appendix A.

The ~~Organochlorine~~ OC Compounds TMDL ~~has been~~was approved by Santa Ana Regional Water Quality Control Board, the State Water Resources Control Board, the Office of Administrative Law ("OAL") and USEPA as follows:

- Regional Board Adoption July 15, 2011
- State Board Adoption: October 16, 2012
- OAL Approval: July 26, 2013
- USEPA Approval: [pending, insert date once approved]

~~. The Organochlorine CompoundOC Compounds TMDL was adopted by the Santa Ana Regional Water Quality Control Board in Resolution No. R8-2011-0037 (modifying Resolution No. R8-2007-0024). The TMDL was approved by OAL on July 26, 2013.~~

I. WLAs for Organochlorine Compounds

a. Responsible Permittees shall implement BMPs to achieve the following WLAs for organochlorine compounds:

OC Compounds TMDL	Total DDT	Chlordane	Total PCBs	Toxaphene
San Diego Creek	128.3 g/yr	NA	NA	1.9 g/yr
Upper Newport Bay	51.8 g/yr	30.1 g/yr	29.8 g/yr	NA
Lower Newport Bay	19.1 g/yr	11.0 g/yr	78.1 g/yr	NA

II. Compliance Determination

a. Compliance with the final requirements for the Fecal Coliform TMDL shall be determined pursuant to Provision XVIII.B.

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b. For Permittees that opt to comply with the OC Compounds TMDL pursuant to Provision XVIII.B.1.a, the plan, shall include the following:

i. The tasks identified for MS4 Permittees in Table NB-OCs-13 of the Basin Plan Amendment for the OC Compounds TMDL.

c. The Responsible Permittees shall implement BMPs to achieve the WLAs by December 31, 2020.

III. Monitoring and Reporting Requirements

a. Monitoring

i. Responsible Permittees shall conduct monitoring consistent with the requirements of the TMDL. Such monitoring can be integrated into the overall monitoring requirements specified in Attachment A, Monitoring and Reporting Program.

b. Reporting

i. Responsible Permittees shall submit reports consistent with the requirements of the TMDL.

I. ~~Chlordane~~

~~A. As soon as possible, but no later than December 31, 2015~~2020~~, discharges of urban runoff must not transport more than 30.1 grams of chlordane into Upper Newport Bay per year.~~

~~B. As soon as possible, but no later than December 31,~~ 2020~~2015, discharges of urban runoff must not transport more than 11.0 grams of chlordane into Lower Newport Bay per year.~~

~~C. Discharges of urban runoff must not transport more than 0.1 gram of chlordane into the Rhine Channel per year.~~

~~II. DDT, Total~~

~~A. As soon as possible, but no later than December 31, 2020, Discharges discharges of urban runoff must not transport more than 51.8 grams of total DDT into Upper Newport Bay per year.~~

~~B. As soon as possible, but no later than December 31, 2015~~2020~~, discharges of urban runoff must not transport more than 19.1 grams of total DDT into Lower Newport Bay per year.~~

~~C. As soon as possible, but no later than December 31, 2020, discharges of urban runoff must not transport more than 128.3 grams of total DDT into San Diego Creek and its tributaries per year.~~

~~D. Discharges of urban runoff must not transport more than 0.7 gram of total DDT into the Rhine Channel per year.~~

~~III. Dieldrin~~

~~Discharges of urban runoff must not transport more than 0.13 gram of Dieldrin into the Rhine Channel per year. IV. PCB~~

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A. As soon as possible, but no later than December 31, 2020, Discharges discharges of urban runoff must not transport more than 29.8 grams of PCBs into Upper Newport Bay per year.

B. As soon as possible, but no later than December 31, 2020152015, discharges of urban runoff must not transport more than 78.1 grams of total PCBs into Lower Newport Bay per year.

C. Discharges of urban runoff must not transport more than 4.1 grams of total PCB into the Rhine Channel per year.

IV. Toxaphene

As soon as possible, but no later than December 31, 2020, discharges of urban runoff must not transport more than 1.9 grams of Toxaphene into San Diego Creek and its tributaries per year.

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Appendix
~~F~~E

~~Waste Load Allocations~~Total Maximum Daily Loads for ~~the~~ Diazinon ~~&~~ and Chlorpyrifos ~~TMDL for~~in the ~~Upper Newport Bay and~~ San Diego Creek and Newport Bay Watersheds (Resolution No. R8-2003-0039)

~~The following waste load allocations ("WLAs") apply to discharges of urban runoff from MS4s owned or controlled by those Co-permitees discharging into Upper Newport Bay or San Diego Creek as indicated.~~

~~The WLAs in this~~ Appendix E incorporates the waste load allocations (~~"~~WLAs~~"~~) assigned to urban runoff as identified in the Total Maximum Daily Loads for Diazinon and Chlorpyrifos in the San Diego Creek and Newport Bay Watersheds ~~are based on the~~ (Diazinon and~~&~~ Chlorpyrifos TMDL). Responsible Co-Permittees are identified in Appendix A.

The Diazinon and~~&~~ Chlorpyrifos TMDL ~~has been~~was approved by Santa Ana Regional Water Quality Control Board, the State Water Resources Control Board, the Office of Administrative Law ("OAL") and USEPA as follows:

- Regional Board Adoption: April 4, 2003
- State Board Adoption: TBD[13]
- OAL Approval: January 5, 2004
- USEPA Approval: TBD[13]

~~. The Diazinon & Chlorpyrifos TMDL was adopted by the Santa Ana Regional Water Quality Control Board in Resolution No. R8-2003-0039. The TMDL was approved by OAL on January 5, 2004 and February 13, 2004.~~

I. WLAs for ~~Fecal Coliform~~Diazinon and Chlorpyrifos

a. Responsible Permittees shall implement BMPs to achieve the following WLAs for diazinon and chlorpyrifos in San Diego Creek:

Category	Diazinon (ng/L)		Chlorpyrifos (ng/L)	
	Acute	Chronic[1]	Acute	Chronic[1]
Wasteload Allocation	72	45	18	12.6

1 Chronic means 4-consecutive day average.

[13] TMDL adoption, approval, and effective dates are included to the extent these dates are readily available on the Regional Board's website. Permittees request that the Regional Board work with Permittees to identify any missing dates for these TMDLs.

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b. Responsible Permittees shall implement BMPs to achieve the following WLAs for diazinon and chlorpyrifos in Newport Bay:

Category	Acute (ng/L)	Chronic (ng/L)[1]
Wasteload Allocation	18	8.1

1 Chronic means 4-consecutive day average.

II. Compliance Determination

a. Compliance with the final requirements for the Diazinon and Chlorpyrifos TMDL shall be determined pursuant to Provision XVIII.B.

b. Achievement of the WLAs for this TMDL was demonstrated prior to December 1, 2007. Pursuant to Appendix E, Provision III, Responsible Permittees shall continue to verify achievement of the WLAs through the monitoring and reporting program.

c. The Responsible Permittees were required to implement BMPs to achieve WLAs by December 1, 2007.

III. Monitoring and Reporting Requirements

a. Monitoring

i. Responsible Permittees shall conduct monitoring consistent with the requirements of the TMDL. Such monitoring can be integrated into the overall monitoring requirements specified in Attachment A, Monitoring and Reporting Program.

b. Reporting

i. Responsible Permittees shall submit reports consistent with the requirements of the TMDL.

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~~I. Chlorpyrifos~~

~~A. The acute concentrations or CMC (24-hour average concentration) of Chlorpyrifos in representative samples of urban runoff discharged into Upper Newport Bay must not exceed 18 ng/L.~~

~~B. The chronic concentrations or CCC (4-consecutive day average) of Chlorpyrifos in representative samples of urban runoff discharged into Upper Newport Bay must not exceed 8.1 ng/L.~~

~~C. The acute concentrations or CMC (24-hour average concentration) of Chlorpyrifos in representative samples of urban runoff in San Diego Creek must not exceed 18 ng/L.~~

~~D. The chronic concentration or CCC (4-consecutive day average) of Chlorpyrifos in representative samples of urban runoff in San Diego Creek must not exceed 12.6 ng/L.~~

~~II. Diazinon~~

~~A. The acute concentrations or CMC (24-hour average concentration) of Diazinon in representative samples of urban runoff in San Diego Creek must not exceed 72 ng/L.~~

~~B. The chronic concentrations or CCC (4-consecutive day average) of Diazinon in representative samples of urban runoff in San Diego Creek must not exceed 45 ng/L.~~

Appendix
~~G~~F

~~Waste Load Allocations~~Total Maximum Daily Load for Toxics ~~Pollutants (Metals) into~~in the San Diego Creek~~, Rhine Channel,~~ and Newport Bay Watersheds

~~The following waste load allocations ("WLAs") apply to discharges of urban runoff from MS4s owned or controlled by those Co-permitees discharging into San Diego Creek and Newport Bay as indicated.~~

~~The WLAs in this~~ Appendix F ~~are based on~~incorporates the waste load allocations (~~"~~WLAs~~"~~) assigned to urban runoff as identified in the Total Maximum Daily Loads for Toxics in the San Diego Creek and Newport Bay Watershed (Toxics ~~Pollutants (Metals)~~ TMDL). Responsible Co-Permittees are identified in Appendix A.

The Toxics ~~Pollutants~~ TMDL ~~has been~~was ~~approved by Santa Ana Regional Water Quality Control Board, the State Water Resources Control Board, the Office of Administrative Law ("OAL") and~~ promulgated by USEPA~~.~~ ~~The Toxics Pollutants TMDL was adopted by the Santa Ana Regional Water Quality Control Board in Resolution No. R8-2003-0039. The TMDL was promulgated by USEPA~~ on June ~~17~~14, 2002. Several pollutant-waterbody combinations in the Toxics TMDL have been subsequently superceded by Basin Plan Amendments adopted by the Regional Board (diazinon and chlorpyrifos; organchlorinated compounds). Therefore, the WLAs for the Toxics TMDL are limited to the pollutants identified in this Appendix F. Other Basin Plan Amendments, such as selenium, are currently under development and are anticipated to be adopted during

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the term of this Order. Once any additional Basin Plan Amendments that supersede WLAs contained in the Toxics TMDL are effective, this Order will be re-opened and modified accordingly.

I. WLAs for Selenium, Metals, Mercury and Chromium

a. Responsible Permittees shall implement BMPs to achieve the following WLAs for selenium in the San Diego Creek watershed:

WLAs for Selenium				
Base flows (<20 cfs)	Small flows (21 – 181 cfs)	Medium flows (182 – 814 cfs)	Large flows (> 814 cfs)	Annual Total[1]
0.4 lbs/yr	1.0 lbs/yr	1.0 lbs/yr	5.3 lbs/yr	7.6 lbs/yr

1. Sum of loading capacity for San Diego Creek only (based on 5 µg/L applied to all flow tiers)

b. Responsible Permittees shall implement BMPs to achieve the following WLAs for metals in the San Diego Creek watershed:

WLAs for Dissolved Metals in San Diego Creek[1]							
	Base flow (<20 cfs) Hardness @ 400 mg/L		Small flows (21-181 cfs) Hardness @ 322 mg/L		Med. flows (182 – 815 cfs) Hardness @ 236 mg/L		Large flows (>815 cfs) Hardness @ 197 mg/L
	Acute (µg/L)	Chronic (µg/L)	Acute (µg/L)	Chronic (µg/L)	Acute (µg/L)	Chronic (µg/L)	Acute (µg/L)
Cd	19.1	6.2	15.1	5.3	10.8	4.2	8.9
Cu	50	29.3	40	24.3	30.2	18.7	25.5
Pb	281	10.9	224	8.8	162	6.3	134
Zn	379	382	316	318	243	244	208

1. Actual ambient hardness must be determined for each monitoring sample regardless of which flow condition exists.

c. Responsible Permittees shall implement BMPs to achieve the following WLAs for metals in the Newport Bay watershed:

	Concentration-Based WLAs for Dissolved Metals in Newport Bay	Mass-Based WLAs

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	Acute (µg/L)	Chronic (µg/L)	
Cd[1]	42	9.3	9,589 lbs/yr
Cu	4.8	3.1	3,043 lbs/yr
Pb	210	8.1	17,638 lbs/yr
Zn	90	81	174,057 lbs/yr

1. Values apply to Upper Bay only (estimated as 40% of Newport Bay volume).

d. Responsible Permittees shall implement BMPs to achieve the following WLAs for mercury and chromium in Rhine Channel:

WLAs for Rhine Channel	
Mercury (Hg)	Chromium (Cr)
0.0171 kg/yr	5.66 kg/yr

II. Compliance Determination

a. Compliance with the final requirements for the Toxics TMDL shall be determined pursuant to Provision XVIII.B.

b. For Responsible Permittees who opt to comply with USPEA-promulgated TMDLs pursuant to Provision XVIII.B.1.a, Responsible Permittees shall propose BMPs to achieve WLAs and the schedule to implement the BMPs in the ~~Strategic Compliance Program or equivalent~~ plan.

III. Monitoring and Reporting Requirements

a. Monitoring

i. Responsible Permittees shall propose a monitoring program consistent with the requirements of the TMDL. Such monitoring can be integrated into the overall monitoring requirements specified in Attachment A, Monitoring and Reporting Program.

b. Reporting

i. Responsible Permittees shall submit an annual report consistent with the requirements of the TMDL.

~~I. Cadmium, Dissolved~~

~~A. Discharge of urban runoff must not transport more than 9,589 pounds of dissolved cadmium into Upper Newport Bay per year.~~

~~B. The acute concentration or CMC (24-hour average concentration) of dissolved cadmium in representative samples of urban runoff discharged into Upper Newport Bay must not exceed 42 µg/L.~~

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~~C. The chronic concentration or CCC (4-day or 96-hour average) of dissolved cadmium in representative samples of urban runoff discharged into Upper Newport Bay must not exceed 9.3 µg/L.~~

~~D. Discharges of urban runoff, measured in San Diego Creek at Campus Drive, in the flow categories shown in Table G-1 below, must not exceed the concentrations shown.~~

~~Table G-1: Waste Load Allocations for Cadmium, Dissolved~~

	~~Base Flows <20cfs~~	~~Small Flows 21 to 181 cfs~~	~~Medium Flows 182 to 815 cfs~~	~~Large Flows >815 cfs~~
	~~Hardness: 400mg/L~~	~~Hardness: 322 mg/L~~	~~Hardness: 236 mg/L~~	~~Hardness: 197 mg/L~~
~~Acute (µg/L)~~	~~19.1~~	~~15.1~~	~~10.8~~	~~8.9~~
~~Chronic (µg/L)~~	~~6.2~~	~~5.3~~	~~4.2~~	~~--~~

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~~II. Chromium~~

~~Discharges of urban runoff must not transport more than 5.66 kilograms of chromium into the Rhine Channel per year.~~

~~III. Copper, Dissolved~~

~~A. Discharges of urban runoff must not transport more than 3,043 pounds of dissolved copper into Newport Bay per year.~~

~~B. The acute or criterion maximum concentration ("CMC") (24-hour average concentration) of dissolved copper in representative samples of urban runoff discharged into Newport Bay must not exceed 4.8 µg/L.~~

~~C. The chronic or criterion continuous concentration ("CCC") (4 consecutive day or 96-hour average concentration) of dissolved copper in representative samples of urban runoff discharged into Newport Bay must not exceed 3.1 µg/L.~~

~~D. Discharges of urban runoff, measured in San Diego Creek at Campus Drive, in the flow categories shown in Table G-2 below must not exceed the following concentrations:~~

~~Table G-2: Waste Load Allocations for Copper, Dissolved~~

	~~Base Flows <20cfs~~	~~Small Flows 21 to 181 cfs~~	~~Medium Flows 182 to 815 cfs~~	~~Large Flows >815 cfs~~
	~~Hardness: 400mg/L~~	~~Hardness: 322 mg/L~~	~~Hardness: 236 mg/L~~	~~Hardness: 197 mg/L~~
~~Acute (µg/L)~~	~~50~~	~~40~~	~~30.2~~	~~25.5~~
~~Chronic (µg/L)~~	~~29.3~~	~~24.3~~	~~18.7~~	~~--~~

~~IV. Lead, Dissolved~~

~~A. Discharges of urban runoff must not transport more than 17,638 pounds of dissolved lead into Newport Bay per year.~~

~~B. The acute concentration or CMC (24-hour average concentration) of dissolved lead in representative samples of urban runoff discharged into Newport Bay must not exceed 210 µg/L.~~

~~C. The chronic concentration or CCC (4 consecutive day or 96-hour average concentration) of dissolved lead in representative samples of urban runoff discharged into Newport Bay must not exceed 8.1 µg/L.~~

~~D. Discharges of urban runoff, measured in San Diego Creek at Campus Drive and in the flow categories shown in Table G-3 below, must not exceed the following concentrations:~~

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~~Table G-3: Waste Load Allocations for Lead, Dissolved~~

	~~Base Flows ≤20cfs~~	~~Small Flows 21 to 181 cfs~~	~~Medium Flows 182 to 815 cfs~~	~~Large Flows >815 cfs~~
	~~Hardness: 400mg/L~~	~~Hardness: 322 mg/L~~	~~Hardness: 236 mg/L~~	~~Hardness: 197 mg/L~~
~~Acute (µg/L)~~	~~281~~	~~224~~	~~162~~	~~134~~
~~Chronic (µg/L)~~	~~10.9~~	~~8.8~~	~~6.3~~	~~--~~

~~V. Mercury~~

~~Discharges of urban runoff must not transport more than 0.0171 kilogram of mercury into the Rhine Channel per year.~~

~~VI. Selenium~~

~~A. The pollutant loads of selenium and flow, specified below in Table G-4, must be measured in San Diego Creek at Campus Drive. Pollutant loads must be calculated to exclude loads attributed to allocated sources specified in the USEPA TMDL for Toxic Pollutants for San Diego Creek and Newport Bay.~~

~~B. Discharges of urban runoff, in the in the flow categories in Table G-4 below, must not transport the pollutant loads in excess of the Waste Load Allocations shown in Table G-4 on an annual basis.~~

~~Table G-4: Waste Load Allocations for Selenium~~

	~~Base Flows <20cfs~~	~~Small Flows 21 to 181 cfs~~	~~Medium Flows 182 to 814 cfs~~	~~Large Flows >814 cfs~~	~~Annual Total~~
~~Maximum Permissible Annual Load (lbs./year)~~	~~0.4~~	~~1.0~~	~~1.0~~	~~5.3~~	~~7.6~~

~~VII. Zinc, Dissolved~~

~~A. Discharges of urban runoff must not transport more than 174,057 pounds of dissolved zinc into Newport Bay per year.~~

~~B. The acute concentration or CMC (24-hour average concentration) of dissolved zinc in representative samples of urban runoff discharged into Newport Bay must not exceed 90 µg/L.~~

~~C. The chronic concentration or CCC (4 consecutive day or 96-hour average concentration) of dissolved zinc in representative samples of urban runoff discharged into Newport Bay must not exceed 81 µg/L.~~

~~D. Discharges of urban runoff, measured in San Diego Creek at Campus Drive, in the flow categories shown in Table G-5 below must not exceed the concentrations shown.~~

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~~Table G-5: Waste Load Allocations for Zinc, Dissolved~~

	~~Base Flows <20cfs~~	~~Small Flows 21 to 181 cfs~~	~~Medium Flows 182 to 815 cfs~~	~~Large Flows >815 cfs~~
	~~Hardness: 400mg/L~~	~~Hardness: 322 mg/L~~	~~Hardness: 236 mg/L~~	~~Hardness: 197 mg/L~~
~~Acute (µg/L)~~	~~379~~	~~316~~	~~243~~	~~208~~
~~Chronic (µg/L)~~	~~382~~	~~318~~	~~244~~	~~--~~

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APPENDIX
~~H~~G

~~Waste Load Allocations~~Total Maximum Daily Loads for Metals in the San Gabriel River Watershed ~~for Coyote Creek~~

~~The following~~Appendix G incorporates the waste load allocations (~~"~~WLAs~~"~~) ~~apply to discharges of urban runoff from MS4's owned or controlled by those Co-permitees discharging into Coyote Creek.~~ assigned to urban runoff as identified in the Total Maximum Daily Loads for Metals in the San Gabriel River Watershed (San Gabriel River TMDLs). The WLAs apply to Coyote Creek, which discharges to the San Gabriel River. Responsible Co-Permittees are identified in Appendix A.

~~These requirements are based on the~~The San Gabriel River Metals TMDL was promulgated by the USEPA on March 26, 2007. The Los Angeles Regional Water Quality Control Board adopted a Basin Plan Amendment to incorporate an implementation plan and compliance schedule for this TMDL.

I. WLAs for Metals

a. Responsible Permittees shall implement BMPs to achieve the following final WLAs for total recoverable copper, lead, and zinc in Coyote Creek:

	WLAs Daily Maximum (kg/day)		
	Copper	**Lead**	**Zinc**
Dry Weather[1]	0.941	NA	NA
Wet Weather[2]	24.71 µg/L x daily storm volume (L)	96.99 µg/L x daily storm volume (L)	144.57 µg/L x daily storm volume (L)

1. Calculated based upon the median flow at LACDPW gauge station F354-R of 19 cfs multiplied by the numeric target of 20 µg/L minus direct air deposition of 0.002 kg/day.
2. In Coyote Creek, wet weather TMDLs apply when the maximum daily flow in the creek is equal to or greater than 156 cfs measured at LACDPW gauge station F354-R, located at the bottom of the creek, just above the Long Beach WRP.

II. Compliance Determination

a. Compliance with the final requirements for the San Gabriel River Metals TMDL shall be determined pursuant to Provision XVIII.B.

b. For Responsible Permittees who opt to comply with USPEA-promulgated TMDLs pursuant to Provision XVIII.B.1.a, Responsible Permittees shall propose BMPs to achieve WLAs and the schedule to implement the BMPs in the plan.

c. The Responsible Permittees shall comply with final WLAs by September 30, 2026.

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I. Monitoring and Reporting Requirements

a. Monitoring

i. Responsible Permittees shall conduct monitoring consistent with the requirements of the TMDL. Such monitoring can be integrated into the overall monitoring requirements specified Attachment A, Monitoring and Reporting Program.

b. Reporting

i. Responsible Permittees shall submit reports consistent with the requirements of the TMDL.

~~Runoff samples and flow volumes must be taken at flow gauge station F354-R, located just above the Long Beach Water Reclamation Plant. The daily storm volume must be generated by a rain event that produces a peak flow that is equal or greater than 156 cfs.~~

~~I. Copper~~

~~A. Discharges of urban runoff in Coyote Creek must not transport more than 0.941 kilogram of total recoverable copper per day during dry weather[14].~~

~~B. The mass of total recoverable copper in wet weather urban runoff that is transported daily in Coyote Creek must not exceed 24.71 µg/L multiplied by the daily storm volume in liters.~~

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~~[14] Calculated based upon the median flow at LACDPW Station F354-R of 19 cfs multiplied by the numeric target of 20 µg/L, minus direct air deposition of 0.002 kg/d.~~

~~II. Lead~~

~~The mass of total recoverable lead in wet weather urban runoff that is transported daily in Coyote Creek must not exceed 96.99 µg/L multiplied by the daily storm volume in liters.~~

~~III. Zinc~~

~~The mass of total recoverable zinc in wet weather urban runoff that is transported daily in Coyote Creek must not exceed 144.57 µg/L multiplied by the daily storm volume in liters.~~

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Attachment A

STATE OF CALIFORNIA
CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
SANTA ANA REGION

3737 Main Street, Suite 500, Riverside, CA 92501-3348
(951) 782-4130 ● Fax (951) 781-6288
http://www.waterboards.ca.gov/santaana

MONITORING AND REPORTING PROGRAM NO. R8-2014-0002

for

Order No. R8-2014-0002
NPDES Permit No. CAS618030

Orange County Flood Control District, the County of Orange
And
The Incorporated Cities therein within the Santa Ana Region

Area-wide Urban Storm Water Runoff

June XX, 2014

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Revision No.	Date Requested	Approval Date

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I. General

A. The requirements of this Monitoring and Reporting Program ("MRP"), as presented or later amended, may be met through the Co-permittees' participation in state-wide, national, regional or local monitoring programs, subject to the discretion of the Executive Officer.
B. The Executive Officer is authorized to review and approve proposed changes to this MRP. The Executive Officer will provide a minimum of 30-days for public review prior to approving any proposed changes.
C. To avoid duplication of effort, monitoring work performed by parties other than the Co-permittees may be substituted for work described in the MRP provided that the work meets the requirements of the MRP and Order No. R8-2014-0002.
D. The Co-permittees may supplement monitoring data that is required to be collected by this MRP and subsequent amendments with other valid data sources for the purpose of improving any related analysis.
E. Except for Priority Toxic Pollutants identified in the California Toxics Rule, all sample collection, handling, storage, and analysis must be completed in conformance with 40 CFR Part 136; with adopted guidance developed by the State Water Resources Control Board pursuant to California Water Code Section 13383.5; or with other methods satisfactory to the Executive Officer.
F. Unless otherwise specified differently, the Minimum Levels ("MLs") published in Appendix 4 of the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries if California (State Implementation Plan or "SIP") must be used for the analyses of all samples.
G. The term "acute", as used in Order No R8-2014-0002 and the MRP, shall have the same meaning as "criterion maximum concentration" or "CMC" (24-hour average concentration).
H. The term "chronic", as used in Order No R8-2014-0002 and the MRP, shall have the same meaning as "criterion continuous concentration" or "CCC" (4-day or 96-hour average concentration).
I. Each Co-permittee is responsible for the accuracy and completeness of the monitoring program(s) and related products for the watershed(s) to which the Co-permittee discharges. However, the PRINCIPAL PERMITTEE may develop and implement those programs and submit related work products on behalf of the Co-permittees.
J. Unless paper copies are expressly requested by Regional Board staff, all reports and submittals must be provided in an electronic format consistent with written guidance provided by the Executive Officer.

II. Water Quality Monitoring

A. Goals

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The Co-permittees must develop and implement an effective water quality monitoring program to achieve the following goals:

1. To develop useful information in support an effective program to control the discharge of pollutants in urban runoff.
2. To characterize the condition of water quality in receiving waters with respect to water quality standards; identify trends; and identify pollutants found in urban runoff that may adversely affect the beneficial uses of the receiving waters.
3. To characterize pollutant loads or concentrations in discharges from the MS4s relative to applicable waste load allocations and identify and quantify significant water quality problems related to urban runoff.
4. To identify and quantify other sources of pollutants to the maximum extent possible (e.g. atmospheric deposition, legacy pollutants, etc.) that may adversely affect the beneficial uses of the receiving waters.
5. To identify the sources of, and to prohibit illicit discharges.
6. To identify those waters, which without additional action to control pollution from urban runoff, cannot reasonably be expected to attain or maintain applicable water quality standards necessary to sustain the beneficial uses designated in the Basin Plan.
7. To objectively evaluate the effectiveness of BMPs implemented according to the Co-permittees' related programs, including, to the extent possible, quantifying the reasonably achievable reductions of pollutants in discharges or the receiving waters that are attributable to the BMP(s).
8. To evaluate and describe the costs and benefits of BMPs, implemented according to the Co-permittees' related programs, to the public and stakeholders.

B. Water Quality Monitoring Plan Development

1. The Co-permittees must prepare a draft Water Quality Monitoring Plan according to the goals, requirements, and specifications described in this Section (Section II.), State Board Resolution No. 2012-0012, and Order No. R8-2014-0002. The recommendations made by Southern California Coastal Water Research Project on the Newport Bay watershed monitoring based on evaluation of existing monitoring programs (presented at the Santa Ana Regional Board meeting on April 25, 2014) should be followed. The initial draft Plan must be submitted for approval to the Executive Officer within 6 months of the adoption of Order No. R8-2014-0002.
2. To the extent possible, the Co-permittees will develop one Water Quality Monitoring Plan that incorporates all of the elements described below. However, if this is not possible, additional Plans may be submitted.
3. ~~2~~. The Water Quality Monitoring Plan must describe processes for determining compliance with each of the Waste Load Allocations ("WLAs") and requirements in Appendices B through H of Order No. R8-2014-0002. The Plan(s) must include cycles of monitoring, analysis, and reporting for all of the WLAs.

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a. A complete cycle must be as short as practicable, comply with applicable TMDL deadlines and assessment periods, ~~or otherwise must~~and should not exceed once every 5 years.
b. A complete cycle should consider the availability of data and a reasonable period during which BMPs may affect water quality
c. Any required data collection and analyses must comply with those specified in the relevant TMDL, including averaging and assessment periods, where provided

4~~3~~. The Water Quality Monitoring Plan must also include, at a minimum, descriptions of the locations of ID/IC, receiving, and outfall monitoring locations; an explanation for the locations' selection; the sampling frequencies; parameters to be sampled; descriptions of sampling methods; and the data analysis and reporting schedule (see Subsection K below).

5~~4~~. The Water Quality Monitoring Plan must be written in an instructive manner for the benefit of persons responsible for its implementation.

6~~5~~. Until the initial draft Water Quality Monitoring Plan is approved, the Co- permittees must continue monitoring as described in the 2013-2014
Annual Progress Report. Changes to the monitoring are prohibited except with the approval of the Executive Officer.

7~~6~~. By August 1 of each year following the approval of the initial Water Quality Monitoring Plan, the Co-permittees must submit subsequent proposed changes to the Plan for approval by the Executive Officer. Certain changes to specific monitoring activities covered under the Plan that are inherently dynamic and/or iterative, which may occur after the August 1 deadline, may be submitted, in written form, after the August 1 deadline to the Executive Officer, as an addendum to any proposed changes to the Plan that were submitted by the August 1 deadline. The Executive Officer will provide a minimum of 30-days for public review and comment on the proposed changes. If no changes are proposed, the Executive Officer must be notified so in writing.

8~~7~~. Except for inconsequential grammatical or technical corrections, the Water Quality Monitoring Plan may be amended by the Co-permittees only with the approval of the Executive Officer.

9~~8~~. The Co-permittees must fully implement the Water Quality Monitoring Plan and any subsequent changes as approved by the Executive Officer.

10~~9~~. The approved Water Quality Monitoring Plan, as amended, must be posted for public access at ocwatersheds.com or using another media outlet acceptable to the Executive Officer. The posted Plan must be full, true, and accurate.

C. General Water Quality Monitoring Requirements

1. The Water Quality Monitoring Plan must be designed to achieve the following:
   a. Determine if discharges of urban runoff exceed water quality standards or, where substitutive, each of the waste load allocations ("WLAs") found in Appendices A through G of Order No. R8-20~~0~~14-

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0002. These determinations must be made according to scheduled cycles of monitoring, analysis, and reporting that will be developed according to Section XVIII.G. of the Order.

b. Objectively evaluate the effectiveness of the best management practices being implemented in the watersheds to meet the respective waste load allocations.

2. The sampling method and practice must minimize bias.

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3. Water quality parameters that are tested using valid field instruments are not required to be analyzed by a laboratory.
4. The Co-permittees must employ sample collection methods that support regional comparisons of data, unless site conditions make alternate methods necessary.
5. For each monitoring location and event, the Co-permittees must record observed conditions or circumstances that may influence monitoring results or affect conclusions made from the monitoring data.

D. Outfall Monitoring Requirements

The water quality monitoring program must include representative monitoring of urban runoff from MS4 outfalls under storm and dry-weather conditions.

1. The Co-permittees must identify representative outfall monitoring locations in the permit area.
2. Each outfall monitoring location must be sampled every two years on an alternating basis; some sites may be sampled every odd year while the remainder will be sampled every even year. The nature, number and distribution of samples are described below in this Section.
3. Stream gauges, or equally-effective methods, must be deployed during sampling events for the purpose of estimating mass loading of pollutants at each of the monitoring locations and for calculating flow-weighted event mean concentrations.
4. The Co-permittees must sample urban runoff produced by three separate storm events ("wet-weather sample") per season. The Executive Officer may allow exceptions to sampling three storm events when climatic conditions create good cause.
    a. The Co-permittees must make a reasonable effort so that one of the three sampled storm events is of the first storm water runoff of each season.
        i. A sample for this event must be collected from each outfall monitoring location during the applicable even or odd monitoring year. Each sample must represent the "first flush" of the storm and consist of a composite of discrete samples.
        ii. A second sample for this event must be collected after the storm's first hour; this sample must consist of a composite of discrete samples collected every two (2) hours during a 96-hour period or until flow is insufficient to allow sampling.
        iii. Except for the "first flush" samples, discrete samples must be composited into a single sample.
    b. For storm events occurring after the first storm event of the season, a minimum of three (3) composite samples must be collected at each outfall monitoring location during the applicable even or odd monitoring year.

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i. Each sample must consist of a composite of discrete samples collected ~~hourly~~ every two hours during a 24-hour period or until flow is insufficient to allow sampling.
ii. The 24-hour period must begin two hours after "first flush" sampling is initiated.

c. The Co-permittees must provide the date and duration of the storm event(s) sampled, rainfall estimates of the storm event which generated the sampled discharge, and the duration between the storm event sampled and the end of the previous measurable storm event.

5. The Co-permittees must sample outfalls biannually (2 times per year) during sampling years under dry-weather conditions ("dry-weather sample") at each outfall monitoring location during the applicable even or odd monitoring year. Each sample must consist of a composite of discrete samples collected ~~each hour~~hourly during a 24-hour period.
6. All wet-weather and dry-weather samples must be tested for the parameters indicated in Table 1 below.
7. In addition to the parameters indicated in Table 1, samples must be tested in the manner as follows:
   a. Diazinon, chlorpyrifos, malathion, and dimethoate must be tested for in dry-weather samples that must be taken monthly from outfall monitoring locations discharging into Newport Bay.
   b. A Priority Pollutant scan must be completed on wet-weather samples taken of runoff from the first storm of the season each year.
   c. Glyphosate must be tested for in dry-weather samples taken from monitoring sites that are outfalls dominated by urban runoff, as opposed to rising groundwater.
   d. Additional parameters that are known or suspected to contribute to the impairment of the beneficial uses of the receiving waters must also be tested for at the direction of the Executive Officer.
   e. The Co-permittees may remove an analyte from the suite of constituents to monitor if an analyte is not detected upon completion of annual monitoring. Removal of an analyte may occur for individual monitoring sites or from either storm event sampling or dry weather sampling or both.

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Table 1: Outfall Monitoring Parameters

Parameter		Wet-Weather Samples	Dry-Weather Samples	Sediment Samples
Nutrients	Nitrate plus nitrate	X	X	
	Total ammonia	X	X	
	Total Kjeldahl nitrogen	X	X	
	Total phosphate	X	X	
	Orthophosphate	X	X	
Dissolved organic carbon		X		
Total organic carbon		X	X	X
Total suspended solids		X	X	
Volatile suspended solids		X	X	
Chloride		X	X	X
Sulfate		X	X	X
Turbidity		X	X	
pH		X	X	X
Oil and grease			X	
Temperature		X	X	
Dissolved oxygen		X	X	
Electrical conductivity		X	X	
Hardness		X	X	
Particle size distribution				X
Total and dissolved heavy metals	Cadmium	X	X	X
	Chromium	X	X	X
	Copper	X	X	X
	Lead	X	X	X
	Mercury	X	X	X
	Nickel	X	X	X
	Selenium	X	X	X
	Silver	X	X	X
	Zinc	X	X	X
Organo-phosphate pesticide	Chlorpyrifos	X		
	Diazinon	X		
	Dimethoate	X		
	Malathion	X		
Bacterial indicators	Total coliform	X	X	
	Fecal coliform	X	X	
	Enterococcus	X	X	

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E. Receiving Waters Monitoring Requirements

The Water Quality Monitoring Program must include monitoring in the receiving waters of the outfalls monitored in Section II.C. above.

1. Each receiving water monitoring location must be sampled every two years on an alternating basis; some sites may be sampled every odd year while the remainder will be sampled every even year. The nature, number and distribution of samples are described below in this Section.
2. The Co-permittees must sample sediment under dry-weather conditions ("sediment sample") quarterly (4 times per year) during sampling years at receiving water monitoring locations to be specified in the Water Quality Monitoring Plan.
3. All sediment samples must be tested for the parameters indicated in ~~Table 1 above~~Table 2 below.
4. In addition to the parameters indicated in ~~Table 1~~Table 2, samples must be tested in the manner as follows:
    a. Sediment samples taken from Newport Bay must be tested for Total DDT, Dieldrin, Chlordane, PCBs, and Toxaphene.
    b. Additional parameters that are known or suspected to contribute to the impairment of the beneficial uses of the receiving waters must also be tested for at the direction of the Executive Officer.
5. Wet-weather sampling events may not be consecutive and must be separated by a minimum of two (2) days of dry weather (no precipitation).
6. Samples taken for receiving water monitoring must be tested for the parameters shown in Table 2 below and in the following manner:
    a. Measurements of specific conductance, pH, temperature, and dissolved oxygen must be taken of the water column's profile at one-meter increments, from the water surface to the bottom of each monitoring location.
    b. Water samples that are tested for nutrients must be collected near the surface of the water at the monitoring location.
    c. Water samples that are tested for metals, pesticides, total and dissolved organic carbon, and toxicity must consist of a composite of samples collected at the monitoring location in a manner that represents the average concentrations in the water column.

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7. Wet-weather, dry-weather, and sediment samples taken from Upper Newport Bay must also be tested for selenium.
8. Sediment samples taken from representative receiving water monitoring locations must also be tested once each year for benthic infauna using methods in the Region 8 Storm Water Ambient Monitoring Program ("SWAMP") Field Operations Manual.
9. Sediment samples taken from monitoring locations in Upper Newport Bay must also be tested for organochlorine pesticides and PCBs.
10. Additional parameters that are known to contribute to the impairment of the beneficial uses of the receiving waters must also be tested for at the direction of the Executive Officer.

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Table 2: Parameters for receiving water monitoring

Parameter		Wet-Weather Samples	Dry-Weather Samples	Sediment Samples
Nutrients	Nitrate plus nitrate	X	X	
	Total ammonia	X	X	
	Total Kjeldahl nitrogen	X	X	
	Total phosphate	X	X	
	Orthophosphate	X	X	
Dissolved organic carbon			X	
Total organic carbon		X	X	X
Total suspended solids		X	X	
Volatile suspended solids		X	X	
Turbidity		X	X	
pH		X	X	X
Oil and grease			X	
Temperature		X	X	
Dissolved oxygen		X	X	
Electrical conductivity		X	X	
Hardness		X	X	
Particle size distribution				X
Total and dissolved heavy metals	Cadmium	X	X	X
	Chromium	X	X	X
	Copper	X	X	X
	Lead	X	X	X
	Mercury	X	X	X
	Nickel	X	X	X
	Silver	X	X	X
	Zinc	X	X	X
Organo-phosphate pesticides	Chlorpyrifos		X	X
	Diazinon		X	X
Bacterial indicators	Total *coliform*	X	X	
	Fecal *coliform*	X	X	
	Enterococcus	X	X	
Glyphosate		X	X	

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F. Toxicity Testing

~~The water quality monitoring program must include toxicity testing, analyzed using USEPA's Test of Significant Toxicity approach~~[1].

1. ~~Whole effluent t~~Toxicity testing must be performed twice per season on *wet-weather samples* taken from representative outfall monitoring locations, during the applicable even or odd monitoring year using *Ceriodaphnia*, sea urchin fertilization, and mysid survival and growth as follows:
   i. Toxicity testing must be performed on *wet-weather samples* representing the "first-flush" of the first storm of the season (See Provision II.D.4.a.i. above).
   ii. Toxicity testing must also be performed on *wet-weather samples* taken from the second and third sampling events that represent the 24-hour period following the "first-flush" (See Provision II.D.4.b. above).
2. ~~Whole effluent~~T~~t~~oxicity testing must be performed twice per season on *wet- weather samples* taken from receiving water monitoring locations during the applicable even or odd monitoring year using sea urchin fertilization~~, sea urchin embryo development,~~ and mysid survival and growth.
3. All Toxicity tests of *wet-weather samples* must be performed using 100%, 50%, 25%, 12.5%, and 6.25% dilutions.
4. ~~Whole effluent~~T~~t~~oxicity testing must be performed on *dry-weather samples* using *Ceriodaphnia*, *Selanastrum*, and *Hyalella azteca* as follows:
   a. Twice each year on samples taken from monitoring locations during the applicable even or odd monitoring year in Carbon Creek Coyote Creek East Garden Grove-Wintersburg Channel, Bolsa Chica Channel, and Fullerton Creek.
   b. Four times per year, on a quarterly basis, during the applicable even or odd monitoring year on samples taken from monitoring locations in Peters Canyon Wash, San Diego Creek at Campus Drive and Harvard Avenue, and Santa Ana Delhi Channel.
5. ~~Whole effluent~~T~~t~~oxicity testing must be performed quarterly (four times per year) during the applicable even or odd monitoring year on representative *dry-weather* samples in Newport Bay using sea urchin fertilization~~, sea urchin embryo development,~~ and/or mysid survival and growth.
6. All Toxicity tests of *dry-weather samples* must be performed using 100% and 50% dilutions. If Toxicity tests in the 100% and 50% dilutions produce a zero percent survival of the test organisms within the first hour, additional dilutions must be tested using the same test organism for the

[1] ~~USEPA. 2010. *National Pollutant Discharge Elimination System Test of Significant Toxicity Implementation Document.* EPA 833-R-10-003. US Environmental Protection Agency, Office of Wastewater Management, Washington D.C.~~

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purpose of more accurately estimating the dilution threshold that produces the same toxic effect.

7. Toxicity tests must be performed on *sediment samples* collected once annually ~~pursuant to Section II.E.2. above~~ using a 10-day amphipod (*Eohaustorius estuaries*) survival test in solid-phase sediment and a 48-hour bivalve (*Mytilus galloprovincialis*) embryo development test at the sediment-water Interface at applicable even or odd year sampling sites for the Receivin~~i~~g Waters Program.
8. If Toxicity tests of *sediment samples* collected in two consecutive monitoring years (even or odd years) indicate zero percent survival of the test organisms within the first hour, Toxicity Identification Evaluations must be performed on samples taken from those same locations during the third consecutive monitoring year of sampling. a. Toxicity Identification Evaluations must be performed in substantial conformance with published and generally-accepted methods[2].

G. Benthic Invertebrate Taxonomy

1. The water quality monitoring program for the harbors and estuaries must include annual identification of the taxonomy of benthic invertebrate communities. Taxonomy must be identified in those sediment samples taken from monitoring locations in waters of the U.S. during their scheduled even or odd sample years consistent with the Receiving Water Monitoring Program requirements.

H. Illicit Discharges and Illicit Connections

The Water Quality Monitoring Plan must include monitoring to detect illicit discharges and illicit connections.

1. ~~Monitoring must occur~~The Co-permittees must monitor a minimum of 30 monitoring stations annually during the dry season (May 1 through September 30).
2. Monitoring to detect illicit discharges and illicit connections must occur at the locations and frequencies specified in the initial Water Quality Monitoring Plan. Annual changes to monitoring locations and frequencies shall be provided in the revised Water Quality Monitoring Plan that is due August 1 (pursuant to Part II.B.6).
3. For each monitoring station, the Co-permittees must characterize the base line hydrology of the dry-weather discharges and the water quality parameters of the discharge. Based on this information, the Co-permittees must employ statistical flow and water quality parameter thresholds that indicate when an illicit discharge may have occurred or when an illicit connection may exist. The Co-permittees must also utilize odor, color, clarity, unusual wildlife morbidity or mortality, sheen staining, corrosion, unnatural deposits, and other subjective indicators to identify

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suspected illicit discharges or illicit connections.

4. The Co-permittee that is the local jurisdiction must initiate (or cause to be initiated) an investigation to trace the source of the suspected illicit discharge or illicit connection (source investigation) where indicators developed pursuant to Part II.H.3 are found.

~~3~~5. When dry-weather discharges are found at the monitoring locations, the discharge must be tested for the parameters specified in Table 3 below using the test method type(s) indicated.

6. A source investigation must occur in substantial conformance with a common set of written techniques and procedures developed by the Permittees as part of the written program described in Provision VII.D.

a. Except as provided for in Section XVII, indications of a potential illicit discharge or connection must be investigated within three (3) business days of the Co-permittee (including the Principal Permittee) becoming aware of it.

b. A source investigation may only be regarded as concluded after the cause(s) of the illicit discharge has been identified or additional monitoring fails to detect a subsequent exceedance of the same parameter(s) after 180 days. In the interim, the Co-permittee that is the local jurisdiction must put forth a good faith effort to identify the source of an identified illicit discharge or illicit connection.

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[2] E.g. U.S. EPA. 2007. Sediment Toxicity Identification Evaluation (TIE) Phases I, II, and III Guidance Document EPA/600/R-07/080, Office of Research and Development. Washington, DC. Available at: http://www.epa.gov/nheerl/publications/files/Sediment TIE Guidance Document.pdf

Table 3: Parameters for Illicit Discharge and Illicit Connection Discharge Monitoring

Parameter		Test Method Type	
		Field	Laboratory
Ammonia		X	X
Nitrate		X	X
Soluble phosphorus		X	X
Total organic carbon ("TOC")			X
pH		X	
Oil and grease (if oil sheen is present) or Total petroleum hydrocarbons			X
Temperature		X	
Dissolved oxygen		X	
Electrical conductivity		X	
Hardness		X	
Dissolved heavy metals	Arsenic		X
	Cadmium		X
	Hexavalent chromium	X	
	Total chromium		X
	Copper	X	X
	Lead		X
	Mercury		X
	Nickel		X
	Selenium		X
	Silver		X
	Zinc		X
Organo-phosphate pesticides	Diazinon		X
	Chlorpyrifos		X
	Malathion		X
	Dimethoate		X
Bacterial indicators	Total coliform		X
	Fecal coliform		X
	Enterococcus		X
MBAS		X	

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I. Bacterial Indicators

The Water Quality Monitoring Plan must include an effective monitoring program for bacterial indicators.

1. The Co-permittees must sample discharges from the outfalls/tributaries and ocean water in the surf zone 25-yards up-coast and 25-yards down-coast from those discharges on a weekly basis.
    a. Samples must be measured for total coliform, fecal coliform, and *Enterococcus*.
    b. At the time of sample collection, the Co-permittees must estimate the flow rate of the discharge from the respective outfall/tributary and measure and record the temperature of the discharge and of the surf zone down-coast from the outfall/tributary.
    c. Samples must not be collected on days where rainfall has occurred.
    d. If no hydrologic connection exists between the outfall and the surf zone, only a down-coast sample is needed.
2. The Co-permittees must sample dry-weather discharges at representative monitoring locations.
    a. Samples must be measured for total coliform, fecal coliform, and *Enterococcus*.
    b. Sample events must be coordinated with the Orange County Health Care Agency and the Orange County Sanitation District or their successors in order to augment their monitoring program and improve the collective data's ability to resolve trends, comparisons, and correlations within and between the sites.

J. Bioassessment Monitoring

1. The Co-permittees must conduct bioassessment monitoring in conformance with the Surface Water Ambient Monitoring Program ("SWAMP").
2. Bioassessment monitoring must be completed at the monitoring locations specified by the most recent Stormwater Monitoring Coalition ("SMC") monitoring plan.

~~3. Co-permittees must perform a minimum of one Causal Assessment per year to identify the likely causes of the biological condition at the monitoring locations.~~

~~4. Causal Assessments must be conducted according to the USEPA Stressor Identification Guidance Document (2000) or an equivalent guidance acceptable to the Executive Officer~~.

3~~5~~. The bioassessment monitoring locations and parameters may ~~must~~ be adjusted during the monitoring year pursuant to recommendations from the SMC so that they are consistent with the most recent SMC monitoring plan. The water quality parameters that may be ~~5. The bioassessments must include~~ monitored ~~ing of~~in urban runoff are ~~for the parameters~~ shown in Table 4 below. In addition, the bioassessment monitoring may also ~~.~~

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~~6. The bioassessments must~~ include toxicity testing using *Selenastrum*, *Hyallela Azteca*, and *Ceriodaphnia* in 100% and 50% dilutions.

4~~7~~. Toxicity tests which produce a zero percent survival of the test organisms within the first hour must be evaluated using Toxicity Identification Evaluations.

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Table 4: Bioassessment water quality test parameters

Nutrients	Nitrate plus nitrate	Hardness	
	Total ammonia	Dissolved heavy metals	Arsenic
	Total Kjeldahl nitrogen		Cadmium
	Total phosphorus		Chromium
	Orthophosphate		Copper
Total organic carbon			Lead
Total suspended solids			Mercury
Chloride			Nickel
Sulfate			Selenium
Turbidity			Silver
pH			Zinc
Oil and grease (if oil sheen is present)		Organo-phosphate pesticides	Diazinon
Temperature			Chlorpyrifos
Dissolved oxygen			Malathion
Electrical conductivity			Dimethoate

K. Data Analyses

1. The Water Quality Monitoring Plan must include a schedule of statistically-valid analyses that will be performed on collected data.
2. The schedule of analyses must include a description of the statistical analyses that will be performed, the purpose of each analysis, the data sets and sub-sets that will be analyzed, and the time periods or thresholds at which each analysis will be performed.
3. The schedule of analyses must satisfy schedules specified in this MRP, established in relevant adopted TMDLs, and this Order.
4. The Water Quality Monitoring Plan must include the supporting rationale for the schedule of analyses.

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5. The applicable schedule of analyses and the results of the performed analyses must be reported in the Annual Progress Report.

L. Special Studies

1. The water quality monitoring program must include the performance of special studies. The special studies must be carried out for those purposes in Section II.A. above, where other elements of the monitoring program are insufficient.
2. The Co-permittees shall provide written documentation of any special studies to be performed under the MRP including a schedule of proposed milestones, a description of work products to be completed, and the achievement of milestones as well as any changes/updates for any special studies currently being implemented. This information shall be provided in the revised Water Quality Monitoring Program that is due August 1 (pursuant to Part II.B.6). ~~The Co-permittees must provide a written work plan each year in the Annual Progress Report which describes the progress of ongoing special studies and special studies which are proposed for the next reporting period. The work plan must include a schedule of proposed milestones and a description of work products expected as part of completion of the special studies and the achievement of milestones.~~

III. Program Effectiveness Assessments and Reporting

A. All reports and plans required by this Order must be signed by a duly authorized representative for the Principal Permittee and submitted to the Executive Officer of the Regional Board under penalty of perjury.
B. The Co-permittees must submit all information and materials necessary to comply with, or demonstrate compliance with, the requirements of this Order to the Principal Permittee in a timely manner. All submittals by the Co-permittees must be signed by a duly authorized representative for the respective Co-permittee under penalty of perjury.
C. Data transmittals to the Regional Board must be in the form developed by the Stormwater Monitoring Coalition ("SMC") and approved by the State Water Resources Control Board in the document entitled "Standardized Data Exchange Formats" for the purpose of providing a standard format for all data transfers and allow data to be universally shared and evaluated as part of various programs.
D. The Co-permittees must submit an Annual Progress Report to the Executive Officer of the Regional Board and to the Regional Administrator of the USEPA – Region 9 no later than November 15th of each year. The reporting period must address actions taken to comply with the requirements of Order No. R8-2014-0002 and this MRP through June 1 of the reporting year. The Annual Progress Report must include the following:
    a. A schedule of all actions required by Order No. R8-2014-0002 during the reporting period~~, any outstanding actions required by Order No. R8-2014-~~

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~~0002 and Order No. R8-2009-0030,~~ and the status of efforts to carry out the scheduled actions~~ and satisfy the related requirements~~.

b. The results of each Co-permittees' program effectiveness assessment and the results of the Principal Permittee's overall evaluation of those results.

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c. The results of water quality monitoring; the results of scheduled analyses of the water quality monitoring data; and any related conclusions reached by the Co-permittees.
d. The status of special studies carried out according to the previous reporting period's work plan and the work plan for the upcoming reporting period (See Section II.K. above)
e. The status of efforts to reduce and/or eliminate the discharge of trash and debris (See Subsection VII.D. of Order No. R8-2014-0002).
f. The status of efforts to detect and mitigate SSOs (See Subsection VII.E. of Order No. R8-2014-0002).
g. The unified fiscal analysis (See Section XX of Order No. R8-2014-0002).

IV. Reporting Schedule Summary

Table 5, below, summarizes information that must be reported to the Executive Officer and the items' deadlines. Deliverables are in the order in which they appear in Order No. R8-2014-0002. The table is provided for the convenience of the reader and should not be used as a substitute for reviewing the contents of Order No. R8-2014-0002, this MRP, or the Technical Report.

A. With the exception of deliverables with capitalized titles, Order No. R8-2014-0002, this MRP, and this summary do not establish formal nomenclature. Deliverables with no formal nomenclature may be identified in a manner suitable to the Co-permittees, but they must be identified by a written statement of purpose, declaring which Provision(s) they are intended to comply with.

B. Deliverables that are submitted with the Annual Progress Report do not need to consist of separate documents; they may be incorporated into the Annual Progress Report. But they must be readily-identifiable, denoted elements (e.g. separate chapters) and include a statement of purpose as described above.

C. The Co-permittees are encouraged to submit deliverables in an electronic format. To preserve their authenticity, all deliverables submitted in an electronic format must not be readily-alterable.

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Table 5: Reporting Schedule Summary

Deliverable	Source Provision(s)	Deadline
Draft plan	IV.C.1. and XVIII.H.1.	Varies, but generally triggered by water quality monitoring results and analyses. Due within 6 months of the Co-permittees becoming aware of an exceedance of WLAs or water quality standards. Due within 90 days if requested in writing by the Executive Officer.
Legal authority assessment report	VI.B.	Reported as needed as part of Annual Progress Report.
Trash and debris BMP report	VII.E.1.	Reported as part of Annual Progress Report.
Trash and debris technology evaluation report	VII.E.2.	Reported as part of Annual Progress Report.
BMP retrofit study updates	XII.A.8.	12 months from date of adoption.
Structural treatment control BMP waiver notice	XII.L.	30-days prior to Co-permittee's issuance of the waiver.
Draft watershed maps	XII.N.3.	6 months from date of adoption.
General audience survey	XIII.E.1.b.	60 months from the date of adoption.
Initial imminent threat notice	XVII.A.1.	24 hours of Co-permittees becoming aware.
Imminent threat report	XVII.A.2.	5 business days after initial imminent threat notice.
Known/suspected WDR violations report	XVII.C.	30-days following the end of each calendar quarter: January 30, April 30, July 30th, and October 30th of each year.
WLA compliance determination plan	XVIII.G.	6 months from date of adoption.
Program Effectiveness Assessment	XIX.D.	Reported as part of the Annual Progress Report
Unified fiscal analysis	XX.A.	Reported as part of the Annual Progress Report
Report of Waste Discharge	XXIII.A.	180-days before expiration of this Order.
Water Quality Monitoring Plan	XXIV.I. and MRP II.B.1.	6 months from date of adoption
Revised Water Quality Monitoring Plan	MRP II.B.6	August 1 each year
Annual Progress Report	XXIV.I. and MRP III.D.	Annually by November 15th of each year.

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Ordered by:

Kurt V. Berchtold
Executive Officer

Date

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CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

SANTA ANA REGION

3737 Main Street, Suite 500, Riverside, CA 92501-3348
(951) 782-4130 Fax (951) 781-6288
http://www.waterboards.ca.gov/santaana

DRAFT TECHNICAL REPORT

FOR

ORDER NO. R8-2014-0002
NPDES PERMIT NO. CAS618030

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM ("NPDES") PERMIT
AND
WASTE DISCHARGE REQUIREMENTS

For

The County of Orange, Orange County Flood Control District
And
The Incorporated Cities of Orange County within the Santa Ana Region

Area-wide Urban Storm Water Runoff

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September XX, 2014

I. PURPOSE

The purpose of this Technical Report is to describe the principal facts, the methodology, and the significant legal and policy matters considered by Santa Ana Regional Water Quality Control Board staff ("Regional Board staff") in preparing Order No. R8-2014-0002 ("Order"). This Technical Report also serves as a fact sheet and contains some subheadings and content which generally follow the information described in 40 CFR Parts 124.8 and 124.56.

II. CONTACT INFORMATION

Order No. R8-2014-0002 and other related documents are available at the Santa Ana Regional Water Quality Control Board's ("Regional Board") web site at:

http://www.waterboards.ca.gov/santaana/water_issues/programs/stormwater/oc_permit.shtml

The documents referenced in this Technical Report and in the Order are also available for public review at the Regional Board office at the address below. These and other public records are available for inspection during regular business hours from 8:00 am to 5:00 pm Monday through Friday, except for State Holidays.

The Regional Board office address is:

3737 Main Street, Suite 500
Riverside CA 92501-3348

Persons interested in reviewing or obtaining copies of public records are encouraged to do so by appointment. An appointment can be made by e-mail, facsimile, telephone, or in person. Requests by mail should be made to the attention of "File Review Request" at the Regional Board office address shown above. Contact information for other means of communication is as follows:

Phone: (951) 782-4499
Facsimile: (951) 781-6288
E-mail: FileReview8@waterboards.ca.gov

Appointments are not mandatory, but they will help Regional Board staff fulfill requests efficiently and prevent delays while records are being located, retrieved, and reviewed, if necessary.

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The following are the contact information for Regional Board staff involved in the preparation of Order No. R8-2014-0002:

Adam Fischer, MESM (principal author) Environmental Scientist adam.fischer@waterboards.ca.gov (951) 320-6363	Michelle Beckwith Senior Environmental Scientist Coastal Section Chief michelle.beckwith@waterboards.ca.gov (951) 782-4433
Hope Smythe Environmental Program Manager Division Chief Hope.smythe@waterboards.ca.gov (951) 782-4493	Joanne Schneider (TMDLs) Environmental Program Manager Division Chief Joanne.schneider@waterboards.ca.gov

III. BACKGROUND

In 1987, the Clean Water Act was amended to include Section 402(p) which established a framework for regulating municipal and industrial storm water discharges under the National Pollutant Elimination Discharge System ("NPDES"). Section 402(p) requires owners and operators of municipal separate storm sewer systems ("MS4s") to have NPDES permits for discharges of storm water to waters of the U.S. On November 16, 1990, the United States Environmental Protection Agency ("USEPA") amended its NPDES permit regulations to include requirements for storm water discharges. These regulations are codified in the Code of Federal Regulations, Title 40, Parts 122, 123, and 124 (40CFR Parts 122, 123, and 124). Section 402(p) and 40 CFR Parts 122, 123, and 124. As detailed in this Technical Report, these regulations, along with other statutes, plans, and policies, form the basis for the requirements in Order No. R8-2014-0002.

On July 13, 1990, the Regional Board adopted Order No. 90-71 (NPDES Permit No. CA 8000180). This was the first version of NPDES Permit No. CAS618030, implementing USEPA's new NPDES permit regulations for discharges from MS4s. Since then, the Regional Board has adopted three other versions of NPDES Permit No. CAS618030: Order No. 96-31, Order No. R8-2002-0010, and

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Order No. R8-2009-0030. Order No. R8-2014-0002 is a fifth version ("fifth-term") of NPDES Permit No. CAS618030.

IV. PERMITTED ENTITIES

The Co-permittees whose discharges of urban runoff to waters of the U.S. are authorized by this Order are as follows:

County of Orange
Orange County Flood Control District
City of Anaheim
City of Brea
City of Costa Mesa
City of Cypress
City of Fountain Valley
City of Fullerton
City of Garden Grove
City of Huntington Beach
City of Irvine
City of La Habra
City of La Palma
City of Laguna Woods
City of Lake Forest
City of Los Alamitos
City of Newport Beach
City of Orange City
of Placentia City of
Santa Ana City of
Seal Beach City of
Stanton
City of Tustin City
of Villa Park City of
Westminster City of
Yorba Linda

The County of Orange includes a total of 34 cities, including the Co-permittees listed above. The remaining unlisted cities lie entirely within the San Diego Region. Because the boundaries of the Santa Ana Region are largely defined by watershed boundaries and often cross political boundaries, three of the listed Co-permittees discharge into both the Santa Ana Region and the San Diego Region. These cities are Laguna Hills, Laguna Woods, and Lake Forest.

All of the above Co-permittees fall into one of two categories. They are either a medium or large municipality that respectively services a population of greater than 100,000 or 250,000 people, or they are a small municipality that is interrelated to a medium or large municipality. Section 402(p) of the Clean Water Act requires that both of these categories of dischargers obtain an NPDES permit.

All of the above Co-permittees in this Order have individual and shared responsibilities to comply with the requirements of this Order. The County of Orange continues to be the Principal Permittee and, as such, has certain other responsibilities in addition to those as a Co-permittee. In order to emphasize these overlapping responsibilities, this Order refers to all of the Co-permittees collectively as "Co-permittees", including the Principal Permittee. When

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referencing the Principal Permittee, a requirement of this Order is unique to the County of Orange.

V. PERMITTED DISCHARGES

Order No. R8-2014-0002 regulates the discharge of urban runoff into waters of the U.S. from MS4s operated by the Co-permittees listed in Section IV above. The term "urban runoff" is not defined in the Code of Federal Regulations or in the Federal Register. For the purposes of the Order, urban runoff is defined as the combination of storm water runoff and authorized non-storm water runoff from residential, commercial, industrial, and construction areas within the permitted area. Discharges of urban runoff often contain wastes, as defined in California Water Code, and pollutants, as defined in the Clean Water Act. Wastes may, and pollutants will by definition, adversely affect the quality of the receiving waters.

This Order authorizes the discharge of urban runoff from the Co-permittees' MS4s. This includes authorization for certain non-storm water discharges. Authorized non-storm water discharges are subject to both the requirements herein and the requirements of the "De Minimus" Permit. This Order does not authorize the Co-permittees' non-storm water discharges that are subject to NPDES Permit No. CAG918002, for discharges to surface waters of certain groundwater at sites within the San Diego Creek/Newport Bay watersheds. Authorization for such discharges must be obtained through the process described in NPDES Permit No. CAG918002. The purpose of excluding discharges subject to NPDES Permit No. CAG918002 is to avoid regulatory overlap that could potentially create cross-purposes and confusion.

In summary, MS4s are defined in 40CFR122.26(b)(8) as "a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains)…designed or used for collecting or conveying storm water". Due to the broad inclusion of the definition, portions of MS4s in the permit area will include open channels that are waters of the U.S. In these cases, the channels are considered receiving waters whose beneficial uses must be protected.

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VI. APPLICABLE STATUTES, REGULATIONS, PLANS, AND POLICIES

A. Legal Authorities – Federal Clean Water Act and California Water Code

Order No. R8-2014-0002 is issued pursuant to Section 402 of the Clean Water Act and implementing regulations adopted by the USEPA, and pursuant to Chapter 5.5, Division 7 of the California Water Code (commencing with Section 13370).

The objective of the Clean Water Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." To carry out this objective, the Clean Water Act requires permit programs to regulate the discharge of pollutants and dredge or fill material to the navigable waters of the U.S. and to regulate the use and disposal of sewage sludge. Section 402 of the Clean Water Act provides the legal authority to issue NPDES permits for the discharge of pollutants to waters of the U.S. NPDES permits may be issued by states which have been authorized to implement certain provisions of the Clean Water Act. The USEPA authorized the state of California to implement the NPDES permit program on May 14, 1973.

The Porter-Cologne Water Quality Control Act (California Water Code section 13000 *et seq.*) established the State Water Resources Control Board and the nine regional water quality control boards. The boards are the principal state agencies with primary responsibility for the coordination and control of water quality. The Santa Ana Regional Water Quality Control Board has the primary responsibility for the coordination and control of water quality in the Santa Ana Region.

The regional water quality control boards implement the Clean Water Act through Chapter 5.5 of the California Water Code, commencing with Section 13370. Section 13377, in part, provides the regional water quality control boards with the authority to issue waste discharge requirements to ensure compliance with all applicable provisions of the Clean Water Act.

Clean Water Act Section 402(p) requires the USEPA, or authorized states, to issue NPDES permits for storm water discharges from municipal separate storm sewer systems ("MS4s") to water of the U.S. Clean Water Act Section 402(p)(3)(B) allows such NPDES permits to be issued on a system-wide or jurisdiction-wide basis. Section 402(p)(3)(B)(ii) requires that these NPDES permits "effectively prohibit non-storm water discharges" into the MS4s. Section

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402(p)(3)(B)(iii) requires these NPDES permits to "require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants."

B. Federal and California Endangered Species Acts

This Order does not authorize any act that results in the taking of a threatened or endangered species or any act that is prohibited, or becomes prohibited in the future under either the California Endangered Species Act (Fish and Game Code Sections 2050 to 2115.5) or the Federal Endangered Species Act (16 United States Code Sections 1531 to 1544). This Order requires compliance with requirements to protect the beneficial uses of waters of the U.S. The Co-permittees are responsible for meeting the requirements of the applicable Endangered Species Acts.

C. California Environmental Quality Act

The action to adopt an NPDES Permit is exempt from the provisions of Chapter 3 of the California Environmental Quality Act ("CEQA") (Public Resources Code Section 21100 *et seq.*) pursuant to CWC Section 13389. (*County of Los Angeles v. Cal. Water Boards* (2006) 143 Cal. App. 4th 985.)

D. State and Federal Regulations, Plans and Policies

1. Water Quality Control Plan for the Santa Ana River Basin

The Clean Water Act requires the regional boards to establish water quality standards for each water body in their region. The requirements of this Order are designed to attain and maintain water quality standards. Water quality standards include beneficial uses, water quality objectives and criteria that are established at levels that protect beneficial uses, and a policy to prevent degrading of waters ("anti-degradation policy").

On January 24, 1995, the Santa Ana Regional Water Quality Control Board adopted the *Water Quality Control Plan for the Santa Ana River Basin* ("Basin Plan"). The Santa Ana Regional Water Quality Control Board has amended the

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Basin Plan on multiple occasions since 1995. The Basin Plan designated beneficial uses, establishes water quality objectives, and contains implementation programs and policies to achieve those objectives for all waters in the Santa Ana Region. The Basin Plan identifies the following existing and potential beneficial uses for surface waters in the Santa Ana Region:

- Municipal and domestic supply
- Agricultural supply
- Industrial service and process supply
- Groundwater recharge
- Navigation
- Hydropower generation
- Water contact recreation
- Non-contact water recreation
- Commercial and sport fishing
- Warm freshwater and limited warm freshwater habitats
- Cold freshwater habitat
- Preservation of biological habitats of special significance
- Wildlife habitat
- Preservation of rare, threatened or endangered species
- Marine habitat
- Shellfish harvesting
- Spawning, reproduction and development of aquatic habitats
- Estuarine habitat

2. Water Quality Control Plan for Ocean Waters of California

In 1972, the State Water Resources Control Board ("State Board") adopted the Water Quality Control Plan for Ocean Waters of California ("Ocean Plan"). The State Board adopted the most-recent amended Ocean Plan on September 15, 2009. The Office of Administrative Law approved it on March 10, 2010 and USEPA approved it on October 8, 2010.

The Ocean Plan is applicable in its entirety to ocean waters of the State. In order to protect beneficial uses, the Ocean Plan establishes water quality objectives and a program of implementation. Pursuant to California Water Code Sections 13263 and 13377, the requirements of this Order implement the Ocean Plan.

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The Ocean Plan identifies the beneficial uses of ocean waters of the State as summarized below:

- Industrial water supply
- Water contact and non-contact recreation
- Navigation
- Commercial and sport fishing
- Mariculture
- Preservation and enhancement of designated Areas of Special Biological Significance
- Rare and endangered species
- Marine habitat
- Fish spawning and shellfish harvesting

The Santa Ana Region includes two Areas of Special Biological Significance ("ASBS"), the Robert B. Badham and Irvine Coast ASBS'. In the Ocean Plan, these are known as ASBS 32 and ASBS 33 respectively. Locally, these ASBS' are known as 'Newport Coast' and 'Crystal Cove', respectively. Both of these areas were designated as ASBS' by the State Board on April 18, 1974.

The Ocean Plan prohibits the discharge of waste to designated Areas of Biological Significance unless an exception to Ocean Plan requirements is issued by the State Board. On March 20, 2012, the State Board approved Resolution No. 2012-0012, which includes exceptions to the Ocean Plan prohibition for certain discharges to various ASBS'. This includes exceptions for discharges from the City of Newport Beach to Newport Coast and Crystal Cove and from The Irvine Company, the Department of Parks and Recreation and the Department of Transportation to Crystal Cove.

Specific terms, prohibitions, and special conditions were adopted in Attachment "B" to Resolution No. 2012-0012 to provide protections for ASBS'. Resolution No. 2012-0012 grants *exceptions* for the City of Newport Beach and others, but does not authorize discharges to ASBS'. This Order grants the actual *authorization* to discharge to ASBS' only to the City of Newport Beach. The other dischargers are not Co-permittees under this Order. The protections in Attachment "B" to Resolution No. 2012-0012 have been incorporated into this Order as if fully set forth herein and are applicable to discharges from the City of Newport Beach.

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3. Water Quality Control Plan for Enclosed Bays and Estuaries – Part 1 Sediment Quality

   On September 16, 2008, the State Board adopted the Water Quality Control Plan for Enclosed Bays and Estuaries – Part 1 Sediment Quality ("Sediment Quality Control Plan"). The Sediment Quality Control Plan became effective on August 25, 2009. The Sediment Quality Control Plan establishes: 1) narrative sediment quality objectives to protect benthic communities from exposure to contaminants in sediment and to protect human health; and 2) a program of implementation using a 'multiple lines of evidence' approach to interpret the narrative sediment quality objectives. The requirements of this Order implement the Sediment Quality Control Plan.

4. Anti-degradation Policy

   Federal regulations (40CFR131.12) require that the state water quality standards include an anti-degradation policy consistent with the Federal Anti-degradation Policy. The State Board established California's anti-degradation policy in State Board Resolution No. 68-16, "Statement of Policy with Respect to Maintaining the Quality of the Waters of the State". State Board Resolution No. 68-16 incorporates the Federal Anti-degradation Policy where the federal policy applies under federal law.

   The Santa Ana Regional Water Quality Control Board's Basin Plan implements and incorporates by reference both the State and Federal Anti-degradation Policies. State Board Resolution No. 68-16 and 40 CFR131.12 require that the Santa Ana Regional Water Quality Control Board maintain high quality waters of the State until it is demonstrated that any change in quality will be consistent with maximum benefit to the people of the State, will not unreasonably affect beneficial uses, and will not result in water quality less than that described in the Santa Ana Regional Water Quality Control Board's policies. State Board Resolution No. 68-16 requires that discharges of waste be regulated to meet best practicable treatment or control to assure that pollution or nuisance will not occur and that the highest water quality, consistent with the maximum benefit to the people of the State, will be maintained.

   The discharges authorized by this Order are consistent with the anti-degradation provisions of 40CFR131.12 and State Board Resolution No. 68-16. As required by 40CFR122.44(a), the Co-permittees must comply with the "maximum extent

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practicable" standard set forth in Clean Water Act Section 402(p) for discharges of pollutants in urban runoff from MS4s.

Many of the waters within the area covered by this Order are impaired and listed on the State's Clean Water Act Section 303(d) List. The Santa Ana Regional Water Quality Control Board has established TMDLs to address the impairments. This Order requires Co-permittees to implement WLAs set forth in TMDLs. This Order requires Co-permittees to implement effective processes and programs, and effectively prohibit non-storm water discharges into the MS4. Water-quality based effluent limits ("WQBELs") are developed as part of plans implemented by the Co-permittees to achieve WLAs. This Order does not authorize an increase in the amount of wastes discharged.

5. Anti-backsliding Requirements

Clean Water Act Sections 402(o) and 303(d)(4) and 40CFR122.44(l) prohibit backsliding in NPDES permits. These anti-backsliding provisions require effluent limitations in a reissued permit to be as stringent as those in the previous permit, with some exceptions where limitations may be relaxed. All effluent limitations and other conditions in this Order are at least as stringent as the effluent limitations in the previous versions of the NPDES permit; therefore, this permit is consistent with the federal anti-backsliding requirements.

6. Clean Water Act Section 303(d) List

Clean Water Act Section 303(d)(1) requires each state to identify specific water bodies within its boundaries where water quality standards are not being met or are not expected to be met after technology-based effluent limitations on point sources of pollutants have been complied with. Water bodies that do not meet water quality standards are considered impaired and are placed on the state's "303(d) List". For each listed water body, the state or USEPA is required to establish a TMDL of each pollutant that is impairing the water quality standards in that water body. Periodically, the USEPA approves the state's 303(d) List.

A TMDL is the sum of the allowable pollutant loads of a single pollutant from all contributing point sources (waste load allocations), non-point sources (load allocations), the contribution from background sources, and a margin of safety (40 CFR 130.2(i)). MS4 discharges are considered point source discharges and are assigned waste load allocations. A TMDL is a tool for implementing water

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quality standards and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable pollutant loads from various sources to a water body and thereby provides the basis to establish water quality-based controls. By implementing these controls, dischargers should provide the pollutant load reduction needed for a water body to meet water quality standards.

Most recently, the USEPA approved the state of California's 2010 303(d) List of impaired water bodies on October 11, 2011. The 2010 303(d) List includes certain receiving waters in the Santa Ana Region. Since 2002, USEPA and the Santa Ana Regional Water Quality Control Board have established TMDLs to address water quality impairments. These TMDLs establish waste load allocations ("WLAs") for discharges from MS4s.

Clean Water Act Section 402(p)(3)(B)(iii) requires the Santa Ana Regional Water Quality Control Board to require Co-permittees to employ "management practices, control techniques and system, design, and engineering methods and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." Clean Water Act Section 402(a)(1) also requires states to issue permits with conditions necessary to carry out the provisions of the Clean Water Act. Federal regulations also require that NPDES permits contain WQBELs consistent with the assumptions and requirements of all available WLAs (40 CFR 122.44(d)(1)(vii)(B)). California Water Code requires that NPDES permits include limitations necessary to implement water quality control plans. Therefore, this Order includes WQBELs and other provisions to implement the TMDL WLAs for discharges from MS4s.

7. Other Regulations, Plans, and Policies

This Order implements all other applicable federal regulations and State regulations, plans and policies, including 40CFR131.38 (Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California), also known as the California Toxics Rule or "CTR"; the State Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California, also known as the State Implementation Policy of "SIP".

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E. Unfunded Mandates

Article XIII B, Section 6(a) of the California Constitution provides that whenever "any state agency mandates a new program or higher level of service on any local government, the state shall provide a subvention of funds to reimburse that local government for the costs of the program or increased level of service." The requirements of this Order do not constitute state mandates that are subject to a subvention of funds for several reasons, including, but not limited to, the following.

First, the requirements of this Order do not constitute a new program or a higher level of service as compared to the requirements contained in the previous Fourth Term Permits. The overarching requirement to impose controls to reduce the pollutants in discharges from MS4s is dictated by the Clean Water Act and is not new to this permit cycle (33 USC section 1342(p)(3)(B)). The inclusion of new and advanced measures as the MS4 programs evolve and mature over time is anticipated under the Clean Water Act (55 CFR 47990, 48052 (Nov. 16, 1990)) and, to the extent requirements in this Order are interpreted as new advanced measures, they do not constitute a new program or higher level of service.

Second, and more broadly, mandates that are imposed by federal law are exempt from the requirement that the local agency's expenditures be reimbursed (Cal. Const., art. XIII B, section 9, subd. (b)). This Order implements federally-mandated requirements under the Clean Water Act and its requirements are therefore not subject to subvention of funds. This includes federal requirements to effectively prohibit non-storm water discharges, to reduce the discharge of pollutants in storm water to the MEP, and to include such other provisions as the Administrator or the State determines appropriate for the control of such pollutants (33 USC section 1342(p)(3)(B)). Federal cases have held these provisions require the development of permits and permit provisions on a case-by-case basis to satisfy federal requirements. (*Natural Resources Defense Council, Inc., v. USEPA* (9th Cir. 1992) 966 F.2d 1292, 1308, fn. 17.)

The authority exercised under this Order is not reserved state authority under the CWA's savings clause (cf. *Burbank v. State Water Resources Control Bd.* (2005) 35 Cal.4th 613, 627-628 [relying on 33 USC section 1370. The savings clause allows a state to develop requirements which are not "less stringent" than federal requirements]). Instead, the authority under this Order is part of a federal mandate to develop pollutant reduction requirements for municipal separate storm sewer systems. To this extent, it is entirely federal authority that forms the

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legal basis to establish the permit provisions. (See *City of Rancho Cucamonga v. Regional Water Quality Control Board, Santa Ana Region* (2006) 135 Cal.App.4th 1377, 1389; *Building Industry Ass'n of San Diego Co. v. State Water Resources Control Bd*. (2004) 124 Cal.App.4th 866, 882-883.)

The MEP standard is a flexible standard that balances a number of considerations, including technical feasibility, cost, public acceptance, regulatory compliance, and effectiveness. (*Building Ind. Ass'n, supra*, 124 Cal.App.4th at pp. 873-874, 889.) Such considerations change over time with advances in technology and with experience gained in storm water management (55 FR 47990, 48052 (Nov. 16, 1990)). Accordingly, a determination of whether the conditions contained in this Order exceed the requirements of federal law cannot be based on a point by point comparison of the permit conditions and the minimum control measures that are required "at a minimum" to reduce pollutants to the maximum extent practicable and to protect water quality (40 CFR 122.34). Rather, the appropriate focus is whether the permit conditions, as a whole, exceed the MEP standard.

The requirements of the Order, taken as a whole rather than individually, are necessary to reduce the discharge of pollutants to the MEP and to protect water quality. The Santa Ana Regional Water Quality Control Board finds that the requirements of the Order are practicable, do not exceed federal law, and thus do not constitute an unfunded mandate. These findings are the expert conclusions of the principal state agency charged with implementing the NPDES program in California (CWC sections 13001, 13370).

It should also be noted that the provisions in this Order to effectively prohibit non-storm water discharges are also mandated by the CWA (33 USC section 1342(p)(3)(B)(ii)). Likewise, the provisions of this Order to implement TMDLs are federal mandates. The Clean Water Act requires TMDLs to be developed for water bodies that do not meet federal water quality standards (33 USC section 1313(d)). Once the USEPA or a state establishes or adopts a TMDL, federal law requires that permits must contain effluent limitations consistent with the assumptions and requirements of any applicable waste load allocation in a TMDL (40 CFR 122.44(d)(1)(vii)(B)).

Third, the Co-permittees' obligations under this Order are similar to, and in many respects less stringent than, the obligations of non-municipal dischargers who are issued NPDES permits for storm water discharges. With a few inapplicable exceptions, the Clean Water Act regulates the discharge of pollutants from point

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sources (33 USC section 1342) and the Porter-Cologne Water Quality Control Act regulates the discharge of waste (CWC section 13263), both without regard to the source of the pollutant or waste. As a result, the "costs incurred by local agencies" to protect water quality reflect an overarching regulatory scheme that places similar requirements on governmental and non-governmental dischargers. (See *County of Los Angeles v. State of California* (1987) 43 Cal.3d 46, 57-58 [finding comprehensive workers' compensation scheme did not create a cost for local agencies that was subject to state subvention].)

The Clean Water Act and the Porter-Cologne Water Quality Control Act largely regulate storm water with an even hand, but to the extent there is any relaxation of this even-handed regulation, it is in favor of the local agencies. Generally, the Clean Water Act requires point-source dischargers, including dischargers of storm water associated with industrial or construction activity, to comply strictly with water quality standards (33 USC section 1311(b)(1)(C); *Defenders of Wildlife v. Browner* (9th Cir. 1999) 191 F.3d 1159, 1164-1165 [noting that industrial discharges must strictly comply with water quality standards]). As discussed in prior State Water Board decisions, certain provisions of this Order do not require strict compliance with water quality standards (State Water Board Order No. WQ 2001-0015, p. 7). Those provisions of this Order regulate the discharge of waste in municipal storm water under the Clean Water Act's MEP standard, not the BAT/BCT standard that applies to other types of discharges. These provisions, therefore, regulate the discharge of waste in municipal storm water more leniently than the discharge of waste from non-governmental sources.

Fourth, the Co-permittees have requested permit coverage in lieu of compliance with the complete prohibition against the discharge of pollutants contained in Clean Water Act section 301(a) (33 USC section 1311(a)). To the extent that the Co-permittees have voluntarily availed themselves of the permit, the program is not a state mandate. (Accord, *County of San Diego v. State of California* (1997) 15 Cal.4th 68, 107-108.)

Fifth, the local agency Co-permittees' responsibility for preventing discharges of waste that can create conditions of pollution or nuisance from conveyances that are within their ownership or control under state law predates the enactment of Article XIIIB, Section (6) of the California Constitution.

Finally, even if any of the permit provisions could be considered unfunded mandates, under Government Code section 17556, subdivision (d), a state

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mandate is not subject to reimbursement if the local agency has the authority to charge a fee. The Co-permittees have the authority to levy service charges, fees, or assessments sufficient to pay for compliance with this Order, subject to certain voting requirements contained in the California Constitution. (See Cal. Const., Art. XIII D, section 6, subd. (c); see also *Howard Jarvis Taxpayers Ass'n v. City of Salinas* (2002) 98 Cal.App.4th 1351, 1358-1359.) Numerous activities contribute to the pollutant loading in the MS4. Local agencies can levy service charges, fees, or assessments on these activities, independent of real property ownership. (See, e.g., *Apartment Ass'n of Los Angeles County, Inc., v. City of Los Angeles* (2001) 24 Cal.4th 830, 842 [upholding inspection fees associated with renting property].) The authority and ability of a local agency to defray the cost of a program without raising taxes indicates that a program does not entail a cost subject to subvention. (*Clovis Unified School Dist. V. Chiang* (2010) 188 Cal.App.4th 794, 812, citing Connell v. Sup. Ct. (1997) 59 Cal.App.4th 382, 401; *County of Fresno v. State of California* (1991) 53 Cal. 3d. 482, 487-488.)

VII. REGULATORY BASIS FOR PERMIT REQUIREMENTS

Order No. R8-2014-0002 is based on Section 402(p) of the Clean Water Act; 40CFR Parts 122, 123, and 124; and the Porter-Cologne Water Quality Control Act (Division 7 of the California Water Code, Section 13000 *et seq*.). This Order is also based on the Water Quality Control Plan for the Santa Ana River Basin ("Basin Plan"); all applicable provisions of state-wide water quality control plans and policies adopted by the State Water Resources Control Board ("State Board"); the California Toxics Rule ("CTR"); and the CTR Implementation Plan.

The Basin Plan was revised and adopted by the Regional Board and it became effective on January 24, 1995. Since then, the Basin Plan has been amended to incorporate requirements related to Total Maximum Daily Loads ("TMDLs", discussed later in this Section). The Basin Plan contains water quality objectives and beneficial uses for water bodies in the Santa Ana Region. Under the Clean Water Act, both beneficial uses and the water quality objectives to protect them are collectively referred to as "water quality standards". The Basin Plan also incorporates by reference all State Board water quality control plans and policies, including the 1990 Water Quality Control Plan for Ocean Waters, known as the "Ocean Plan".

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VIII. METHOD FOR THE DEVELOPMENT OF ORDER NO. R8-2014-0002

A. Results of Audits

During the term of Order No. R8-2009-0030, Regional Board staff performed 14 audits of 12 of the Co-permittees. The audits were performed on one or more elements of the Co-permittees' storm water programs and included reviews of the target Co-permittee's Program Effectiveness Assessments ("PEAs"). Audits were largely carried out using process mapping techniques in addition to comparisons of actual program outcomes with permit requirements.

Regional Board staff review has found that the "iterative process" has been hampered by the disuse of performance metrics. In most cases, the Co-permittees tracked and reported outcomes of program activities in their PEAs without any performance metrics to provide context. This renders the information of little use. For example, Co-permittees commonly report on the number of curb-miles swept as part of street-sweeping programs. This reporting approach does not allow evaluation of the data by comparing it to the target number of curb-miles that were supposed to be swept or inter-annual comparisons.

Regional Board staff highlighted this issue with an audit performed on the City of Santa Ana's Program Management, Public Education, and Existing Development elements of their storm water program in 2010. This audit focused on Section C of the City's 2008-2009 PEA, which contains the outcomes from these program elements. Because the format used by the City was one used by the Co-permittees, the conclusions of that audit also generally apply to the other Co-permittee's PEAs. In Section C, the City tracked and reported 21 objective outcomes from implementing their program. Of those, 19 outcomes were reported without comparison to a performance metric, even when a performance metric was prescribed in the Permit. Consequently, City staff was collecting data on 19 outcomes but was not using the information in a constructive manner in their PEA, not even to evaluate compliance in an overt way.

Fundamentally, the permit describes systems of actions that the Co-permittees must carry out to comply with the permit, but more importantly, to reduce pollutants in urban runoff. The permit describes these systems with different levels of detail. As a result, the Co-permittees often must better define these systems in a practical way in their program planning documents, such as the Drainage Area Management Plan or Local Implementation Plans, to describe how they will comply.

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There is a presumption that carrying out the actions prescribed in the permit and related planning documents will improve water quality. However, the degree of effectiveness, or correlation between specific actions and improvements in water quality, is not known. For example, an incremental improvement in water quality cannot be attributed to a particular public education campaign. This dilemma is the basis for accepting the "iterative process" to reducing pollutants to ultimately achieve water quality objectives. The "iterative process" allows for a large degree of experimentation by the Co-permittees and Regional Board staff to discover the most effective combination of actions. On the basis of objective information, the "iterative process" allows Co-permittees to amend their program planning documents to improve their programs. The "iterative process" also informs the permit process, allowing the Regional Board to also make improvements in the permit through subsequent re-authorizations.

The "iterative process" is described best in the Receiving Water Limitations language in the Order. This language was generally originated by the USEPA and communicated by the State Water Resources Control Board ("State Board") in Order WQ 99-05. The State Board's language has been modified in this Order but its purposes have not been altered. The "iterative process" is also referenced in the findings of the past two versions of NPDES Permit No. CAS618030.

No time schedule is prescribed in the Receiving Water Limitations language over which to execute the "iterative process". The key step to trigger the process is a "determination…that a discharge is causing or contributing to the exceedance of an applicable water quality standard" described in Subsection IV.C. of the Order. Because of the variance in storm water quality and the infrequency of storm events, the time period may be on the order of years to make the determination and to initiate the "iterative process" described by Order WQ 99-05. In fact, the "iterative process" in Order WQ 99-05 has never been initiated before in the Santa Ana Region in spite of the Co-permittees' collection of substantial water quality data. This is largely attributed to a poorly-defined trigger to initiate the "iterative process".

The "iterative process" as a whole relies on some form of feedback to evaluate program performance and identify the need for improvements if necessary. The Co-permittees have spent significant resources implement their storm water programs. The Co-permittees track and report program outcomes, fulfilling part of the iterative process. But do not consistently place much of the data in context by comparing it to objective metrics to evaluate performance. The result is that

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there has been no comprehensive effort to assess the effectiveness of the Co-permittees' program activities.

Requirements for reports on program effectiveness first appeared in the fourth-term permit, Order No. R8-2009-0030, as Program Effectiveness Assessments ("PEAs"). However, the requirements stopped short of mandating that the Assessments rely on the use of objective performance metrics or standards for various program elements. Although discussed, the use of objective performance metrics or standards was phrased as a recommendation in the fourth-term permit.

There is a definite need for the Co-permittees to use indicators of the performance of their programs' activities. Water quality data can be collected to assess the *overall* performance of the Co-permittees' storm water programs. But water quality data cannot always be used to evaluate the effectiveness of *specific* program activities or even of combinations of program activities. Sufficient water quality data would have to be collected over extended periods of time to directly correlate specific program activities with incremental improvements in water quality. During this time, the different Co-permittees may adopt new activities and/or abandoned others. This continual evolution of the Co-permittees' program activities during a monitoring period can confound the effort to correlate program activities with changes in water quality. Other types of performance metrics are needed.

Performance metrics include water quality standards and measurable and verifiable permit requirements; but these do not comprehensively address all of the Co-permittees' program activities. Additional performance metrics need to be established by the Co-permittees to carry out a comprehensive assessment of program activities. For example, some cities have established agronomic fertilizer rates as a performance metric for applying fertilizer to turf grass in public parks and properties.

The structure and language of the past permit can be improved to promote the "iterative process". Interviews with Co-permittees' staff revealed that their focus is on permit compliance. This appears to have caused the Co-permittees to comply with the letter of the permit with less emphasis on the intended "iterative process". Where the permit provides specific direction, the Co-permittees generally make an effort to comply using available resources. Since the past permits did not detail how to assess program effectiveness in a meaningful way, there has been insufficient incentive for Co-permittees to fully apply the iterative

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process. The requirements of this Order attempt to address this apparent disconnect between "compliance" and "program performance" by better defining the "iterative process" and mandating its practice.

The past practice of incorporating by reference best management practices in the Drainage Area Management Plan and the Local Implementation Plan does not appear to promote the "iterative process". Past versions of NPDES Permit No. 618030 relied on the development of the Drainage Area Management Plan ("DAMP") by the Co-permittees[1]. The DAMP and its companion plans and programs describe the storm water management controls that the Co-permittees would carry out in order to comply with the permit. The permit then required that the Co-permittees implement the DAMP. The more recent fourth-term permit expanded this requirement to include Local Implementation Plans developed by each Co-permittee for their respective jurisdiction.

The past strategy of 'incorporating by reference' best management practices in the Drainage Area Management Plan and the Local Implementation Plan effectively made many of the practices described in those Plans mandatory. Failure to execute the commitment or its elements could cause the Co-permittees to be out of compliance with the permit and subject them to civil liability.

The ability of the Regional Board to enforce the DAMP or LIPs depends on how objectively the program activities are described or whether or not the activities can be measured or verified. Of the DAMP and the LIPs, only the DAMP's content was controlled by a process for approval by the Executive Officer. The result was a logical effort by at least a few Co-permittees to amend their Local Implementation Plans to remove any objective enforceable requirements and subsequent potential liabilities. Best management practices became "opportunities" that the Co-permittee might or might not follow through on. Without any commitment for their implementation, missed "opportunities" are not enforceable.

The fear of being subject to enforcement may discourage the Co-permittees from documenting innovations that could potentially improve the Co-permittees storm water programs and the permit. Evidently, in the absence of oversight, the relationship motivates the Co-permittees to eliminate any concrete commitments that might cause them to be out of compliance.

[1] For purposes of discussion, DAMP and LIP generally refer to companion plans and programs such as the 2011 Model Water Quality Management Plan and the Technical Guidance Document.

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This is not to assert that the Co-permittees have not made innovations in their storm water programs or carried out best management practices to reduce pollutants in urban runoff. During many of the audits, Regional Board staff discovered that many Co-permittees were running off-the-books storm water programs. Innovations and best management practices were occurring, but they were not described in the Drainage Area Management Plan or the Local Implementation Plan. By keeping these efforts out of the DAMP or LIPs, the Co-permittees prevent them from becoming permit requirements and thus liabilities. The result is that the *documented* elements of the storm water program have become stagnant even as innovations have occurred undocumented.

In summary, the Co-permittees have not taken full advantage of the "iterative process" to improve their storm water programs. The 'incorporation by reference' relationship between the permit and the DAMP and LIPs is likely a significant factor that discourages the Co-permittees from making changes to the plans that might become enforcement liabilities. Where allowed, the Co-permittees have managed potential enforcement liabilities by eliminating objective commitments from the plans. Where innovative strategies are employed, they are not documented in the plans.

It is likely that other factors, such as organization size (the Co-permittees collectively) and related span of control, disproportionate influence among larger and smaller cities, and differing levels of interest among Co-permittees also significantly affect the management of the storm water program. But these are matters that are not easily addressed by this Order.

Therefore, this Order refocuses the Co-permittees' efforts on the "iterative process" to improve their storm water programs and ultimately achieve water quality objectives. The "iterative process" is not defined specifically by USEPA, the State Water Resources Control Board, or the Regional Water Quality control Board. In business, the "iterative process" is an objective process improvement technique for arriving at a decision or objective by repeating rounds of analysis or a system of actions. Performed well, the "iterative process" is a cost control method that can save the Co-permittees money. The process involves subsequent evaluation and improvement with each cycle.

The purpose of the "iterative process" is ultimately to arrive at some decision or desired outcome. The "iterative process" is typically applied in circumstances where there is great uncertainty; where costs of errors are high; or where a full commitment of resources to achieve a risky outcome is undesirable. This

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process is known by many other names such as a "Plan-Do-Check-Act Cycle" ("PDCA Cycle"), Deming Cycle, and Shewart Cycle.

Objective process improvement techniques have been in practice for over half a century and have been gradually finding their way into storm water regulation. The techniques were introduced into widespread use in Japan in the 1950's by W. Edwards Deming and are generally regarded as being instrumental in transforming the post-war Japanese economy. USEPA prescribes objective process improvement techniques ("measurable goals") in their Storm Water Phase II Rule, promulgated in 1999, for small MS4s. In 2008, USEPA published *Evaluating the Effectivenes of Municipal Stormwater Programs*, describing the "iterative process" as a process improvement technique.

Co-permittees under the NPDES program have also begun developing process improvement techniques. With the participation of the Co-permittees, the California Stormwater Quality Association published the *Municipal Stormwater Program Effeciveness Assessment Guide* in 2007 ("2007 Guide")[2]. This document attempts to describe an objective process for developing a system of measuring the performance of the Co-permittees' storm water programs. Although the 2007 Guide was referenced in the fourth-term permit in regards to performing Program Effectiveness Assessments, the process was not fully put into practice by the Co-permittees. Gradual efforts were made, but the process has not been fully implemented.

In storm water regulation, the "iterative process" serves multiple purposes. First, it allows the Co-permittees, regulatory staff, and the public to assess compliance with the requirments of this Order. It tracks progress towards meeting water quality objectives. It justifies the Co-permittees' commitment of resources, including the cessation of ineffective program activities. It provides feedback to storm water program managers, in part, to identify the most effective program activities. Last, it may establish correlations between reductions in pollutant loads into receiving waters and program activities.

To refocus the Co-permittees, this Order partly de-couples the DAMP and LIP from the permit requirements. Planning documents are still required, but their purpose is principally to maintain transparency of the Co-permittees' storm water programs. To do so, the planning documents must fully and accurately reflect the Co-permittees' storm water programs.

[2] Available for a fee at www.casqa.org

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This Order continues virtually all of the objective requirements of the fourth-term permit, such as commercial and industrial inspections. But this Order also requires that the Co-permittees have certain effective processes (or mechanisms) instead of prescribing specific objective outcomes. To complement all processes and objective requirements, the Co-permittees must also develop and apply objective performance measures to assess the programs' effectiveness.

Program activities and their related performance measures will necessarily include the objective requirements of the permit, such as requisite numbers of inspections. But not all of the Co-permittees' program activities are mandated directly by a permit requirement. Under the fourth-term permit, these program activities are described in the DAMP or LIP. They were therefore mandated by way of being incorporated by reference in the permit.

Now, program activities that are only described in the DAMP or LIP have been incorporated into this Order. However, program activities have been generally synthesized rather than stated directly. The Order describes these program activities more generally as required programs, processes, or mechanisms. These mandated programs, processes, or mechanisms are intended to accomplish the same purposes as the specific program activities described in the DAMP or LIP. Using general descriptions, instead of mandating specific program activities in the DAMP or LIP, is intended to allow the Co-permittees greater flexibility to add or discontinue certain program activities or modify their level of effort.

This flexibility is tempered in three ways. First, the Co-permittees must continue to meet the objective requirements of this Order where prescribed. Second, the Co-permittees must perform program activities that satisfy the general goals prescribed by this Order. Last, the Co-permittees must meet the MEP standard required by this Order and the Clean Water Act.

The Co-permittees' storm water program is initially generally-presumed to meet the MEP standard required by this Order and the Clean Water Act. Therefore, unless specified otherwise in this Order, it must be continued unless the Co-permittees can provide objective evidence that the program must be modified. This evidence is provided by Program Effectiveness Assessments. Co-permittees may modify program activities, but the program as a whole must work to achieve the general goals prescribed by this Order. Those general goals appear in this Order along with expressed requirements to have effective

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mechanisms or processes to achieve those goals. "Effectiveness" must be measured using the objective requirements prescribed by this Order or, where not prescribed, developed by the Co-permittees.

Consequently, there will be two kinds of objective performance metrics: those described in the language of this Order and those developed by the Co-permittees. Failure to achieve the objective requirements of this Order will be regarded as violations of this Order. However, failure to achieve objective performance metrics developed by the Co-permittees is not a violation of this Order.

In the absence of objective requirements for specific program activities, program activities will be evaluated: 1) by determining which prescribed general goal(s) that an activity is intended to achieve; 2) if there is (are) one or more objective performance metrics being used to assess the performance of the activity; and 3) if the performance metric(s) is (are) valid. A program activity that lacks any of these evaluative elements will be in violation of this Order.

B. The "Iterative Process"

Essentially, this Order requires more explicitly that the Co-permittees engage in an "iterative process" for their program activities. This process is outlined in the conceptual model below (Figure 1). The process shown is adapted from W. Edwards Deming's PDCA Cycle.

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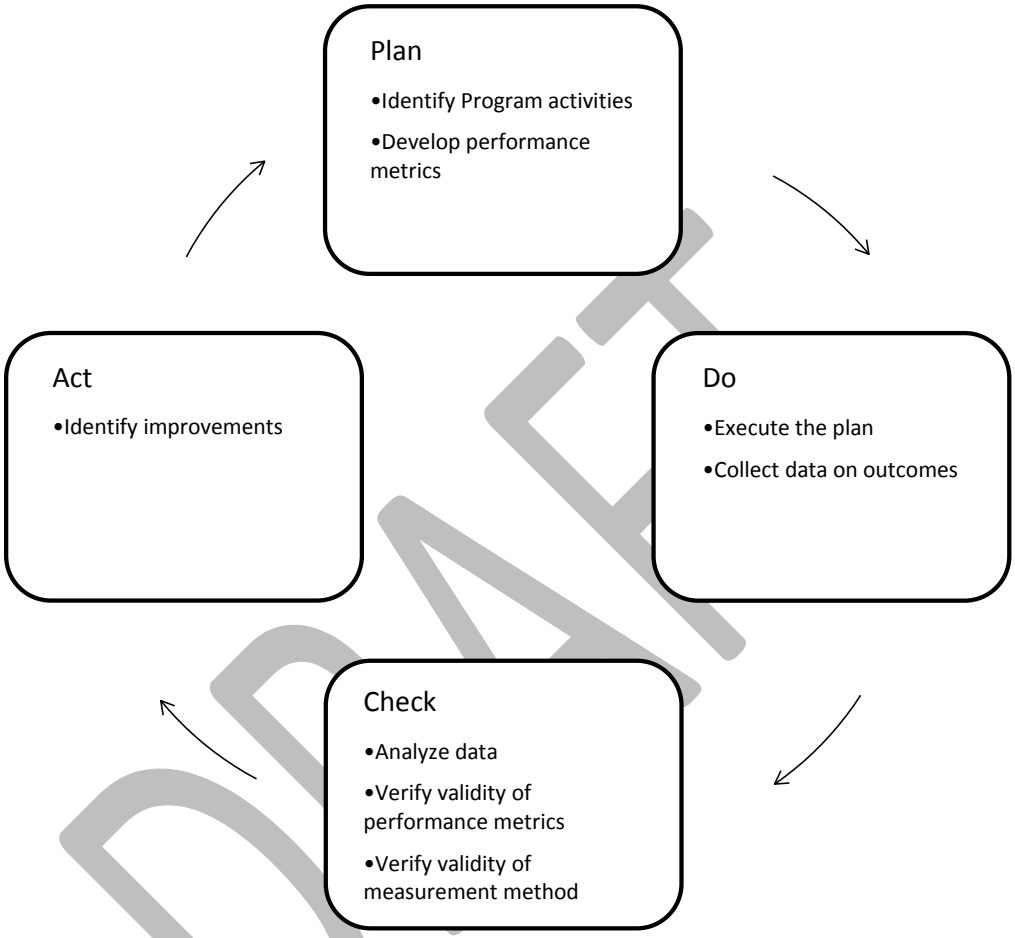
Figure 1: Conceptual Model of the "Iterative Process"



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The “iterative process” applies to both the Co-permittees’ development and execution of their storm water programs and to the development of future reauthorizations of NPDES Permit No. CAS618030. The “iterative process” can be used at multiple time scales, from days to decades. There is a reasonable expectation that the program activities prescribed in the permit and developed by the Co-permittees will ultimately improve receiving water quality and that the choice and method of measuring program outcomes are valid. However, errors may be discovered and adaptive measures may be necessary to improve the effectiveness of the program activities or to improve the methods of measuring effectiveness.

Within this Order, the "iterative process" cycle is driven by several mechanisms. First, Section IV's receiving water limitations language necessarily requires the Co-permittees to use receiving water quality monitoring data to evaluate if water quality standards are being met. Receiving water quality monitoring data is generated through the Monitoring and Reporting Program and the data is analyzed based on a schedule developed by the Co-permittees but subject to the approval of the Executive Officer.

The "iterative process" is also driven by waste load allocations developed as part of TMDLs described in Section XVIII of this Order. Many waste load allocations include numeric effluent limits, where TMDL compliance dates have passed, or numeric action levels, where compliance dates have not passed. Both are kinds of water quality based effluent limits and are shown in Appendices B through H. Waste load allocations and their related requirements are the vehicle for meeting water quality standards for those waters listed pursuant to Clean Water Act Section 303(d).

The "iterative process" is lastly driven by the Co-permittees' performance of annual Program Effectiveness Assessments described in Section XIX of this Order. The Co-permittees must use measurable and verifiable (objective) performance standards or metrics to evaluate the effectiveness of their BMPs. These performance standards are found within this Order but others will need to be developed by the Co-permittees to evaluate BMPs that are not prescribed directly by this Order. The performance standards that are not found in this Order are not enforceable on the Co-permittees; in these cases, the "iterative process" itself is enforced by this Order, rather than the outcome. Unlike water quality standards and waste load allocations, these performance standards are not direct measures of BMPs' effects on receiving water quality. But they are important to measure the effectiveness of BMPs in achieving goals, such as those related to public education and personnel training, whose purpose is to indirectly improve water quality.

This Order has also been written with the purpose of limiting the number of planning documents necessary to implement the storm water programs. With the exception of the TMDLs, this Order does not require new planning documents. In simple terms, the Co-permittees' best management practices are applied at three spatial scales; at the permit-area scale, at the watershed scale, and at the

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local jurisdiction scale. All of these scales are collectively addressed in the DAMP, LIPs, and the TMDL-related planning documents. Any changes to the storm water programs can be represented in any of these documents without the need to develop additional, separate plans.

The Co-permittees must continue to use the planning documents already prepared to the extent that the plans fully document their program activities, including best management practices. It will be necessary to review and amend those planning documents to add activities not already documented, to develop performance metrics and methods for measuring those metrics, to consolidate and possibly abandon some plans, and to generally update the Co-permittees' storm water programs to comply with this Order. The Co-permittees can re-write their planning documents if they choose to. But this is a matter for the Co-permittees' editorial discretion and is not required by this Order.

C. Plain Language

California Government Code Section 6219(a) states that "Each department, commission, office, or other administrative agency of state government shall write each document that it produces in plain, straightforward language, avoiding technical terms as much as possible, and using a coherent and easily readable style." This requirement is more commonly known as the State's "plain language requirement". Order No. R8-2014-0002 and this Technical Report have been prepared with careful consideration of the plain language requirement.

There are a variety of indicators for measuring the 'readability' of a document. These indicators include the Flesch Kincaid Reading Ease, Flesch Kincaid Grade Level, and the Gunning Fog Score. These first two indicators are widely available in common word-processing software and were applied to the Order and Technical Report. The results indicate that a person that has achieved a college junior level of education should be able to readily understand these documents. Given the technical and legal subject matter, the readability of the Order and this Technical Report is appropriate and satisfies the State plain language requirement.

D. Internet References

This Order includes numerous references to web pages in order to save paper and simplify the presentation of the permit and related documents. In an electronic format, the permit and related documents may contain live links to web

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sites. These links and web site addresses may become broken or outdated during the term of this Order. Consequently, these references have been provided for the convenience of the reader. Regional Board staff will make every effort to update broken or outdated internet references in electronic versions of this Order posted at the Regional Board's web site. Readers who become aware of broken or outdated reference or links are asked to contact Regional Board staff in the Contact Information (SectionII) above to assist in this effort.

IX. PUBLIC PROCESS AND NOTIFICATION

On October 3, 2013, the County of Orange ("County"), acting on behalf of the Co-permittees, submitted the Report of Waste Discharge ("ROWD") for the fifth-term NPDES Permit No. CAS618030 ("Permit"). At the recommendation of Regional Board staff, the ROWD emphasized changes that the Co-permittees were requesting in the new permit. The requested changes included changes to the requirements of NDPES Permit No. CAS618030 and to the accompanying Monitoring and Reporting Program.

On October 30, 2013, Regional Board staff sent the County of Orange a Notice of Incomplete Report of Waste Discharge ("Incomplete Notice"). The Incomplete Notice consisted of a cover letter and a table of responses to each of the requested changes described in the Co-permittees' ROWD. The responses largely were requests for additional information to justify the requested changes, requests for more detailed recommendations, and requests for descriptions of how the changes would improve the Co-permittees' storm water program and how the improvement would be measured. In the Incomplete Notice, Regional Board staff requested that the County respond by November 30, 2013.

On October 30, 2013, County staff requested an extension of time to respond to the Incomplete Notice. The request was granted orally and confirmed in a letter dated November 7, 2013. The new deadline was December 18, 2013.

The November 7, 2013 letter included a request to meet and confer on the County's anticipated response. County staff was advised that their requested changes to the Monitoring and Reporting Program could be addressed after the adoption of the fifth-term Permit. In that event, Regional Board staff could withdraw requests for information in the Incomplete Notice related to changes to the Monitoring and Reporting Program. This way, efforts to change the fifth-term Permit could proceed separately from efforts to change the Monitoring and Reporting Program.

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On December 11, 2013, Regional Board staff met with County staff and other representatives of the Co-permittees. During that meeting Regional Board staff agreed to limit the scope of the October 30, 2013 Incomplete Notice to exclude matters related to the Monitoring and Reporting Program. County staff also outlined their anticipated response to the Incomplete Notice. Subsequent to that meeting, Regional Board staff amended the Incomplete Notice to limit the scope accordingly in a letter dated December 12, 2013.

X. ECONOMIC CONSIDERATIONS

California Water Code Section 13241 requires the Santa Ana Regional Water Quality Control Board to consider certain factors, including economic considerations, in the adoption of water quality objectives. California Water Code Section 13263 requires the Santa Ana Regional Water Quality Control Board to take into consideration the provisions of California Water Code Section 13241 in adopting waste discharge requirements.

In *City of Burbank v. State Water Resources Control Bd.* (2005) 35 Cal. 4th 613, the California Supreme Court considered whether regional boards must comply with California Water Code Section 13241 when issuing waste discharge requirements under California Water Code Section 13263(a) by taking into account the costs a Co-permittee will incur in complying with the permit's requirements. The Court concluded that whether it is necessary to consider such cost information depends on whether those restrictions meet or exceed the requirements of the federal Clean Water Act. The Court ruled that regional boards may not consider the factors in California Water Code Section 13241, including economics, to justify imposing pollutant restrictions that are less stringent than applicable federal law requires.

California Water Code Section 13377 specifies that discharge permits issued by regional boards must meet the federal standards set by federal law. In effect, Section 13377 forbids a regional board from considering any economic hardship on the part of the permit holder if doing so would result in the dilution of the requirements set by Congress in the Clean Water Act. Similarly, Section 13263 cannot authorize what federal law forbids and cannot authorize a regional board to use compliance costs to justify pollutant restrictions that do not comply with the Clean Water Act. However, when conditions or provisions in an NPDES permit are more stringent than federal law requires, California Water Code Section 13263 requires that the regional board consider the factors described in

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California Water Code Section 13241 as they apply to those specific conditions or provisions.

As described in Section VI.E. above, the Regional Board finds that the conditions and provisions of this Order are not more stringent than the minimum federal requirements. Clean Water Act sections 402(p)(3)(B)(ii) and (iii) require MS4 permits to include requirements to effectively prohibit non-storm water discharges into the MS4s; to require controls to reduce the discharge of pollutants in in storm water to the maximum extent practicable; and such other provisions as the USEPA or the State determines appropriate.

The requirements in this Order may be more specific and detailed than those in the federal regulations under 40CFR122.26 or in USEPA guidance, but they are not more stringent. The requirements have been designed to be consistent with and within the federal statutory requirements in Clean Water Act sections 402(p)(3)(B)(ii) and (iii) and the related federal regulations and guidance. Consistent with federal law, all of the conditions and provisions in this Order could have been included in a permit adopted by USEPA in lieu of a permit issued by the State through the regional boards.

The inclusion of numeric Water Quality-Based Effluent Limits in this Order (e.g. WLAs) does not cause this Order to be more stringent than federal law. Federal law authorizes both narrative and numeric effluent limitations to meet state water quality standards. Both are equally allowable and the inclusion of either or both best management practice-based or Water Quality-Based Effluent Limits does not make an NPDES permit more stringent. Therefore, the Regional Board is not required to consider the factors set forth in California Water Code Section 13241.

Similarly, the Regional Board is not required to consider the factors in California Water Code Section 13241 to adopt permit requirements for the effective prohibition on the discharge of non-storm water discharges into the MS4; or for controls to reduce the discharge of pollutants in storm water to the MEP; or other provisions that the Regional Board has determined appropriate. These general requirements are mandated by federal law.

This Order includes monitoring and reporting requirements that are designed to demonstrate that the Co-permittees are complying with the municipal storm water requirements of the Clean Water Act. Clean Water Act Section 308(a) and 40 CFR122.41(h), (j) through (l); 122.44(i); and 122.48 require that NPDES permits specify monitoring and reporting requirements. Monitoring and reporting

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requirements are also required by 40CFR122.26(d)(1)(iv)(D); 122.26(d)(1)(v)(B); 122.26(d)(2)(i)(F); 122.26(d)(2)(iii)(D); 122.26(d)(2)(iv)(B)(2); and 122.42(c). The Regional Board is also authorized by California Water Code Section 13383 to establish monitoring, reporting, and recordkeeping requirements that implement federal and state laws and regulations through NPDES permits.

Notwithstanding the above, the Regional Board has taken into account economic considerations. In doing so, however, it is not necessary for the Regional Board to perform a Cost-Benefit analysis or other formal economic analyses. Because of the lack of comprehensive or sufficiently-reliable economic data on both costs and benefits, performing a formal economic analysis is not practical at this time. However, the Regional Board will consider what limited economic information is available.

The USEPA, the State Water Resources Control Board, and the regional boards have attempted to evaluate the costs and benefits of municipal storm water programs. The resulting studies show a large variability in reported costs and that there is difficulty in obtaining reliable cost information.

In 1999, the USEPA summarized the conclusions of multiple studies performed to determine the cost of storm water management programs as part of its Phase II expansion of the NPDES storm water program[3]. The USEPA determined that the range of benefits from its Phase II expansion exceeds the range of regulatory costs. As part of their analysis, the USEPA reported that, based on appropriate cost data provided by 26 MS4 operators subject to Phase I, the average annual program costs were $9.08 per household (1998 dollars)[4]. The USEPA also reported that the average annual Phase II program costs were $9.16 per household (1998 dollars), comparable to the per-household costs of the Phase I program.

In 2003, staff of the Los Angeles Regional Water Quality Control Board performed a study of Phase I MS4 program costs[5]. Self-reported cost data provided in the MS4 operators' annual reports was used. The average annual cost in Los Angeles County was estimated to be $12.50 per household (2002 dollars)

[3] Federal Register/Vol. 64 No. 235/Wednesday, December 8, 1999/Rules and Regulations. P. 68791-68792.
[4] USEPA's cost estimates should be regarded as gross indicators of compliance costs, not actual compliance costs. See Government Accountability Office, May 2007. Further Implementation and Better Cost Data Needed to Determine Impact of EPA's Storm Water Program on Communities. GAO-07-479.
[5] Los Angeles Water Quality Control Board, 2005. Review and Analysis of Budget Data Submitted by the Permitees for Fiscal Years 2000-2003. P. 2.

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In 2005, the State Water Resources Control Board commissioned a study by the California State University, Sacramento to assess costs of the Phase I MS4 program throughout the state[6]. The annual cost ranged from $18 to $46 per household (2005 dollars). The Fresno-Clovis Metropolitan Area represented the lower end of the range and the city of Encinitas represented the upper end.

For comparison purposes, the per-household cost information above has been adjusted for inflation using the average Consumer Price Index. All values were adjusted to 2013 dollars. The results are shown in Table TR-1 below.

Table TR-1: Comparison of estimates of MS4 program costs (per household)

Study	Reported Value(s)	Inflation-Adjusted Value (2013 dollars)
USFPA 1999	$9.08 (Phase I) $9.16 (Phase II)	$12.98 (Phase I) $13.10 (Phase II)
Los Angeles Regional Water Quality Control Board, 2003	$12.50	$16.19
State Water Resources Control Board, 2005	$18 to $46	$21.48 to $54.90

A proper economic analysis of the cost of the Phase I program would involve a comparison of the MS4 operators' costs with and without the Phase I program. The result would be the marginal cost. Many of the reported Phase I program costs are not attributed solely to the program. In many cases, program elements such as street sweeping and litter control in general, are services that have been performed by the MS4 operators long before they were required by any Clean Water Act permit.

Therefore, the actual costs of the Phase I program for a Co-permittee is some portion of the reported costs. The State Water Resources Control Board's 2005 study, discussed earlier, estimated that 38% of the reported program costs could

[6] State Water Resources Control Board, 2005. NPDES Stormwater Cost Survey. P. ii.

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be fully attributed to the MS4 permits. The remainder was attributed to the costs of pre-existing services provided by the Co-permittees[7]. Similarly, in their 2000 Annual Progress Report, the County of Orange reported that 20% of the program costs could be fully attributed to the MS4 permit[8, 9].

California Water Code Section 13241 includes the need to consider "economic considerations" under certain circumstances. Economic considerations include both the costs of compliance and also the economic benefit of protecting the beneficial uses of waters of the state. There is some information available to estimate the costs of MS4 permits. However, this is often not the same for estimating the benefits of protecting beneficial uses. Some beneficial uses, such as Industrial Process Supply for example, may have their value more readily monetized because there is a well-established market for the resource.

For other beneficial uses, monetizing their value is much more difficult. Certain techniques, such as Willingness to Pay and Travel Cost Analysis, have been employed by the USEPA at a national scale and in local studies in the Santa Ana Region, to value such things as beach recreation (a proxy for Water Contact and Non-Water Contact Recreation beneficial uses). But these techniques are more costly, typically requiring surveys of users or potential users. As the result, they are infrequently employed. However, two studies are useful in this report.

As part of their Phase II expansion of the NPDES program, the USEPA estimated that willingness to pay to improvements in freshwater quality for fishing and boating is approximately $158 to $210 per household (1998 dollars)[10]. Another study, conducted by California State University, Sacramento, reported that the annual household willingness to pay for state-wide clean water is approximately $180 per household (2005 dollars)[11].

Both of the above studies represent efforts to estimate the benefits of protecting beneficial uses. Both of these estimates considerably exceed the annual per-household costs of the MS4 programs summarized in Table TR-1 above[12].

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[7] *Ibid*, P. 58.
[8] County of Orange, 2000, 2000 Annual Progress Report, P. 60.
[9] More recent data from the County of Orange is not available because the County no longer reports it.
[10] *Ibid*. P. 68793.
[11] State Water Resources Control Board, 2005. NPDES Storm Water Cost Survey. P. iv.
[12] It is not necessary to adjust these figures for inflation because they can be appropriately compared to costs that occur in the same years (1998 and 2005 respectively).

XI. GENERAL EXPLANATION OF PERMIT REQUIREMENTS

This Order is fundamentally based, in part, on the standard described in Clean Water Act Section 402(p)(3)(B)(iii), requiring "controls to reduce the discharge of pollutants to the maximum extent practicable." Section 402(p)(3)(B)(iii) also requires "such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." Further details on the basis of this Order are provided elsewhere in this Technical Report.

The "maximum extent practicable" ("MEP") standard is the federal technology-based standard that MS4 owners and operators must satisfy to comply with this Order. The regulatory provisions that further detail the MEP standard are found in 40 CFR Sections 122.26(d)(2)(iv) and 122.44(k)(2). Section XII of this Technical Report further explains the requirements of this Order which implement the more detailed regulatory provisions.

Section 301(b)(1)(A) of the Clean Water Act and 40 CFR Section 122.44(a) require that NPDES permits include technology-based effluent limitations. A technology-based effluent limitation is based on the capability of a model treatment method to reduce a pollutant to a certain concentration. Technology-based effluent limitations, in this case the MEP standard, represent the minimum level of control that must be imposed in a permit issued pursuant to Clean Water Act Section 402.

Neither Congress nor the USEPA has specifically defined the term "maximum extent practicable". Rather, the MEP standard is a flexible and evolving standard. Congress established the MEP standard so that administrative bodies would have "the tools to meet the fundamental goals of the Clean Water Act in the context of storm water pollution"[13]. The standard allows permit writers flexibility to tailor permits to the site-specific nature of MS4s and to require a combination of pollution controls that differ in different permits[14].

To provide clarification to the regional water quality control boards, the State Water Resources Control Board's Office of Chief Counsel issued a memorandum dated February 11, 1993 regarding the definition of "maximum extent practicable". In the memorandum, the Office of Chief Counsel interpreted the MEP standard to entail a "serious attempt to comply" and that "practical solutions

[13] Building Industry Ass'n of San Diego County v. State Water Resources Control Board (2004) 124 Cal.App.4th 866, 884.
[14] In re City of Irving, Texas, Municipal Storm Sewer System, (July 16, 2001), 10 E.A.D. 111 (E.P.A.), *6.

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may not be lightly rejected". The memorandum states, "[in] selecting BMPs which will achieve MEP, it is important to remember that municipalities will be responsible to reduce the discharge of pollutants in storm water to *the maximum extent practicable*. This means choosing effective BMPs, and rejecting applicable BMPs only where other effective BMPs will serve the same purpose, the BMPs would not be technically feasible, or the cost would be prohibitive." The memorandum further states that, "[after] selecting a menu of BMPs, it is of course the responsibilities of the discharger to insure that all BMPs are implemented."

This Order includes requirements for the implementation of programs in accordance with 40 CFR Sections 122.26(d)(2)(iv)(A) through (D). In summary, these requirements are intended to implement:

1) control measures to reduce pollutants in runoff from commercial and residential areas;
2) programs to detect and remove illicit discharges and improper disposal into the MS4;
3) programs monitor and control pollutants from certain industrial facilities; and
4) programs to implement and maintain structural and non-structural BMPs to reduce pollutants in storm water runoff from construction sites.

All of these programs have been detailed in the Co-permittees' 2003 DAMP and related planning documents. The essential elements of the programs have been synthesized from those documents and incorporated into the requirements of this Order.

This Order also includes numeric design standards for storm water runoff from new development and redevelopment in support of the MEP standard. The inclusion of these numeric design standards is supported by State Water Resources Control Board Order WQ 2000-11. This Order also includes more specific requirements for carrying out the "iterative process" of periodically evaluating and modifying or adding BMPs. These requirements support the MEP standard's evolving and flexible nature.

The Order uses the language "each Co-permittee" or "a Co-permittee" in many provisions to require performance of specific tasks, to accomplish a goal, or to have certain processes or mechanisms. This language is intended to clearly

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indicate the responsible party for satisfying the provision. The language is not intended to dictate the specific manner in which the provision must be satisfied.

For example, each Co-permittee may adopt its own specific mechanisms to satisfy a permit requirement or the Co-permittees may collectively develop a uniform mechanism that is adopted by each of them. In the event that a required mechanism is not adopted, this language makes it clear that the Co-permittee lacking the mechanism is responsible for the violation and not the Principal Permittee or the Co-permittees collectively.

The Order has been written to include virtually all of the requirements of the fourth-term permit. As explained above, the Order also incorporates key elements of the 2003 DAMP and its companion documents. In particular, the Order incorporates elements of the 2011 Model Water Quality Management Plan and the Technical Guidance Document. However, the elements are not incorporated verbatim or incorporated by reference. Instead, the Order generally requires that the Co-permittees have effective processes or mechanisms to accomplish various purposes. In most cases, this Order does not dictate an outcome. Where specific outcomes are dictated (e.g. 10 Million "impressions"), they are typically carried over from the previous permit.

The processes and mechanisms required by this Order are based on those described or inferred from the Co-permittees' existing program. The Co-permittees' program is largely found in the 2003 DAMP and its companion documents and the LIPs. As explained earlier, Regional Board staff has found that the program, as practiced, is not always documented. In addition, Regional Board staff found through audits that certain important processes or mechanisms were absent from the Co-permittees' planning documents, were not in place, or were deficient. This Order includes processes and mechanisms that represent an attempt to more fully flesh out the Co-permittees' programs and address these issues.

The Co-permittees have various plans and programs whose development predates this Order. This Order avoids describing these plans and programs by their names. Instead, this Order requires that the Co-permittees have written plans and programs, and then describes their required elements. This approach avoids the appearance that the contents of those preexisting plans and programs supersede the requirements of this Order. Although many plans and programs certainly exist, they must comply with this Order. In some cases, those plans

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and programs will need to be reviewed and updated in order for the Co-permittees to comply with this Order.

The federal NPDES regulations require applicants for MS4 permits to develop a proposed management program (40 CFR Section 122.26(d)(2)(iv)). The management program must include a "comprehensive planning process" and, where necessary, "intergovernmental coordination" for the "duration of the permit". The continued requirement for written plans and programs satisfies the federal requirement for a "proposed management program".

XII. EXPLANATION OF SPECIFIC PERMIT REQUIREMENTS

A. Sections I and II: General Responsibilities

Sections I and II establish the basic responsibilities of all of the Co-permittees, including the Principal Permittee. These Sections are designed to require implementation of the "iterative process". This process includes planning and documentation of program activities, execution, tracking of outcomes, and evaluation through comparison with performance metrics. These requirements are included in this Order pursuant to Clean Water Act Section 402(p)(3)(B)(iii) which, in part, allows the state to include provisions appropriate for the control of pollutants.

These Sections also describe the basic responsibilities for internal and external coordination within and among the Co-permittees respectively. These Sections require maintenance of records and the submission of reports that are adequate to determine compliance. Finally, these Sections require that the Co-permittees establish and maintain adequate legal authority to carry out the responsibilities necessary to comply with this Order.

B. Section III: Discharge Limitations/Prohibitions

Section III emphasizes the Co-permittees' responsibility to effectively prohibit the discharge of illicit/illegal discharges into their MS4s, unless authorized by a separate NPDES permit, or not otherwise prohibited as described. Clean Water Act Section 402(p) forms the basis of the requirements of this Section. MS4 permits (1) "shall include a requirement to effectively prohibit non-storm water discharges into the storm sewers" and (2) "shall require [i] controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering

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methods, and [ii] such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." (CWA § 402(p)(3)(B)(ii-iii)).

To satisfy these requirements, Section III expressly requires the Co-permittees to effectively prohibit discharges into the MS4 unless authorized by an NPDES permit. This section also prohibits discharges where pollutants have not been reduced to the MEP, with some exceptions. Section III includes provisions that prescribe programs to reduce allowable non-storm water discharges from both private and public property.

Discharges that are not prohibited are described in Table 2 and are exempt from the non-storm water discharge prohibition. These discharges have been continued from the previous permit with changes. Many of the discharges in Table 2 are listed in 40 CFR 122.26(d)(2)(iv)(B)(1) as being exempt unless "such discharges or flows are identified as significant sources of pollutants" to waters of the U.S.

Table 2 now includes discharges authorized by USEPA pursuant to Sections 104(a) or 104(b) of the Comprehensive Environmental Repsonse, Compensation, and Liability Act ("CERCLA"). These discharges typically consist of short-term, high-volume discharges from groundwater extraction well development or redevelopment or from state-required testing of potable water treatment plants, and occur as part of USEPA-authorized groundwater remediation action under CERCLA.

This Order authorizes the Co-permittees to discharge certain non-storm water subject to limitations and prohibitions. "*De Minimus*" discharges are authorized by this Order, subject to the requirements of NPDES Permit No. CAG998001. The requirements include the need to submit a report of waste discharge in any allowable format, including submittal of a Notice of Intent form. However, the Co-permittees are encouraged to submit these reports of waste discharge in a uniform electronic format.

Additional non-storm water discharges that are not authorized by separate NPDES permits or exempted in Table 2 are authorized by this Order. These include discharges from swimming pools and diversions from waters of the U.S. This Section also includes various limitations and prohibitions which are permitted by 40 CFR Section 122.44. 40 CFR Section 122.44 allows the use of discharge prohibitions, technology-based effluent limitations, and water quality-based effluent limitations. All of the limitations and prohibitions in this Order are

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continued from the previous Permit and are derived from the Basin Plan or NPDES permits.

C. Section IV: Receiving Water Limitations

Section IV has been modified to more closely align with the State Water Resources Control Board's precedential orders described in Section VII of this Technical Report. The language of this Section was modified particularly to align with language found in Order No. 99-05.

Receiving water limitations are included in all NPDES permits issued pursuant to CWA section 402. Section 402(p)(3)(B)(iii) of the CWA authorizes the inclusion of "such other provisions as the Administrator or the State determines appropriate for the control of [] pollutants." This requirement gives USEPA or the State permitting authority discretion to determine what permit conditions are necessary to control pollutants. In its Phase I Storm Water Regulations, Final Rule, USEPA elaborated on these requirements, stating that, "permits for discharges from municipal separate storm sewer systems must require controls to reduce the discharge of pollutants to the maximum extent practicable, and where necessary water quality-based controls" (see 55 Fed. Reg. 47990, 47994 (Nov. 16, 1990)). USEPA reiterated in its Phase II Stormwater Regulations, Final Rule, that MS4 "permit conditions must provide for attainment of applicable water quality standards (including designated uses), allocations of pollutant loads established by a TMDL, and timing requirements for implementation of a TMDL."[15] USEPA Region IX has also affirmed the agency's position that MS4 discharges must meet water quality standards in a series of comment letters on MS4 permits issued by various California regional water boards[16].

California Water Code section 13377 requires that NPDES permits include limitations necessary to implement water quality control plans. Both the State Water Board and Regional Water Board have previously concluded that discharges from the MS4 contain pollutants that have the reasonable potential to cause or contribute to excursion above water quality standards. As such, inclusion of receiving water limitations is appropriate to control MS4 discharges.

The inclusion of receiving water limitations is also consistent with the Ninth Circuit Court of Appeal's ruling in *Defenders of Wildlife v. Browner* (191 F.3d

[15] See, e.g., Phase II Stormwater Regulations, Final Rule, 64 Fed. Reg. 68722, 68737.
[16] See, e.g., letter from Alexis Strauss, Acting Director, Water Division, USEPA Region IX, to Walt Pettit, Executive Director, State Water Board, re: SWRCB/OCC File A-1041 for Orange County, dated January 21, 1998.

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1159, 1166 (1999)). This ruling shows that the permitting authority has discretion regarding the nature and timing of requirements that it includes as MS4 permit conditions to attain water quality standards.

The Ninth Circuit Court of Appeals recently explained that, "[w]ater quality standards are used as a supplementary basis for effluent limitations [guidelines] so that numerous dischargers, despite their individual compliance with technology based effluent limitations, can be regulated to prevent water quality from falling below acceptable levels" (*NRDC v. County of Los Angeles* (2011) 673 F.3d 880, 886). Receiving water limitations are necessary to protect the beneficial uses of the receiving waters and are included in this Order to ensure that individual and collective discharges from the MS4 do not cause or contribute to exceedances of water quality standards.

The receiving water limitations in this Order consist of all applicable numeric or narrative water quality objectives or criteria, or limitations to implement the applicable water quality objectives or criteria for receiving waters contained in Chapter 4 of the Basin Plan, or in water quality control plans or policies adopted by the State Water Resources Control Board ("State Board"). These include Resolution No. 68-16. Or in federal regulations, these water quality objectives or criteria include, but are not limited to, 40 CFR sections 131.12 and 131.38. The water quality objectives in the Basin Plan and other State Board plans and policies have been approved by USEPA. Combined with the designated beneficial uses, the water quality objectives constitute the water quality standards required under federal law.

The receiving water limitations language in this Order is based on precedential State Board Orders WQ 98-01 and WQ 99-05. This Order includes three main provisions related to receiving water limitations. First, consistent with CWA Section 402(p)(B)(3)(iii) and 40 CFR section 122.44(d)(1), it includes a provision stating that discharges from the MS4 that cause or contribute to an exceedance of receiving water limitations are prohibited. This is also in accord with the State Water Board's finding in Order WQ 98-01 ("The [State Board] agrees that the NPDES permit must prohibit discharges that "cause" or "contribute" to violations of water quality standards."). Second, it includes a provision stating that discharges from the MS4 of stormwater or non-stormwater, for which a Permittee is responsible, shall not cause or contribute to a condition of nuisance[17].

[17] Wat. Code, § 13377 ("the state board or the regional boards shall . . . issue waste discharge requirements and dredged or fill material permits which apply and ensure compliance with all applicable provisions of the [CWA], thereto, together with any more stringent effluent standards or limitations

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Third, it includes a provision that states that Permittees shall achieve these two prohibitions "through timely implementation of control measures and other actions to reduce pollutants in the discharges in accordance with the storm water management program and its components and other requirements of this Order including any modifications." This third provision elucidates the process by which Permittees are expected to achieve the first two provisions and then outlines the "iterative process" whereby certain actions are required when exceedances of receiving water limitations occur and discharges from the MS4 are implicated.

To implement this "iterative process", Section IV of this Order requires the development of a plan revising the storm water management program and its components to include additional BMPs, an implementation schedule and additional monitoring to address the exceedances; and implementing the revised storm water management program. This protocol also includes assessing the effectiveness of BMPs based in part on monitoring results; and, based on the results of the assessment, taking additional actions such as implementing additional BMPs and/or modifying BMPs to improve their effectiveness. This protocol is consistent with USEPA's expectations for MS4 permits[18].

D. Section V: Implementation Agreement

Section V requires that the Co-permittees have inter-agency and inter-Co-permittee agreements that are necessary to satisfy the requirements of the Order. Various agreements have been reported to exist to carry out certain programs, such as the SSO program. Some agreements may need to be reviewed and updated in order to comply with the Order. Section V is supported by 40 CFR Section 122.26(d)(2)(i) which recognizes that a "series of contracts" may be necessary to comply with an MS4 permit; and by 40 CFR Section 122.26(d)(2)(i)(D), which requires "interagency agreements among coapplicants" for MS4 permit coverage.

E. Section VI: Legal Authority/Enforcement

Section VI largely continues requirements that the Co-permittees secure and maintain the legal authority to control the discharge of pollutants according to the requirements of this Order. In summary, 40 CFR 122.26(d)(2)(i) requires

necessary to implement waste quality control plans, or for the protection of beneficial uses, or to prevent nuisance").

[18] See, e.g., USEPA 2002 memorandum, "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs."

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applicants for MS4 discharges to demonstrate adequate legal authority that enables them to: control the contribution of pollutants from industrial activity; prohibit illicit discharges; control spills, dumping, or disposal of materials other than storm water; control the contribution of pollutants between MS4s through interagency agreements; require compliance with ordinances, permits, contracts, or orders; and carry out inspection, surveillance, and monitoring procedures necessary to determine compliance. Section VI is intended to support the requirements of 40 CFR 122.26(d)(2)(i).

This Order describes requirements but does not grant the Co-permittees any authorities that may be necessary to comply. The Co-permittees typically secure this authority through their municipal ordinances. All of the Co-permittees are reported to have adopted model water quality ordinances to comply with past versions of this Order. These water quality ordinances include measures to enforce compliance through inspections and sanctions if necessary.

This Order, and past versions, requires the Co-permittees to impose a series of effective, progressive sanctions to compel compliance with regulatory requirements related the control of discharges of pollutants to their MS4s. This Order adds new requirements for the Co-permittees to track and evaluate challenges to their authority. Where a valid challenge is discovered, the Co-permittees must report it along with a plan to make their authority adequate.

F. Section VII: Illicit Discharges, Illicit Connections, and Illegal Dumping; Litter, Debris and Trash Control

Section VII includes requirements intended to cause the Co-permittees to effectively prohibit illicit discharges and illicit connections ("ID/IC") and to detect and remove improper disposal to MS4s in accordance with 40 CFR 122.26(d)(2)(iv)(B). Illicit discharges are defined in the Glossary of this Order and exclude discharges that are authorized under an NPDES permit. As noted there, the definition provided in the Glossary comes from 40 CFR 122.26(b)(2).

In its 1990 rulemaking, USEPA explained that the illicit discharge detection and elimination program requirement was intended to begin to implement the Clean Water Act's provision requiring permits to "effectively prohibit non-storm water discharges." (55 Fed.Reg. 47990, 47995.) Discharges in Table 2 of this Order are not illicit discharges. Illicit connections are not defined in this Order but are conveyances for illicit discharges.

Section VII clarifies the Co-permittees' responsibilities with respect to illegal dumping (or improper disposal), which was described briefly in the previous

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permit. The Co-permittees' responsibility is limited to illegally dumped material that has the potential to result in a discharge of pollutants to an MS4. This Order also clarifies that Sanitary Sewer Overflows ("SSOs") are a sub-class of illicit discharges.

Section VII describes requirements for programs to address illicit discharges, illicit connections, and illegal dumping. These requirements are based on the Co-permittees' current ID/IC program, the "Countywide Area Spill Control Program", and State Water Resources Control Board Order No. 2006-0003-DWQ, "Statewide General Waste Discharge Requirements for Wastewater Collection Agencies" (Order No. 2006-0003-DWQ). Except for general requirements for IDICs as a whole, this Order does not create new SSO requirements for Co-permittees already subject to Order No. 2006-0003-DWQ.

Section VII requires that the Co-permittees initiate source investigations based on objective and subjective dry-season monitoring results. Source investigations are triggered by subjective observations and statistical thresholds for hydrology and pollutant parameters. The thresholds are established for each monitoring station based on ongoing collections of data. According to the Co-permittees, these statistical thresholds have been developed based on control charts, which are used to identify extreme outliers in a collection of monitoring data. Extreme outliers are monitoring results that fall outside an established number of standard deviations for the data set. These extreme values may indicate the occurrence of an illicit discharge or illicit connection. Their occurrence is a trigger for source investigations. Consequently, they function as numeric action levels.

The approach required by Section VII and practiced by the Co-permittees during the previous permit term to triggering source investigations represents an application of statistical theories for quality control[19]. Applying theories of quality control, the variation in pollutant concentrations in water quality data sets is attributed to "common causes" and "special causes". Applied to runoff quality control, special causes are identifiable, discrete events that can be corrected to improve water quality. Common causes are essentially random noise where there are no specific events that can be identified and addressed to improve water quality. Source investigations may be useful for addressing special causes, but are unlikely to be effective at addressing common causes.

In practice, control charts and similar statistical tools identify extreme outliers that may be well above water quality standards. These extreme outliers trigger

[19] E.g. Deming, W.E. (1975) On probability as a basis for action, *The American Statistician*, 29(40, p. 146-152; Wheeler, D. J. & Chambers, D. S. (1992*) Understanding Statistical Process Control*, ISBN 0-945320-13-2

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source investigations that are performed to identify and eliminate their special causes. As special causes are eliminated, the variation in water quality should lessen over time. New extreme outliers can then be identified and investigated. Each successive round of investigations should eliminate more special causes, reduce variation, and improve water quality. At some point though, source investigators may not be able to identify special causes even though pollutant levels continue to exceed water quality standards. At that point, exceedances may be the result of common causes and require a different approach.

Examples where this pollutant behavior could occur are where pollutants are from ubiquitous sources, such as pathogens, nutrients, or litter. In these examples, source investigations would be useful to resolve discrete events, such as sewage spills, regular fertilization work by a single or group of influential dischargers such as nurseries or golf courses, or litter from scheduled festivals or other public gatherings. But source investigations would not be useful to address more random events such as pathogen, nutrient, or litter pollution caused by the collective actions of numerous independent individuals within a monitored watershed. Other more preventative BMPs, such as public education, might be more effective for common causes.

The use of control charts and similar statistical tools allows the permittees to methodically use source investigations to identify and eliminate special causes of water quality standard exceedances. At the same time, the Co-permittees can avoid using source investigations on common causes, which may be more effectively addressed with more general, preventative BMPs.

Section VII also includes specific requirements for a program to reduce and/or eliminate the discharge of trash and debris to waters of the U.S. The program must include an objective evaluation of measures employed for this purpose. Those measures include 'soft measures' such as public education and litter collection, and 'hard measures' such as trash booms and structural controls. The Co-permittees are not expected to evaluate each measure individually unless doing so would be practical and would provide useful information.

Section VII includes new requirements that effectively require that the Co-permittees formally evaluate new technologies for the control of trash and debris. An evaluation is not necessarily required to be objective. Subjective factors, such as a structural control's ease of accessibility and maintenance, may also be considered, consistent with the MEP standard. The Principal Permittee must demonstrate that formal evaluations are occurring, and report them in the Annual Progress Report. This requirement is intended to cause the Co-permittees to actively consider new technologies, share information on those technologies, and

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in some situations, to provide a means for feedback to vendors to improve products. This requirement is not intended to cause the Co-permittees to develop formal standards or processes by which vendors must demonstrate the efficacy of their products; the Co-permittees may rely on other objective third-party sources of information for this purpose.

G. Sections VIII, IX, and X: Municipal Inspections of Construction, Industrial, and Commercial Sites

Sections VIII, IX, and X continue earlier requirements for inspections of construction, industrial and commercial sites within each Co-permittees' jurisdiction with some modifications. The requirements of these Sections are supported by 40 CFR Sections 122.26(d)(2)(iv)(D), 122.26(d)(2)(iv)(C), and 122.26(d)(2)(iv)(A), which require programs to implement control measures for pollutants in runoff from construction, industrial, and commercial sites respectively. Certain other relevant control measures for these sites (e.g. public education) are described in other Sections of this Order.

The scope of what constitutes a construction site has not been changed in Section VIII. However, Co-permittees are now only required to inspect construction sites whose actual or expected duration exceeds two weeks. This modification has been made recognizing that many construction projects may begin and conclude without being subject to a rain event and before Co-permittees' staff can inspect them. This modification is intended to allow Co-permittees to prioritize projects that have a longer duration. The Co-permittees must necessarily track all construction sites in order to identify projects whose duration exceeds two weeks and consequently require inspection.

Sections IX and X both require that the Co-permittees maintain inventories of industrial and commercial sites. This, and past, versions of NPDES Permit No. CAS618030 do not provide narrative definitions to distinguish between "industrial" and "commercial" businesses. However, there is a need to provide some guidance to the Co-permittees on how to classify businesses in their jurisdictions.

Some common definitions describe "industrial" as referring to a business involved in the manufacture of goods whereas "commercial" is a term referring to a business whose sole motivation is gaining profit. In this sense, "industrial" is a sub-category of "commercial" sites. Other common definitions cast "industrial" and "commercial" as similarly overlapping categories: "industrial" businesses engage in manufacturing goods (for sale) while "commercial" businesses engage

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in the sale or trade of goods. For the purposes of this Order, these common definitions are workable and there is no need for the creation of regulatory definitions in this Order.

In keeping with common definitions of “industrial” and “commercial” businesses, the list of activities that guide the Co-permittees’ development of their commercial business inventory has been modified. The list has been placed in alphabetical order. “Transportation, storage, or transfer of pre-production plastic pellets, powders, or grindings” has been replaced with “Transportation services for passengers, parcels, or freight”. This category excludes business that manufacture products from plastic pellets, powders, or grindings and properly places them in the Co-permittees’ industrial inventory. The new category will also include transportation services for passengers and a wide variety of goods, including plastics.

This Order continues requirements for industrial and commercial facilities to be classified into three categories: “high-priority”, “medium-priority”, and “low-priority”. For both industrial and commercial sites, “high-priority” sites must be inspected once per year; “medium-priority” sites must be inspected once every two years; and “low-priority” sites must be inspected once per permit term (5 years). This Order continues the previous permit’s criteria for distributing the Co-permittees’ inventory of sites among these categories with some modifications.

The previous permit provided criteria for categorizing some industrial sites in the “high-priority” category but otherwise left the Co-permittees’ significant discretion. The Co-permittees developed further guidance in the 2003 DAMP. The permit criteria and the 2003 DAMP guidance determined the distribution of industrial sites among the priority categories; this subsequently determined the industrial inspection burden each Co-permittee bears.

For commercial sites, the previous permit prescribed a minimum priority distribution: 10% were to be “high-priority; 20% were to be “medium-priority”; and the remainder was, by default, “low-priority”. Additional criteria was described that would cause some sites to be moved into higher priority categories. This prescriptiveness was triggered by the findings of audits during the third-term permit where certain Co-permittees were found to be exercising their discretion to minimize their inspection burden in violation of the MEP standard. The basis of the prescribed distribution was the “best professional judgment” of Regional Board staff who were also experienced site inspectors.

In their Report of Waste Discharge, the Co-permittees have requested changes to the priority distributions for both industrial and commercial sites. The principal

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basis of this request was analyses of self-reported inspection outcomes. The Co-permittees' analyses conclude that their inspections are "demonstrating consistent high levels of compliance from year to year".

For construction sites, the Co-permittees reported that the percentage of inspections resulting in their staff finding a violation has been consistently less than 10%. For industrial and commercial sites, "consistent high levels of compliance" means 78% to 89% compliance. The Co-permittees give some credit to their inspection programs, but also credit new requirements in the Construction General Permit, adopted during the previous permit term, and published guidance from CASQA.

The Co-permittees have implicitly established site "compliance" as a performance indicator for their inspection programs. This performance indicator is flawed. Inspections cannot detect "compliance" with great certainty; they can only detect "noncompliance" with certainty. Assuming that an inspector could determine that a site is incompliance exaggerates the scope of the inspector's observations. An inspector can know what violations are discovered; but they cannot know what violations they have not. Inspectors are unlikely to discover every instance of noncompliance in a single inspection. Inspections are observations that amount to a snapshot in time of a site's condition. Even if an inspector could conclude that a site is in absolute compliance during a single inspection, site conditions can change and that conclusion may be short-lived.

Inspection outcomes can be influenced by the manner in which sites are selected, in how the inspection is carried out, and how it is recorded. This influence can go either way in terms of how it affects "levels of compliance". Inspections are not completely unbiased activities and inspection outcomes are a poor indication of the effectiveness of an inspection program.

There are several ways that inspections are biased. First, the site selection may be purposefully biased to increase or decrease the chance of discovering violations. For example, the criteria in the permit is intended to prioritize sites that are expected to pose a greater threat to water quality, possibly due to a greater likelihood of having violations. Second, the manner of the inspection can introduce bias. Whether or not Co-permittees choose to provide prior notice to the site operators will increase or decrease the likelihood of discovering violations. Additionally, how the inspection is documented will also introduce bias. An inspector may choose to not record a discovered violation if it was quickly remedied during the inspection. Or, when entered into the Co-permittees database, either the discovery of the short-lived violation or the outcome of compliance may be recorded, thereby affecting the overall program outcomes.

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These and other factors negatively influence the validity and reliability of the Co-permittees' stated measure of effectiveness (percent compliance/non-compliance) for their overall inspection programs. Nonetheless, this Order provides some relief for the Co-permittees' inspection burden, but not on the basis provided by the Co-permittees.

The regulatory burden that this Order places on the Co-permittees is not fully described by 'inspection frequencies' or even the total number of inspections. The regulatory burden is better described by the total expected number of inspections over the permit term *and* the level of effort needed for each inspection.

The total expected number of inspections is calculated using the inspection frequencies, the total number of facilities, and how facilities are distributed among the priority categories (high, medium, and low). The level of effort is not easily measured, but can be characterized by the type of inspection. For the sake of discussion, there are two types: "inspection from vehicle" and "personal visit". Inspections from vehicles are essentially patrols that typically take significantly less time and effort than personal visits.

The previous permit did not dictate the type of inspection directly. The type of inspection was dictated indirectly by the DAMP. The DAMP describes the inspection protocols and those protocols became mandatory through their incorporation by reference in the previous permit. The DAMP protocols indicate that all inspections were to be by personal visits.

As with the previous permit, this Order does not dictate the type of inspection. But it also does not incorporate the DAMP protocol. The result is that this Order gives the Co-permittees substantial discretion to amend their protocol and select the type of inspection that is suitable to the individual characteristics of a site.

The Co-permittees have recommended that the type of inspection be dictated by the site's priority ranking. This is inappropriate. A high-priority site with a history of past violations benefits from the deterrent effect and education of a personal visit, but a cursory and incomplete inspection of any site by any method has little value. Alternately, a site that invites access, is easily visible from a vehicle, and has no observed violations is generally suitable for an inspection from a vehicle. A site's priority ranking does not necessarily indicate if the site has characteristics that make it suitable for an inspection from a vehicle.

The regulatory relief that this Order provides for both industrial and commercial site inspections is reasonable and proportional to the degree of compliance reported by the Co-permittees in the Annual Progress Reports. According to the

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report of waste discharge, the Co-permittees performed 25,622 commercial and 10,937 industrial site inspections over the permit term. As shown in Table TR-2 below, the previous permit required that the Co-permittees should have performed an expected 22,810 commercial and 9,486 industrial inspections[20]. The actual number of inspections performed over the past permit term exceeds the expected number.

This accomplishment indicates that the Co-permittees *collectively* have the resources to comply with the previous permit in both terms of number of inspections and level of effort. However, collective effort is not the measure used to determine compliance. Audits and reviews of individual Co-permittees and their reports show that a few have not complied either with the number of inspections, their distribution among the priority categories, or both. In cases where inspections were not correctly distributed among the priority categories, the principal cause appeared to be insufficient information management systems to direct inspection resources; not insufficient personnel or attention. This suggests that the inspection burden is problematic for some Co-permittees. However, evidence of widespread hardship on the Co-permittees has not been provided. Therefore only a moderate amount of regulatory relief is appropriate.

This Order changes the previous permit's commercial site distribution from 10% high-priority, 20% medium-priority, and 70% low-priority to one that more closely resembles a Pareto distribution or, more commonly the "80-20 rule". This distribution applies to many situations and was roughly approximated by the previous permit's distribution. A precise application of a Pareto distribution over three categories results in a 4%, 16%, and 80% distribution. This Order adjusts this distribution slightly for ease of use and requires commercial sites to be distributed as 5% high-priority, 15% medium-priority, and 80% low-priority[21].

To demonstrate the regulatory relief from industrial and commercial facility inspections that this Order provides, Regional Board staff compared the expected number of inspections that would be required under the requirements of this Order and Co-permittee's proposed Options 1 and 2. The related requirements were applied to the last permit term's reported industrial and commercial inventory to calculate the expected number of inspections that would have been required over the previous 5-year term. This allows a comparison of the inspection burden produced by the requirements of this Order and the Co-permittees' Options 1 and 2. This is a backwards-looking comparison and does

[20] The term "expected number of inspections", like with any "expected" value described in this Order, is used as a measure of predicting the anticipated inspection burden. The calculation of an "expected" value is a planning tool that describes outcomes under different circumstances; it is not a technique for measuring compliance.
[21] This adjustment increases the number of expected inspections by 2% versus without the adjustment.

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not predict the inspection burden in the future. But it is useful to illustrate the degree of regulatory relief each scenario could provide.

The comparison is shown in Table TR-2 below in terms of numbers of inspections. The comparison does not take into consideration the reduction in level of effort caused by allowing some inspections to occur from a vehicle. This cannot be calculated without knowing which sites have the characteristics appropriate for an inspection from a vehicle. The grey columns in Table TR-2 also show the percent change relative to the expected total inspections that were necessary to comply during the previous permit.

Table TR- 2: Comparison of the number Expected Inspections

Site Type	Reported inspections over 5 years (2008-2013)	Expected inspections over 5 years (pre previous permit's requirements)	Expected inspections over 5 years (per this Order's requirements)	Expected inspections over 5 years (Option 1)	Expected inspections over 5 years (Option 2)
Commerical	25,622	22,810	18,114 (26% decrease)	15,251 (51% decrease)	13,418 (57% decrease)
Industrial	10,937	9,486	9,486 (no change)	1,036 (89% decrease)	5,181 (45% decrease)
Total	36,559	32,296	27, 600 (15% decrease)	16,287 (50% decrease)	18, 599 (42% decrease)

Table TR-2 shows that, based on the annual inventory reported over the previous permit's term, Option 1 requires the least number of total expected commercial and industrial site inspections, reducing them by 50% over the previous permit. Option 1 proposes that many lower-priority sites would be inspected on an as-needed basis. Since the number of 'as-needed' inspections is not known, the total number of expected inspections over the permit term cannot be reliably estimated under Option 1. However, the *minimum* number of total expected inspections under Option 1 would be 16,287. Option 2 reduces the number of expected inspections by 42% over the previous permit. In comparison, this Order reduces the number of expected inspections by 15%.

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Additional reductions in the regulatory burden under this Order and Options 1 and 2 are achieved by allowing the Co-permittees to perform inspections by vehicle, reducing the level of effort. Reductions in the regulatory burden caused by this improved flexibility cannot be reliably measured. Reductions in the total number of expected inspections are more easily measured.

Considering the degree of compliance that the Co-permittees have achieved over the past permit term does not demonstrate widespread hardship that deserves the relief that either Option 1 or Option 2 would provide. This Order provides a reasonable degree of regulatory relief by decreasing the number of expected inspections by approximately 15% and by allowing inspections from vehicles.

For construction sites, this Order also provides regulatory relief by limiting inspections to those construction sites that have an expected or actual duration of two weeks. As with commercial and industrial sites, this Order now also allows inspections from vehicles. Although difficult to measure, both of these permit modifications allow regulatory relief that is proportional to the Co-permittees' apparent ability to comply.

H. Section XI: Residential Program

40 CFR Section 122.26(d)(2)(iv)(A) requires, in part, that applicants for MS4 permits employ structural and source control measures to reduce pollutants from residential areas. The previous permit describes a separate public education and enforcement program for residential areas. The requirements largely overlapped with requirements in public education and illicit discharges/illicit connections. Residential areas will continue to be addressed in this Order through more general requirements in Public Education and elsewhere. Specific requirements have been removed in this Order so that the Co-permittees can prioritize water quality issues based on feedback gained through the iterative process. This Order reserves Section XI as a placeholder so that there is general continuity between the organization of the previous permit and this one.

I. <u>Section XII: New Development (Including Significant Redevelopment)</u>

The requirements of Section XII are intended to satisfy 40 CFR Section 122.26(d)(2)(iv)(A)(2) to reduce the discharge of pollutants from areas of new development and significant redevelopment. Section XII also includes a requirement that is intended to advance work to retrofit existing flood control facilities to remove pollutants as required by 40 CFR Section 122.26(d)(2)(iv)(A)(4). 40 CFR Section 122.26(d)(2)(iv)(A) requires, in part, the

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applicants for MS4 permits provide both "structural and source control measures to reduce pollutants from runoff from commercial and residential areas".

Section XII has been expanded to incorporate synthesized elements of the 2011 Model Water Quality Management Plan and its accompanying Technical Guidance Document. Requirements regarding the sizing of structural treatment controls, LID prioritization, Hydrologic Conditions of Concern, and classification of "priority projects", which require P~~p~~roject Water Quality Management Plans ("WQMPs"), and "non-priority projects" have been retained in this Order with modifications.

40 CFR Section 122.26(d)(2)(iv)(A)(2) requires, in part, that the Co-permittees' management program include "a description of planning procedures including a comprehensive master plan to develop, implement, and enforce controls to reduce the discharge of pollutants from [MS4s] which receive discharges from areas of new development and significant redevelopment." Section XII of this Order includes requirements for the Co-permittees to address these planning requirements in part through their existing planning procedures.

The State of California has delegated land use planning authorities to the counties and incorporated cities and seldom is involved in local land use and development decisions. California Government Code Sections 65000 *et seq.* generally establishes a framework for local planning procedures, but cities and counties adopt their own unique responses to the issues that they face.

At the broadest levels, the Co-permittees develop General Plans and Specific Plans. These and other land-use planning mechanisms fit within the meaning of "planning procedures" and "comprehensive master plan[s]" used in 40 CFR 122.26(d)(2)(iv)(A)(2). Because each Co-permittee generally has their own land use planning authorities and related procedures, requirements pertaining to planning procedures are best addressed at the local level; the Principal Permittee may develop guidance, but cannot compel implementation by the other Co-permittees. Consequently, Section XII requires that the Co-permittees each address their planning procedures through the General Plan update process, Specific Plan process, and others on an opportunistic basis.

The Co-permittees have broad authority to regulate activities within their communities. The scope of regulated activities and the manner in which they are regulated can vary among Co-permittees. The intent of Section XII in this Order and the past has been to cause the Co-permittees to exercise their authority so that the potential water quality impacts of past and future urban development are minimized. The challenge has been how to best identify that subset of projects,

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from the varied universe of projects that each Co-permittee regulates, which have a significant potential to impact water quality, and to develop a process that efficiently and effectively addresses those impacts.

In order to better address the challenge of identifying appropriate projects, clarifying language has been added to Section XII.

- Subsection XII.B. makes it clear that Co-permittees must consider the whole of the project in classifying a project as a priority or non-priority project.
- In Subsection XII.B.5., projects consisting of the replacement, upgrade, or installation of dry utilities, sanitary sewer, or water supply distribution lines in existing transportation rights of way have been excluded from "redevelopment projects" that are priority projects. This is because the scope of such projects is too narrow to afford opportunities to include structural treatment control BMPs.
- The language of Subsection XII.B.5. has been modified to allow a Co-permittee to permit the continued use of structural treatment controls installed as part of a previously-approved Project WQMP when a portion of the site is redeveloped. This allowance does not apply if the old Project WQMP was not properly approved or implemented.
- In Subsection XII.M., language has been included to allow Co-permittees to exclude projects that do not affect areas that are exposed to storm water, or which are not sources of urban runoff, from being considered non-priority projects.

The previous permit defines categories of projects for which the Co-permittees' approval requires the preparation of a P~~p~~roject WQMP. The Co-permittees have sought to limit this requirement to projects that are subject to "discretionary approval". This term has not been defined by the Co-permittees but is presumed to have the same meaning as "discretionary action" under CEQA. The strict application of the term under CEQA would essentially allow one Co-permittee to permit a project without a Project WQMP, whereas the same project in another city
would require a Project WQMP due to local preferences and permitting idiosyncrasies[22].
Whatever the meaning, the Co-permittees' application of the term must not be used to contradict the requirements of this Order or to undermine the MEP standard. As such, the term "discretionary" has been omitted with respect to new development projects in this Order.

[22] Leon, Jorge, July 7, 2000, Post-Hearing Brief, The Cities of Bellflower, Burbank, et al. v. California Regional Water Quality Control Board et al., File Nos. A-1280; A1280(a); A-1280(b), State Water Resources Control Board.

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Section XXII of this Order requires new developments that are regulated by the Co-permittees to employ source-control, site-design and structural treatment controls to remove pollutants from urban runoff. This Order is intended to provide the Co-permittees with a method to address the water quality impacts of new development consistent with the requirements of CEQA and 40 CFR Section 122.26(d)(2)(iv)(A). These requirements are intended to address projects that may have an impact on water quality.

New development projects are classified into two types: priority and non-priority projects. Priority projects must employ source-control, site-design, and structural treatment controls. Non priority projects must employ source-control and site-design controls, but do not have to employ structural treatment controls unless practicable. A non-priority project may be required to use off-site structural treatment controls if available. Priority projects are differentiated from non-priority projects by the categories shown in Subsection XII.B.5. of this Order.

For priority projects, Co-permittees must have a Project Water Quality Management Plan ("WQMP") prepared. The P~~p~~roject WQMP is intended to accomplish several purposes. First, the P~~p~~roject WQMP documents the rationale behind the selection of structural treatment controls. Second the Project WQMP functions as an enforcement mechanism to provide for the proper construction, operation and maintenance of structural treatment controls for both the project proponent and their successors and assigns over the life of the project. For some larger projects, the P~~p~~roject WQMP can serve as a planning document for the design, construction, and funding of regional and sub-regional structural treatment controls. As such, it is important that subsequent Project WQMPs and Non-Priority Project Water Quality Plans ~~non-priority project plans~~ be consistent with the larger P~~p~~roject WQMP. It is also important that P~~p~~roject WQMPs be protected against loss or damage in a manner that is commensurate with the expected duration of the project.

This order promotes regional and sub-regional structural treatment controls essentially by permitting their use where they have been planned for according to the requirements of this Order. In the absence of a planned or proposed structural treatment control facility, structural treatment controls must be on-site for a project. Regardless of the location of the structural treatment controls, all priority projects must have source and site-design controls. Even when there is an offsite structural treatment control available for a project, that project may be required to employ certain pretreatment controls in order to protect the offsite facility from requiring an unusual level of maintenance or from experiencing premature failure. This order anticipates that the operator of the offsite facility

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will establish pretreatment criteria for new developments that discharge into the facility.

This order requires the Co-permittees to establish a program for the improvement of Pproject WQMPs. The Co-permittees must have written technical guidance for the preparation of Pproject WQMPs. The 2011 Model WQMP and its accompanying Technical Guidance Document are expected to serve this purpose. These documents may require some modifications in order to comply with this Order. However, since this Order no longer incorporates the documents by reference, the Co-permittees may make the necessary changes independently, without the Executive Officer's approval. In a similar way, resulting Pproject WQMP process improvements may also be made independently. However, all changes are governed by the requirements of this Order.

1. Hierarchy for Structural Treatment Controls

This Order maintains the hierarchy for the selection of structural treatment controls for priority projects that was prescribed in the previous permit. In order to communicate this clearly, this Order establishes terminology to categories and subcategories of structural treatment controls. This terminology is defined in the Glossary of the Order and is explained here.

The hierarchy requires the greatest preferential consideration for retention LID best management practices. Retention LID BMPs are a subcategory of LID BMPs where the design capture volume is either infiltrated into the ground; used for irrigation, process water, or other purposes; or is evaporated or evapotranspirated. Co-permittees are responsible for demonstrating in the Pproject WQMP that retention LID BMPs, located either on or off-site, are given priority consideration according to this Order's requirements, before considering any of the subsequent categories of structural treatment controls in the hierarchy.

The second category of structural treatment controls that must be considered are biotreatment control BMPs. As indicated by the name, biotreatment control BMPs are a subcategory of LID BMPs that principally remove pollutants through a combination of infiltration, evapotranspiration, biological uptake or transformations, or degradation. While a significant portion of the design capture volume is typically infiltrated or evapotranspirated, this is incidental and no particular portion must be treated in either manner. After passing through a biotreatment control BMP and partly evaportranspirating and infiltrating, the remaining portion of the design capture volume is typically discharged from the

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site. Where retention LID BMPs are infeasible, biotreatment control BMPs must be used onsite or offsite where feasible.

This Order requires that biotreatment control BMPs be designed to treat 1.5 times the design capture volume. This requirement is based on the findings of Appendix D, BMP Performance Guidance, to the Ventura County Technical Guidance Manual for Storm Water Quality Control Measures (Manual Update 2011)[23]. In summary, the Ventura County Technical Guidance Manual found that biotreatment control BMPs that were sized to treat 1.5 times the design capture volume could provide equivalent or better reductions in loads compared to retention LID BMPs for all pollutants of concern. The Regional Board recognizes that the Ventura County study was based on local hydrologic and soil conditions. The Co-permittees have been invited to estimate a similar factor using local conditions for biotreatment control BMPs in Orange County, but have not done so.

Structural treatment controls that employ retention as a treatment mechanism rank the highest in the hierarchy established by this Order and the previous permit. In a well-designed and properly-operating facility, pollutants in storm water are not discharged into surface waters, making retention the most reliable treatment mechanism among those used in structural treatment controls. Since retention LID BMPs employ retention as the sole mechanism for pollutant removal, they are given the highest priority in the hierarchy. Biotreatment control BMPs employ retention on an incidental basis. But the retained portion of the design capture volume is significant and, by using the 1.5 factor, may be comparable to the volume of retention LID BMPs. Consequently, biotreatment control BMPs are ranked second in the hierarchy.

The last category of structural treatment controls in this Order's hierarchy are non-LID BMPs. These structural treatment controls principally use filter media such as perlite, zeolite, sand, or some proprietary or non-proprietary media to physically remove pollutants in storm water. The media may develop microbial communities in biofilms that coat portions of the media. Biofilms can assist in removing pollutants through biological uptake and transformation, but these are incidental mechanisms and the biofilm may even adversely affect the hydraulic performance of the facility.

This Order does not require that a single structural treatment control BMP be used to treat the design capture volume for a drainage area on a priority project

[23] Available at: www.waterboards.ca.gov/losangeles/water_issues/programs/stormwater/municipal/ventura_ms4/VenturaTGM/Ventura%20Stormwater%20TGM%20Final%207-13-11.pdf

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site. A series of structural treatment controls may be used if necessary. The selection and sizing of controls must correspond with this Order's hierarchy. For example, if a retention LID BMP cannot treat the entire design capture volume, the remaining portion may be treated in a biotreatment control BMP. If is infeasible for both the retention LID and biotreatment control BMP to treat the entire design capture volume, then a non-LID BMP may be employed to treat the remaining portion. Under extremely limited circumstance should a site treat the design capture volume or any portion thereof using a non-LID BMP without having demonstrated in the Project WQMP that the volume could not have been treated
using a BMP higher up on the hierarchy. The only circumstance where this could occur is where an off-site LID BMP will be used.

Subsection XII.H. of this Order establishes a specific protocol for selecting non-LID BMPs. This protocol largely carries over from the previous permit. It requires that the Co-permittees categorize non-LID BMPs by type and then assign a performance rating of "high", "medium", and "low" to each category relevant to a variety of expected pollutants. In response to Regional Board staff observations of convenient mis-categorizations, this Order requires that BMP categories include only those controls that employ the same principal of operation; use similar treatment mechanisms; and which can reasonably be expected to exhibit generally similar performance in the removal of pollutants. The rating must be based on the best available objective evidence and include field performance test data that is specific to the BMP.

The non-LID BMP selection protocol also requires that project types be related to various pollutants which can be reasonable expected to be found in urban runoff from those project types. Co-permittees must select non-LID BMPs that provide for either a "medium" or "high" level of treatment for those projects. Numeric performance thresholds must be used to distinguish the levels of treatment. The performance ratings for Non-LID BMPs must be reviewed bi-annually so that they are supported by the best available information.

Structural treatment control BMPs are storm water infrastructure. Like other infrastructure, these facilities may pose environmental hazards such as flooding, providing habitat for disease vectors, creating nuisances such as odors or midges, adversely affecting groundwater or soil remediation efforts, or presenting physical hazards to people, nearby structures, or traffic. This Order establishes an obligation on the Co-permittees to mitigate these potential environmental hazards to an acceptable level consistent with the requirements of CEQA.

This Order also requires that structural treatment controls substantially conform to published and generally-accepted engineering design criteria. These

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requirements are related to hazard mitigation because, in many cases, engineering design criteria have been established to address potential environmental hazards. Minor deviation from published design criteria is generally acceptable and may be done to accommodate LID BMPs at a project site. However, unnecessary deviation is not acceptable.

2. Integration of Project WQMPs into the Development Application Process

This Order establishes a procedure for the integration of P~~p~~roject WQMPs into the development application process. This procedure is derived from the 2011 Model WQMP and furthers the effort to "develop, implement, and enforce controls to reduce the discharge of pollutants from [MS4s] which receive discharges from areas of new development and significant redevelopment" down to the project-level according to 40 CFR 122.26(d)(2)(iv)(A)(2).

This Order requires that P~~p~~roject WQMPs be developed in two phases. In the first phase, a preliminary P~~p~~roject WQMP must be prepared prior to a project's development application being regarded as complete according to the Permit Streamlining Act. The preliminary project WQMP must be approved before the project is approved by the Co-permittees' decision-making body.

The purpose of preparing a preliminary P~~p~~roject WQMP prior to the development application being complete is to promote consideration of structural treatment controls as early in the development approval process as possible. Structural treatment controls often compete for space with other structural elements of a project such as building footprints, utilities, and landscaping. As such, they should be given equal consideration so that they can be integrated into a site in the most economical manner possible. The preliminary P~~p~~roject WQMP should be sufficiently detailed to demonstrate that adequate consideration has been given
to the sizing, location, type of structural treatment control and the related BMP hierarchy, such that it can be reasonably expected to be constructible and to operate as intended.

Once the development application is complete, a project is typically approved after environmental review occurs under CEQA. It is important that structural treatment controls be described in the circulated CEQA document. This circulation helps to educate the public on how the Co-permittee addresses the potential water quality impacts of the project and how the potential environmental hazards of structural treatment controls are addressed. For this purpose, the Co-permittees are encouraged to also describe their related inspection and enforcement programs. Where applicable, the circulated document is a useful

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compliance monitoring tool for the Regional Board and other interested agencies such as the California Coastal Commission and the Department of Fish and Wildlife.

The second phase of Project WQMP development begins after project approval. During this phase, additional project details are developed, including details on source- control, site-design, and structural treatment controls. Because multiple departments can be working on developing separate aspects of a project, there is potential for inconsistencies to develop between different project plans and the preliminary P~~p~~roject WQMP. This has the potential to affect BMP selection, the likelihood that a structural treatment control will be built, or the likelihood that it will function as intended. This Order requires that the Co-permittees enforce substantial conformance between project plans and preliminary and final P~~p~~roject WQMPs. At the end of the second phase, a final P~~p~~roject WQMP is approved and the project is approved to initiate construction.

3. Non-Priority Projects

This Order identifies all other projects as "non-priority projects". Certain non-priority projects must employ source control and site design BMPs. The approach to defining non-priority projects which require BMPs is narrower than the previous permit. These non-priority projects include those that include modifications or improvements that are or affect areas that are, exposed to storm water or which may be sources of urban runoff.

The previous permit required source control and site design BMPs regardless of the risk of storm water pollution. Due to the broad range of projects subject to the Co-permittees' approval, this inclusive approach challenged projects that would occur entirely indoors or whose scope was too narrow to offer opportunities to incorporate the required BMPs in a practicable way. This Order requires a narrower group of non-priority projects employ source control and site design BMPs and, as with the previous permit, that the selection of those BMPs be documented in a Non-Priority Project Water Quality Plan~~Non-Priority Project Plan~~.

This Order does not require non-priority projects to employ structural treatment controls. But some kinds of site design BMPs bear a strong resemblance to structural treatment controls. In some cases, they could be modified in a practicable way to substantially conform to published and generally-accepted engineering design criteria. Where such opportunities occur, this Order requires that the Co-permittee pursue them.

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As indicated earlier, a non-priority project may be required to use an off-site structural treatment control BMP where it is available. This may occur in situations where the non-priority project lies within a larger plan of development that was subject to a Project WQMP. This may also occur where a city or other public entity has constructed or plans to construct a regional or sub-regional structural treatment control.

J. Section XIII: Public Education

Section XIV of the Order requires that the Co-permittees implement an effective public education program. The requirements of Section XIV are based on 40 CFR Sections 122.26(d)(2)(iv)(A)(6), (B)(6), and (D)(4). Public education has been a core element of the Co-permittees' storm water program for over a decade.

Section XIV is intended to raise public awareness of pollution in urban runoff and to take action to reduce that pollution. The changes to the requirements in this Order have been largely influenced by USEPA's document "Getting in Step: A Guide for Conducting Watershed Outreach Campaigns"[24]. Changes were also made to generally support the effective execution of public education campaigns described in the Co-permittee's report of waste discharge received on October 4, 2013.

This Order retains the objective requirement for the Co-permittees to achieve 10 Million impressions annually. The subject audience has been refined. The subject audience is now termed the "general audience" which is defined as residents that are school age and up, and commercial and industrial establishments. The Co-permittees are required to create specific messages for sub-groups within the general audience. The Co-permittees are required to perform a statistically valid survey on the general audience to evaluate how well the purposes of the program have been achieved.

In addition, this Order now requires that the Co-permittees initiate public education campaigns that address a minimum of three high-priority pollution issues during the term of the permit. Other than to initiate campaigns on three issues, this Order does not specify any particular milestones or other performance metrics for those campaigns. Instead, the Co-permittees must

[24] USEPA. 2003. Getting in Step: A Guide for Conducting Watershed Outreach Campaigns. EPA 841-B-03-002. [http://www.epa.gov/owow/watershed/outreach/documents /getnstep.pdf [PDF - 3.27 MB - 136 pp]]. U.S. Environmental Protection Agency, Office of Water, Washington, DC

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identify goals and performance metrics. The Co-permittees must permit public input on the overall campaigns, including the goals and performance metrics.

The scale of the three issues (permit area, watershed, or city) has been left to the discretion of the Co-permittees. Each scale does not necessarily have to involve the same set of issues. In the most complex form, each city could elect to focus on a unique set of issues, resulting in over 75 different public education campaigns. In its simplest form, the Co-permittees would initiate three campaigns over the entire permit area.

This Order defines "target audiences" for addressing the three high-priority pollution issues. The target audience includes persons believed to have the greatest influence on the selected pollution issues. The Co-permittees have the discretion to select both the pollution issues and the target audiences but must document their rationale for their selection in a written plan for the public education program.

K. Section XIV: Municipal Facilities

Section XIV has been rewritten to incorporate key elements of Section 5 of the 2003 DAMP. This includes the development of an inspection program for fixed facilities and field activities, following Integrated Pest Management, Pesticide, and Fertilizer Guidelines, and staff training. Objective requirements found in Section XIV of the previous permit have also been largely retained. The programs described in Section are required by 40 CFR 122.26(d)(2)(iv)(A)(3), (A)(4) [retrofit], (A)(5) and (A)(6).

L. Section XV: Municipal Construction Projects and Activities

Section XV retains all of the requirements of the previous permit to comply with the requirements of the Construction General Permit (NPDES Permit No. CAS000002). In the absence of Section XV, the Co-permittees would still be required to comply with the Construction General Permit. The inclusion of storm water runoff from construction sites in this Order consolidates permitting efforts for construction sites and discharges of urban runoff from MS4s. The language of Section XV has been modified to minimize conflicts with the requirements of the Construction General Permit regarding the submittal of a report of waste discharge to obtain coverage, and notices to terminate coverage. Language has been added to emphasize that the post-construction BMP requirements of this Order prevail over those in the Construction General Permit.

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M. Section XVI: Training Programs

Section XVI largely reorganizes the requirements of the previous permit with some modifications. The requirements of Section XVI are supported by 40 CFR 122.26(d)(2)(iv) which requires, in part, that applicants for MS4 permits describe staff available to implement their storm water program. In order for staff to be effective in implementing the Co-permittees' storm water programs, staff need to be aware of their employer's obligation to reduce the discharge of pollutants to the MEP and their duties to help fulfill that obligation. Section XVI contains requirements appropriate to fulfill this need. These requirements are included in this Order according to Clean Water Act Section 402(p)(3)(B)(iii) which, in part, establishes the MEP standard and allows the state to include provisions appropriate for the control of pollutants.

Section XVI describes personnel that must receive training and a minimum training curriculum for certain groups of personnel. Refresher training must be given once every two years instead of once each year; initial training for new employees must still be given within 6 months of hire. Refresher training frequencies have been reduced because existing employees have accumulated training and experience during the past few permit terms. A significant body of institutional knowledge has likely been developed to reinforce the storm water programs and to justify reducing the intensity of the training program.

The scope of personnel requiring training has been expanded to more generally include "staff, contractors, and vendors whose duties or responsibilities directly or indirectly affect the Co-permittees' capacity to satisfy the requirements of this Order". For some Co-permittees, this may mean that additional personnel will require training. Subsection XVI.B. establishes a minimum baseline of subject matter for training for all affected personnel and additional subject matter for certain personnel. But generally, the training "must be commensurate with the duties and responsibilities of the affected personnel".

Section XVI also now requires that the Co-permittees employ objective methods to individually evaluate trained personnel. It also now requires that training records be maintained for a minimum of three years. A registry or similar mechanism is also required largely to facilitate tracking and reporting for the Principal Permittee and to permit training records to follow staff that change employment between different Co-permittees. The training program must be reviewed and updated annually to achieve continual improvement. The Co-permittees may implement a single training program, individual programs, or some hybrid of the two. Therefore, the review and update may occur collectively,

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coordinated by the Principal Permittee, or be performed individually by each Co-permittee according to how the training program is implemented.

N. Section XVII: Notification Requirements

Section XVII continues the previous permit's requirements for the Co-permittees to report within 24-hours, sites or incidents that pose an imminent threat to human health or the environment. The initial report must be followed by a written report in 5 business days. Section XVII clarifies that the written report is to be submitted 5 business days after the initial report.

Section XVII now incorporates quarterly reporting requirements that were located in Section VI of the previous permit. This move consolidates these more-frequent reporting requirements, relative to the Annual Progress Report, and is intended to make them easier to locate for the reader.

O. Section XVIII: Total Maximum Daily Load Implementation

The waste load allocations (WLAs) and related requirements for adopted and approved TMDLs have been included in this Order. These WLAs and requirements are to be included in this Order according to the related implementation plans described in the Basin Plan. Federal regulations require that NPDES permits contain WQBELs consistent with the assumptions and requirements of all available WLAs (40 CFR Section 122.44(d)(1)(vii)(B)).

This Order provides several pathways to complying with the TMDL-related requirements of Section XVIII. These pathways are dependent on the condition of the receiving water and the status of the TMDLs' compliance deadline. Unless a future compliance deadline in specified in Appendices A through G, all WLAs and requirements therein must be complied with immediately unless the Co-permittees elect to develop a plan to comply with the WLA as described below.

WLAs are essentially mechanisms to attain water quality standards and to avoid causing or contributing to exceedances of water quality standards. Consequently, the process to meet the WLAs or develop plans to meet the WLAs is intended to also satisfy the process to comply with water quality standards. However, meeting the WLAs and complying with water quality standards are independent requirements that are not equivalent. Provisions in both Subsections IV.D. and XVIII.C. are included in this Order to establish the relationship between the two processes; compliance with the process in Subsection XVIII.C. satisfies the process in Subsection IV.D.

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If discharges from the responsible Co-permittees' MS4s meet the WLAs, the responsible Co-permittees must continue implementing their storm water programs in order to maintain attainment of the WLAs. The responsible Co-permittees must also implement a monitoring program that must be developed according to MRP R8-2014-0002. The monitoring program must necessarily include efforts to establish whether or not discharges from MS4s continue to meet WLAs. The "iterative process" must continue to be implemented, however, so long as WLAs and water quality standards are met, the process will focus on improving the efficiency of the Co-permittees' efforts to comply.

If discharges from the responsible Co-permittees' MS4s do not meet the WLAs and the compliance deadline has passed, or compliance must be achieved immediately (where no deadline is specified), responsible Co-permittees will be regarded as being in violation of this Order unless they have initiated efforts to develop and implement a plan to meet the WLAs. The effort to develop and implement a plan to meet the WLAs begins with the submittal of a notice to the Executive Officer of the Co-permittee's intent to develop the plan. The plan must be developed and implemented according to the requirements in Subsection XVIII.C. Failure to comply with the requirements of Subsection XVIII.C. will nullify the effort to develop and implement a plan to comply with the WLA and immediate compliance with the WLA will be required by default.

The failure to comply with the requirements of Subsection XVIII.C. will not subject Co-permittees to enforcement action. Alternately, the Executive Officer will notify the Co-permittees in writing that they have defaulted on the requirements of Subsection XVIII.C. and must comply with WLAs. Subsequently discharges which have occurred in violation of the WLA(s) will be subject to enforcement action. However, notification of default by the Executive Officer is a courtesy and will not be a prerequisite to enforcement action. Maintaining compliance, or an immediate return to compliance, with Subsection XVIII.C. will serve as an alternative to immediate compliance with WLAs during the development phase of a plan.

Once a plan to meet the WLAs has been finalized and approved by the Executive Officer, it must be implemented according to Provision XVIII.D. The requirements of those plans become WQBELs in lieu of immediate compliance with WLAs. Failure to implement the plan will subject the responsible Co-permittee(s) to enforcement action whether or not discharges are known to exceed WLAs.

Development of a plan to meet the WLAs in lieu of immediate compliance with WLAs is optional. A Co-permittee may choose to develop a plan whether or not

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discharges are meet the WLAs. If a Co-permittee is developing a plan, or a plan is approved, compliance with Subsection XVIII.C., or the WQBELs which have been developed within an approved plan, respectively serves in lieu of immediate compliance with WLAs. This Order places higher priority on the development of plans for WLAs that are being violated by requiring the submittal of a draft plan 12 months earlier than plans for WLAs that are not known to be violated.

All plans to comply with WLAs are subject to the "iterative process". This process allows the Co-permittees to improve the effectiveness of BMPs based on water quality monitoring data analysis and objective performance metrics, including the WLAs. If, despite compliance with the WQBELs in the plan, discharges continue to exceed WLAs, the "iterative process" requires improvements to the plan. Improvements may also be made in the interest of cost-effectiveness provided that water quality will not be compromised and the MEP standard is satisfied. The content of the plans is controlled and, except for inconsequential grammatical and technical changes, is subject to the approval of the Executive Officer.

Co-permittees may also submit a plan that does not propose new BMPs or modifications of existing BMPs. Provision XVIII.C.2.g. requires that such a plan include objective evidence that there is a trend in pollutant loads or concentrations indicating that WLAs can be attained without further intervention. All plans are subject to public review prior to the approval of the Executive Officer.

The Regional Board submits an Integrated Report to the USEPA to comply with the reporting requirements of CWA Sections 303(d), 305(b), and 314. The Integrated Report list the attainment status of water bodies relative to water quality standards. According to USEPA guidance, water bodies are placed in one of five categories of "attainment status" in the Integrated Report[25]. Water bodies in Category 5 indicate that at least one beneficial use is not being supported or is threatened and a TMDL is required. These water bodies are placed in on the 303(d) list.

Water bodies in Category 4 indicate that at least one beneficial use is not being supported or is threatened but a TMDL is not needed. Impaired water bodies may be placed in Category 4a if a TMDL has been adopted and approved. Impaired water bodies may be placed in Category 4b if other pollution control requirements required by a local, state or federal authority are stringent enough

[25] USEPA, 2005. Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act.

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to implement applicable water quality standards within a reasonable period of time. Water bodies may be placed in Category 4c if the failure to meet an applicable water quality standard is not caused by a pollutant, but caused by other types of pollution.

Impaired water bodies can be included in Category 4b if there are acceptable "pollution control requirements" required by a local, state or federal authority stringent enough to implement applicable water quality standards within a reasonable period of time (e.g. a compliance date is set). When evaluating whether a particular set of pollution controls are "requirements", the USEPA considers a number of factors. These include:

1) The authority (local, state, federal) under which the controls are required and will be implemented with respect to sources contributing to the water quality impairment (examples may include: self-executing state or local regulations, permits, and contracts and grant/funding agreements that require implementation of necessary controls);
2) Existing commitments made by the sources and completion or soon-to-be-completed implementation of the controls (including an analysis of the amount of actual implementation that has already occurred);
3) The certainty of the dedicated funding for the implementation of the controls; and
4) Other relevant factors as determined by USEPA depending on case-specific circumstances.[26]

Impaired water bodies can be included in Category 4c if the failure to meet an applicable water quality standard is not caused by a pollutant, but is caused by other types of pollution. Pollution is defined in the Clean Water Act as "the mad-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water". (Clean Water Act Section 502(19) In some cases, pollution does not result from a pollutant and a TMDL is not required. These causes may include segments impaired solely due to lack of adequate flow, stream channelization or hydro-modification. In these situations, there may be water quality management actions that can address the causes of the impairment, but a TMDL may not be required for their implementation.

In specific cases, implementation of plans to comply with WLAs and other TMDL requirements may demonstrate that TMDLs are not necessary for impaired water

[26] Ibid

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bodies. This conclusion must be supported by analytical documentation that demonstrates that technology-based effluent limitations required by the Clean Water Act; more stringent effluent limitations required by state, local, or federal authority; and/or other pollution control requirements required by local, state, or federal authority are stringent enough to satisfy water quality standards within a reasonable period of time. This would change the attainment status to Category 4b or 4c.

The water bodies placed in Category 4b or 4c of the Integrated Report must show a record that they are attaining water quality standards or supporting the identified beneficial uses, or will attain water quality standards or support identified beneficial uses in a reasonable period of time. This will allow the water bodies to be appropriately removed from the 303(d) List.

P. Section XIX: Program Effectiveness Assessments

Section XIX of the previous permit contained provisions the allowed revisions to the DAMP and controlled its content. Because the DAMP is no longer incorporated by reference into this Order and the Co-permittees can generally amend the DAMP and other related planning documents, the previous permit's requirements in Section XIX are not necessary. The previous content of Section XIX has been replaced with requirements for the performance of Program Effectiveness Assessments. The rationale for this change has been provided earlier in this Technical Report in Section VIII.C. above.

Section XIX requires that each Co-permittee have a program in place to objectively assess the effectiveness of best management practices employed in each of the elements of their storm water programs. Each Co-permittee's program must be documented in writing. The Principal Permittee is tasked with developing a model program effectiveness assessment. These requirements set the expectation that common features of each of the Co-permittees' programs will generally be assessed in a similar way, but that there is no requirement that a completely uniform set of methods will be applied across each program. But each of the Co-permittees' programs must have the elements described in Section XIX.C.

The first required element are conceptual generalized models of pollution process(es). The development of conceptual models is the first step in developing more detailed quantitative models and eventually to developing solutions. They establish and communicate a baseline of understanding of a process. They can help identify parts of a process that are not well understood.

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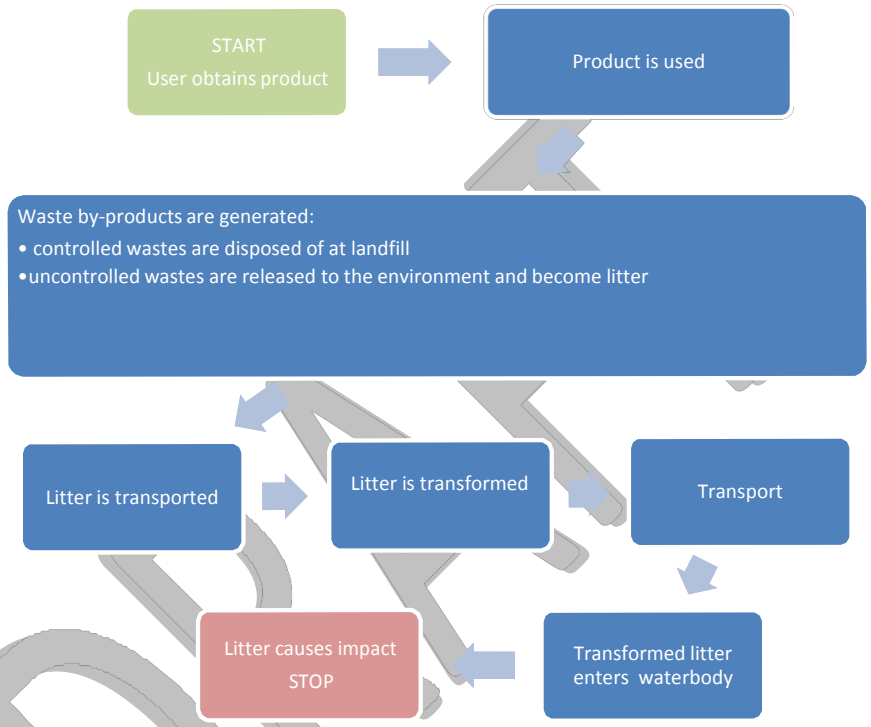
And they can help identify opportunities where interventions or best management practices may be effective in getting a desired outcome. An example of a conceptual generalized model is provided below:

Figure 2: Example of a Conceptual Generalized Model for Litter Pollution



An examination of the example model above may reveal certain things:

- *Flaws may be discovered in the model*. This example model assumes that controlled wastes will never become litter.
- *Opportunities may be realized*. For example, examining this assumption, a program manager learns that certain public waste cans are more prone to falling over or releasing trash on windy days.
- *New best management practices are developed.* Specifications are developed for new waste can purchases and old waste cans are phased out.
- *And new performance measures are applied*. The phase-out project is tracked as percent complete.

The required second element is an inventory of best management practices and where in the pollution process they are applied. This establishes a baseline condition and sets the context for monitoring and reporting results. Placing best management practices in relation to the pollution process can help identify imbalances and gaps. An imbalance may occur where BMPs disproportionately focus on prevention OR treatment of pollution. A gap may occur where there is a missed opportunity to implement a BMP in the pollution process.

The third element is a system to objectively measure the performance of the best management practices or groups of practices. This will include using performance measures prescribed by this Order and measures that will need to be developed by the Co-permittees. While the performance measures prescribed by this Order are enforceable if not achieved, performance measures developed by the Co-permittees will not be enforceable. However, failure to implement the "iterative process" when voluntary performance measures are not achieved will subject the Co-permittees to enforcement.

The final element is to evaluate the validity of the program. This element involves considering if the performance measures are genuinely relevant to what they are intended to measure. It also involves evaluating if the method used to measure outcomes is also valid. As part of this element, Co-permittees are encouraged to develop "S.M.A.R.T." goals. S.M.A.R.T. goals are goals that are Specific, Measurable, Attainable, Realistic, and Timely.

For example, the Co-permittees could establish the following performance metric: *Annually increase the proportion of new volunteers for coastal clean-up events.* This metric is a S.M.A.R.T. goal because it specifically relates to a target audience and events; with baseline data, it can be measured; it is realistic; and can be measured annually. The goal will logically require a combination of tactics to be realized, such as social media targeted at past participants and their friends and associates, along with traditional media favored by target demographics. But the goal permits broad experimentation without the threat of enforcement action if it is not achieved.

Q. <u>Section XX: Fiscal Analysis</u>

Section XX continues all of the requirements of the previous permit unchanged in substance with one modification. It has been re-written in a manner designed to make it clear that three fiscal years must be reported: the previous, current, and future years. A requirement has been added so that fiscal reports conform to USEPA reporting guidance if such guidance becomes available.

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R. Sections XXI and XXII: Provisions and Permit Modification

Section XXI establishes procedures for public review and comment on any reports that are submitted according to this Order's requirements and which are subject to the Executive Officer's approval. Section XXI grants the Executive Officer the authority to review and approve changes to the Monitoring and Reporting Program, subject to public review and comment.

Section XXI no longer requires that the Co-permittees implement the DAMP or other related, previously-approved plans or reports, except for those that are described as needing approval from the Executive Officer elsewhere in this Order. As discussed earlier, the DAMP and other previously-approved plans or reports, constitute all or a large part of written plans, procedures, or programs required elsewhere in this Order. They are still necessary to demonstrate compliance with various requirements, although they may need to be updated or revised.

Section XXI continues the previous permit's requirements to report enforcement actions or discharges that may have an impact on human health and the environment and certain activities on land or facilities outside of the Co-permittees' jurisdiction that may be contributing pollutants to waters of the U.S.

No changes have been made to the language of Section XXII.

S. Section XXIII: Permit Expiration and Renewal

Section XXIII establishes the expiration date of this Order. However, Provision XXIV.R. establishes that this Order will continue in full force and effect past its expiration date until a new permit is issued or the Regional Board rescinds this Order. Section XIII states that this Order is effective 50-days after the date of its adoption except where the Regional Administrator of the USEPA has objections. The previous Order is also withdrawn at that time. However, the Regional Board retains the authority to enforce the previous Order for any violations of its provisions or conditions at the time it was in effect.

T. Section XXIV: Standard Provisions

Section XXIV has been modified to incorporate standard provisions consistent with State Board policies regarding the preparation of NPDES permits. Standard Provisions apply to all NPDES permits according to 40 CFR Section 122.41.

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Dischargers must comply with all standard provisions and with those additional conditions that are applicable under 40 CFR Section 122.42.

U. Appendices B through H

Appendices B through H contains WLAs and requirements for 6 TMDLs that are applicable to the permit area. The WLAs and requirements have been selected from those identified in the adopted TMDLs based on their applicability to the Co-permittees and their appropriateness to the Co-permittees' discharges.

Appendices B through H do not provide instruction on *how* the WLAs will be complied with. That instruction is located in Section XVIII of the Order. Appendices B through H are references containing *what* must be complied with.

Appendices B through H are subject to change during the term of this Order. In order to make changes, this Order may be modified, revoked, or issued as described in Finding 7 and Subsection XXII.A. of the Order. Appendices B through H in particular may be amended in order to incorporate any requirements imposed upon the Co-permittees though the TMDL process. This process may result in new TMDLs or modifications to existing TMDLs.

V. Appendix A

Appendix A is a table showing which Co-permittees discharge into watersheds for which TMDLs have been adopted. Many Co-permittees discharge into more than one watershed. The table does not identify what portions of what cities drain into the watersheds. For some cities, their entire area may drain into a single watershed. For others, only a small portion may drain into another watershed.

This apportioning affects the level of responsibility (e.g. cost sharing) that each Co-permittee may assume for compliance with WLAs and other TMDL requirements. However, this apportioning is a matter that is addressed among the Co-permittees. The inclusion of the table in Appendix A is intended to identify the respective responsibilities of the Co-permittees to comply with WLAs and other TMDL requirements. It is not intended to indicate their level of responsibility.

The cities of Fountain Valley, Garden Grove, Huntington Beach, Villa Park, and Westminster are not shown in Appendix A. These Co-permittees do not discharge to waters for which there is an adopted TMDL.

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Appendix A makes certain clarifications regarding the Nutrient TMDL, Fecal Coliform TMDL, and the Coyote Creek Metals TMDL. Appendix H shows that the cities of Laguna Hills and Laguna Woods contribute discharges for which pollutants are controlled by the Nutrient TMDL and the Fecal Coliform TMDL. These cities were not noted in these TMDLs at the time of their adoption. This is because the City of Laguna Woods was incorporated in 1999, at about the same time that these TMDLs were adopted in 1999 and 2000 respectively. In the case of the City of Laguna Hills, the City annexed its portion located in the Santa Ana Region in 2000. As the result of this timing, both cities were inadvertently omitted from the Nutrient and Fecal Coliform TMDLs. Prior to incorporation or annexation, the areas of both cities were under the control of the County and still discharged into the Newport Bay watershed. Appendix A recognizes that the responsible parties have changed and clarifies that the responsible parties for these discharges are the cities of Laguna Hills and Laguna Woods.

For the Coyote Creek Metals TMDL, the table in Appendix A differs from the USEPA's TMDL[27]. This TMDL includes Table 7-1 which lists the cities in the San Gabriel Watershed by watershed sub-basin, including the Coyote Creek watershed. Appendix A reiterates that list but adds the City of Stanton and removes the City of Garden Grove. The City of Yorba Linda is shown in Appendix A conditionally.

The City of Stanton has been added because a review of County watershed maps shows that a small portion at its northern edge, bound by Beach Boulevard, Starr Street, and Fern Avenue (estimated at less than one acre) drains into the Coyote Creek watershed[28]. The same watershed maps show that the City of Garden Grove does not drain into the Coyote Creek watershed.

The City of Yorba Linda drains partly towards the Coyote Creek watershed. However, Orange County Water District has reported that this flow is diverted away from the Coyote Creek watershed and to the Santa Ana River by a gate located in the fore bay to Miller Retarding Basin located at the southwest corner of the intersection of East Orangethorpe Avenue and North Miller Street. When open, the gate allows flow to continue down Carbon Creek where it may enter

[27] The Coyote Creek Metals TMDL is formally known as the "Total Maximum Daily Loads for Metals and Selenium: San Gabriel River and Impaired Tributaries" and is available at: http://www.waterboards.ca.gov/losangeles/water_issues/programs/tmdl/Established/San%20Gabriel%20River%20Metals%20TMDL/final_sangabriel_metalstmdl_3-27-07.pdf

[28] The County's watershed map is available at: http://ocwatersheds.com/civicax/filebank/blobdload.aspx?BlobID=10612

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Coyote Creek. Although the City of Yorba Linda is shown in Appendix A, the City is only subject to the Coyote Creek Metals TMDL requirements if flows are allowed to enter Coyote Creek.

XIII. Monitoring and Reporting Program

Monitoring and Reporting Program ("MRP") No. R8-2014-0002 is an attachment to Order No. R8-2014-0002. It contains requirements for both water quality monitoring and for program effectiveness assessments. The water quality monitoring requirements include requirements for the development of a Water Quality Monitoring Plan. The Water Quality Monitoring Plan must address monitoring to address illicit discharges/illicit connections, water quality standards attainment or non-attainment; and compliance with waste load allocations.

The Co-permittees have been implementing a water quality monitoring program for several decades. This program, in one form or another, has served multiple purposes beyond compliance with MS4 Permits requirements. This Order essentially requires re-documentation of the current program and provides the Co-permittees with an opportunity to make improvements in the process. Certain limitations to those improvements are established by requirements in the MRP. However, the Executive Officer is authorized to amend the MRP, particularly if important program improvements are hindered by the MRP. The newly-documented program will be subject to review and approval by the Executive Officer.

The requirements in this Order and the MRP for effectiveness assessments are consistent with 40 CFR 122.42(c)(1), which requires reports of the "status of implementing the components of the storm water management program that are established as permit conditions." This includes use of the "iterative process" as well as other "management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants" as described in Clean Water Act Section 402(p)(3)(B)(iii).

The MRP contains requirements for both dry-weather and wet-weather monitoring as part of a Water Quality Monitoring Plan. The dry-weather monitoring requirements are based on the requirements of 40 CFR 122.26(d)(1)(iv)(D), (d)(1)(v)(B), and (d)(2)(iv)(B). The wet-weather monitoring requirements are based on the requirements of 40 CFR 122.269d)(2)(iii), (d)(2)(iii)(A) and (d)(2)(iii)(A)(1) through (4); and 40 CFR 122.21(g)(7)(i) through (ii). Requirements related to

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monitoring and reporting pollutant loads are consistent with 40 CFR 122.26(d)(2)(iii)(B) and (d)(2)(v).

The MRP requirements allow the Co-permittees to use monitoring work performed by others to substitute for work required by the MRP. The MRP requirements also allow the Co-permittees to supplement their own monitoring work with work performed by others to improve any related analyses. The substituted or supplemental monitoring work must meet the requirements of the MRP in order to be valid. The MRP has been written with the intent of encouraging the Co-permittees' participation in state-wide, national, regional, or local monitoring programs in order to avoid duplication of work, improve related analyses of monitoring results, promote cooperation among other NPDES permitees and other institutions interested in water quality, and generally strengthen the body of scientific and technical knowledge of water quality. In this spirit, Provision XXI.B.2. of the Order requires the Co- permittees to make the results of field and laboratory analyses available to the public.

The State Water Resources Control Board ("State Board") adopted Resolution No. 2012-0012, which approves exceptions to the California Ocean Plan for certain discharges into Areas of Special Biological Significance ("ASBS'"). Resolution No. 2012-0012 became effective on March 20, 2012. Attachment B to the Resolution established limitations on point source storm water discharges to ASBS'. Among the Co-permittees, the City of Newport Beach is affected by Resolution No. 2012-0012. This Order requires the City of Newport Beach to comply with the Resolution, including monitoring of its discharge. The Monitoring and Reporting Plan must incorporate this monitoring effort.

The State Board has also adopted the Water Quality control Plan for Enclosed Bays and Estuaries of California – Part 1 Sediment Quality. This Plan became effective on August 25, 2009. The MRP includes requirements for the Co-permittees to monitor sediments in enclosed bays or estuary receiving waters consistent with this Plan.

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ATTACHMENT A

County of Orange Detailed Comments
Draft Order No. R8-2014-0002

Appendix A-1

2009 Presentation to Santa Ana Regional Board
Storage and Reuse Systems for Stormwater Management

Storage and Reuse Systems for Stormwater Mangement

Preliminary Cost and Performance Estimates for Residential Land Use in Irvine, CA

Eric Strecker, P.E.

Geosyntec consultants

Summary of Study

- Compared hypothetical scenarios for rainwater harvesting and reuse systems (cisterns)
  - single lot scenario
  - 100 ac neighborhood scenario
- Compared resulting costs and for both scenarios
- Performed modeling (long term simulation) analysis for neighborhood scenario
- Evaluated water quality loading differences between rainwater harvesting and reuse systems and typical bioretention installation for single family residential
- Performed preliminary review of applicable codes

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Rainwater harvesting and Reuse Systems

Impervious Area

- Roof tops
- Driveways
- Streets

Stormwater Conveyance and Pretreatment

- Pipes
- Filters

Storage

- Cistern
- Storage Basin
- Underground Vault

Treatment

- UV treatment
- Filtration

Pumping and Piping

- Pipes back to house (purple)

Indoor Use and Irrigation

- Toilet flushing
- Yard and Garden irrigation

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Single Lot Scenario

- Two reuse demands were examined: 1) indoor use only (toilet flushing), and 2) indoor and outdoor use (toilets and irrigation)

- Lot Characteristics:
  - 0.1 acres
  - 69% impervious area
    - Roof area - 2400 ft^2
    - Other (patio) - 600 ft^2
  - 3.5 people/house
  - Toilet use/capita = 18.5

- Method assumptions:
  - Rational Method
    - Impervious Runoff Coeff. (0.9)
    - Precipitation Depth – 0.8 in (85th percentile for large parts of Orange County)
    - Toilet use / house = 65 gal/day
    - Irrigation /house = 77 gal/day (Avg. from Irvine Water District data)

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Single Lot Scenario Results

Water Collected From:	Roof	Roof + Other Impervious area
Demand Scenario	**Average Drawdown Time (days)**	
Toilets only	17	21
Both Toilets & Outdoor uses	7.6	9.5

Note: Outdoor demand assumes that irrigation demand is immediate; more sophisticated modeling would allow more accurate characterize of irrigation demand, but for purposes of this analyses, it was assumed to be immediate. This likely significantly overstates the demand for irrigation.

Geosyntec consultants

Neighborhood Scenario

- Two reuse demands were examined: 1) indoor use only (toilet flushing), and 2) indoor and outdoor use (toilets and irrigation)

- Neighborhood Properties:
  - 100 acres – 60 % impervious
  - 0.1 acre lots at 4.5 du/ac = 450 houses
  - 3.5 people/house
  - Toilet use/capita = 18.5
  - Basin used to store runoff

- Method assumptions:
  - Rational Method
    - Impervious Runoff Coeff. (0.9)
    - Precipitation Depth – 0.8 in (85th percentile for large parts of Orange County)
    - Toilet use / house = 65 gal/day
    - Irrigation /house = 77 gal/day (Avg. from Irvine Water District data)

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Neighborhood Scenario Results

Demand Scenario	Average Drawdown Time (days)
Toilets only	45
Both Toilets & Outdoor uses	10

Note: Outdoor demand assumes that irrigation demand is immediate; more sophisticated modeling would allow more accurate characterize of irrigation demand, but for purposes of this analyses, it was assumed to be immediate. This likely significantly overstates the demand for irrigation.

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General Cost List

Item	Description	Cost	Reference/Source
TANKS			
Galvanized steel	200 gal	$225	Fairfax County, 2005
Polyethylene	165 gal	$160	Fairfax County, 2005
Fiberglass	350 gal	$660	Fairfax County, 2005
Plastic	800 gal	$400	Plastic-mart.com
Plastic	1100 gal	$550	Plastic-mart.com
Plastic	1350	$600	Plastic-mart.com
Plastic cone	1500 gal w/metal stand	$1500	Plastic-mart.com
Plastic	2500 gal	$900	Plastic-mart.com
Plastic	5000 gal	$3000	Plastic-mart.com
Plastic	10000 gal	$6000	Plastic-mart.com
[1] Dry Det. Basin(1997)	$C = 12.4V^{0.760}$: for 1 ac-ft	$41,600	stormwatercenter.net
[2] Below Ground Vault	$C = 38.1 (V / 0.02832)^{0.6816}$	$55,300	fhwa.dot.gov
Concrete	1,000,000 gal above g. (O&P)	$548,000	RSMeans
Steel	1,000,000 gal above g. (O&P)	$467,000	RSMeans
TREATMENT			
UV (house-scale)	Whole system - 12 gpm	$700-$900	rainwatercollection.com
UV bulb	Life: 10,000 hrs or 14 months	$80-$110	rainwatercollection.com
UV (neighborhood-scale)	Whole system - 200 gpm	$10,000	Bigbrandwater.com
Downspout filter	Placed in Gutter	$20 - $500	many online
1st Flush Diverter	Vertical pipe w/ ball float	$50-$100	raintankdepot.com
PUMP	1 hp (all in one package)	$575 - varies	rainwatercollection.com
PIPING (Purple)			
to Tank (lot)	PVC: 2”-6” (O&P)	$2-$12 / LF	RSMeans
to House (lot)	PVC: 2”-6” (O&P)	$2-$12 / LF	RSMeans
to Tank (neighbor.)	Concrete: 6” – 18” (O&P)	$15-$30 /LF	RSMeans
to House (neighbor.)	HDPE- 4” – 10” (O&P)	$11-$27 / LF	RSMeans
to Irrigation	PVC: 2”-6” (O&P)	$2-$12 / LF	RSMeans
Backflow prev. valve	Each	$100-$200	web
STENCILS	Non-potable water	----	
INSTALLATION	Percentage of material cost	40 % – 50%	

[1] This dry detention cost equation - Brown and Schueler, 1997: C is the construction, design and permitting cost and V is the volume (cu-ft) need to control the 10-year design storm. In this case, the 0.8” storm runoff volume was used in place of the 10-yr design storm volume.

[2] This below ground storage vault equation - Weigand et al., 1986:C is the construction cost estimate (1995 dollars), and V is the runoff volume (cubic meters)

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Single Lot Costs

Item	Description	Cost
TANKS		
Plastic	1100 gal and 1350 gal	$550
TREATMENT		
UV	Whole system - 12 gpm	$800
UV bulb	Life: 10,000 hrs or 14 months	$80-$110
Downspout filter	Placed in Gutter	$250
1st FLUSH DIVERTER	Vertical pipe w/ ball float	$100
PUMP	1 hp (all in one package)	$575
PIPING (Purple)		
to Tank (lot)	PVC: 2”-6” (O&P) 20ft	$8 / LF
to House (lot)	PVC: 2”-6” (O&P) 50ft	$8/ LF
to Irrigation	PVC: 2”-6” (O&P) 50ft	$8 / LF
Backflow prev. valve	each	$200
STENCILS	Non-potable water	----
INSTALLATION	40% of material cost	$1400
TOTAL		**$4,900**

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Neighborhood Costs

Item	Description	Cost	Units Assumed
TANKS			
Dry Det. Basin(1997)	$C = 12.4V^{0.760}$	$119,000	174,000ft^3
Below Ground Vault	$C = 38.1 (V / 0.02832)^{0.6816}$	$142,000	174,000ft^3
TREATMENT			
UV - neighborhood	Whole system - 200 gpm	$10000	
Catch basin filters	1 every 2 acres	$2000	50 catch basins
PUMP		$50,000	
PIPING (Purple)			
to Tank (neighbor.)	Concrete: 6” – 18” (O&P)	$15-$30 /LF	$23 - 14000 ft
to House (neighbor.)	HDPE- 4” – 10” (O&P)	$11-$27 / LF	$19 - 14000 ft
to Irrigation	PVC: 2”-6” (O&P)	$2-$12 / LF	$8 - 60 ft /house
Backflow prev. valve	each	$100-$200	$200 per house
STENCILS	Non-potable water	----	
INSTALLATION	40% of material cost	$470,000	
TOTAL		**$1,650,000**	

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SWMM Modeling Analysis

- Long term (40 yr) analysis of the neighborhood scenario was performed using SWMM. Two scenarios analyzed:
  - 0.8 inch design storm
  - 1.6 inch design storm
- Modeling assumptions:
  1. Toilet flushing – same as scenarios and applied as constant rate
  2. Irrigation – monthly values (from the IRWD) applied as constant rates by month (i.e. demand occurs continuously during and after storm event)
  3. Overflow from tanks considered to be untreated bypass
  4. Same total area and impervious areas in both studies

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SWMM Modeling Results

	Units	Scenario			
		A	**B**	**C**	**D**
		Toilet Flushing Only, 0.8" design storm	Toilet Flushing + Irrigation, 0.8" design storm	Toilet Flushing Only, 1.6" design storm	Toilet Flushing + Irrigation, 1.6" design storm
Average Annual Drawdown Time	**days**	**47**	**8.5**	**94**	**17**
Average Stormwater % Capture and Reuse	**%**	**32%**	**55%**	**41%**	**68%**
Avg Annual Volume of Stormwater Reused	MG | CCF	5.2 | 6,950	8.8 | 11,800	6.5 | 8,700	10.9 | 14,620
Avg % of Total Residential Demand Satisfied	**%**	**6.2%**	**11%**	**7.8%**	**13%**

Note: Outdoor demand assumes that irrigation demand is immediate; more sophisticated modeling would allow more accurate characterize of irrigation demand, but for purposes of this analyses, it was assumed to be immediate. This likely significantly overstates the demand for irrigation.

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Pollutant Loading Example

Assumptions

- Median Runoff EMC for TSS for HSFD: **70 mg/L**
- Median Effluent Concentration for TSS for Media Filters from International BMP Database: **15 mg/L**
- % Captured by cistern per SWMM (Scenario B – 0.8" design storm with toilet and irrigation re-use): **55%**
- % Captured by Bioretention with Underdrains per DAMP requirement: **80%** (requires approx 0.4" design storm)
- Bypass from both BMPs assumed to be untreated

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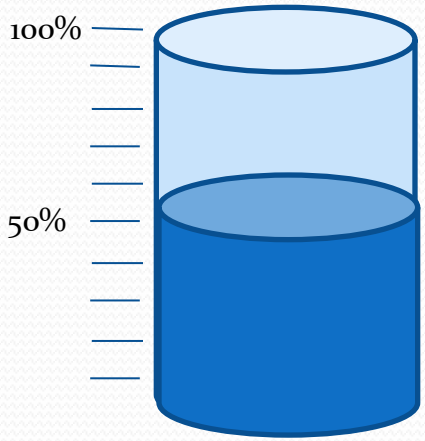
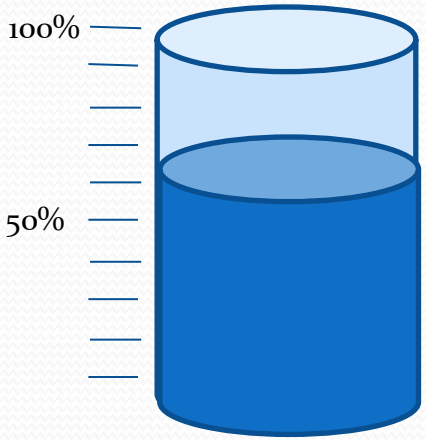
Pollutant Loading Example

Results – Average Annual TSS Load Removed

Cisterns and Re-Use: **55%**



Bioretention with Underdrains: **63%**



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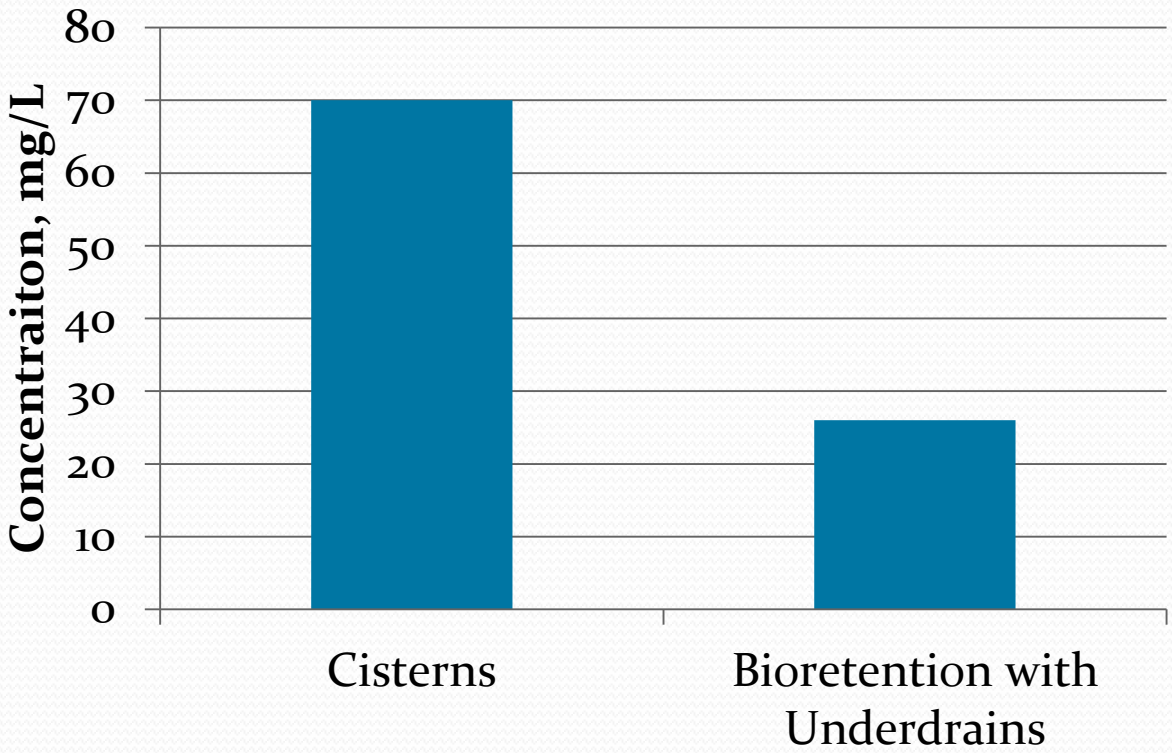
Pollutant Loading Example

Results – Average Annual TSS Concentration with BMPs



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Rainwater Harvesting - Code and Regulations

Applicable Codes

- Title 24—Building Standards Code (plumbing code)
  - Mechanical design and installation procedures
- Title 22—Social Security (recycled water quality standards)
  - Current technologies can meet this requirement (filtration, UV, and others)
- Title 17—Public Health (public water system cross-connection and backflow prevention)

Preliminary Conclusions

Since state codes do not currently recognize rainwater harvesting and reuse, discretion in approval will likely reside at the county and/or City levels through local codes and ordinances.

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ATTACHMENT A

County of Orange Detailed Comments
Draft Order No. R8-2014-0002

Appendix A-2

The Water Report Issue #65:
Stormwater Retention on Site, An Analysis Of Feasibility and Desirability, Strecker and Poresky (2009)

The Water Report™

Water Rights, Water Quality & Water Solutions in the West

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STORMWATER RETENTION ON SITE

AN ANALYSIS OF FEASIBILITY AND DESIRABILITY

by Eric W. Strecker, PE, and Aaron Poresky, EIT, Geosyntec Consultants (Portland, OR)

INTRODUCTION

Both nationally and in various localities, there is increasing regulatory pressure to maximize or require the retention of stormwater on site with compliance often linked to matching post-development runoff with predevelopment hydrology.

For example, in California the recently adopted Ventura Municipal Separate Storm Sewer System (MS4) NPDES permit requires retention on site — via infiltration, evapotranspiration and/or harvest and "re-use" — of precipitation from storms ranging up in size to the permit-defined "design storm" (Standard Urban Stormwater Mitigation Plan (SUSMP) depth of 3/4 of a inch — "design storms" are events defined in regulation and reflected in stormwater system design). There is an exception allowed where it is not feasible to retain the entire volume: the project may then retain "only" 70 percent of the SUSMP storm on site and mitigate the remaining volume off site. Another example is the North Orange County permit, which requires that infiltration, evapotranspiration, and/or harvest and re-use be employed to manage the water quality design storm, unless infeasible.

Nationally, the recent Energy Independence and Security Act (EISA) Section 438 requires that any Federal project with over 5,000 square feet of impervious area "maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow." Guidance for compliance with this provision allows either retention of the 90th percentile, 24-hour storm event or a model-based evaluation of discharge rates and volumes, matching predevelopment with post-development runoff hydrology. In effect , both of these conditions mandate substantial on site retention.

These permits/regulations have "narrowed" the traditional definition of Low Impact Development (LID) down to only a few elements — i.e., infiltration, evapotranspiration and/or harvest and use. This narrowing precludes management options present in the broader LID definition, such as detention and bio-filtration in vegetation-based facilities that provide incidental infiltration and evapotranspiration, but have a surface discharge point (e.g. bioretention with underdrains).

Nationally, the US Environmental Protection Agency (EPA) has also limited the definition of LID in some of their various guidance documents. For example, *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, December 2007 (EPA 841-F-07-006) includes the definition: "LID comprises a set of approaches and practices that are designed to reduce runoff of water and pollutants from the site at which they are generated. By means of **infiltration, evapotranspiration, and reuse of rainwater**, LID techniques manage water and water pollutants at the source and thereby prevent or reduce the impact of development on rivers, streams, lakes, coastal waters, and ground water." (Emphasis added) It should be noted that other EPA documents include

Stormwater On Site

LID Definitions

Harvested Water

Natural Balance

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definitions with the broader definition of filtration and surface release (see **Table 1**). It also should be noted that even in the guidance that includes the narrowed definition, in most cases the examples and guidance details include filtration and surface release of runoff.

Table 1. Summary of Filtration and Surface Release Inclusion in LID Definitions and associated guidance

Document/Reference	Filtration and Surface Release	
	In Definition	In Guidance/Examples
Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, December 2007 (EPA 841-F-07-006)	No	Yes
Low Impact Development (LID) Literature Review, October 2000 (EPA-841-B-00-005	Yes	Yes
Low-Impact Development: An Integrated Environmental Design Approach (Prepared by the Prince George's County Maryland Department of Environmental Resources Programs and Planning Division, with assistance from EPA), June 1999	Yes	Yes
Polluted Runoff (Nonpoint Source Pollution) Low Impact Development (LID), Last updated on Thursday, January 15th, 2009 Additional information from linked factsheet: *Design Principles for Stormwater Management on Compacted, Contaminated Soils in Dense Urban Areas*, April 2008 (EPA-560-F-07-231)	Not Clear	Yes
Low Impact Development (LID) and Other Green Design Strategies, Last updated on October 09, 2008	No	Not Clear

To date, the retention of stormwater on site has been primarily been accomplished via infiltration and, to a much more limited extent, evapotranspiration. Only in a few cases has harvest and use (the authors believe that stormwater that is captured and used is not ”re-used”) been employed on a site scale (typically as a part of a Leadership in Energy and Environmental Design (LEED) rating process). Uses for harvested water typically include non-potable uses such as irrigation and toilet flushing and in some cases process water for industrial uses.

The feasibility and desirability of retaining stormwater on site up to some design storm level has not been vetted technically on a national or regional scale. For example, in the EPA *Reducing Stormwater Costs* Guidance referenced above there is virtually no assessment via monitoring or modeling information of the potential results of the case studies presented. It is primarily a compendium of antidotal information. There has been almost no consideration of the natural water balance (i.e., predevelopment conditions) in technical guidance or whether infiltrating more volume than occurs under natural conditions (as would tend to result from matching runoff hydrology without matching evapotranspiration) could, in many cases, cause problems. This paper attempts to present some of the considerations for retaining on site to determine whether it is feasible and/or desirable. It focuses on Southern California examples, but the factors discussed are applicable to much of the West and beyond.

It should be noted that “retaining stormwater on site” in its contemporary usage typically only refers to not having surface discharges result from specific “design storm” events. This usage ignores the fact that infiltrated or evapotranspirated stormwater is not actually “retained” on site — it either enters a deeper aquifer, flows as shallow interflow which may emerge elsewhere or, in the case of evapotranspiration, escapes to rain another day.

The authors believe that, while one should try to maximize the retention of stormwater on site, such retention should not be mandated, as site specific circumstances often indictate wiser alternatives.

PERFORMANCE OF STORMWATER BEST MANAGEMENT PRACTICES (BMPs)

General Considerations

In order to assess the performance of stormwater treatment Best Management Practices (BMPs), it is important to understand the range of factors which may impact BMP performance. BMP performance is effected by: runoff patterns; pollutant types and forms; the storage volume and/or treatment rate; the ability to recover storage capacity (for BMPs that rely on storage); the treatment processes for released flows (to surface waters or groundwaters); and operations and maintenance issues that affect the ability of the BMP to continue operations (Strecker, et. al., 2006). For storage-based BMPs, methods for recovering storage capacity include: surface discharge; evapotranspiration; deeper infiltration; and putting the stored water to use. For systems which include cisterns (harvest and use), one of the most critical factors is the ability to quickly recover storage capacity before the next storm event arrives. Typically, if storage capacity cannot be recovered within two-to-four days, then the amount of runoff bypassing storage becomes significant due to the cistern being partially to nearly full.

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Stormwater On Site

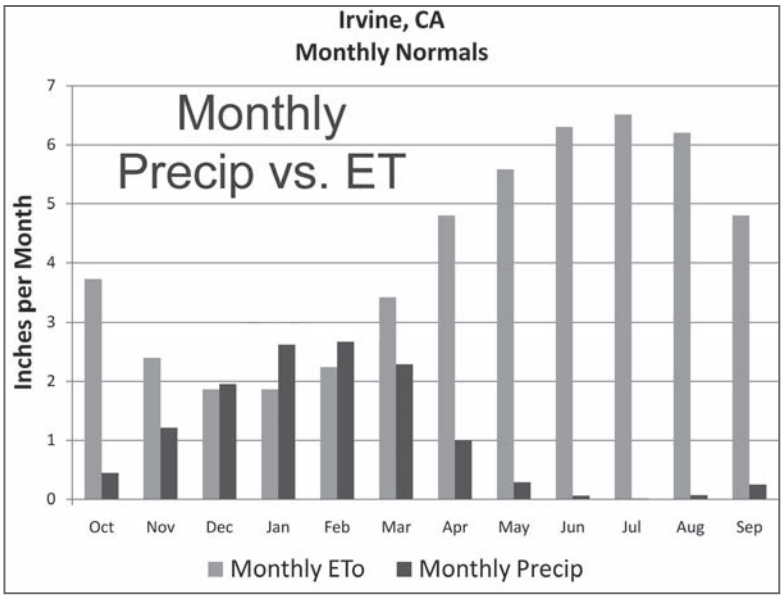
Storage Capacity Recovery

Weather and Resulting Runoff Patterns

In Southern California and the West Coast in general, precipitation patterns in most urban areas are affected by the presence or absence of a high pressure ridge that in essence blocks-out low pressure storm systems. Typically, once the high pressure ridge is absent a series of storms arrives, delivering "back-to-back" storms until a high pressure ridge re-establishes. Storms arrive about every two to three days during this period. If the storage capacity is not quickly recovered, these back-to-back storms can result in storage-based BMPs that are full or partially full when the next storm arrives, which then causes significant bypass or overflow to occur. In Southern California, most precipitation arrives from December to March. **Figure 1** shows the monthly normal rainfall in Irvine California (and monthly **e**vapo**t**ranspiration (ET)). Monthly normals tend to mask the patterns that occur within specific months in the period of record. **Figure 2** shows a typical precipitation pattern for the same gage, which includes the effect of 'back-to-back" storm events on a weekly timescale in an actual year. These weather patterns indicate that the recovery of storage on a sub-weekly time scale is critical to ensure that sequential storms do not result in excessive bypass or overflow of BMPs. Study of typical storm patterns indicates that storage capacity should be regenerated within two-to-three days to maximize the stormwater management performance when harvesting stormwater.

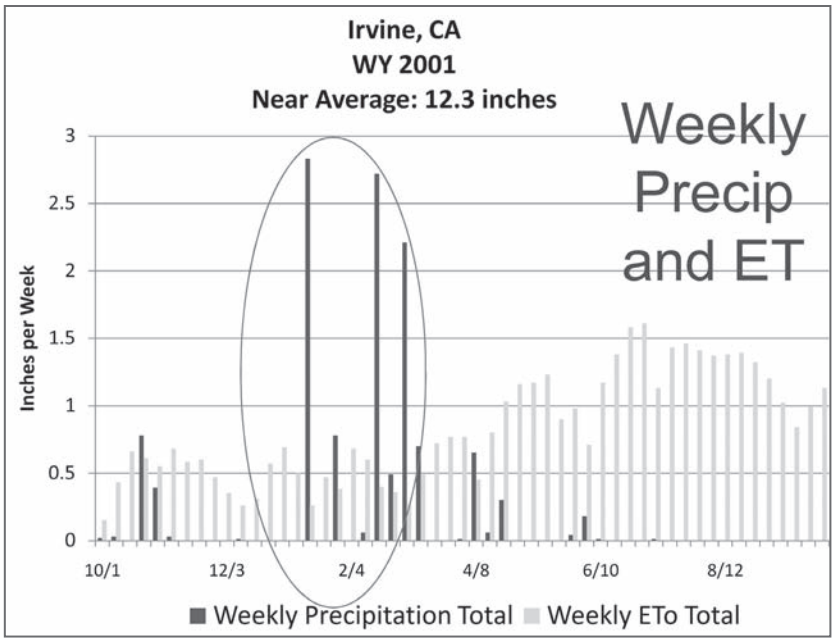
Precipitation v. "ET"

Figure 1. Monthly Precipitation vs. Monthly Evapotranspiration for Irvine, California.



Precipitation Pattern

Figure 2. Typical Precipitation Pattern Showing Back-to-Back Storms at Irvine California for a Near Average Water Year.



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Stormwater On Site

Infiltration Issues

Infiltration is the primary method that is employed to retain stormwater on site. This is because, when it can be accomplished, infiltration is the method most likely to be successful. However, the authors believe that three key questions/issues need to be addressed when considering infiltration strategies if unintended, problematic consequences are to be avoided.

Key infiltration considerations include:

- Can you do it?
- Should you do it and, if so, to what extent?
- If you do employ infiltration, what factors need to be addressed to insure a desirable outcome?

Infiltration: Can You Do It?

Soil Factors

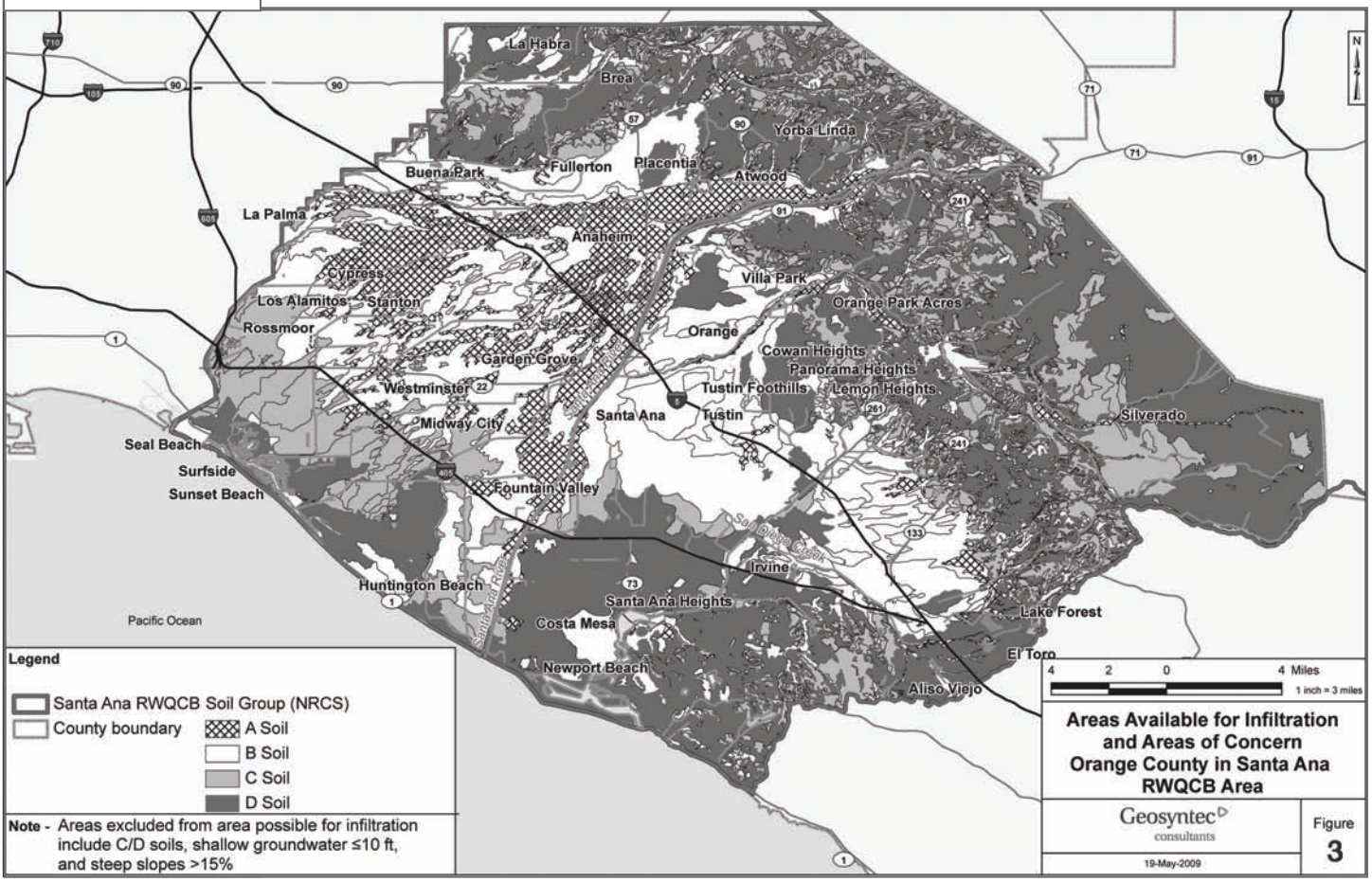
Underlying soils greatly affect the ability to infiltrate. In much of Southern California (and the West) urban areas are situated atop soils that are difficult for infiltration. Some practitioners have suggested soil amendments as a strategy for increasing infiltration. However, amending soils typically only addresses surface soils, so if underlying soils are still difficult for infiltration, soil amendments may only be increasing the storage available (vs. significantly increasing underlying infiltration rates). **Figure 3** presents a map that shows underling soils for the North Orange County, California permit area. It is expected that, in general, infiltration will only be successful in areas with A and B soil types. Of course, in mapping broader soils groups, there may be pockets where infiltration is more feasible. However, the converse is also true. In this Orange County example, a little over 58% of the permit area has C and D soil types that would be unlikely to promote infiltration at an acceptable rate. Infiltration facilities that ignore low underlying infiltration rates in their design would tend to be full for much of the wet season, resulting in substantial bypass/overflow, thereby greatly reducing retention on site. Infiltration facilities designed with lower infiltration rates in mind would have shallower allowable ponding depths and thus require a greater amount of site area, possibly promoting sprawl. To ascertain feasibility, maps like this should be developed prior to requiring infiltration or on site stormwater retention.

Infiltration Rates & Design

Infiltration: Should You Do It?

The next question is "should you (or how much should you) infiltrate?" In many areas there are unnatural (e.g., solvent) or natural (e.g., selenium) plumes or soil contamination that infiltration could negatively impact by either moving or spreading the contaminants. Infiltration in industrial areas is often not desirable due to general concerns about groundwater contamination resulting from potentially elevated

Figure 3. Soil types for North Orange County MS4 NPDES Permit Area



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Stormwater On Site

Water Balance Consequences

pollutant concentrations in industrial stormwater runoff. Geotechnical issues associated with steep slopes or expansive soils may also be an issue for infiltration. Depth to groundwater typically limits infiltration to areas with 10 or more feet of separation from the bottom of infiltration facilities to groundwater. Finally, in some locations upgradient of an ephemeral stream, increased infiltration may cause undesirable habitat type changes downstream of the site due to increased periods of base flows that result in vegetation changes (e.g. conversion of dry wash to a thickly vegetated system). There has been a lack of consideration of the overall water balance consequences that a "retention on site" requirement may have in terms of habitat.

As an example, **Figure 4** presents a map of the North Orange County permit area that shows the areas remaining with good potential for infiltration after consideration of some of the issues covered above. The area remaining within the permit area for consideration of infiltration is less than 23 percent of the permit area, even without considering habitat issues or regulated facilities (small contamination areas shown as dots). There are large urbanized areas where infiltration would not be either feasible or desirable.

Groundwater Quality

Infiltration: Do It Carefully

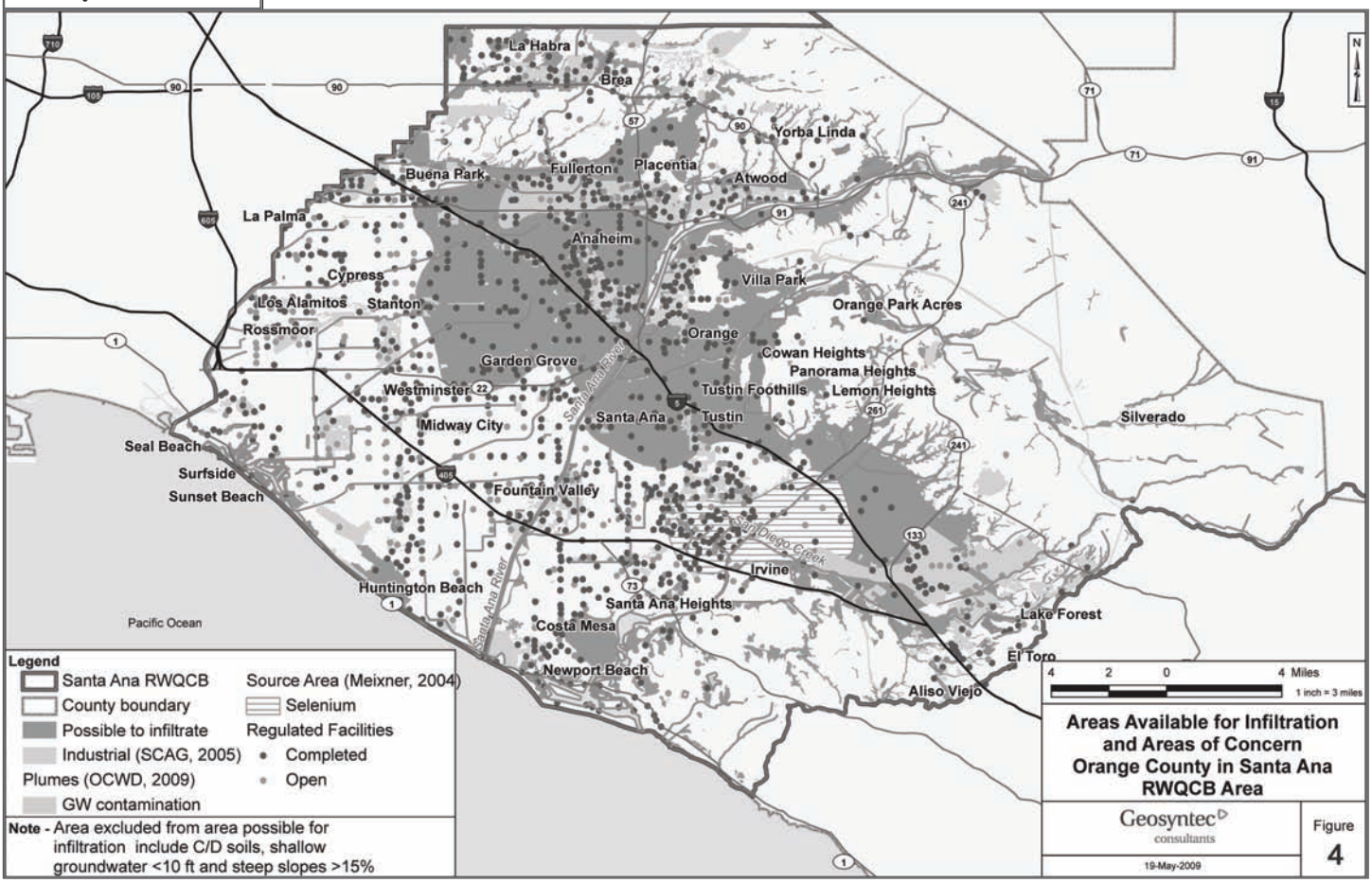
Finally, infiltration should be done carefully to ensure that groundwater quality is protected and widespread stormwater management facility failure does not occur. Proper treatment of infiltrating water should occur before this water reaches groundwater either via treatment with BMPs or ensuring that soils are adequate to provide treatment while passing infiltrating water. Infiltration facilities have often failed due to poor maintenance and operation of the facilities. One needs to think through how to design infiltration facilities to minimize maintenance issues, including whether widely-distributed infiltration facilities can be maintained as adequately as one centralized facility. Water districts that utilize groundwater should obviously be involved in decisions about where and how to infiltrate stormwater so that groundwater supplies are protected.

Maintenance Issues

Infiltration: Summary

Infiltration must be done carefully to ensure that it can be successful on a long-term basis as well as be protective of water supplies. The best opportunities for successful infiltration are in areas where groundwater is actively managed for water supply. Such areas are unlikely to face as many water balance hindrances or other issues. For example, areas along the Santa Ana River are actively managed for recharge and withdrawals by the Orange County Water District. These localities provide the best opportunity for successful infiltration.

Figure 4. Areas available for infiltration for the North Orange County Permit Area



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Stormwater On Site

Development Factors

Precipitation v. ET

In Soil Storage Recovery

Water Balance

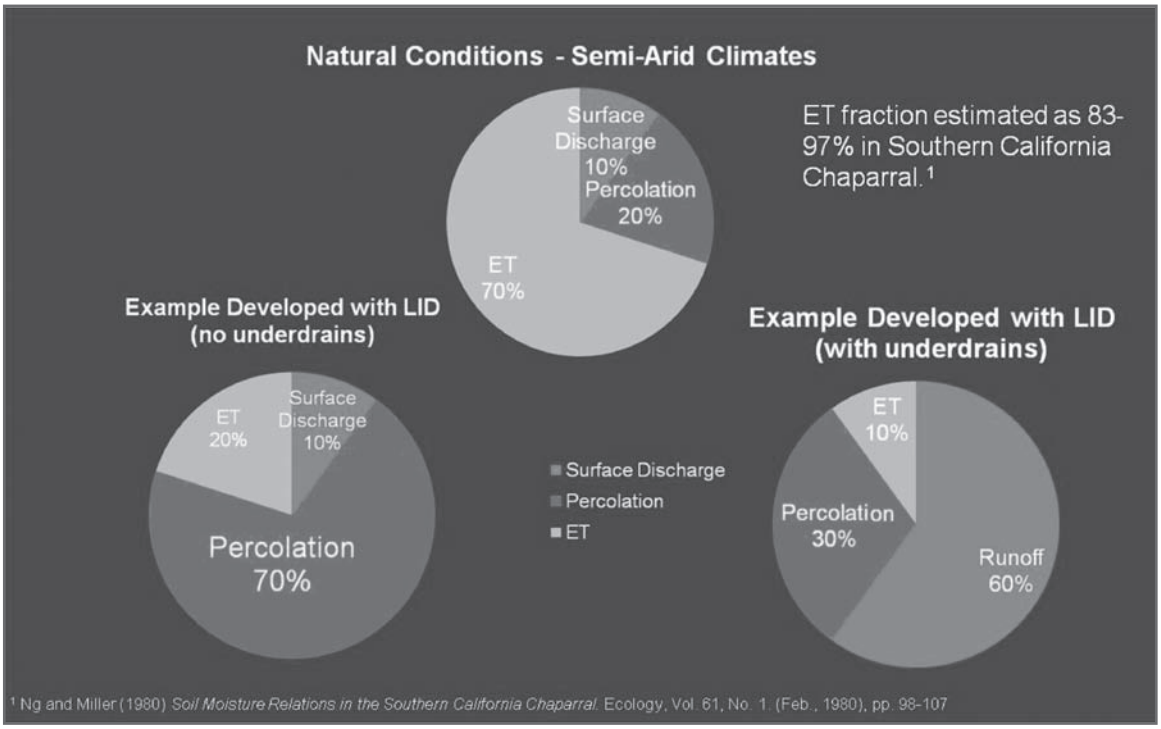
EVAPOTRANSPIRATION (ET)

After an area undergoes development there will be less available area for **e**vapo**t**ranspiration (ET)to occur. This holds true even when vegetated roofs, pervious pavements, and other "green" development practices are employed and is especially true for high density projects. Some analysts have compared monthly or seasonal ET to precipitation levels to assess the potential for ET losses as a significant retain-runoff on site measure. This is particularly inappropriate on the West Coast in light of the region's tendency for back-to-back storm events.

Refer again to **Figures 1 and 2** appearing above. **Figure 1** shows monthly normal comparisons of precipitation versus ET, while **Figure 2** shows precipitation and ET as weekly totals for an example year. While the former suggests that ET matches or exceeds precipitation on a monthly normal bases, it does not account for back-to-back storms or the fact that months with higher than normal rainfall would be the same months that correspond to lower than normal ET. **Figure 2** clearly demonstrates that ET cannot keep up with precipitation on a weekly basis in critical periods of the typical back-to-back storms of an average year. During these critical periods, the storage provided in soils would not have recovered in time for subsequent rainfall. While ET of stormwater should be maximized, it almost certainly will not be able to match pre-development levels and is likely a minor component of retaining stormwater on site (without storage and use for irrigation).

ET is a very important consideration when assessing the ability to mimic predevelopment runoff volume. **Figure 5** presents typical arid southwest water balances for: undisturbed areas; areas developed with infiltration facilities (Example Developed with LID – no underdrains); and for areas developed using LID with underdrains. Predevelopment ET can range upwards of 80 to 97 percent of the precipitation on an average annual basis. It is very unlikely that predevelopment ET will be matched by post-development ET due to reduction in vegetated open soils areas. So, the choice for development, particularly high density development, is to either have more runoff than predevelopment or more infiltration, or a combination of the two. This fact and its ramifications have not been considered during the development of on site retention requirements that are focused on surface hydrology versus overall hydrology (including sub-surface).

Figure 5. Typical Water Balance from Precipitation in Arid Southwest Climate



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Stormwater On Site

Harvest Demand

Model Assumptions

Capture & Use Levels

Biofiltration Comparison

CAPTURE & USE ("RE-USE")

In most all cases where infiltration is not feasible or possible, the only option remaining to meet the retain on site requirements is to capture (harvest) and use the stormwater. In North Orange County, for example, this would be the option in about 77 percent of the permit area or more.

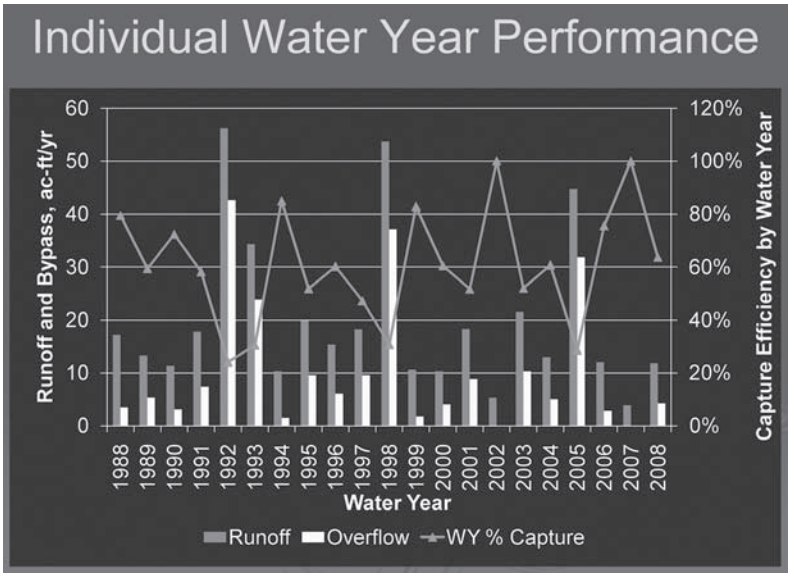
The key factor for success of capture and use of stormwater as a means to retaining water on site is the rate at which storage can be made available for subsequent events. This means having a demand for the captured water that is high enough, especially during the rainy season. The two most obvious uses for captured stormwater are for irrigation and toilet flushing. There are significant code issues with capture and use for internal non-potable demand in many jurisdictions. In addition, there are water rights issues associated with capture of stormwater in some areas (e.g., Colorado and Utah). These limitations are not the focus of this article. Other potential uses include process water for commercial or industrial purposes. A scenario for a residential development was conducted to illustrate the potential for capture and use of stormwater. This scenario is discussed next.

Capture and Use: Residential Scenario

Your authors modeled and evaluated a100-acre residential catchment with 60 percent overall impervious area using a continuous simulation model (SWMM) as an example of a capture-and-use scenario. It was assumed that infiltration losses would be minimal (due to shallow groundwater depth, poor soils for infiltration and/or other issues). A tank (above ground storage) of 1.3 million gallons (equivalent to the runoff from the catchment resulting from a 0.8 inch storm event — the water quality design storm) was evaluated with toilet flushing and irrigation uses combined. Toilet flushing assumed 65 gallons per day per dwelling unit at 4.5 units per acre. For simplicity, irrigation demands were assumed to equal the monthly average ET levels for the 30 acres of landscaped areas. It was also assumed that irrigation was always on, even during rainfall (note that irrigation demands during and after rainfall are significantly over-estimated in this analysis). A 21-year hourly long-term simulation model was run to ascertain the potential effectiveness of such a system for retaining runoff on-site. We also evaluated potential pollutant removal results as compared to biofiltration with an underdrain (surface water release).

Overall the system resulted in an estimated capture and use of stormwater of about 48% of the total runoff volume (52% bypassing with no treatment — though one could treat the bypass as well). The capture and use levels varied annually from less than 30 percent to 100 percent for the 21 water years evaluated (**Figure 6**).

Figure 6. Predicted Annual Runoff and Overflow for Example Cistern System



Using data from International BMP Database (see: www.bmpdatabase.org), a comparison of total loadings performance to a biofiltration system with underdrains was made. This comparison showed that the biofiltration system reduced **t**otal **s**uspended **s**olids (TSS) loads by about 63% compared to 48% for the cistern scenario for the 21-year simulation. So, in this case the assumption that retain on site is the most effective at reducing pollutant loadings is not valid, unless one also required treatment of the bypassed flows (in essence an additional BMP treatment requirement). Finally, the average annual potable water saved was on the order of about 10 percent of the average annual demand.

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Stormwater On Site

Another scenario was run doubling the size of the cistern tank to 2.6 million gallons (equivalent to a 1.6 inch design storm). Under this scenario, the capture and use level went up to about 57 percent (so doubling the tank size resulted in another nine percent of the runoff being captured and used). Again, this emphasizes the point that being able to drain the cistern relatively rapidly is the key to success for capture and use.

Capture and Use: Limiting Factors

Evaluation Factors

As illustrated in these examples, one should evaluate carefully potential scenarios to help ensure that choices made regarding retention on site requirements actually result in the desired results. Evaluation should consider land use and density assumptions as well as assessment of local precipitation and runoff patterns, irrigation needs, and ability to use water for toilet flushing or other non-potable uses.

Rapid Storage Recovery

For capture and use to work, the storage must be quickly recovered. Irrigation typically is not an effective use for recovering storage quickly as irrigation needs during wet periods are minimal and in some cases (i.e., colder climates) there is no irrigation demand for long periods. In addition, much of the arid southwest is encouraging "xeri-scaping" (drought tolerant plants), which is likely much more effective at reducing potable demand than capture and use for irrigation. Xeriscape plant pallets typically do not like to be saturated for long periods, as would occur via over-irrigation if irrigation use was maximized. Further, use of a water-loving plant palate to maximize the use of captured runoff during normal and wet years could exert an additional demand for potable water during dry years.

Toilet Use Ratio

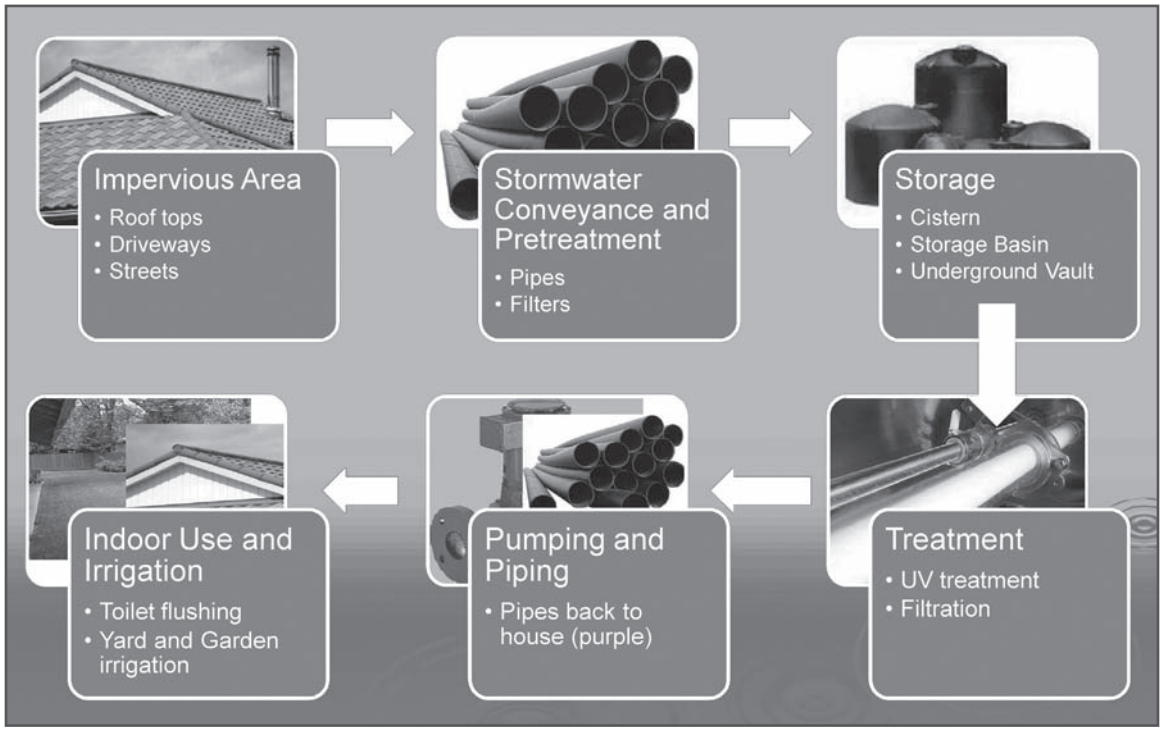
For toilet flushing to be effective, there needs to be a high enough ratio of Toilet Users To Impervious Area (TUTIA). Perhaps in high-rise condominiums, office buildings, institutional buildings, etc. this ratio would be high enough to drain the tank sufficiently fast and in these cases capture and use should be considered.

However, there would be a "competition" for reclaimed water in much of the arid west. Reclaimed water systems tend to be limited in their ability to distribute water in the wetter and colder periods of the year due to low irrigation demands. In addition, in some locations use of reclaimed water for toilet flushing is required in high density projects. One has to question if the capture and use of stormwater that may result in reclaimed water being discharged is an effective strategy. Under this scenario, the captured stormwater would not be reducing potable water demand.

Infrastructure Needs

Finally, there is significant infrastructure (**Figure 7**) that would be required to employ cistern and use on a site basis, including piping, storage, treatment, pumping, and separate piping (purple pipes). Questions about sustainability for these systems need to be explored and assessed.

Figure 7. Typical Components of a Stormwater Harvest and Use system.



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Stormwater On Site

Key Considerations

Unique Factors

CONCLUSIONS

In Summary:

- Infiltration is often not broadly feasible, effective and/or desirable. While it should be maximized where appropriate, studies are needed to identify suitable areas and also identify areas where infiltration may be feasible but not appropriate.
- Precipitation/runoff patterns in California and much of the West limit the ability of evapotranspiration-based BMPs to achieve retention on site requirements. Evapotranspiration of stormwater should be maximized, but will not be a significant component of retaining stormwater on site in densely developed areas.
- Precipitation/runoff patterns coupled with landscaping and reclaimed water considerations limit the applications where capture and use of runoff can be effective. Generally, only scenarios with high indoor demand and no competing requirements to use reclaimed water can be expected to provide a complete and reliable stormwater solution. Capture and use should be maximized in these cases, but in other cases it should be carefully considered against other options such as biofiltration and discharge to determine which option is most effective in meeting stormwater management goals.
- The overall water balance should be considered when making choices on proper levels of infiltration versus surface runoff.
- There needs to be more technical vetting of "retain on site" and stormwater harvest and use before these approaches are made mandatory.

Each watershed and site has unique soils, topography, groundwater, water quality, land uses, receiving water sensitivities, wastewater strategies, etc. which should be considered when evaluating retention on site as a requirement or strategy. The authors believe that management approaches that are "one size fit all" are not appropriate and in many cases would likely lead to undesirable results.

Proper Stormwater Management Includes:

- Source controls
- Infiltration where feasible and appropriate
- Maximizing ET losses
- Harvest and use where it makes sense
- Capture and treat with effective (i.e. vegetated) BMPs where it makes sense

We believe that significant progress could be made by improving BMP selection and design guidance for all BMPs to better target unit processes (i.e. physical, biological, chemical treatment processes) to the pollutants and parameters of concern for each watershed.

For Additional Information:

Eric Strecker, Principal, GeoSyntec Consultants (Portland, OR)
503/ 222-9518 or email: estrecker@geosyntec.com
Aaron Poresky, Senior Staff Engineering Specialist, GeoSyntec Consultants (Portland, OR)
503/ 222-9518 or email: aporesky@geosyntec.com

Eric Strecker, P.E. is a Principal and Water Resources Practice Leader with Geosyntec Consultants in Portland, Oregon. He has over 25 years of stormwater management experience, including national level applied research efforts for EPA, FHWA, WERF, and NCHRP as well as state and local stormwater management, design and research projects throughout the United States. He is a Principal Investigator for the International BMP Database.

Aaron Poresky, E.I.T. has more than four years of experience in water resources and urban stormwater management. At Geosyntec, he has been involved in a variety of projects including structural BMP design and evaluation, water quality planning and impact analysis, hydromodification planning and impact analysis, stormwater policy support, and modeling methodology development. Key project areas have included stormwater retrofit planning and design for a variety of municipal and private clients, modeling methodology development and implementation, new development stormwater planning, and regulatory analysis. Mr. Poresky has been an invited speaker on the topics of modeling, BMP design, and stormwater policy.

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Disneyland RESORT

CERTIFIED MAIL
RETURN RECEIPT REQUESTED AND
VIA EMAIL adam.fischer@waterboards.ca.gov

June 19, 2014

Mr. Adam Fischer
California Regional Water Quality Control Board
Santa Ana Region
3737 Main St., Suite 500
Riverside, CA 92501-3339

Subject: Comments on Draft Orange County Municipal Separate Storm Sewer System ("MS4") Permit, Draft Order No. R8-2014-0002, NPDES Permit No. CAS618030.

Dear Mr. Fischer:

The Disneyland Resort greatly appreciates the opportunity to comment on the Draft Orange County Municipal Separate Storm Sewer System ("MS4") Permit, NPDES Permit No. CAS618030 prepared by the California Regional Water Quality Control Board Santa Ana Region ("RWQCB") for implementation by the Orange County Flood Control District, the County of Orange and the Incorporated Cities therein within the Santa Ana Region for Urban Runoff.

The current draft of the MS4 permit does not provide the option for a project applicant to participate in an alternative compliance and in lieu program in the event that structural treatment control BMPs are not feasible. This option is currently provided in existing NPDES Permit, Order No. R8-2009-0030 and the County's Model Water Quality Management Plan, and similar provisions should be restored. The alternative compliance and in lieu program supports current efforts to develop on-site treatment control BMPs as part of sub-watershed retrofit strategies. The omission of the alternative compliance and in lieu program option may limit the Resort's proactive compliance efforts and may hinder redevelopment.

17.1

The alternative compliance option would provide mechanisms for improvement of water quality in cases where on-site treatment control BMPs are not feasible and opportunities for off-site treatment control BMPs are available. Since the use of BMP credits is implemented prior to final occupancy of the project and often years before the credits are needed, there are greater and earlier water quality benefits. This proactive implementation addresses larger areas than initially needed and ultimately, more water is infiltrated improving overall storm water quality and recharge of the groundwater. Inclusion of a simple, flexible, and protective pathway to allow for the creation and use of BMP credits (i.e., a water quality bank) would address this concern.

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Tel 714.781.4000

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To accomplish this goal, modifications to existing draft permit language would be needed for XII.L as noted below.

The following revisions to Section XII.L are requested:

L. BMP Credits and Waiver of Structural Treatment Control BMPs

1. Co-permittees are authorized to accept BMP credits generated through the implementation of structure treatment BMP retrofits to treat stormwater runoff from non-project areas as alternatives to on-site structural treatment control BMPs and to approve a Project WQMP relying on these BMP credits if all of the following conditions are met:

a. The Project WQMP demonstrates that it is technically or economically infeasible to implement treatment control BMPs on-site,

b. Source and site design BMPs have been incorporated to maximize the infiltration of urban runoff,

c. The project WQMP demonstrates that the use of the water quality credit would result in equivalent or better water quality performance in comparison to on-site treatment of the DCV,

17.1

d. The BMP(s) used to generate the BMP credits meet all of the following criteria:

i. The BMP(s) generating the BMP credits is/are part of an approved project WQMP[1], including assignment of operations and maintenance responsibilities for the life of all projects relying on the credits generated.

ii. The BMP(s) generating the BMP credits is/are constructed, serviceable, and satisfactory to the Co-permittee prior to final occupancy of the project relying on these credits.

ii. The project and the BMP(s) generating the water quality credit are both located within the same watershed.

e. The project applicant or Co-permittee maintains a tracking system for BMP credits and substantiation of this tracking system is recorded with each Project WQMP that relies on the BMP credits. The tracking system must include:

i. Inventory of BMPs providing BMP credits and their respective Project WQMPs, including the quantity of credits that are generated.

[1] The BMP generating the BMP credit could be part of the same Project WQMP as the project using the credit, or could have been approved as part of a prior Project WQMP.

ii. Inventory of the Project WQMPs that rely on BMP credits, and the respective BMPs that supplied these credits, including a running total of the remaining credits for each BMP.

2. Co-permittees are authorized to waive their requirement to ~~provide~~ require structural treatment control BMPs (see Provision XII.C.1 above) to remove pollutants and subsequently approve a WQMP if all of the following conditions are met:

17.1

a. The cost of employing structural treatment control BMPs has been demonstrated in the project WQMP to disproportionately outweigh the pollution control benefits.

b. Source and site design BMPs have been incorporated to maximize the infiltration of urban runoff.

c. The Executive Officer has been provided written notice of the Co-Permittee's intent to issue the waiver, along with adequate supporting documentation, at least 30-days prior to issuance by the Co-permittee.

d. The Executive Officer approves the proposed waiver, or takes no action on the waiver within 30 days.

If you have any questions or require additional information, please do not hesitate to contact me at 714-781-3563.

Sincerely,

Janina Jarvis
Manager, Environmental Compliance
Disneyland Resort

Name/Title: Jane Webb, Owner/Inspector

Representing: F.A.S.T. FIRE PRO.

Comments: Order No. R8-2009-0030 NPDES No. CAS618030 As amended by Order No. R8-2010-0062, Section XXI 5 Required the permittees to develop BMPs for fire hydrant/Sprinkler testing or flushing, non-emergency fire fighting....

1.1

Recommend adoption of CALFIRE "Water Based Fire Protection System Discharge Best Management Practices Manual" into the 2014 Orange County MS4 Permit.

The manual was developed in conjunction with the California Water Boards, Division of Water Quality Storm Water Division.

From:	Garrison, Noah
To:	WB-RB8-SantaAna
Cc:	Kheyfets, Anna; Dyer, Johanna; Devine, Jon; Fischer, Adam@Waterboards
Subject:	Comments on Draft Order R8-2014-0002, North Orange County MS4 Permit
Date:	Friday, June 20, 2014 3:20:46 PM
Attachments:	NRDC North OC Regional MS4 Comment 6-20-14 FINAL.pdf Center for Watershed Protection - Impacts of Impervious Cover on Aquatic Systems.pdf Curriero - Association between Extreme Precipitation and Waterborne Disease Outbreaks 2001.pdf EPA - Reducing Stormwater Costs through LID Strategies and Practices.pdf EPA R3 Capacasa Letter to Sakai re Prince George Cty MS4 Objection 8-8-12.pdf 1991 EPA Elliott Memo.pdf

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Dear Mr. Fischer:

Attached please find comments and documents in support from the Natural Resources Defense Council on Draft Order No. R8-2014-0002, the North Orange County MS4 Permit. This email will be followed by 2 additional emails containing documents in support of our comment. Please do not hesitate to contact us with any questions, and we look forward to working with you on the permit adoption process.

Best,
Noah Garrison

Noah Garrison | Staff Attorney - Water Program | Natural Resources Defense Council
Office: 310-434-2300 | 1314 2nd Street, Santa Monica, CA 90401
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From:	Garrison, Noah
To:	WB-RB8-SantaAna
Cc:	Kheyfets, Anna; Dyer, Johanna; Devine, Jon; Fischer, Adam@Waterboards
Subject:	Comments on Draft Order R8-2014-0002, North Orange County MS4 Permit - supplemental documents
Date:	Friday, June 20, 2014 3:23:32 PM
Attachments:	Haile 1999 SMBRP EPI Journal Article.pdf Horner - Investigation of Feasibility and Benefits of LID for Ventura County.pdf Horner Gretz - 12-2011 Investigation of Feasibility and Benefits of LID.pdf GAO - Water Quality-Better Data and Evaluation of Urban Runoff Programs.pdf Garn USGS - Effects of lawn fertilizer on nutrient concentration in runoff Wisconsin.pdf Given et al - Regional Public Health Cost Estimates.pdf Regional Board Amicus Brief - Malibu.pdf LA County Mun Stormwater BS 080548.pdf Pruss - 1998 Review of epidemiological studies on health effects.pdf

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Supplemental Documents 1

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From:	Garrison, Noah
To:	WB-RB8-SantaAna
Cc:	Kheyfets, Anna; Dyer, Johanna; Devine, Jon; Fischer, Adam@Waterboards
Subject:	Comments on Draft Order R8-2014-0002, North Orange County MS4 Permit - supplemental documents
Date:	Friday, June 20, 2014 3:25:02 PM
Attachments:	Ventura County Low Impact Development Technical Guidance Manual -07-13-2011.pdf

---

Supplemental Documents 2

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June 20, 2014

Via electronic mail

Mr. Kurt V. Berchtold
Executive Officer and Members of the Board
California Regional Water Quality Control Board, Santa Ana Region
373 Main Street, Suite 500
Riverside, CA 92501-3348
Email: santaana@waterboards.ca.gov

Re: Comments on Tentative Order R8-2014-0002, North Orange County MS4 Permit

Dear Mr. Berchtold:

On behalf of the Natural Resources Defense Council ("NRDC"), we are writing with regard to the Draft National Pollutant Discharge Elimination System (NPDES) Permit and Waste Discharge Requirements for Orange County Flood Control District, the County of Orange and the Incorporated Cities therein within the Santa Ana Region (Area-wide Urban Runoff from Municipal Separate Storm Sewer Systems ("MS4s")) Draft Permit ***R8-2014-0002***, NPDES Permit No. CAS 618030 ("Draft Permit"). We appreciate the opportunity to submit these comments to the Santa Ana Regional Water Quality Control Board ("Regional Board").

I. Stormwater Runoff is a Leading Source of Water Pollution in the Orange County Region

The U.S. Environmental Protection Agency ("EPA") considers urban runoff to be "one of the most significant reasons that water quality standards are not being met nationwide."[1] As the EPA has stated:

10.1

> Most stormwater runoff is the result of the man-made hydrologic modifications that normally accompany development. The addition of impervious surfaces, soil compaction, and tree and vegetation removal result in alterations to the movement of water through the environment. As interception, evapotranspiration, and infiltration are reduced and precipitation is converted to overland flow, these modifications affect not only the characteristics of the developed site but also the

[1]U.S. General Accounting Office (June 2001) *Water Quality: Urban Runoff Programs*, Report No. GAO-01-679.

> watershed in which the development is located. Stormwater has been identified as one of the leading sources of pollution for all waterbody types in the United States. Furthermore, the impacts of stormwater pollution are not static; they usually increase with more development and urbanization.[2]

A 2012 study of the effects of urban development on stream ecosystems by the U.S. Geological Survey showed that urban development impacts stream chemistry, hydrology, habitat, and species composition, and that communities of invertebrate species "Begin to Degrade at the Earliest Stages of Urban Development."[3]

In the North Orange County Region, the Regional Board has found that:

10.1

- "The discharge of pollutants from MS4s may cause or threaten to cause the concentrations of pollutants in receiving waters to exceed applicable water quality objectives. Discharges from MS4s may result in alterations to the hydrology of receiving waters that negatively impact their physical integrity. These conditions may impair or threaten to impair designated beneficial uses resulting in a condition of pollution, contamination or nuisance." (Draft Permit, at Finding 11);

- "Land development has created, and continues to create, new sources of non-storm water discharges and pollutants in storm water discharges as human population density increases. This brings higher levels of car emissions, car maintenance wastes, municipal sewage, pesticides, household hazardous wastes, pet wastes, and trash. Development typically converts natural ground cover to impervious surfaces such as paved highways, streets, rooftops, and parking lots. Pollutants deposited on these sources are dumped or washed off by non-storm water or storm water flows into and from the MS4s. As a result of the increased imperviousness in urban areas, less rain water can infiltrate through and flow over vegetated soil where physical, chemical, and biological processes can remove pollutants. Therefore, runoff leaving a developed area can contain greater pollutant loads and have significantly greater runoff volume, velocity, and peak flow rate than pre-development runoff conditions from the same area. Certain best management practices can minimize these impacts to water quality." (Draft Permit, at Finding 12);

- "[C]ommon pollutants in urban runoff include total suspended solids, sediment, pathogens (e.g., bacteria, viruses, protozoa), heavy metals (e.g., cadmium, copper, lead, and zinc), petroleum products and polynuclear aromatic hydrocarbons, synthetic organics (e.g., pesticides, herbicides, and PCBs), nutrients (e.g., nitrogen and phosphorus),

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[2]U.S. Environmental Protection Agency (December 2007) *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices*, at v.
[3]U.S. Geological Survey (2012) *Effects of Urban Development on Stream Ecosystems in Nine Metropolitan Study Areas Across the United States*, at 4; see generally, 1-5. Available at: http://pubs.usgs.gov/circ/1373/. Available at http://pubs.usgs.gov/circ/1373/.

oxygen-demanding substances (e.g., decaying vegetation, animal waste), detergents, and trash." (Draft Permit, at Finding 14); and,

- "Pollutants in runoff discharged from the MS4s risk adversely affecting human health and aquatic organisms. Adverse human health effects include gastrointestinal diseases and infections. Adverse physiological responses to pollutants in runoff include impaired reproduction, growth anomalies and mortality in aquatic organisms. These responses may be the result of different mechanism, including bioaccumulation of toxicants. During bioaccumulation, toxicants carry up the food chain and may affect both aquatic and non-aquatic organism, including human health. Increased volume, velocity, rate, and duration of storm water runoff greatly accelerate the erosion of downstream natural channels. This alters stream channels and habitats and can adversely affect aquatic and terrestrial organisms." (Draft Permit, at Finding 15.)

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Discharges of polluted urban runoff result in elevated bacteria levels and increased illness rates among swimmers, and the association between heavy precipitation (leading to increased runoff) and waterborne disease outbreaks is well documented.[4] Swimming or contact with waters contaminated by stormwater runoff can lead to fever, chills, ear infections and discharge, coughing and respiratory ailments, vomiting, diarrhea and other gastrointestinal illness, and skin rashes.[5] In a peer-reviewed evaluation of 22 selected epidemiological studies from around the world, scientists found that 19 of 22 studies showed that adverse health effects were significantly related to fecal indicator bacteria or bacterial pathogens.[6]

The Regional Board itself has acknowledged that "microbial contamination of the beaches from urban runoff and other sources has resulted in a number of health advisories issued by the Orange County Health Officer." (2009 Permit (as amended by Order R8-2010-0062, at Finding 36).) And the health impacts do come at tremendous public health and financial cost—one study demonstrated that swimming at polluted beaches in Orange County caused between 200,000 and 486,200 excess cases of gastroenteritis per year, in turn resulting in annual health costs of between $6.6 and $16.2 million (depending on the epidemiological model used) per year.[7]

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[4]Curriero et al., (August 2001) *The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States, 1949-1994,* American Journal of Public Health, 91:8 1194-1199.

[5]See, e.g., Haile, et al. (1999) *The Health Effects of Swimming in Ocean Water Contaminated by Storm Drain Runoff*, Epidemiology 10(4): 355-63; Haile, R. W. et al (1996) *An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay,* Santa Monica Bay Restoration Project, 70 pp.

[6]Pruss, A. (1998) *Review of epidemiological studies on health effects from exposure to recreational waters*, International Journal of Epidemiology 27:1-9.

[7]Given, S., et al. (2006) Regional Public Health Cost Estimates of Contaminated Coastal Waters: A Case Study of Gastroenteritis at Southern California Beaches, Environmental Science & Technology 40(16): 4851-4858, at 4856.

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Without question, swimming in stormwater runoff-contaminated water has a high cost for the region. The Draft Permit establishes requirements critical to addressing this pollution.

II. Legal Background

In order to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters," (33 U.S.C. § 1251(a)), the federal Clean Water Act ("CWA") prohibits the discharge of any pollutant from a point source into a water of the United States except as in compliance with the Act. (33 U.S.C. §§ 1311(a), 1342.) Point sources, such as MS4s, can comply with the CWA by obtaining a discharge permit under the National Pollutant Discharge Elimination System ("NPDES") program. (33 U.S.C. § 1342(b), (p).) Regulations under 40 C.F.R. section 122.4(d) prohibit the issuance of a NPDES Permit "[w]hen the imposition of conditions cannot ensure compliance with the applicable water quality requirements of all affected States." Further, renewal permits—like the 2012 Permit at issue—may not contain weaker standards than those contained in the previous permit, except under limited circumstances. (33 U.S.C. § 1342(o); 40 C.F.R. § 122.44(l).) Federal and state laws additionally require implementation of an antidegradation policy that mandates that existing water quality in navigable waters be maintained unless degradation is justified by specific findings. (See, 40 C.F.R. § 131.12(a)(1).)

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The CWA requires each state to adopt water quality standards for all waters within its boundaries and submit them to the EPA for approval. (33 U.S.C. §§ 1311(b)(1)(C), 1313.) Water quality standards include maximum permissible pollutant levels that must be sufficiently stringent to protect public health and enhance water quality, consistent with the uses for which the water bodies have been designated. (33 U.S.C. § 1313(c)(2)(A).) They provide the reference point "to prevent water quality from falling below acceptable levels." (*PUD No. 1 of Jefferson County v. Washington Dep't of Ecology* (1994) 511 U.S. 700, 704 [quotation omitted].) States also must identify as impaired any water bodies that fail to meet water quality standards. (33 U.S.C. § 1313(d).)

A. Clean Water Act Section 402(p)

Like all NPDES permits, MS4 permits must ensure that discharges from storm sewers do not cause or contribute to a violation of water quality standards. (33 U.S.C. § 1311(a); 1313; 1341(a); 1342(p).)[8] In addition, for MS4s covered under the NPDES program, permits:

> shall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practices, control techniques and system, design and engineering methods, and such other provisions as the Administrator or the State determines appropriate for the control of such pollutants.

[8]See, e.g., State Board Order No. WQ 99-05, *Own Motion to Review the Petition of Environmental Health Coalition to Review Waste Discharge Requirements Order No. 96-03*.

(33 U.S.C. § 1342(p)(3)(B)(iii).) The Clean Water Act's "maximum extent practicable" ("MEP") standard does not grant unbridled leeway to Permittees in developing controls to reduce the discharge of pollution. (See, e.g., *Defenders of Wildlife v. Babbitt* (D.D.C. 2001) 130 F. Supp. 2d 121, 131; *Environmental Defense Center, Inc. v. U.S. E.P.A* (9th Cir. 2003) 344 F.3d 832, 853.) The MEP standard "imposes a clear duty on the agency to fulfill the statutory command to the extent that it is feasible or possible." (*Defenders of Wildlife v. Babbitt,* 130 F. Supp. 2d at 131; *Friends of Boundary Waters Wilderness v. Thomas,* 53 F.3d 881, 885 (8th Cir. 1995) ("feasible" means "physically possible"). As one state hearing board held:

> [MEP] means to the fullest degree technologically feasible for the protection of water quality, except where costs are wholly disproportionate to the potential benefits…. This standard requires more of Permittees than mere compliance with water quality standards or numeric effluent limitations designed to meet such standards…. The term "maximum extent practicable" in the stormwater context implies that the mitigation measures in a stormwater permit must be more than simply adopting standard practices. This definition applies particularly in areas where standard practices are already failing to protect water quality….

10.1

(*North Carolina Wildlife Fed. Central Piedmont Group of the NC Sierra Club v. N.C. Division of Water Quality* (N.C.O.A.H. October 13, 2006) 2006 WL 3890348, Conclusions of Law 21-22 (internal citations omitted).)

Nor is MEP a static requirement—the standard anticipates and in fact requires new and additional controls to be included with each successive permit. As EPA has explained, NPDES permits, including the MEP standard, will "evolve and mature over time" and must be flexible "to reflect changing conditions." (55 Fed. Reg. 47990, 48052.) "EPA envisions application of the MEP standard as an iterative process. MEP should continually adapt to current conditions and BMP effectiveness and should strive to attain water quality standards. Successive iterations of the mix of BMPs and measurable goals will be driven by the objective of assuring maintenance of water quality standards." (64 Fed. Reg. 68722, 68754.) In other words, successive iterations of permits for a given jurisdiction will necessarily evolve, and contain new, and more stringent requirements for controlling the discharge of pollutants in runoff.

Although requiring compliance with MEP may be sufficient to achieve water quality standards and other common permit terms, the Clean Water Act independently requires that MS4 permits achieve water quality standard compliance.[9] EPA has stated "all permits for MS4s must include

[9]See, 33 U.S.C. § 1311(a); 1313; 1341(a); 1342(p); 40 C.F.R. § 122.44(d)(1) (permits must contain, as applicable, any requirements necessary to "[a]chieve water quality standards established under section 303 of the CWA, including State narrative criteria for water quality"); Memorandum from E. Donald Elliott, Assistant Administrator and General Counsel, U.S. Environmental Protection Agency, to Nancy J. Marvel, Regional Counsel Region IX, re: Compliance with Water Quality Standards in NPDES Permits Issued to Municipal Separate Storm Sewer Systems, Jan. 9, 1991 ("EPA Elliott Memo"). But see, *Defenders of Wildlife v.*

any requirements necessary to achieve compliance with [water quality standards]."[10] Notwithstanding this requirement, permits also require "such other provisions as the Administrator or the State determines appropriate for the control of such pollutants." This language in section 1342(p) has been held by California courts to grant "the EPA (and/or a state approved to issue the NPDES permit) . . . the discretion to impose 'appropriate' water pollution controls in addition to those that come within the definition of 'maximum extent practicable.'" (*Building Industry Ass'n of San Diego County v. State Water Resources Control Bd.* (2004) 124 Cal.App.4th 866, 883 (citing *Defenders of Wildlife v. Browner* (1999) 191 F.3d 1159, at 1165–1167).) As a result, the MEP standard represents a statutory floor, rather than limit, for permit requirements.[11]

B. Orange County MS4 Permits and State Board Order 99-05

In 2009, the Santa Ana Regional Board adopted an NPDES permit for MS4s in North Orange County, which was intended to address the harm caused by pollutants conveyed via storm drains to surface waters in the North Orange County area. The permit regulated the County of Orange, Orange County Flood Control District, and 26 incorporated cities of Orange County within the Santa Ana Region.

10.1

Importantly, the 2009 Permit, as did the previous 2002 permit, contained Receiving Water Limitations ("RWLs"), which required that "discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters." (2009 Permit, at Part VI.1.) The Permittees were directed to begin remedial measures immediately if discharges violate water quality standards. (*Id.*, at Part VI.) If exceedances of water quality standards persisted, notwithstanding control measures, the Dischargers were required to "achieve compliance" by preparing a compliance report that identifies the violations and by adopting pollution control measures to correct them. (*Id.*)

Complying with this "iterative process" assisted Dischargers in meeting water quality goals, but did not excuse violations of water quality standards. A long history of MS4 permitting in California confirms this. For example, an earlier MS4 permit for Orange County had included language stating, "The permittees will not be in violation of [the receiving water limitations] so long as they are in compliance with the requirements [of the iterative process set forth in the permit]."[12] Similarly, a permit for Los Angeles County, approved by the State Water Resources

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Browner (9th Cir. 1999) 191 F.3d 1159, 1166 (holding that permitting authority is not required to impose strict water quality-based effluent limitations, but has the authority to do so).

[10] EPA Elliott Memo, at 1; *In re: Government of the District of Columbia Municipal Separate Storm Sewer System* (EPA 2002) 10 E.A.D. 323, 2002 WL 257698.

[11] See also, *Building Industry Ass'n of San Diego County v. State Water Resources Control Bd.* (2004) 124 Cal.App.4th 866, 883; *Defenders of Wildlife v. Browner* (9th Cir. 1999) 191 F.3d 1159, at 1165–1167.

[12] See Order No. 96-31, at Part IV.1.

Control Board ("State Board"), had included language stating "the permittees will not be in violation of [receiving water limitations] so long as they are in compliance with [the iterative process set forth in the permit]."[13] But EPA objected to that provision, (which MS4 permits for Vallejo and Riverside County had additionally adopted), as a "safe harbor," meaning the provision deemed the permittees in compliance with the permit regardless of whether water quality standards were then met. In response, the State Board adopted Order No. 99-05, which directed the Regional Boards to include receiving water limitations language devised by EPA, without a safe harbor provision, into all future MS4 permits.[14] As the Los Angeles Regional Board has rightly pointed out with regard to provisions which excuse compliance with water quality standards, under this framework, "The Regional Board did not include a safe harbor in [its MS4] Permit and, under California law, could not have done so."[15]

10.1

III. Permit Provisions

A. The Approach Taken in the Draft Permit Creates Illegal Safe Harbors that Violate Federal Anti-Backsliding and Antidegradation Requirements

Unlike the prior 2009 Permit, which simply states that "discharges from the MS4s shall not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface waters or groundwaters," the draft 2014 Permit states that "discharges from the Co-permittees' MS4s must not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface or ground waters or cause or contribute to a condition of nuisance *unless* a draft plan . . . has been submitted or, if final, is being fully implemented." (2009 Permit, at Part IV.1.; Draft Permit, at Part IV.A. (emphasis added)). These safe harbors, little different from those objected to by EPA more than a decade ago, render the RWLs inoperative and excuse compliance with both narrative and numeric water quality standards; If a Permittee meets the program requirements for submission of a compliance action plan, it is deemed to *legally* comply with the Draft Permit's RWLs, regardless of whether the RWLs are *actually* achieved. The safe harbor

10.2

[13]See, State Board Order No. WQ 98-01, *Own Motion to Review the Petition of Environmental Health Coalition to Review Waste Discharge Requirements Order No. 96-03*, at 6-7.
[14]See, State Board WQ Order 99-05.
[15]Brief of Amicus Curiae California Regional Water Quality Control Board, Los Angeles Region, in *Santa Monica Baykeeper v. City of Malibu* No. CV 08-1465-AHM (PLAx) (C.D. Cal.) (filed Feb. 5, 2010), at 8. The Receiving Water Limitations provisions requiring strict compliance with water quality standards were upheld by a California State Court. (*In re L.A. County Mun. Storm Water Permit Litigation.*, No. BS 080548 at 4-7 (L.A. Super. Ct. Mar. 24, 2005)). That court additionally found that the Receiving Water Limitations did not exceed federal requirements as, "the terms of the Permit taken, as a whole, constitute the Los Angeles Regional Board's definition of MEP, including, but not limited to, the challenged [RWL] Permit Provisions." (*Id.* at 7-8).

provisions violate multiple provisions of the CWA and other federal and state regulations, and render the Draft Permit unlawful.[16]

1. The Draft Permit's Safe Harbor Provisions Violate Federal Anti-Backsliding Requirements

The Clean Water Act and federal regulations prohibit backsliding, or weakening of permit terms, from the previous permit. (See, 33 U.S.C. § 1342(o)(1); 40 C.F.R. § 122.44(l)(1).) By providing a safe harbor waiving requirements to meet Water Quality Standards, the Draft Permit flatly violates these federal requirements.

10.2

Courts have found that, for RWL language nearly identical to that of the 2009 Permit (or 2002 Permit), the prohibition against discharges that cause or contribute to a violation of water quality standards requires strict compliance with those standards. "Succinctly put, the [Receiving Water Limitations] incorporate[] the pollution standards promulgated in other agency documents such as the Basin Plan, and prohibit[] stormwater discharges that 'cause or contribute to the violation' of those incorporated standards." (*Natural Resources Defense Council v. Los Angeles County* (9th Cir. 2013) 725 F.3d 1194, 1199.) In contrast, the Draft Permit deems a Permittee submitting a plan for actions to be taken to achieve compliance to be in compliance with RWLs, even if a Permittee's discharges actually cause or contribute to an exceedance of water quality standards. Thus, the Draft Permit excuses discharges of pollution and violations of water quality standards that the previous permit prohibited.

Section 402(o) of the Clean Water Act (33 U.S.C. § 1342(o)), generally prohibits relaxation of, among other things, an effluent limitation[17] "necessary to meet water quality standards . . . schedules of compliance, established pursuant to any State law or regulations . . . or any other Federal law or regulation, or required to implement any applicable water quality standard established pursuant to" the CWA. (See, 33 U.S.C. § 1342(o)(1) (referencing 33 U.S.C. § 1311(b)(1)(C).)[18] The safe harbors, which violate this prohibition against backsliding, fail to

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[16] These exemptions from requirements to meet the RWLs are also imprudent; water quality standards are established at levels necessary to protect the environment and public health. Failing to ensure compliance with water quality standards, through provisions that deem Permittees to be in compliance regardless of whether water quality standards are actually met, does *not* protect the environment, and does *not* protect public health.

[17] Receiving Water Limitations constitute effluent limitations under the CWA. (See 33 U.S.C. § 1362(11).) But even if this were not the case, the safe harbors would still be unlawful, as EPA's anti-backsliding regulations under 40 C.F.R. § 122.44(l)(1) require that "effluent limitations, *standards or conditions* must be at least as stringent as the final effluent limitations, standards, or conditions in the previous permit. . . ." (Emphasis added.)

[18] EPA has recognized that even providing additional time for compliance for a provision required by the previous permit violates anti-backsliding requirements. (Letter from Jon M. Capacasa, Director Water Protection Division, EPA Region III to Jay Sakai, Maryland Department of the Environment, re: Specific Objection to Prince George's County Phase I Municipal Separate

satisfy any enumerated exception to the provision. (See, 33 U.S.C. § 1313(d)(4); section 402(o)(2).)[19] Neither are they lawful under section 402(o)(3), which serves as a "*safety clause* that provides an absolute limitation on backsliding,"[20] and states that in no event shall a permit "be renewed, reissued, or modified to contain a less stringent effluent limitation if the implementation of such limitation would result in a violation of a water quality standard" under 33 U.S.C. § 1313. (33 U.S.C. § 1342(o)(3).) The Draft Permit, by explicitly excusing violations of RWLs which prohibit discharges that cause or contribute to a violation of water quality standards, fails to meet this federally mandated minimum level of protection.

2. The Draft Permit's Safe Harbor Provisions Violate State and Federal Antidegradation Requirements

10.2

The overall goal of the Clean Water Act is the complete elimination of the discharge of pollutants into waters of the United States. (33 U.S.C. § 1251(a)(1).) To help meet this goal, states must implement an antidegradation policy. However, the permit does not comply with applicable antidegradation requirements.

The federal antidegradation policy contains a three "Tier" test for determining when increases in pollutant loadings or adverse changes to water quality may be allowed.[21] (40 C.F.R. § 131.12.) Tier I antidegradation analysis applies to *all* waters of the United States,[22] applying "a minimum level of protection to all waters . . . even seriously degraded water bodies . . . prohibiting any additional pollution that would affect existing uses."[23]

NPDES permit renewals or modifications such as the Draft Permit are subject to both state and federal antidegradation requirements, which mandate that existing water quality in navigable waters be maintained, unless degradation is justified based on specific findings.[24] In no case

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Storm Sewer System (MS4) Permit MD0068284, at 3. The additional time allotted by the new Permit to achieve compliance with RWLs, required in the 2001 Permit, for Permittees developing a WMP or an EWMP therefore constitutes a less stringent limitation.

[19]See also, EPA (September 2010) NPDES Permit Writers' Manual ("NPDES Manual), at 7-1 to 7-3.

[20]See EPA, NPDES Manual at 7-4.

[21]California has established a state antidegradation policy, which incorporates the federal antidegradation policy and establishes additional requirements. (See, State Board Resolution 68-16; *see also In the Matter of the Petition of Rimmon C. Fay*, State Board Order No. WQ 86-17 at 16-19.)

[22]64 Fed. Reg. 46058, 46063, *Revisions to the National Pollutant Discharge Elimination System Program and Federal Antidegradation Policy in Support of Revisions to the Water Quality Planning and Management Regulation*.

[23]Brawer, J.M., "Antidegradation Policy and Outstanding Natural Resource Waters in the Northern Rocky Mountain States," 20 Pub. Land & Resources L. Rev. 13, 18 (1999).

[24]*See*, SWRCB Order No. WQ 86-17; EPA, Region IX, *Guidance on Implementing the Antidegradation Provisions of 40 C.F.R. § 131.12,* at 2-4 (June 3, 1987) ("EPA Antidegradation Guidance").

may water quality be lowered to a level that would interfere with existing or designated uses. By potentially allowing for discharges from the MS4 to violate water quality standards, in effect degrading those waters, while deeming Permittees to be in compliance with Permit requirements, the Permit fails to properly implement antidegradation requirements. Nor has the Regional Board provided any data, analysis, or findings, which must be accomplished on a pollutant-by-pollutant and beneficial-use-by beneficial use basis, to support degradation. (*See, Associacion de Gente Unida for El Agua v. Central Valley Regional Board* (2012) 210 Cal.App.4th 1255, 1268-69, 1271-72 (citing St. Water Res. Control Bd., Guidance Memorandum (Feb. 16, 1995); 40 CFR 131.12(a)(1).)[25] In past instances when a Regional Board has failed to provide adequate findings to verify that water quality will be maintained, the State Board has remanded the orders to the Regional Board for further proceedings, and the Draft Permit should be revised to avoid that event here.[26]

10.2

B. The Draft Permit's Development Planning Requirements Must Require On-Site Retention of at least the 85th Percentile Storm

We strongly support that the Draft Permit establishes requirements for new development and redevelopment projects to retain stormwater runoff on-site. A principal reason to adopt such an approach is the superior pollutant load reduction capacity of low impact development practices that retain runoff on-site, for a variety of climatic scenarios, including for the North Orange County region.[27]

10.3

The Draft Permit requires, under one provision, that the runoff from the 85th percentile, 24-hour rain event must be retained on-site. (Draft Permit, at XII.D(1)(a)-(b).) This requirement, which was also included in the previous North Orange County permit, results in retention of stormwater runoff with no off-site discharge in the large majority of storms. The 85th percentile requirement is consistent with on-site retention requirements of other permits throughout California, as well

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[25]The Permit's reference to antidegradation is limited to a cursory summary of the legal requirements, and a conclusion that "[t]his Order requires the Co-permittees to implement programs and policies necessary to improve water quality; the order does not allow any degradation of water quality." (Draft Permit, at p. 13, Finding 25.) Simply claiming that no degradation will occur does not satisfy the requirements of the Clean Water Act. (*Associacion de Gente Unida*, 210 Cal.App.4th at 1260-61; see also, *American Funeral Concepts-American Cremation Soc'y v. Board of Funeral Directors and Embalmers* (1982) 136 Cal.App.3d 303, 309.)

[26]See, e.g., SWRCB Order No. WQ 86-17, at 28.

[27]See, Dr. Richard Horner and Jocelyn Gretz (December 2011) Investigation of the Feasibility and Benefits of Low-Impact Site Design Practices Applied to Meet Various Potential Stormwater Runoff Regulatory Standards ("Horner and Gretz Runoff Study"); see also, Horner, Richard. Report for Ventura County; Horner, Richard. Initial Investigation for San Francisco Bay Area; Horner, Richard. Supplementary Investigation for San Francisco Bay Area; Horner, Richard. Report for San Diego Region.

as in permits and ordinances found in all corners of the United States. Similar or more stringent requirements are included in the following permits:

Ventura County: MS4 permit requires on-site retention of ninety-five percent of rainfall from the 85th percentile storm; off-site mitigation allowed if on-site retention is technically infeasible;[28]

San Diego: MS4 permit requires on-site retention of the 85th percentile storm;[29]

However, the 85th percentile standard is actually less stringent than required by permits in many other parts of the county. For example, permits in the following locations require retention that generally exceeds the 85th percentile storm volume for much of North Orange County:

10.3

Washington, D.C.: MS4 permit requires retention of the first 1.2 inches of stormwater (which represents the 90th percentile storm) for all new development and redevelopment over 5,000 square feet.[30]

West Virginia: Statewide Phase II MS4 permit requires on-site retention of "the first one inch of rainfall from a 24-hour storm" event unless infeasible;[31] and,

Philadelphia, PA: Infiltrate the first one inch of rainfall from all impervious surfaces; if on-site infiltration is infeasible, the same performance must be achieved off-site.[32]

Further, research conducted by Dr. Richard Horner, a member of the National Academy of Sciences Panel on Reducing Stormwater Discharge Contributions to Water Pollution demonstrates that, for five different types of land use development or redevelopment projects in Southern California, the full 85th percentile, or even the full 95th percentile, 24-hour precipitation event could be retained on-site using *only* infiltration practices on sites overlying soils classified as Group C (typically containing 20 to 40 percent clay) under the Natural Resources

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[28]Los Angeles Regional Water Quality Control Board (July 8, 2010) Ventura County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R4-2009-0057; NPDES Permit No. CAS004002.
[29]San Diego Regional Water Quality Control Board (December 16, 2014) South Orange County MS4 Permit, Order No. R9-2013-0001, NPDES Permit No. CAS0109266.
[30]U. S. EPA (2011) Fact Sheet, National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit No. DC0000221 (Government of the District of Columbia).
[31]State of West Virginia Department of Environmental Protection, Division of Water and Waste Management, General National Pollution Discharge Elimination System Water Pollution Control Permit, NPDES Permit No. WV0116025 at 13-14 (June 22, 2009).
[32]City of Philadelphia (Jan. 29, 2008) Stormwater Management Guidance Manual 2.0, at 1.1, available at.

10.3 Conservation Service (NRCS) major soil orders classification scheme.[33] Critically, even for sites overlying Group D soils (typically 40 percent or more clay with substantially restricted water transmissivity) and assuming *no* infiltration was feasible, greater than 50 percent of the 85th percentile storm (or between 37 and 62 percent of annual runoff) could be retained at each development type using only rooftop runoff dispersion or rooftop harvest and reuse techniques.[34] Additional retention under these scenarios could be achieved through use of evaporation practices, green roofs, or, in cases where some infiltration is feasible, use of infiltration BMPs.

10.4 NRDC does support use of regional (or "off-site") retention projects that may provide multiple benefits, including increased local water supply, where runoff is *conveyed* from a project site to a regional facility that will retain that runoff, albeit at a different location, with no discharge to receiving waters. This process typically does not implicate significant water quality concerns—where the same, specific quantum of runoff from the project is ultimately retained, 100 percent of the pollution contained in that particular volume of water will be prevented from reaching receiving waters. In contrast, where a project performs off-site mitigation or retrofit at some other location within the same watershed or sub-watershed that is not hydrologically connected to the original project site, it raises substantial concerns as to whether the alternate location will provide equal water quality benefits to the receiving surface water. Among the issues presented by this form of off-site mitigation are: whether the off-site mitigation will be performed at a similar land use type, whether the mitigation project will achieve equivalent pollutant load reduction, and if so, what pollutants it will be monitored for. In practice it may prove exceedingly difficult to assess the equivalency of benefits to surface water quality from retention at one site to the next.

1. The Draft Permit Must Require a Determination that it is Technically Infeasible to Retain the Design Storm On-Site Before Biofiltration is Authorized.

10.5 While we support the inclusion of strong retention standards for stormwater runoff, we are concerned by Draft Permit provisions allowing for use of biofiltration and off-site mitigation even where on-site retention is feasible. Because retention of the 85th Percentile Storm event has been established as MEP in California Permits,[35] the project proponent must meet this standard or demonstrate that it cannot be met.

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[33] Horner and Gretz Runoff Study, at Table 16 p. 35; Natural Resources Conservation Service, Distribution Maps of Dominant Soil Orders (http://soils.usda.gov/technical/classification/orders/, last accessed December 16, 2011).

[34] Horner and Gretz Runoff Study, at Table 16 p. 35; 27-34. We note as well that even in areas characterized regionally as underlain by D soils, site specific investigation may establish substantial potential for infiltration of runoff.

[35] See, e.g., Ventura County MS4 Permit, Order No. R4-2009-0057; San Francisco Bay Area MS4 Permit, Order No. R2-2009-0074; North Orange County MS4 Permit, Order No. R8-2009-0030; South Orange County MS4 Permit, Order No. R9-2009-0002.

The jurisdictions identified in sections above have recognized the paramount importance of mandating on-site retention of a certain quantity of stormwater since, in contrast to retention practices, which ensure that 100 percent of the pollutant load in the retained volume of runoff does not reach receiving waters, biofiltration practices (or tree-box filters and other similar practices) that treat and then discharge runoff through an underdrain result in the release of pollutants to receiving waters. Indeed, in order to achieve equivalent pollutant load reduction benefits to the use of on-site retention, biofiltration practices would have to be 100 percent effective at filtering pollutants from the same volume of runoff, which they are invariably not. As a result, while biofiltration practices (or conventional flow-through practices) may be appropriate for on-site treatment when coupled with an off-site mitigation requirement in cases of technical infeasibility (discussed further below), they are not a proper substitute for low impact development ("LID") practices that retain water on-site.

10.5

This conclusion is borne out by data presented in the Draft Ventura County Technical Guidance Manual, which estimated pollutant removal efficiency for total suspended solids to be 54-89 percent, and for total zinc to be 48-96 percent.[36] Biofiltration has additionally been shown to be a particularly ineffective method of pollutant removal for addressing nitrogen or phosphorous, two common contaminants found in stormwater.[37] The Draft Ventura Technical Guidance report, for example, indicated that biofiltration achieves pollutant removal efficiency for total nitrogen at between only 21-54 percent,[38] as compared with 100 percent for runoff retained on-site. As a result, even where a multiplier is applied requiring 1.5 times as much runoff be treated using biofiltration as would otherwise be retained, biofiltration may achieve substantially less pollution reduction as would retention.

---

[36] Ventura County Low Impact Development Technical Guidance Manual, July 13, 2011, at D-7.

[37] Lawn irrigation has been identified as a "hot spot" for nutrient contamination in urban watersheds—lawns "contribute greater concentrations of Total N, Total P and dissolved phosphorus than other urban source areas . . . source research suggests that nutrient concentrations in lawn runoff can be as much as four times greater than other urban sources such as streets, rooftops or driveways." Center for Watershed Protection (March 2003) *Impacts of Impervious Cover on Aquatic Systems* at 69; see also H.S. Garn (2002) *Effects of lawn fertilizer on nutrient concentration in runoff from lakeshore lawns, Lauderdale Lakes, Wisconsin*. U.S. Geological Survey Water- Resources Investigations Report 02-4130 (In an investigation of runoff from lawns in Wisconsin, runoff from fertilized lawns contained elevated concentrations of phosphorous and dissolved phosphorous).

[38] Ventura County Low Impact Development Technical Guidance Manual, July 13, 2011, at D-7. See also, BASMAA (December 1, 2010) *Draft Model Bioretention Soil Media Specifications-MRP Provision C.3.c.iii*, at Annotated Bibliography section 3.0 (noting nutrient removal from synthetic stormwater runoff demonstrated only 55 to 65 percent of total Kjeldahl nitrogen removal and that only 20 percent of nitrate is removed from the runoff).

IV. Conclusion

We appreciate this opportunity to comment on the Draft Permit. Please feel free to contact us with any questions or concerns you may have.

Sincerely,

Noah Garrison
Staff Attorney*
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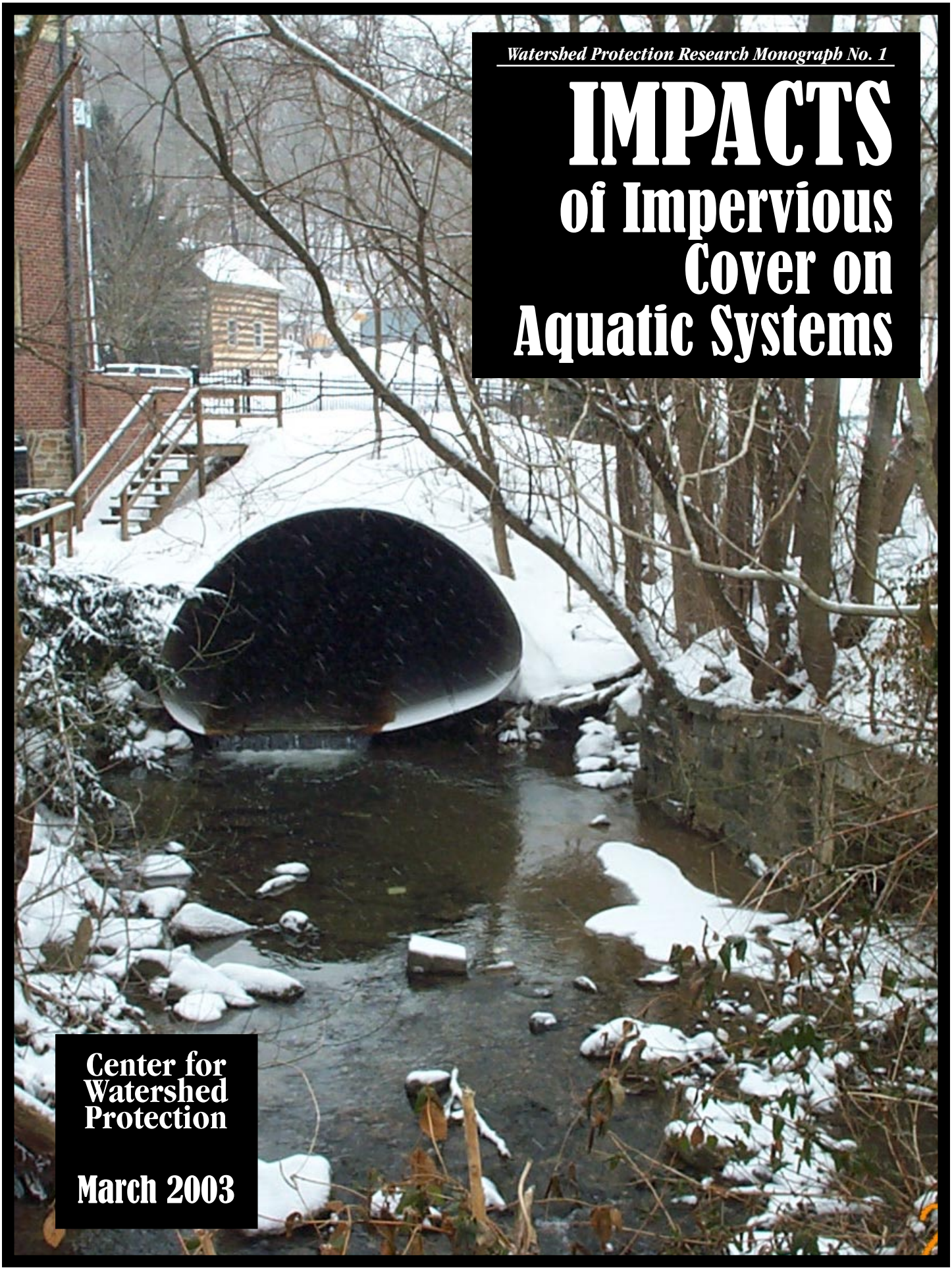

Watershed Protection Research Monograph No. 1

IMPACTS of Impervious Cover on Aquatic Systems

Center for Watershed Protection

March 2003

Cover photograph Ellicott City, Maryland 2003.
Courtesy Anne Kitchell, Center for Watershed Protection.

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Impacts of Impervious Cover on Aquatic Systems

March 2003

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Foreword

We are extremely pleased to launch the first edition of a new series called *Watershed Protection Research Monographs*. Each monograph will synthesize emerging research within a major topical area in the practice of watershed protection. The series of periodic monographs will replace our journal *Watershed Protection Techniques,* which lapsed in 2002. We hope this new format will provide watershed managers with the science and perspectives they need to better protect and restore their local watersheds.

This monograph was written to respond to many inquiries from watershed managers and policy makers seeking to understand the scientific basis behind the relationship between impervious cover and the health of aquatic ecosystems. It reviews more than 225 research studies that have explored the impact of impervious cover and other indicators of urbanization on aquatic systems. This report comprehensively reviews the available scientific data on how urbanization influences hydrologic, physical, water quality, and biological indicators of aquatic health, as of late 2002.

Our intention was to organize the available scientific data in a manner that was accessible to watershed leaders, policy-makers and agency staff. In addition, the research itself, which spans dozens of different academic departments and disciplines, was conducted in many different eco-regions, climatic zones, and stream types. In order to communicate across such a wide audience, we have resorted to some simplifications, avoided some important particulars, refrained from some jargon, and tried, wherever possible, to use consistent terminology. Thus, the interpretations and conclusions contained in this document are ours alone, and our readers are encouraged to consult the original sources when in doubt.

We would also like to note that the Center for Watershed Protection and the University of Alabama are currently developing a major national database on stormwater quality. The database will contain nearly 4,000 station-storm events collected by municipalities as part of the U.S. EPA's National Pollutant Discharge Elimination System (NPDES) Phase I Stormwater Permit Program. We anticipate releasing a data report in late 2003 that will provide a much needed update of stormwater event mean concentrations (EMCs).

As of this writing, many research efforts are underway that will further test and refine these relationships (most notably, the U.S. Geological Survey gradients initiative, but also many other local, state and academic efforts). We hope that this report provides a useful summary of the existing science, suggests some directions for new research, and stimulates greater discussion of this important topic in watershed management. We also feel it is time for a major conference or symposium, where this diverse community can join together to discuss methods, findings and the important policy implications of their research.

Acknowledgments

Putting this first research monograph together took a lot of energy, editing and analysis, and many Center staff devoted their time and energy over the last two years to get it done. The project team consisted of Karen Cappiella, Deb Caraco, Samantha Corbin, Heather Holland, Anne Kitchell, Stephanie Linebaugh, Paul Sturm, and Chris Swann. Special thanks are extended to Tiffany Wright, who worked tirelessly to assemble, edit and otherwise polish the final draft.

I am also grateful to Michael Paul of Tetratech, Inc., who graciously provided us with an extensive literature review from his PhD days at the University of Georgia that contained many obscure and hard to find citations. Portions of this monograph were developed as part of a literature review conducted as part of a work assignment for the U.S. EPA Office of Wastewater Management in 2001, which proved indispensable in our efforts. Lastly, I would like to thank the hundreds of scientists who have contributed their time and data to explore and test the relationships between urbanization and aquatic health.

Tom Schueler
Center for Watershed Protection

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Acronyms and Abbreviations

B-IBI	Benthic Index of Biotic Integrity
BOD	Biological Oxygen Demand
BSD	Better Site Design
C-IBI	Combined Index of Biotic Integrity
cfs	cubic feet per second
COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflow
Cu	Copper
DOC	Dissolved Organic Carbon
du/ac	dwelling units per acre
EMC	Event Mean Concentration
EPT	Ephemeroptera, Plecoptera and Trichoptera
FC	Forest Cover
GIS	Geographic Information Systems
IBI	Index of Biotic Integrity
IC	Impervious Cover
ICM	Impervious Cover Model
lbs/ac	pounds per acre
LWD	Large Woody Debris
mg/kg	milligrams per kilogram
mg/l	milligrams per liter (equal to ppm)
MPN	Most Probable Number
MTBE	Methyl Tertiary-Butyl Ether
N	Number of Studies
N/R	data not reported
NO_2	Nitrite
NO_3	Nitrate
NO_x	Nitrogen Oxides
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Unit
NURP	National Urban Runoff Program
PAH	Polycylic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
ppb	Parts per billion (equal to ug/l)
ppm	Parts per million (equal to mg/l)
RBP	Rapid Bioassessment Protocol
SLAMM	Source Loading Assessment/ Management Model
SPMD	Semi-Permeable Membrane Device
SSO	Sanitary Sewer Overflow
STP	Stormwater Treatment Practice
TC	Turf Cover
TDS	Total Dissolved Solids
TKN	Total Kjeldhal Nitrogen
TMDL	Total Maximum Daily Load
Total N	Total Nitrogen
Total P	Total Phosphorous
TOC	Total Organic Carbon
TSS	Total Suspended Solids
ug/l	micrograms per liter (equal to ppb)
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compound
WLF	Water Level Fluctuation
WTP	Wastewater Treatment Plant

Chapter 1: Introduction

This research monograph comprehensively reviews the available scientific data on the impacts of urbanization on small streams and receiving waters. These impacts are generally classified according to one of four broad categories: changes in hydrologic, physical, water quality or biological indicators. More than 225 research studies have documented the adverse impact of urbanization on one or more of these key indicators. In general, most research has focused on smaller watersheds, with drainage areas ranging from a few hundred acres up to ten square miles.

Streams vs. Downstream Receiving Waters

Urban watershed research has traditionally pursued two core themes. One theme has evaluated the direct impact of urbanization on small streams, whereas the second theme has explored the more indirect impact of urbanization on downstream receiving waters, such as rivers, lakes, reservoirs, estuaries and coastal areas. This report is organized to profile recent research progress in both thematic areas and to discuss the implications each poses for urban watershed managers.

When evaluating the direct impact of urbanization on streams, researchers have emphasized hydrologic, physical and biological indicators to define urban stream quality. In recent years, impervious cover (IC) has emerged as a key paradigm to explain and sometimes predict how severely these stream quality indicators change in response to different levels of watershed development. The Center for Watershed Protection has integrated these research findings into a general watershed planning model, known as the impervious cover model (ICM). The ICM predicts that most stream quality indicators decline when watershed IC exceeds 10%, with severe degradation expected beyond 25% IC. In the first part of this review, we critically analyze the scientific basis for the ICM and explore some of its more interesting technical implications.

While many researchers have monitored the quality of stormwater runoff from small watersheds, few have directly linked these pollutants to specific water quality problems within streams (e.g., toxicity, biofouling, eutrophication). Instead, the prevailing view is that stormwater pollutants are a downstream export. That is, they primarily influence downstream receiving water quality. Therefore, researchers have focused on how to estimate stormwater pollutant loads and then determine the water quality response of the rivers, lakes and estuaries that receive them. To be sure, there is an increasing recognition that runoff volume can influence physical and biological indicators within some receiving waters, but only a handful of studies have explored this area. In the second part of this review, we review the impacts of urbanization on downstream receiving waters, primarily from the standpoint of stormwater quality. We also evaluate whether the ICM can be extended to predict water quality in rivers, lakes and estuaries.

This chapter is organized as follows:

1.1 A Review of Recent Urban Stream Research and the ICM
1.2 Impacts of Urbanization on Downstream Receiving Waters
1.3 Implications of the ICM for Watershed Managers

1.1 A Review of Recent Urban Stream Research and the ICM

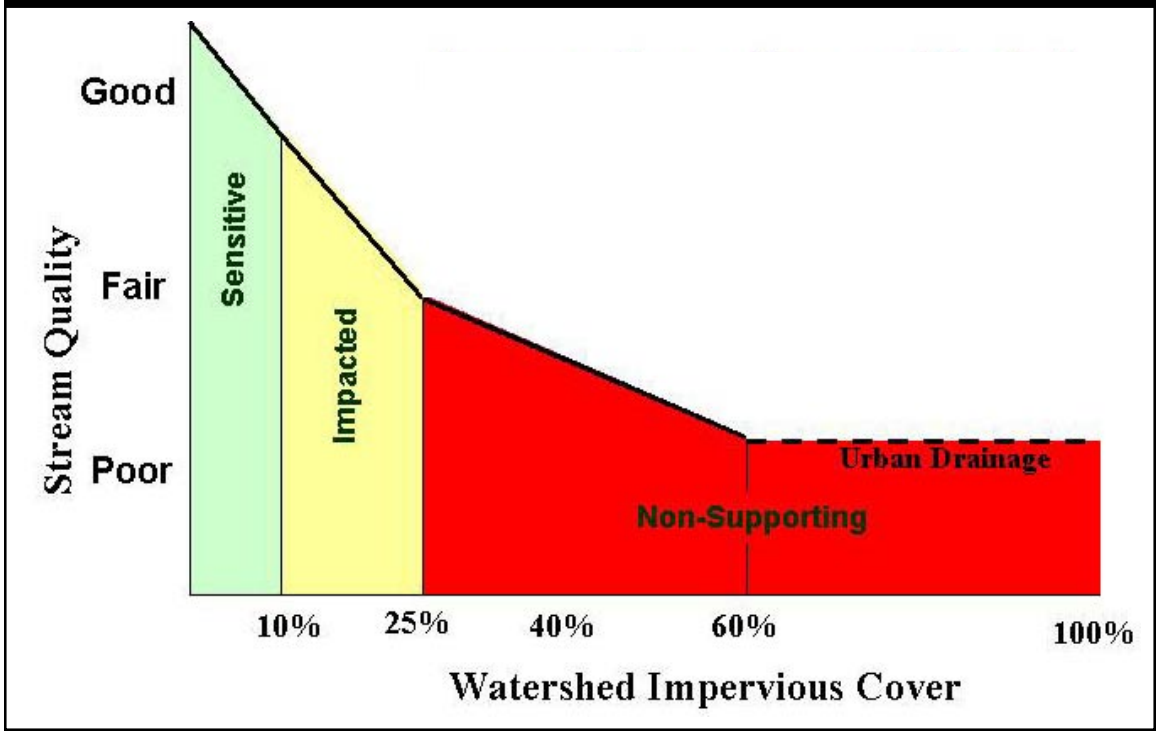
In 1994, the Center published "The Importance of Imperviousness," which outlined the scientific evidence for the relationship between IC and stream quality. At that time, about two dozen research studies documented a reasonably strong relationship between watershed IC and various indicators of stream quality. The research findings were subsequently integrated into the ICM (Schueler, 1994a and CWP, 1998). A brief summary of the basic assumptions of the ICM can be found in Figure 1. The ICM has had a major influence in watershed planning, stream classification and land use regulation in many communities. The ICM is a deceptively simple model that raises extremely complex and profound policy implications for watershed managers.

The ICM has been widely applied in many urban watershed settings for the purposes of small watershed planning, stream classification, and supporting restrictive development regulations and watershed zoning. As such, the ICM has stimulated intense debate among the planning, engineering and scientific communities. This debate is likely to soon spill over into the realm of politics and the courtroom, given its potential implications for local land use and environmental regulation. It is no wonder that the specter of scientific uncertainty is frequently invoked in the ICM debate, given the land use policy issues at stake. In this light, it is helpful to review the current strength of the evidence for and against the ICM.

The ICM is based on the following assumptions and caveats:

- Applies only to 1st, 2nd and 3rd order streams.
- Requires accurate estimates of percent IC, which is defined as the total amount of impervious cover over a subwatershed area.
- Predicts potential rather than actual stream quality. It can and should be expected that some streams will depart from the predictions of the model. For example, monitoring indicators may reveal poor water quality in a stream classified as "sensitive" or a surprisingly high biological diversity

Figure 1: Impervious Cover Model



score in a "non-supporting" one. Consequently, while IC can be used to initially diagnose stream quality, supplemental field monitoring is recommended to actually confirm it.

- Does not predict the precise score of an individual stream quality indicator but rather predicts the average behavior of a group of indicators over a range of IC. Extreme care should be exercised if the ICM is used to predict the fate of individual species (e.g., trout, salmon, mussels).

- "Thresholds" defined as 10 and 25% IC are not sharp "breakpoints," but instead reflect the expected transition of a composite of individual indicators in that range of IC. Thus, it is virtually impossible to distinguish real differences in stream quality indicators within a few percentage points of watershed IC (e.g., 9.9 vs. 10.1%).

- Should only be applied within the ecoregions where it has been tested, including the mid-Atlantic, Northeast, Southeast, Upper Midwest, and Pacific Northwest.

- Has not yet been validated for non-stream conditions (e.g., lakes, reservoirs, aquifers and estuaries).

- Does not currently predict the impact of watershed treatment.

In this section, we review available stream research to answer four questions about the ICM:

1. Does recent stream research still support the basic ICM?
2. What, if any, modifications need to be made to the ICM?
3. To what extent can watershed practices shift the predictions of the ICM?
4. What additional research is needed to test the ICM?

1.1.1 Strength of the Evidence for the ICM

Many researchers have investigated the IC/stream quality relationship in recent years. The Center recently undertook a comprehensive analysis of the literature to assess the scientific basis for the ICM. As of the end of 2002, we discovered more than 225 research studies that measured 26 different urban stream indicators within many regions of North America. We classified the research studies into three basic groups.

The first and most important group consists of studies that directly test the IC/stream quality indicator relationship by monitoring a large population of small watersheds. The second and largest group encompasses secondary studies that indirectly support the ICM by showing significant differences in stream quality indicators between urban and non-urban watersheds. The third and last group of studies includes widely accepted engineering models that explicitly use IC to directly predict stream quality indicators. Examples include engineering models that predict peak discharge or stormwater pollutant loads as a direct function of IC. In most cases, these relationships were derived from prior empirical research.

Table 1 provides a condensed summary of recent urban stream research, which shows the impressive growth in our understanding of urban streams and the watershed factors that influence them. A negative relationship between watershed development and nearly all of the 26 stream quality indicators has been established over many regions and scientific disciplines. About 50 primary studies have tested the IC/stream quality indicator relationship, with the largest number looking at biological indicators of stream health, such as the diversity of aquatic insects or fish. Another 150 or so secondary studies provide evidence that stream quality indicators are significantly different between urban and non-urban watersheds, which lends at least indirect support for the ICM and suggests that additional research to directly test the IC/stream quality indicator

Table 1: The Strength of Evidence: A Review of the Current Research on Urban Stream Indicators

Stream Quality Indicator	#	IC	UN	EM	RV	Notes
Increased Runoff Volume	2	Y	Y	Y	N	extensive national data
Increased Peak Discharge	7	Y	Y	Y	Y	type of drainage system key
Increased Frequency of Bankfull Flow	2	?	Y	N	N	hard to measure
Diminished Baseflow	8	?	Y	N	Y	inconclusive data
Stream Channel Enlargement	8	Y	Y	N	Y	stream type important
Increased Channel Modification	4	Y	Y	N	?	stream enclosure
Loss of Riparian Continuity	4	Y	Y	N	?	can be affected by buffer
Reduced Large Woody Debris	4	Y	Y	N	?	Pacific NW studies
Decline in Stream Habitat Quality	11	Y	Y	N	?	
Changes in Pool Riffle/Structure	4	Y	Y	N	?	
Reduced Channel Sinuosity	1	?	Y	N	?	straighter channels
Decline in Streambed Quality	2	Y	Y	N	?	embeddedness
Increased Stream Temperature	5	Y	Y	N	?	buffers and ponds also a factor
Increased Road Crossings	3	?	Y	N	?	create fish barriers
Increased Nutrient Load	30+	?	Y	Y	N	higher stormwater EMCs
Increased Sediment Load	30+	?	Y	N	Y	higher EMCs in arid regions
Increased Metals & Hydrocarbons	20+	?	Y	Y	N	related to traffic/VMT
Increased Pesticide Levels	7	?	Y	N	Y	may be related to turf cover
Increased Chloride Levels	5	?	Y	N	Y	related to road density
Violations of Bacteria Standards	9	Y	Y	N	Y	indirect association
Decline in Aquatic Insect Diversity	33	Y	Y	N	N	IBI and EPT
Decline in Fish Diversity	19	Y	Y	N	N	regional IBI differences
Loss of Coldwater Fish Species	6	Y	Y	N	N	trout and salmon
Reduced Fish Spawning	3	Y	Y	N	?	
Decline in Wetland Plant Diversity	2	N	Y	N	?	water level fluctuation
Decline in Amphibian Community	5	Y	Y	N	?	few studies

#: *total number of all studies that evaluated the indicator for urban watersheds*
IC: *does balance of studies indicate a progressive change in the indicator as IC increases? Answers: Yes, No or No data (?)*
UN: *If the answer to IC is no, does the balance of the studies show a change in the indicator from non-urban to urban watersheds? Yes or No*
EM *Is the IC/stream quality indicator relationship implicitly assumed within the framework of widely accepted engineering models? Yes, No or No models yet exist (?)*
RV: *If the relationship has been tested in more than one eco-region, does it generally show major differences between ecoregions? Answers: Yes, No, or insufficient data (?)*

relationship is warranted. In some cases, the IC/stream quality indicator relationship is considered so strongly established by historical research that it has been directly incorporated into accepted engineering models. This has been particularly true for hydrological and water quality indicators.

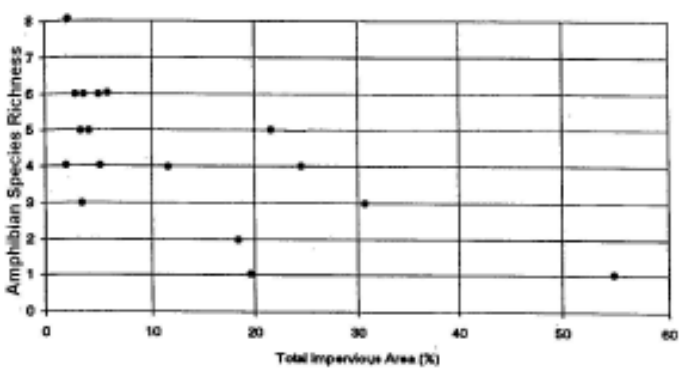
1.1.2 Reinterpretation of the ICM

Although the balance of recent stream research generally supports the ICM, it also offers several important insights for interpreting and applying the ICM, which are discussed next.

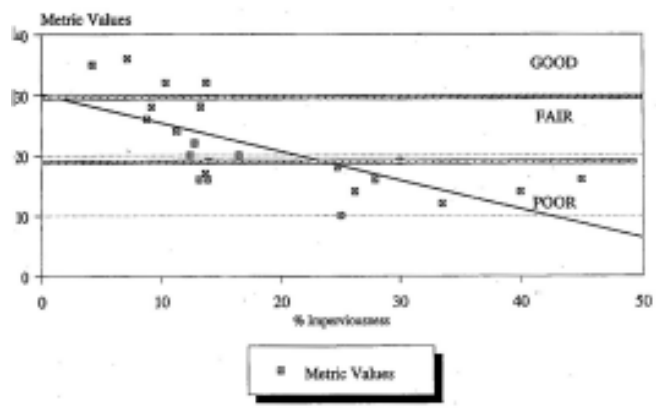
Statistical Variability

Scatter is a common characteristic of most IC/stream quality indicator relationships. In most cases, the overall trend for the indicator is down, but considerable variation exists along the trend line. Often, linear regression equations between IC and individual stream quality indicators produce relatively modest correlation coefficients (reported r^2 of 0.3 to 0.7 are often considered quite strong).

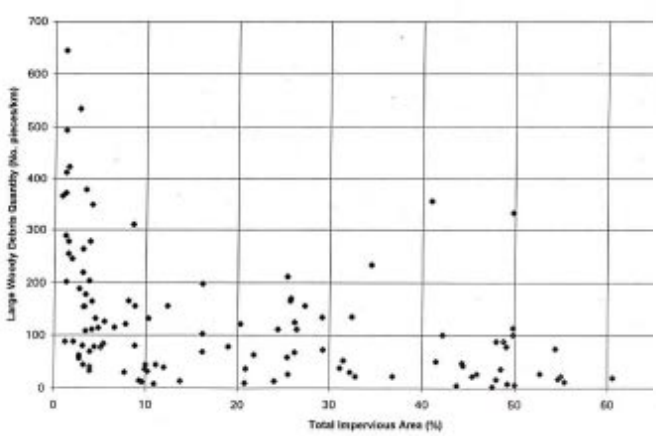
Figure 2 shows typical examples of the IC/stream quality indicator relationship that illustrate the pattern of statistical variability. Variation is always encountered when dealing with urban stream data (particularly so for biological indicators), but several patterns exist that have important implications for watershed managers.



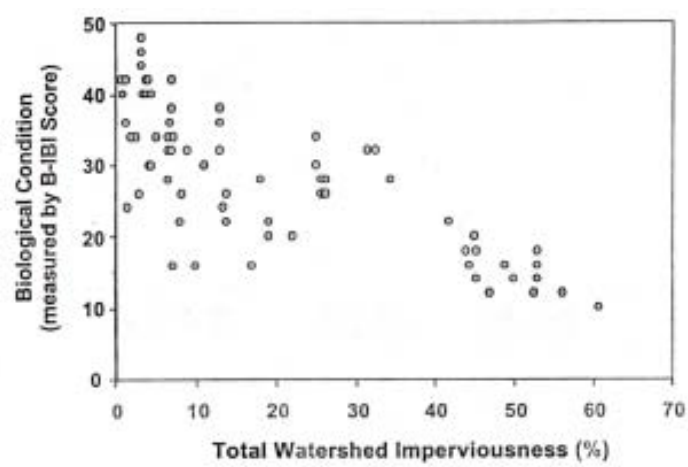
a. Fish IBI vs. IC in Fairfax, VA (Fairfax County, 2001)



b. CPSS vs. IC in Montgomery County, MD (MNCPPC, 2000)



c. Large Woody Debris vs. IC (Booth *et al.*, 1997)



d. Biological Condition vs. Total Watershed IC (Booth, 2000)

Figure 2: Typical Scatter Found in IC/Stream Quality Indicator Research

The first pattern to note is that the greatest scatter in stream quality indicator scores is frequently seen in the range of one to 10% IC. These streams, which are classified as "sensitive" according to the ICM, often exhibit low, moderate or high stream quality indicator scores, as shown in Figure 2. The key interpretation is that sensitive streams have the potential to attain high stream quality indicator scores, but may not always realize this potential.

Quite simply, the influence of IC in the one to 10% range is relatively weak compared to other potential watershed factors, such as percent forest cover, riparian continuity, historical land use, soils, agriculture, acid mine drainage or a host of other stressors. Consequently, watershed managers should never rely on IC alone to classify and manage streams in watersheds with less than 10% IC. Rather, they should evaluate a range of supplemental watershed variables to measure or predict actual stream quality within these lightly developed watersheds.

The second important pattern is that variability in stream quality indicator data is usually dampened when IC exceeds 10%, which presumably reflects the stronger influence of stormwater runoff on stream quality indicators. In particular, the chance that a stream quality indicator will attain a high quality score is sharply diminished at higher IC levels. This trend becomes pronounced within the 10 to 25% IC range and almost inevitable when watershed IC exceeds 25%. Once again, this pattern suggests that IC is a more robust and reliable indicator of overall stream quality beyond the 10% IC threshold.

Other Watershed Variables and the ICM

Several other watershed variables can potentially be included in the ICM. They include forest cover, riparian forest continuity and turf cover.

Forest cover (FC) is clearly the main rival to IC as a useful predictor of stream quality in urban watersheds, at least for humid regions of North America. In some regions, FC is simply the reciprocal of IC. For example, Horner and May (1999) have demonstrated a strong interrelationship between IC and FC for subwatersheds in the Puget Sound region (Figure 3). In other regions, however, "pre-

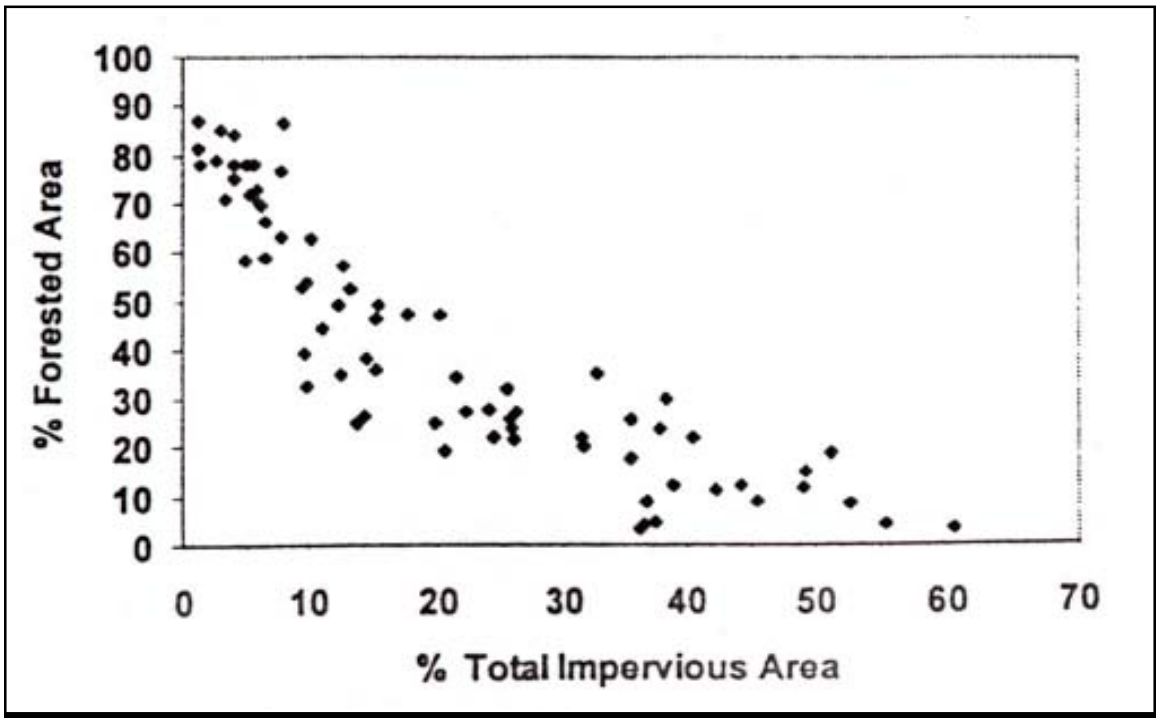


Figure 3: Relationship of IC and FC in Puget Sound Subwatersheds (Horner and May, 1999)

development" land use represents a complex mosaic of crop land, pasture and forest. Therefore, an inverse relationship between FC and IC may not be universal for subwatersheds that have witnessed many cycles of deforestation and cultivation.

It should come as little surprise that the progressive loss of FC has been linked to declining stream quality indicators, given that forested watersheds are often routinely used to define natural reference conditions for streams (Booth, 2000 and Horner *et al.*, 2001). Mature forest is considered to be the main benchmark for defining pre-development hydrology within a subwatershed, as well. Consequently, FC is perhaps the most powerful indicator to predict the quality of streams within the "sensitive" category (zero to 10% IC).

To use an extreme example, one would expect that stream quality indicators would respond quite differently in a subwatershed that had 90% FC compared to one that had 90% crop cover. Indeed, Booth (1991) suggests that stream quality can only be maintained when IC is limited to less than 10% <u>and</u> at least 65% FC is retained within a subwatershed. The key management implication then is that stream health is best managed by simultaneously minimizing the creation of IC and maximizing the preservation of native FC.

FC has also been shown to be useful in predicting the quality of terrestrial variables in a subwatershed. For example, the Mid-Atlantic Integrated Assessment (USEPA, 2000) has documented that watershed FC can reliably predict the diversity of bird, reptile and amphibian communities in the mid-Atlantic region. Moreover, the emerging discipline of landscape ecology provides watershed managers with a strong scientific foundation for deciding where FC should be conserved in a watershed. Conservation plans that protect and connect large forest fragments have been shown to be effective in conserving terrestrial species.

Riparian forest continuity has also shown considerable promise in predicting at least some indicators of stream quality for urban watersheds. Researchers have yet to come up with a standard definition of riparian continuity, but it is usually defined as the proportion of the perennial stream network in a subwatershed that has a fixed width of mature streamside forest. A series of studies indicates that aquatic insect and fish diversity are associated with high levels of riparian continuity (Horner *et al.,* 2001; May *et al.*, 1997; MNCPPC, 2000; Roth *et al.,* 1998). On the other hand, not much evidence has been presented to support the notion that riparian continuity has a strong influence on hydrology or water quality indicators.

One watershed variable that received little attention is the fraction of watershed area maintained in turf cover (TC). Grass often comprises the largest fraction of land area within low-density residential development and could play a significant role in streams that fall within the "impacted" category (10 to 25% IC). Although lawns are pervious, they have sharply different properties than the forests and farmlands they replace (i.e., irrigation, compacted soils, greater runoff, and much higher input of fertilizers and pesticides, etc.). It is interesting to speculate whether the combined area of IC and TC might provide better predictions about stream health than IC area alone, particularly within impacted subwatersheds.

Several other watershed variables might have at least supplemental value in predicting stream quality. They include the presence of extensive wetlands and/or beaverdam complexes in a subwatershed; the dominant form of drainage present in the watershed (tile drains, ditches, swales, curb and gutters, storm drain pipes); the average age of development; and the proximity of sewer lines to the stream. As far as we could discover, none of these variables has been systematically tested in a controlled population of small watersheds. We have observed that these factors could be important in our field investigations and often measure them to provide greater insight into subwatershed behavior.

Lastly, several watershed variables that are closely related to IC have been proposed to predict stream quality. These include popula-

tion, percent urban land, housing density, road density and other indices of watershed development. As might be expected, they generally track the same trend as IC, but each has some significant technical limitations and/or difficulties in actual planning applications (Brown, 2000).

Individual vs. Multiple Indicators

The ICM does not predict the precise score of individual stream quality indicators, but rather predicts the average behavior of a group of indicators over a range of IC. Extreme care should be exercised if the ICM is used to predict the fate of individual indicators and/or species. This is particularly true for sensitive aquatic species, such as trout, salmon, and freshwater mussels. When researchers have examined the relationship between IC and individual species, they have often discovered lower thresholds for harm. For example, Boward *et al.* (1999) found that brook trout were not found in subwatersheds that had more than 4% IC in Maryland, whereas Horner and May (1999) asserted an 8% threshold for sustaining salmon in Puget Sound streams.

The key point is that if watershed managers want to maintain an individual species, they should be very cautious about adopting the 10% IC threshold. The essential habitat requirements for many sensitive or endangered species are probably determined by the *most sensitive* stream quality indicators, rather than the *average behavior* of all stream quality indicators.

Direct Causality vs. Association

A strong relationship between IC and declining stream quality indicators does not always mean that the IC is directly responsible for the decline. In some cases, however, causality can be demonstrated. For example, increased stormwater runoff volumes are directly caused by the percentage of IC in a subwatershed, although other factors such as conveyance, slope and soils may play a role.

In other cases, the link is much more indirect. For these indicators, IC is merely an index of the cumulative amount of watershed development, and more IC simply means that a greater number of known or unknown pollutant sources or stressors are present. In yet other cases, a causal link appears likely but has not yet been scientifically demonstrated. A good example is the more than 50 studies that have explored how fish or aquatic insect diversity changes in response to IC. While the majority of these studies consistently shows a very strong negative association between IC and biodiversity, they do not really establish which stressor or combination of stressors contributes most to the decline. The widely accepted theory is that IC changes stream hydrology, which degrades stream habitat, and in turn leads to reduced stream biodiversity.

Regional Differences

Currently, the ICM has been largely confirmed within the following regions of North America: the mid-Atlantic, the Northeast, the Southeast, the upper Midwest and the Pacific Northwest. Limited testing in Northern California, the lower Midwest and Central Texas generally agrees with the ICM. The ICM has not been tested in Florida, the Rocky Mountain West, and the Southwest. For a number of reasons, it is not certain if the ICM accurately predicts biological indicators in arid and semiarid climates (Maxted, 1999).

Measuring Impervious Cover

Most researchers have relied on total impervious cover as the basic unit to measure IC at the subwatershed level. The case has repeatedly been made that effective impervious cover is probably a superior metric (e.g., only counting IC that is hydraulically connected to the drainage system). Notwithstanding, most researchers have continued to measure total IC because it is generally quicker and does not require extensive (and often subjective) engineering judgement as to whether it is connected or not. Researchers have used a wide variety of techniques to estimate subwatershed IC, including satellite imagery, analysis of aerial photographs, and derivation from GIS land use layers. Table 2 presents some standard land use/IC relationships that were developed for suburban regions of the Chesapeake Bay.

Table 2: Land Use/IC Relationships for Suburban Areas of the Chesapeake Bay
(Cappiella and Brown, 2001)

Land Use Category	Sample Number (N)	Mean IC (SE)	Land Use Category	Sample Number (N)	Mean IC (SE)
Agriculture	8	**1.9** – 0.3	Institutional	30	**34.4** – 3.45
Open Urban Land	11	**8.6** – 1.64	Light	20	**53.4** – 2.8
2 Acre Lot Residential	12	**10.6** – 0.65	Commercia	23	**72.2** – 2.0
1 Acre Lot Residential	23	**14.3** – 0.53	Churches	8	**39.9** – 7.8 1
1/2 Acre Lot Residential	20	**21.2** – 0.78	Schools	13	**30.3** – 4.8
1/4 Acre Lot Residential	23	**27.8** – 0.60	Municipals	9	**35.4** – 6.3
1/8 Acre Lot Residential	10	**32.6** – 1.6	Golf	4	**5.0** – 1.7
Townhome Residential	20	**40.9** – 1.39	Cemeteries	3	**8.3** – 3.5
Multifamily Residential	18	**44.4** – 2.0	Parks	4	**12.5** – 0.7

Three points are worth noting. First, it is fair to say that most researchers have spent more quality control effort on their stream quality indicator measurements than on their subwatershed IC estimates. At the current time, no standard protocol exists to estimate subwatershed IC, although Cappiella and Brown (2001) presented a useful method. At best, the different methods used to measure IC make it difficult to compare results from different studies, and at worst, it can introduce an error term of perhaps +/- 10% from the true value within an individual subwatershed. Second, it is important to keep in mind that IC is not constant over time; indeed, major changes in subwatershed IC have been observed within as few as two years. Consequently, it is sound practice to obtain subwatershed IC estimates from the most recent possible mapping data, to ensure that it coincides with stream quality indicator measurements. Lastly, it is important to keep in mind that most suburban and even rural zoning categories exceed 10% IC (see Table 2). Therefore, from a management standpoint, planners should try to project future IC, in order to determine the future stream classification for individual subwatersheds.

1.1.3 Influence of Watershed Treatment Practices on the ICM

The most hotly debated question about the ICM is whether widespread application of watershed practices such as stream buffers or stormwater management can mitigate the impact of IC, thereby allowing greater development density for a given watershed. At this point in time, there are fewer than 10 studies that directly bear on this critical question. Before these are reviewed, it is instructive to look at the difficult technical and scientific issues involved in detecting the effect of watershed treatment, given its enormous implications for land use control and watershed management.

The first tough issue is how to detect the effect of watershed treatment, given the inherent scatter seen in the IC/stream quality indicator relationship. Figure 4 illustrates the "double scatter" problem, based on three different urban stream research studies in Delaware, Maryland and Washington. A quick inspection of the three plots shows how intrinsically hard it is to distinguish the watershed treatment effect. As can be seen, stream quality indicators in subwatersheds with treatment tend to

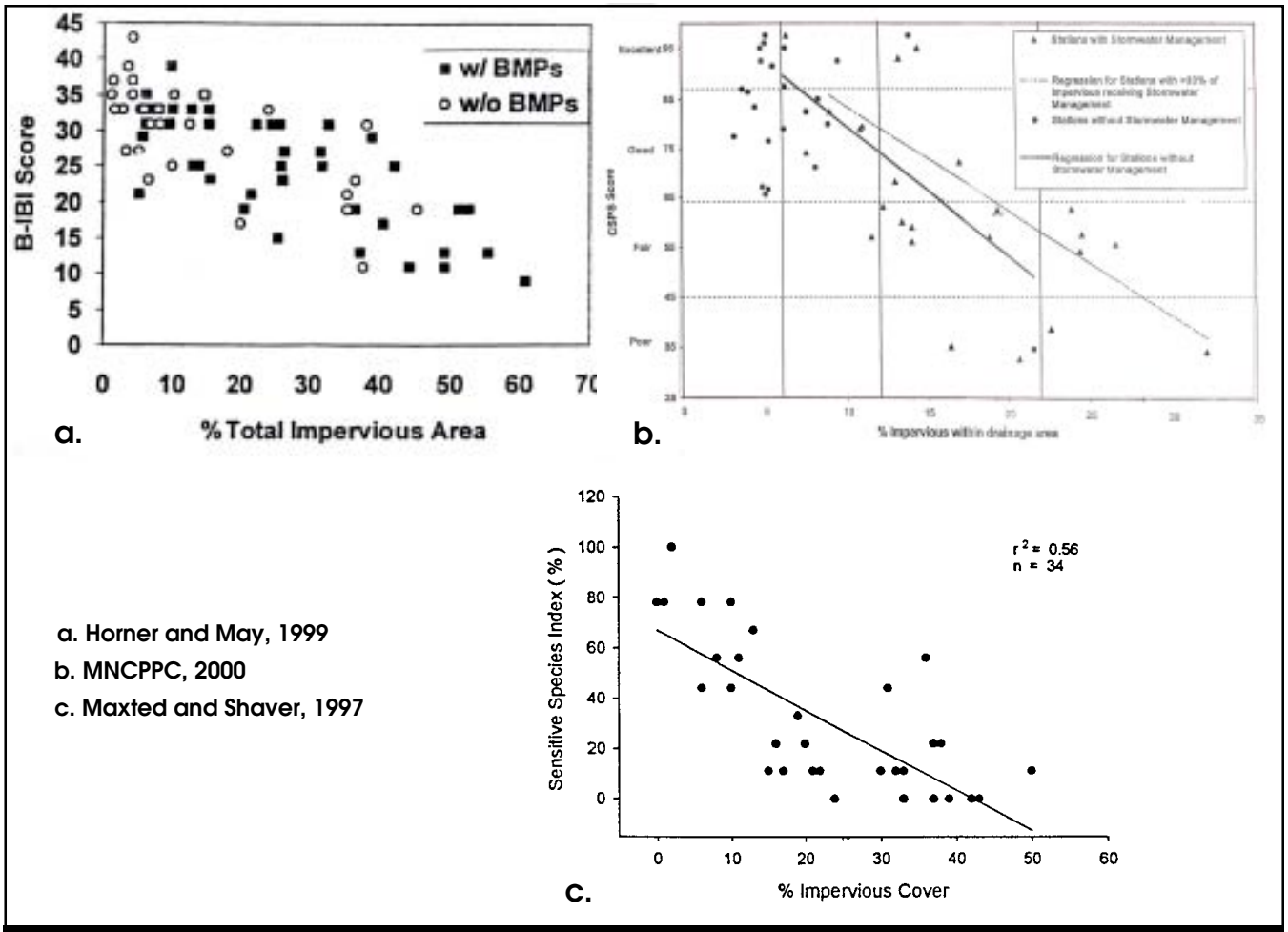


Figure 4: The Double Scatter Problem: Difficulties in Detecting the Effect of Watershed Treatment

overplot those in subwatersheds that lack treatment. While subtle statistical differences may be detected, they are not visibly evident. This suggests that the impact of watershed treatment would need to be extremely dramatic to be detected, given the inherent statistical variability seen in small watersheds (particularly so within the five to 25% IC range where scatter is considerable).

In an ideal world, a watershed study design would look at a controlled population of small urban watersheds that were developed with and without watershed practices to detect the impact of "treatment." In the real world, however, it is impossible to strictly control subwatershed variables. Quite simply, no two subwatersheds are ever alike. Each differs slightly with respect to drainage area, IC, forest cover, riparian continuity, historical land use, and percent watershed treatment. Researchers must also confront other real world issues when designing their watershed treatment experiments.

For example, researchers must carefully choose which indicator or group of indicators will be used to define stream health. IC has a negative influence on 26 stream quality indicators, yet nearly all of the watershed treatment research so far has focused on just a few biological indicators (e.g., aquatic insect or fish diversity) to define stream health. It is conceivable that watershed treatment might have no effect on biological indicators, yet have a positive influence on hydrology, habitat or water quality indicators. At this point, few of these indicators have been systematically

tested in the field. It is extremely doubtful that any watershed practice can simultaneously improve or mitigate all 26 stream quality indicators, so researchers must carefully interpret the outcomes of their watershed treatment experiments.

The second issue involves how to quantify watershed treatment. In reality, watershed treatment collectively refers to dozens of practices that are installed at individual development sites in the many years or even decades it takes to fully "build out" a subwatershed. Several researchers have discovered that watershed practices are seldom installed consistently across an entire subwatershed. In some cases, less than a third of the IC in a subwatershed was actually treated by any practice, because development occurred prior to regulations; recent projects were exempted, waived or grandfathered; or practices were inadequately constructed or maintained (Horner and May, 1999 and MNCPPC, 2000).

Even when good coverage is achieved in a watershed, such as the 65 to 90% reported in studies of stormwater ponds (Jones *et al*., 1996; Maxted, 1999; Maxted and Shaver, 1997), it is still quite difficult to quantify the actual quality of treatment. Often, each subwatershed contains its own unique mix of stormwater practices installed over several decades, designed under diverse design criteria, and utilizing widely different stormwater technologies. Given these inconsistencies, researchers will need to develop standard protocols to define the extent and quality of watershed treatment.

Effect of Stormwater Ponds

With this in mind, the effect of stormwater ponds and stream buffers can be discussed. The effect of larger stormwater ponds in mitigating the impacts of IC in small watersheds has received the most scrutiny to date. This is not surprising, since larger ponds often control a large fraction of their contributing subwatershed area (e.g. 100 to 1,000 acres) and are located on the stream itself, therefore lending themselves to easier monitoring. Three studies have evaluated the impact of large stormwater ponds on downstream aquatic insect communities (Jones *et al.*, 1996; Maxted and Shaver, 1997; Stribling *et al.*, 2001). Each of these studies was conducted in small headwater subwatersheds in the mid-Atlantic Region, and none was able to detect major differences in aquatic insect diversity in streams with or without stormwater ponds.

Four additional studies statistically evaluated the stormwater treatment effect in larger populations of small watersheds with varying degrees of IC (Horner and May, 1999; Horner *et al.,* 2001; Maxted, 1999; MNCPPC, 2000). These studies generally sampled larger watersheds that had many stormwater practices but not necessarily complete watershed coverage. In general, these studies detected a small but positive effect of stormwater treatment relative to aquatic insect diversity. This positive effect was typically seen only in the range of five to 20% IC and was generally undetected beyond about 30% IC. Although each author was hesitant about interpreting his results, all generally agreed that perhaps as much as 5% IC could be added to a subwatershed while maintaining aquatic insect diversity, given effective stormwater treatment. Forest retention and stream buffers were found to be very important, as well. Horner *et al.* (2001) reported a somewhat stronger IC threshold for various species of salmon in Puget Sound streams.

Some might conclude from these initial findings that stormwater ponds have little or no value in maintaining biological diversity in small streams. However, such a conclusion may be premature for several reasons. First, the generation of stormwater ponds that was tested was not explicitly designed to protect stream habitat or to prevent downstream channel erosion, which would presumably promote aquatic diversity. Several states have recently changed their stormwater criteria to require extended detention for the express purpose of preventing downstream channel erosion, and these new criteria may exert a stronger influence on aquatic diversity. Instead, their basic design objective was to maximize pollutant removal, which they did reasonably well.

The second point to stress is that streams with larger stormwater ponds should be considered "regulated streams" (Ward and Stanford, 1979), which have a significantly altered aquatic insect community downstream of the ponds. For example, Galli (1988) has reported that on-stream wet stormwater ponds shift the trophic structure of the aquatic insect community. The insect community above the pond was dominated by shredders, while the insect community below the pond was dominated by scrapers, filterers and collectors. Of particular note, several pollution-sensitive species were eliminated below the pond. Galli reported that changes in stream temperatures, carbon supply and substrate fouling were responsible for the downstream shift in the aquatic insect community. Thus, while it is clear that large stormwater ponds can be expected to have a negative effect on aquatic insect diversity, they could still exert positive influence on other stream quality indicators.

Effect of Stream Buffers

A handful of studies have evaluated biological indicator scores for urban streams that have extensive forest buffers, compared to streams where they were mostly or completely absent (Horner and May, 1999; Horner *et al.,* 2001; May *et al.*, 1997; MNCPPC, 2000; Roth *et al.,* 1998; Steedman, 1988). Biological indicators included various indices of aquatic insect, fish and salmon diversity. Each study sampled a large population of small subwatersheds over a range of IC and derived a quantitative measure to express the continuity, width and forest cover of the riparian buffer network within each subwatershed. Riparian forests were hypothesized to have a positive influence on stream biodiversity, given the direct ways they contribute to stream habitat (e.g., shading, woody debris, leaf litter, bank stability, and organic carbon supply).

All five studies detected a small to moderate positive effect when forested stream buffers were present (frequently defined as at least two-thirds of the stream network with at least 100 feet of stream side forest). The greatest effect was reported by Horner and May (1999) and Horner *et al.* (2001) for salmon streams in the Puget Sound ecoregion. If excellent riparian habitats were preserved, they generally reported that fish diversity could be maintained up to 15% IC, and good aquatic insect diversity could be maintained with as much as 30% IC. Steedman (1988) reported a somewhat smaller effect for Ontario streams. MNCPPC (2000), May *et al.* (1997), and Roth *et al.* (1998) could not find a statistically significant relationship between riparian quality and urban stream quality indicators but did report that most outliers (defined as higher IC subwatersheds with unusually high biological indicator scores) were generally associated with extensive stream side forest.

1.1.4 Recommendations for Further ICM Research

At this point, we recommend three research directions to improve the utility of the ICM for watershed managers. The **first direction** is to expand basic research on the relationship between IC and stream quality indicators that have received little scrutiny. In particular, more work is needed to define the relationship between IC and hydrological and physical indicators such as the following:

- Physical loss or alteration of the stream network
- Stream habitat measures
- Riparian continuity
- Baseflow conditions during dry weather

In addition, more watershed research is needed in ecoregions and physiographic areas where the ICM has not yet been widely tested. Key areas include Florida, arid and semiarid climates, karst areas and mountainous regions. The basic multiple subwatershed monitoring protocol set forth by Schueler (1994a) can be used to investigate IC/stream quality relationships, although it would be wise to measure a wider suite of subwatershed variables beyond IC (e.g., forest cover, turf cover, and riparian continuity).

The **second** research direction is to more clearly define the impact of watershed treatment on stream quality indicators. Based on

the insurmountable problems encountered in controlling variation at the subwatershed level, it may be necessary to abandon the multiple watershed or paired watershed sampling approaches that have been used to date. Instead, longitudinal monitoring studies within individual subwatersheds may be a more powerful tool to detect the effect of watershed treatment. These studies could track changes in stream quality indicators in individual subwatersheds over the entire development cycle: pre-development land use, clearing, construction, build out, and post construction. In most cases, longitudinal studies would take five to 10 years to complete, but they would allow watershed managers to measure and control the inherent variability at the subwatershed level and provide a "before and after" test of watershed treatment. Of course, a large population of test subwatersheds would be needed to satisfactorily answer the watershed treatment question.

The **third** research direction is to monitor more non-supporting streams, in order to provide a stronger technical foundation for crafting more realistic urban stream standards and to see how they respond to various watershed restoration treatments. As a general rule, most researchers have been more interested in the behavior of sensitive and impacted streams. The non-supporting stream category spans a wide range of IC, yet we do not really understand how stream quality indicators behave over the entire 25 to 100% IC range.

For example, it would be helpful to establish the IC level at the upper end of the range where streams are essentially transformed into an artificial conveyance system (i.e., become pipes or artificial channels). It would also be interesting to sample more streams near the lower end of the non-supporting category (25 to 35% IC) to detect whether stream quality indicators respond to past watershed treatment or current watershed restoration efforts. For practical reasons, the multiple subwatershed sampling approach is still recommended to characterize indicators in non-supporting streams. However, researchers will need to screen a large number of non-supporting subwatersheds in order to identify a few subwatersheds that are adequate for subsequent sampling (i.e., to control for area, IC, development age, percent watershed treatment, type of conveyance systems, etc.).

1.2 Impacts of Urbanization on Downstream Receiving Waters

In this section, we review the impacts of urbanization on downstream receiving waters, primarily from the standpoint of impacts caused by poor stormwater quality. We begin by looking at the relationship between IC and stormwater pollutant loadings. Next, we discuss the sensitivity of selected downstream receiving waters to stormwater pollutant loads. Lastly, we examine the effect of watershed treatment in reducing stormwater pollutant loads.

1.2.1 Relationship Between Impervious Cover and Stormwater Quality

Urban stormwater runoff contains a wide range of pollutants that can degrade downstream water quality (Table 3). Several generalizations can be supported by the majority of research conducted to date. First, the unit area pollutant load delivered by stormwater runoff to receiving waters increases in direct proportion to watershed IC. This is not altogether surprising, since pollutant load is the product of the average pollutant concentration and stormwater runoff volume. Given that runoff volume increases in direct proportion to IC, pollutant loads must automatically increase when IC increases, as long the average pollutant concentration stays the same (or increases). This relationship is a central assumption in most simple and complex pollutant loading models (Bicknell *et al.*, 1993; Donigian and Huber, 1991; Haith *et al.*, 1992; Novotny and Chester, 1981; NVPDC, 1987; Pitt and Voorhees, 1989).

The second generalization is that stormwater pollutant concentrations are generally similar

Table 3: Summary of Urban Stormwater Pollutant Loads on Quality of Receiving Waters

Pollutants in Urban Stormwater	WQ Impacts To:					Higher Unit Load?	Load a function of IC?	Other Factors Important in Loading
	R	L	E	A	W			
Suspended Sediment	Y	Y	Y	N	Y	Y (ag)	Y	channel erosion
Total Nitrogen	N	N	Y	Y	N	Y (ag)	Y	septic systems
Total Phosphorus	Y	Y	N	N	Y	Y (ag)	Y	tree canopy
Metals	Y	Y	Y	?	N	Y	Y	vehicles
Hydrocarbons	Y	Y	Y	Y	Y	Y	?	related to VMTs and hotspots
Bacteria/Pathogens	Y	Y	Y	N	Y	Y	Y	many sources
Organic Carbon	N	?	?	?	Y	Y	Y	
MTBE	N	N	N	Y	Y	Y	?	roadway, VMTs
Pesticides	?	?	?	?	Y	Y	?	turf/landscaping
Chloride	?	Y	N	Y	Y	Y	?	road density
Trash/Debris	Y	Y	Y	N	?	Y	Y	curb and gutters

Major Water Quality Impacts Reported for:
R = River, L = Lake, E = Estuary, A = Aquifer, W = Surface Water Supply
Higher Unit Area Load? Yes (compared to all land uses) (ag): with exception of cropland
Load a function of IC? Yes, increases proportionally with IC

at the catchment level, regardless of the mix of IC types monitored (e.g., residential, commercial, industrial or highway runoff). Several hundred studies have examined stormwater pollutant concentrations from small urban catchments and have generally found that the variation within a catchment is as great as the variation between catchments. Runoff concentrations tend to be log-normally distributed, and therefore the long term "average" concentration is best expressed by a median value. It should be kept in mind that researchers have discovered sharp differences in pollutant concentrations for smaller, individual components of IC (e.g., rooftops, parking lots, streets, driveways and the like). Since most urban catchments are composed of many kinds of IC, this mosaic quality tempers the variability in long term pollutant concentrations at the catchment or subwatershed scale.

The third generalization is that median concentrations of pollutants in urban runoff are usually higher than in stormwater runoff from most other non-urban land uses. Consequently, the unit area nonpoint pollutant load generated by urban land normally exceeds that of nearly all watershed land uses that it replaces (forest, pasture, cropland, open space — see Table 3). One important exception is cropland, which often produces high unit area sediment and nutrient loads in many regions of the country. In these watersheds, conversion of intensively managed crops to low density residential development may actually result in a slightly decreased sediment or nutrient load. On the other hand, more intensive land development (30% IC or more) will tend to equal or exceed cropland loadings.

The last generalization is that the effect of IC on stormwater pollutant loadings tends to be weakest for subwatersheds in the one to 10% IC range. Numerous studies have suggested that other watershed and regional factors may have a stronger influence, such as the underlying geology, the amount of carbonate rock in the watershed, physiographic region, local soil types, and most important, the relative fraction of forest and crop cover in the subwatershed (Herlihy *et al*., 1998 and Liu *et al.,* 2000). The limited influence of IC on pollutant loads is generally consistent with the finding for hydrologic, habitat and biological indicators over this narrow range of IC. Once again, watershed managers are advised to track other watershed indicators in the sensitive stream category, such as forest or crop cover.

1.2.2 Water Quality Response to Stormwater Pollution

As noted in the previous section, most ICM research has been done on streams, which are directly influenced by increased stormwater. Many managers have wondered whether the ICM also applies to downstream receiving waters, such as lakes, water supply reservoirs and small estuaries. In general, the exact water quality response of downstream receiving waters to increased nonpoint source pollutant loads depends on many factors, including the specific pollutant, the existing loading generated by the converted land use, and the geometry and hydraulics of the receiving water. Table 3 indicates the sensitivity of rivers, lakes, estuaries, aquifers and water supply reservoirs to various stormwater pollutants.

Lakes and the ICM

The water column and sediments of urban lakes are impacted by many stormwater pollutants, including sediment, nutrients, bacteria, metals, hydrocarbons, chlorides, and trash/debris. Of these pollutants, limnologists have always regarded phosphorus as the primary lake management concern, given that more than 80% of urban lakes experience symptoms of eutrophication (CWP, 2001a).

In general, phosphorus export steadily increases as IC is added to a lake watershed, although the precise amount of IC that triggers eutrophication problems is unique to each urban lake. With a little effort, it is possible to calculate the specific IC threshold for an individual lake, given its internal geometry, the size of its contributing watershed, current in-lake phosphorus concentration, degree of watershed treatment, and the desired water quality goals for the lake (CWP, 2001a). As a general rule, most lakes are extremely sensitive

to increases in phosphorus loads caused by watershed IC. Exceptions include lakes that are unusually deep and/or have very small drainage area/lake area ratios. In most lakes, however, even a small amount of watershed development will result in an upward shift in trophic status (CWP, 2001a).

Reservoirs and the ICM

While surface water supply reservoirs respond to stormwater pollutant loads in the same general manner as lakes, they are subject to stricter standards because of their uses for drinking water. In particular, water supply reservoirs are particularly sensitive to increased turbidity, pathogens, total organic carbon, chlorides, metals, pesticides and hydrocarbon loads, in addition to phosphorus (Kitchell, 2001). While some pollutants can be removed or reduced through expanded filtering and treatment at drinking water intakes, the most reliable approach is to protect the source waters through watershed protection and treatment.

Consequently, we often recommend that the ICM be used as a "threat index" for most drinking water supplies. Quite simply, if current or future development is expected to exceed 10% IC in the contributing watershed, we recommend that a very aggressive watershed protection strategy be implemented (Kitchell, 2001). In addition, we contend that drinking water quality cannot be sustained once watershed IC exceeds 25% and have yet to find an actual watershed where a drinking water utility has been maintained under these conditions.

Small Tidal Estuaries and Coves and the ICM

The aquatic resources of small tidal estuaries, creeks, and coves are often highly impacted by watershed development and associated activities, such as boating/marinas, wastewater discharge, septic systems, alterations in freshwater flow and wetland degradation and loss. Given the unique impacts of eutrophication on the marine system and stringent water quality standards for shellfish harvesting, the stormwater pollutants of greatest concern in the estuarine water column are nitrogen and fecal coliform bacteria. Metals and hydrocarbons in stormwater runoff can also contaminate bottom sediments, which can prove toxic to local biota (Fortner *et al*., 1996; Fulton *et al.*, 1996; Kucklick *et al.*, 1997; Lerberg *et al.*, 2000; Sanger *et al.,* 1999; Vernberg *et al.*, 1992).

While numerous studies have demonstrated that physical, hydrologic, water quality and biological indicators differ in urban and non-urban coastal watersheds, only a handful of studies have used watershed IC as an indicator of estuarine health. These studies show significant correlations with IC, although degradation thresholds may not necessarily adhere to the ICM due to tidal dilution and dispersion. Given the limited research, it is not fully clear if the ICM can be applied to coastal systems without modification.

Atmospheric deposition is considered a primary source of nitrogen loading to estuarine watersheds. Consequently, nitrogen loads in urban stormwater are often directly linked to IC. Total nitrogen loads have also been linked to groundwater input, especially from subsurface discharges from septic systems, which are common in low density coastal development (Swann, 2001; Valiela *et al.*, 1997; Vernberg *et al.*, 1996a). Nitrogen is generally considered to be the limiting nutrient in estuarine systems, and increased loading has been shown to increase algal and phytoplankton biomass and cause shifts in the phytoplankton community and food web structure that may increase the potential for phytoplankton blooms and fish kills (Bowen and Valiela, 2001; Evgenidou *et al.*, 1997; Livingston, 1996).

Increased nitrogen loads have been linked to declining seagrass communities, finfish populations, zooplankton reproduction, invertebrate species richness, and shellfish populations (Bowen and Valiela, 2001; Rutkowski *et al*., 1999; Short and Wyllie-Echeverria, 1996; Valiela and Costa, 1988). Multiple studies have shown significant increases in nitrogen loading as watershed land use becomes more urban (Valiela *et al.,* 1997; Vernberg *et al.* 1996a; Wahl *et al.,* 1997). While a few studies

link nitrogen loads with building and population density, no study was found that used IC as an indicator of estuarine nitrogen loading.

The second key water quality concern in small estuaries is high fecal coliform levels in stormwater runoff, which can lead to the closure of shellfish beds and swimming beaches. Waterfowl and other wildlife have also been shown to contribute to fecal coliform loading (Wieskel *et al.*, 1996). Recent research has shown that fecal coliform standards are routinely violated during storm events at very low levels of IC in coastal watersheds (Mallin *et al.,* 2001; Vernberg *et al.*, 1996b; Schueler, 1999). Maiolo and Tschetter (1981) found a significant correlation between human population and closed shellfish acreage in North Carolina, and Duda and Cromartie (1982) found greater fecal coliform densities when septic tank density and IC increased, with an approximate threshold at 10% watershed IC.

Recently, Mallin *et al.* (2000) studied five small North Carolina estuaries of different land uses and showed that fecal coliform levels were significantly correlated with watershed population, developed land and IC. Percent IC was the most statistically significant indicator and could explain 95% of the variability in fecal coliform concentrations. They also found that shellfish bed closures were possible in watersheds with less than 10% IC, common in watersheds above 10% IC, and almost certain in watersheds above 20% IC. While higher fecal coliform levels were observed in developed watersheds, salinity, flushing and proximity to pollution sources often resulted in higher concentrations at upstream locations and at high tides (Mallin *et al.*, 1999). While these studies support the ICM, more research is needed to prove the reliability of the ICM in predicting shellfish bed closures based on IC.

Several studies have also investigated the impacts of urbanization on estuarine fish, macrobenthos and shellfish communities. Increased PAH accumulation in oysters, negative effects of growth in juvenile sheepshead minnows, reduced molting efficiency in copepods, and reduced numbers of grass shrimp have all been reported for urban estuaries as compared to forested estuaries (Fulton *et al.,* 1996). Holland *et al. (*1997) reported that the greatest abundance of penaid shrimp and mummichogs was observed in tidal creeks with forested watersheds compared to those with urban cover. Porter *et al.* (1997) found lower grass shrimp abundance in small tidal creeks adjacent to commercial and urban development, as compared to non-urban watersheds.

Lerberg *et al.* (2000) studied small tidal creeks and found that highly urban watersheds (50% IC) had the lowest benthic diversity and abundance as compared to suburban and forested creeks, and benthic communities were numerically dominated by tolerant oligochaetes and polychaetes. Suburban watersheds (15 to 35% IC) also showed signs of degradation and had some pollution tolerant macrobenthos, though not as markedly as urban creeks. Percent abundance of pollution-indicative species showed a marked decline at 30% IC, and the abundance of pollution-sensitive species also significantly correlated with IC (Lerberg *et al*., 2000). Holland *et al*. (1997) reported that the variety and food availability for juvenile fish species was impacted at 15 to 20% IC.

Lastly, a limited amount of research has focused on the direct impact of stormwater runoff on salinity and hypoxia in small tidal creeks. Blood and Smith (1996) compared urban and forested watersheds and found higher salinities in urban watersheds due to the increased number of impoundments. Fluctuations in salinity have been shown to affect shellfish and other aquatic populations (see Vernberg, 1996b). When urban and forested watersheds were compared, Lerberg *et al.* (2000) reported that higher salinity fluctuations occurred most often in developed watersheds; significant correlations with salinity range and IC were also determined. Lerberg *et al.* (2000) also found that the most severe and frequent hypoxia occurred in impacted salt marsh creeks and that dissolved oxygen dynamics in tidal creeks were comparable to dead-end canals common in residential marina-style

coastal developments. Suburban watersheds (15 to 35% IC) exhibited signs of degradation and had some pollution-tolerant macrobenthic species, though not to the extent of urban watersheds (50% IC).

In summary, recent research suggests that indicators of coastal watershed health are linked to IC. However, more research is needed to clarify the relationship between IC and estuarine indicators in small tidal estuaries and high salinity creeks.

1.2.3 Effect of Watershed Treatment on Stormwater Quality

Over the past two decades, many communities have invested in watershed protection practices, such as stormwater treatment practices (STPs), stream buffers, and better site design, in order to reduce pollutant loads to receiving waters. In this section, we review the effect of watershed treatment on the quality of stormwater runoff.

Effect of Stormwater Treatment Practices
We cannot directly answer the question as to whether or not stormwater treatment practices can significantly reduce water quality impacts at the watershed level, simply because no controlled monitoring studies have yet been conducted at this scale. Instead, we must rely on more indirect research that has tracked the change in mass or concentration of pollutants as they travel through individual stormwater treatment practices. Thankfully, we have an abundance of these performance studies, with nearly 140 monitoring studies evaluating a diverse range of STPs, including ponds, wetlands, filters, and swales (Winer, 2000).

These studies have generally shown that stormwater practices have at least a moderate ability to remove many pollutants in urban stormwater. Table 4 provides average removal efficiency rates for a range of practices and stormwater pollutants, and Table 5 profiles the mean storm outflow concentrations for various practices. As can be seen, some groups of practices perform better than others in removing certain stormwater pollutants. Consequently, managers need to carefully choose which practices to apply to solve the primary water quality problems within their watersheds.

It is also important to keep in mind that site-based removal rates cannot be extrapolated to the watershed level without significant adjustment. Individual site practices are never implemented perfectly or consistently across a watershed. At least three discount factors need to be considered: bypassed load, treatability and loss of performance over time. For a review on how these discounts are derived, consult Schueler and Caraco (2001). Even under the most optimistic watershed implementation scenarios, overall pollutant reduc-

Table 4: The Effectiveness of Stormwater Treatment Practices in Removing Pollutants - Percent Removal Rate (Winer, 2000)

Practice	N	TSS	TP	OP	TN	NOx	Cu	Zn	Oil/ Grease[1]	Bacteria
Dry Ponds	9	47	19	N/R	25	3.5	26	26	3	44
Wet Ponds	43	80	51	65	33	43	57	66	78	70
Wetlands	36	76	49	48	30	67	40	44	85	78
Filtering Practices[2]	18	86	59	57	38	-14	49	88	84	37
Water Quality Swales	9	81	34	1.0	84	31	51	71	62	-25
Ditches[3]	9	31	-16	N/R	-9.0	24	14	0	N/R	0
Infiltration	6	95	80	85	51	82	N/R	N/R	N/R	N/R

1: Represents data for Oil and Grease and PAH
2: Excludes vertical sand filters
3: Refers to open channel practices not designed for water quality
N/R = Not Reported

Table 5: Median Effluent Concentrations from Stormwater Treatment Practices (mg/l) (Winer, 2000)

Practice	N	TSS	TP	OP	TN	NOx	Cu[1]	Zn[1]
Dry Ponds[2]	3	28	0.18	N/R	0.86	N/R	9.0	98
Wet Ponds	25	17	0.11	0.03	1.3	0.26	5.0	30
Wetlands	19	22	0.20	0.07	1.7	0.36	7.0	31
Filtering Practices[3]	8	11	0.10	0.07	1.1	0.55	9.7	21
Water Quality Swales	7	14	0.19	0.09	1.1	0.35	10	53
Ditches[4]	3	29	0.31	N/R	2.4	0.72	18	32

1. Units for Zn and Cu are micrograms per liter (Fg/l)
2. Data available for Dry Extended Detention Ponds only
3. Excludes vertical sand filters
4. Refers to open channel practices not designed for water quality
N/R = Not Reported

tions by STPs may need to be discounted by at least 30% to account for partial watershed treatment.

Even with discounting, however, it is evident that STPs can achieve enough pollutant reduction to mimic rural background loads for many pollutants, as long as the watershed IC does not exceed 30 to 35%. This capability is illustrated in Figure 5, which shows phosphorus load as a function of IC, with and without stormwater treatment.

Effect of Stream Buffers/Riparian Areas
Forested stream buffers are thought to have very limited capability to remove stormwater pollutants, although virtually no systematic monitoring data exists to test this hypothesis. The major reason cited for their limited removal capacity is that stormwater generated from upland IC has usually concentrated before it reaches the forest buffer and therefore crosses the buffer in a channel, ditch or storm drain pipe. Consequently, the opportunity to filter runoff is lost in many forest buffers in urban watersheds.

Effect of Better Site Design
Better site design (BSD) is a term for nonstructural practices that minimize IC, conserve natural areas and distribute stormwater treatment across individual development sites. BSD is also known by many other names, including conservation development, low-impact development, green infrastructure, and sustainable urban drainage systems. While

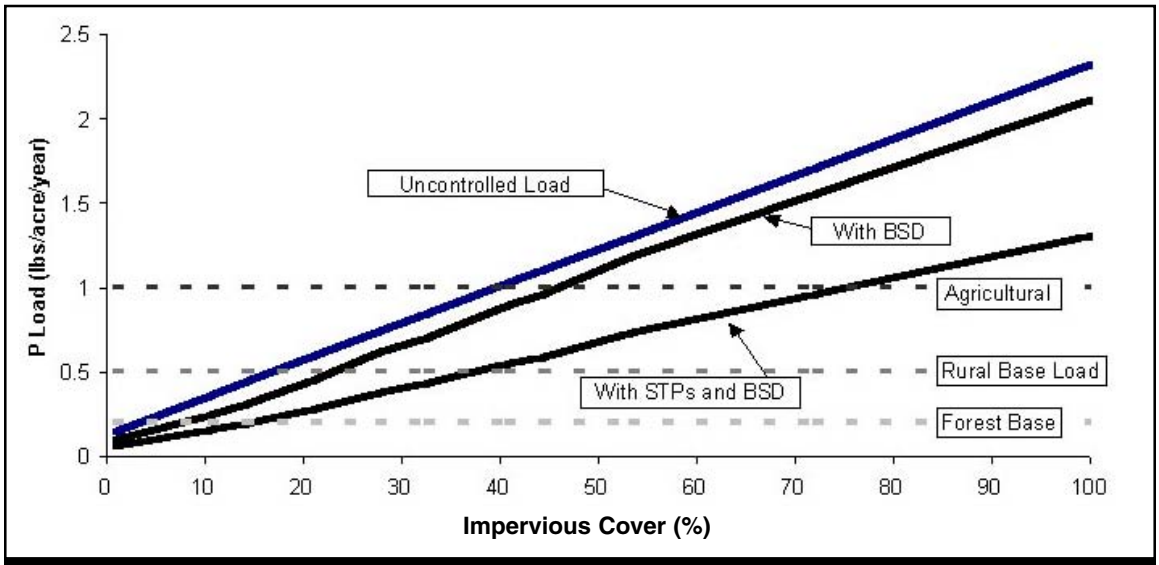


Figure 5: Estimated Phosphorus Load as a Function of Impervious Cover, Discounted Stormwater Treatment and Better Site Design (Schueler and Caraco, 2001)

some maintain that BSD is an alternative to traditional STPs, most consider it to be an important complement to reduce pollutant loads.

While BSD has become popular in recent years, only one controlled research study has evaluated its potential performance, and this is not yet complete (i.e. Jordan Cove, CT).

Indirect estimates of the potential value of BSD to reduce pollutant discharges have been inferred from modeling and redesign analyses (Zielinski, 2000). A typical example is provided in Figure 5, which shows the presumed impact of BSD in reducing phosphorus loadings. As is apparent, BSD appears to be a very effective strategy in the one to 25% IC range, but its benefits diminish beyond that point.

1.3 Implications of the ICM for Watershed Managers

One of the major policy implications of the ICM is that in the absence of watershed treatment, it predicts negative stream impacts at an extremely low intensity of watershed development. To put this in perspective, consider that a watershed zoned for two-acre lot residential development will generally exceed 10% IC, and therefore shift from a sensitive to an impacted stream classification (Cappiella and Brown, 2001). Thus, if a community wants to protect an important water resource or a highly regarded species (such as trout, salmon or an endangered freshwater mussel), the ICM suggests that there is a maximum limit to growth that is not only quite low, but is usually well below the current zoning for many suburban or even rural watersheds. Consequently, the ICM suggests the unpleasant prospect that massive down-zoning, with all of the associated political and legal carnage involving property rights and economic development, may be required to maintain stream quality.

It is not surprising, then, that the ICM debate has quickly shifted to the issue of whether or not watershed treatment practices can provide adequate mitigation for IC. How much relief can be expected from stream buffers, stormwater ponds, and other watershed practices, which might allow greater development density within a given watershed? Only a limited amount of research has addressed this question, and the early results are not reassuring (reviewed in section 1.1.3). At this early stage, researchers are still having trouble detecting the impact of watershed treatment, much less defining it. As noted earlier, both watershed research techniques and practice implementation need to be greatly improved if we ever expect to get a scientifically defensible answer to this crucial question. Until then, managers should be extremely cautious in setting high expectations for how much watershed treatment can mitigate IC.

1.3.1 Management of Non-Supporting Streams

Most researchers acknowledge that streams with more than 25% IC in their watersheds cannot support their designated uses or attain water quality standards and are severely degraded from a physical and biological standpoint. As a consequence, many of these streams are listed for non-attainment under the Clean Water Act and are subject to Total Maximum Daily Load (TMDL) regulations. Communities that have streams within this regulatory class must prepare implementation plans that demonstrate that water quality standards can ultimately be met.

While some communities have started to restore or rehabilitate these streams in recent years, their efforts have yielded only modest improvements in water quality and biological indicators. In particular, no community has yet demonstrated that they can achieve water quality standards in an urban watershed that exceeds 25% IC. Many communities are deeply concerned that non-supporting streams may never achieve water quality standards, despite massive investments in watershed restoration. The ICM suggests that water quality standards may need to be sharply revised for streams with more than 25% IC, if they are ever to come into attainment. While states have authority to create more achievable standards for non-supporting streams within the regulatory framework of the Clean Water Act (Swietlik, 2001), no state has yet exercised this authority. At this time, we are not aware of any water quality standards that are based on the ICM or similar urban stream classification techniques.

Two political perceptions largely explain why states are so reticent about revising water quality standards. The first is a concern that they will run afoul of anti-degradation provisions within the Clean Water Act or be accused of “backsliding” by the environmental community. The second concern relates to the demographics of watershed organizations across the country. According to recent surveys, slightly more than half of all watershed organizations

represent moderately to highly developed watersheds (CWP, 2001a). These urban watershed organizations often have a keen interest in keeping the existing regulatory structure intact, since it is perceived to be the only lever to motivate municipalities to implement restoration efforts in non-supporting streams.

However, revised water quality standards are urgently needed to support smart growth efforts. A key premise of smart growth is that it is more desirable to locate new development within a non-supporting subwatershed rather than a sensitive or impacted one (i.e., concentrating density and IC within an existing subwatershed helps prevent sprawl from encroaching on a less developed one). Yet while smart growth is desirable on a regional basis, it will usually contribute to already serious problems in non-supporting watersheds, which makes it even more difficult to meet water quality standards.

This creates a tough choice for regulators: if they adopt stringent development criteria for non-supporting watersheds, their added costs can quickly become a powerful barrier to desired redevelopment. If, on the other hand, they relax or waive environmental criteria, they contribute to the further degradation of the watershed. To address this problem, the Center has developed a "smart watersheds" program to ensure that any localized degradation caused by development within a non-supporting subwatershed is more than compensated for by improvements in stream quality achieved through municipal restoration efforts (CWP, in press). Specifically, the smart watersheds program includes 17 public sector programs to treat stormwater runoff, restore urban stream corridors and reduce pollution discharges in highly urban watersheds. It is hoped that communities that adopt and implement smart watershed programs will be given greater flexibility to meet state and federal water quality regulations and standards within non-supporting watersheds.

1.3.2 Use of the ICM for Urban Stream Classification

The ICM has proven to be a useful tool for classifying and managing the large inventory of streams that most communities possess. It is not unusual for a typical county to have several thousand miles of headwater streams within its political boundaries, and the ICM provides a unified framework to identify and manage these subwatersheds. In our watershed practice, we use the ICM to make an initial diagnosis rather than a final determination for stream classification. Where possible, we conduct rapid stream and subwatershed assessments as a final check for an individual stream classification, particularly if it borders between the sensitive and impacted category. As noted earlier, the statistical variation in the IC/stream quality indicator makes it difficult to distinguish between a stream with 9% versus 11% IC. Some of the key criteria we use to make a final stream classification are provided in Table 6.

1.3.3 Role of the ICM in Small Watershed Planning

The ICM has also proven to be an extremely important tool for watershed planning, since it can rapidly project how streams will change in response to future land use. We routinely estimate existing and future IC in our watershed planning practice and find that it is an excellent indicator of change for subwatersheds in the zero to 30% IC range. In particular, the ICM often forces watershed planners to directly confront land use planning and land conservation issues early in the planning process.

On the other hand, we often find that the ICM has limited planning value when subwatersheds exceed 30% IC for two practical reasons. First, the ICM does not differentiate stream conditions within this very large span of IC (i.e., there is no difference in the stream quality prediction for a subwatershed that has 39.6% IC versus one that has 58.4% IC). Second, the key management question for non-supporting watersheds is whether or not

they are potentially restorable. More detailed analysis and field investigations are needed to determine, in each subwatershed, the answer to this question. While a knowledge of IC is often used in these feasibility assessments, it is but one of many factors that needs to be considered.

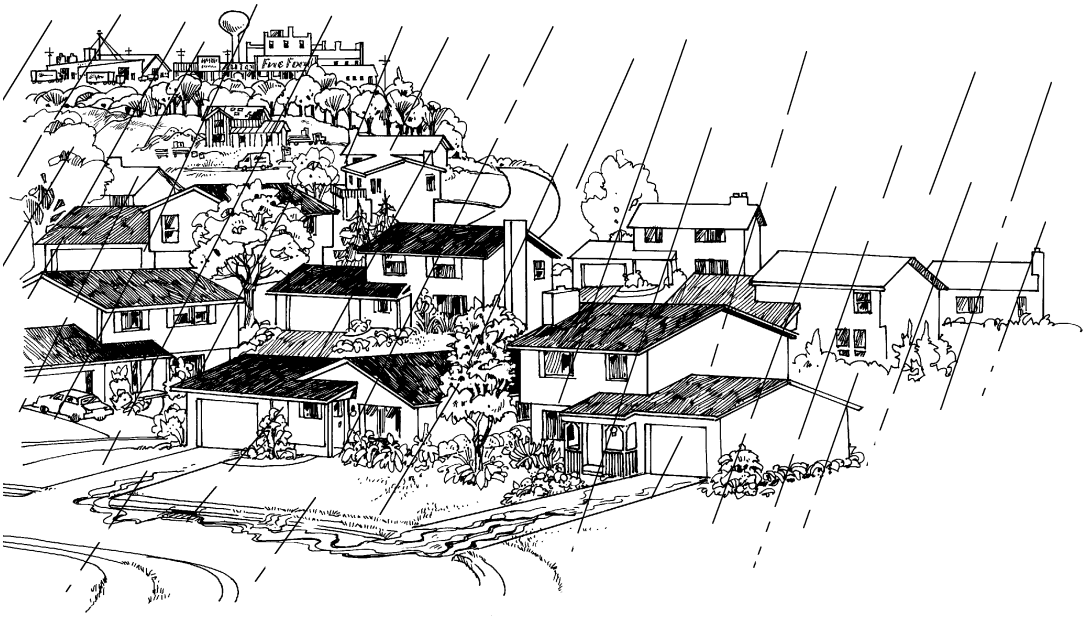
Lastly, we have come to recognize several practical factors when applying the ICM for small watershed planning. These include thoughtful delineation of subwatershed boundaries, the proper accounting of a direct drainage area in larger watersheds, and the critical need for the most recent IC data. More guidance on these factors can be found in Zielinski (2001).

Impervious cover is not a perfect indicator of existing stream quality. A number of stream and subwatershed criteria should be evaluated in the field before a final classification decision is made, particularly when the stream is on the borderline between two classifications. We routinely look at the stream and subwatershed criteria to decide whether a borderline stream should be classified as sensitive or impacted. Table 6 reviews these additional criteria.

Table 6: Additional Considerations for Urban Stream Classification
Stream Criteria
Reported presence of rare, threatened or endangered species in the aquatic community (e.g., freshwater mussels, fish, crayfish or amphibians) Confirmed spawning of cold-water fish species (e.g., trout) Fair/good, good, or good to excellent macro invertebrate scores More than 65% of EPT species present in macro-invertebrate surveys No barriers impede movement of fish between the subwatershed and downstream receiving waters Stream channels show little evidence of ditching, enclosure, tile drainage or channelization Water quality monitoring indicates no standards violations during dry weather Stream and flood plain remain connected and regularly interact Stream drains to a downstream surface water supply Stream channels are generally stable, as determined by the Rosgen level analysis Stream habitat scores are rated at least fair to good
Subwatershed Criteria
Contains terrestrial species that are documented as rare, threatened and endangered Wetlands, flood plains and/or beaver complexes make up more than 10% of subwatershed area Inventoried conservation areas comprise more than 10% of subwatershed area More than 50% of the riparian forest corridor has forest cover and is either publicly owned or regulated Large contiguous forest tracts remain in the subwatershed (more than 40% in forest cover) Significant fraction of subwatershed is in public ownership and management Subwatershed connected to the watershed through a wide corridor Farming, ranching and livestock operations in the subwatershed utilize best management practices Prior development in the subwatershed has utilized stormwater treatment practices

1.4 Summary

The remainder of this report presents greater detail on the individual research studies that bear on the ICM. Chapter 2 profiles research on hydrologic indicators in urban streams, while Chapter 3 summarizes the status of current research on the impact of urbanization on physical habitat indicators. Chapter 4 presents a comprehensive review of the impact of urbanization on ten major stormwater pollutants. Finally, Chapter 5 reviews the growing body of research on the link between IC and biological indicators within urban streams and wetlands.



Chapter 2: Hydrologic Impacts of Impervious Cover

The natural hydrology of streams is fundamentally changed by increased watershed development. This chapter reviews the impacts of watershed development on selected indicators of stream hydrology.

This chapter is organized as follows:

2.1 Introduction
2.2 Increased Runoff Volume
2.3 Increased Peak Discharge Rates
2.4 Increased Bankfull Flow
2.5 Decreased Baseflow
2.6 Conclusions

2.1 Introduction

Fundamental changes in urban stream hydrology occur as a result of three changes in the urban landscape that accompany land development. First, large areas of the watershed are paved, rendering them impervious. Second, soils are compacted during construction, which significantly reduces their infiltration capabilities. Lastly, urban stormwater drainage systems are installed that increase the efficiency with which runoff is delivered to the stream (i.e., curbs and gutters, and storm drain pipes). Consequently, a greater fraction of annual rainfall is converted to surface runoff, runoff occurs more quickly, and peak flows become larger. Additionally, dry weather flow in streams may actually decrease because less groundwater recharge is available. Figure 6 illustrates the change in hydrology due to increased urban runoff as compared to pre-development conditions.

Research has demonstrated that the effect of watershed urbanization on peak discharge is more marked for smaller storm events. In particular, the bankfull, or channel forming flow, is increased in magnitude, frequency and duration. Increased bankfull flows have strong ramifications for sediment transport and channel enlargement. All of these changes in the natural water balance have impacts on the physical structure of streams, and ultimately affect water quality and biological diversity.

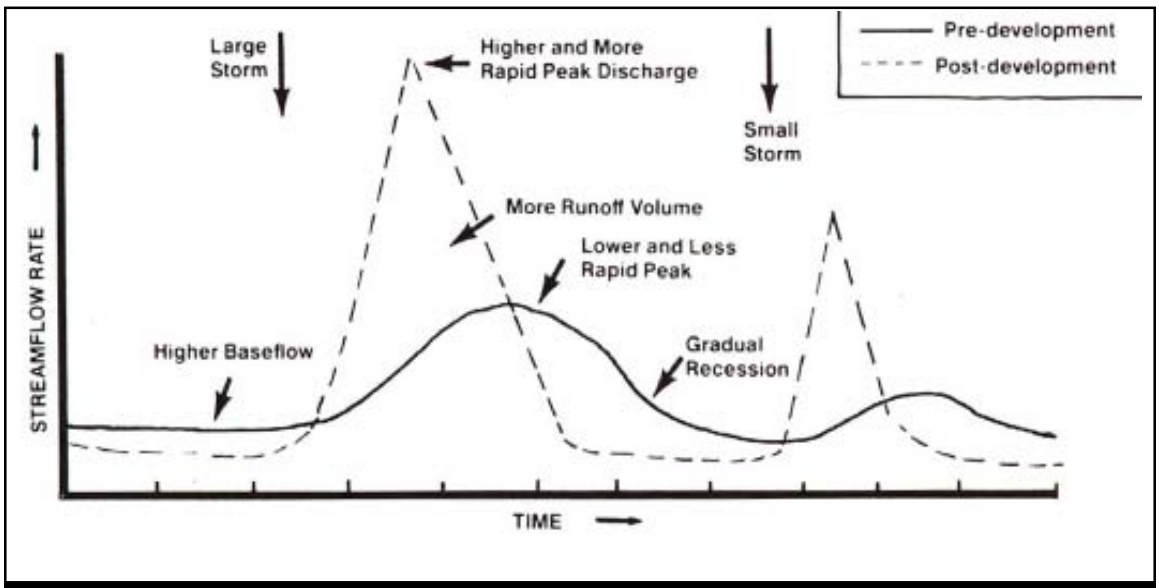
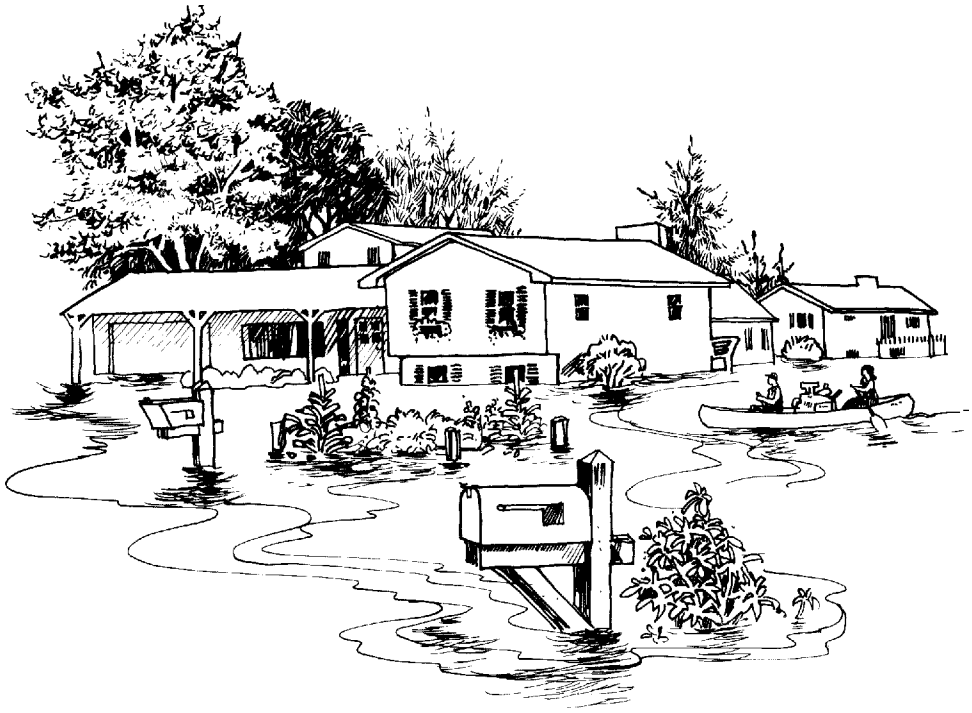


Figure 6: Altered Hydrograph in Response to Urbanization (Schueler, 1987)

The relationship between watershed IC and stream hydrology is widely accepted, and has been incorporated into many hydrologic engineering models over the past three decades. Several articles provide a good summary of these (Bicknell *et al.*, 1993; Hirsch *et al.*, 1990; HEC, 1977; Huber and Dickinson, 1988; McCuen and Moglen, 1988; Overton and Meadows, 1976; Pitt and Voorhees, 1989; Schueler, 1987; USDA, 1992; 1986).

The primary impacts of watershed development on stream hydrology are as follows:

- Increased runoff volume
- Increased peak discharge rates
- Increased magnitude, frequency, and duration of bankfull flows
- Diminished baseflow

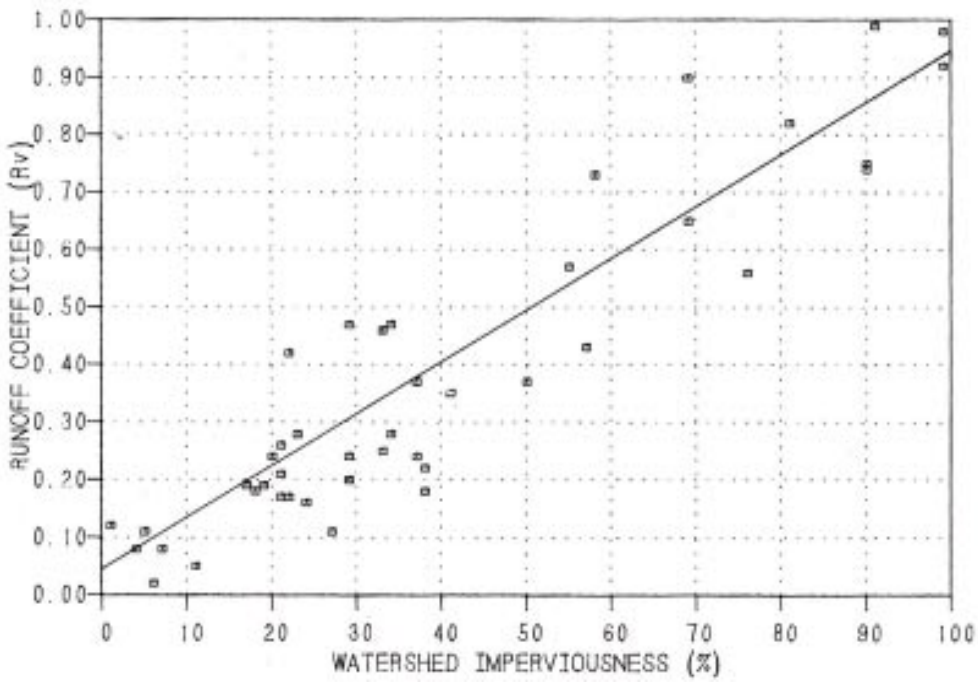


2.2 Increased Runoff Volume

Impervious cover and other urban land use alterations, such as soil compaction and storm drain construction, alter infiltration rates and increase runoff velocities and the efficiency with which water is delivered to streams. This decrease in infiltration and basin lag time can significantly increase runoff volumes. Table 7 reviews research on the impact of IC on runoff volume in urban streams. Schueler (1987) demonstrated that runoff values are directly related to subwatershed IC (Figure 7). Runoff data was derived from 44 small catchment areas across the country for EPA's Nationwide Urban Runoff Program.

Table 8 illustrates the difference in runoff volume between a meadow and a parking lot, as compiled from engineering models. The parking lot produces more than 15 times more runoff than a meadow for the same storm event.

Urban soils are also profoundly modified during the construction process. The compaction of urban soils and the removal of topsoil can decrease the infiltration capacity, causing increases in runoff volumes (Schueler, 2000). Bulk density is often used to measure soil compaction, and Table 9 illustrates how bulk density increases in many urban land uses.



Note: 44 small urban catchments monitored during the national NURP study

Figure 7: Runoff Coefficient vs. IC (Schueler, 1987)

Table 7: Research Review of Increased Runoff Volume and Peak Discharge in Urban Streams

Reference	Key Finding	Location
Increased Runoff Volume		
Schueler, 1987	Runoff coefficients were found to be strongly correlated with IC at 44 sites nationwide.	U.S.
Neller, 1988	Urban watershed produced more than seven times as much runoff as a similar rural watershed. Average time to produce runoff was reduced by 63% in urban watersheds compared to rural watersheds.	Australia
Increased Peak Discharge		
Hollis, 1975	Review of data from several studies showed that floods with a return period of a year or longer are not affected by a 5% watershed IC; small floods may be increased 10 times by urbanization; flood with a return period of 100 years may be doubled in size by a 30% watershed IC.	N/A
Leopold, 1968	Data from seven nationwide studies showed that 20% IC can cause the mean annual flood to double.	U.S.
Neller, 1988	Average peak discharge from urban watersheds was 3.5 times higher than peak runoff from rural watersheds.	Australia
Doll *et al.*, 2000	Peak discharge was greater for 18 urban streams versus 11 rural Piedmont streams.	NC
Sauer *et al.*, 1983	Estimates of flood discharge for various recurrence intervals showed that less than 50% watershed IC can result in a doubling of the 2-year, 10-year, and 100-year floods.	U.S.
Leopold, 1994	Watershed development over a 29-year period caused the peak discharge of the 10-year storm to more than double.	MD
Kibler *et al.*, 1981	Rainfall/runoff model for two watersheds showed that an increase in IC caused a significant increase in mean annual flood.	PA
Konrad and Booth, 2002	Evaluated streamflow data at 11 streams and found that the fraction of annual mean discharges was exceeded and maximum annual instantaneous discharges were related to watershed development and road density for moderately and highly developed watersheds.	WA

Table 8: Hydrologic Differences Between a Parking Lot and a Meadow (Schueler, 1994a)

Hydrologic or Water Quality Parameter	Parking Lot	Meadow
Runoff Coefficient	0.95	0.06
Time of Concentration (minutes)	4.8	14.4
Peak Discharge, two-year, 24-hour storm (cfs)	4.3	0.4
Peak Discharge Rate, 100-year storm (cfs)	12.6	3.1
Runoff Volume from one-inch storm (cu. ft)	3,450	218
Runoff Velocity @ two-year storm (ft/sec)	8	1.8

Key Assumptions:

2-yr, 24-hr storm = 3.1 in; 100-yr storm = 8.9 in.

Parking Lot: 100% imperviousness; 3% slope; 200ft flow length; hydraulic radius =.03; concrete channel; suburban Washington C values

Meadow: 1% impervious; 3% slope; 200 ft flow length; good vegetative condition; B soils; earthen channel

Source: Schueler, 1994a

Table 9: Comparison of Bulk Density for Undisturbed Soils and Common Urban Conditions (Schueler, 2000)

Undisturbed Soil Type or Urban Condition	Surface Bulk Density (grams/cubic centimeter)	Urban Condition	Surface Bulk Density (grams/cubic centimeter)
Peat	0.2 to 0.3	Urban Lawns	1.5 to 1.9
Compost	1.0	Crushed Rock Parking Lot	1.5 to 1.9
Sandy Soils	1.1 to 1.3	Urban Fill Soils	1.8 to 2.0
Silty Sands	1.4	Athletic Fields	1.8 to 2.0
Silt	1.3 to 1.4	Rights-of-Way and Building Pads (85%)	1.5 to 1.8
Silt Loams	1.2 to 1.5	Rights-of-Way and Building Pads (95%)	1.6 to 2.1
Organic Silts/Clays	1.0 to 1.2	Concrete Pavement	2.2
Glacial Till	1.6 to 2.0	Rock	2.65

2.3 Increased Peak Discharge Rate

Watershed development has a strong influence on the magnitude and frequency of flooding in urban streams. Peak discharge rates are often used to define flooding risk. Doll *et al.* (2000) compared 18 urban streams with 11 rural streams in the North Carolina Piedmont and found that unit area peak discharge was always greater in urban streams (Figure 8). Data from Seneca Creek, Maryland also suggest a similar increase in peak discharge. The watershed experienced significant growth during the 1950s and 1960s. Comparison of pre- and post-development gage records suggests that the peak 10-year flow event more than doubled over that time (Leopold, 1994).

Hollis (1975) reviewed numerous studies on the effects of urbanization on floods of different recurrence intervals and found that the effect of urbanization diminishes when flood recurrence gets longer (i.e., 50 and 100 years). Figure 9 shows the effect on flood magnitude in urban watersheds with 30% IC, and shows the one-year peak discharge rate increasing by a factor of 10, compared to an undeveloped watershed. In contrast, floods with a 100-year recurrence interval only double in size under the same watershed conditions.

Sauer *et al.* (1983) evaluated the magnitude of flooding in urban watersheds throughout the United States. An equation was developed for estimating discharge for floods of two-year, 10-year, and 100-year recurrence intervals. The equations used IC to account for increased runoff volume and a basin development factor to account for sewers, curbs and gutters, channel improvements and drainage development. Sauer noted that IC is not the dominant factor in determining peak discharge rates for extreme floods because these storm events saturate the soils of undeveloped watersheds and produce high peak discharge rates. Sauer found that watersheds with 50% IC can increase peak discharge for the two-year flood by a factor of four, the 10-year flood by a factor of three, and the 100-year flood by a factor of 2.5, depending on the basin development factor (Figure 10).

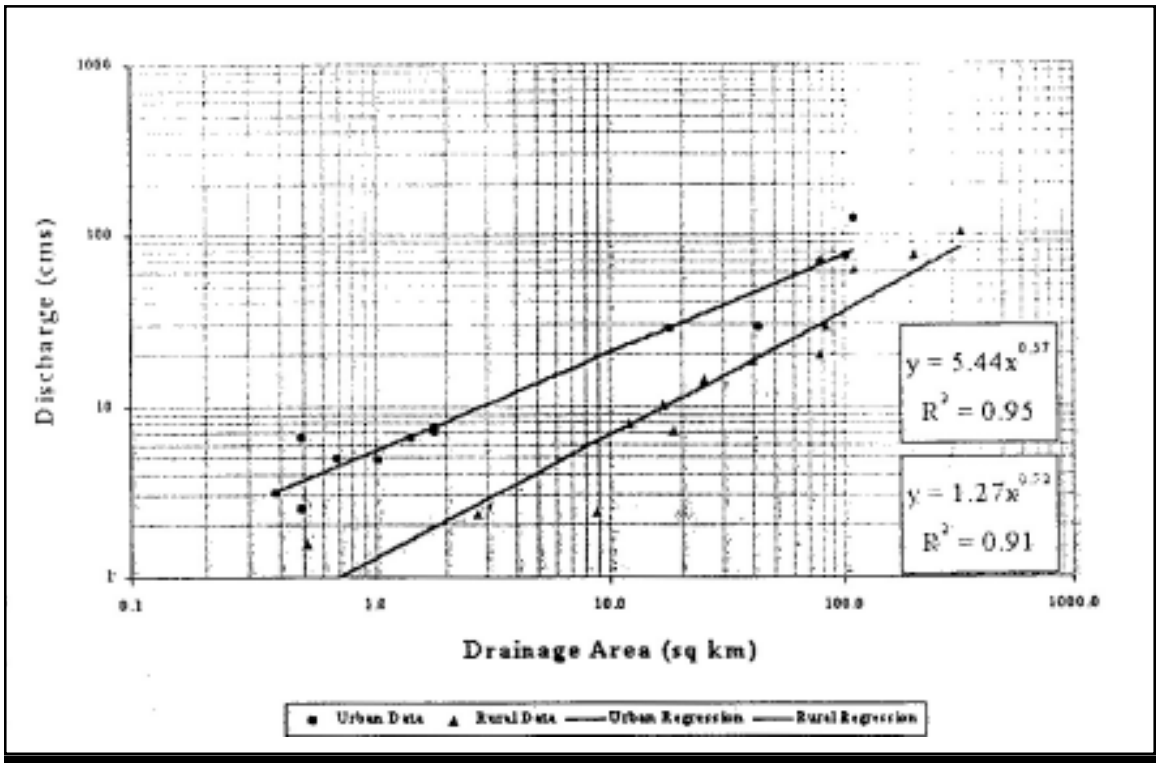


Figure 8: Peak Discharge for Urban and Rural Streams in North Carolina (Doll *et al.*, 2000)

2.4 Increased Bankfull Flow

Urbanization also increases the frequency and duration of peak discharge associated with smaller flood events (i.e., one- to two-year return storms). In terms of stream channel morphology, these more frequent bankfull flows are actually much more important than large flood events in forming the channel. In fact, Hollis (1975) demonstrated that urbanization increased the frequency and magnitude of bankfull flow events to a greater degree than the larger flood events.

An example of the increase in bankfull flow in arid regions is presented by the U.S. Geological Survey (1996), which compared the peak discharge rate from two-year storm events before and after watersheds urbanized in Parris Valley, California. Over an approximately 20-year period, watershed IC increased by 13.5%, which caused the two-year peak flow to more than double. Table 10 reviews other research studies on the relationship between watershed IC and bankfull flows in urban streams.

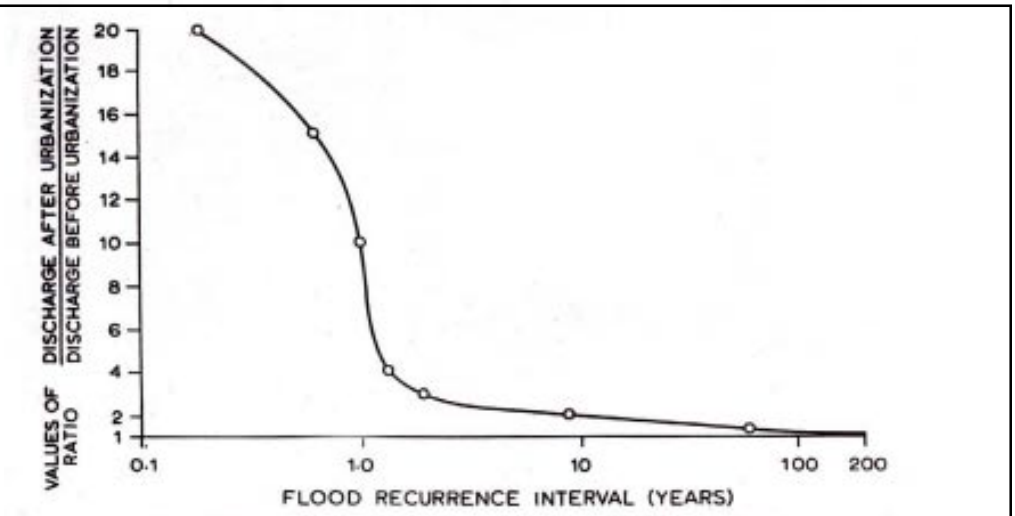


Fig. 3. Effect on flood magnitudes of paving 20% of a basin (based on Figure 2).

Figure 9: Effect on Flood Magnitudes of 30% Basin IC (Hollis, 1975)

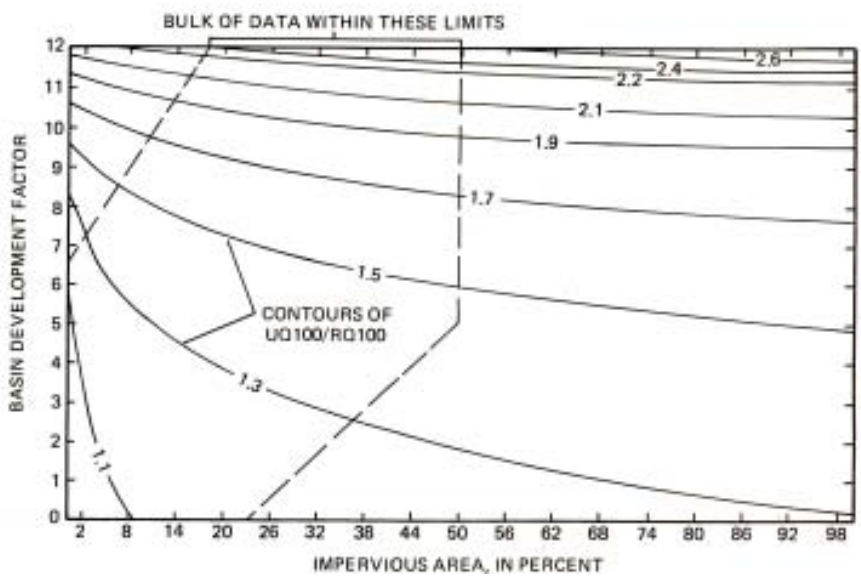


Figure 10: Relationship of Urban/Rural 100-Year Peak Flow Ratio to Basin Development Factor and IC (Sauer *et al.*, 1983)

Table 10: Research Review of Increased Bankfull Discharge in Urban Streams

Reference	Key Finding	Location
Booth and Reinelt, 1993	Using a simulation model and hydrologic data from four watersheds, it was estimated that more than 10% watershed IC may cause discharge from the two-year storm under current conditions to equal or exceed discharge from the 10-year storm under forested conditions.	WA
Fongers and Fulcher, 2001	Bankfull flow of 1200 cfs was exceeded more frequently over time with urbanization, and exceedence was three times as frequent from 1930s to 1990s.	MI
USGS, 1996	Over a 20-year period, IC increased 13.5%, and the two-year peak flow more than doubled in a semi-arid watershed.	CA
Henshaw and Booth, 2000	Two of three watersheds in the Puget Sound lowlands showed increasing flashiness over 50 years with urbanization.	WA
Leopold, 1968	Using hydrologic data from a nine-year period for North Branch Brandywine Creek, it was estimated that for a 50% IC watershed, bankfull frequency would be increased fourfold.	PA
Leopold, 1994	Bankfull frequency increased two to seven times after urbanization in Watts Branch.	MD
MacRae, 1996	For a site downstream of a stormwater pond in Markham, Ontario hours of exceedence of bankfull flows increased by 4.2 times after the watershed urbanized (34% IC)	Ontario

Leopold (1968) evaluated data from seven nationwide studies and extrapolated this data to illustrate the increase in bankfull flows due to urbanization. Figure 11 summarizes the relationship between bankfull flows over a range of watershed IC. For example, watersheds that have 20% IC increase the number of flows equal to or greater than bankfull flow by a factor of two. Leopold (1994) also observed a dramatic increase in the frequency of the bankfull event in Watts Branch, an urban subwatershed in Rockville, Maryland. This watershed experienced significant urban development during the 1950s and 1960s. Leopold compared gage records and found that the bankfull storm event frequency increased from two to seven times per year from 1958 to 1987.

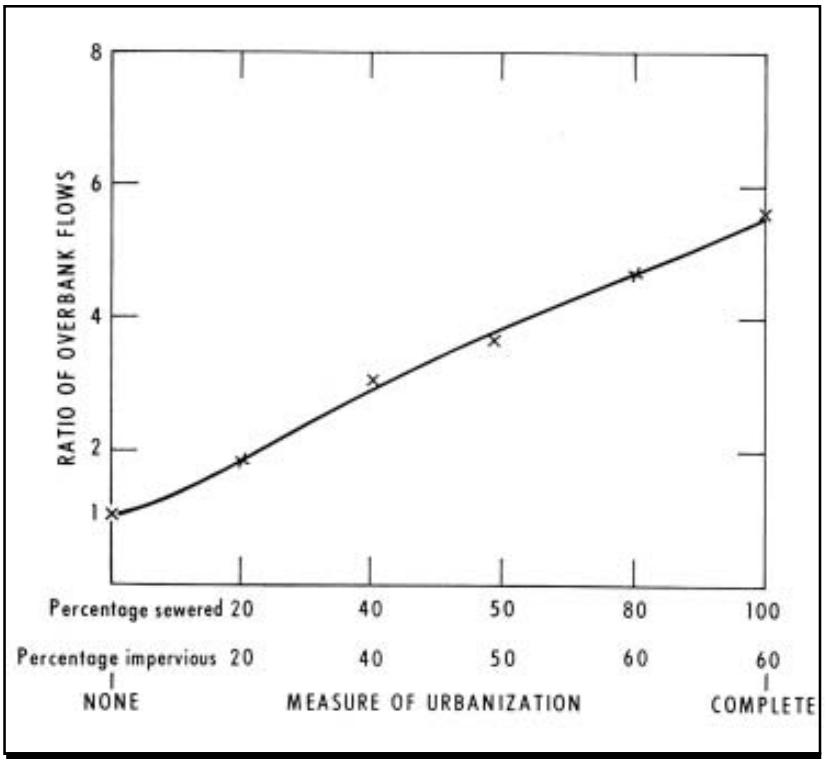


Figure 11: Increase in Bankfull Flows Due to Urbanization (Leopold, 1968)

More recent data on bankfull flow frequency was reported for the Rouge River near Detroit, Michigan by Fongers and Fulcher (2001). They noted that channel-forming flow (1200 cfs) was exceeded more frequently as urbanization increased in the watershed and had become three times more frequent between 1930 and 1990 (Figure 12).

McCuen and Moglen (1988) have documented the increase in duration of bankfull flows in response to urbanization using hydrology models. MacRae (1996), monitored a stream in Markham, Ontario downstream of a stormwater pond and found that the hours of

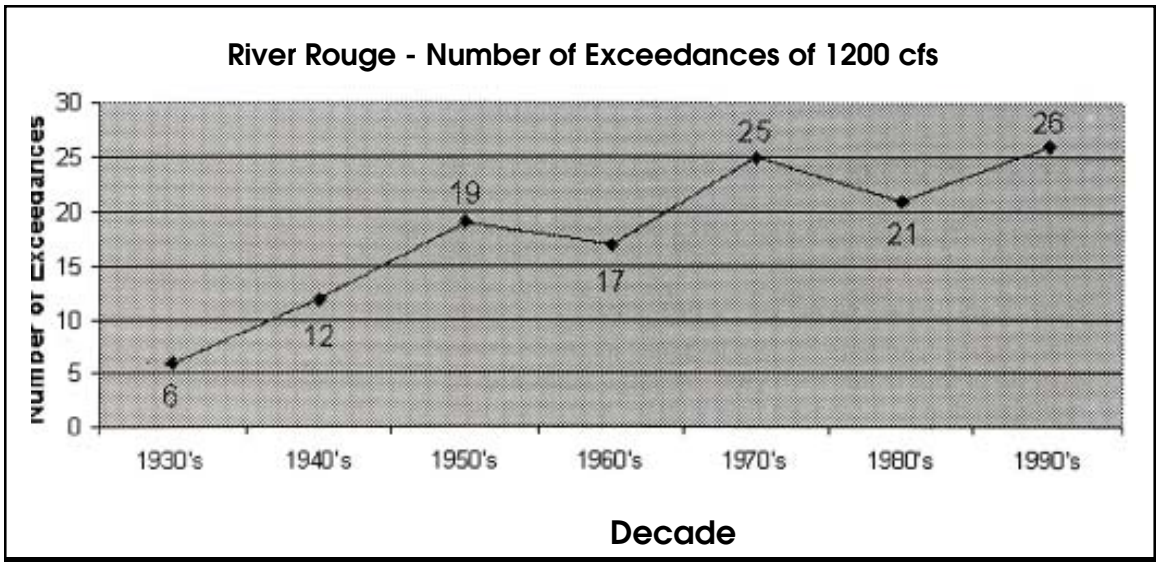


Figure 12: Increase in Number of Exceedences of Bankfull Flow Over Time With Urbanization in the Rouge River, MT (Fongers and Fulcher, 2001)

exceedence of bankfull flows increased by a factor of 4.2 once watershed IC exceeded 30%. Modeling for seven streams also downstream of stormwater ponds in Surrey, British Columbia also indicated an increase in bankfull flooding in response to watershed development (MacRae, 1996).

Watershed IC also increases the "flashiness" of stream hydrographs. Flashiness is defined here as the percent of daily flows each year that exceeds the mean annual flow. Henshaw and Booth (2000) evaluated seven urbanized watersheds in the Puget Sound lowland streams and tracked changes in flashiness over 50 years (Figure 13). The most urbanized watersheds experienced flashy discharges. Henshaw and Booth concluded that increased runoff in urban watersheds leads to higher but shorter-duration peak discharges.

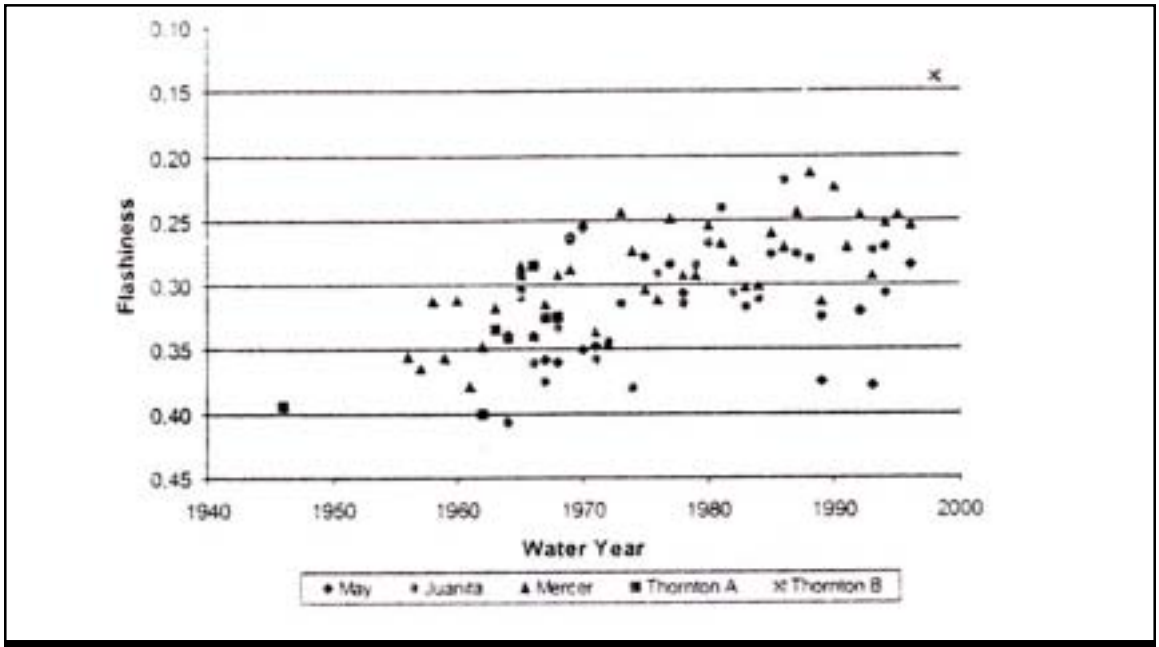


Figure 13: Percent of Gage Reading Above Mean Annual Flow for Puget Sound Lowland Streams (Henshaw and Booth, 2000)

2.5 Decreased Baseflow

As IC increases in a watershed, less groundwater infiltration is expected, which can potentially decrease stream flow during dry periods, (i.e. baseflow). Several East Coast studies provide support for a decrease in baseflow as a result of watershed development. Table 11 reviews eight research studies on baseflow in urban streams.

Klein (1979) measured baseflow in 27 small watersheds in the Maryland Piedmont and reported an inverse relationship between IC and baseflow (Figure 14). Spinello and Simmons (1992) demonstrated that baseflow in two urban Long Island streams declined seasonally as a result of urbanization (Figure 15). Saravanapavan (2002) also found that percentage of baseflow decreased in direct proportion to percent IC for 13 subwatersheds of the Shawsheen River watershed in Massachusetts (Figure 16).

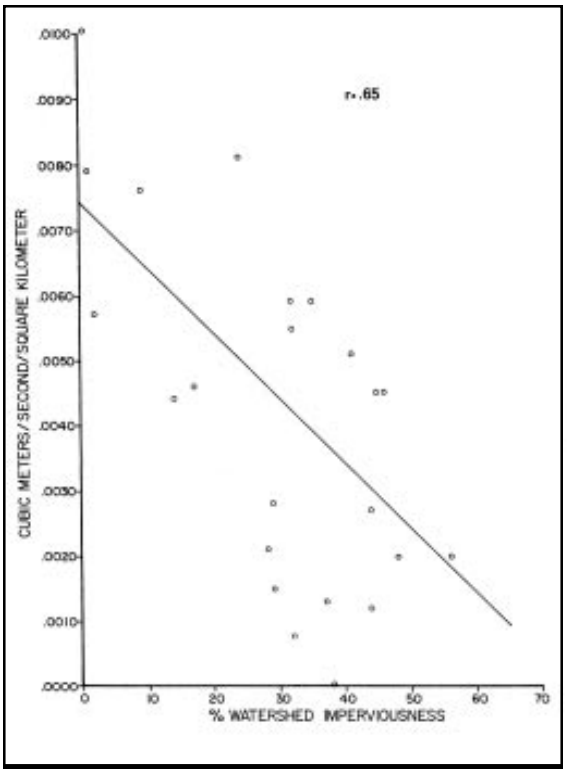
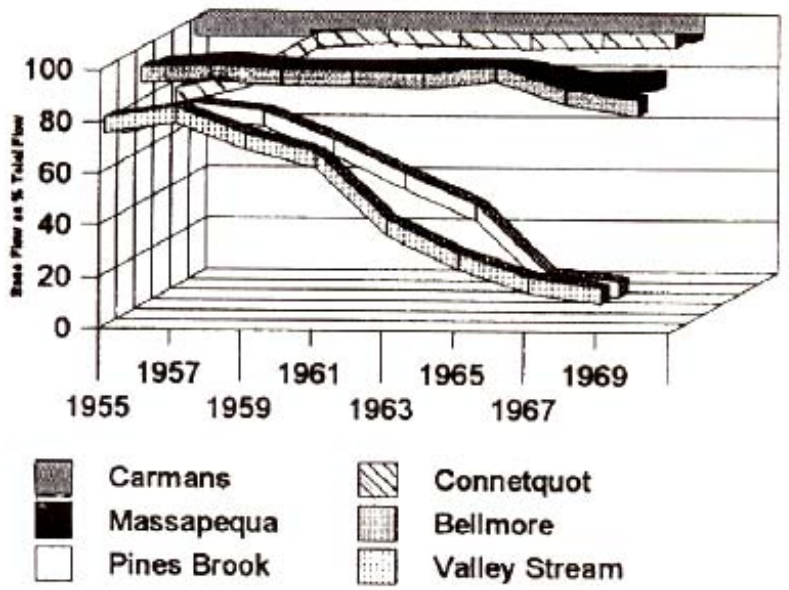


Figure 14: Relationship Between Baseflow and Watershed IC in the Streams on Maryland Piedmont (Klein, 1979)

Table 11: Research Review of Decreased Baseflow in Urban Streams

Reference	Key Finding	Location
Finkenbine *et al.*, 2000	Summer base flow was uniformly low in 11 streams when IC reached 40% or greater.	Vancouver
Klein, 1979	Baseflow decreased as IC increased in Piedmont streams.	MD
Saravanapavan, 2002	Percentage of baseflow decreased linearly as IC increased for 13 subwatersheds of Shawsheen River watershed.	MA
Simmons and Reynolds, 1982	Dry weather flow dropped 20 to 85% after development in several urban watersheds on Long Island.	NY
Spinello and Simmons, 1992	Baseflow in two Long Island streams went dry as a result of urbanization.	NY
Konrad and Booth, 2002	No discernable trend over many decades in the annual seven day low flow discharge for 11 Washington streams.	WA
Wang *et al.*, 2001	Stream baseflow was negatively correlated with watershed IC in 47 small streams, with an apparent breakpoint at 8 to 12% IC.	WI
Evett *et al.*, 1994	No clear relationship between dry weather flow and urban and rural streams in 21 larger watersheds.	NC



Notes:

Carmans and Connetquot: Rural/suburban, watersheds are unsewered

Bellmore and Massapequa: Moderately urbanized, not sewered until 1989

Valley Stream and Pine Brook: Urbanized and densely populated watersheds, sewer systems completed in 1960s

1953-1964: Period of sanitary sewer construction in eastern Nassau County

1962-1966: Drought years

Figure 15: Baseflow Response to Urbanization in Long Island Streams (Spinello and Simmons, 1992)

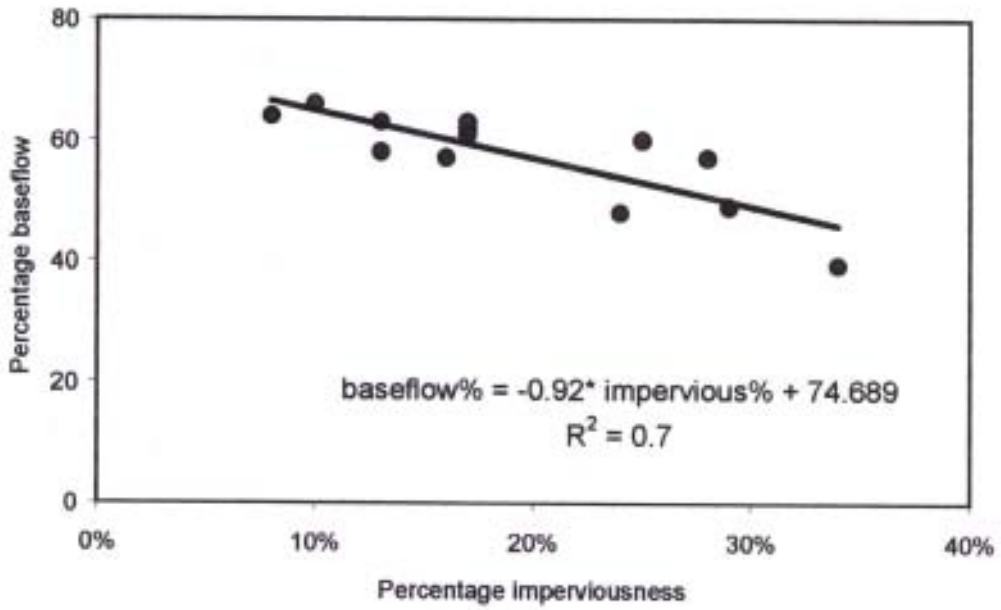


Figure 16: Relationship Between Percentage Baseflow and Percent IC in Massachusetts Streams (Saravanapan, 2002)

Finkebine *et al.* (2000) monitored summer baseflow in 11 streams near Vancouver, British Columbia and found that stream base flow was uniformly low due to decreased groundwater recharge in watersheds with more than 40% IC (Figure 17). Baseflow velocity also consistently decreased when IC increased (Figure 18). The study cautioned that other factors can affect stream baseflow, such as watershed geology and age of development.

Other studies, however, have not been able to establish a relationship between IC and declining baseflow. For example, a study in North Carolina could not conclusively determine that urbanization reduced baseflow in larger urban and suburban watersheds in that area (Evett *et al.*, 1994). In some cases, stream baseflow is supported by deeper aquifers or originate in areas outside the surface watershed boundary. In others, baseflow is augmented by leaking sewers, water pipes and irrigation return flows.

This appears to be particularly true in arid and semi-arid areas, where baseflow can actually increase in response to greater IC (Hollis, 1975). For instance, Crippen and Waananen (1969) found that Sharon Creek near San Francisco changed from an ephemeral stream into a perennial stream after urban development. Increased infiltration from lawn watering and return flow from sewage treatment plants are two common sources of augmented baseflows in these regions (Caraco, 2000a).

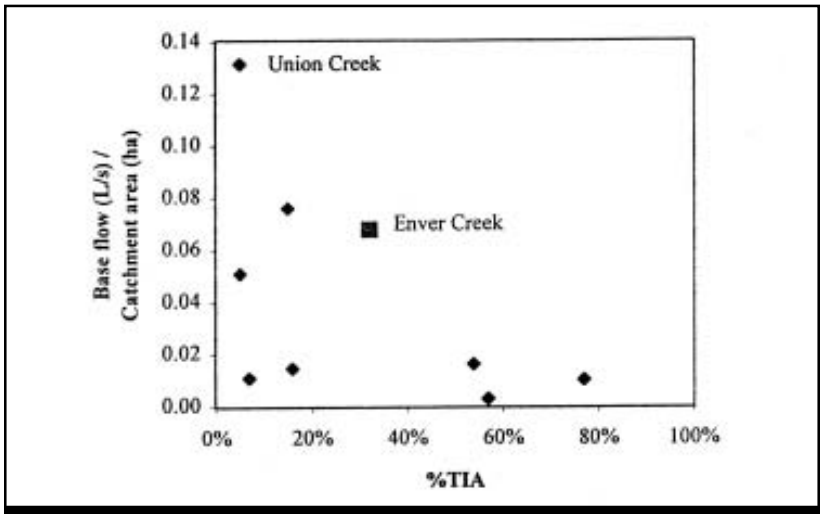


Figure 17: Effect of IC on Summer Baseflow in Vancouver Streams (Finkerbine *et al.*, 2000)

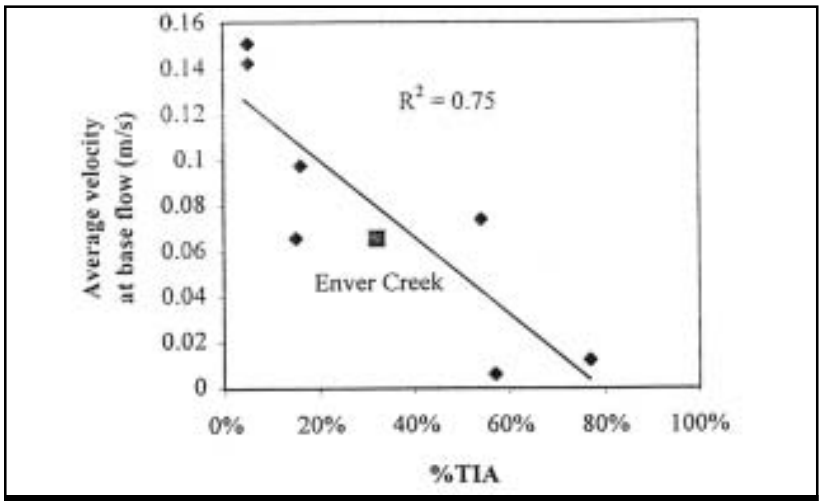


Figure 18: Effect of Watershed IC on Summer Stream Velocity in Vancouver Streams (Finkerbine *et al.*, 2000)

2.6 Conclusions

The changes in hydrology indicators caused by watershed urbanization include increased runoff volume; increased peak discharge; increased magnitude, frequency and duration of bankfull flows; flashier/less predictable flows; and decreased baseflow. Many studies support the direct relationship between IC and these indicators. However, at low levels of watershed IC, site-specific factors such as slope, soils, types of conveyance systems, age of development, and watershed dimensions often play a stronger role in determining a watershed's hydrologic response.

Overall, the following conclusions can be drawn from the relationship between watershed IC and hydrology indicators:

- Strong evidence exists for the direct relationship between watershed IC and increased stormwater runoff volume and peak discharge. These relationships are considered so strong that they have been incorporated into widely accepted engineering models.
- The relationship between IC and bankfull flow frequency has not been extensively documented, although abundant data exists for differences between urban and non-urban watersheds.
- The relationship between IC and declining stream flow is more ambiguous and appears to vary regionally in response to climate and geologic factors, as well as water and sewer infrastructure.

The changes in hydrology indicators caused by watershed urbanization directly influence physical and habitat characteristics of streams. The next chapter reviews how urban streams physically respond to the major changes to their hydrology.

Chapter 3: Physical Impacts of Impervious Cover

A growing body of scientific literature documents the physical changes that occur in streams undergoing watershed urbanization. This chapter discusses the impact of watershed development on various measures of physical habitat in urban stream channels and is organized as follows:

3.1 Difficulty in Measuring Habitat
3.2 Changes in Channel Geometry
3.3 Effect on Composite Indexes of Stream Habitat
3.4 Effect on Individual Elements of Stream Habitat
3.5 Increased Stream Warming
3.6 Alteration of Stream Channel Network
3.7 Conclusion

This chapter reviews the available evidence on stream habitat. We begin by looking at geomorphological research that has examined how the geometry of streams changes in response to altered urban hydrology. The typical response is an enlargement of the cross-sectional area of the stream channel through a process of channel incision, widening, or a combination of both. This process triggers an increase in bank and/or bed erosion that increases sediment transport from the stream, possibly for several decades or more.

Next, we examine the handful of studies that have evaluated the relationship between watershed development and composite indicators of stream habitat (such as the habitat Rapid Bioassessment Protocol, or RBP). In the fourth section, we examine the dozen studies that have evaluated how individual habitat elements respond to watershed development. These studies show a consistent picture. Generally, streams with low levels of IC have stable banks, contain considerable large woody debris (LWD) and possess complex habitat structure. As watershed IC increases, however, urban streambanks become increasingly unstable, streams lose LWD, and they develop a more simple and uniform habitat structure. This is typified by reduced pool depths, loss of pool and riffle sequences, reduced channel roughness and less channel sinuosity.

Water temperature is often regarded as a key habitat element, and the fifth section describes the stream warming effect observed in urban streams in six studies. The last section looks at the effect of watershed development on the stream channel network as a whole, in regard to headwater stream loss and the creation of fish barriers.

3.1 Difficulty in Measuring Habitat

The physical transformation of urban streams is perhaps the most conspicuous impact of watershed development. These dramatic physical changes are easily documented in sequences of stream photos with progressively greater watershed IC (see Figure 19). Indeed, the network of headwater stream channels generally disappears when watershed IC exceeds 60% (CWP).

3.1.1 The Habitat Problem

It is interesting to note that while the physical impacts of urbanization on streams are widely accepted, they have rarely been documented by the research community. As a consequence, no predictive models exist to quantify how physical indicators of stream habitat will decline in response to watershed IC, despite the fact that most would agree that some kind of decline is expected (see Table 12).

Figure 19: Urban Stream Channels with Progressively Greater IC

The main reason for this gap is that "habitat" is extremely hard to define, and even more difficult to measure in the field. Most indices of physical habitat involve a visual and qualitative assessment of 10 or more individual habitat elements that are perceived by fishery and stream biologists to contribute to quality stream habitat. Since these indices include many different habitat elements, each of which is given equal weight, they have not been very useful in discriminating watershed effects (Wang *et al.*, 2001).

Researchers have had greater success in relating individual habitat elements to watershed conditions, such as large woody debris (LWD), embeddedness, or bank stability. Even so, direct testing has been limited, partly because individual habitat elements are hard to measure and are notoriously variable in both space and time. Consider bank stability for a moment. It would be quite surprising to see a highly urban stream that did not have unstable banks. Yet, the hard question is exactly how would bank instability be quantitatively measured? Where would it be measured — at a point, a cross-section, along a reach, on the left bank or the right?

Geomorphologists stress that no two stream reaches are exactly alike, due to differences in gradient, bed material, sediment transport, hydrology, watershed history and many other factors. Consequently, it is difficult to make controlled comparisons among different streams. Indeed, geomorphic theory stresses that individual stream reaches respond in a highly dynamic way to changes in watershed hydrology and sediment transport, and can take several decades to fully adjust to a new equilibrium.

Table 12: Physical Impacts of Urbanization on Streams

Specific Impacts
Sediment transport modified Channel enlargement Channel incision Stream embeddedness Loss of large woody debris Changes in pool/riffle structure Loss of riparian cover Reduced channel sinuosity Warmer in-stream temperatures Loss of cold water species and diversity Channel hardening Fish blockages Loss of 1st and 2nd order streams through storm drain enclosure

Returning to our example of defining bank stability, how might our measure of bank instability change over time as its watershed gradually urbanizes, is built out, and possibly reaches a new equilibrium over several decades? It is not very surprising that the effect of watershed development on stream habitat is widely observed, yet rarely measured.

3.2 Changes in Stream Geometry

As noted in the last chapter, urbanization causes an increase in the frequency and duration of bankfull and sub-bankfull flow events in streams. These flow events perform more "effective work" on the stream channel, as defined by Leopold (1994). The net effect is that an urban stream channel is exposed to more shear stress above the critical threshold needed to move bank and bed sediments (Figure 20). This usually triggers a cycle of active bank erosion and greater sediment transport in urban streams. As a consequence, the stream channel adjusts by expanding its cross-sectional area, in order to effectively accommodate greater flows and sediment supply. The stream channel can expand by incision, widening, or both. Incision refers to stream down-cutting through the streambed, whereas widening refers to lateral erosion of the stream bank and its flood plain (Allen and Narramore, 1985; Booth, 1990; Morisawa and LaFlure, 1979).

3.2.1 Channel Enlargement

A handful of research studies have specifically examined the relationship between watershed development and stream channel enlargement (Table 13). These studies indicate that stream cross-sectional areas can enlarge by as much as two to eight times in response to urbanization, although the process is complex and may take several decades to complete (Pizzuto *et al*., 2000; Caraco, 2000b; Hammer, 1972). An example of channel enlargement is provided in Figure 21, which shows how a stream cross-section in Watts Branch near Rockville, Maryland has expanded in response to nearly five decades of urbanization (i.e., watershed IC increased from two to 27%).

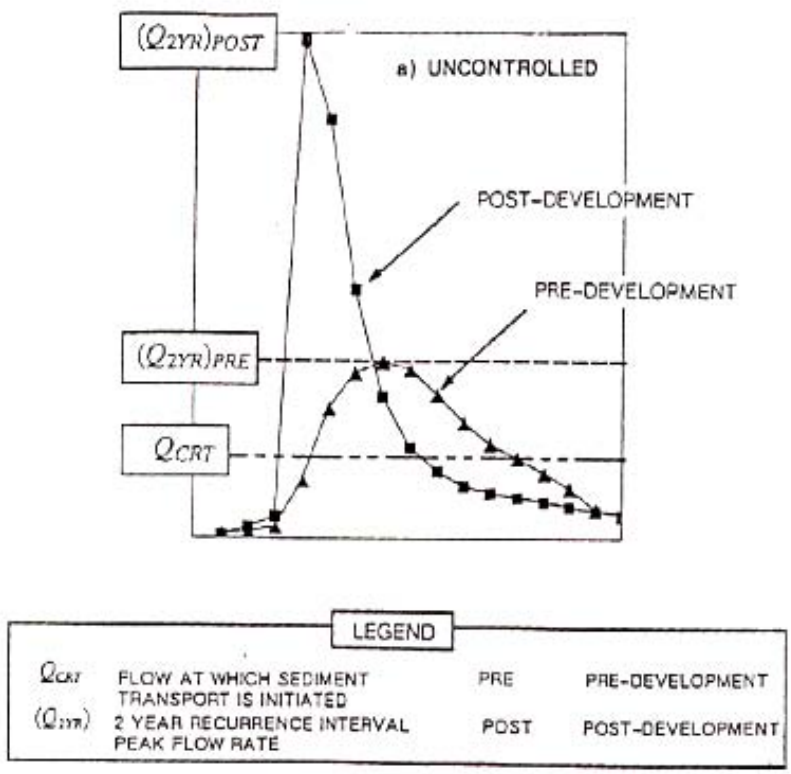


Figure 20: Increased Shear Stress from a Hydrograph (MacRae and Rowney, 1992)

Table 13: Research Review of Channel Enlargement and Sediment Transport in Urban Streams		
Reference	**Key Finding**	**Location**
% IC used as Indicator		
Caraco, 2000b	Reported enlargement in ratios of 1.5 to 2.2 for 10 stream reaches in Watts Branch and computed ultimate enlargement ratios of 2.0	MD
MacCrae and De Andrea, 1999	Introduced the concept of ultimate channel enlargement based on watershed IC and channel characteristics.	Ontario, TX
Morse, 2001	Demonstrated increased erosion rates with increases in IC (channels were generally of the same geomorphic type).	ME
Urbanization Used as Indicator		
Allen and Narramore, 1985	Enlargement ratios in two urban streams ranged from 1.7 to 2.4.	TX
Bledsoe, 2001	Reported that channel response to urbanization depends on other factors in addition to watershed IC including geology, vegetation, sediment and flow regimes.	N/A
Booth and Henshaw, 2001	Evaluated channel cross section erosion rates and determined that these rates vary based on additional factors including the underlying geology, age of development and gradient.	WA
Hammer, 1972	Enlargement ratios ranged from 0.7 to 3.8 in urban watersheds.	PA
Neller, 1989	Enlargement ratios in small urban catchments ranged from two to 7.19, the higher enlargement ratios were primarily from incision occurring in small channels.	Australia
Pizzuto *et al.*, 2000	Evaluated channel characteristics of paired urban and rural streams and demonstrated median bankfull cross sectional increase of 180%. Median values for channel sinuosity were 8% lower in urban streams; Mannings N values were found to be 10% lower in urban streams.	PA
Hession *et al.*, *in press*	Bankfull widths for urban streams were significantly wider than non-urban streams in 26 paired streams. Forested reaches were consistently wider than non-forested reaches in urban streams.	MD, DE, PA
Dartiguenave *et al.*, 1997	Bank erosion accounted for up to 75% of the sediment transport in urban watersheds.	TX
Trimble, 1997	Demonstrated channel enlargement over time in an urbanizing San Diego Creek; Bank erosion accounted for over 66% of the sediment transport.	CA

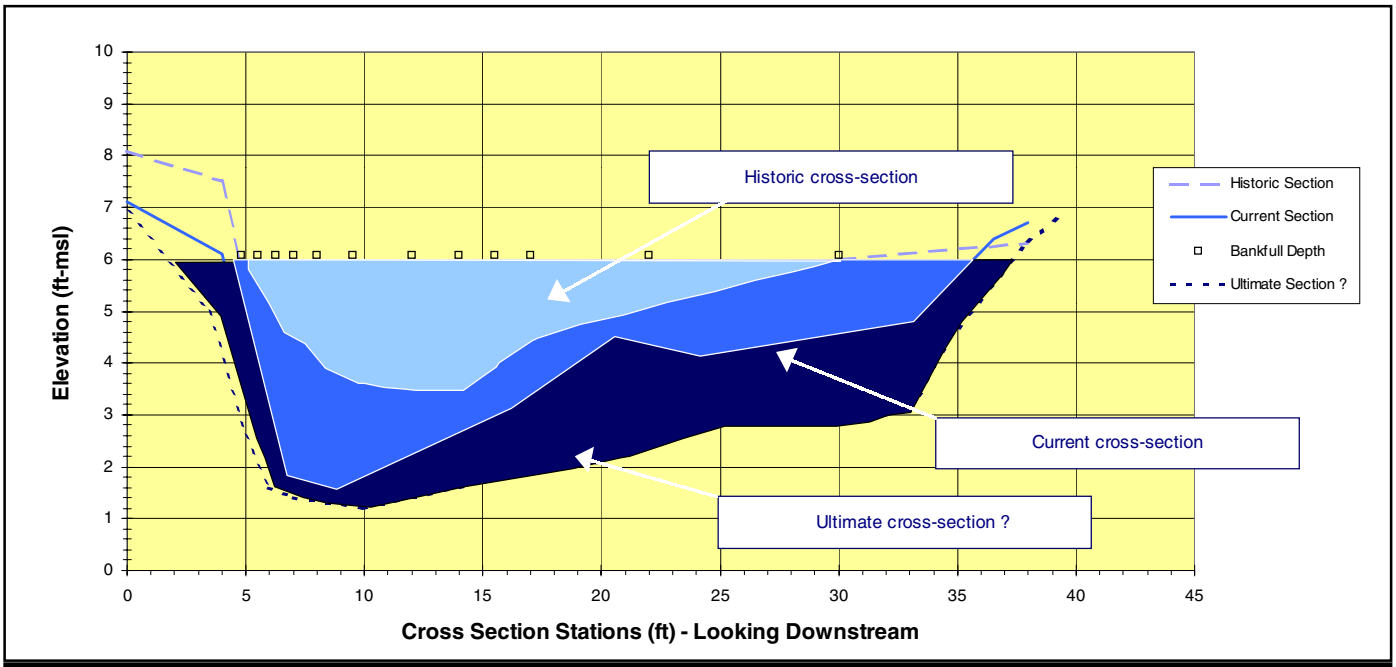


Figure 21: Stream Channel Enlargement in Watts Branch, MD 1950-2000 (Caraco, 2000b)

Some geomorphologists suggest that urban stream channels will reach an "ultimate enlargement" relative to pre-developed channels (MacRae and DeAndrea, 1999) and that this can be predicted based on watershed IC, age of development, and the resistance of the channel bed and banks. A relationship between ultimate stream channel enlargement and watershed IC has been developed for alluvial streams in Texas, Vermont and Maryland (Figure 22). Other geomorphologists such as Bledsoe (2001) and Booth and Henshaw (2001) contend that channel response to urbanization is more complex, and also depends on geology, grade control, stream gradient and other factors.

Channel incision is often limited by grade control caused by bedrock, cobbles, armored substrates, bridges, culverts and pipelines. These features can impede the downward erosion of the stream channel and thereby limit the incision process. Stream incision can become severe in streams that have softer substrates such as sand, gravel and clay (Booth, 1990). For example, Allen and Narramore (1985) showed that channel enlargement in chalk channels was 12 to 67% greater than in shale channels near Dallas, Texas. They attributed the differences to the softer substrate, greater velocities and higher shear stress in the chalk channels.

Neller (1989) and Booth and Henshaw (2001) also report that incised urban stream channels possess cross-sectional areas that are larger than would be predicted based on watershed area or discharge alone. This is due to the fact that larger floods are often contained within the stream channel rather than the floodplain. Thus, incised channels often result in greater erosion and geomorphic change. In general, stream conditions that can foster incision include erodible substrates, moderate to high stream gradients, and an absence of grade control features.

Channel widening occurs more frequently when streams have grade control and the stream has cut into its bank, thereby expanding its cross-sectional area. Urban stream channels often have artificial grade controls caused by frequent culverts and road crossings. These grade controls often cause localized sediment deposition that can reduce the capacity of culverts and bridge crossings to pass flood waters.

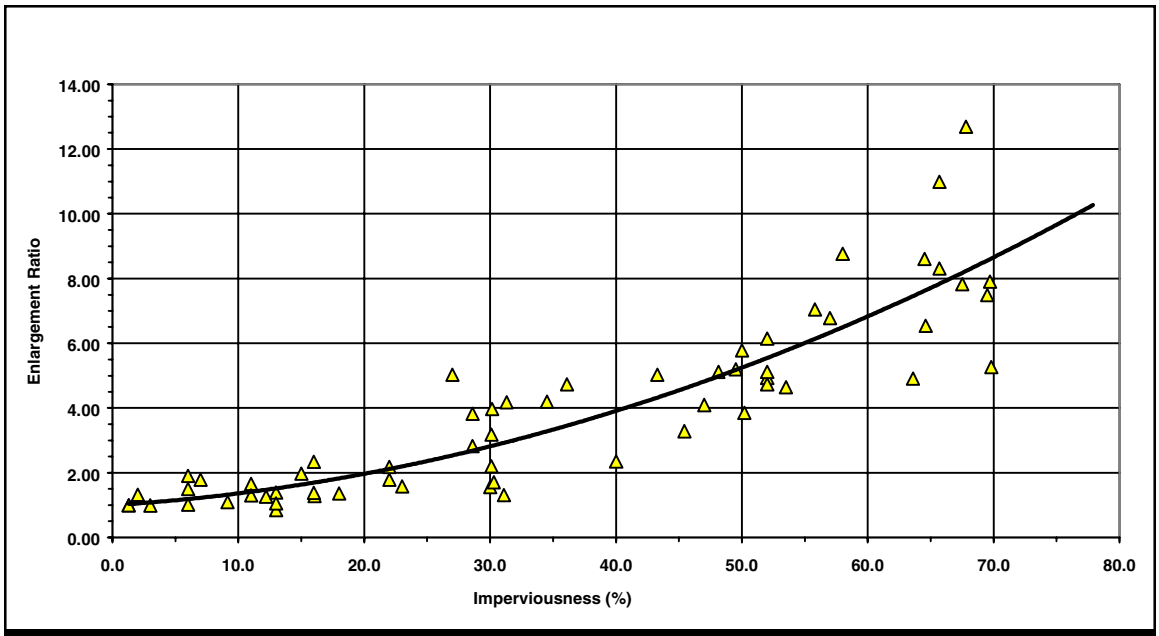


Figure 22: Ultimate Channel Enlargement in MD, UT and TX Alluvial Streams (MacRae and DeAndrea, 1999 and CWP, 2001b)

The loss of flood plain and riparian vegetation has been strongly associated with watershed urbanization (May *et al.*, 1997). A few studies have shown that the loss of riparian trees can result in increased erosion and channel migration rates (Beeson and Doyle, 1995 and Allmendinger *et al.*, 1999). For example, Beeson and Doyle (1995) found that meander bends with vegetation were five times less likely to experience significant erosion from a major flood than non-vegetated meander bends.Hession *et al.* (in press) observed that forested reaches consistently had greater bankfull widths than non-forested reaches in a series of urban streams in Pennsylvania, Maryland and Delaware.

3.2.2 Effect of Channel Enlargement on Sediment Yield

Regardless of whether a stream incises, widens, or does both, it will greatly increase sediment transport from the watershed due to erosion. Urban stream research conducted in California and Texas suggests that 60 to 75% of the sediment yield of urban watersheds can be derived from channel erosion (Trimble, 1997 and Dartingunave *et al.*, 1997) This can be compared to estimates for rural streams where channel erosion accounts for only five to 20% of the annual sediment yield (Collins *et al.*, 1997 and Walling and Woodward, 1995).

Some geomorphologists speculate that urban stream channels will ultimately adjust to their post-development flow regime and sediment supply. Finkenbine *et al.* (2000) observed these conditions in Vancouver streams, where study streams eventually stabilized two decades after the watersheds were fully developed. In older urban streams, reduced sediment transport can be expected when urbanization has been completed. At this point, headwater stream channels are replaced by storm drains and pipes, which can transport less sediment. The lack of available sediment may cause downstream channel erosion, due to the diminished sediment supply found in the stream.

3.3 Effect on Composite Measures of Stream Habitat

Composite measures of stream habitat refer to assessments such as EPA's Habitat Rapid Bioassessment Protocol (RBP) that combine multiple habitat elements into a single score or index (Barbour *et al*., 1999). For example, the RBP requires visual assessment of 10 stream habitat elements, including embeddedness, epifaunal substrate quality, velocity/depth regime, sediment deposition, channel flow status, riffle frequency, bank stabilization, streambank vegetation and riparian vegetation width. Each habitat element is qualitatively scored on a 20 point scale, and each element is weighted equally to derive a composite score for the stream reach.

To date, several studies have found a relationship between declining composite habitat indicator scores and increasing watershed IC in different eco-regions of the United States. A typical pattern in the composite habitat scores is provided for headwater streams in Maine (Morse, 2001; Figure 23). This general finding has been reported in the mid-Atlantic, Northeast and the Northwest (Black and Veatch, 1994; Booth and Jackson, 1997; Hicks and Larson, 1997; Maxted and Shaver, 1997; Morse, 2001; Stranko and Rodney, 2001).

However, other researchers have found a much weaker relationship between composite habitat scores and watershed IC. Wang and his colleagues (2001) found that composite habitat scores were not correlated with watershed IC in Wisconsin streams, although it was correlated with individual habitat elements, such as streambank erosion. They noted that many agricultural and rural streams had fair to poor composite habitat scores, due to poor riparian management and sediment deposition. The same basic conclusion was also reported for streams of the Maryland Piedmont (MNCPPC, 2000).

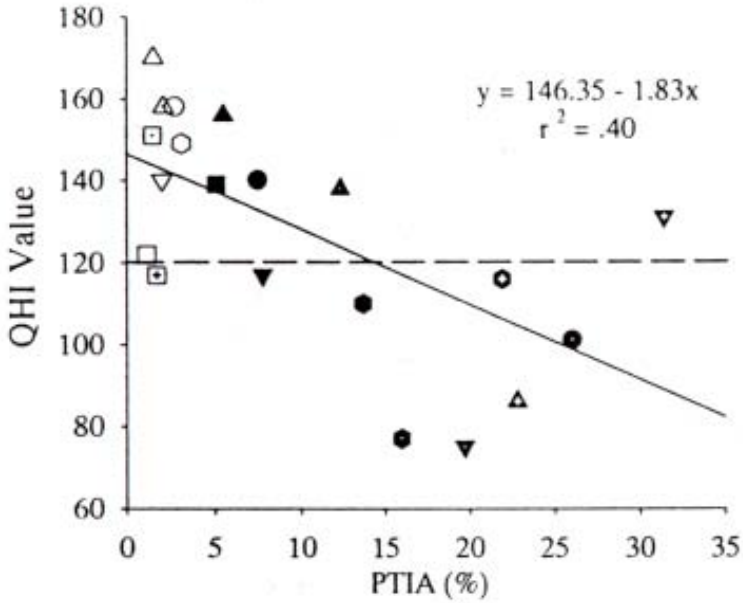


Figure 23: Relationship Between Habitat Quality and IC in Maine Streams (Morse, 2001)

3.4 Effect on Individual Elements of Stream Habitat

Roughly a dozen studies have examined the effect of watershed development on the degradation of individual stream habitat features such as bank stability, embeddedness, riffle/pool quality, and loss of LWD (Table 14). Much of this data has been acquired from the Pacific Northwest, where the importance of such habitat for migrating salmon has been a persistent management concern.

3.4.1 Bank Erosion and Bank Stability

It is somewhat surprising that we could only find one study that related bank stability or bank erosion to watershed IC. Conducted by Booth (1991) in the streams of the Puget Sound lowlands, the study reported that stream banks were consistently rated as stable in watersheds with less than 10% IC, but became progressively more unstable above this threshold. Dozens of stream assessments have found high rates of bank erosion in urban streams, but none, to our knowledge, has systematically related the prevalence or severity of bank erosion to watershed IC. As noted earlier, this may reflect the lack of a universally recognized method to measure comparative bank erosion in the field.

3.4.2 Embeddedness

Embeddedness is a term that describes the extent to which the rock surfaces found on the stream bottom are filled in with sand, silts and clay. In a healthy stream, the interstitial pores between cobbles, rock and gravel generally lack fine sediments, and are an active habitat zone and detrital processing area. The increased sediment transport in urban streams can rapidly fill up these pores in a process known as embedding. Normally, embeddedness is visually measured in riffle zones of streams. Riffles tend to be an important habitat for aquatic insects and fish (such as darters and sculpins). Clean stream substrates are also critical to trout and salmon egg incubation and embryo development. May *et al.* (1997) demonstrated that the percent of fine sediment particles in riffles generally increased with watershed IC (Figure 24). However, Finkenbine *et al.* (2000) reported that embeddedness eventually decreased slightly after watershed land use and sediment transport had stabilized for 20 years.

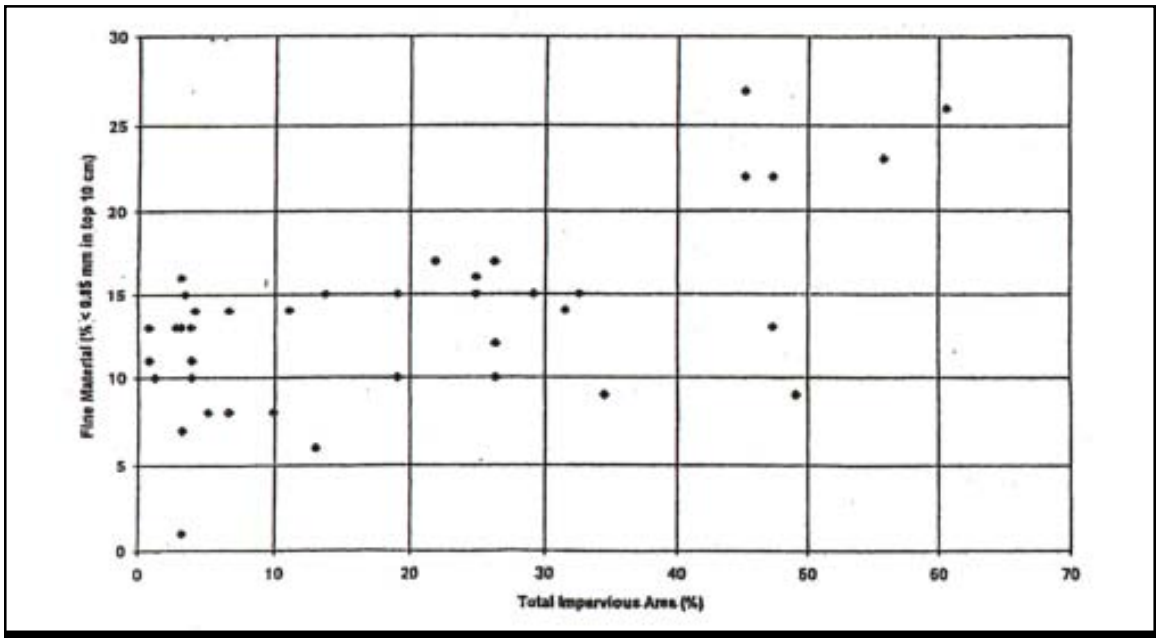


Figure 24: Fine Material Sediment Deposition as a Function of IC in Pacific Northwest Streams (Horner *et al.*, 1997)

Table 14: Research Review of Changes in Urban Stream Habitat		
Reference	**Key Finding**	**Location**
% IC Used as Indicator		
Black & Veatch, 1994	Habitat scores were ranked as poor in five subwatersheds that had greater than 30% IC.	MD
Booth and Jackson, 1997	Increase in degraded habitat conditions with increases in watershed IC.	WA
Hicks and Larson, 1997	Reported a reduction in composite stream habitat indices with increasing watershed IC.	MA
May *et al.*, 1997	Composite stream habitat declined most rapidly during the initial phase of the watershed urbanization, when percent IC exceeded the 5-10% range.	WA
Stranko and Rodney, 2001	Composite index of stream habitat declined with increasing watershed IC in coastal plain streams.	MD
Wang *et al.*, 2001	Composite stream habitat scores were not correlated with watershed IC in 47 small watersheds, although channel erosion was. Non-urban watersheds were highly agricultural and often lacked riparian forest buffers.	WI
MNCPPC, 2000	Reported that stream habitat scores were not correlated with IC in suburban watersheds.	MD
Morse, 2001	Composite habitat values tended to decline with increases in watershed IC.	ME
Booth, 1991	Channel stability and fish habitat quality declined rapidly after 10% watershed IC.	WA
Booth *et al.*, 1997	Decreased LWD with increased IC.	PNW
Finkenbine *et al.*, 2000	LWD was scarce in streams with greater than 20% IC in Vancouver.	B.C.
Horner & May, 1999	When IC levels were >5%, average LWD densities fell below 300 pieces/kilometer.	PNW
Horner *et al.*, 1997	Interstitial spaces in streambed sediments begin to fill with increasing watershed IC.	PNW
Urbanization Used as Indicator		
Dunne and Leopold, 1978	Natural channels replaced by storm drains and pipes; increased erosion rates observed downstream.	MD
May *et al.*, 1997	Forested riparian corridor width declines with increased watershed IC.	PNW
MWCOG, 1992	Fish blockages caused by bridges and culverts noted in urban watersheds.	D.C.
Pizzuto *et al.*, 2000	Urban streams had reduced pool depth, roughness, and sinuosity, compared to rural streams; Pools were 31% shallower in urban streams compared to non-urban ones.	PA
Richey, 1982	Altered pool/riffle sequence observed in urban streams.	WA
Scott *et al.*, 1986	Loss of habitat diversity noted in urban watersheds.	PNW
Spence *et al.*, 1996	Large woody debris is important for habitat diversity and anadromous fish.	PNW

3.4.3 Large Woody Debris (LWD)

LWD is a habitat element that describes the approximate volume of large woody material (< four inches in diameter) found in contact with the stream. The presence and stability of LWD is an important habitat parameter in streams. LWD can form dams and pools, trap sediment and detritus, stabilize stream channels, dissipate flow energy, and promote habitat complexity (Booth *et al.,* 1997). LWD creates a variety of pool features (plunge, lateral, scour and backwater); short riffles; undercut banks; side channels; and a range of water depths (Spence *et al.*, 1996). Urban streams tend to have a low supply of LWD, as increased stormwater flows transport LWD and clears riparian areas. Horner *et al.* (1997) presents evidence from Pacific Northwest streams that LWD decreases in response to increasing watershed IC (Figure 25).

3.4.4 Changes in Other Individual Stream Parameters

One of the notable changes in urban stream habitat is a decrease in pool depth and a general simplification of habitat features such as pools, riffles and runs. For example, Richey (1982) and Scott *et al.* (1986) reported an increase in the prevalence of glides and a corresponding altered riffle/pool sequence due to urbanization. Pizzuto *et al.* (2000) reported a median 31% decrease in pool depth in urban streams when compared to forested streams. Pizzuto *et al.* also reported a modest decrease in channel sinuosity and channel roughness in the same urban streams in Pennsylvania.

Several individual stream habitat parameters appear to have received no attention in urban stream research to date. These parameters include riparian shading, wetted perimeter, various measures of velocity/depth regimes, riffle frequency, and sediment deposition in pools. More systematic monitoring of these individual stream habitat parameters may be warranted.

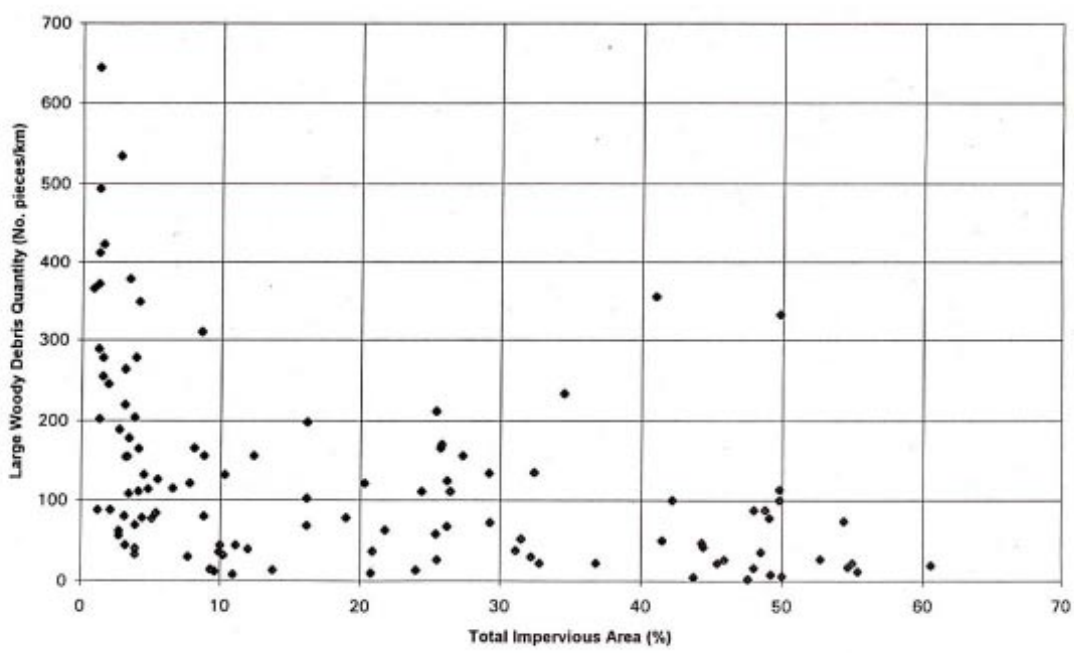


Figure 25: LWD as a Function of IC in Puget Sound Streams (Horner *et al.*, 1997)

3.5 Increased Stream Warming

IC directly influences our local weather in urban areas. This effect is obvious to anyone walking across a parking lot on a hot summer day, when temperatures often reach a scorching 110 to 120 degrees F. Parking lots and other hard surfaces tend to absorb solar energy and release it slowly. Furthermore, they lack the normal cooling properties of trees and vegetation, which act as natural air conditioners. Finally, urban areas release excess heat as a result of the combustion of fossil fuels for heating, cooling and transportation. As a result, highly urban areas tend to be much warmer than their rural counterparts and are known as urban heat islands. Researchers have found that summer temperatures tend to be six to eight degrees F warmer in the summer and two to four degrees F warmer during the winter months.

Water temperature in headwater streams is strongly influenced by local air temperatures. Summer temperatures in urban streams have been shown to increase by as much as five to 12 degrees F in response to watershed development (Table 15). Increased water temperatures can preclude temperature-sensitive species from being able to survive in urban streams.

Figure 26 shows the stream warming phenomenon in small headwater streams in the Maryland Piedmont.

Galli (1990) reported that stream temperatures throughout the summer increased in urban watersheds. He monitored five headwater streams in the Maryland Piedmont with different levels of IC. Each urban stream had mean temperatures that were consistently warmer than a forested reference stream, and stream warming appeared to be a direct function of watershed IC. Other factors, such as lack of riparian cover and the presence of ponds, were also demonstrated to amplify stream warming, but the primary contributing factor appeared to be watershed IC.

Johnson (1995) studied how stormwater influenced an urban trout stream in Minnesota and reported up to a 10 degree F increase in stream water temperatures after summer storm events. Paul *et al.* (2001) evaluated stream temperatures for 30 subwatersheds to the Etowah River in Georgia, which ranged from five to 61% urban land. They found a correlation between summer daily mean water temperatures and the percentage of urban land in a subwatershed.

Table 15: Research Review of Thermal Impacts in Urban Streams

Reference	Key Finding	Location
%IC Used as Indicator		
Galli, 1990	Increase in stream temperatures of five to 12 degrees Fahrenheit in urban watersheds; stream warming linked to IC.	MD
Urbanization Used as Indicator		
Johnson, 1995	Up to 10 degrees Fahrenheit increases in stream temperatures after summer storm events in an urban area	MN
LeBlanc *et al.*, 1997	Calibrated a model predicting stream temperature increase as a result of urbanization	Ontario
MCDEP, 2000	Monitoring effect of urbanization and stormwater ponds on stream temperatures revealed stream warming associated with urbanization and stormwater ponds	MD
Paul *et al.*, 2001	Daily mean stream temperatures in summer increased with urban land use	GA

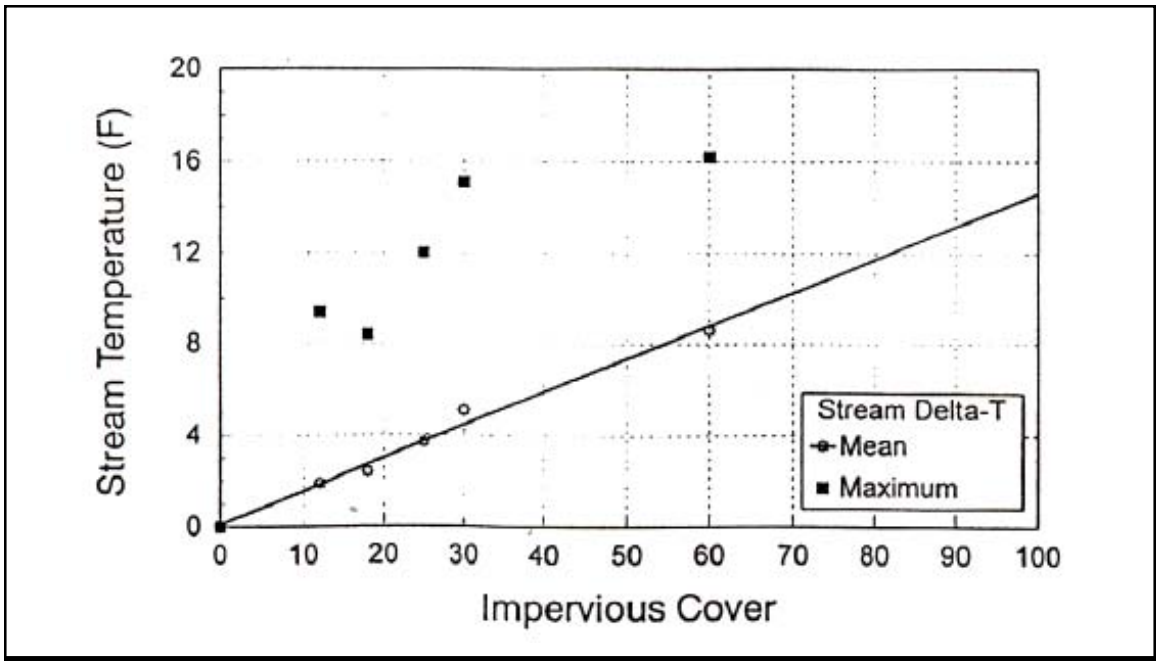


Figure 26: Stream Temperature Increase in Response to IC in Maryland Piedmont Streams (Galli, 1990)

Discharges from stormwater ponds can also contribute to stream warming in urban watersheds. Three studies highlight the temperature increase that can result from stormwater ponds. A study in Ontario found that baseflow temperatures below wet stormwater ponds increased by nine to 18 degrees F in the summer (SWAMP, 2000a, b). Oberts (1997) also measured change in the baseflow temperature as it flowed through a wetland/wet pond system in Minnesota. He concluded that the temperature had increased by an average of nine degrees F during the summer months. Galli (1988) also observed a mean increase of two to 10 degrees F in four stormwater ponds located in Maryland.

3.6 Alteration of Stream Channel Networks

Urban stream channels are often severely altered by man. Channels are lined with rip rap or concrete, natural channels are straightened, and first order and ephemeral streams are enclosed in storm drain pipes. From an engineering standpoint, these modifications rapidly convey flood waters downstream and locally stabilize stream banks. Cumulatively, however, these modifications can have a dramatic effect on the length and habitat quality of headwater stream networks.

3.6.1 Channel Modification

Over time, watershed development can alter or eliminate a significant percentage of the perennial stream network. In general, the loss of stream network becomes quite extensive when watershed IC exceeds 50%. This loss is striking when pre- and post-development stream networks are compared (Figure 27). The first panel illustrates the loss of stream network over time in a highly urban Northern Virginia watershed; the second panel shows how the drainage network of Rock Creek has changed in response to watershed development.

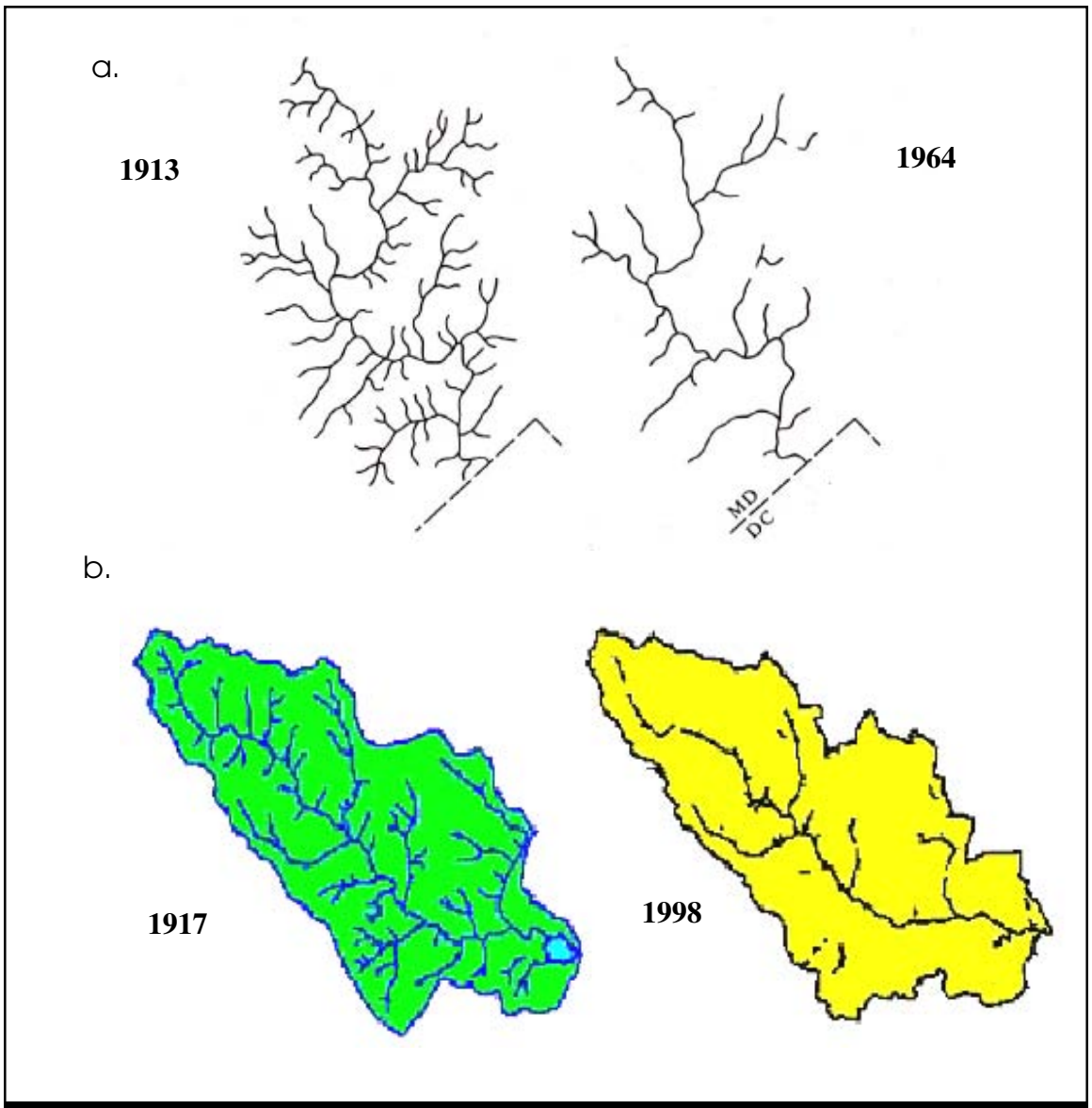


Figure 27: a. Drainage Network of Rock Creek, D.C. (Dunne and Leopold, 1978) and b. Drainage Network of Four Mile Run, VA Before and After Urbanization (NVRC, 2001)

In a national study of 269 gaged urban watersheds, Sauer *et al.* (1983) observed that channelization and channel hardening were important watershed variables that control peak discharge rates. The channel modifications increase the efficiency with which runoff is transported through the stream channel, increasing critical shear stress velocities and causing downstream channel erosion.

3.6.2 Barriers to Fish Migration

Infrastructure such as bridges, dams, pipelines and culverts can create partial or total barriers to fish migration and impair the ability of fish to move freely in a watershed. Blockages can have localized effects on small streams where non-migratory fish species can be prevented from re-colonizing upstream areas after acutely toxic events. The upstream movement of anadromous fish species such as shad, herring, salmon and steelhead can also be blocked by these barriers. Figure 28 depicts the prevalence of fish barriers in the Anacostia Watershed (MWCOG, 1992).

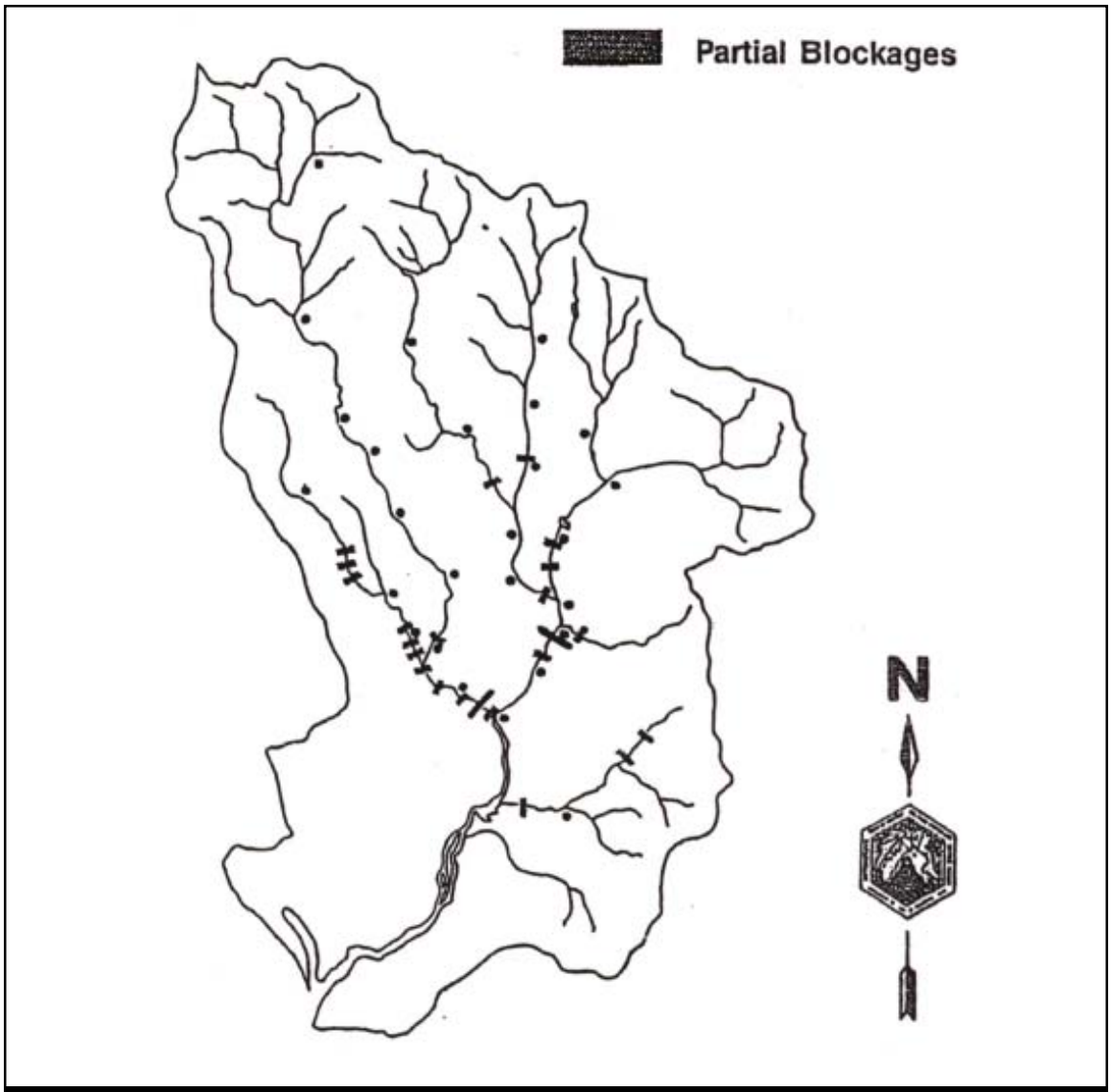


Figure 28: Fish Migration Barriers in the Anacostia Watershed of D.C. and MD (MWCOG, 1992)

3.7 Conclusion

Watershed development and the associated increase in IC have been found to significantly degrade the physical habitat of urban streams. In alluvial streams, the effects of channel enlargement and sediment transport can be severe at relatively low levels of IC (10 to 20%). However, the exact response of any stream is also contingent upon a combination of other physical factors such as geology, vegetation, gradient, the age of development, sediment supply, the use and design of stormwater treatment practices, and the extent of riparian buffers (Bledsoe, 2001).

Despite the uncertainty introduced by these factors, the limited geomorphic research to date suggests that physical habitat quality is almost always degraded by higher levels of watershed IC. Even in bedrock-controlled channels, where sediment transport and channel enlargement may not be as dramatic, researchers have noted changes in stream habitat features, such as embeddedness, loss of LWD, and stream warming.

Overall, the following conclusions can be made about the influence of watershed development on the physical habitat of urban streams:

- The major changes in physical habitat in urban streams are caused by the increased frequency and duration of bankfull and sub-bankfull discharges, and the attendant changes in sediment supply and transport. As a consequence, many urban streams experience significant channel enlargement. Generally, channel enlargement is most evident in alluvial streams.

- Typical habitat changes observed in urban streams include increased embeddedness, reduced supply of LWD, and simplification of stream habitat features such as pools, riffles and runs, as well as reduced channel sinuosity.

- Stream warming is often directly linked to watershed development, although more systematic subwatershed sampling is needed to precisely predict the extent of warming.

- Channel straightening, hardening and enclosure and the creation of fish barriers are all associated with watershed development. More systematic research is needed to establish whether these variables can be predicted based on watershed IC.

- In general, stream habitat diminishes at about 10% watershed IC, and becomes severely degraded beyond 25% watershed IC.

While our understanding of the relationship between stream habitat features and watershed development has improved in recent years, the topic deserves greater research in three areas. First, more systematic monitoring of composite habitat variables needs to be conducted across the full range of watershed IC. In particular, research is needed to define the approximate degree of watershed IC where urban streams are transformed into urban drainage systems.

Second, additional research is needed to explore the relationship between watershed IC and individual and measurable stream habitat parameters, such as bank erosion, channel sinuosity, pool depth and wetted perimeter. Lastly, more research is needed to determine if watershed treatment such as stormwater practices and stream buffers can mitigate the impacts of watershed IC on stream habitat. Together, these three research efforts could provide a technical foundation to develop a more predictive model of how watershed development influences stream habitat.

Chapter 4: Water Quality Impacts of Impervious Cover

This chapter presents information on pollutant concentrations found in urban stormwater runoff based on a national and regional data assessment for nine categories of pollutants. Included is a description of the Simple Method, which can be used to estimate pollutant loads based on the amount of IC found in a catchment or subwatershed. This chapter also addresses specific water quality impacts of stormwater pollutants and explores research on the sources and source areas of stormwater pollutants.

This chapter is organized as follows:

4.1 Introduction
4.2 Summary of National and Regional Stormwater Pollutant Concentration Data
4.3 Relationship Between Pollutant Loads and IC: The Simple Method
4.4 Sediment
4.5 Nutrients
4.6 Trace Metals
4.7 Hydrocarbons (PAH and Oil and Grease)
4.8 Bacteria and Pathogens
4.9 Organic Carbon
4.10 MTBE
4.11 Pesticides
4.12 Deicers
4.13 Conclusion

4.1 Introduction

Streams are usually the first aquatic system to receive stormwater runoff, and their water quality can be compromised by the pollutants it contains. Stormwater runoff typically contains dozens of pollutants that are detectable at some concentration, however small. Simply put, any pollutant deposited or derived from an activity on land will likely end up in stormwater runoff, although certain pollutants are consistently more likely to cause water quality problems in receiving waters. Pollutants that are frequently found in stormwater runoff can be grouped into nine broad categories: sediment, nutrients, metals, hydrocarbons, bacteria and pathogens, organic carbon, MTBE, pesticides, and deicers.

The impact that stormwater pollutants exert on water quality depends on many factors, including concentration, annual pollutant load, and category of pollutant. Based on nationally reported concentration data, there is considerable variation in stormwater pollutant concentrations. This variation has been at least partially attributed to regional differences, including rainfall and snowmelt. The volume and regularity of rainfall, the length of snow accumulation, and the rate of snowmelt can all influence stormwater pollutant concentrations.

The annual pollutant load can have long-term effects on stream water quality, and is particularly important information for stormwater managers to have when dealing with non-point source pollution control. The Simple Method is a model developed to estimate the pollutant load for chemical pollutants, assuming that the annual pollutant load is a function of IC. It is an effective method for determining annual sediment, nutrient, and trace metal loads. It cannot always be applied to other stormwater pollutants, since they are not always correlated with IC.

The direct water quality impact of stormwater pollutants also depends on the type of pollutant, as different pollutants impact streams differently. For example, sediments affect stream habitat and aquatic biodiversity; nutrients cause eutrophication; metals, hydrocarbons, deicers, and MTBE can be toxic to aquatic life; and organic carbon can lower dissolved oxygen levels.

The impact stormwater pollutants have on

water quality can also directly influence human uses and activities. Perhaps the pollutants of greatest concern are those with associated public health impacts, such as bacteria and pathogens. These pollutants can affect the availability of clean drinking water and limit consumptive recreational activities, such as swimming or fishing. In extreme situations, these pollutants can even limit contact recreational activities such as boating and wading.

It should be noted that although there is much research available on the effects of urbanization on water quality, the majority has not been focused on the impact on streams, but on the response of lakes, reservoirs, rivers and estuaries. It is also important to note that not all pollutants are equally represented in monitoring conducted to date. While we possess excellent monitoring data for sediment, nutrients and trace metals, we have relatively little monitoring data for pesticides, hydrocarbons, organic carbon, deicers, and MTBE.

4.2 Summary of National and Regional Stormwater Pollutant Concentration Data

4.2.1 National Data

National mean concentrations of typical stormwater pollutants are presented in Table 16. National stormwater data are compiled from the Nationwide Urban Runoff Program (NURP), with additional data obtained from the U.S.Geological Survey (USGS), as well as initial stormwater monitoring conducted for EPA's National Pollutant Discharge Elimination System (NPDES) Phase I stormwater program.

In most cases, stormwater pollutant data is reported as an event mean concentration (EMC), which represents the average concentration of the pollutant during an entire stormwater runoff event.

When evaluating stormwater EMC data, it is important to keep in mind that regional EMCs can differ sharply from the reported national pollutant EMCs. Differences in EMCs between regions are often attributed to the variation in the amount and frequency of rainfall and snowmelt.

4.2.2 Regional Differences Due to Rainfall

The frequency of rainfall is important, since it influences the accumulation of pollutants on IC that are subsequently available for wash-off during storm events. The USGS developed a national stormwater database encompassing 1,123 storms in 20 metropolitan areas and used it as the primary data source to define regional differences in stormwater EMCs. Driver (1988) performed regression analysis to determine which factors had the greatest influence on stormwater EMCs and determined that annual rainfall depth was the best overall predictor. Driver grouped together stormwater EMCs based on the depth of average annual rainfall, and Table 17 depicts the regional rainfall groupings and general trends for each

region. Table 18 illustrates the distribution of stormwater EMCs for a range of rainfall regions from 13 local studies, based on other monitoring studies. In general, stormwater EMCs for nutrients, suspended sediment and metals tend to be higher in arid and semi-arid

Table 16: National EMCs for Stormwater Pollutants

Pollutant	Source	EMCs		Number of Events
		Mean	Median	
Sediments (mg/l)				
TSS	(1)	78.4	54.5	3047
Nutrients (mg/l)				
Total P	(1)	0.32	0.26	3094
Soluble P	(1)	0.13	0.10	1091
Total N	(1)	2.39	2.00	2016
TKN	(1)	1.73	1.47	2693
Nitrite & Nitrate	(1)	0.66	0.53	2016
Metals (Fg/l)				
Copper	(1)	13.4	11.1	1657
Lead	(1)	67.5	50.7	2713
Zinc	(1)	162	129	2234
Cadmium	(1)	0.7	N/R	150
Chromium	(4)	4	7	164
Hydrocarbons (mg/l)				
PAH	(5)	3.5	N/R	N/R
Oil and Grease	(6)	3	N/R	N/R
Bacteria and Pathogens (colonies/ 100ml)				
Fecal Coliform	(7)	15,038	N/R	34
Fecal Streptococci	(7)	35,351	N/R	17
Organic Carbon (mg/l)				
TOC	(11)	17	15.2	19 studies
BOD	(1)	14.1	11.5	1035
COD	(1)	52.8	44.7	2639
MTBE	(8)	N/R	1.6	592
Pesticides (Fg/l)				
Diazinon	(10)	N/R	0.025	326
	(2)	N/R	0.55	76
Chlorpyrifos	(10)	N/R	N/R	327
Atrazine	(10)	N/R	0.023	327
Prometon	(10)	N/R	0.031	327
Simazine	(10)	N/R	0.039	327
Chloride (mg/l)				
Chloride	(9)	N/R	397	282

Sources: (1) Smullen and Cave, 1998; (2) Brush et al., 1995; (3) Baird et al., 1996; (4) Bannerman et al., 1996; (5) Rabanal and Grizzard, 1995; (6) Crunkilton et al., 1996; (7) Schueler, 1999; (8) Delzer, 1996; (9) Environment Canada, 2001; (10) USEPA, 1998; (11) CWP, 2001a N/R - Not Reported

Table 17: Regional Groupings by Annual Rainfall Amount (Driver, 1988)

Region	Annual Rainfall	States Monitored	Concentration Data
Region I: Low Rainfall	<20 inches	AK, CA, CO, NM, UT	Highest mean and median values for Total N, Total P, TSS and COD
Region II: Moderate Rainfall	20 40 inches	HA, IL, MI, MN, MI, NY, TX, OR, OH, WA, WI	Higher mean and median values than Region III for TSS, dissolved phosphorus and cadmium
Region III: High Rainfall	>40 inches	FL, MD, MA, NC, NH, NY, TX, TN, AR	Lower values for many parameters likely due to the frequency of storms and the lack of build up in pollutants

regions and tend to decrease slightly when annual rainfall increases (Table 19).

It is also hypothesized that a greater amount of sediment is eroded from pervious surfaces in arid or semi-arid regions than in humid regions due to the sparsity of protective vegetative cover. Table 19 shows that the highest concentrations of total suspended solids were recorded in regions with least rainfall. In addition, the chronic toxicity standards for several metals are most frequently exceeded during low rainfall regions (Table 20).

4.2.3 Cold Region Snowmelt Data

In colder regions, snowmelt can have a significant impact on pollutant concentrations. Snow accumulation in winter coincides with pollutant build-up; therefore, greater concentrations of pollutants are measured during snowmelt events. Sources of snowpack pollution in urban areas include wet and dry atmospheric deposition, traffic emissions, urban litter, deteriorated infrastructure, and deicing chemicals and abrasives (WERF, 1999).

Oberts *et al.* (1989) measured snowmelt pollutants in Minnesota streams and found that as much as 50% of annual sediment, nutrient, hydrocarbon and metal loads could be attributed to snowmelt runoff during late winter and early spring. This trend probably applies to any region where snow cover persists through much of the winter. Pollutants accumulate in the snowpack and then contribute high concentrations during snowmelt runoff. Oberts (1994) described four types of snowmelt runoff events and the resulting pollutant characteristics (Table 21).

A typical hydrograph for winter and early spring snow melts in a northern cold climate is portrayed in Figure 29. The importance of snowpack melt on peak runoff during March 1989 can clearly be seen for an urban watershed located in St. Paul, Minnesota.

Major source areas for snowmelt pollutants include snow dumps and roadside snowpacks. Pollutant concentrations in snow dumps can be as much as five times greater than typical stormwater pollutant concentrations (Environment Canada, 2001). Snow dumps and packs accumulate pollutants over the winter months and can release them during a few rain or snow melt events in the early spring. High levels of chloride, lead, phosphorus, biochemical oxygen demand, and total suspended solids have been reported in snow pack runoff (La Barre *et al*, 1973; Oliver *et al.*, 1974; Pierstorff and Bishop, 1980; Scott and Wylie, 1980; Van Loon, 1972).

Atmospheric deposition can add pollutants to snow piles and snowpacks. Deposited pollutants include trace metals, nutrients and particles that are primarily generated by fossil fuel combustion and industrial emissions (Boom and Marsalek, 1988; Horkeby and Malmqvist, 1977; Malmqvist, 1978; Novotny and Chester, 1981; Schrimpff and Herrman, 1979).

Table 18: Stormwater Pollutant Event Mean Concentration for Different U.S. Regions (Units: mg/l, except for metals which are in *F*g/l)

		Region I - Low Rainfall				Region II - Moderate Rainfall			Region III - High Rainfall				Snow
	National	Phoenix, AZ	San Diego, CA	Boise, ID	Denver, CO	Dallas, TX	Marquette, MI	Austin, TX	MD	Louisville, KY	GA	FL	MN
Reference	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(11)	(12)
Annual Rainfall (in.)	N/A	7.1"	10"	11"	15"	28"	32"	32"	41"	43"	51"	52"	N/R
Number of Events	3000	40	36	15	35	32	12	N/R	107	21	81	N/R	49
Pollutant													
TSS	78.4	227	330	116	242	663	159	190	67	98	258	43	112
Total N	2.39	3.26	4.55	4.13	4.06	2.70	1.87	2.35	N/R	2.37	2.52	1.74	4.30
Total P	0.32	0.41	0.7	0.75	0.65	0.78	0.29	0.32	0.33	0.32	0.33	0.38	0.70
Soluble P	0.13	0.17	0.4	0.47	N/R	N/R	0.04	0.24	N/R	0.21	0.14	0.23	0.18
Copper	14	47	25	34	60	40	22	16	18	15	32	1.4	N/R
Lead	68	72	44	46	250	330	49	38	12.5	60	28	8.5	100
Zinc	162	204	180	342	350	540	111	190	143	190	148	55	N/R
BOD	14.1	109	21	89	N/R	112	15.4	14	14.4	88	14	11	N/R
COD	52.8	239	105	261	227	106	66	98	N/R	38	73	64	112

Sources: Adapted from Caraco, 2000a: (1) Smullen and Cave, 1998; (2) Lopes et al.; 1995; (3) Schiff, 1996; (4) Kjelstrom, 1995 (computed); (5) DRCOG, 1983, (6) Brush et al., *1995; (7) Steuer* et al., *1997; (8) Barrett* et al., *1995; (9) Barr, 1997; (10) Evaldi* et al., *1992; (11) Thomas and McClelland, 1995; (12) Oberts, 1994 N/R = Not Reported; N/A = Not Applicable*

Table 19: Mean and Median Nutrient and Sediment Stormwater Concentrations for Residential Land Use Based on Rainfall Regions (Driver, 1988)

Region	Total N (median)	Total P (median)	TSS (mean)
Region I: Low Rainfall	4	0.45	320
Region II: Moderate Rainfall	2.3	0.31	250
Region III: High Rainfall	2.15	0.31	120

Table 20: EPA 1986 Water Quality Standards and Percentage of Metal Concentrations Exceeding Water Quality Standards by Rainfall Region (Driver, 1988)

	Cadmium	Copper	Lead	Zinc
EPA Standards	10 *F*g/l	12 *F*g/l	32 *F*g/l	47 *F*g/l
Percent Exceedance of EPA Standards				
Region I: Low Rainfall	1.5%	89%	97%	97%
Region II: Moderate Rainfall	0	78%	89%	85%
Region III: High Rainfall	0	75%	91%	84%

Table 21: Runoff and Pollutant Characteristics of Snowmelt Stages (Oberts, 1994)

Snowmelt Stage	Duration /Frequency	Runoff Volume	Pollutant Characteristics
Pavement	Short, but many times in winter	Low	Acidic, high concentrations of soluble pollutants; Chloride, nitrate, lead; total load is minimal
Roadside	Moderate	Moderate	Moderate concentrations of both soluble and particulate pollutants
Pervious Area	Gradual, often most at end of season	High	Dilute concentrations of soluble pollutants; moderate to high concentrations of particulate pollutants depending on flow
Rain-on-Snow	Short	Extreme	High concentrations of particulate pollutants; moderate to high concentrations of soluble pollutants; high total load

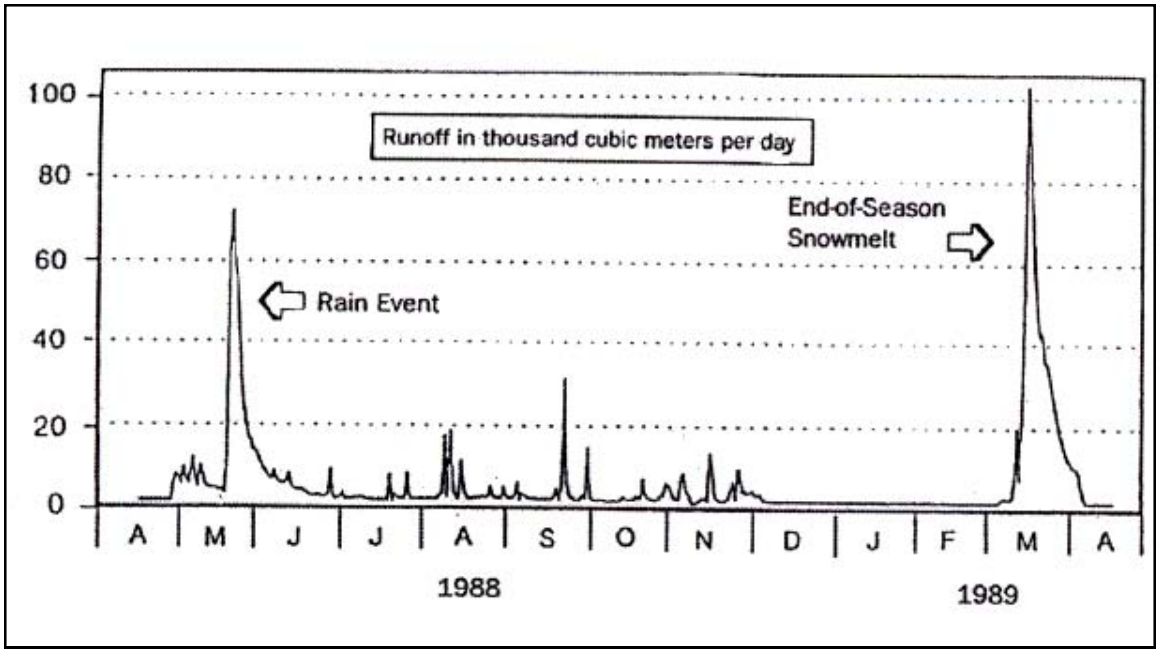


Figure 29: Snowmelt Runoff Hydrograph for Minneapolis Stream (Oberts, 1994)

4.3 Relationship Between Pollutant Loads and IC: The Simple Method

Urban stormwater runoff contains a wide range of pollutants that can degrade downstream water quality. The majority of stormwater monitoring research conducted to date supports several generalizations. First, the unit area pollutant load delivered to receiving waters by stormwater runoff increases in direct proportion to watershed IC. This is not altogether surprising, since pollutant load is the product of the average pollutant concentration and stormwater runoff volume. Given that runoff volume increases in direct proportion to IC, pollutant loads must automatically increase when IC increases, as long the average pollutant concentration stays the same (or increases). This relationship is a central assumption in most simple and complex pollutant loading models (Bicknell *et al.*, 1993; Donigian and Huber, 1991; Haith *et al.*, 1992; Novotny and Chester, 1981; NVPDC, 1987; Pitt and Voorhees, 1989).

Recognizing the relationship between IC and pollutant loads, Schueler (1987) developed the "Simple Method" to quickly and easily estimate stormwater pollutant loads for small urban watersheds (see Figure 30). Estimates of pollutant loads are important to watershed managers as they grapple with costly decisions on non-point source control. The Simple Method is empirical in nature and utilizes the extensive regional and national database (Driscoll, 1983; MWCOG, 1983; USEPA, 1983). Figure 30 provides the basic equations to estimate pollutant loads using the Simple

Figure 30: The Simple Method - Basic Equations

The Simple Method estimates pollutant loads as the product of annual runoff volume and pollutant EMC, as:

$$(1)\ L = 0.226 * R * C * A$$

Where: L = Annual load (lbs), and:
R = Annual runoff (inches)
C = Pollutant concentration in stormwater, EMC (mg/l)
A = Area (acres)
0.226 = Unit conversion factor

For bacteria, the equation is slightly different, to account for the differences in units. The modified equation for bacteria is:

$$(2)\ L = 1.03 * 10^{-3} * R * C * A$$

Where: L = Annual load (Billion Colonies), and:
R = Annual runoff (inches)
C = Bacteria concentration (#/100 ml)
A = Area (acres)
$1.03 * 10^{-3}$ = Unit conversion factor

Annual Runoff

The Simple Method calculates the depth of annual runoff as a product of annual runoff volume and a runoff coefficient (Rv). Runoff volume is calculated as:

$$(3)\ R = P * P_j * Rv$$

Where: R = Annual runoff (inches), and:
P = Annual rainfall (inches)
P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)
Rv = Runoff coefficient

In the Simple Method, the runoff coefficient is calculated based on IC in the subwatershed. The following equation represents the best fit line for the data set (N=47, R^2=0.71).

$$(4)\ Rv=0.05+0.9Ia$$

Where: Rv = runoff coefficient, and:
Ia = Impervious fraction

Method. It assumes that loads of stormwater pollutants are a direct function of watershed IC, as IC is the key independent variable in the equation.

The technique requires a modest amount of information, including the subwatershed drainage area, IC, stormwater runoff pollutant EMCs, and annual precipitation. With the Simple Method, the investigator can either divide up land use into specific areas (i.e. residential, commercial, industrial, and roadway) and calculate annual pollutant loads for each land use, or utilize a generic urban land use. Stormwater pollutant EMC data can be derived from the many summary tables of local, regional, or national monitoring efforts provided in this chapter (e.g., Tables 16, 18, 22, 28, 30, 35, 36, 40, and 44). The model also requires different IC values for separate land uses within a subwatershed. Representative IC data from Cappiella and Brown (2001) were provided in Table 2 (Chapter 1).

Additionally, the Simple Method should not be used to estimate annual pollutant loads of deicers, hydrocarbons and MTBE, because they have not been found to be correlated with IC. These pollutants have been linked to other indicators. Chlorides, hydrocarbons and MTBE are often associated with road density and vehicle miles traveled (VMT). Pesticides are associated with turf area, and traffic patterns and "hotspots" have been noted as potential indicators for hydrocarbons and MTBE.

Limitations of the Simple Method

The Simple Method should provide reasonable estimates of changes in pollutant export resulting from urban development. However, several caveats should be kept in mind when applying this method.

The Simple Method is most appropriate for assessing and comparing the relative stormflow pollutant load changes from different land uses and stormwater treatment scenarios. The Simple Method provides estimates of storm pollutant export that are probably close to the "true" but unknown value for a development site, catchment, or subwatershed. However, it is very important not to overemphasize the precision of the load estimate obtained. For example, it would be inappropriate to use the Simple Method to evaluate relatively similar development scenarios (e.g., 34.3% versus 36.9% IC). The Simple Method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment or subwatershed. More sophisticated modeling is needed to analyze larger and more complex watersheds.

In addition, the Simple Method only estimates pollutant loads generated during storm events. It does not consider pollutants associated with baseflow during dry weather. Typically, baseflow is negligible or non-existent at the scale of a single development site and can be safely neglected. However, catchments and subwatersheds do generate significant baseflow volume. Pollutant loads in baseflow are generally low and can seldom be distinguished from natural background levels (NVPDC, 1979).

Consequently, baseflow pollutant loads normally constitute only a small fraction of the total pollutant load delivered from an urban area. Nevertheless, it is important to remember that the load estimates refer only to storm event derived loads and should not be confused with the total pollutant load from an area. This is particularly important when the development density of an area is low. For example, in a low density residential subwatershed (IC < 5%), as much as 75% of the annual runoff volume could occur as baseflow. In such a case, annual baseflow load may be equivalent to the annual stormflow load.

4.4 Sediment

Sediment is an important and ubiquitous pollutant in urban stormwater runoff. Sediment can be measured in three distinct ways: Total Suspended Solids (TSS), Total Dissolved Solids (TDS) and turbidity. TSS is a measure of the total mass suspended sediment particles in water. The measurement of TSS in urban stormwater helps to estimate sediment load transported to local and downstream receiving waters. Table 22 summarizes stormwater EMCs for total suspended solids, as reported by Barrett *et al.* (1995), Smullen and Cave (1998), and USEPA (1983). TDS is a measure of the dissolved solids and minerals present in stormwater runoff and is used as a primary indication of the purity of drinking water. Since few stormwater monitoring efforts have focused on TDS, they are not reported in this document. Turbidity is a measure of how suspended solids present in water reduce the ability of light to penetrate the water column. Turbidity can exert impacts on aquatic biota, such as the ability of submerged aquatic vegetation to receive light and the ability of fish and aquatic insects to use their gills (Table 23).

4.4.1 Concentrations

TSS concentrations in stormwater across the country are well documented. Table 18 reviews mean TSS EMCs from 13 communities across the country and reveals a wide range of recorded concentrations. The lowest concentration of 43 mg/l was reported in Florida, while TSS reached 663 mg/l in Dallas, Texas. Variation in sediment concentrations has been attributed to regional rainfall differences (Driver, 1988); construction site runoff (Leopold, 1968); and bank erosion (Dartiguenave *et al.*, 1997). National values are provided in Table 22.

Turbidity levels are not as frequently reported in national and regional monitoring summaries. Barrett and Malina (1998) monitored turbidity at two sites in Austin, Texas and reported a mean turbidity of 53 NTU over 34 storm events (Table 22).

4.4.2 Impacts of Sediment on Streams

The impacts of sediment on aquatic biota are well documented and can be divided into impacts caused by suspended sediment and those caused by deposited sediments (Tables 23 and 24).

In general, high levels of TSS and/or turbidity can affect stream habitat and cause sedimentation in downstream receiving waters. Deposited sediment can cover benthic organisms such as aquatic insects and freshwater mussels. Other problems associated with high sediments loads include stream warming by reflecting radiant energy due to increased turbidity (Kundell and Rasmussen, 1995), decreased flow capacity (Leopold, 1973), and increasing overbank flows (Barrett and Malina, 1998). Sediments also transport other pollutants which bind to sediment particles. Significant levels of pollutants can be transported by sediment during stormwater runoff events,

Table 22: EMCs for Total Suspended Solids and Turbidity

Pollutant	EMCs		Number of Events	Source
	Mean	Median		
TSS (mg/l)	78.4	54.5	3047	Smullen and Cave, 1998
	174	113	2000	USEPA, 1983
Turbidity (NTU)	53	N/R	423	Barrett and Malina, 1998

N/R = Not Reported

Table 23: Summary of Impacts of Suspended Sediment on the Aquatic Environment (Schueler and Holland, 2000)
Abrades and damages fish gills, increasing risk of infection and disease
Scouring of periphyton from stream (plants attached to rocks)
Loss of sensitive or threatened fish species when turbidity exceeds 25 NTU
Shifts in fish community toward more sediment-tolerant species
Decline in sunfish, bass, chub and catfish when month turbidity exceeds 100 NTU
Reduces sight distance for trout, with reduction in feeding efficiency
Reduces light penetration causing reduction in plankton and aquatic plant growth
Adversely impacts aquatic insects, which are the base of the food chain
Slightly increases the stream temperature in the summer
Suspended sediments can be a major carrier of nutrients and metals
Reduces anglers chances of catching fish

Table 24: Summary of Impacts of Deposited Sediments on the Aquatic Environment (Schueler and Holland, 2000)
1. Physical smothering of benthic aquatic insect community
2. Reduced survival rates for fish eggs
3. Destruction of fish spawning areas and eggs
4. Embeddedness of stream bottom reduced fish and macroinvertebrate habitat value
5. Loss of trout habitat when fine sediments are deposited in spawning or riffle-runs
6. Sensitive or threatened darters and dace may be eliminated from fish community
7. Increase in sediment oxygen demand can deplete dissolved oxygen in streams
8. Significant contributing factor in the alarming decline of freshwater mussels
9. Reduced channel capacity, exacerbating downstream bank erosion and flooding
10. Reduced flood transport capacity under bridges and through culverts
11. Deposits diminish scenic and recreational values of waterways

including trace metals, hydrocarbons and nutrients (Crunkilton *et al.,* 1996; Dartiguenave *et al*., 1997; Gavin and Moore, 1982; Novotny and Chester, 1989; Schueler 1994b).

4.4.3 Sources and Source Areas of Sediment

Sediment sources in urban watersheds include stream bank erosion; erosion from exposed soils, such as from construction sites; and washoff from impervious areas (Table 25).

As noted in this chapter, streambank erosion is generally considered to be the primary source of sediment to urban streams. Recent studies by Dartiguenave *et al.* (1997) and Trimble (1997) determined that streambank erosion contributes the majority of the annual sediment budget of urban streams. Trimble (1997) directly measured stream cross sections, sediment aggradation and suspended sediment loads and determined that two-thirds of the annual sediment budget of a San Diego, California watershed was supplied by streambank erosion. Dartiguenave *et al.* (1997) developed a GIS based model in Austin, Texas to determine the effects of stream bank erosion on the annual sediment budget. They compared modeled sediment loads from the watershed with the actual sediment loads measured at USGS gaging stations and concluded that more than 75% of the sediment load came from streambank erosion. Dartiguenave *et al.* (1997) reported that sediment load per unit area increases with increasing IC (Figure 31).

Sediment loads are also produced by washoff of sediment particles from impervious areas and their subsequent transport in stormwater runoff sediment. Source areas include parking lots, streets, rooftops, driveways and lawns. Streets and parking lots build up dirt and grime from the wearing of the street surface, exhaust particulates, "blown on" soil and organic matter, and atmospheric deposition. Lawn runoff primarily contains soil and organic matter. Urban source areas that produce the highest TSS concentrations include streets, parking lots and lawns (Table 26).

Parking lots and streets are not only responsible for high concentrations of sediment but also high runoff volumes. The SLAMM source loading model (Pitt and Voorhees, 1989) looks at runoff volume and concentrations of pollutants from different urban land uses and predicts stream loading. When used in the Wisconsin and Michigan subwatersheds, it demonstrated that parking lots and streets were responsible for over 70% of the TSS delivered to the stream. (Steuer *et al*., 1997; Waschbusch *et al.*, 2000).

Table 25: Sources and Loading of Suspended Solids Sediment in Urban Areas

Sources	Loading	Source
Bank Erosion	75% of stream sediment budget	Dartinguenave *et al.*, 1997
	66% of stream sediment budget	Trimble, 1997
Overland Flow- Lawns	397 mg/l (geometric mean)	Bannerman *et al.*, 1993
	262 mg/l	Steuer *et al.*, 1997
	11.5% (estimated; 2 sites)	Waschbusch *et al.*, 2000
Construction Sites	200 to 1200 mg/l	Table 27
Washoff from Impervious Surfaces	78 mg/l (mean)	Table 16

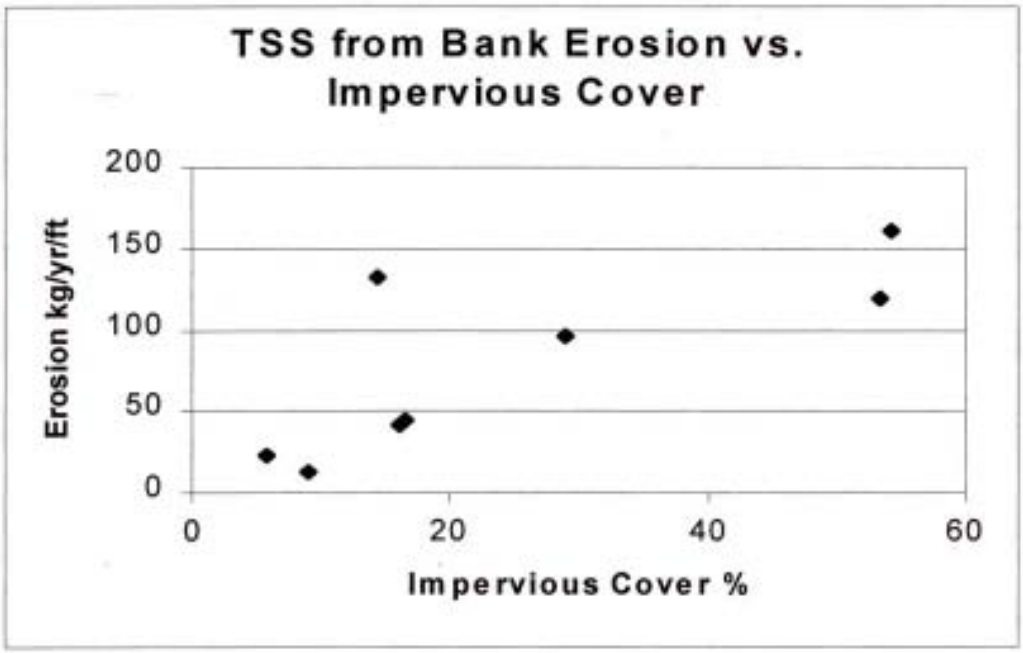


Figure 31: TSS from Bank Erosion vs. IC in Texas Streams (Daringuenave *et al.*, 1997)

The third major source of sediment loads is erosion from construction sites. Several studies have reported extremely high TSS concentrations in construction site runoff, and these findings are summarized in Table 27. TSS concentrations from uncontrolled construction sites can be more than 150 times greater than those from undeveloped land (Leopold, 1968) and can be reduced if erosion and sediment control practices are applied to construction sites.

Table 26: Source Area Geometric Mean Concentrations for Suspended Solids in Urban Areas

Source Area	Suspended Solids (mg/l)		
Source	(1)	(2)	(3)
Commercial Parking Lot	110	58	51
High Traffic Street	226	232	65
Medium Traffic Street	305	326	51
Low Traffic Street	175	662	68
Commercial Rooftop	24	15	18
Residential Rooftop	36	27	15
Residential Driveway	157	173	N/R
Residential Lawn	262	397	59

Sources: (1) Steuer et al., 1997; (2) Bannerman et al., 1993; (3) Waschbusch et al., 2000; N/R = Not Reported

Table 27: Mean TSS Inflow and Outflow at Uncontrolled, Controlled and Simulated Construction Sites

Source	Mean Inflow TSS Concentration (mg/l)	Mean Outflow TSS Concentration (mg/l)	Location
Uncontrolled Sites			
Horner *et al.*, 1990	7,363	281	PNW
Schueler and Lugbill,1990	3,646	501	MD
York and Herb, 1978	4,200	N/R	MD
Islam *et al.*, 1988	2,950	N/R	OH
Controlled Sites			
Schueler and Lugbill, 1990	466	212	MD
Simulated Sediment Concentrations			
Jarrett, 1996	9,700	800	PA
Sturm and Kirby, 1991	1,500-4,500	200-1,000	GA
Barfield and Clar, 1985	1,000-5,000	200-1,200	MD
Dartiguenave *et al.*, 1997	N/R	600	TX

N/R = Not Reported

4.5 Nutrients

Nitrogen and phosphorus are essential nutrients for aquatic systems. However, when they appear in excess concentrations, they can exert a negative impact on receiving waters. Nutrient concentrations are reported in several ways. Nitrogen is often reported as nitrate (NO_3) and nitrite (NO_2), which are inorganic forms of nitrogen; total nitrogen (Total N), which is the sum of nitrate, nitrite, organic nitrogen and ammonia; and total Kjeldhal nitrogen (TKN), which is organic nitrogen plus ammonia.

Phosphates are frequently reported as soluble phosphorus, which is the dissolved and reactive form of phosphorus that is available for uptake by plants and animals. Total phosphorus (Total P) is also measured, which includes both organic and inorganic forms of phosphorus. Organic phosphorus is derived from living plants and animals, while inorganic phosphate is comprised of phosphate ions that are often bound to sediments.

4.5.1 Concentrations

Many studies have indicated that nutrient concentrations are linked to land use type, with urban and agricultural watersheds producing the highest nutrient loads (Chessman *et al.* 1992; Paul *et al.*, 2001; USGS, 2001b and Wernick *et al.*,1998). Typical nitrogen and phosphorus EMC data in urban stormwater runoff are summarized in Table 28.

Some indication of the typical concentrations of nitrate and phosphorus in stormwater runoff are evident in Figures 32 and 33. These graphs profile average EMCs in stormwater runoff recorded at 37 residential catchments across the U.S. The average nitrate EMC is remarkably consistent among residential neighborhoods, with most clustered around the mean of 0.6 mg/l and a range of 0.25 to 1.4 mg/l. The concentration of phosphorus during storms is also very consistent with a mean of 0.30 mg/l and a rather tight range of 0.1 to 0.66 mg/l (Schueler, 1995).

The amount of annual rainfall can also influence the magnitude of nutrient concentrations in stormwater runoff. For example, both Caraco (2000a) and Driver (1988) reported that the highest nutrient EMCs were found in stormwater from arid or semi-arid regions.

Table 28: EMCs of Phosphorus and Nitrogen Urban Stormwater Pollutants

Pollutant	EMCs (mg/l)		Number of Events	Source
	Mean	Median		
Total P	0.315	0.259	3094	Smullen and Cave, 1998
	0.337	0.266	1902	USEPA, 1983
Soluble P	0.129	0.103	1091	Smullen and Cave, 1998
	0.1	0.078	767	USEPA, 1983
Total N	2.39	2.00	2016	Smullen and Cave, 1998
	2.51	2.08	1234	USEPA, 1983
TKN	1.73	1.47	2693	Smullen and Cave, 1998
	1.67	1.41	1601	USEPA, 1983
Nitrite & Nitrate	0.658	0.533	2016	Smullen and Cave, 1998
	0.837	0.666	1234	USEPA, 1983

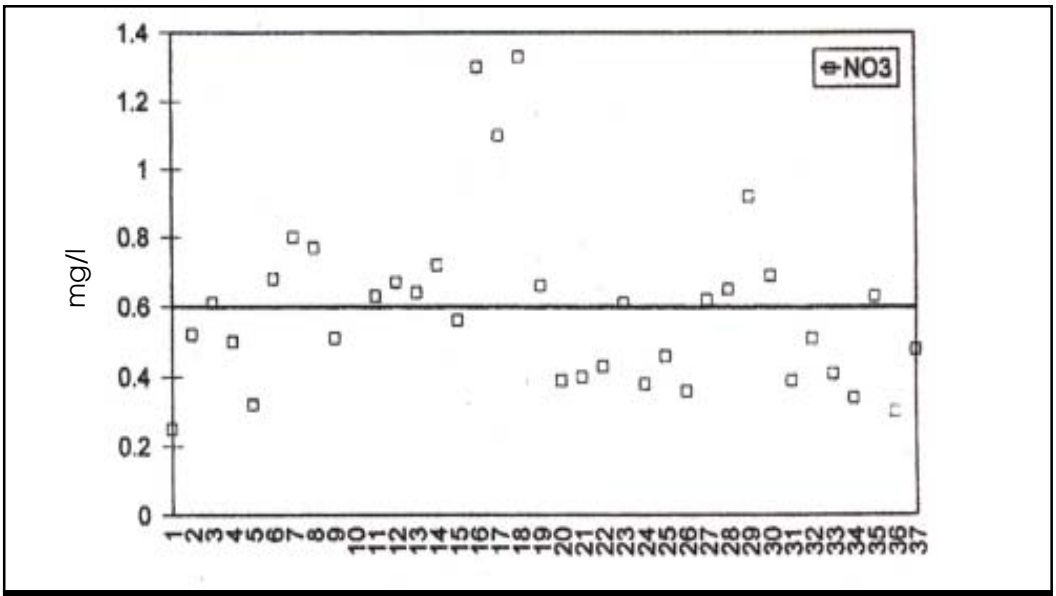


Figure 32: Nitrate-Nitrogen Concentration in Stormwater Runoff at 37 Sites Nationally (Schueler, 1999)

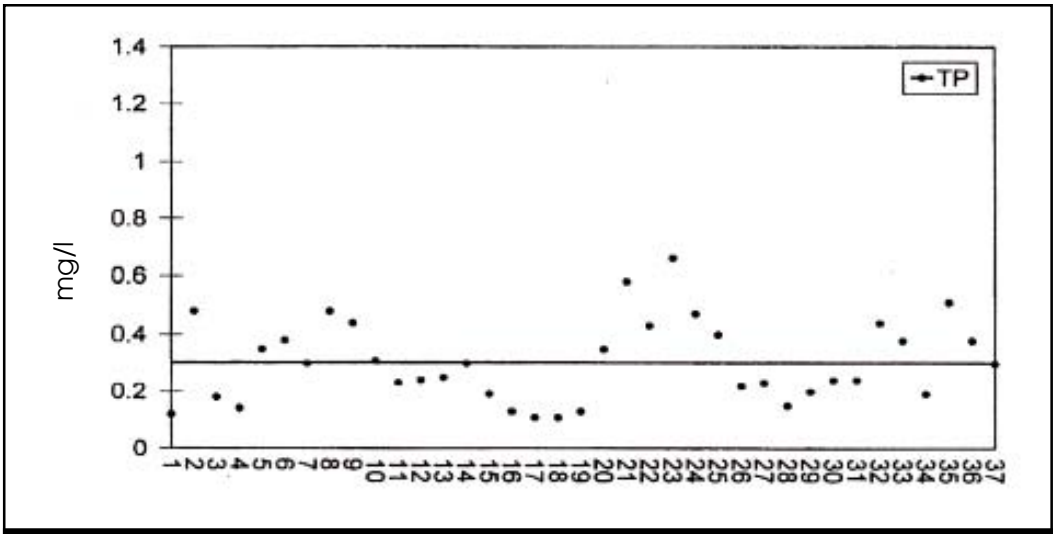


Figure 33: Total Phosphorus Concentration in Stormwater at 37 Sites Nationally (Schueler, 1999)

4.5.2 Impacts of Nutrients on Streams

Much research on the impact of nutrient loads has been focused on lakes, reservoirs and estuaries, which can experience eutrophication. Nitrogen and phosphorus can contribute to algae growth and eutrophic conditions, depending on which nutrient limits growth (USEPA, 1998). Dissolved oxygen is also affected by eutrophication. When algae or aquatic plants that are stimulated by excess nutrients die off, they are broken down by bacteria, which depletes the oxygen in the water. Relatively few studies have specifically explored the impact of nutrient enrichment on urban streams. Chessman *et al*. (1992) studied the limiting nutrients for periphyton growth in a variety of streams and noted that the severity of eutrophication was related to low flow conditions. Higher flow rates in streams may cycle nutrients faster than in slow flow rates, thus diminishing the extent of stream eutrophication.

4.5.3 Sources and Source Areas of Nutrients

Phosphorus is normally transported in surface water attached to sediment particles or in soluble forms. Nitrogen is normally transported by surface water runoff in urban watersheds. Sources for nitrogen and phosphorus in urban stormwater include fertilizer, pet waste, organic matter (such as leaves and detritus), and stream bank erosion. Another significant source of nutrients is atmospheric deposition. Fossil fuel combustion by automobiles, power plants and industry can supply nutrients in both wet fall and dry fall. The Metropolitan Washington Council of Governments (MWCOG, 1983) estimated total annual atmospheric deposition rates of 17 lbs/ac for nitrogen and 0.7 lbs/ac for phosphorus in the Washington, D.C. metro area.

Research from the upper Midwest suggests "hot spot" sources can exist for both nitrogen and phosphorus in urban watersheds. Lawns, in particular, contribute greater concentrations of Total N, Total P and dissolved phosphorus than other urban source areas. Indeed, source research suggests that nutrient concentrations in lawn runoff can be as much as four times greater than other urban sources such as streets, rooftops or driveways (Bannerman *et al.*, 1993; Steuer *et al.*, 1997 and Waschbusch *et al.*, 2000) (Table 29). This finding is significant, since lawns can comprise more than 50% of the total area in suburban watersheds. Lawn care, however, has seldom been directly linked to elevated nutrient concentrations during storms. A very recent lakeshore study noted that phosphorus concentrations were higher in fertilized lawns compared to unfertilized lawns, but no significant difference was noted for nitrogen (Garn, 2002).

Wash-off of deposited nutrients from IC is thought to be a major source of nitrogen and phosphorus during storms (MWCOG, 1983). While the concentration of nitrogen and phosphorus from parking lots and streets is lower than lawns, the volume of runoff is significantly higher. In two studies using the SLAMM source loading model (Pitt and Voorhees, 1989), parking lots and streets were responsible for over 30% of the nitrogen and were second behind lawns in their contributions to the phosphorus load (Steuer *et al.*, 1997; Waschbusch *et al.*, 2000).

Table 29: Source Area Monitoring Data for Total Nitrogen and Total Phosphorous in Urban Areas

Source Area	Total N (mg/l)	Total P (mg/l)		
Source	(1)	(1)	(2)	(3)
Commercial Parking Lot	1.94	0.20	N/R	0.10
High Traffic Street	2.95	0.31	0.47	0.18
Med. Traffic Street	1.62	0.23	1.07	0.22
Low Traffic Street	1.17	0.14	1.31	0.40
Commercial Rooftop	2.09	0.09	0.20	0.13
Residential Rooftop	1.46	0.06	0.15	0.07
Residential Driveway	2.10	0.35	1.16	N/R
Residential Lawn	9.70	2.33	2.67	0.79
Basin Outlet	1.87	0.29	0.66	N/R

(1) Steuer et al., 1997; (2) Bannerman et al., 1993; (3) Waschbusch et al., 2000; N/R= Not Reported

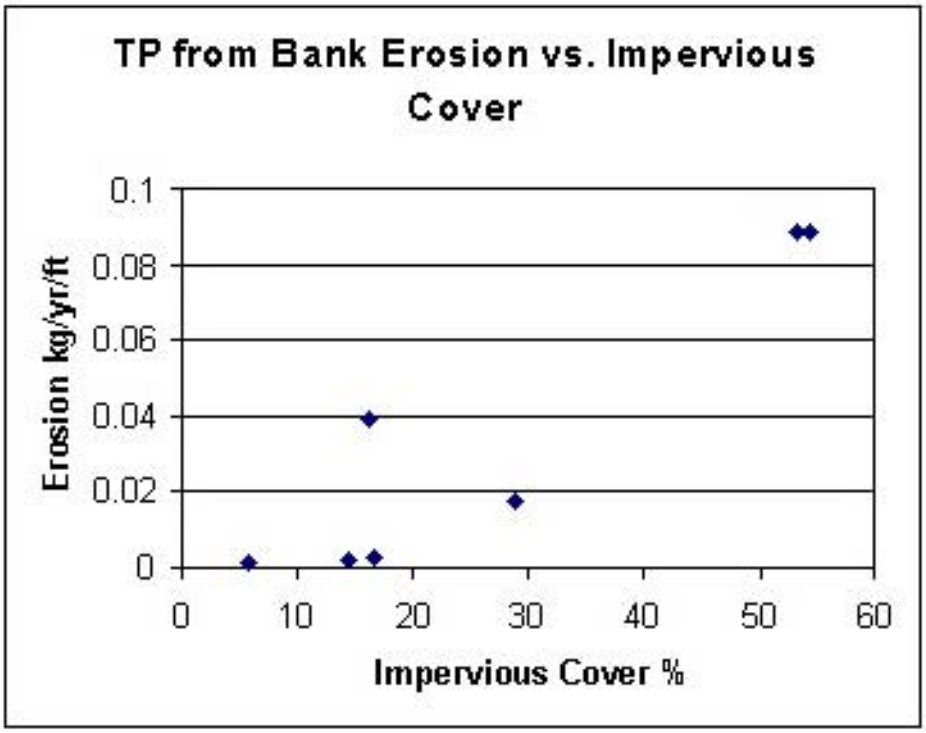


Figure 34: Total Phosphorus from Bank Erosion as a Function of IC in Texas Streams (Dartiguenave *et al.*, 1997)

Streambank erosion also appears to be a major source of nitrogen and phosphorus in urban streams. Both nitrogen and phosphorus are often attached to eroded bank sediment, as indicated in a recent study by Dartiguenave *et al.* (1997) in Austin, Texas. They showed that channel erosion contributed nearly 50% of the Total P load shown for subwatersheds with IC levels between 10 and 60 % (Figure 34). These findings suggest that prevention or reduction of downstream channel erosion may be an important nutrient reduction strategy for urban watersheds.

Snowmelt runoff generally has higher nutrient EMCs, compared to stormwater runoff. Oberts (1994) found that TKN and nitrate EMCs were much higher in snowmelt at all sites. The same pattern has also been observed for phosphorus EMCs during snowmelt and stormwater runoff. Zapf-Gilje *et al*. (1986) found that the first 20% of snowmelt events contained 65% of the phosphorus and 90% of the nitrogen load. Ayers *et al.* (1985) reported that a higher percentage of the annual nitrate, TKN and phosphorus load was derived from snowmelt runoff compared to stormwater runoff in an urban Minnesota watershed, which presumably reflects the accumulation of nutrients in the snowpack during the winter.

4.6 Trace Metals

Many trace metals can be found at potentially harmful concentrations in urban stormwater. Certain metals, such as zinc, copper, lead, cadmium and chromium, are consistently present at concentrations that may be of concern. These metals primarily result from the use of motor vehicles, weathering of metals and paints, burning of fossil fuels and atmospheric deposition.

Metals are routinely reported as the total recoverable form or the dissolved form. The dissolved form refers to the amount of metal dissolved in the water, which excludes metals attached to suspended particles that cannot pass through a 0.45 micron filter. Total recoverable refers to the concentration of an unfiltered sample that is treated with hot dilute mineral acid. In general, the toxicity of metals is related more to the dissolved form than the recoverable form.

4.6.1 Concentrations

Stormwater EMCs for zinc, copper, lead, cadmium and chromium vary regionally and are reviewed in Table 30. Regional differences in trace metal concentrations and water quality standard exceedence appears to be related to climate. In general, drier regions often have a

Table 30: EMCs and Detection Frequency for Metals in Urban Stormwater

Metal	Detection Frequency(1)	EMCs (Fg/l)		Number of Events	Source
		Mean	Median		
Zinc	94%	162	129	2234	Smullen and Cave, 1998
		176	140	1281	USEPA, 1983
Copper	91%	13.5	11.1	1657	Smullen and Cave, 1998
		66.6	54.8	849	USEPA, 1983
Lead	94%	67.5	50.7	2713	Smullen and Cave, 1998
		175(2)	131 (2)	1579	USEPA, 1983
Cadmium	48%	0.7	N/R	150	USEPA, 1983
		0.5	N/R	100	USEPA, 1993
		N/R	0.75 **R** 0.96 **C** 2.1 **I**	30	Baird *et al.*, 1996
		3 **I** 1**U**	N/R	9	Doerfer and Urbonas, 1993
Chromium	58%	4	N/R	32	Baird *et al.*, 1996
		N/R	2.1 **R** 10 **C** 7 **I**	30	Baird *et al.*, 1996
		N/R	7	164	Bannerman *et al.*, 1993

N/R = Not Reported; R- Residential, C- Commercial, I- Industrial; (1) as reprinted in USEPA, 1983; (2) Lead levels have declined over time with the introduction of unleaded gasoline

Table 31: Average Total Recoverable and Dissolved Metals for 13 Stormwater Flows and Nine Baseflow Samples from Lincoln Creek in 1994 (Crunkilton *et al.*, 1996)

	Total Recoverable		Dissolved	
Metal (Fg/l)	Storm Flow	Baseflow	Storm Flow	Baseflow
Lead	35	3	1.7	1.2
Zinc	133	22	13	8
Copper	23	7	5	4
Cadmium	0.6	0.1	0.1	0.1

higher risk of exceeding trace metal concentration standards.

Crunkilton *et al.* (1996) measured recoverable and dissolved metals concentrations in Lincoln Creek, Wisconsin and found higher EMCs during storm events compared to baseflow periods (Table 31). They also found that total recoverable metal concentrations were almost always higher than the dissolved concentration (which is the more available form).

4.6.2 Impacts of Trace Metals on Streams

Although a great deal is known about the concentration of metals in urban stormwater, much less is known about their possible toxicity on aquatic biota. The primary concern related to the presence of trace metals in streams is their potential toxicity to aquatic organisms. High concentrations can lead to bioaccumulation of metals in plants and animals, possible chronic or acute toxicity, and contamination of sediments, which can affect bottom dwelling organisms (Masterson and Bannerman, 1994). Generally, trace metal concentrations found in urban stormwater are not high enough to cause acute toxicity (Field and Pitt, 1990). The cumulative accumulation of trace metal concentrations in bottom sediments and animal tissues are of greater concern. Some evidence exists for trace metal accumulation in bottom sediments of receiving waters and for bioaccumulation in aquatic species (Bay and Brown, 2000 and Livingston, 1996).

Relatively few studies have examined the chronic toxicity issue. Crunkilton *et al.* (1996) found that concentrations of lead, zinc and copper exceeded EPA's Chronic Toxicity Criteria more than 75% of the time in stormflow in stormwater samples for Lincoln Creek in Wisconsin. When exposed to storm and base flows in Lincoln Creek, *Ceriodaphnia dubia*, a common invertebrate test species, demonstrated significant mortality in extended flow-through tests. Around 30% mortality was recorded after seven days of exposure and 70% mortality was recorded after 14 days.

Crunkilton *et al.* (1996) also found that significant mortality in bullhead minnows occurred in only 14% of the tests by the end of 14 days, but mortality increased to 100% during exposures of 17 to 61 days (see Table 32). In a related study in the same watershed, Masterson and Bannerman (1994) determined that crayfish in Lincoln Creek had elevated levels of lead, cadmium, chromium and copper when compared to crayfish from a reference stream. The Lincoln Creek research provides limited evidence that prolonged exposure to trace metals in urban streams may result in significant toxicity.

Most toxicity research conducted on urban stormwater has tested for acute toxicity over a short period of time (two to seven days). Shorter term whole effluent toxicity protocols are generally limited to seven days (Crunkilton *et al.*, 1996). Research by Ellis (1986) reported delayed toxicity in urban streams. Field and Pitt (1990) demonstrated that pollutants deposited to the stream during storm events

may take upwards of 10 to 14 days to exert influence. The research suggests that longer term in-situ and flow-through monitoring are needed to definitively answer the question whether metal levels in stormwater can be chronically toxic.

An additional concern is that trace metals co-occur with other pollutants found in urban stormwater, and it is not clear whether they interact to increase or decrease potential toxicity. Hall and Anderson (1988) investigated the toxicity and chemical composition of urban stormwater runoff in British Columbia and found that the interaction of pollutants changed the toxicity of some metals. In laboratory analysis with *Daphnia pulex*, an aquatic invertebrate, they found that the toxicity of iron was low and that its presence reduced the toxicity of other metals. On the other hand, the presence of lead increased the toxicity of copper and zinc.

Interaction with sediment also influences the impact of metals. Often, over half of the trace metals are attached to sediment (MWCOG, 1983). This effectively removes the metals from the water column and reduces the availability for biological uptake and subsequent bioaccumulation (Gavin and Moore, 1982 and OWML, 1983). However, metals accumulated in bottom sediment can then be resuspended during storms (Heaney and Huber, 1978). It is important to note that the toxic effect of metals can be altered when found in conjunction with other substances. For instance, the presence of chlorides can increase the toxicity of some metals. Both metals and chlorides are common pollutants in snowpacks (see section 4.2 for more snow melt information).

4.6.3 Sources and Source Areas of Trace Metals

Research conducted in the Santa Clara Valley of California suggests that cars can be the dominant loading source for many metals of concern, such as cadmium, chromium, copper, lead, mercury and zinc (EOA, Inc., 2001). Other sources are also important and include atmospheric deposition, rooftops and runoff from industrial and residential sites.

The sources and source areas for zinc, copper, lead, chromium and cadmium are listed in Table 33. Source areas for trace metals in the urban environment include streets, parking lots, snowpacks and rooftops. Copper is often found in higher concentrations on urban streets, because some vehicles have brake pads that contain copper. For example, the Santa Clara study estimated that 50% of the total copper load was due to brake pad wear (Woodward-Clyde, 1992). Sources of lead include atmospheric deposition and diesel fuel emissions, which frequently occur along rooftops

Table 32: Percentage of In-situ Flow-through Toxicity Tests Using Daphnia *magna* and Pimephales *promelas* with Significant Toxic Effects from Lincoln Creek (Crunkilton *et al.*, 1996)

Species	Effect	Percent of Tests with Significant ($p<0.05$) Toxic Effects as Compared to Controls According to Exposure				
		48 hours	96 hours	7 days	14 days	17-61 days
D. *magna*	Mortality	0	N/R	36%	93%	N/R
	Reduced Reproduction	0	N/R	36%	93%	N/R
P. *promelas*	Mortality	N/R	0	0	14%	100%
	Reduced Biomass	N/R	N/R	60%	75%	N/R

N/R = Not Reported

and streets. Zinc in urban environments is a result of the wear of automobile tires (estimated 60% in the Santa Clara study), paints, and weathering of galvanized gutters and downspouts. Source area concentrations of trace metals are presented in Table 34. In general, trace metal concentrations vary considerably, but the relative rank among source areas remains relatively constant. For example, a source loading model developed for an urban watershed in Michigan estimated that parking lots, driveways and residential streets were the primary source areas for zinc, copper and cadmium loads (Steuer *et al.*, 1997).

Table 33: Metal Sources and Source Area "Hotspots" in Urban Areas

Metal	Sources	Source Area Hotspots
Zinc	tires, fuel combustion, galvanized pipes, roofs and gutters, road salts **estimate of 60% from tires*	parking lots, commercial and industrial rooftops, and streets
Copper	auto brake linings, pipes and fittings, algacides, and electroplating **estimate of 50% from brake pad wear*	parking lots, commercial roofs and streets
Lead	diesel fuel, paints and stains	parking lots, rooftops, and streets
Cadmium	component of motor oil and corrodes from alloys and plated surfaces	parking lots, rooftops, and streets
Chromium	found in exterior paints and corrodes from alloys and plated surfaces	most frequently found in industrial and commercial runoff

Sources: Bannerman et al., 1993; Barr, 1997; Steuer et al., 1997; Good, 1993; Woodward - Clyde, 1992

Table 34: Metal Source Area Concentrations in the Urban Landscape (Fg/l)

Source Area	Dissolved Zinc	Total Zinc	Dissolved Copper		Total Copper	Dissolved Lead		Total Lead		
Source	(1)	(2)	(1)	(2)	(2)	(1)	(3)	(1)	(3)	(2)
Commercial Parking Lot	64	178	10.7	9	15	N/R	N/R	40	N/R	22
High Traffic Street	73	508	11.2	18	46	2.1	1.7	37	25	50
Medium Traffic Street	44	339	7.3	24	56	1.5	1.9	29	46	55
Low Traffic Street	24	220	7.5	9	24	1.5	.5	21	10	33
Commercial Rooftop	263	330	17.8	6	9	20	N/R	48	N/R	9
Residential Rooftop	188	149	6.6	10	15	4.4	N/R	25	N/R	21
Residential Driveway	27	107	11.8	9	17	2.3	N/R	52	N/R	17
Residential Lawn	N/R	59	N/R	13	13	N/R	N/R	N/R	N/R	N/R
Basin Outlet	23	203	7.0	5	16	2.4	N/R	49	N/R	32

Sources: (1) Steuer et al., 1997; (2) Bannerman et al., 1993; (3) Waschbusch, 2000; N/R = Not Reported

4.7 Hydrocarbons: PAH, Oil and Grease

Hydrocarbons are petroleum-based substances and are found frequently in urban stormwater. The term "hydrocarbons" is used to refer to measurements of oil and grease and polycyclic-aromatic hydrocarbons (PAH). Certain components of hydrocarbons, such as pyrene and benzo[b]fluoranthene, are carcinogens and may be toxic to biota (Menzie-Cura , 1995). Hydrocarbons normally travel attached to sediment or organic carbon. Like many pollutants, hydrocarbons accumulate in bottom sediments of receiving waters, such as urban lakes and estuaries. Relatively few studies have directly researched the impact of hydrocarbons on streams.

4.7.1 Concentrations

Table 35 summarizes reported EMCs of PAH and oil and grease derived from storm event monitoring at three different areas of the U.S. The limited research on oil and grease concentrations in urban runoff indicated that the highest concentrations were consistently found in commercial areas, while the lowest were found in residential areas.

4.7.2 Impacts of Hydrocarbons on Streams

The primary concern of PAH and oil and grease on streams is their potential bioaccumulation and toxicity in aquatic organisms. Bioaccumulation in crayfish, clams and fish has been reported by Masterson and Bannerman (1994); Moring and Rose (1997); and Velinsky and Cummins (1994).

Table 35: Hydrocarbon EMCs in Urban Areas

Hydrocarbon Indicator	EMC Mean	Number of Events	Source	Location
PAH (Fg/l)	3.2*	12	Menzie-Cura, 1995	MA
	7.1	19	Menzie-Cura, 1995	MA
	13.4	N/R	Crunkilton *et al.*, 1996	WI
Oil and Grease (mg/l)	1.7 **R** 9 **C** 3 **I**	30	Baird *et al.*, 1996	TX
	3	N/R	USEPA, 1983	U.S.
	5.4*	8	Menzie-Cura, 1995	MA
	3.5	10	Menzie-Cura, 1995	MA
	3.89 **R** 13.13 **C** 7.10 **I**	N/R	Silverman *et al.*, 1988	CA
	2.35 **R** 5.63 **C** 4.86 **I**	107	Barr, 1997	MD

*N/R = Not Reported; R = Residential, C = Commercial, I = Industrial; * = geometric mean, ** = median*

Moring and Rose (1997) also showed that not all PAH compounds accumulate equally in urban streams. They detected 24 different PAH compounds in semi-permeable membrane devices (SPMDs), but only three PAH compounds were detected in freshwater clam tissue. In addition, PAH levels in the SPMDs were significantly higher than those reported in the clams.

While acute PAH toxicity has been reported at extremely high concentrations (Ireland *et al.*, 1996), delayed toxicity has also been found (Ellis, 1986). Crayfish from Lincoln Creek had a PAH concentration of 360 Fg/kg, much higher than the concentration thought to be carcinogenic (Masterson and Bannerman, 1994). By comparison, crayfish in a non-urban stream had undetectable PAH levels. Toxic effects from PAH compounds may be limited since many are attached to sediment and may be less available, with further reduction occurring through photodegradation (Ireland *et al.,* 1996).

The metabolic effect of PAH compounds on aquatic life is unclear. Crunkilton *et al.* (1996) found potential metabolic costs to organisms, but Masterson and Bannerman (1994) and MacCoy and Black (1998) did not. The long-term effect of PAH compounds in sediments of receiving waters remains a question for further study.

4.7.3 Sources and Source Areas of Hydrocarbons

In most residential stormwater runoff, hydrocarbon concentrations are generally less than 5mg/l, but the concentrations can increase to five to 10 mg/l within some commercial, industrial and highway areas (See Table 35). Specific **"**hotspots**"** for hydrocarbons include gas stations, commuter parking lots, convenience stores, residential parking areas and streets (Schueler and Shepp, 1993). These authors evaluated hydrocarbon concentrations within oil and grease separators in the Washington Metropolitan area and determined that gas stations had significantly higher concentrations of hydrocarbons and trace metals, as compared to other urban source areas. Source area research in an urban catchment in Michigan showed that commercial parking lots contributed 64% of the total hydrocarbon load (Steuer *et al.*, 1997). In addition, highways were found to be a significant contributor of hydrocarbons by Lopes and Dionne (1998).

4.8 Bacteria and Pathogens

Bacteria are single celled organisms that are too small to see with the naked eye. Of particular interest are coliform bacteria, typically found within the digestive system of warm-blooded animals. The coliform family of bacteria includes fecal coliform, fecal streptococci and Escherichia coli, which are consistently found in urban stormwater runoff. Their presence confirms the existence of sewage or animal wastes in the water and indicates that other harmful bacteria, viruses or protozoans may be present, as well. Coliform bacteria are indicators of potential public health risks and not actual causes of disease.

A pathogen is a microbe that is actually known to cause disease under the right conditions. Two of the most common waterborne pathogens in the U.S. are the protozoans *Cryptosporidium parvum* and *Giardia lambia*. *Cryptosporidium* is a waterborne intestinal parasite that infects cattle and domestic animals and can be transmitted to humans, causing life-threatening problems in people with impaired immune systems (Xiao *et al.*, 2001). *Giardia* can cause intestinal problems in humans and animals when ingested (Bagley *et al.,* 1998). To infect new hosts, protozoans create hard casings known as oocysts (*Cryptosporidium*) or cysts (*Giardia*) that are shed in feces and travel through surface waters in search of a new host.

4.8.1 Concentrations

Concentrations of fecal coliform bacteria in urban stormwater typically exceed the 200 MPN/100 ml threshold set for human contact recreation (USGS, 2001b). Bacteria concentrations also tend to be highly variable from storm to storm. For example, a national summary of fecal coliform bacteria in stormwater runoff is shown in Figure 35 and Table 36. The variability in fecal coliform ranges from 10 to 500,000 MPN/100ml with a mean of 15,038 MPN/100ml (Schueler, 1999). Another national database of more than 1,600 stormwater events computed a mean concentration of 20,000

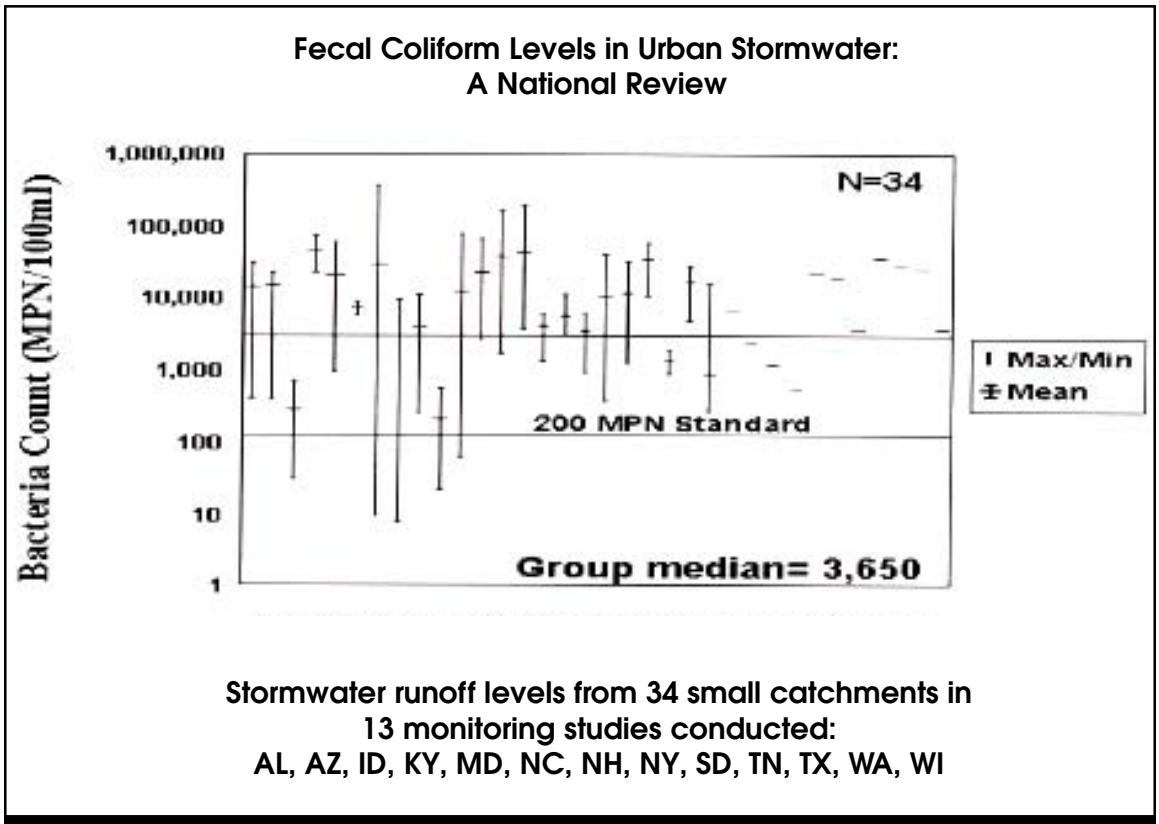


Figure 35: Fecal Coliform Levels in Urban Stormwater (Schueler, 1999)

Table 36: Bacteria EMCs in Urban Areas

Bacteria Type	EMCs (MPN/100ml) Mean	Number of Events	Source	Location
Fecal Coliform	15,038	34	Schueler, 1999	U.S.
	20,000	1600	Pitt, 1998	U.S.
	7,653	27	Thomas and McClelland, 1995	GA
	20,000 **R*** 6900 **C** 9700 **I**	30*	Baird *et al.*, 1996	TX
	77,970	21 watersheds	Chang *et al.*, 1990	TX
	4,500	189	Varner, 1995	WA
	23,500	3	Young and Thackston, 1999	TN
Fecal Strep	35,351	17	Schueler, 1999	U.S.
	28,864 **R**	27	Thomas and McClelland, 1995	GA
	56,000 **R** * 18,000 **C** 6,100 **I**	30*	Baird *et al.*, 1996	TX

*N/R = Not Reported, R = Residential Area, C = Commercial Area, I = Industrial Area, * = Median*

MPN/100ml for fecal coliform (Pitt, 1998). Fecal streptococci concentrations for 17 urban sites across the country had a mean of 35,351 MPN/100ml (Schueler, 1999).

Young and Thackston (1999) showed that bacteria concentrations at four sites in metro Nashville were directly related to watershed IC. Increasing IC reflects the cumulative increase in potential bacteria sources in the urban landscape, such as failing septic systems, sewage overflows, dogs, and inappropriate discharges. Other studies show that concentrations of bacteria are typically higher in urban areas than rural areas (USGS, 1999a), but they are not always directly related to IC. For example, Hydroqual (1996) found that concentrations of fecal coliform in seven subwatersheds of the Kensico watershed in New York were generally higher for more developed basins, but fecal coliform concentrations did not directly increase with IC in the developed basins (Figure 36).

There is some evidence that higher concentrations of coliform are found in arid or semi-arid watersheds. Monitoring data from semi-arid regions in Austin, San Antonio, and Corpus Christi, Texas averaged 61,000, 37,500 and 40,500 MPN/100ml, respectively (Baird *et al.*,1996 and Chang *et al.* 1990). Schiff (1996), in a report of Southern California NPDES monitoring, found that median concentrations of fecal coliform in San Diego were 50,000 MPN/100ml and averaged 130,000 MPN/100ml in Los Angeles. In all of these arid and semi-arid regions, concentrations were significantly higher than the national average of 15,000 to 20,000 MPN/100ml.

Concentrations of *Cryptosporidium* and *Giardia* in urban stormwater are shown in Table 37. States *et al.* (1997) found high concentrations of *Cryptosporidium* and *Giardia* in storm samples from a combined sewer in Pittsburgh (geometric mean 2,013 oocysts/100ml and 28,881 cysts/100ml). There is evidence that urban stormwater runoff may have higher concentrations of *Cryptosporidium* and *Giardia* than other surface waters, as reported in Table 38 (Stern, 1996). Both pathogens were detected in about 50% of urban stormwater samples, suggesting some concern for drinking water supplies.

4.8.2 Impacts of Bacteria and Pathogens on Streams

Fecal coliform bacteria indicate the potential for harmful bacteria, viruses, or protozoans and are used by health authorities to determine public health risks. These standards were established to protect human health based on exposures to water during recreation and drinking. Bacteria standards for various water uses are presented in Table 39 and are all easily exceeded by typical urban stormwater concentrations. In fact, over 80,000 miles of streams and rivers are currently in non-attain-

Table 37: *Cryptosporidium* and *Giardia* EMCs

Pathogens	Units	EMCs		Number of Events	Source
		Mean	Median		
Cryptosporidium	oocysts	37.2	3.9	78	Stern, 1996
	oocysts/100ml	2013	N/R	N/R	States *et al.*, 1997
Giardia	cysts	41.0	6.4	78	Stern, 1996
	cysts/100ml	28,881	N/R	N/R	States *et al.*, 1997

N/R= Not reported

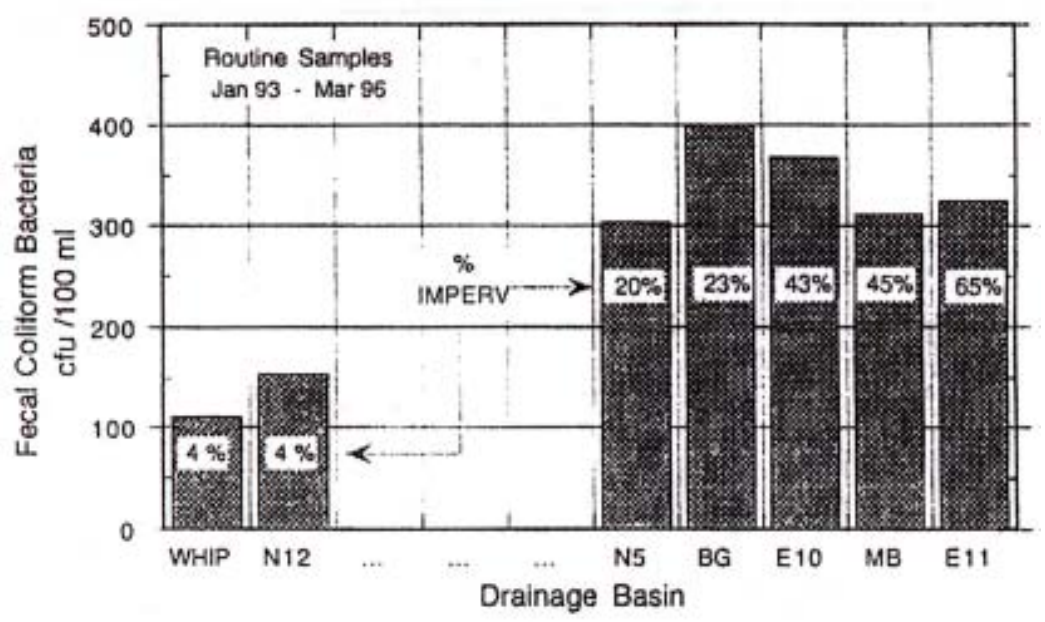


Figure 36: Relationship Between IC and Fecal Coliform Concentrations in New York Streams (Hydroqual, 1996)

Table 38: Percent Detection of *Giardia* cysts and *Cryptosporidium* oocysts in Subwatersheds and Wastewater Treatment Plant Effluent in the New York City Water Supply Watersheds (Stern, 1996)

Source Water Sampled	Number of Sources/ Number of Samples	Percent Detection			
		Total *Giardia*	Confirmed *Giardia*	Total *Cryptosporidium*	Confirmed *Cryptosporidium*
Wastewater Effluent	8/147	41.5%	12.9%	15.7%	5.4%
Urban Subwatershed	5/78	41.0%	6.4%	37.2%	3.9%
Agricultural Subwatershed	5/56	30.4%	3.6%	32.1%	3.6%
Undisturbed Subwatershed	5/73	26.0%	0.0%	9.6%	1.4%

Table 39: Typical Coliform Standards for Different Water Uses (USEPA, 1998)

Water Use	Microbial Indicator	Typical Water Standard
Water Contact Recreation	Fecal Coliform	<200 MPN per 100ml
Drinking Water Supply	Fecal Coliform	<20 MPN per 100ml
Shellfish Harvesting	Fecal Coliform	<14 MPN/ 100ml
Treated Drinking Water	Total Coliform	No more than 1% coliform positive samples per month
Freshwater Swimming	E.Coli	<126 MPN per 100ml

Important Note: Individual state standards may employ different sampling methods, indicators, averaging periods, averaging methods, instantaneous maximums and seasonal limits. MPN = most probable number. Higher or lower limits may be prescribed for different water use classes.

ment status because of high fecal coliform levels (USEPA, 1998).

4.8.3 Sources and Source Areas of Bacteria and Pathogens

Sources of coliform bacteria include waste from humans and wildlife, including livestock and pets. Essentially, any warm-blooded species that is present in significant numbers in a watershed is a potential culprit. Source identification studies, using methods such as DNA fingerprinting, have put the blame on species such as rats in urban areas, ducks and geese in stormwater ponds, livestock from hobby farms, dogs and even raccoons (Blankenship, 1996; Lim and Olivieri, 1982; Pitt, 1998; Samadpour and Checkowitz, 1998).

Transport of bacteria takes place through direct surface runoff, direct inputs to receiving waters, or indirect secondary sources. Source areas in the urban environment for direct runoff include lawns and turf, driveways, parking lots and streets. For example, dogs have high concentrations of fecal coliform in their feces and have a tendency to defecate in close proximity to IC (Schueler, 1999). Weiskel *et al.* (1996) found that direct inputs of fecal coliform from waterfowl can be very

important; these inputs accounted for as much as 67% of the annual coliform load to Buttermilk Bay, Massachusetts.

Indirect sources of bacteria include leaking septic systems, illicit discharges, sanitary sewer overflows (SSOs), and combined sewer overflows (CSOs). These sources have the potential to deliver high coliform concentrations to urban streams. In fact, extremely high bacteria concentrations are usually associated with wastewater discharges. CSOs and SSOs occur when the flow into the sewer exceeds the capacity of the sewer lines to drain them. CSOs result from stormwater flow in the lines, and SSOs are a result of infiltration problems or blockages in the lines.

Illicit connections from businesses and homes to the storm drainage system can discharge sewage or washwater into receiving waters. Illicit discharges can often be identified by baseflow sampling of storm sewer systems. Leaking septic systems are estimated to comprise between 10 and 40% of the systems, and individual inspections are the best way to determine failing systems (Schueler, 1999).

There is also evidence that coliform bacteria can survive and reproduce in stream sediments and storm sewers (Schueler, 1999). During a storm event, they often become resuspended and add to the in-stream bacteria load. Source area studies reported that end of pipe concentrations were an order of magnitude higher than any source area on the land surface; therefore, it is likely that the storm sewer system itself acts as a source of fecal coliform (Bannerman *et al.*, 1993 and Steuer *et al.*, 1997). Resuspension of fecal coliform from fine stream sediments during storm events has been reported in New Mexico (NMSWQB, 1999). The sediments in-stream and in the storm sewer system may be significant contributors to the fecal coliform load.

Sources of *Cryptosporidium* and *Giardia* include human sewage and animal feces. *Cryptosporidium* is commonly found in cattle, dogs and geese. Graczyk *et al.* (1998) found that migrating Canada geese were a vector for *Cryptosporidium* and *Giardia*, which has implications for water quality in urban ponds that support large populations of geese.

4.9 Organic Carbon

Total organic carbon (TOC) is often used as an indicator of the amount of organic matter in a water sample. Typically, the more organic matter present in water, the more oxygen consumed, since oxygen is used by bacteria in the decomposition process. Adequate levels of dissolved oxygen in streams and receiving waters are important because they are critical to maintain aquatic life. Organic carbon is routinely found in urban stormwater, and high concentrations can result in an increase in Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). BOD and COD are measures of the oxygen demand caused by the decay of organic matter.

4.9.1 Concentrations

Urban stormwater has a significant ability to exert a high oxygen demand on a stream or receiving water, even two to three weeks after an individual storm event (Field and Pitt, 1990). Average concentrations of TOC, BOD and COD in urban stormwater are presented in Table 40. Mean concentrations of TOC, BOD and COD during storm events in nationwide studies were 17 mg/l, 14.1 mg/l and 52.8 mg/l, respectively (Kitchell, 2001 and Smullen and Cave,1998).

4.9.2 Impacts of Organic Carbon on Streams

TOC is primarily a concern for aquatic life because of its link to oxygen demand in streams, rivers, lakes and estuaries. The initial effect of increased concentrations of TOC, BOD or COD in stormwater runoff may be a depression in oxygen levels, which may persist for many days after a storm, as deposited organic matter gradually decomposes (Field and Pitt, 1990).

TOC is also a concern for drinking water quality. Organic carbon reacts with chlorine during the drinking water disinfection process and forms trihalomethanes and other disinfection by-products, which can be a serious drinking water quality problem (Water, 1999). TOC concentrations greater than 2 mg/l in treated water and 4 mg/l in source water can result in unacceptably high levels of disinfection byproducts and must be treated to reduce TOC or remove the disinfection byproducts (USEPA, 1998). TOC can also be a carrier for other pollutants, such as trace metals, hydrocarbons and nutrients.

4.9.3 Sources and Source Areas of Total Organic Carbon

The primary sources of TOC in urban areas appear to be decaying leaves and other organic matter, sediment and combustion by-products. Source areas include curbs, storm drains, streets and stream channels. Dartiguenave *et al.* (1997) determined that about half of the annual TOC load in urban watersheds of Austin, TX was derived from the eroding streambanks.

Table 40: EMCs for Organic Carbon in Urban Areas

Organic Carbon Source	EMCs (mg/l)		Number of Events	Source
	Mean	Median		
Total Organic Carbon (TOC)	32.0	N/R	423	Barrett and Malina, 1998
	17	15.2	19 studies	Kitchell, 2001
Biological Oxygen Demand (BOD)	14.1	11.5	1035	Smullen and Cave, 1998
	10.4	8.4	474	USEPA, 1983
Chemical Oxygen Demand (COD)	52.8	44.7	2639	Smullen and Cave, 1998
	66.1	55	1538	USEPA, 1983

N/R = Not Reported

4.10 MTBE

Methyl tertiary butyl-ether (MTBE) is a volatile organic compound (VOC) that is added to gasoline to increase oxygen levels, which helps gas burn cleaner (called an oxygenate). MTBE has been used as a performance fuel additive since the 1970s. In 1990, the use of oxygenates was mandated by federal law and concentrations of MTBE in gasoline increased. Today, MTBE is primarily used in large metropolitan areas that experience air pollution problems. Since 1990, MTBE has been detected at increasing levels in both surface water and groundwater and is one of the most frequently detected VOCs in urban watersheds (USGS, 2001a). EPA has declared MTBE to be a potential human carcinogen at high doses. In March 2000, a decision was made by EPA to follow California's lead to significantly reduce or eliminate the use of MTBE in gasoline.

4.10.1 Concentrations

MTBE is highly soluble in water and therefore not easily removed once it enters surface or ground water. Delzer (1999) detected the presence of MTBE in 27% of the shallow wells monitored in eight urban areas across the country (Figure 37). Detection frequency was significantly higher in New England and Denver, as shown in Table 41. In a second study conducted in 16 metropolitan areas, Delzer (1999) found that 83% of MTBE detections occurred between October and March, the time when MTBE is primarily used as a fuel additive. The median MTBE concentration was 1.5 ppb, well below EPA's draft advisory level of 20 ppb (Delzer, 1996).

4.10.2 Impacts of MTBE on Streams

The primary concerns regarding MTBE are that it is a known carcinogen to small mammals, a suspected human carcinogen at higher

Table 41: MTBE Detection Frequency

Location	Detection Frequency	Source	Year
211 shallow wells in eight urban areas	27%	Delzer	1999
Surface water samples in 16 metro areas	7%	Delzer	1996

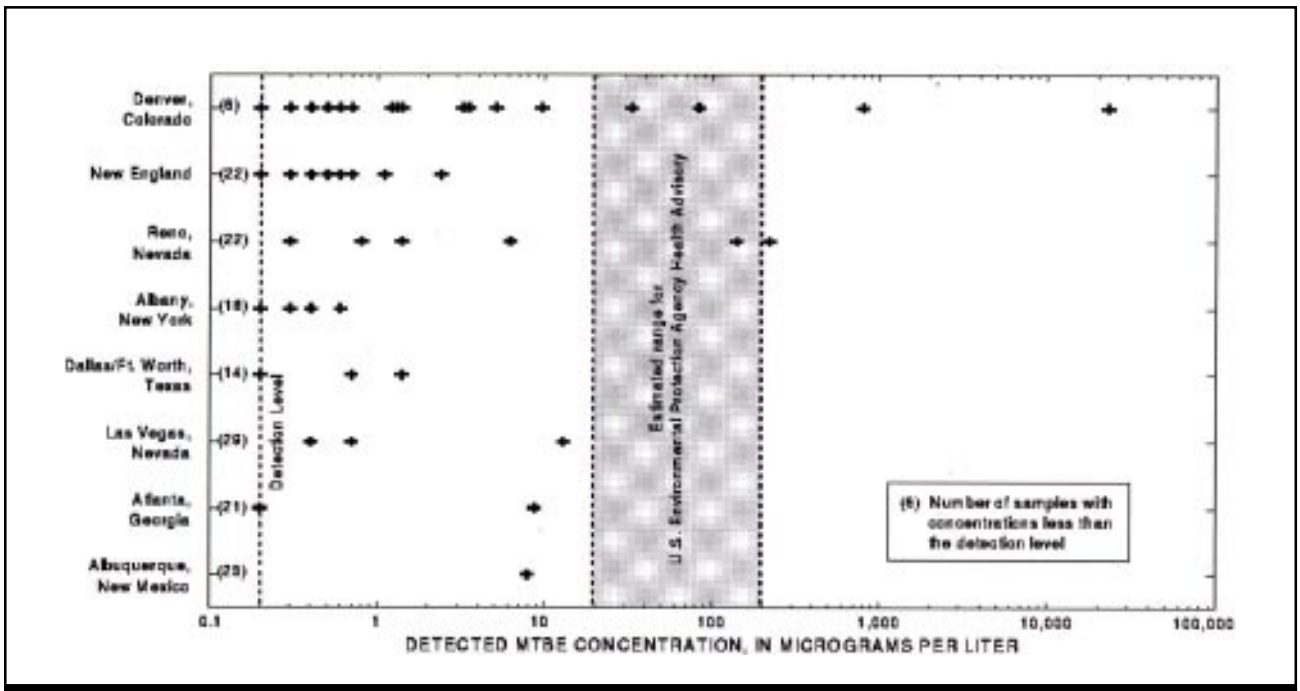


Figure 37: MTBE Concentrations in Surface Water from Eight Cities (Delzer, 1996)

doses and may possibly be toxic to aquatic life in small streams (Delzer, 1996). MTBE can also cause taste and odor problems in drinking water at fairly low concentrations. EPA issued a Drinking Water Advisory in 1997 that indicated that MTBE concentrations less than 20 ppb should not cause taste and odor problems for drinking water. However, the Association of California Water Agencies reports that some consumers can detect MTBE at levels as low as 2.5 ppb (ACWA, 2000). Because MTBE is frequently found in groundwater wells, it is thought to be a potential threat to drinking water (Delzer, 1999). For example, Santa Monica, California reportedly lost half of its groundwater drinking water supply due to MTBE contamination (Bay and Brown, 2000). MTBE has also been detected in human blood, especially in people frequently exposed to gasoline, such as gas station attendants (Squillace *et al.*, 1995).

4.10.3 Sources and Source Areas of MTBE

Since MTBE is a gasoline additive, its potential sources include any area that produces, transports, stores, or dispenses gasoline, particularly areas that are vulnerable to leaks and spills. Leaking underground storage tanks are usually associated with the highest MTBE concentrations in groundwater wells (Delzer, 1999). Vehicle emissions are also an important source of MTBE. Elevated levels are frequently observed along road corridors and drainage ditches. Once emitted, MTBE can travel in stormwater runoff or groundwater. Main source areas include heavily used multilane highways. Gas stations may also be a hotspot source area for MTBE contamination.

Another potential source of MTBE is watercraft, since two cycle engines can discharge as much as 20 to 30% of their fuel through the exhaust (Boughton and Lico, 1998). MTBE concentrations are clearly associated with increased use of gas engines, and there is concern that MTBE is an increasing component of atmospheric deposition (Boughton and Lico, 1998 and UC Davis, 1998).

4.11 Pesticides

Pesticides are used in the urban environment to control weeds, insects and other organisms that are considered pests. EPA estimates that nearly 70 million pounds of active pesticide ingredients are applied to urban lawns each year as herbicides or insecticides. Herbicides are used on urban lawns to target annual and perennial broadleaf weeds, while insecticides are used to control insects. Many types of pesticides are available for use in urban areas. Immerman and Drummond (1985) report that 338 different active ingredients are applied to lawns and gardens nationally. Each pesticide varies in mobility, persistence and potential aquatic impact. At high levels, many pesticides have been found to have adverse effects on ecological and human health. Several recent research studies by the USGS have shown that insecticides are detected with the greatest frequency in urban streams, and that pesticide detection frequency increases in proportion to the percentage of urban land in a watershed (Ferrari *et al.*, 1997; USGS, 1998, 1999a-b, 2001b). A national assessment by the USGS

Table 42: Median Concentrations and Detection Frequency of Herbicides and Insecticides in Urban Streams

Pollutant	Detection Frequency	Median Concentration (Fg/l)	Number of Samples	Source
Insecticides				
Diazinon	75%	0.025	326	USGS, 1998b
	92%	0.55	76	Brush *et al.*, 1995
	17%	0.002	1795	Ferrari *et al.*, 1997
Chlorpyrifos	41%	Non Detect	327	USGS, 1998b
	14%	0.004	1218	Brush *et al.*, 1995
Carbaryl	46%	Non Detect	327	USGS, 1998b
	22%	0.003	1128	Ferrari *et al.*, 1997
Herbicides				
Atrazine	86%	0.023	327	USGS, 1998b
	72%	0.099	2076	Ferrari *et al.*, 1997
Prometon	84%	0.031	327	USGS, 1998b
	56%	0.029	1531	Ferrari *et al.*, 1997
Simazine	88%	0.039	327	USGS, 1998b
	17%	0.046	1995	Ferrari *et al.*, 1997
2,4 -D	67%	1.1	11	Dindorf, 1992
	17%	0.035	786	Ferrari *et al.*, 1997
Dicamba	22%	1.8	4	Dindorf, 1992
MCPP	56%	1.8	10	Dindorf, 1992
MCPA	28%	1.0	5	Dindorf, 1992

(2001a) also indicates that insecticides are usually detected at higher concentrations in urban streams than in agricultural streams.

4.11.1 Concentrations

Median concentrations and detection frequency for common pesticides are shown in Table 42. Herbicides that are frequently detected in urban streams include atrazine; simazine; prometon; 2,4-D; dicamba; MCPP; and MCPA. Insecticides are also frequently encountered in urban streams, including diazinon, chlorpyrifos, malathion, and carbaryl. A USGS (1996) study monitored 16 sites in Gills Creek in Columbia, South Carolina over four days. This study reported that pesticide detection frequency increased as percent urban land increased.

Wotzka *et al.* (1994) monitored herbicide levels in an urban stream in Minneapolis, Minnesota during more than 40 storms. They found herbicides, such as 2,4-D; dicamba; MCPP; and MCPA in 85% of storm runoff events sampled. Total herbicide EMCs ranged from less than one to 70 µg/l. Ferrari *et al.* (1997) analyzed 463 streams in the mid-Atlantic region for the presence of 127 pesticide compounds. At least one pesticide was detected at more than 90% of the streams sampled.

Diazinon is one of the most commonly detected insecticides in urban stormwater runoff and dry weather flow. Diazinon was detected in 75% of National Water Quality Assessment (NAWQA) samples, 92% of stormflow samples from Texas, and 100% of urban stormflow samples in King County, Washington (Brush *et al.*, 1995 and USGS, 1999b). Diazinon is most frequently measured at concentrations greater than freshwater aquatic life criteria in urban stormwater (USGS, 1999a). USGS reports that diazinon concentrations were generally higher during urban stormflow (Ferrari *et al.,* 1997).

4.11.2 Impacts of Pesticides on Streams

Many pesticides are known or suspected carcinogens and can be toxic to humans and aquatic species. However, many of the known health effects require exposure to higher concentrations than typically found in the environment, while the health effects of chronic exposure to low levels are generally unknown (Ferrari *et al.*, 1997).

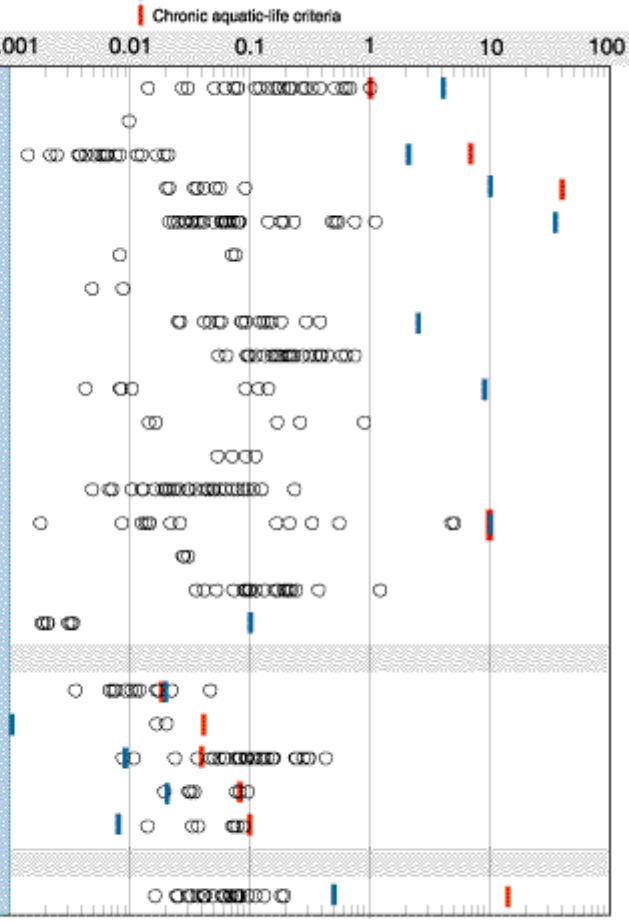
Studies that document the toxicity of insecticides and herbicides in urban stormwater have been focused largely on diazinon. Diazinon is responsible for the majority of acute toxicity in stormwater in Alameda County, California and King County, Washington (S.R. Hansen & Associates, 1995). Concentrations of diazinon in King County stormwater frequently exceed the freshwater aquatic life criteria (Figure 38). Similarly, research on Sacramento, California streams revealed acute toxicity for diazinon in 100% of stormwater samples using *Ceriodaphnia* as the test organism (Connor, 1995). Diazinon has a half-life of 42 days and is very soluble in water, which may explain its detection frequency and persistence in urban stormwater. Diazinon is also reported to attach fairly readily to organic carbon; consequently, it is likely re-suspended during storm events.

Insecticide concentrations exceeding acute and chronic toxicity thresholds for test organisms such as *Ceriodaphnia* have frequently been found in urban stormwater in New York, Texas, California, and Washington (Scanlin and Feng, 1997; Brush *et al.*, 1995; USGS, 1999b). The possibility exists that pesticides could have impacts on larger bodies of water, but there is a paucity of data on the subject at this time.

4.11.3 Sources and Source Areas of Pesticides

Sources for pesticides in urban areas include applications by homeowners, landscaping contractors and road maintenance crews. Source areas for pesticides in urban areas include lawns in residential areas; managed turf, such as golf courses, parks, and ball fields; and rights-of-way in nonresidential areas. Storage areas, which are subject to spills and leaks, can also be a source area. A study in San Francisco was able to trace high diazinon concentrations in some streams back to just a few households which had applied the pesticide at high levels (Scanlin and Feng, 1997). Two herbicides, simazine and atrazine, were detected in over 60% of samples in King County, WA stormwater but were not identified as being sold in retail stores. It is likely these herbicides are applied to nonresidential areas such as rights-of-way, parks and recreational areas (USGS, 1999b). Because pesticides are typically applied to turf, IC is not a direct indicator for pesticide concentrations, although they can drift onto paved surfaces and end up in stormwater runoff.

Active ingredient and trade name[1] example in parentheses	Freshwater aquatic-life criteria, in parts per billion (-- no aquatic-life criteria exist)			Concentration, in parts per billion (ppb)
Herbicide	Acute	Chronic	RMC	
2,4-D (Weedone)	[4]10	[4]1	[5,2]4	
Acetochlor (Guardian)	--	--	--	
Atrazine (AAtrex)	[4]70	[4]7	[5]2	
Dicamba (Banvel)	[4]390	[4]39	[5]10	
Dichlobenil (Casoron)	--	--	[2]37	
Dichlorprop (2,4-DP)	--	--	--	
EPTC (Eptam)	--	--	--	
MCPA (Kilsem)	--	--	[5]2.6	
MCPP (Mecoprop)	--	--	--	
Metolachlor (Dual)	--	--	[5]8	
Napropamide (Devrinol)	--	--	--	
Oxadiazon (Ronstar)	--	--	--	
Prometon (Pramitol)	--	--	--	
Simazine (Princep)	[4]100	[4]10	[2,5]10	
Tebuthiuron (Spike)	--	--	--	
Triclopyr (Garlon)	[4]5,600	[4]560	--	
Trifluralin (Treflan)	--	--	[5]0.1	
Insecticide				
Carbaryl (Sevin)	[4]0.17	[4]0.017	[2]0.02	
Chlorpyrifos (Dursban)	[3,7]0.083	[3,7]0.041	[2]0.001	
Diazinon (Diazinon)	[6]0.16	[6]0.04	[2]0.009	
gamma-HCH (Lindane)	[3]0.95	[7]0.08	[2]0.02	
Malathion (Malathion)	--	[3]0.1	[2]0.008	
Fungicide				
Pentachlorophenol (Penta)	[3,8]19	[3,8]15	[5]0.5	



1 Use of trade names is for descriptive purposes and does not imply endorsement by the U.S. Geological Survey, the Department of Ecology, or King County
2 National Academy of Sciences and National Academy of Engineering, 1973
3 U.S. Environmental Protection Agency, 1998
4 Norris and Dost, 1991, Table 3
5 Ministers of Health Canada and Environment Canada, 1995
6 Menconi and Cox, 1994
7 State of Washington, 1992
8 Criteria are pH dependent; values shown calculated at pH of 7.8

Figure 38: Concentrations of Pesticides in Stormwater in King County, WA (S.R. Hansen & Associates, 1995 and USGS, 1999b)

4.12 Deicers

Deicers are substances used to melt snow and ice to keep roads and walking areas safe. The most commonly used deicer is sodium chloride, although it may also be blended with calcium chloride or magnesium chloride. Other less frequently used deicers include urea and glycol, which are primarily used at airports to deice planes. Table 43 summarizes the composition, use and water quality effects of common deicers.

Chlorides are frequently found in snowmelt and stormwater runoff in most regions that experience snow and ice in the winter months (Oberts, 1994 and Sherman, 1998). Figure 39 shows that the application of deicer salts has increased since 1940 from 200,000 tons to 10 to 20 million tons per year in recent years (Salt Institute, 2001). Several U.S. and Canadian studies indicate severe inputs of road salts on water quality and aquatic life (Environment Canada, 2001 and Novotny *et al.*, 1999).

Table 43: Use and Water Quality Effect of Snowmelt Deicers (Ohrel, 1995; Sills and Blakeslee, 1992)

Deicer	Description	Use	Water Quality Effect
Chlorides	Chloride based deicer usually combined with Na, Ca or Mg	Road Deicer and Residential Use	Cl complexes can release heavy metals, affect soil permeability, impacts to drinking water, potential toxic effects to small streams
Urea	Nitrogen-based fertilizer product	Used as alternative to glycol	Increased nitrogen in water and potential toxicity to organisms
Ethylene Glycol	Petroleum based organic compounds, similar to antifreeze	Used at airports for deicing planes	Toxicity effects, high BOD and COD, hazardous air pollutant

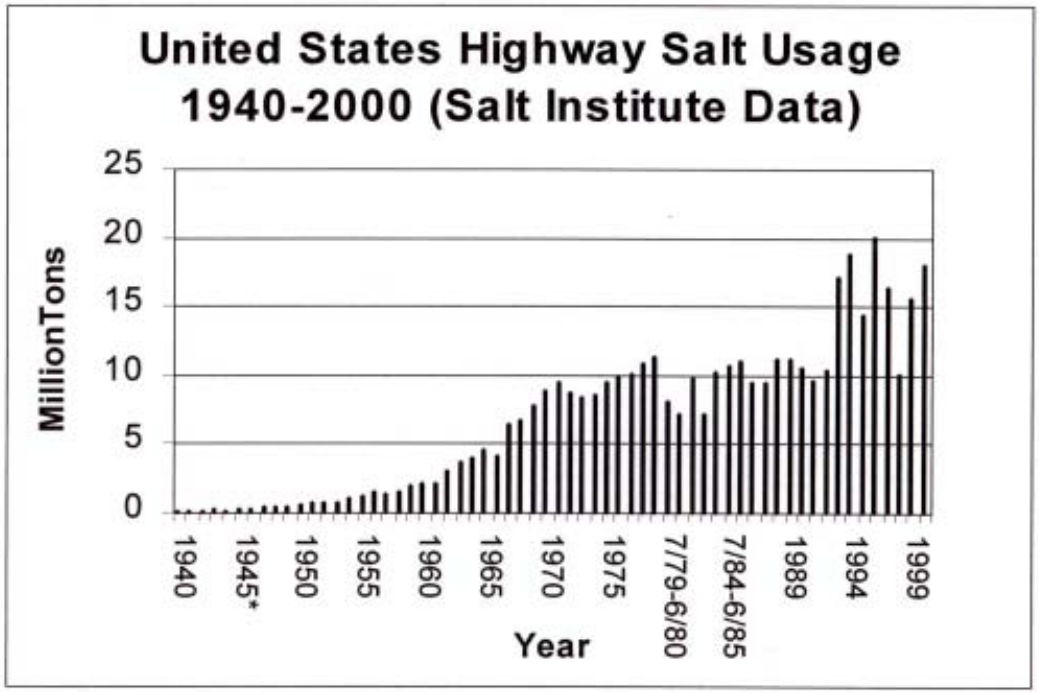


Figure 39: U.S. Highway Salt Usage Data (Salt Institute, 2001)

4.12.1 Concentrations

Chloride concentrations in snowmelt runoff depend on the amount applied and the dilution in the receiving waters. Data for snowmelt and stormwater runoff from several studies are presented in Table 44. For example, chloride concentrations in Lincoln Creek in Wisconsin were 1,612 mg/l in winter snowmelt runoff, as compared to 40 mg/l in non-winter runoff (Novotny *et al.*, 1999 and Masterson and Bannerman, 1994). Chloride concentrations in the range of 2,000 to 5,000 mg/l have been reported for Canadian streams (Environment Canada, 2001). Novotny *et al.* (1999) monitored chloride concentrations in snowmelt near Syracuse, New York and found that residential watersheds had higher chloride concentrations than rural watersheds.

Concentrations of glycol in stormwater runoff are also highly variable and depend on the amount of deicer used, the presence of a recovery system, and the nature of the precipitation event. Corsi *et al*. (2001) monitored streams receiving stormwater runoff from a Wisconsin airport. They found concentrations of propylene glycol as high as 39,000 mg/l at airport outfall sites during deicing operations and concentrations of up to 960 mg/l during low-flow sampling at an airport outfall site.

4.12.2 Impacts of Deicers on Streams

Chloride levels can harm aquatic and terrestrial life and contaminate groundwater and drinking water supplies (Ohrel, 1995). Generally, chloride becomes toxic to many organisms when it reaches concentrations of 500 to1,000 mg/l (Environment Canada, 2001). These concentrations are common in small streams in snow regions, at least for short periods of time. Many plant species are relatively intolerant to high salt levels in wetland swales and roadside corridors. Fish are also negatively affected by high chloride concentrations, with sensitivity as low as 600 mg/l for some species (Scott and Wylie, 1980).

Table 45 compares the maximum chloride concentrations for various water uses in eight states (USEPA, 1988). Snowmelt chloride concentrations typically exceed these levels.

Table 44: EMCs for Chloride in Snowmelt and Stormwater Runoff in Urban Areas

Form of Runoff	EMCs (mg/l)	Number of Events	Sources	Location
	Mean			
Snowmelt	116*	49	Oberts, 1994	MN
	2119	N/R	Sherman, 1998	Ontario
	1267 **R** 474 **U**	N/R	Novotny *et al.*, 1999	NY
	1612	N/R	Masterson and Bannerman, 1994	WI
	397	282	Environment Canada, 2001	Ontario, Canada
Non-winter Storm Event	42	61	Brush *et al.*, 1995	TX
	45	N/R	Sherman, 1998	Ontario
	40.5	N/R	Masterson and Bannerman, 1994	WI

*N/R = Not Reported, R = residential, U = urban, * = Median*

Chloride is a concern in surface drinking water systems because it can interfere with some of the treatment processes and can cause taste problems at concentrations as low as 250 mg/l. Chloride is also extremely difficult to remove once it enters the water.

Glycol-based deicers have been shown to be highly toxic at relatively low concentrations in streams receiving airport runoff. These deicers contain many proprietary agents, which may increase their toxicity and also make it very difficult to set standards for their use (Hartwell *et al.*, 1995). Corsi *et al.* (2001) observed acute toxicity of *Ceriodaphnia dubia*, *Pimephelas promelax*, *Hyalela azteca*, and *Chironimus tentans* in Wisconsin streams that experienced propylene glycol concentrations of 5,000 mg/l or more. Chronic toxicity was observed for *Ceriodaphnia dubia* and *Pimephelas promelax* at propylene glycol concentrations of 1,500 mg/l in the same study. In addition, glycol exerts an extremely high BOD on receiving waters, which can quickly reduce or eliminate dissolved oxygen. Glycol can also be toxic to small animals that are attracted by its sweet taste (Novotny *et al.*, 1999).

As with many urban pollutants, the effects of chloride can be diluted in larger waterbodies. In general, small streams are more likely to experience chloride effects, compared to rivers, which have a greater dilution ability.

4.12.3 Sources and Source Areas of Deicers

The main sources for deicers in urban watersheds include highway maintenance crews, airport deicing operations, and homeowner applications. Direct road application is the largest source of chloride, by far. Source areas include roads, parking lots, sidewalks, storm drains, airport runways, and snow collection areas. Because deicers are applied to paved surfaces, the primary means of transport to streams is through stormwater and meltwater runoff. Therefore, concentrations of deicer compounds are typically associated with factors such as road density or traffic patterns.

Table 45: Summary of State Standards for Salinity of Receiving Waters (USEPA, 1988)

State	Limiting Concentration (mg/l)	Beneficial Use
CO	250*	Drinking water
IL	500	General water supply
	250	Drinking water
IN	500	Drinking water
MA	250	Class A waters
MN	250	Drinking water
	500	Class A fishing and recreation
OH	250	Drinking water
SD	250	Drinking water
	100	Fish propagation
VA	250	Drinking water

** Monthly average*

4.13 Conclusion

IC collects and accumulates pollutants deposited from the atmosphere, leaked from vehicles, or derived from other sources. The pollutants build up over time but are washed off quickly during storms and are often efficiently delivered to downstream waters. This can create water quality problems for downstream rivers, lakes and estuaries.

As a result of local and national monitoring efforts, we now have a much better understanding of the nature and impacts of stormwater pollution. The typical sample of urban stormwater is characterized by high levels of many common pollutants such as sediment, nutrients, metals, organic carbon, hydrocarbons, pesticides, and fecal coliform bacteria. Other pollutants that have more recently become a concern in urban areas include MTBE, deicers, and the pathogens *Cryptosporidium* and *Giardia*. Concentrations of most stormwater pollutants can be characterized, over the long run, by event mean storm concentrations. Monitoring techniques have also allowed researchers to identify source areas for pollutants in the urban environment, including stormwater hotspots, which generate higher pollutant loads than normal development.

In general, most monitoring data shows that mean pollutant storm concentrations are higher in urban watersheds than in non-urban ones. For many urban pollutants, EMCs can be used to predict stormwater pollutant loads for urban watersheds, using IC as the key predictive variable. While a direct relationship between IC and pollutant concentrations does not usually exist, IC directly influences the volume of stormwater and hence, the total load. A few exceptions are worth noting. MTBE, deicers, and PAH appear to be related more to traffic or road density than IC. Additionally, MTBE and PAH concentrations may be greater at hotspot source areas, which are not always widely or uniformly distributed across a watershed. Pesticides, bacteria and pathogens are often associated with turf areas rather than IC. Bacteria and pathogen sources also include direct inputs from wildlife and inappropriate sewage discharges that are not uniformly distributed across a watershed and are not directly related to IC.

Further research into the relationship between stormwater pollutant loads and other watershed indicators may be helpful. For example, it would be interesting to see if turf cover is a good indicator of stream quality for impacted streams. Other important watershed indicators worth studying are the influence of watershed treatment practices, such as stormwater practices and stream buffers.

The direct effects of stormwater pollutants on aquatic systems appears to be a function of the size of the receiving water and the initial health of the aquatic community. For example, a small urban stream receiving high stormwater pollutant concentrations would be more likely to experience impacts than a large river, which is diluted by other land uses. Likewise, organisms in sensitive streams should be more susceptible to stormwater pollutants than pollution-tolerant organisms found in non-supporting streams.

Overall, the following conclusions can be made:

- Sediment, nutrient and trace metal loads in stormwater runoff can be predicted as a function of IC, although concentrations are not tightly correlated with watershed IC.
- Violations of bacteria standards are indirectly associated with watershed IC.
- It is not clear whether loads of hydrocarbons, pesticides or chlorides can be predicted on the basis of IC at the small watershed level.
- More research needs to be conducted to evaluate the usefulness of other watershed indicators to predict stormwater pollutant loads. For example, traffic, road density or hotspots may be useful in predicting MTBE, deicer and hydrocarbon loads. Also, watershed turf cover may be useful in predicting pesticide and bacterial loads.

- Most research on pollutants in stormwater runoff has been conducted at the small watershed level. Additional research is needed to evaluate the impact of watershed treatment, such as stormwater and buffer practices to determine the degree to which these may change stormwater concentrations or loads.
- Regional differences are evident for many stormwater pollutants, and these appear to be caused by either differences in rainfall frequency or snowmelt.

Chapter 5: Biological Impacts of Impervious Cover

This chapter reviews research on the impact of urbanization on the aquatic community, focusing on aquatic insects, fish, amphibians, freshwater mussels, and freshwater wetlands. Specifically, the relationship between the health of the aquatic community and the amount of watershed IC is analyzed within the context of the Impervious Cover Model (ICM).

The chapter is organized as follows:

5.1 Introduction
5.2 Indicators and General Trends
5.3 Effects on Aquatic Insect[1] Diversity
5.4 Effects on Fish Diversity
5.5 Effects on Amphibian Diversity
5.6 Effects on Wetland Diversity
5.7 Effects on Freshwater Mussel Diversity
5.8 Conclusion

5.1 Introduction

A number of studies, crossing different ecoregions and utilizing various techniques, have examined the link between watershed urbanization and its impact on stream and wetland biodiversity. These studies reveal that a relatively small amount of urbanization has a negative effect on aquatic diversity, and that as watersheds become highly urban, aquatic diversity becomes extremely degraded. As documented in prior chapters, hydrologic, physical, and water quality changes caused by watershed urbanization all stress the aquatic community and collectively diminish the quality and quantity of available habitat. As a result, these stressors generally cause a decline in biological diversity, a change in trophic structure, and a shift towards more pollution-tolerant organisms.

Many different habitat conditions are critical for supporting diverse aquatic ecosystems. For example, streambed substrates are vulnerable to deposition of fine sediments, which affects spawning, egg incubation and fry-rearing. Many aquatic insect species shelter in the large pore spaces among cobbles and boulders, particularly within riffles. When fine sediment fills these pore spaces, it reduces the quality and quantity of available habitat. The aquatic insect community is typically the base of the food chain in streams, helps break down organic matter and serves as a food source for juvenile fish.

Large woody debris (LWD) plays a critical role in the habitat of many aquatic insects and fish. For example, Bisson *et al.* (1988) contend that no other structural component is more important to salmon habitat than LWD, especially in the case of juvenile coho salmon. Loss of LWD due to the removal of stream side vegetation can significantly hinder the survival of more sensitive aquatic species. Since LWD creates different habitat types, its quality and quantity have been linked to salmonid rearing habitat and the ability of multiple fish species to coexist in streams.

The number of stream crossings (e.g., roads, sewers and pipelines) has been reported to increase directly in proportion to IC (May *et al*., 1997). Such crossings can become partial or total barriers to upstream fish migration, particularly if the stream bed downcuts below the fixed elevation of a culvert or pipeline. Fish barriers can prevent migration and recolonization of aquatic life in many urban streams.

Urbanization can also increase pollutant levels and stream temperatures. In particular, trace metals and pesticides often bind to sediment particles and may enter the food chain, particularly by aquatic insects that collect and filter particles. While in-stream data is rare, some data are available for ponds. A study of trace

[1]*Throughout this chapter, the term "aquatic insects" is used rather than the more cumbersome but technically correct "benthic macroinvertebrates."*

metal bioaccumulation of three fish species found in central Florida stormwater ponds discovered that trace metal levels were significantly higher in urban ponds than in non-urban control ponds, often by a factor of five to 10 (Campbell, 1995; see also Karouna-Renier, 1995). Although typical stormwater pollutants are rarely acutely toxic to fish, the cumulative effects of sublethal pollutant exposure may influence the stream community (Chapter 4).

Table 46 summarizes some of the numerous changes to streams caused by urbanization that have the potential to alter aquatic biodiversity. For a comprehensive review of the impacts of urbanization on stream habitat and biodiversity, the reader should consult Wood and Armitage (1997) and Hart and Finelli (1999).

Table 46: Review of Stressors to Urban Streams and Effects on Aquatic Life

Stream Change	Effects on Organisms
Increased flow volumes/ Channel forming storms	Alterations in habitat complexity Changes in availability of food organisms, related to timing of emergence and recovery after disturbance Reduced prey diversity Scour-related mortality Long-term depletion of LWD Accelerated streambank erosion
Decreased base flows	Crowding and increased competition for foraging sites Increased vulnerability to predation Increased fine sediment deposition
Increase in sediment transport	Reduced survival of eggs and alevins, loss of habitat due to deposition Siltation of pool areas, reduced macroinvertebrate reproduction
Loss of pools and riffles	Shift in the balance of species due to habitat change Loss of deep water cover and feeding areas
Changes in substrate composition	Reduced survival of eggs Loss of inter-gravel fry refugial spaces Reduced aquatic insect production
Loss of LWD	Loss of cover from predators and high flows Reduced sediment and organic matter storage Reduced pool formation and organic substrate for aquatic insects
Increase in temperature	Changes in migration patterns Increased metabolic activity, increased disease and parasite susceptibility Increased mortality of sensitive fish
Creation of fish blockages	Loss of spawning habitat for adults Inability to reach overwintering sites Loss of summer rearing habitat, Increased vulnerability to predation
Loss of vegetative rooting systems	Decreased channel stability Loss of undercut banks Reduced streambank integrity
Channel straightening or hardening	Increased stream scour Loss of habitat complexity
Reduction in water quality	Reduced survival of eggs and alevins Acute and chronic toxicity to juveniles and adult fish Increased physiological stress
Increase in turbidity	Reduced survival of eggs Reduced plant productivity Physiological stress on aquatic organisms
Algae blooms	Oxygen depletion due to algal blooms, increased eutrophication rate of standing waters

5.2 Indicators and General Trends

Stream indicators are used to gauge aquatic health in particular watersheds. The two main categories of stream indicators are **biotic** and **development** indices. **Biotic** indices use stream diversity as the benchmark for aquatic health and use measures, such as species abundance, taxa richness, EPT Index, native species, presence of pollution-tolerant species, dominance, functional feeding group comparisons, or proportion with disease or anomalies. **Development** indices evaluate the relationship between the degree of watershed urbanization and scores for the biotic indices. Common development indices include watershed IC, housing density, population density, and percent urban land use.

5.2.1 Biological Indicators

Biotic indices are frequently used to measure the health of the aquatic insect or fish community in urban streams. Because many aquatic insects have limited migration patterns or a sessile mode of life, they are particularly well-suited to assess stream impacts over time. Aquatic insects integrate the effects of short-term environmental variations, as most species have a complex but short life cycle of a year or less. Sensitive life stages respond quickly to environmental stressors, but the overall community responds more slowly. Aquatic insect communities are comprised of a broad range of species, trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects. Unlike fish, aquatic insects are abundant in most small, first and second order streams. Individuals are relatively easy to identify to family level, and many "intolerant" taxa can be identified to lower taxonomic levels with ease.

Fish are good stream indicators over longer time periods and broad habitat conditions because they are relatively long-lived and mobile. Fish communities generally include a range of species that represents a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, and piscivores). Fish tend to integrate the effects of lower trophic levels; thus, their community structure reflects the prevailing food sources and habitat conditions. Fish are relatively easy to collect and identify to the species level. Most specimens can be sorted and identified in the field by experienced fisheries scientists and subsequently released unharmed.

A review of the literature indicates that a wide variety of metrics are used to measure the aquatic insect and fish community. Community indices, such as the Index of Biotic Integrity (IBI) for fish and the Benthic Index of Biotic Integrity (B-IBI) for the aquatic insect community are a weighted combination of various metrics that typically characterize the community from "excellent" to "poor." Common metrics of aquatic community are often based on a composite of measures, such as species richness, abundance, tolerance, trophic status, and native status. Combined indices (C-IBI) measure both fish and aquatic insect metrics and a variety of physical habitat conditions to classify streams. Table 47 lists several common metrics used in stream assessments. It should be clearly noted that community and combined indices rely on different measurements and cannot be directly compared. For a comprehensive review of aquatic community indicators, see Barbour *et al.*(1999).

5.2.2 Watershed Development Indices

Watershed IC, housing density, population density, and percent urban land have all been used as indices of the degree of watershed development. In addition, reverse indicators such as percent forest cover and riparian continuity have also been used. The majority of studies so far have used IC to explore the relationship between urbanization and aquatic diversity. Percent urban land has been the second most frequently used indicator to describe the impact of watershed development. Table 48 compares the four watershed development indices and the thresholds where significant impacts to aquatic life are typically observed.

Table 47: Examples of Biodiversity Metrics Used to Assess Aquatic Communities

Measurement	Applied to:	Definition of Measurement
Abundance	Fish, Aquatic Insects	Total number of individuals in a sample; sometimes modified to exclude tolerant species.
Taxa Richness	Fish, Aquatic Insects	Total number of unique taxa identified in a sample. Typically, an increase in taxa diversity indicates better water and habitat quality.
EPT Index	Aquatic Insects	Taxa belonging to the following three groups: *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), *Trichoptera* (caddisflies). Typically, species in these orders are considered to be pollution-intolerant taxa and are generally the first to disappear with stream quality degradation.
Native Status	Fish	Native vs. non-native taxa in the community.
Specific Habitat	Fish	Riffle benthic insectivorous individuals. Total number of benthic insectivores. Often these types of individuals, such as darters, sculpins, and dace are found in high velocity riffles and runs and are sensitive to physical habitat degradation.
		Minnow species Total number of minnow species present. Often used as an indicator of pool habitat quality. Includes all species present in the family Cyprinidae, such as daces, minnows, shiners, stonerollers, and chubs.
Tolerant Species	Fish, Aquatic Insects	The total number of species sensitive to and the number tolerant of degraded conditions. Typically, intolerant species decline with decreasing water quality and stream habitat. A common high pollution-tolerant species that is frequently used is Chironomids.
Dominance	Fish, Aquatic Insects	The proportion of individuals at each station from the single most abundant taxa at that particular station. Typically, a community dominated by a single taxa may be indicative of stream degradation.
Functional Feeding Group Comparisons	Fish	Omnivores/ Generalists: The proportion of individuals characterized as omnivores or generalists to the total number of individuals. Typically, there is a shift away from specialized feeding towards more opportunistic feeders under degraded conditions as food sources become unreliable.
		Insectivores: The proportion of individuals characterized as insectivores to the total number of individuals. Typically, the abundance of insectivores decreases relative to increasing stream degradation.
	Aquatic Insects	Others: The proportion of individuals characterized as shredders, scrapers, or filter feeders to the total number of individuals. Typically, changes in the proportion of functional feeders characterized as shredders can be reflective of contaminated leaf matter. In addition, an overabundance of scrapers over filterers can be indicative of increased benthic algae.
Disease/ Anomalies	Fish	Proportion of individuals with signs of disease or abnormalities. This is ascertained through gross external examination for abnormalities during the field identification process. Typically, this metric assumes that incidence of disease and deformities increases with increasing stream degradation.

** This table is not meant to provide a comprehensive listing of metrics used for diversity indices; it is intended to provide examples of types of measures used in biological stream assessments (see Barbour* et al.*, 1999).*

5.2.3 General Trends

Most research suggests that a decline in both species abundance and diversity begins at or around 10% watershed IC (Schueler, 1994a). However, considerable variations in aquatic diversity are frequently observed from five to 20% IC, due to historical alterations, the effectiveness of watershed management, prevailing riparian conditions, co-occurrence of stressors, and natural biological variation (see Chapter 1).

Figures 40 through 42 display the negative relationship commonly seen between biotic indices and various measures of watershed development. For example, stream research in the Maryland Piedmont indicated that IC was the best predictor of stream condition, based on a combined fish and aquatic insect IBI (MNCPPC, 2000). In general, streams with less than 6% watershed IC were in "excellent" condition, whereas streams in "good" condition had less than 12% IC, and streams in "fair" condition had less than 20%. Figure 40 shows the general boundaries and typical variation seen in MNCPPC stream research.

Figure 41 illustrates that B-IBI scores and Coho Salmon/Cutthroat Trout Ratio are a function of IC for 31 streams in Puget Sound, Washington. The interesting finding was that "good" to "excellent" B-IBI scores (greater than 25) were reported in watersheds that had less than 10% IC, with eight notable outliers. These outliers had greater IC (25 to 35%) but similar B-IBI scores. These outliers are unique in that they had a large upstream wetland and/or a large, intact riparian corridor upstream (i.e. >70% of stream corridor had buffer width >100 feet).

Figure 42 depicts the same negative relationship between watershed urbanization and fish-IBI scores but uses population density as the primary metric of development (Dreher, 1997). The six-county study area included the Chicago metro area and outlying rural watersheds. Significant declines in fish-IBI scores were noted when population density exceeded 1.5 persons per acre.

The actual level of watershed development at which an individual aquatic species begins to decline depends on several variables, but may be lower than that indicated by the ICM. Some researchers have detected impacts for individual aquatic species at watershed IC levels as low as 5%. Other research has suggested that the presence of certain stressors, such as sewage treatment plant discharges (Yoder and Miltner, 2000) or construction sites (Reice, 2000) may alter the ICM and lower the level of IC at which biodiversity impacts become evident.

Table 48: Alternate Land Use Indicators and Significant Impact Levels (Brown, 2000; Konrad and Booth, 2002)

Land Use Indicator	Level at which Significant Impact Observed	Typical Value for Low Density Residential Use	Comments
% IC	10-20%	10%	Most accurate; highest level of effort and cost
Housing Density	>1 unit/acre	1 unit/acre	Low accuracy in areas of substantial commercial or industrial development; less accurate at small scales
Population Density	1.5 to 8+ people/acre	2.5 people/acre	Low accuracy in areas of substantial commercial or industrial development; less accurate at small scales
% Urban Land Use	33% (variable)	10-100%	Does not measure intensity of development; moderately accurate at larger watershed scales
Road Density	5 miles/square mile	2 miles/square mile	Appears to be a potentially useful indicator

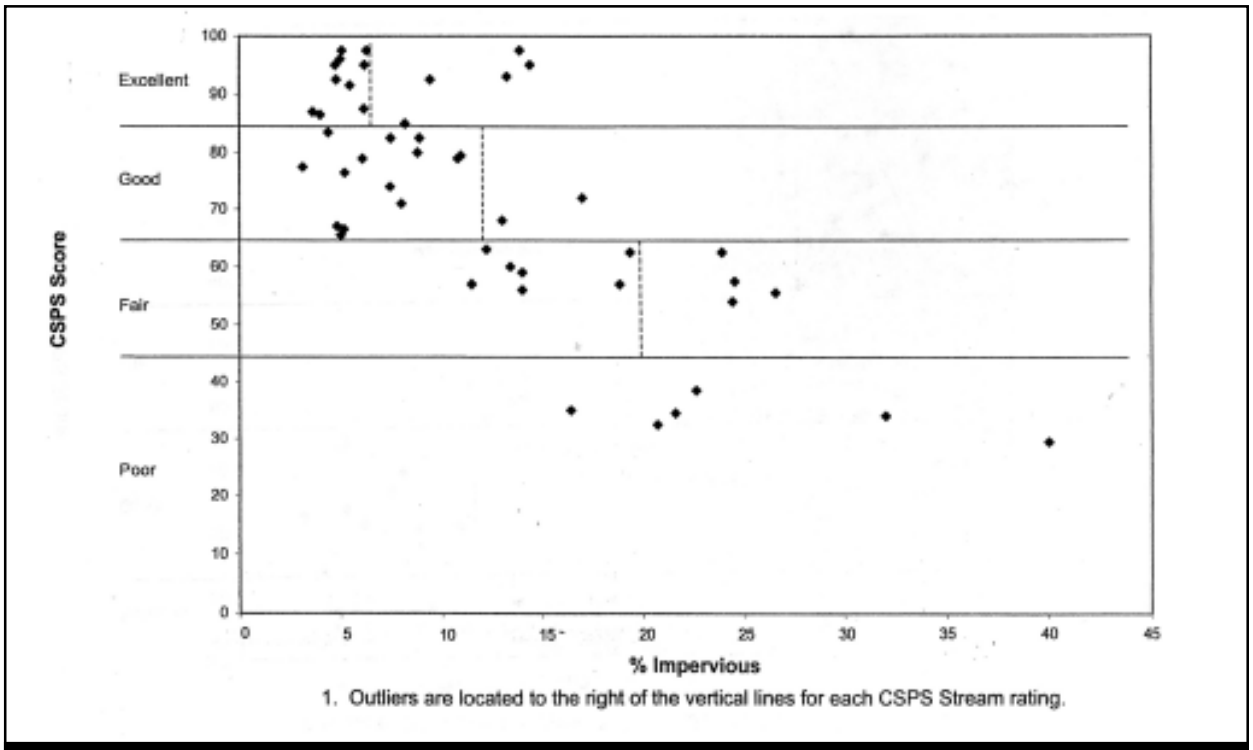


Figure 40: Combined Fish and Benthic IBI vs. IC in Maryland Piedmont Streams (MNCPPC, 2000)

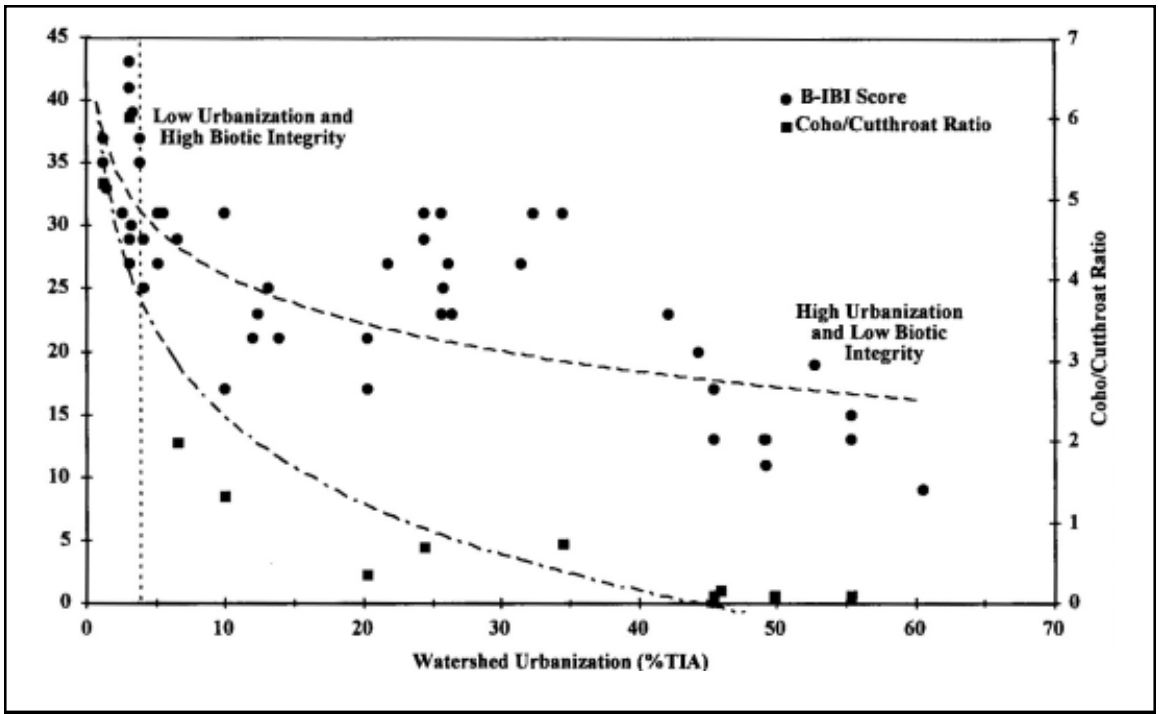


Figure 41: Relationship Between B-IBI, Coho/Cutthroat Ratios, and Watershed IC in Puget Sound Streams (Horner *et al.*, 1997)

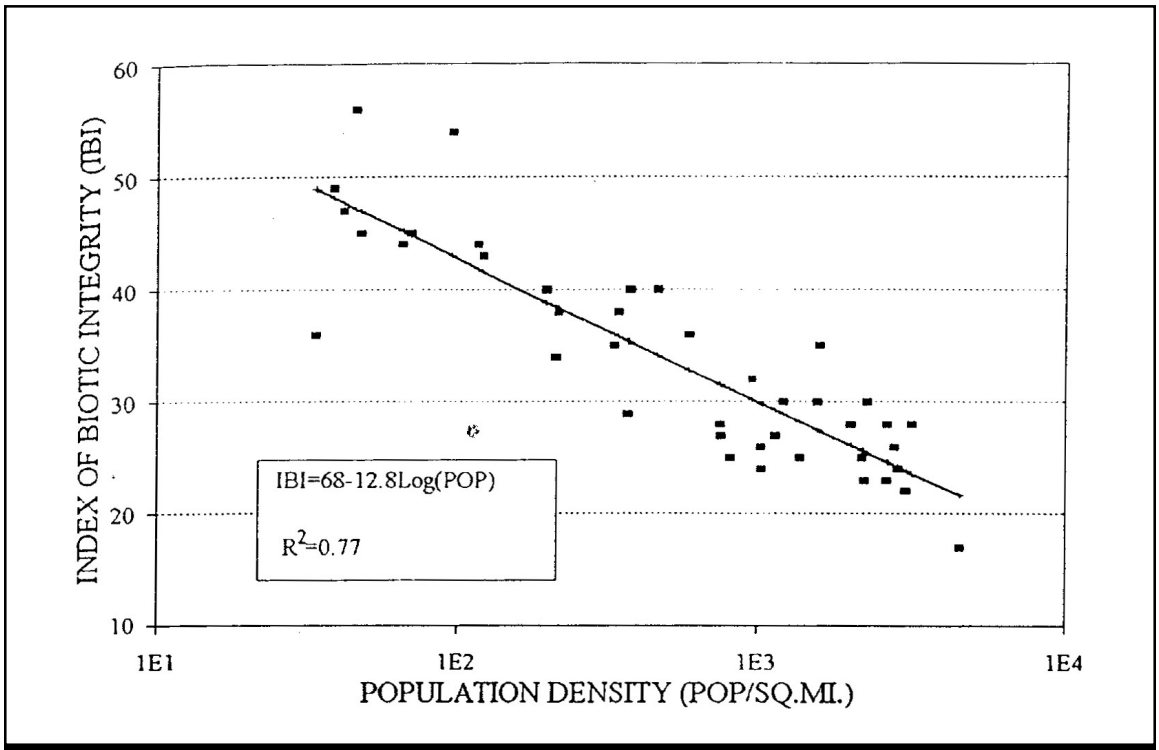


Figure 42: Index for Biological Integrity as a Function of Population Density in Illinois (Dreher, 1997)

5.3 Effects on Aquatic Insect Diversity

The diversity, richness and abundance of the aquatic insect community is frequently used to indicate urban stream quality. Aquatic insects are a useful indicator because they form the base of the stream food chain in most regions of the country. For this reason, declines or changes in aquatic insect diversity are often an early signal of biological impact due to watershed development. The aquatic insect community typically responds to increasing development by losing species diversity and richness and shifting to more pollution-tolerant species. More than 30 studies illustrate how IC and urbanization affect the aquatic insect community. These are summarized in Tables 49 and 50.

5.3.1 Findings Based on IC Indicators

Klein (1979) was one of the first researchers to note that aquatic insect diversity drops sharply in streams where watershed IC exceeded 10 to 15%. While "good" to "fair" diversity was noted in all headwater streams with less than 10% IC, nearly all streams with 12% or more watershed IC recorded "poor" diversity. Other studies have confirmed this general relationship between IC and the decline of aquatic insect species diversity. Their relationships have been an integral part in the development of the ICM. The sharp drop in aquatic insect diversity at or around 12 to 15% IC was also observed in streams in the coastal plain and Piedmont of Delaware (Maxted and Shaver, 1997).

Impacts at development thresholds lower than 10% IC have also been observed by Booth (2000), Davis (2001), Horner *et al.* (1997) and Morse (2001). There seems to be a general recognition that the high levels of variability observed below 10% IC indicate that other factors, such as riparian condition, effluent discharges, and pollution legacy may be better indicators of aquatic insect diversity (Horner and May, 1999; Kennen, 1999; Steedman, 1988; Yoder *et al.*, 1999).

The exact point at which aquatic insect diversity shifts from fair to poor is not known with absolute precision, but it is clear that few, if any, urban streams can support diverse aquatic insect communities with more than 25% IC. Indeed, several researchers failed to find aquatic insect communities with good or excellent diversity in any highly urban stream (Table 52). Indeed, MNCPPC (2000) reported that all streams with more than 20% watershed IC were rated as "poor."

Several good examples of the relationship between IC and B-IBI scores are shown in Figures 43 through 45. Figure 43 depicts the general trend line in aquatic insect diversity as IC increased at 138 stream sites in Northern Virginia (Fairfax County, 2001). The survey study concluded that stream degradation occurred at low levels of IC, and that older developments lacking more efficient site design and stormwater controls tended to have particularly degraded streams. Figures 44 and 45 show similar trends in the relationship between IC and aquatic insect B-IBI scores in Maryland and Washington streams. In particular, note the variability in B-IBI scores observed below 10% IC in both research studies.

Often, shift in the aquatic insect community from pollution-sensitive species to pollution-tolerant species occurs at relatively low IC levels (<10%). This shift is often tracked using the EPT metric, which evaluates sensitive species found in the urban stream community in the orders of *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies). EPT species frequently disappear in urban streams and are replaced by more pollution-tolerant organisms, such as chironomids, tubificid worms, amphipods and snails.

In undisturbed streams, aquatic insects employ specialized feeding strategies, such as shredding leaf litter, filtering or collecting organic matter that flows by, or preying on other insects. These feeding guilds are greatly reduced in urban streams and are replaced by grazers, collectors and deposit feeders. Maxted and Shaver (1997) found that 90% of sensitive

Table 49: Recent Research Examining the Relationship Between IC and Aquatic Insect Diversity in Streams

Index	Key Finding (s)	Source	Location
Community Index	Three years stream sampling across the state at 1000 sites found that when IC was >15%, stream health was never rated good based on a C-IBI.	Boward *et al.*, 1999	MD
Community Index	Insect community and habitat scores were all ranked as poor in five subwatersheds that were greater than 30% IC.	Black and Veatch, 1994	MD
Community Index	Puget sound study finds that some degradation of aquatic invertebrate diversity can occur at any level of human disturbance (at least as measured by IC). 65% of watershed forest cover usually indicates a healthy aquatic insect community.	Booth, 2000	WA
Community Index	In a Puget Sound study, the steepest decline of B-IBI was observed after 6% IC. There was a steady decline, with approximately 50% reduction in B-IBI at 45% IC.	Horner *et al.*, 1997	WA
Community Index	B-IBI decreases with increasing urbanization in study involving 209 sites, with a sharp decline at 10% IC. Riparian condition helps mitigate effects.	Steedman, 1988	Ontario
Community Index	Wetlands, forest cover and riparian integrity act to mitigate the impact of IC on aquatic insect communities.	Horner *et al.*, 2001	WA, MD, TX
Community Index	B-IBI declines for aquatic insect with increasing IC at more than 200 streams.	Fairfax Co., 2001	VA
Community Index	Two-year stream study of eight Piedmont watersheds reported B-IBI scores declined sharply at an IC threshold of 15-30%.	Meyer and Couch,2000	GA
Community Index	Montgomery County study; subwatersheds with <12% IC generally had streams in good to excellent condition based on a combined fish and aquatic insect IBI. Watersheds with >20% IC had streams in poor condition.	MNCPPC, 2000	MD
Community Index	Study of 1st, 2nd, and 3rd order streams in the Patapsco River Basin showed negative relationship between B-IBI and IC.	Dail *et al.*, 1998	MD
Community Index	While no specific threshold was observed, impacts were seen at even low levels of IC. B-IBI values declined with increasing IC, with high scores observed only in reaches with <5% IC or intact riparian zones or upstream wetlands.	Horner and May, 1999	WA
Community Index	The C-IBI also decreased by 50% at 10-15% IC. These trends were particularly strong at low-density urban sites (0-30% IC).	Maxted and Shaver, 1997	DE
Diversity	In both coastal plain and Piedmont streams, a sharp decline in aquatic insect diversity was found around 10-15% IC.	Shaver *et al.*, 1995	DE
Diversity	In a comparison of Anacostia subwatersheds, there was significant decline in the diversity of aquatic insects at 10% IC.	MWCOG, 1992	DC
Diversity	In several dozen Piedmont headwater streams, aquatic diversity declined significantly beyond 10-12% IC.	Klein, 1979	MD
EPT Value	In a 10 stream study with watershed IC ranging from three to 30%, a significant decline in EPT values was reported as IC increased (r2 = 0.76).	Davis, 2001	MO
Sensitive Species	In a study of 38 wadeable, non-tidal streams in the urban Piedmont, 90% of sensitive organisms were eliminated from the benthic community after watershed IC reaches 10-15%.	Maxted and Shaver, 1997	DE
Species Abundance EPT values	For streams draining 20 catchments across the state, an abrupt decline in species abundance and EPT taxa was observed at approximately 6% IC.	Morse, 2001	ME

Table 50: Recent Research Examining the Relationship of Other Indices of Watershed Development on Aquatic Insect Diversity in Streams

Biotic	Key Finding (s)	Source	Location
Percent Urban Land use			
Community Index	Study of 700 streams in 5 major drainage basins found that the amount of urban land and total flow of municipal effluent were the most significant factors in predicting severe impairment of the aquatic insect community. Amount of forested land in drainage area was inversely related to impairment severity.	Kennen, 1999	NJ
Community Index	All 40 urban sites sampled had fair to very poor B-IBI scores, compared to undeveloped reference sites.	Yoder, 1991	OH
Community Index	A negative correlation between B-IBI and urban land use was noted. Community characteristics show similar patterns between agricultural and forested areas the most severe degradation being in urban and suburban areas.	Meyer and Couch, 2000	GA
EPT Value, Diversity, Community Index	A comparison of three stream types found urban streams had lowest diversity and richness. Urban streams had substantially lower EPT scores (22% vs 5% as number of all taxa, 65% vs 10% as percent abundance) and IBI scores in the poor range.	Crawford and Lenat, 1989	NC
Sensitive Species	Urbanization associated with decline in sensitive taxa, such as mayflies, caddisflies and amphipods while showing increases in oligochaetes.	Pitt and Bozeman, 1982	CA
Sensitive Species	Dramatic changes in aquatic insect community were observed in most urbanizing stream sections. Changes include an abundance of pollution-tolerant aquatic insect species in urban streams.	Kemp and Spotila, 1997	PA
Diversity	As watershed development levels increased, the aquatic insect diversity declined.	Richards *et al.*, 1993	MN
Diversity	Significant negative relationship between number of aquatic insect species and degree of urbanization in 21 Atlanta streams.	Benke *et al.*, 1981	GA
Diversity	Drop in insect taxa from 13 to 4 was noted in urban streams.	Garie and McIntosh, 1986	NJ
Diversity	Aquatic insect taxa were found to be more abundant in non-urban reaches than in urban reaches of the watershed.	Pitt and Bozeman, 1982	CA
Diversity	A study of five urban streams found that as watershed land use shifted from rural to urban, aquatic insect diversity decreased.	Masterson and Bannerman, 1994	WI
Other Land Use Indicators			
Community Index	Most degraded streams were found in developed areas, particularly older developments lacking newer and more efficient stormwater controls.	Fairfax Co., 2001	VA
Diversity	Urban streams had sharply lower aquatic insect diversity with human population above four persons/acre in northern VA.	Jones and Clark, 1987	VA
EPT Value	Monitoring of four construction sites in three varying regulatory settings found that EPT richness was related to enforcement of erosion and sediment controls. The pattern demonstrated that EPT richness was negatively affected as one moved from upstream to at the site, except for one site.	Reice, 2000	NC
Sensitive Species	In a Seattle study, aquatic insect community shifted to chironomid, oligochaetes and amphipod species that are pollution-tolerant and have simple feeding guild.	Pedersen and Perkins,1986	WA

species (based on EPT richness, % EPT abundance, and Hilsenhoff Biotic Index) were eliminated from the aquatic insect community when IC exceeded 10 to 15% in contributing watersheds of Delaware streams (Figure 46). In a recent study of 30 Maine watersheds, Morse (2001) found that reference streams with less than 5% watershed IC had significantly more EPT taxa than more urban streams. He also observed no significant differences in EPT Index values among streams with six to 27% watershed IC (Figure 47).

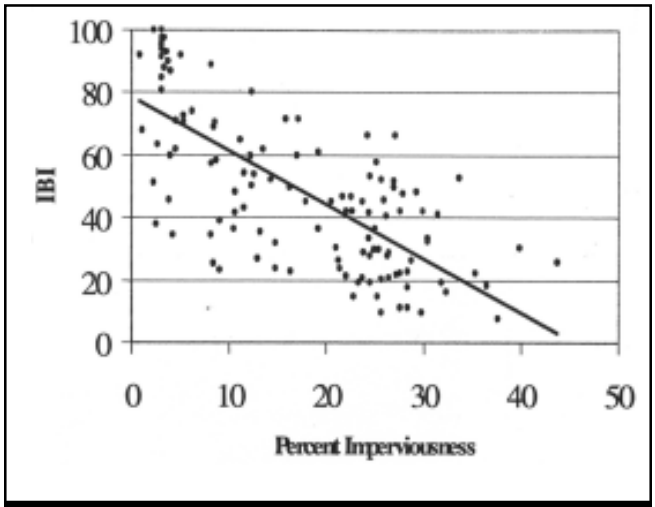


Figure 43: Trend Line Indicating Decline in Benthic IBI as IC Increases in Northern VA Streams (Fairfax County, 2001)

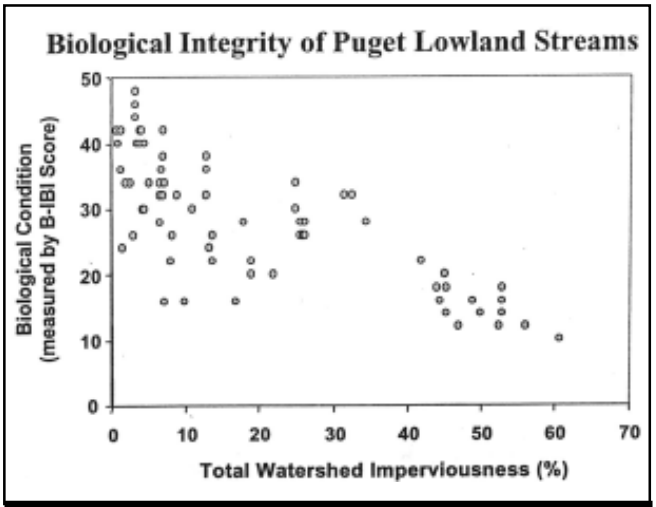


Figure 44: Relationship Between IC and B-IBI Scores in Aquatic Insects in Streams of the Puget Sound Lowlands (Booth, 2000)

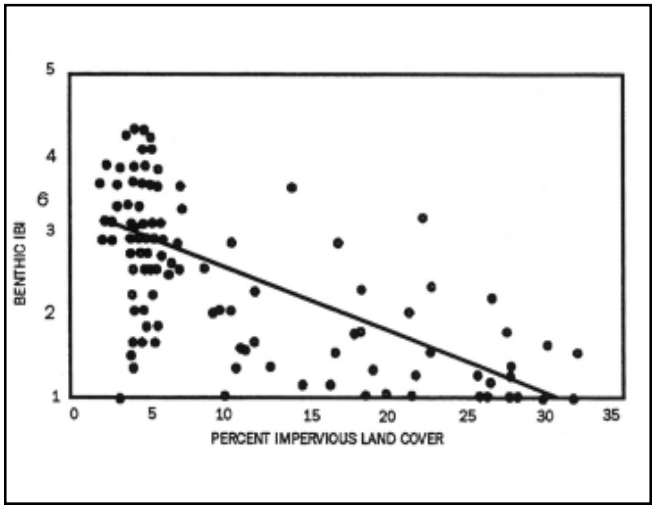


Figure 45: IC and B-IBI at Stream Sites in the Patapsco River Basin, MD (Dail *et al.*, 1998)

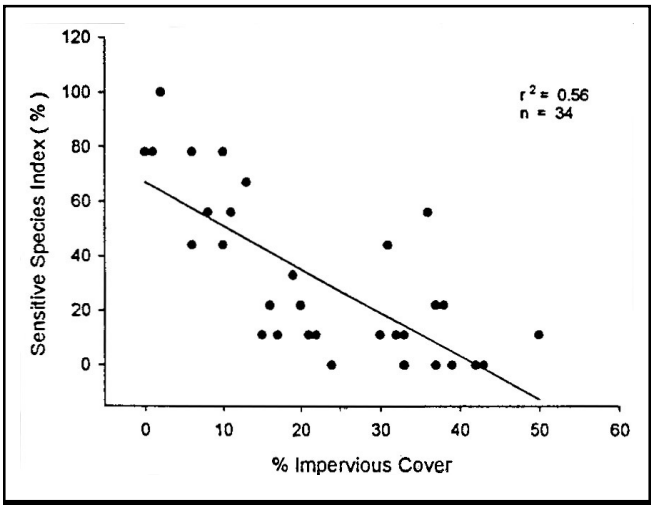


Figure 46: IC vs. Aquatic Insect Sensitivity - EPT Scores in Delaware Streams (Maxted and Shaver, 1997)

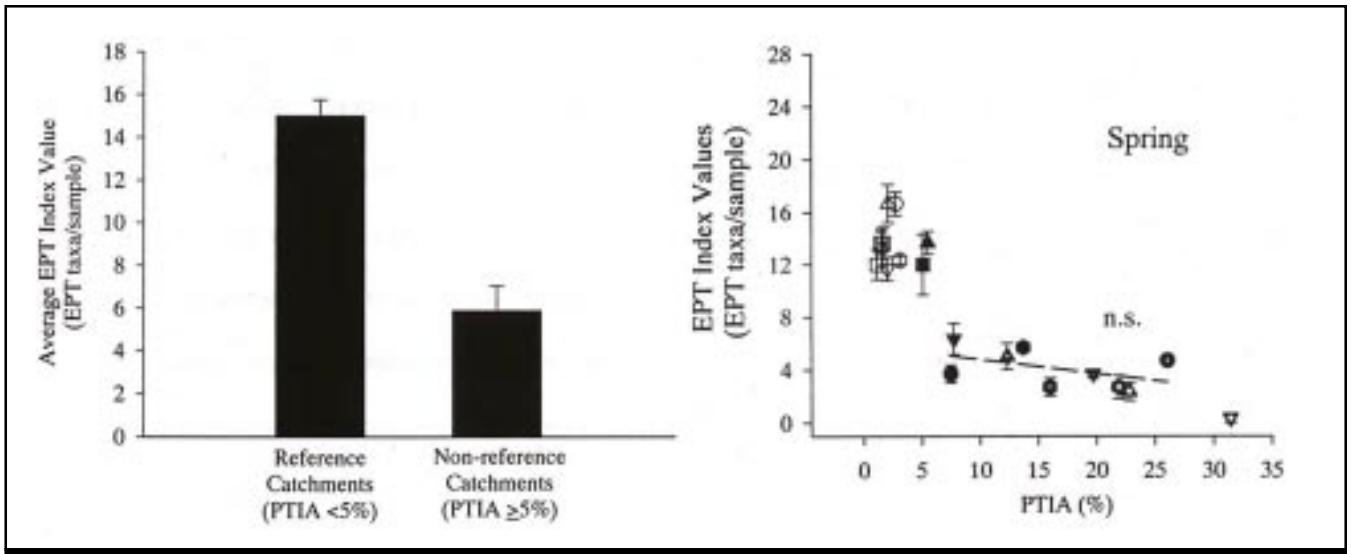


Figure 47: Average and Spring EPT Index Values vs.% IC in 20 Small Watersheds in Maine (Morse, 2001)

5.3.2 Findings Based on Other Development Indicators

Development indices, such as percent urban land use, population density, and forest and riparian cover have also been correlated with changes in aquatic insect communities in urban streams. Declines in benthic IBI scores have frequently been observed in proportion to the percent urban land use in small watersheds (Garie and McIntosh, 1986; Kemp and Spotila, 1997; Kennen, 1999; Masterson and Bannerman, 1994; Richards *et al.*, 1993; USEPA, 1982).

A study in Washington state compared a heavily urbanized stream to a stream with limited watershed development and found that the diversity of the aquatic insect community declined from 13 taxa in reference streams to five taxa in more urbanized streams (Pedersen and Perkins, 1986). The aquatic insect taxa that were lost were poorly suited to handle the variable erosional and depositional conditions found in urban streams. Similarly, a comparison of three North Carolina streams with different watershed land uses concluded the urban watershed had the least taxa and lowest EPT scores and greatest proportion of pollution-tolerant species (Crawford and Lenat, 1989).

Jones and Clark (1987) monitored 22 streams in Northern Virginia and concluded that aquatic insect diversity diminished markedly once watershed population density exceeded four or more people per acre. The population density roughly translates to ½ - 1 acre lot residential use, or about 10 to 20 % IC. Kennen (1999) evaluated 700 New Jersey streams and concluded that the percentage of watershed forest was positively correlated with aquatic insect density. Meyer and Couch (2000) reported a similar cover relationship between aquatic insect diversity and watershed and riparian forest cover for streams in the Atlanta, GA region. A study in the Puget Sound region found that aquatic insect diversity declined in streams once forest cover fell below 65% (Booth, 2000).

5.4 Effects on Fish Diversity

Fish communities are also excellent environmental indicators of stream health. In general, an increase in watershed IC produces the same kind of impact on fish diversity as it does for aquatic insects. The reduction in fish diversity is typified by a reduction in total species, loss of sensitive species, a shift toward more pollution-tolerant species, and decreased survival of eggs and larvae. More than 30 studies have examined the relationship between watershed development and fish diversity; they are summarized in Tables 51 and 52. About half of the research studies used IC as the major index of watershed development, while the remainder used other indices, such as percent urban land use, population density, housing density, and forest cover.

5.4.1 Findings Based on IC Indicators

Recent stream research shows a consistent, negative relationship between watershed development and various measures of fish diversity, such as diversity metrics, species loss and structural changes.

Typically, a notable decline in fish diversity occurs around 10 to 15% watershed IC (Boward *et al.*, 1999; Galli, 1994; Klein, 1979; Limburg and Schmidt, 1990; MNCPPC, 2000; MWCOG, 1992; Steward, 1983). A somewhat higher threshold was observed by Meyer and Couch (2000) for Atlanta streams with 15 to 30% IC; lower thresholds have also been observed (Horner *et al.*, 1997 and May *et al.*, 1997). A typical relationship between watershed IC and fish diversity is portrayed in Figure 48, which shows data from streams in the Patapsco River Basin in Maryland (Dail *et al.*, 1998). Once again, note the variability in fish-IBI scores observed below 10% IC.

Wang *et al.* (1997) evaluated 47 Wisconsin streams and found an apparent threshold around 10% IC. Fish-IBI scores were "good" to "excellent" below this threshold, but were consistently rated as "fair" to "poor." Additionally, Wang documented that the total number of fish species drops sharply when IC increases (Figure 49). Often, researchers also reported that increases in IC were strongly correlated with several fish metrics, such as increases in non-native and pollution-tolerant species in streams in Santa Clara, California (EOA, Inc., 2001).

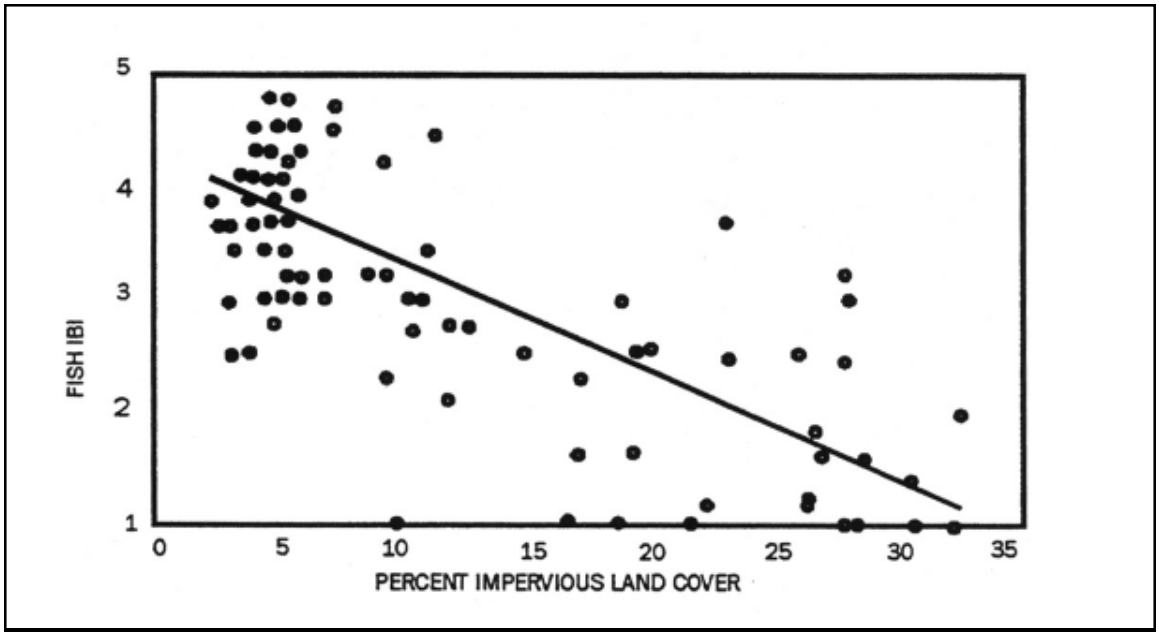


Figure 48: Fish-IBI vs. Watershed IC for Streams in the Patapsco River Basin, MD (Dail *et al.*, 1998)

Table 51: Recent Research Examining the Relationship Between Watershed IC and the Fish Community

Biotic	Key Finding (s)	Source	Location
Abundance	Brown trout abundance and recruitment declined sharply at 10-15% IC.	Galli, 1994	MD
Salmonids	Seattle study showed marked reduction in coho salmon populations noted at 10-15% IC at nine streams.	Steward, 1983	WA
Anadromous Fish Eggs	Resident and anadromous fish eggs and larvae declined in 16 subwatersheds draining to the Hudson River with >10% IC area.	Limburg and Schmidt, 1990	NY
Community Index	1st, 2nd, and 3rd order streams in the Patapsco River Basin showed negative relationship between IBI and IC.	Dail *et al.*, 1998	MD
Community Index	Fish IBI and habitat scores were all ranked as poor in five subwatersheds that were greater than 30% IC.	Black and Veatch, 1994	MD
Community Index	In the Potomac subregion, subwatersheds with < 12% IC generally had streams in good to excellent condition based on a combined fish and aquatic insect IBI. Watersheds with >20% IC had streams in poor condition.	MNCPPC, 2000	MD
Community Index	In a two-year study of Piedmont streams draining eight watersheds representing various land uses in Chattahochee River Basin, fish community quality dropped sharply at an IC threshold of 15-30%.	Meyer and Couch, 2000	GA
Diversity	Of 23 headwater stream stations, all draining <10% IC areas, rated as good to fair; all with >12% were rated as poor. Fish diversity declined sharply with increasing IC between 10-12%.	Schueler and Galli, 1992	MD
Diversity, Sensitive Species	Comparison of 4 similar subwatersheds in Piedmont streams, there was significant decline in the diversity of fish at 10% IC. Sensitive species (trout and sculpin) were lost at 10-12%.	MWCOG, 1992	MD
Diversity, Community Index	In a comparison of watershed land use and fish community data for 47 streams between the 1970s and 1990s, a strong negative correlation was found between number species and IBI scores with effective connected IC. A threshold of 10% IC was observed with community quality highly variable below 10% but consistently low above 10% IC.	Wang *et al.*, 1997	WI
Diversity	In several dozen Piedmont headwater streams fish diversity declined significantly in areas beyond 10-12% IC.	Klein, 1979	MD
Diversity , Abundance, Non-native Species	IC strongly associated with several fisheries species and individual-level metrics, including number of pollution-tolerant species, diseased individuals, native and non-native species and total species present	EOA, Inc., 2001	CA
Juvenile Salmon Ratios	In Puget Sound study, the steepest decline of biological functioning was observed after six percent IC. There was a steady decline, with approximately 50% reduction in initial biotic integrity at 45% IC area.	Horner *et al.*, 1997	WA
Juvenile Salmon Ratio	Physical and biological stream indicators declined most rapidly during the initial phase of the urbanization process as total IC area exceeded the five to 10% range.	May *et al.*, 1997	WA
Salmonoid	Negative effects of urbanization (IC) with the defacto loss of non-structural BMPs (wetland forest cover and riparian integrity) on salmon ratios	Horner *et al.*, 2001	WA, MD, TX
Salmonoid, Sensitive Species	While no specific threshold was observed (impacts seen at even low levels of IC), Coho/cutthroat salmon ratios >2:1 were found when IC was < 5%. Ratios fell below one at IC levels below 20 %.	Horner and May, 1999	WA
Sensitive species, Salmonid	Three years stream sampling across the state (approximately 1000 sites), MBSS found that when IC was >15%, stream health was never rated good based on CBI, and pollution sensitive brook trout were never found in streams with >2% IC.	Boward *et al.*, 1999	MD
Sensitive Species, Salmonids	Seattle study observed shift from less tolerant coho salmon to more tolerant cutthroat trout population between 10 and 15% IC at nine sites.	Luchetti and Feurstenburg 1993	WA

Sensitive fish are defined as species that strongly depend on clean and stable bottom substrates for feeding and/or spawning. Sensitive fish often show a precipitous decline in urban streams. The loss of sensitive fish species and a shift in community structure towards more pollution-tolerant species is confirmed by multiple studies. Figure 50 shows the results of a comparison of four similar subwatersheds in the Maryland Piedmont that were sampled for the number of fish species present (MWCOG, 1992). As the level of watershed IC increased, the number of fish species collected dropped. Two sensitive species, including sculpin, were lost when IC increased from 10 to 12%, and four more species were lost when IC reached 25%. Significantly, only two species remained in the fish community at 55% watershed IC.

Salmonid fish species (trout and salmon) and anadromous fish species appear to be particularly impacted by watershed IC. In a study in the Pacific Northwest, sensitive coho salmon were seldom found in watersheds above 10 or 15% IC (Luchetti and Feurstenburg, 1993 and Steward, 1983). Key stressors in urban streams, such as higher peak flows, lower dry weather flows, and reduction in habitat complexity (e.g. fewer pools, LWD, and hiding places) are believed to change salmon species composition, favoring cutthroat trout populations over the natural coho populations (WDFW, 1997).

A series of studies from the Puget Sound reported changes in the coho/cutthroat ratios of juvenile salmon as watershed IC increased (Figure 51). Horner *et al.* (1999) found Coho/Cutthroat ratios greater than 2:1 in watersheds with less than 5 % IC. Ratios fell below 1:1 when IC exceeded 20%. Similar results were reported by May *et al.* (1997). In the mid-Atlantic region, native trout have stringent temperature and habitat requirements and are seldom present in watersheds where IC exceeds 15% (Schueler, 1994a). Declines in trout spawning success are evident above 10% IC. In a study of over 1,000 Maryland streams, Boward *et al.* (1999) found that sensitive brook trout were never found in streams that had more than 4% IC in their contributing watersheds.

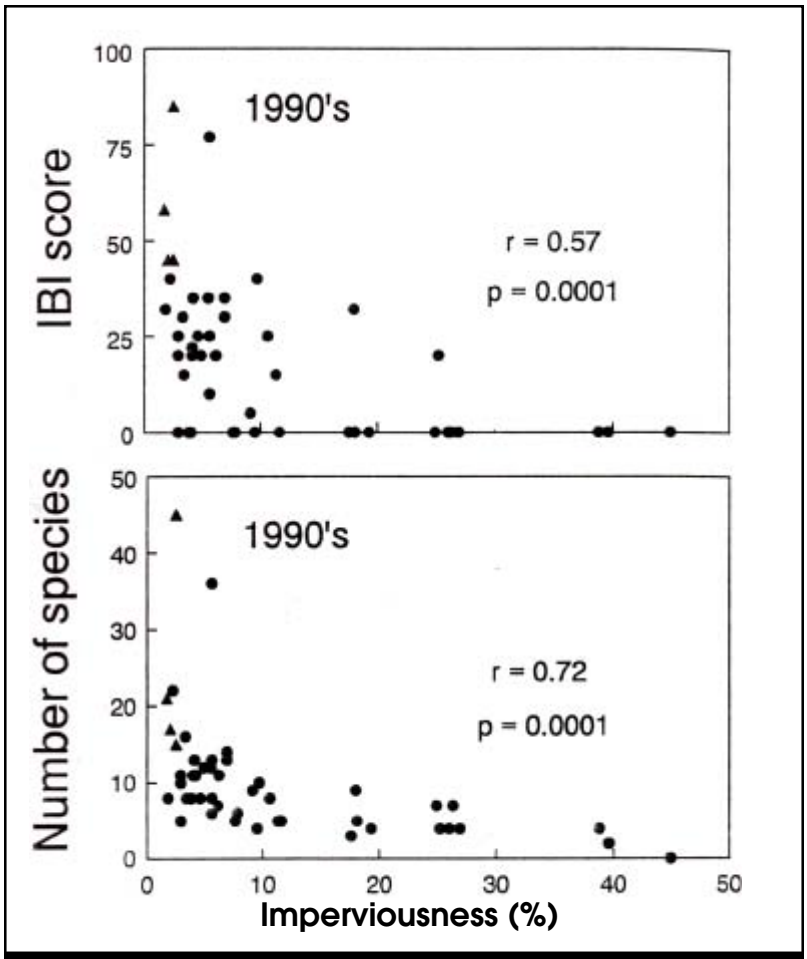


Figure 49: Fish-IBI and Number of Species vs. % IC in Wisconsin Streams (Wang *et al.*, 1997)

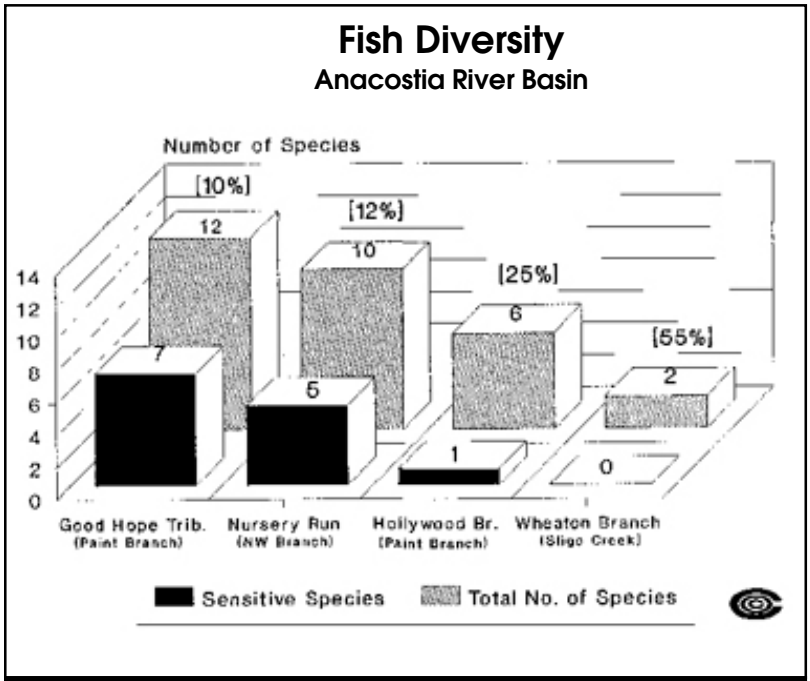


Figure 50: IC and Effects on Fish Species Diversity in Four Maryland Subwatersheds (MWCOG, 1992)

Table 52: Recent Research Examining Urbanization and Freshwater Fish Community Indicators

Biotic	Key Finding (s)	Source	Location
	Urbanization		
Community Index	All 40 urban sites sampled had fair to very poor IBI scores, compared to undeveloped reference sites.	Yoder, 1991	OH
Community Index	Negative correlations between biotic community and riparian conditions and forested areas were found. Similar levels of fish degradation were found between suburban and agricultural; urban areas were the most severe.	Meyer and Couch, 2000	GA
Community Index	Residential urban land use caused significant decrease in fish-IBI scores at 33%. In more urbanized Cuyahoga, a significant drop in IBI scores occurred around 8% urban land use in the watershed. When watersheds smaller than 100mi^2 were analyzed separately, the level of urban land associated with a significant drop in IBI scores occurred at around 15%. Above one du/ac, most sites failed to attain biocriteria regardless of degree of urbanization.	Yoder *et al.*, 1999	OH
Community Index, Abundance	As watershed development increased to about 10%, fish communities simplified to more habitat and trophic generalists and fish abundance and species richness declined. IBI scores for the urbanized stream fell from the good to fair category.	Weaver, 1991	VA
Diversity	A study of five urban streams found that as land use shifted from rural to urban, fish diversity decreased.	Masterson and Bannerman, 1994	WI
Diversity, Community Index	A comparison of three stream types found urban streams had lowest diversity and richness. Urban streams had IBI scores in the poor range.	Crawford and Lenat, 1989	NC
Salmon Spawning, Flooding Frequency	In comparing three streams over a 25-year period (two urbanizing and one remaining forested), increases in flooding frequencies and decreased trends in salmon spawning were observed in the two urbanizing streams, while no changes in flooding or spawning were seen in the forested system.	Moscript and Montgomery, 1997	WA
Sensitive Species	Observed dramatic changes in fish communities in most urbanizing stream sections, such as absence of brown trout and abundance of pollution-tolerant species in urban reaches.	Kemp and Spotila, 1997	PA
Sensitive Species, Diversity	Decline in sensitive species diversity and composition and changes in trophic structure from specialized feeders to generalists was seen in an urbanizing watershed from 1958 to 1990. Low intensity development was found to affect warm water stream fish communities similarly as more intense development.	Weaver and Garman, 1994	VA
Warm Water Habitat Biocriteria	25-30% urban land use defined as the upper threshold where attainment of warm water habitat biocriterion is effectively lost. Non-attainment also may occur at lower thresholds given the co-occurrence of stressors, such as pollution legacy, WTPs and CSOs.	Yoder and Miltner, 2000	OH
Community Index, Habitat	The amount of urban land use upstream of sample sites had a strong negative relationship with biotic integrity, and there appeared to be a threshold between 10 and 20% urban land use where IBI scores declined dramatically. Watersheds above 20% urban land invariably had scores less than 30 (poor to very poor). Habitat scores were not tightly correlated with degraded fish community attributes.	Wang *et al.*, 1997	WI
Community Index	A study in the Patapsco Basin found significant correlation of fish IBI scores with percent urbanized land over all scales (catchment, riparian area, and local area).	Roth *et al.*, 1998	MD

Table 52 (continued): Recent Research Examining Urbanization and Freshwater Fish Community Indicators

Biotic	Key Finding (s)	Source	Location
Urbanization			
Sensitive Species	Evaluated effects of runoff in both urban and non-urban streams; found that native species dominated the non-urban portion of the watershed but accounted for only seven percent of species found in the urban portions of the watershed.	Pitt, 1982	CA
Other Land Use Indicators			
Community Index, Habitat	Atlanta study found that as watershed population density increased, there was a negative impact on urban fish and habitat. Urban stream IBI scores were inversely related to watershed population density, and once density exceeded four persons/acre, urban streams were consistently rated as very poor.	Couch *et al.*, 1997	GA
Community Index	In an Atlanta stream study, modified IBI scores declined once watershed population density exceeds four persons/acre in 21 urban watersheds	DeVivo *et al.*, 1997	GA
Community Index	In a six-county study (including Chicago, its suburbs and outlying rural/agricultural areas), streams showed a strong correlation between population density and fish community assessments such that as population density increased, community assessment scores went from the better - good range to fair - poor. Significant impacts seen at 1.5 people/acre.	Dreher, 1997	IL
Community Index	Similarly, negative correlations between biotic community and riparian conditions and forested areas were also found. Similar levels of fish degradation were found between suburban and agricultural; urban areas were the most severe.	Meyer and Couch, 2000	GA
Community Index	Amount of forested land in basin directly related to IBI scores for fish community condition.	Roth *et al.*, 1996	MD
Salmonid, Sensitive Species	Species community changes from natural coho salmon to cutthroat trout population with increases in peak flow, lower low flow, and reductions in stream complexity.	WDFW, 1997	WA

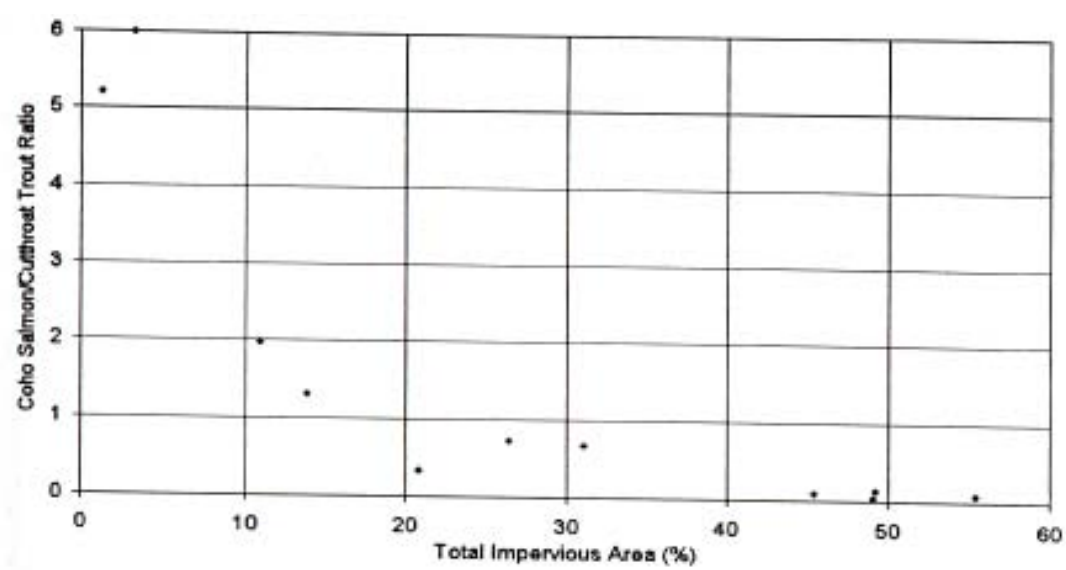


Figure 51: Coho Salmon/Cutthroat Trout Ratio for Puget Sound Streams (Horner *et al.*, 1997)

Many fish species have poor spawning success in urban streams and poor survival of fish eggs and fry. Fish barriers, low intragravel dissolved oxygen, sediment deposition and scour are all factors that can diminish the ability of fish species to successfully reproduce. For example, Limburg and Schmidt (1990) discovered that the density of anadromous fish eggs and larvae declined sharply in subwatersheds with more than 10% IC.

5.4.2 Findings Based on Other Development Indicators

Urban land use has frequently been used as a development indicator to evaluate the impact on fish diversity. Streams in urban watersheds typically had lower fish species diversity and richness than streams located in less developed watersheds. Declines in fish diversity as a function of urban land cover have been documented in numerous studies (Crawford and Lenat, 1989; Masterson and Bannerman, 1994; Roth *et al., 1998;* Yoder, 1991, and Yoder *et al.*, 1999). USEPA (1982) found that native fish species dominated the fish community of non-urban streams, but accounted for only 7% of the fish community found in urban streams. Kemp and Spotila (1997) evaluated streams in Pennsylvania and noted the loss of sensitive species (e.g. brown trout) and the increase of pollution-tolerant species, such as sunfish and creek chub (Figure 52).

Wang *et al.* (1997) cited percentage of urban land in Wisconsin watersheds as a strong negative factor influencing fish-IBI scores in streams and observed strong declines in IBI scores with 10 to 20% urban land use. Weaver and Garman (1994) compared the historical changes in the warm-water fish community of a Virginia stream that had undergone significant urbanization and found that many of the sensitive species present in 1958 were either absent or had dropped sharply in abundance when the watershed was sampled in 1990. Overall abundance had dropped from 2,056 fish collected in 1958 to 417 in 1990. In addition, the 1990 study showed that 67% of the catch was bluegill and common shiner, two species that are habitat and trophic "generalists." This shift in community to more habitat and trophic generalists was observed at 10% urban land use (Weaver, 1991).

Yoder *et al.* (1999) evaluated a series of streams in Ohio and reported a strong decrease in warm-water fish community scores around 33% residential urban land use. In the more urbanized Cuyahoga streams, sharp drops in

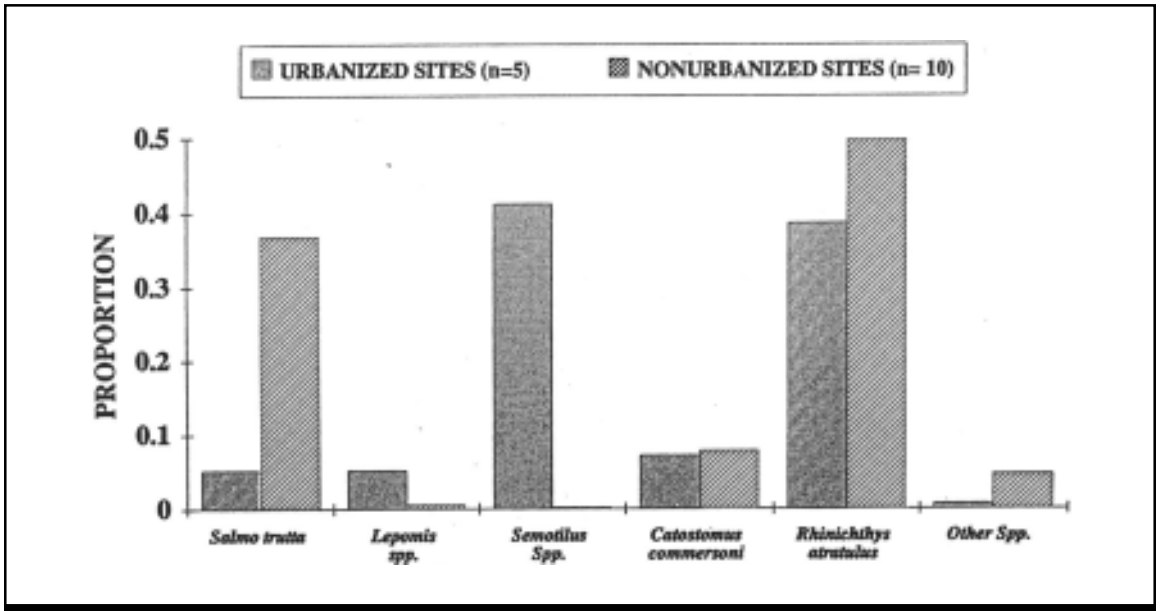


Figure 52: Mean Proportion of Fish Taxa in Urban and Non-Urban Streams, Valley Forge Watershed, PA (Kemp and Spotila, 1997)

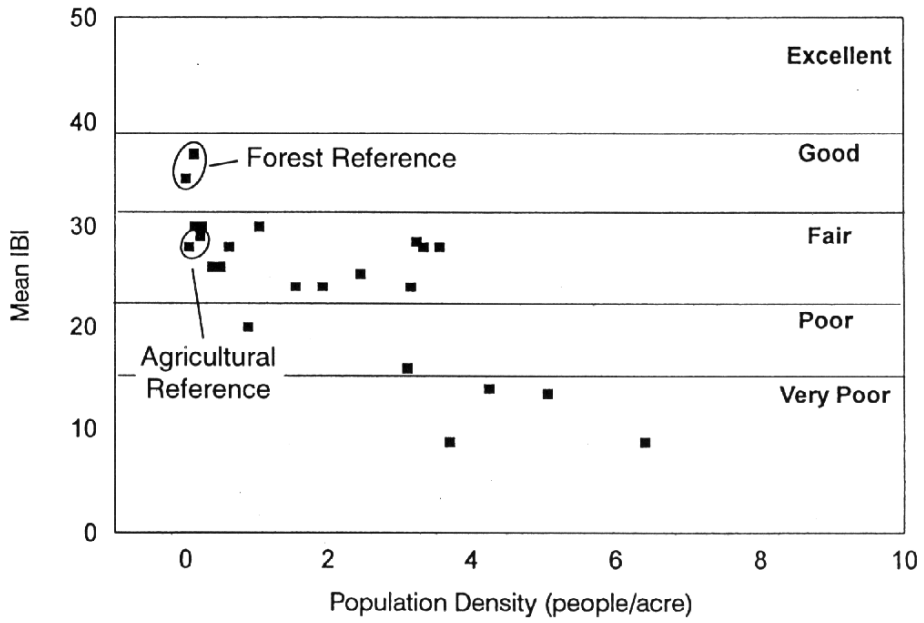


Figure 53: Relationship Between Watershed Population Density and Stream IBI Scores in Georgia Streams (DeVivo *et al.*, 1997)

fish-IBI scores occurred around 8% urban land use, primarily due to certain stressors which functioned to lower the non-attainment threshold. When watersheds smaller than 100mi^2 were analyzed separately, the percentage of urban land use associated with a sharp drop in fish-IBI scores was around 15%. In a later study, Yoder and Miltner (2000) described an upper threshold for quality warm-water fish habitat at 25 to 30% urban land use.

Watershed population and housing density have also been used as indicators of the health of the fish community. In a study of 21 urban watersheds in Atlanta, DeVivo *et al.* (1997) observed a shift in mean fish-IBI scores from "good to fair" to "very poor" when watershed population density exceeded four people/acre (Figure 53). A study of Midwest streams in metropolitan Illinois also found a negative relationship between increase in population density and fish communities, with significant impacts detected at population densities of 1.5 people or greater per acre (Dreher, 1997). In the Columbus and Cuyahoga watersheds in Ohio, Yoder *et al*. (1999) concluded that most streams failed to attain fish biocriteria above one dwelling unit/acre.

5.5 Effects on Amphibian Diversity

Amphibians spend portions of their life cycle in aquatic systems and are frequently found within riparian, wetland or littoral areas. Relatively little research has been conducted to directly quantify the effects of watershed development on amphibian diversity. Intuitively, it would appear that the same stressors that affect fish and aquatic insects would also affect amphibian species, along with riparian wetland alteration. We located four research studies on the impacts of watershed urbanization on amphibian populations; only one was related to streams (Boward *et al.,* 1999), while others were related to wetlands (Table 53).

A primary factor influencing amphibian diversity appears to be water level fluctuations (WLF) in urban wetlands that occur as a result of increased stormwater discharges. Chin (1996) hypothesized that increased WLF and other hydrologic factors affected the abundance of egg clutches and available amphibian breeding habitat, thereby ultimately influencing amphibian richness. Increased WLF can limit reproductive success by eliminating mating habitat and the emergent vegetation to which amphibians attach their eggs.

Taylor (1993) examined the effect of watershed development on 19 freshwater wetlands in King County, WA and concluded that the additional stormwater contributed to greater annual WLF. When annual WLF exceeded about eight inches, the richness of both the wetland plant and amphibian communities dropped sharply. Large increases in WLF were consistently observed in freshwater wetlands when IC in upstream watersheds exceeded 10 to 15%. Further research on streams and wetlands in the Pacific northwest by Horner *et al.* (1997) demonstrated the correlation between watershed IC and diversity of amphibian species. Figure 54 illustrates the relationship between amphibian species abundance and watershed IC, as documented in the study.

Table 53: Recent Research on the Relationship Between Percent Watershed Urbanization and the Amphibian Community

Indicator	Key Finding(s)	Reference Year	Location
% IC			
Reptile and Amphibian Abundance	In a three-year stream sampling across the state (approximately 1000 sites), MBSS found only hardy pollution-tolerant reptiles and amphibians in stream corridors with >25% IC drainage area.	Boward *et al.*, 1999	MD
Amphibian Density	Mean annual water fluctuation inversely correlated to amphibian density in urban wetlands. Declines noted beyond 10% IC.	Taylor, 1993	WA
Other Studies			
Species Richness	In 30 wetlands, species richness of reptiles and amphibians was significantly related to density of paved roads on lands within a two kilometer radius.	Findlay and Houlahan, 1997	Ontario
Species Richness	Decline in amphibian species richness as wetland WLF increased. While more of a continuous decline rather than a threshold, WLF = 22 centimeters may represent a tolerance boundary for amphibian community.	Horner *et al.*, 1997	WA
Amphibian Density	Mean annual water fluctuation inversely correlated to amphibian density in urban wetlands.	Taylor, 1993	WA

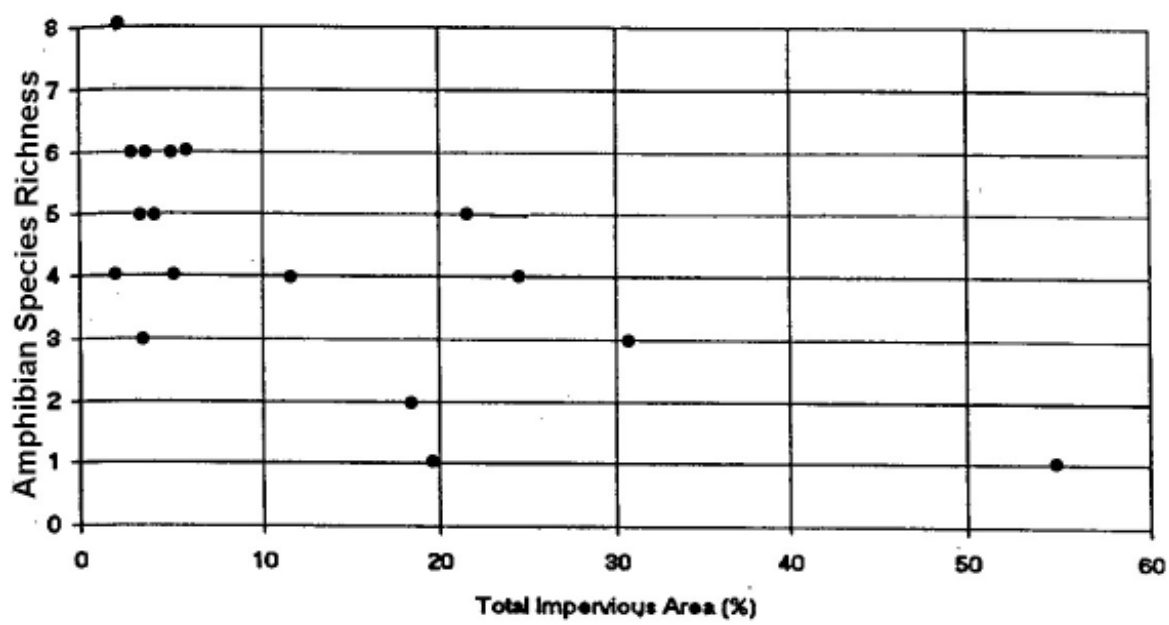


Figure 54: Amphibian Species Richness as a Function of Watershed IC in Puget Sound Lowland Wetlands (Horner *et al.*, 1997)

5.6 Effects on Wetland Diversity

We found a limited number of studies that evaluated the impact of watershed urbanization on wetland plant diversity (Table 54). Two studies used IC as an index of watershed development and observed reduced wetland plant diversity around or below 10% IC (Hicks and Larson, 1997 and Taylor, 1993). WLF and road density were also used as indicators (Findlay and Houlahan, 1997; Horner *et al.*, 1997; Taylor, 1993).

Horner *et al.* (1997) reported a decline in plant species richness in emergent and scrub-shrub wetland zones of the Puget Sound region as WLF increased. They cautioned that species numbers showed a continuous decline rather than a threshold value; however, it was indicated that WLF as small as 10 inches can represent a tolerance boundary for wetland plant communities. Horner further stated that in 90% of the cases where WLF exceeded 10 inches, watershed IC exceeded 21%.

Table 54: Recent Research Examining the Relationship Between Watershed Development and Urban Wetlands

Watershed Indicator Biotic	Key Finding(s)	Reference	Location
% IC			
Insect Community	Significant declines in various indicators of wetland aquatic macro-invertebrate community health were observed as IC increased to 8-9%.	Hicks and Larson, 1997	CT
WLF, Water Quality	There is a significant increase in WLF, conductivity, fecal coliform bacteria, and total phosphorus in urban wetland as IC exceeds 3.5%.	Taylor *et al.*, 1995	WA
Plant Density	Declines in urban wetland plant density noted in areas beyond 10% IC.	Taylor, 1993	WA
Other Watershed Indicators			
Plant Density	Mean annual water fluctuation inversely correlated to plant density in urban wetlands.	Taylor, 1993	WA
Plant Species Richness	Decline in plant species richness in emergent and scrub-shrub wetland zones as WLF increased. While more of a continuous decline, rather than a threshold, WLF=22 centimeters may represent a tolerance boundary for the community	Horner *et al.*, 1997	WA
Plant Species Richness	In 30 wetlands, species richness was significantly related to density of paved roads within a two kilometer radius of the wetland. Model predicted that a road density of 2kilometers per hectare in paved road within 1000 meters of wetland will lead to a 13% decrease in wetland plant species richness.	Findlay and Houlahan,1997	Ontario

5.7 Effects on Freshwater Mussel Diversity

Freshwater mussels are excellent indicators of stream quality since they are filter-feeders and essentially immobile. The percentage of imperiled mussel species in freshwater ecoregions is high (Williams *et al.*, 1993). Of the 297 native mussel species in the United States, 72% are considered endangered, threatened, or of special concern, including 21 mussel species that are presumed to be extinct. Seventy mussel species (24%) are considered to have stable populations, although many of these have declined in abundance and distribution. Modification of aquatic habitats and sedimentation are the primary reasons cited for the decline of freshwater mussels (Williams *et al.,* 1993).

Freshwater mussels are very susceptible to smothering by sediment deposition. Consequently, increases in watershed development and sediment loading are suspected to be a factor leading to reduced mussel diversity. At sublethal levels, silt interferes with feeding and metabolism of mussels in general (Aldridge *et al.*, 1987). Major sources of mortality and loss of diversity in mussels include impoundment of rivers and streams, and eutrophication (Bauer, 1988). Changes in fish diversity and abundance due to dams and impoundments can also influence the availability of mussel hosts (Williams *et al.*, 1992).

Freshwater mussels are particularly sensitive to heavy metals and pesticides (Keller and Zam, 1991). Although the effects of metals and pesticides vary from one species to another, sub-lethal levels of PCBs, DDT, Malathion, Rotenone and other compounds are generally known to inhibit respiratory efficiency and accumulate in tissues (Watters, 1996). Mussels are more sensitive to pesticides than many other animals tested and often act as “first-alerts” to toxicity long before they are seen in other organisms.

We were unable to find any empirical studies relating impacts of IC on the freshwater mussel communities of streams.

5.8 Conclusion

The scientific record is quite strong with respect to the impact of watershed urbanization on the integrity and diversity of aquatic communities. We reviewed 35 studies that indicated that increased watershed development led to declines in aquatic insect diversity and about 30 studies showing a similar impact on fish diversity. The scientific literature generally shows that aquatic insect and freshwater fish diversity declines at fairly low levels of IC (10 to 15%), urban land use (33%), population density (1.5 to eight people/acre) and housing density (>1 du/ac). Many studies also suggest that sensitive elements of the aquatic community are affected at even lower levels of IC. Other impacts include loss of sensitive species and reduced abundance and spawning success. Research supports the ICM, although additional research is needed to establish the upper threshold at which watershed development aquatic biodiversity can be restored.

One area where more research is needed involves determining how regional and climatic variations affect aquatic diversity in the ICM. Generally, it appears that the 10% IC threshold applies to streams in the East Coast and Midwest, with Pacific Northwest streams showing impacts at a slightly higher level. For streams in the arid and semi-arid Southwest, it is unclear what, if any, IC threshold exists given the naturally stressful conditions for these intermittent and ephemeral streams (Maxted, 1999). Southwestern streams are characterized by seasonal bursts of short but intense rainfall and tend to have aquatic communities that are trophically simple and relatively low in species richness (Poff and Ward, 1989).

Overall, the following conclusions can be drawn:

- IC is the most commonly used index to assess the impacts of watershed urbanization on aquatic insect and fish diversity. Percent urban land use is also a common index.

- The ICM may not be sensitive enough to predict biological diversity in watersheds with low IC. For example, below 10% watershed IC, other watershed variables such as riparian continuity, natural forest cover, cropland, ditching and acid rain may be better for predicting stream health.

- More research needs to be done to determine the maximum level of watershed development at which stream diversity can be restored or maintained. Additionally, the capacity of stormwater treatment practices and stream buffers to mitigate high levels of watershed IC warrants more systematic research.

- More research is needed to test the ICM on amphibian and freshwater mussel diversity.

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Glossary

1st order stream: The smallest perennial stream. A stream that carries water throughout the year and does not have permanently flowing tributaries.

2nd order stream: Stream formed by the confluence of two 1st order streams.

3rd order stream: Stream formed by the confluence of two 2nd order streams.

Acute toxicity: Designates exposure to a dangerous substance or chemical with sufficient dosage to precipitate a severe reaction, such as death.

Alluvial: Pertaining to processes or materials associated with transportation or deposition by running water.

Anadromous: Organisms that spawn in freshwater streams but live most of their lives in the ocean.

Annual Pollutant Load: The total mass of a pollutant delivered to a receiving water body in a year.

Bankfull: The condition where streamflow just fills a stream channel up to the top of the bank and at a point where the water begins to overflow onto a floodplain.

Baseflow: Stream discharge derived from ground water that supports flow in dry weather.

Bedload: Material that moves along the stream bottom surface, as opposed to suspended particles.

Benthic Community: Community of organisms living in or on bottom substrates in aquatic habitats, such as streams.

Biological Indicators: A living organism that denotes the presence of a specific environmental condition.

Biological Oxygen Demand (BOD): An indirect measure of the concentration of biologically degradable material present in organic wastes. It usually reflects the amount of oxygen consumed in five days by bacterial processes breaking down organic waste.

Carcinogen: A cancer-causing substance or agent.

Catchment: The smallest watershed management unit. Defined as the area of a development site to its first intersection with a stream, usually as a pipe or open channel outfall.

Chemical Oxygen Demand (COD): A chemical measure of the amount of organic substances in water or wastewater. Non-biodegradable and slowly degrading compounds that are not detected by BOD are included.

Chronic Toxicity: Showing effects only over a long period of time.

Combined Sewer Overflow (CSO): Excess flow (combined wastewater and stormwater runoff) discharged to a receiving water body from a combined sewer network when the capacity of the sewer network and/or treatment plant is exceeded, typically during storm events.

Combined Indices (C-IBI or CSPS): Combined indices that use both fish and aquatic insect metrics and a variety of specific habitat scores to classify streams.

Cryptosporidium parvum: A parasite often found in the intestines of livestock which contaminates water when animal feces interacts with a water source.

Deicer: A compound, such as ethylene glycol, used to melt or prevent the formation of ice.

Dissolved Metals: The amount of trace metals dissolved in water.

Dissolved Phosphorus: The amount of phosphorus dissolved in water.

Diversity: A numerical expression of the evenness and distribution of organisms.

Ecoregion: A continuous geographic area over which the climate is uniform to permit the development of similar ecosystems on sites with similar geophysical properties.

Embeddedness: Packing of pebbles or cobbles with fine-grained silts and clays.

EPT Index: A count of the number of families of each of the three generally pollution-sensitive orders: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

Escherichia coli (E. coli): A bacteria that inhabits the intestinal tract of humans and other warm-blooded animals. Although it poses no threat to human health, its presence in drinking water does indicate the presence of other, more dangerous bacteria.

Eutrophication: The process of over-enrichment of water bodies by nutrients, often typified by the presence of algal blooms.

Fecal coliform: Applied to E. coli and similar bacteria that are found in the intestinal tract of humans and animals. Coliform bacteria are commonly used as indicators of the presence of pathogenic organisms. Their presence in water indicates fecal pollution and potential contamination by pathogens.

Fecal streptococci: Bacteria found in the intestine of warm-blooded animals. Their presence in water is considered to verify fecal pollution.

Fish Blockages: Infrastructures associated with urbanization, such as bridges, dams, and culverts, that affect the ability of fish to move freely upstream and downstream in watersheds. Can prevent re-colonization of resident fish and block the migration of anadromous fish.

Flashiness: Percent of flows exceeding the mean flow for the year. A flashy hydrograph would have larger, shorter-duration hydrograph peaks.

Geomorphic: The general characteristic of a land surface and the changes that take place in the evolution of land forms.

Giardia lamblia: A flagellate protozoan that causes severe gastrointestinal illness when it contaminates drinking water.

Herbicide: Chemicals developed to control or eradicate plants.

Hotspot: Area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

Hydrograph: A graph showing variation in stage (depth) or discharge of a stream of water over a period of time.

Illicit discharge: Any discharge to a municipal separate storm sewer system that is not composed entirely of storm water, except for discharges allowed under an NPDES permit.

Impervious Cover: Any surface in the urban landscape that cannot effectively absorb or infiltrate rainfall.

Impervious Cover Model (ICM): A general watershed planning model that uses percent watershed impervious cover to predict various stream quality indicators. It predicts expected stream quality declines when watershed IC exceeds 10% and severe degradation beyond 25% IC.

Incision: Stream down-cuts and the channel expands in the vertical direction.

Index of Biological Integrity (IBI): Tool for assessing the effects of runoff on the quality of the aquatic ecosystem by comparing the condition of multiple groups of organisms or taxa against the levels expected in a healthy stream.

Infiltration: The downward movement of water from the surface to the subsoil. The infiltration capacity is expressed in terms of inches per hour.

Insecticide: Chemicals developed to control or eradicate insects.

Large Woody Debris (LWD): Fundamental to stream habitat structure. Can form dams and pools; trap sediment and detritus; provide stabilization to stream channels; dissipate flow energy and promote habitat complexity.

Mannings N: A commonly used roughness coefficient; actor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water.

Methyl Tertiary-Butyl Ether: An oxygenate and gasoline additive used to improve the efficiency of combustion engines in order to enhance air quality and meet air pollution standards. MTBE has been found to mix and move more easily in water than many other fuel components, thereby making it harder to control, particularly once it has entered surface or ground waters.

Microbe: Short for microorganism. Small organisms that can be seen only with the aid of a microscope. Most frequently used to refer to bacteria. Microbes are important in the degradation and decomposition of organic materials.

Nitrate: A chemical compound having the formula NO_3. Excess nitrate in surface waters can lead to excessive growth of aquatic plants.

Organic Matter: Plant and animal residues, or substances made by living organisms. All are based upon carbon compounds.

Organic Nitrogen: Nitrogen that is bound to carbon-containing compounds. This form of nitrogen must be subjected to mineralization or decomposition before it can be used by the plant community.

Overbank Flow: Water flow over the top of the bankfull channel and onto the floodplain.

Oxygenate: To treat, combine, or infuse with oxygen.

Peak Discharge: The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Pesticides: Any chemical agent used to control specific organisms, for example, insecticides, herbicides, fungicides and rodenticides.

Piedmont: Any plain, zone or feature located at the foot of a mountain. In the United States, the Piedmont (region) is a plateau extending from New Jersey to Alabama and lying east of the Appalachian Mountains.

Pool: A stream feature where there is a region of deeper, slow-moving water with fine bottom materials. Pools are the slowest and least turbulent of the riffle/run/pool category.

Protozoan: Any of a group of single-celled organisms.

Rapid Bioassessment Protocols (RBP): An integrated assessment, comparing habitat, water quality and biological measures with empirically defined reference conditions.

Receiving Waters: Rivers, lakes, oceans, or other bodies of water that receive water from another source.

Riffle: Shallow rocky banks in streams where water flows over and around rocks disturbing the water surface; often associated with whitewater. Riffles often support diverse biological communities due to their habitat niches and increased oxygen levels created by the water disturbance. Riffles are the most swift and turbulent in the riffle/run/pool category.

Roughness: A measurement of the resistance that streambed materials, vegetation, and other physical components contribute to the flow of water in the stream channel and flood-plain. It is commonly measured as the Manning's roughness coefficient (Manning's N).

Run: Stream feature characterized by water flow that is moderately swift flow, yet not particularly turbulent. Runs are considered intermediate in the riffle/run/pool category.

Runoff Coefficient: A value derived from a site impervious cover value that is applied to a given rainfall volume to yield a corresponding runoff volume.

Salmonid: Belonging to the family Salmonidae, which includes trout and salmon.

Sanitary Sewer Overflow (SSO): Excess flow of wastewater (sewage) discharged to a receiving water body when the capacity of the sewer network and/or treatment plant is exceeded, typically during storm events.

Semi-arid: Characterized by a small amount of annual precipitation, generally between 10 and 20 inches.

Simple Method: Technique used to estimate pollutant loads based on the amount of IC found in a catchment or subwatershed.

Sinuosity: A measure of channel curvature, usually quantified as the ratio of the length of the channel to the length of a straight line along the valley axis. It is, in essence, a ratio of the stream's actual running length to its down-gradient length.

Soluble Phosphorus: The amount of phosphorus available for uptake by plants and animals.

Stormwater: The water produced as a result of a storm.

Subwatershed: A smaller geographic section of a larger watershed unit with a drainage area of between two to 15 square miles and whose boundaries include all the land area draining to a point where two 2nd order streams combine to form a 3rd order stream.

Total Dissolved Solids (TDS): A measure of the amount of material dissolved in water (mostly inorganic salts).

Total Kjeldhal Nitrogen (TKN): The total concentration of nitrogen in a sample present as ammonia or bound in organic compounds.

Total Recoverable Metals: The amount of a metal that is in solution after a representative suspended sediment sample has been digested by a method (usually using a dilute acid solution) that results in dissolution of only readily soluble substances).

Total Maximum Daily Load (TMDL): The maximum quantity of a particular water pollutant that can be discharged into a body of water without violating a water quality standard.

Total Nitrogen (Total N): A measure of the total amount of nitrate, nitrite and ammonia concentrations in a body of water.

Total Organic Carbon (TOC): A measure of the amount of organic material suspended or dissolved in water.

Total Phosphorous (Total P): A measure of the concentration of phosphorus contained in a body of water.

Total Suspended Solids (TSS): The total amount of particulate matter suspended in the water column.

Trophic Level: The position of an organism in a food chain or food pyramid.

Turbidity: A measure of the reduced transparency of water due to suspended material which carries water quality and aesthetic implications. Applied to waters containing suspended matter that interferes with the passage of light through the water or in which visual depth is restricted.

Volatile Organic Compounds (VOC): Chemical compounds which are easily transported into air and water. Most are industrial chemicals and solvents. Due to their low water solubility they are commonly found in soil and water.

The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States, 1948–1994

Frank C. Curriero, PhD, Jonathan A. Patz, MD, MPH, Joan B. Rose, PhD, and Subhash Lele, PhD

Objectives. Rainfall and runoff have been implicated in site-specific waterborne disease outbreaks. Because upward trends in heavy precipitation in the United States are projected to increase with climate change, this study sought to quantify the relationship between precipitation and disease outbreaks.

Methods. The US Environmental Protection Agency waterborne disease database, totaling 548 reported outbreaks from 1948 through 1994, and precipitation data of the National Climatic Data Center were used to analyze the relationship between precipitation and waterborne diseases. Analyses were at the watershed level, stratified by groundwater and surface water contamination and controlled for effects due to season and hydrologic region. A Monte Carlo version of the Fisher exact test was used to test for statistical significance.

Results. Fifty-one percent of waterborne disease outbreaks were preceded by precipitation events above the 90th percentile ($P = .002$), and 68% by events above the 80th percentile ($P = .001$). Outbreaks due to surface water contamination showed the strongest association with extreme precipitation during the month of the outbreak; a 2-month lag applied to groundwater contamination events.

Conclusions. The statistically significant association found between rainfall and disease in the United States is important for water managers, public health officials, and risk assessors of future climate change. (*Am J Public Health.* 2001;91:1194–1199)

According to the US National Assessment on the Potential Consequences of Climate Variability and Change,[1] determining the role of weather in the incidence of waterborne disease outbreaks is a priority public health research issue for this country. Rainfall and runoff have been implicated in individual outbreaks in the United Kingdom and the United States. A waterborne disease outbreak of giardiasis in Montana was related to rainfall,[2] as was the largest reported waterborne disease outbreak ever documented, which occurred in Milwaukee, Wis, in 1993. There, an estimated 403 000 cases of intestinal illness and 54 deaths occurred,[3] and the outbreak was preceded by a period of heavy rainfall and runoff with a subsequent turbidity load that compromised the efficiency of the drinking water treatment plant.[4,5]

Even outbreaks of *Escherichia coli,* generally considered a foodborne pathogen, have been linked to rainfall events. In fact, the largest reported outbreak of *E coli* O157:H7 occurred at a fairground in the state of New York in September 1999 and was linked to contaminated well water. Unusually heavy rainfall, which was preceded by a drought, coincided with this major outbreak.[1] Under conditions of high soil saturation, rapid transport of microbial organisms can be enhanced.

Part of the rationale for this study, conducted through a US Environmental Protection Agency grant for studying the effects of global climate change on public health, comes from projections of more intense rainfall that may accompany global warming. In the past century, average daily temperatures in the conterminous United States increased by approximately 1°F.[6] Warmer air can hold more moisture, and changes in the hydrologic cycle in the United States have been evidenced by increases in cloud cover[7] and total precipitation.[8] Moreover, the type of precipitation has been changing in the United States, with increases in extreme precipitation events (those with an intensity of more than 2 inches per day).[9,6,10] These rainfall patterns are consistent with expectations of a more vigorous hydrologic cycle caused by anthropogenic greenhouse gas warming of the earth's surface.[11–13]

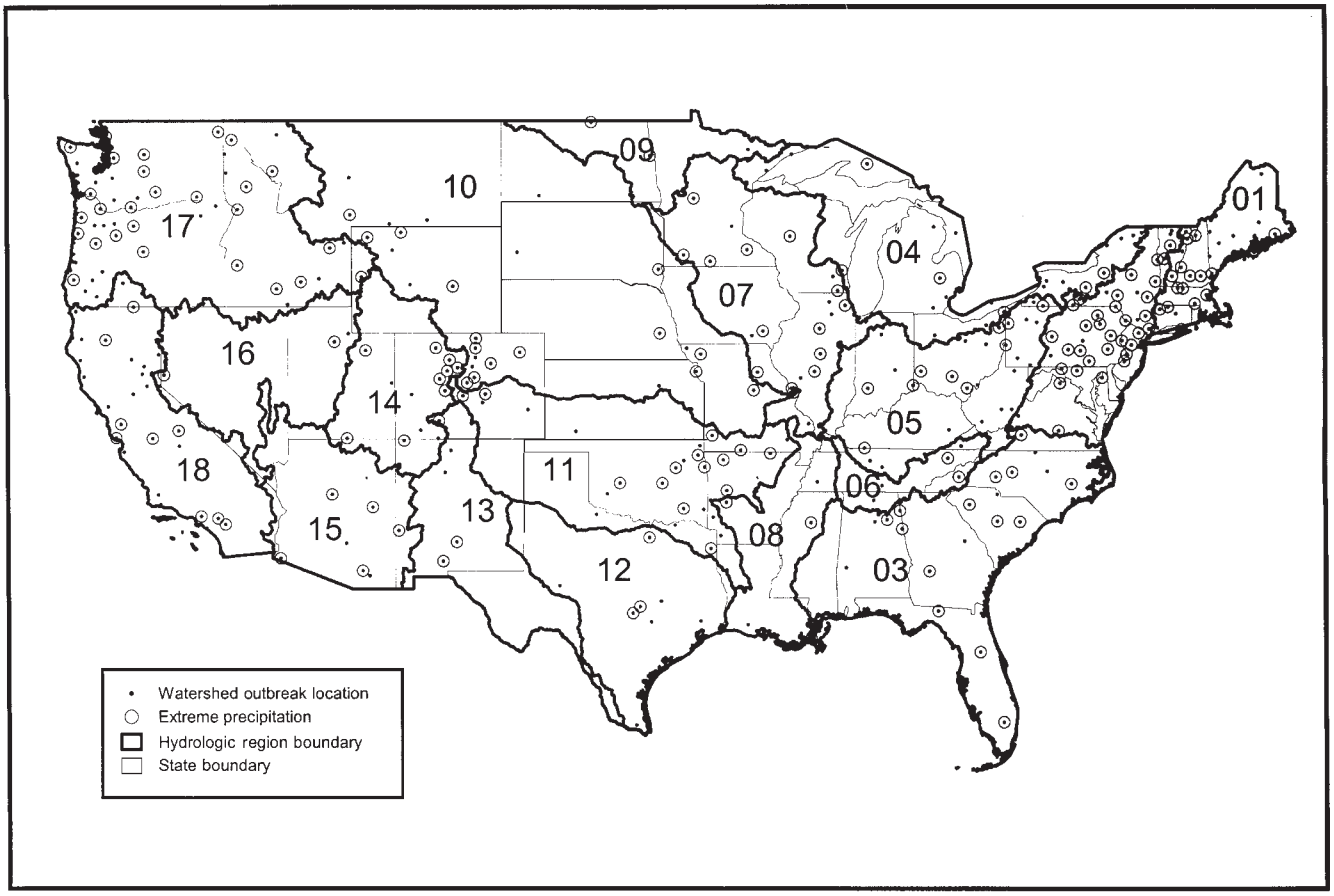
The purpose of our study was to analyze the relationship between precipitation and waterborne diseases, using the complete database of all reported waterborne disease outbreaks in the United States from 1948 to 1994. Rainfall intensity is assumed to be a key determining factor in the fate and transport of pathogenic microorganisms, but the relationship has never been analyzed at the national level.

METHODS

US Waterborne Disease Outbreaks and Precipitation Data Sets

Data on all reported waterborne disease outbreaks in the United States between 1948 and 1994 were obtained from the US Environmental Protection Agency's Office of Research and Development. Included in this data set were the etiologic agent, the community and state where the outbreak occurred, and the month and year of each outbreak. The outbreak source was designated as either surface water or groundwater contamination. The community and state information was geocoded and expressed as longitude and latitude coordinates marking the affected city or county.

A waterborne disease outbreak is defined as an outbreak in which epidemiologic evidence points to a drinking water source from which 2 or more persons become ill at similar times. All recreational outbreaks and outbreaks associated with cross-connections or back-siphonage between sewage and drinking water in the distribution system, including chemical outbreaks, were removed from the database. We excluded these outbreaks to focus the analysis on source waters and watershed contamination and to exclude acci-



Note. Outbreak locations represent the centroid of the affected watershed.

FIGURE 1—Waterborne disease outbreaks and associated extreme levels of precipitation (precipitation in the highest 10% [90th percentile]) within a 2-month lag preceding the outbreak month: United States, 1948–1994.

dental fecal releases associated with recreational outbreaks and infrastructure problems in the distribution system.

The conterminous United States is subdivided into 2105 hydrologic cataloging units called *watersheds*, which are geographic areas representing part or all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature. Watersheds act as the drinking water source for the surrounding area; thus, we chose watersheds as the geographic units for our investigation. Outbreak locations, originally designating the affected city or county, were recoded to correspond to the centroid of the associated watershed. Data on US hydrologic units, a hierarchy of geographic subdivisions including watersheds, were downloaded from the US Geological Survey.[14] Figure 1 includes boundaries for the largest subdivision in this hierarchy (watersheds are the smallest), which divides the United States into 18 distinct hydrologic regions, each containing the drainage area of a major river or the combined drainage areas of a series of rivers.

Total monthly precipitation readings for the more than 16 000 weather stations located across the United States from 1948 through 1994 were downloaded from the National Climatic Data Center.[15] The weather station locations were also coded to the watershed level; each watershed, on the average, contained approximately 7 weather stations. To account for local variations, we replaced recorded total monthly precipitation for each weather station with its corresponding *z* score, which was computed on the basis of the distribution of values recorded for that month from 1948 to 1997. We considered there to be sufficient information to compute *z* scores only if the corresponding distributions contained at least 20 years of recorded data. The *z* score thresholds were chosen to indicate extreme levels of precipitation. For example, *z* scores greater than 0.84, 1.28, and 1.65 correspond, respectively, to total monthly precipitation in the highest 20%, 10%, and 5% observed for that station and month from 1948 to 1994. The maximum *z* score determined from weather station–specific *z* scores within a watershed was used as a measure of extreme precipitation for that watershed.

Statistical Analysis

Figure 1 displays the 548 waterborne disease outbreaks, plotted using the centroid of the affected watershed, within the contermi-

TABLE 1—Waterborne Disease Outbreaks, With Associated Extreme Levels of Precipitation[a] in the Preceding 2 Months: United States, 1948–1994

	Extreme Precipitation		
Outbreak	Yes	No	Total
Yes	268	257	525
No	NC	NC	1 186 695
Total	NC	NC	1 187 220

Note. There were 1 187 220 watershed outbreak possibilities. Shown are the 525 outbreaks for which extreme precipitation data were available. Information regarding extreme precipitation status for watersheds not experiencing an outbreak was not compiled (NC).
[a]Precipitation in the highest 10% (90th percentile).

nous United States that were reported from 1948 to 1994. Of these outbreaks, 51% were preceded within a 2-month lag by an extreme level of precipitation in the highest 10% (or 90th percentile), as indicated in the figure. Several methods, and an accompanying large body of literature, are available to test for spatial clustering of disease events.[16] In this study we were interested in testing whether the outbreaks cluster around extreme precipitation events, as opposed to solely investigating geographic clustering of outbreaks.

Information in Figure 1 can be represented with a 2×2 contingency table, watershed outbreak status×watershed extreme precipitation status. Since this information is collapsed over time, there are a total of 1 187 220 watershed outbreak possibilities (47 years×12 months×2105 watersheds). Table 1 displays extreme precipitation status for only those watersheds known to have experienced an outbreak. Enumerating the bottom row would require determining the extreme precipitation status within a 2-month lag for the remaining watershed outbreak possibilities, a computational burden we wished to avoid. The total number of outbreaks is shown to be 525, not 548, because sufficient precipitation data were not available for 23 outbreak-associated watersheds.

Associations between events in contingency tables are usually described with odds ratios followed by a χ^2-based test of independence. Proceeding in this fashion, however, would require a completely enumerated table. Note that the percentage of coincident events reported (51%) is simply the (1,1) cell (outbreak and extreme precipitation) divided by its marginal total (number of outbreaks). Since the row and column totals in Table 1 are fixed, the (1,1) cell determines the remaining cells and hence the odds ratio; thus, the percentage of coincident events and the odds ratio are equivalent descriptors of association. Also, because the marginal totals are fixed, the Fisher exact test[17] can be used to assess the significance of the association based on the percentage of coincident events. Although the calculation of *P* values in the Fisher exact test requires fully enumerated information as well, the rationale behind the calculation can be approximated with the following Monte Carlo simulation.

The general idea is to repeatedly generate sets of "outbreaks" in a random fashion, tabulating the percentage of these artificial outbreaks that coincide with extreme levels of precipitation at each step. Such a process would produce a distribution of coincident percentages under the assumption of no association, which can then be compared with the observed percentage to compute a *P* value. The following algorithm describes the process for a given set of outbreaks overlaid with extreme precipitation events.

1. Generate a set of outbreaks.
   a. Randomly select watersheds.
   b. Randomly select a month (1–12) and year (1948–1994) for each watershed.
2. Calculate and store the percentage of these outbreaks coincident with extreme levels of precipitation within a given preceding monthly lag.
3. Repeat steps 1 and 2 one thousand times.

The expected percentage of outbreaks coincident with extreme levels of precipitation within a given preceding monthly lag, under the assumption of no association, can be estimated by averaging the Monte Carlo distribution of percentages in step 2.

For the data shown in Table 1, if the 525 waterborne disease outbreaks are clustered both spatially and temporally within watersheds experiencing extreme levels of precipitation, then the observed 51% would be higher than the percentage expected under the assumption of no association. We were therefore interested in testing the one-sided alternative representing a positive association between outbreaks and extreme precipitation. *P* values for such a test can be obtained by dividing by 1000 the number of percentages in step 2 that are higher than their respective observed percentages.

RESULTS

Table 2 cross-tabulates the 548 reported waterborne disease outbreaks by the 18 hydrologic regions and 4 seasons. The distribution of outbreaks across the seasons (column totals) shows that the number of outbreaks is highest during the summer months and lowest during the winter months. The distribution across the hydrologic regions (row totals) may be due to specific hydrologic features present in these regions. The distributional variations across regions and seasons can be controlled for in the Monte Carlo test by restricting the randomization scheme in step 1 of that algorithm to adhere to the marginal totals shown in Table 2. Thus, each artificial set of outbreaks would have identical row and column totals, as shown in Table 2. The resulting test would then be one of conditional association between outbreaks and extreme precipitation, controlling for variations across both regions and seasons.

Of the 548 waterborne disease outbreaks reported between 1948 and 1994, 133 (approximately 24%) were known to be from surface water contamination, 197 (approximately 36%) were known to be from groundwater contamination, and 218 (approximately 40%) had an unknown water contamination source. The outbreak data also included the etiologic agents involved in each outbreak. More than

TABLE 2—Waterborne Disease Outbreaks, by Hydrologic Region and Season: United States, 1948–1994

	Season				
Region	Winter	Spring	Summer	Fall	Total
1	2	8	17	11	38
2	14	27	63	29	133
3	4	5	12	8	29
4	6	2	18	8	34
5	6	9	18	6	39
6	1	1	2	3	7
7	2	12	10	3	27
8	1	1	5	2	9
9	1	0	1	1	3
10	5	5	24	7	41
11	6	9	16	8	39
12	0	3	4	2	9
13	0	1	5	1	7
14	6	6	7	4	23
15	1	3	3	1	8
16	0	1	3	0	4
17	6	17	34	8	65
18	9	6	14	4	33
Total	70	116	256	106	548

Note. Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November.

half the outbreaks were determined to be "acute gastrointestinal illness," about 13% were attributed to *Giardia,* and the remainder were caused by 35 other specific agents.

We used the Monte Carlo test presented above to test the significance of the overlaid information shown in Figure 1 and other associations between waterborne disease outbreaks and extreme precipitation, controlling for the possible confounding effects due to hydrologic region and season. Different scenarios were investigated by varying the preceding monthly lag time and level of extreme precipitation. Separate analyses were performed for outbreaks due to surface water contamination, outbreaks due to groundwater contamination, and the combined data, including outbreaks with an unknown water contamination source. The results, which are presented in Table 3, include for each scenario the observed percentage of outbreaks coincident with extreme precipitation events; an estimated expected percentage of coincident events, assuming no association; and the *P* value testing the significance of the observed percentage.

Results for the association depicted in Figure 1 (combined data, monthly lag 0, 1, 2, and 90th percentile extreme precipitation) indicate that after controlling for variations across regions and seasons, we would have expected 43.2% of the outbreaks to be coincident with extreme precipitation if there was no association between outbreaks and extreme precipitation. The observed percentage of outbreaks coincident with levels of extreme precipitation—51.0%—was highly significant (P=.002). P values of less than .001 in Table 3 indicate the strongest evidence of an association; they occurred when the random selection of watershed outbreaks, for the 1000 iterations performed in step 1 of the Monte Carlo algorithm, did not produce a percentage of outbreaks coincident with this level of extreme precipitation that was higher than the observed percentage.

The association between outbreaks and extreme precipitation remained statistically significant at the .05 level across all of the scenarios we considered for the combined data. The analysis stratified by water contamination source showed that outbreaks due to surface water contamination were most significant for extreme precipitation during the month of the outbreak. Outbreaks due to groundwater contamination, however, showed highest significance for extreme precipitation 2 months prior to the outbreak. This might be expected, considering the direct vs complex routes of exposure.

DISCUSSION

This study represents the first quantitative analysis of the relationship between extreme precipitation and waterborne disease outbreaks at the national level and over an extended period. Our findings show a statistically significant association between weather events and disease. However, we recognize that multiple factors are involved, which must occur simultaneously in time and space. Elements of an outbreak event include (1) a source of contamination (infected humans, domestic animals, or wildlife); (2) fate and transport of the contaminant from source to drinking water supplies; (3) inadequate treatment; and (4) detection and reporting of the outbreak.[18] Given the variability of these factors across the United States, the robustness of our findings demonstrates the important role of extreme wet-weather events in microbial fate and transport and as a contributing factor in US waterborne disease outbreaks.

Incorporating data on other causal components will be important in the development of better predictive models extending beyond this study's limitations. We have partially controlled for source of outbreak by conducting analyses at the watershed level. Watersheds might be expected to maintain some consistency in land use patterns; however, these patterns, inevitably, have changed over the 47 years analyzed. Several state-specific analyses that could include more detailed land use and treatment facility information would, therefore, be of benefit as a follow-up to this national-level study.

Our study is limited by the temporal resolution of the waterborne disease outbreak

TABLE 3—Monte Carlo Simulation Results for the Association Between Waterborne Disease Outbreaks and Extreme Precipitation: United States, 1948–1994

	Extreme Precipitation Percentile								
	Surface Water Contamination			Groundwater Contamination			Combined		
Monthly Lag	80th	90th	95th	80th	90th	95th	80th	90th	95th
Monthly lag 0									
Observed, %	39.1	28.9	22.7	31.2	21.4	13.5	33.3	22.8	16.8
Monte Carlo, %	26.9	17.4	11.7	28.8	18.6	12.4	27.7	17.9	12.0
P	.001	<.001	.001	.229	.173	.314	.001	<.001	.002
Monthly lag 0,1									
Observed, %	55.1	41.7	33.9	53.9	39.3	26.2	52.3	38.3	28.8
Monte Carlo, %	45.5	31.2	21.7	48.0	33.0	22.7	46.5	31.9	22.0
P	.022	.003	.002	.059	.039	.132	.003	.001	<.001
Monthly lag 0,1,2									
Observed, %	65.9	50.8	42.9	71.6	52.1	36.8	68.0	51.0	39.4
Monte Carlo, %	58.9	42.3	30.3	61.6	44.4	31.6	59.9	43.2	30.7
P	.063	.023	.001	.002	.021	.062	<.001	.002	<.001
Monthly lag 1									
Observed, %	34.6	22.8	18.1	33.2	22.8	14.5	31.6	20.3	14.9
Monte Carlo, %	26.8	17.4	11.6	28.7	18.5	12.3	27.5	17.7	11.8
P	.033	.060	.026	.083	.070	.183	.005	.047	.009
Monthly lag 1,2									
Observed, %	54.8	36.5	31.0	57.8	41.7	28.6	54.4	37.5	27.8
Monte Carlo, %	45.4	31.0	21.5	47.7	32.6	22.4	46.3	31.6	21.7
P	.023	.109	.003	.002	.009	.027	<.001	.001	<.001

Note. Shown are results for outbreaks known to be from surface water contamination, outbreaks known to be from groundwater contamination, and the combined data, including outbreaks with an unknown water contamination source. Listed for each monthly lag and extreme precipitation scenario are the observed percentage of outbreaks coincident with extreme precipitation, the Monte Carlo–expected percentage of coincident events, and the corresponding *P* value.

data. These data have been reported in the same way for approximately 50 years. Improved understanding and better prevention might be achieved if outbreak data included start and end dates rather than simply the month of occurrence.[18]

Reporting bias is a key component in the waterborne disease outbreak data. Experts estimate that we may be seeing only a small fraction of the actual outbreaks.[19] With such a bias, many of the cluster detection methods that focus primarily on geographic clustering of diseases would clearly be inappropriate. The method we applied, which is focused more on the clustering of outbreaks around extreme precipitation, is appropriate under the assumption that outbreak reporting is independent of surrounding monthly precipitation.

Although the United States is thought to have high-quality drinking water, the risk of contamination from leaking septic tanks or agricultural runoff remains. One pathogen, *Cryptosporidium*, a protozoan that completes its life cycle within the intestine of mammals, is shed in high numbers of infectious oocysts that are dispersed in feces. It is highly prevalent in ruminants and readily transmitted to humans.[20] In a cross-sectional analysis of 50 livestock farms sampled within the 100-year floodplain in Lancaster County, Pennsylvania, manure samples from 64% of the farms tested positive for *C parvum*.[21] Therefore, it is biologically plausible that increases in rainfall and runoff intensity would result in more contamination of source waters by this parasite.

Our results are also consistent with findings from other studies. For example, Atherholt et al. found that concentrations of *Cryptosporidium* oocysts and *Giardia* cysts in the Delaware River were positively correlated with rainfall.[22] In 1998, a drinking water outbreak of cryptosporidiosis that occurred in Brushy Creek, Tex, was linked to storms that led to sewage contamination of wells and creeks.[23] *Cryptosporidium* oocysts are very small (~5 microns) and are difficult to remove from water; a recent study found that 13% of finished water still contained *Cryptosporidium* oocysts,[24] indicating some passage of microorganisms from source to treated drinking water.

Municipal water systems, even today, can be overburdened by extreme rainfall events. For example, many communities still have combined sewer systems designed to carry both storm water and sanitary wastewater to a sewage treatment plant. During periods of heavy rainfall or snowmelt, the stormwater can exceed the capacity of the sewer system or treatment plant, and these systems are designed to discharge the excess wastewater directly into surface water bodies.[25,26] For northern latitudes and high-elevation regions, the addition of temperature values

could further enhance the analysis by addressing the contribution of snowmelt.

During the heavy rainfall that accompanied the very strong El Niño of 1997 and 1998, a survey of a southwest Florida estuary found higher concentrations of fecal indicator organisms than occurred throughout the rest of the year,[27,28] implicating heavy rainfall as a risk factor for waterborne or seafood-borne disease. In urban watersheds, more than 60% of the annual load of all contaminants is transported during storm events.[29] In general, turbidity increases during storm events, and studies have recently shown a correlation between increases in turbidity and illness in communities.[30,31]

In summary, there is mounting evidence that heavy precipitation and runoff events significantly contribute to the risk of waterborne disease outbreaks. In the future, incorporation of other site-specific parameters, particularly land use patterns and treatment facility specifications, may allow for the development of more localized predictive models that can benefit water managers and public health planners. Our findings provide further insight into the linkage between weather and human disease that can be applied to risk assessments of future climate change. ■

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Contributors

F.C. Curriero developed the statistical methodology and performed all data analyses. J.A. Patz was the principal investigator for this study and conceived and led the overall design of this project. J.B. Rose obtained all the outbreak data and was responsible for plotting them, using a geographic information systems (GIS) format; provided information on the details of the database; and reviewed the article. S. Lele provided expert guidance on the statistical analyses and made revisions to the manuscript.

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The Health Effects of Swimming in Ocean Water Contaminated by Storm Drain Runoff

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Waters adjacent to the County of Los Angeles (CA) receive untreated runoff from a series of storm drains year round. Many other coastal areas face a similar situation. To our knowledge, there has not been a large-scale epidemiologic study of persons who swim in marine waters subject to such runoff. We report here results of a cohort study conducted to investigate this issue. Measures of exposure included distance from the storm drain, selected bacterial indicators (total and fecal coliforms, enterococci, and *Escherichia coli*), and a direct measure of enteric viruses. We found higher risks of a broad range of symptoms, including both upper respiratory and gastrointestinal, for subjects swimming (a) closer to storm drains, (b) in water with high levels of single bacterial indicators and a low ratio of total to fecal coliforms, and (c) in water where enteric viruses were detected. The strength and consistency of the associations we observed across various measures of exposure imply that there may be an increased risk of adverse health outcomes associated with swimming in ocean water that is contaminated with untreated urban runoff. (Epidemiology 1999;10:355–363)

Keywords: environmental epidemiology, gastrointestinal illness, ocean, recreational exposures, sewage, storm drains, waterborne illnesses, waterborne pathogens.

Runoff from a system of storm drains enters the Santa Monica Bay adjacent to Los Angeles County (CA). Even in the dry months of summer 10–25 million gallons of runoff (or non-storm water discharge) per day enter the bay from the storm drain system. Storm drain water is not subject to treatment and is discharged directly into the ocean. Total and fecal coliforms, as well as enterococci, are sometimes elevated in the surf zone adjacent to storm drain outlets; pathogenic human enteric viruses have also been isolated from storm drain effluents, even when levels of all commonly used indicators, including F2 male-specific bacteriophage, were low.[1]

Approximately 50–60 million persons visit Santa Monica Bay beaches annually. Concern about possible adverse health effects due to swimming in the bay has been raised by numerous interested parties.[2] Previous reports indicate that swimming in polluted water (for example, due to sewage) increases risks of numerous adverse health outcomes (Pruss[3] provides a recent review of this literature). To our knowledge, however, there has never been a large epidemiologic study of persons who swim in marine waters contaminated by heavy urban runoff.

These circumstances provided the motivation to study the possible health effects of swimming in the bay. We present here the main results from a large cohort study of people that addressed the issue of adverse health effects of swimming in ocean water subject to untreated urban runoff.

Methods

DESIGN AND SUBJECTS

The exposures of interest were distance swimming from storm drains, levels of bacterial indicators (total coli-

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forms, fecal coliforms, enterococcus, *Escherichia coli*) for pathogens that potentially produce acute illness, and human enteric viruses. We studied three beaches located in Santa Monica Bay (CA) that exhibited a wide range of pathogen indicator counts and a high density of swimmers (Santa Monica, Will Rogers, and Surfrider).

Persons who immersed their heads in the ocean water were potential subjects for this study. There was no restriction based on age, sex, or race. We excluded anyone who swam at the study beaches or in heavily polluted areas (that is, Mothers' Beach in Marina del Rey or near the Santa Monica Pier) within 7 days before the study date, or between the date of the beach interview and the telephone follow-up interview. We excluded subjects who swam on multiple days, as one of our primary questions was whether risk of health outcomes was associated with levels of indicator organisms on the specific day a subject entered the water. We targeted persons bathing within 100 yards upcoast or downcoast of the storm drain and persons bathing greater than 400 yards beyond a storm drain.

For this study, 22,085 subjects were interviewed on the beach from June 25 to September 14, 1995, to ascertain eligibility and willingness to participate. We found that 17,253 of these subjects were eligible and able to participate (that is, had a telephone and were able to speak English or Spanish). Of these, 15,492 (90% of the eligible subjects) agreed to participate. They were interviewed about their age, residence, and swimming, particularly immersion of the head into ocean water. The interviewer noted distance from the storm drain (within the categories 0, 1–50, 51–100, or 400 yards), gender, and race of the subject. (Distances from each drain were marked with inconspicuous objects such as beach towels and umbrellas.)

Nine to 14 days after the beach interview, subjects were interviewed by telephone to ascertain the occurrence(s) of: fever, chills, eye discharge, earache, ear discharge, skin rash, infected cuts, nausea, vomiting, diarrhea, diarrhea with blood, stomach pain, coughing, coughing with phlegm, nasal congestion, and sore throat. For this study we defined *a priori* three groupings of symptoms indicative of gastrointestinal illness or respiratory disease. In particular, following Cabelli *et al*,[4] subjects were classified as having highly credible gastrointestinal illness 1 (HCGI 1) if they experienced at least one of the following: (1) vomiting, (2) diarrhea and fever, or (3) stomach pain and fever. We also classified subjects as having highly credible gastrointestinal illness 2 (HCGI 2) if they had vomiting and fever. Finally, we classified subjects as having significant respiratory disease (SRD) if they had one of the following: (1) fever and nasal congestion, (2) fever and sore throat, or (3) coughing with phlegm.

We were able to contact and interview 13,278 subjects (86% follow-up). Of those interviewed, 1,485 were found to be ineligible because they swam (and immersed their heads) at a study beach or in heavily polluted waters between the day of the beach interview and the telephone follow-up. We excluded 107 subjects because they did not confirm immersing their faces in ocean water, leaving 11,686 subjects. One subject had a missing value for age, which we imputed (as the median value among all subjects) for inclusion in the adjusted analyses (discussed below). For the bacteriological analyses, we excluded an additional 1,227 subjects who had missing values, leaving 10,459 subjects. In the virus analyses we included only the 3,554 subjects who swam within 50 yards of the drain on days when viruses were measured (as the samples were collected only at the storm drain).

Collection and Analysis of Samples for Bacterial Indicators

Samples were collected on days that subjects were interviewed on the beaches. Each day, ankle depth samples were collected from each location (0 yards, 100 yards upcoast and downcoast of the drain, and one sample at 400 yards). One duplicate sample per site was collected daily. Samples were collected in sterile 1 liter polypropylene bottles and transferred on ice to the microbiology laboratory. All samples were analyzed for total coliforms, fecal coliforms, enterococcus, and *E. coli*. Densities of total and fecal coliforms and enterococci were determined using the appropriate membrane filtration techniques in Ref 5. *E. coli* densities were determined by membrane filtration using Hach Method 10029 for m-ColiBlue24 Broth.

Collection and Analysis of Samples for Enteric Viruses

For looking at enteric viruses, we collected samples from the three storm drain sites on Fridays, Saturdays, and Sundays, using Method 9510 C g of Ref 5. Ambient pH, temperature, conductivity, and total dissolved solids were measured. Samples as large as 100 gallons chosen to minimize the impacts of seawater dilution were filtered through electropositive filters at ambient pH. Adsorption filters were eluted in the field with 1 liter of sterile 3% beef extract adjusted to pH 9.0 with sodium hydroxide. Field eluates were reconcentrated in the laboratory using an organic reflocculation procedure.[6] All final concentrates were detoxified before analysis.[7]

All samples were analyzed for infectious human enteric viruses in Buffalo green monkey kidney cells (BGMK) by the plaque assay technique. Ten percent of the final concentrate was tested in this manner to determine whether there were a quantifiable number of viruses present. The remaining concentrate volume was divided in half and analyzed using the liquid overlay technique known as the cytopathic effect (CPE) assay.[8] The CPE assay generally detects a greater number of viruses than the plaque assay, but it is not quantitative. Flasks that did not exhibit CPE were considered to be negative for detectable infectious virus. We further examined any flask exhibiting CPE by the plaque-forming unit method to confirm the presence of infectious viruses.

Statistical Analysis

Our analysis addressed two main questions. First, are there different risks of specific outcomes among subjects swimming 0, 1–50, 51–100, and 400 or more yards from a storm drain? If pathogens in the storm drain result in increased acute illnesses, one would expect higher risks among swimmers closer to the drain. Second, are risks of specific outcomes associated with levels of specific bacterial indicators or enteric viruses?

To address the second question, we estimated risks arising from exposure to levels within categories defined *a priori* by existing standards or expert consensus. Specifically, for total coliforms we defined categories using 1,000 and 10,000 colony-forming units (cfu) per 100 ml as cutpoints, which are based on the California Code of Regulations (S.7958 in Title 17).[9] For fecal coliforms we created categories using cutpoints of 200 and 400 cfu per 100 ml, which reflect criteria set by the State Water Resources Control Board.[10] For enterococcus we used cutpoints of 35 and 104 cfu per 100 ml of water, which were established by the U.S. Environmental Protection Agency.[11] Finally, categories for *E. coli* were selected in meetings with staff from the Santa Monica Bay Restoration Project (SMBRP), Heal the Bay, and the Los Angeles County Department of Health Services. These meetings resulted in initially selecting categories based on cutpoints of 35 and 70 cfu per 100 ml, and then subsequently adding categories using cutpoints of 160 and 320 cfu per 100 ml; the latter were added because it is believed that *E. coli* comprises about 80% of the fecal coliforms. Using these knowledge-based categories, however, assumes a homogeneous risk between cutpoints. This might not be a reasonable assumption because the adequacy of these cutpoints is unclear, and because a large percentage of the subjects were in a single (that is, the lowest) category. Therefore, we further explored the bacteriological relations using categories defined by deciles.

In addition to considering total and fecal coliforms separately, we investigated the potential effect of the ratio of total to fecal coliforms. Motivation for this arose from our expectation that the risk of adverse health outcomes might be higher when the ratio is smaller, indicating a relatively greater proportion of fecal contamination. We used categories of this ratio defined by a cutpoint of 5 (where 5 corresponds to there being 5 times as much total as fecal coliform in the water). The human enteric virus exposure was reported as a dichotomous (that is, virus detected *vs* not detected) measure.

We first calculated simple descriptive statistics giving the number of subjects with each adverse health outcome who swam (1) at the prespecified distances from the drain or (2) in water with the prespecified levels of pathogens. From these counts we estimated the crude risk associated with each exposure. We then used logistic regression to estimate the adjusted relative risks of each outcome. For each exposure/outcome combination, we fit a separate model. All models adjusted for the potential confounding of: age (three categories: 0–12 years, 13–25 years, >25 years); sex; beach; race (four categories: white, black, Latino/a, and Asian/multiethnic/other); California *vs* out-of-state resident; and concern about potential health hazards at the beach (four categories: not at all, somewhat, a little, and very).

Results

Table 1 presents results for each of the adverse health outcomes by distance swimming from the storm drain. Across all distances, risks ranged from about 0.001 (that is, 1 per 1,000) for diarrhea with blood to about 0.1 for runny nose. The risk of numerous outcomes was higher for people who swam at the drain (0 yards away), in comparison with those who swam 1–50, 51–100, or >400 yards from the drain. In particular, we observed increases in risk for fever, chills, ear discharge, coughing with phlegm, HCGI 2, and SRD. In addition, the risks for eye discharge, earache, sore throat, infected cut, and HCGI 1 were also slightly elevated. A handful of outcomes exhibited small increased risks among swimmers at 1–50 yards (skin rash) or at 51–100 yards (cough, cough with phlegm, runny nose, and sore throat). Adjusted estimates of relative risk (RR) comparing swimmers at 0, 1–50, or 51–100 yards from the drain with swimmers at least 400 yards away from the drain showed similar relations as the aforementioned patterns of risks (Table 1). Among the positive associations for swimmers at the drain, RRs ranged in magnitude from about 1.2 (eye discharge, sore throat, HCGI 1) to 2.3 (earache), with varying degrees of precision; most of these RRs ranged from 1.4 to 1.6.

In Table 2 we see that the risk of skin rash increased for the highest prespecified category of total coliforms (that is, >10,000 cfu). Furthermore, the adjusted RR comparing swimmers exposed at this level *vs* those exposed to levels ≤1,000 cfu was 2.6. Whereas the RR for diarrhea with blood also suggested a positive association, this result was based on a single adverse health event (as evinced by the wide 95% CIs). When looking at deciles, in relation to the lowest exposure level (that is, the lowest 10%), we observed increased risks of skin rash at all other levels (Figure 1). The adjusted RRs ranged from 1.6 to 6.2, with five of the nine RRs in the 2–3 range. In addition, there were increased risks of HCGI 2 for all deciles except one (the eighth); the corresponding adjusted RRs ranged from 1.4 to 4.7, with varying levels of precision (Figure 1).

When looking at fecal coliforms, we again observed among those in the highest category (that is, >400 cfu) an increased risk for skin rash (Table 3). There were also *slight* increased risks for infected cut, runny nose, and diarrhea with blood in the highest category, as well as for nausea, vomiting, coughing, sore throat, and HCGI 2 in the middle category (200–400 cfu). The adjusted RRs also indicated positive associations for these outcomes (Table 3). When we used deciles to categorize subjects, however, in comparison with the lowest decile, we only observed marginal increased risks for infection and skin rash (not shown). In our investigation of the ratio of

TABLE 1. Adverse Health Outcomes by Distance Swimming from Drain: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	Distance from Drain (in Yards)										
	>400 (N = 3030)*		51–100 (N = 3311)			1–50 (N = 4518)			0 (N = 827)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR (95% CI)†	No. Ill	Risk	RR (95% CI)†	No. Ill	Risk	RR (95% CI)†
Fever	138	0.046	158	0.048	1.06 (0.84–1.34)	208	0.046	1.07 (0.85–1.33)	59	0.071	1.61 (1.16–2.24)
Chills	72	0.024	85	0.026	1.07 (0.77–1.47)	108	0.024	1.05 (0.77–1.42)	31	0.037	1.60 (1.03–2.50)
Eye discharge	61	0.020	59	0.018	0.88 (0.61–1.27)	73	0.016	0.77 (0.55–1.09)	19	0.023	1.15 (0.67–1.98)
Earache	116	0.038	116	0.035	0.89 (0.68–1.16)	136	0.030	0.81 (0.63–1.04)	38	0.046	1.34 (0.91–1.98)
Ear discharge	21	0.007	19	0.006	0.78 (0.42–1.46)	25	0.006	0.80 (0.45–1.44)	13	0.016	2.09 (1.01–4.33)
Skin rash	23	0.008	30	0.009	1.16 (0.67–2.01)	53	0.012	1.50 (0.91–2.46)	4	0.005	0.62 (0.21–1.83)
Infected cut	17	0.006	16	0.005	0.79 (0.40–1.58)	37	0.008	1.51 (0.84–2.69)	6	0.007	1.48 (0.57–3.87)
Nausea	133	0.044	115	0.035	0.77 (0.60–1.00)	143	0.032	0.75 (0.59–0.95)	40	0.048	1.13 (0.78–1.65)
Vomiting	57	0.019	58	0.018	0.97 (0.67–1.40)	63	0.014	0.76 (0.53–1.09)	25	0.030	1.40 (0.85–2.31)
Diarrhea	204	0.067	163	0.049	0.70 (0.56–0.86)	202	0.045	0.69 (0.56–0.84)	53	0.064	1.04 (0.75–1.44)
Diarrhea with blood	7	0.002	2	0.001	0.26 (0.05–1.26)	3	0.001	0.27 (0.07–1.06)	2	0.002	0.87 (0.15–4.57)
Stomach pain	206	0.068	194	0.059	0.85 (0.70–1.05)	271	0.060	0.93 (0.77–1.12)	61	0.074	1.11 (0.82–1.51)
Cough	209	0.069	263	0.079	1.18 (0.97–1.42)	296	0.066	0.98 (0.82–1.18)	55	0.067	1.01 (0.73–1.38)
Cough and phlegm	90	0.030	114	0.034	1.16 (0.88–1.54)	143	0.032	1.09 (0.83–1.43)	39	0.047	1.65 (1.11–2.46)
Runny nose	273	0.090	351	0.106	1.18 (1.00–1.40)	371	0.082	0.95 (0.80–1.12)	74	0.089	1.10 (0.84–1.46)
Sore throat	190	0.063	244	0.074	1.17 (0.96–1.43)	304	0.067	1.12 (0.93–1.35)	59	0.071	1.25 (0.92–1.71)
HCGI 1	102	0.034	96	0.029	0.88 (0.66–1.17)	121	0.027	0.84 (0.64–1.10)	35	0.042	1.21 (0.81–1.82)
HCGI 2	26	0.009	28	0.008	1.04 (0.61–1.79)	32	0.007	0.90 (0.53–1.53)	15	0.018	1.64 (0.84–3.21)
Significant respiratory disease	139	0.046	177	0.053	1.18 (0.94–1.49)	205	0.045	1.03 (0.82–1.23)	63	0.076	1.78 (1.29–2.45)

The total number of swimmers in each category is given in parentheses (N). HCGI1, highly credible gastrointestinal illness with vomiting, diarrhea and fever or stomach pain and fever. HCGT2, highly credible gastrointestinal illness with vomiting and fever only. Significant respiratory disease, fever and nasal congestion, fever and sore throat or coughing with phlegm.

* Referent category (RR = 1.0).

† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

total to fecal coliforms, we observed a consistent pattern of higher risks for diarrhea and HCGI 2 as the ratio category became lower (not shown, but available in Ref 12). Because any effect of this lower ratio should be stronger when there was a higher degree of contamination, indicated by total coliform counts in excess of 1,000 or 5,000 cfu, we then restricted our analysis to subjects swimming in water above these levels. In the first case, increased risks with decreasing cutpoints were observed for nausea, diarrhea, and HCGI 2.[12] When we restricted our investigation to subjects in water in which the total coliforms exceeded 5,000 cfu, we observed

TABLE 2. Adverse Health Outcomes by Total Coliform Levels: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	Total Coliforms (cfu/100ml)							
	≤1,000 (N = 7,574)*		>1,000–10,000 (N = 1,988)			>10,000 (N = 757)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR†	No. Ill	Risk	RR†
Fever	368	0.049	88	0.044	0.92 (0.72–1.17)	42	0.055	1.23 (0.87–1.73)
Chills	193	0.025	51	0.026	1.03 (0.75–1.42)	9	0.012	0.51 (0.26–1.01)
Eye discharge	151	0.020	21	0.011	0.46 (0.29–0.74)	15	0.020	0.81 (0.47–1.41)
Earache	270	0.036	66	0.033	0.96 (0.72–1.27)	21	0.028	0.86 (0.54–1.38)
Ear discharge	51	0.007	15	0.008	1.22 (0.67–2.23)	2	0.003	0.46 (0.11–1.93)
Skin rash	65	0.009	14	0.007	0.75 (0.41–1.36)	19	0.025	2.59 (1.49–4.53)
Infected cut	49	0.006	11	0.006	0.97 (0.49–1.91)	3	0.004	0.82 (0.25–2.72)
Nausea	292	0.039	69	0.035	0.94 (0.72–1.24)	18	0.024	0.71 (0.43–1.16)
Vomiting	137	0.018	34	0.017	0.90 (0.61–1.33)	9	0.012	0.64 (0.32–1.29)
Diarrhea	434	0.057	85	0.043	0.80 (0.63–1.03)	33	0.044	0.95 (0.65–1.39)
Diarrhea with blood	8	0.001	2	0.001	1.08 (0.22–5.35)	1	0.001	1.73 (0.19–15.88)
Stomach pain	487	0.064	125	0.063	1.05 (0.85–1.29)	29	0.038	0.69 (0.47–1.02)
Cough	546	0.072	133	0.067	0.90 (0.73–1.10)	51	0.067	0.94 (0.69–1.28)
Cough and phlegm	267	0.035	58	0.029	0.81 (0.60–1.09)	27	0.036	1.03 (0.68–1.57)
Runny nose	703	0.093	170	0.086	0.93 (0.78–1.12)	67	0.089	1.06 (0.81–1.40)
Sore throat	534	0.071	116	0.058	0.83 (0.67–1.03)	47	0.062	0.95 (0.69–1.30)
HCGI 1	242	0.032	54	0.027	0.84 (0.62–1.14)	17	0.022	0.74 (0.44–1.23)
HCGI 2	72	0.010	16	0.008	0.89 (0.51–1.55)	5	0.007	0.83 (0.32–2.12)
Significant respiratory disease	396	0.052	84	0.042	0.80 (0.62–1.02)	42	0.055	1.11 (0.79–1.55)

The total number of swimmers in each category is given in parentheses (N).

* Referent category (RR = 1.0).

† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

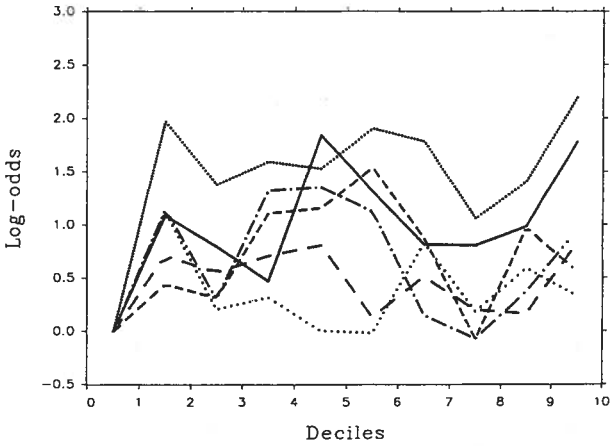

FIGURE 1. Log odds of adverse health outcomes by deciles of exposure for selected bacterial exposures. —, Total coliform and skin rash; – – – ·, total coliform and HCGI 2; · · ·, Enterococci and infected cut; — — —, *E coli* and eye discharge; ···, *E coli* and skin rash; · — ··, *E coli* and infected cut. HCGI 2 = highly credible gastrointestinal illness with vomiting and fever only.

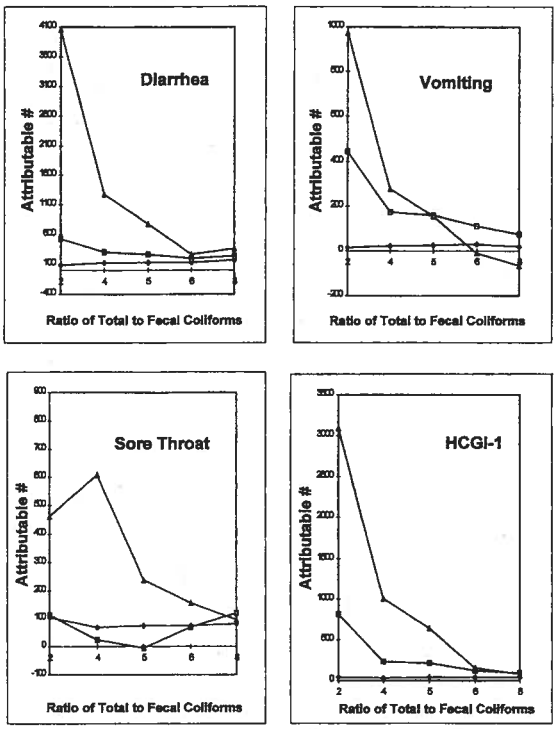

FIGURE 2. Selected attributable numbers/10,000 exposed subjects for total to fecal coliforms. ◆, All days; ■, >1000; ▲, > 5000. HCGI 1 = highly credible gastrointestinal illness with vomiting, diarrhea and fever or stomach pain and fever.

increased risks with eye discharge, ear discharge, skin rash, nausea, diarrhea, stomach pain, nasal congestion, HCGI 1, and HCGI 2.[12] There was a consistent pattern of stronger risk ratios as the cutpoint became lower (when the analyses were restricted to times when total coliforms exceeded 1,000 or 5,000 cfu), with the strongest effects generally observed with the cutpoint of 2, as illustrated in Figure 2 for diarrhea, vomiting, sore throat, and HCGI1.

Table 4 gives results for the relation among enterococci and the adverse health outcomes. Again, we observed an increased risk of skin rash among those in the highest category (that is, >104 cfu). In addition, comparing the highest to other categories of exposure, there

TABLE 3. Adverse Health Outcomes by Fecal Coliform Levels: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	Fecal Coliforms (cfu/100ml)							
	≤200 (N = 8,005)*		>200–400 (N = 768)			>400 (N = 1,636)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR†	No. Ill	Risk	RR†
Fever	381	0.048	39	0.051	1.04 (0.74–1.46)	80	0.049	1.02 (0.80–1.32)
Chills	197	0.025	24	0.031	1.14 (0.74–1.76)	34	0.021	0.78 (0.54–1.14)
Eye discharge	149	0.019	11	0.014	0.70 (0.38–1.31)	30	0.018	0.97 (0.65–1.46)
Earache	275	0.034	26	0.04	0.93 (0.62–1.41)	57	0.035	1.00 (0.75–1.35)
Ear discharge	53	0.007	8	0.010	1.29 (0.60–2.73)	7	0.004	0.56 (0.25–1.24)
Skin rash	69	0.009	5	0.007	0.64 (0.26–1.60)	26	0.016	1.86 (1.17–2.95)
Infected cut	47	0.006	2	0.003	0.40 (0.10–1.65)	15	0.009	1.50 (0.83–2.74)
Nausea	289	0.036	38	0.049	1.29 (0.91–1.84)	57	0.035	0.93 (0.69–1.24)
Vomiting	133	0.017	18	0.023	1.33 (0.81–2.21)	31	0.019	1.07 (0.71–1.60)
Diarrhea	425	0.053	50	0.065	1.17 (0.86–1.60)	81	0.050	0.90 (0.70–1.15)
Diarrhea with blood	7	0.001	1	0.001	1.22 (0.15–10.01)	3	0.002	1.69 (0.42–6.75)
Stomach pain	495	0.062	51	0.066	1.04 (0.77–1.41)	103	0.063	0.98 (0.78–1.23)
Cough	551	0.069	70	0.091	1.34 (1.03–1.74)	117	0.072	1.06 (0.86–1.31)
Cough and phlegm	265	0.033	31	0.040	1.16 (0.79–1.70)	60	0.037	1.10 (0.82–1.47)
Runny nose	722	0.090	72	0.94	1.03 (0.79–1.33)	160	0.098	1.11 (0.93–1.34)
Sore throat	527	0.066	70	0.091	1.40 (1.07–1.82)	106	0.065	0.99 (0.80–1.24)
HCGI 1	239	0.030	28	0.036	1.18 (0.79–1.77)	50	0.031	0.99 (0.72–1.36)
HCGI 2	65	0.008	11	0.014	1.63 (0.85–3.12)	17	0.010	1.13 (0.65–1.95)
Significant respiratory disease	399	0.050	42	0.055	1.08 (0.77–1.50)	85	0.052	1.04 (0.81–1.33)

The total number of swimmers in each category is given in parentheses (N).
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

TABLE 4. Adverse Health Outcomes by Enterococci Levels: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	Enterococci (cfu/100ml)							
	≤35 (N = 7,689)*		>35–104 (N = 1,863)			>104 (N = 857)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR†	No. Ill	Risk	RR†
Fever	371	0.048	84	0.045	0.91 (0.71–1.16)	45	0.053	1.00 (0.72–1.40)
Chills	198	0.026	33	0.018	0.67 (0.46–0.97)	24	0.028	0.94 (0.60–1.48)
Eye discharge	149	0.019	25	0.013	0.69 (0.45–1.07)	16	0.019	1.01 (0.58–1.75)
Earache	270	0.035	57	0.031	0.82 (0.61–1.11)	31	0.036	0.88 (0.59–1.31)
Ear discharge	52	0.007	12	0.006	0.85 (0.45–1.62)	4	0.005	0.53 (0.19–1.51)
Skin rash	74	0.010	13	0.007	0.71 (0.39–1.30)	13	0.015	1.72 (0.89–3.31)
Infected cut	46	0.006	12	0.006	0.95 (0.49–1.82)	6	0.007	0.90 (0.37–2.18)
Nausea	271	0.035	72	0.039	1.07 (0.82–1.41)	41	0.048	1.19 (0.84–1.70)
Vomiting	130	0.017	34	0.018	1.13 (0.77–1.67)	18	0.021	1.20 (0.71–2.04)
Diarrhea	398	0.052	101	0.054	0.99 (0.78–1.25)	57	0.067	1.01 (0.75–1.36)
Diarrhea with blood	8	0.001	0	—	—	3	0.004	2.90 (0.66–12.68)
Stomach pain	464	0.060	126	0.068	1.09 (0.89–1.35)	59	0.069	0.97 (0.72–1.30)
Cough	554	0.072	121	0.065	0.91 (0.73–1.12)	63	0.074	1.00 (0.75–1.34)
Cough and phlegm	266	0.035	59	0.032	0.91 (0.68–1.22)	31	0.036	1.03 (0.69–1.54)
Runny nose	704	0.092	165	0.089	0.96 (0.80–1.15)	85	0.099	1.01 (0.79–1.30)
Sore throat	533	0.069	118	0.063	0.89 (0.72–1.10)	52	0.061	0.80 (0.59–1.09)
HCGI 1	230	0.030	51	0.027	0.92 (0.67–1.26)	36	0.042	1.31 (0.89–1.92)
HCGI 2	67	0.009	14	0.008	0.82 (0.46–1.48)	12	0.014	1.30 (0.67–2.51)
Significant respiratory disease	397	0.052	84	0.045	0.86 (0.67–1.11)	45	0.053	0.98 (0.70–1.37)

The total number of swimmers in each category is given in parentheses (N).
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

were increased risks of nausea, vomiting, diarrhea with blood, HCGI 1, and HCGI 2. Our adjusted RRs suggested similar positive associations, except for diarrhea; although the risk increased from 0.05 to 0.07, the adjusted RR comparing the highest to lowest category was 1.0 (Table 4). When comparing the lowest to higher deciles, we observed increased risks in most categories for infected cut and skin rash (Figure 1). Other adverse health outcomes—infected cut, nausea, diarrhea, diarrhea with blood, HCGI 1, and HCGI 2—exhibited increased risks only in particular quantiles. In comparison with the lowest decile, the risk of each of these outcomes was higher in the 10th decile. For example, the risk for HCGI 2 was 0.007 in the first decile, but 0.015 in the 10th.

Table 5 presents results for *E. coli*. We once again found an increased risk of skin rash in the highest prespecified category (that is, >320 cfu). Furthermore, we observed slight increased risks in this highest category for eye discharge, earache, stomach pain, coughing with phlegm, runny nose, and HCGI 1 (Table 5). In our decile-based analysis, however, we only observed materially increased risks for eye discharge, skin rash, and infection (Figure 1).

Numerous adverse health outcomes exhibited higher risks among subjects swimming on days when samples were positive for viruses (Table 6). In particular, the risk of fever, eye discharge, vomiting, sore throat, HCGI 1, and HCGI 2, and to a lesser extent, chills, diarrhea, diarrhea with blood, cough, coughing with phlegm, and SRD were higher on days when viruses were detected. Our adjusted RR estimates showed similar relations, most ranging from 1.3 to 1.9 (Table 6). Additionally, adjusting for each bacterial indicator (one-at-a-time) also left these results essentially unchanged.[12] As expected, there was an association between presence of virus and fecal coliforms within 50 yards of the drain. The mean density of fecal coliforms when no virus was detected was 234.8 cfu (SD 542.5 cfu); whereas it was 2,233.8 (SD 2,634.1) when viruses were detected (N = 386). The median values were 47.8 and 452.6 cfu, respectively.

Discussion

We observed differences in risk for a number of outcomes when we compared subjects swimming at 0 yards *vs* 400+ yards. Most of the relative risks suggested an approximately 50% increase in risk. Furthermore, as evinced by both the risks and RRs, there is an apparent threshold of increased risk occurring primarily at the drain: no dose response is evinced with increasing closeness to the drain, but there is a jump in risk for many adverse health outcomes among those swimming at the drain. We also found that distance is a reasonably good surrogate for bacterial indicators, with higher levels observed closer to the drain.[12]

For bacterial indicators, we observed a relation among numerous higher exposures and adverse health outcomes. These increases were mostly restricted to the highest knowledge-based categories (no effect was observed below any existing standards). When looking at quantiles, we found higher risks of skin rash and infection at fairly low levels. In contrast with what one might expect, however, there was no clear dose-response pattern across increasing levels of bacteriological exposures.

TABLE 5. Adverse Health Outcomes by E. coli Levels: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	E. coli (cfu/100ml)													
	≤35 (N = 6,104)*		>35–75 (N = 1,620)			>75–160 (N = 1,145)			>160–320 (N = 518)			>320 (N = 991)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR†	No. Ill	Risk	RR†	No. Ill	Risk	RR†	No. Ill	Risk	RR†
Fever	274	0.045	89	0.055	1.22 (0.95–1.56)	61	0.053	1.20 (0.90–1.60)	29	0.056	1.22 (0.81–1.84)	45	0.045	0.98 (0.70–1.37)
Chills	145	0.024	41	0.025	1.00 (0.70–1.44)	28	0.024	1.00 (0.66–1.52)	18	0.035	1.38 (0.82–2.33)	22	0.022	0.79 (0.49–1.26)
Eye discharge	116	0.019	30	0.019	0.99 (0.65–1.49)	14	0.012	0.65 (0.37–1.15)	6	0.012	0.61 (0.26–1.43)	23	0.023	1.36 (0.84–2.19)
Earache	214	0.035	45	0.028	0.75 (0.54–1.04)	33	0.029	0.78 (0.53–1.14)	18	0.035	0.91 (0.55–1.50)	47	0.047	1.25 (0.89–1.77)
Ear discharge	42	0.007	8	0.005	0.60 (0.28–1.28)	5	0.004	0.57 (0.22–1.46)	6	0.012	1.28 (0.52–3.15)	6	0.0066	0.67 (0.27–1.62)
Skin rash	57	0.009	15	0.009	1.01 (0.56–1.80)	7	0.006	0.66 (0.30–1.46)	6	0.012	1.21 (0.49–2.98)	15	0.015	2.04 (1.11–3.76)
Infected cut	42	0.007	7	0.004	0.53 (0.24–1.20)	3	0.003	0.33 (0.10–1.06)	3	0.006	0.66 (0.20–2.19)	9	0.009	1.02 (0.48–2.19)
Nausea	216	0.035	74	0.046	1.22 (0.93–1.61)	34	0.030	0.80 (0.55–1.16)	18	0.035	0.88 (0.53–1.46)	42	0.042	1.03 (0.73–1.47)
Vomiting	107	0.018	31	0.019	1.09 (0.72–1.64)	16	0.014	0.82 (0.48–1.40)	8	0.015	0.87 (0.41–1.85)	20	0.020	1.05 (0.63–1.74)
Diarrhea	310	0.051	101	0.062	1.14 (0.90–1.44)	63	0.055	1.00 (0.75–1.33)	25	0.048	0.80 (0.52–1.23)	56	0.057	0.91 (0.67–1.23)
Diarrhea with blood	5	0.001	3	0.002	2.06 (0.48–8.89)	1	0.001	1.03 (0.12–9.01)	2	0.004	3.98 (0.68–23.21)	0	—	—
Stomach pain	353	0.058	124	0.077	1.28 (1.03–1.59)	70	0.061	1.02 (0.78–1.33)	31	0.060	0.95 (0.64–1.40)	70	0.071	1.06 (0.80–1.40)
Cough	444	0.073	96	0.059	0.81 (0.64–1.02)	86	0.075	1.04 (0.82–1.33)	29	0.056	0.77 (0.51–1.14)	82	0.083	1.14 (0.88–1.48)
Cough and phlegm	226	0.037	41	0.025	0.66 (0.47–0.92)	34	0.030	0.78 (0.54–1.12)	11	0.021	0.53 (0.28–1.00)	43	0.043	1.12 (0.79–1.59)
Runny nose	566	0.093	136	0.084	0.87 (0.71–1.06)	105	0.092	0.96 (0.77–1.20)	38	0.073	0.76 (0.53–1.08)	108	0.109	1.12 (0.89–1.41)
Sore throat	417	0.068	99	0.061	0.86 (0.68–1.08)	82	0.072	1.02 (0.80–1.31)	29	0.056	0.78 (0.52–1.17)	75	0.076	1.04 (0.80–1.37)
HCGI 1	183	0.030	51	0.031	1.03 (0.75–1.42)	30	0.026	0.88 (0.59–1.30)	17	0.033	1.06 (0.63–1.80)	36	0.036	1.12 (0.76–1.64)
HCGI 2	48	0.008	21	0.013	1.55 (0.92–2.64)	8	0.007	0.85 (0.40–1.81)	6	0.012	1.25 (0.51–3.03)	10	0.010	1.04 (0.51–2.13)
Significant respiratory disease	319	0.052	71	0.044	0.82 (0.62–107)	58	0.051	0.96 (0.72–1.28)	21	0.041	0.74 (0.47–1.18)	56	0.057	1.03 (0.76–1.40)

The total number of swimmers in each category is given in parentheses (N).
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

TABLE 6. Number Ill, Risks, and Adjusted Relative Risk (RR) Estimates of Adverse Health Outcomes by Virus

	Viruses				
	No (N = 3,168)*		Yes (N = 386)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR (95% CI)†
Fever	126	0.040	23	0.060	1.56 (0.98–2.50)
Chills	65	0.021	10	0.026	1.25 (0.63–2.50)
Eye discharge	36	0.011	8	0.021	1.86 (0.85–4.09)
Earache	93	0.029	10	0.026	0.92 (0.47–1.80)
Ear discharge	15	0.005	0		
Skin rash	32	0.010	4	0.010	0.97 (0.34–2.82)
Infected cut	31	0.010	2	0.005	0.57 (0.13–2.40)
Nausea	101	0.032	12	0.031	0.93 (0.50–1.73)
Vomiting	44	0.014	10	0.026	1.86 (0.92–3.80)
Diarrhea	130	0.041	21	0.054	1.27 (0.78–2.07)
Diarrhea with blood	2	0.001	1	0.003	5.82 (0.45–75.72)
Stomach pain	191	0.060	23	0.060	0.92 (0.58–1.45)
Cough	181	0.057	28	0.073	1.22 (0.80–1.86)
Cough and phlegm	92	0.029	13	0.034	1.20 (0.66–2.18)
Runny nose	246	0.078	32	0.083	1.01 (0.68–1.49)
Sore throat	198	0.063	32	0.083	1.38 (0.93–2.06)
HCGI 1	72	0.023	15	0.039	1.69 (0.95–3.01)
HCGI 2	22	0.007	6	0.016	2.32 (0.91–5.88)
Significant respiratory disease	133	0.042	21	0.054	1.34 (0.83–2.18)

The total number of swimmers in each category is given in parentheses (N).
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

When looking at the ratio of total to fecal coliforms using the entire dataset, no consistent pattern emerged.[12] This is not entirely surprising inasmuch as an analysis of all data points treats all ratios of similar numerical value equally. Thus, for example, even though a ratio of 5 when the total coliforms are very low may not increase risk, the same ratio may be associated with increased risks when the density of total coliforms is above 1,000 or 5,000 cfu. When the analysis was restricted to swimmers exposed to total coliform densities above 1,000 or 5,000 cfu, a consistent pattern emerged, with higher risks associated with low ratios.[12]

This is the first large-scale epidemiologic study that included measurements of viruses. A number of adverse health effects were reported more often on days when the samples were positive, suggesting assays for viruses may be informative for predicting risk. Norwalk-like viruses are a plausible cause of gastroenteritis.[4,13] Enteroviruses, the most common viruses in sewage effluent, can cause respiratory symptoms. Not only are viruses responsible for many of the symptoms associated with swimming in ocean water but also they die off at slower rates in sea water than do bacteria, and they can cause infection at a much lower dose.[14]

Our design substantially reduced the potential for confounding by restricting the study entirely to swimmers and making comparisons between groups of swimmers (for example, defined by distance from the drain) to estimate relative risks. Previous studies looking at the effects of exposure to polluted recreational water (for example, due to sewage outflows) have been criticized for comparing risks in swimmers with risks in nonswimmers.[4,14,15] In these earlier studies, background risks among subjects who swim *vs* those choosing not to swim may differ because there are many other (potentially noncontrollable) exposures/pathways that can produce the symptoms under investigation. By restricting the present study to swimmers, we have reduced potential differences between the background risks of exposed *vs* unexposed subjects (for example, swimmers choosing to swim at the drain *vs* those swimming at the same beach but farther away from the drain). Furthermore, we were able to adjust our relative risk estimates for a number of additional factors (listed above) that could confound the observed relations. Of course, this does not exclude the possibility that residual confounding in these factors, or other unknown factors, might have confounded the observed relations.

Nevertheless, any actual (that is, causal) effects may be higher than we observed in this study because both distance and pathogenic indicators are proxy measures of the true pathogenic agents. Also, recall that we excluded subjects who frequently entered the water at these beaches. If there is a dose-response relation such that higher cumulative exposures are associated with increased risk, then one may infer that persons who frequently enter the water and immerse their heads (for example, surfers) may have a higher risk of adverse health outcomes than the relatively infrequent swimmers included in this study.

In summary, we observed positive associations between adverse health effects and (1) distance from the drain, (2) bacterial indicators, and (3) presence of enteric viruses. Taken together, these results imply that there may be an increased risk of a broad range of adverse health effects associated with swimming in ocean water subject to urban runoff. Moreover, attributable numbers—that is, estimates of the number of new cases of an adverse health outcome that is attributable to the exposure of interest—reached well into the 100s per

10,000 exposed subjects for many of the positive associations observed here.[12] This finding implies that these risks might not be trivial when we consider the millions of persons who visit these beaches each year. Furthermore, the factors apparently contributing to the increased risk of adverse health outcomes observed here are not unique to Santa Monica Bay (similar levels of bacterial indicators are observed at many other beaches). Consequently, the prospect that untreated storm drain runoff poses a health risk to swimmers is probably relevant to many beaches subject to such runoff, including areas on the East, West, and Gulf coasts of North America, as well as numerous beaches on other continents.

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INVESTIGATION OF THE FEASIBILITY AND BENEFITS OF LOW-IMPACT SITE DESIGN PRACTICES ("LID") FOR VENTURA COUNTY

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ABSTRACT

The Clean Water Act NPDES permit that regulates municipal separate storm sewer systems (MS4s) in Ventura County, California will be reissued in 2007. The draft permit includes provisions for requiring the use of low impact development practices (LID) for certain kinds of development and redevelopment projects. Using six representative development project case studies, the author investigated the practicability and relative benefits of the permit's LID requirements. The results showed that (1) LID site design and source control techniques are more effective than conventional best management practices (BMPs) in reducing runoff rates; (2) Effective Impervious Area (EIA) can practicably be capped at three percent, a standard more protective than that proposed in the draft permit; and (3) in five out of six case studies, LID methods would reduce site runoff volume and pollutant loading to zero in typical rainfall scenarios.

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INTRODUCTION

The Assessment in Relation to Municipal Permit Conditions

This purpose of this study is to investigate the relative water quality and water reuse benefits of three levels of storm water treatment best management practices (BMPs): (1) basic "treat-and-release" BMPs (e.g., drain inlet filters, CDS units), (2) commonly used BMPs that expose runoff to soils and vegetation (extended-detention basins and biofiltration swales and filter strips), and (3) low-impact development (LID) practices. The factors considered in the investigation are runoff volume, pollutant loading, and the availability of water for infiltration or other reuse. In order to assess the differential impact of storm water reduction approaches on these factors, this study examines six case studies typical of development covered by the Ventura County Municipal Separate Storm Sewer System Permit.

Low-impact development methods reduce storm runoff and its contaminants by decreasing their generation at sources, infiltrating into the soil or evaporating storm flows before they can enter surface receiving waters, and treating flow remaining on the surface through contact with vegetation and soil, or a combination of these strategies. Soil-based LID practices often use soil enhancements such as compost, and thus improve upon the performance of more traditional basins and biofilters. For the study's purposes, verification of the practicability and utility of LID practices was based on a modified version of the Planning and Land Development Program (Part 4, section E) in the Draft Ventura County Municipal Separate Storm Sewer System Permit ("Draft Permit"). The Draft Permit requires that Effective Impervious Area (EIA) of certain types of new development and redevelopment projects be limited to five percent of

total development project area. EIA is defined as hardened surface hydrologically connected via sheet flow or a discrete hardened conveyance to a drainage system or receiving water body. (Draft Permit p. 50) The study modified this requirement to three percent, as a way to test both the feasibility of meeting the higher, five percent standard in the draft permit and because as the lower, three percent EIA is essential to protect the Ventura County aquatic environment (see Attachment A).

The Draft Permit further requires minimizing the overall percentage of impervious surfaces in new development and redevelopment projects to support storm water infiltration. The Draft Permit also directs an integrated approach to minimizing and mitigating storm water pollution, using a suite of strategies including source control, LID, and treatment control BMPs. (Draft Permit p. 50) It is noted in this section of the document that impervious surfaces can be rendered "ineffective" if runoff is dispersed through properly designed vegetated swales. In testing the practicability of the draft permit's requirements and a three percent EIA standard, this study broadened this approach to encompass not only vegetated swales (channels for conveyance at some depth and velocity) but also vegetated filter strips (surfaces for conveyance in thin sheet flow) and bioretention areas (shallow basins with a range of vegetation types in which runoff infiltrates through soil either to groundwater or a subdrain for eventual surface discharge). The Draft Permit's stipulation of "properly designed" facilities was interpreted to entail, among other requirements, either determination that existing site soils can support runoff reduction through infiltration or that soils will be amended using accepted LID techniques to attain this objective. Finally, the study further broadened implementation options to include water harvesting (collection and storage for use in, for example, irrigation or gray water systems), roof downspout infiltration trenches, and porous pavements.

The Draft permit was interpreted to require management of EIA, other impervious area (what might be termed Not-Connected Impervious Area, NCIA), and pervious areas as follows:

- Runoff from EIA is subject to treatment control and the Draft Permit's Hydromodification Mitigation Control requirements before discharge.

- NCIA must be drained onto a properly designed vegetated surface or its runoff managed by one of the other options discussed in the preceding paragraph. To the extent NCIA runoff is not eliminated prior to discharge from the site in one of these ways, it is subject to treatment control and the Draft Permit's Hydromodification Mitigation Control requirements before discharge.

- Runoff from pervious areas is subject to treatment control and the Draft Permit's Hydromodification Mitigation Control requirements before discharge. This provision applies to pervious areas that both do and do not receive drainage from NCIA.

Where treatment control BMPs are required to manage runoff from the site, the Draft Permit's Volumetric or Hydrodynamic (Flow Based) Treatment Control design bases were assumed to apply. The former basis applies to storage-type BMPs, like ponds, and requires capturing and treating either the runoff volume from the 85th percentile 24-hour rainfall event for the location, the volume of annual runoff to achieve 80 percent or more volume treatment, or the volume of runoff produced from a 0.75 inch storm event. The calculations in this analysis used the 0.75-inch quantity. The Hydrodynamic basis applies to flow-through BMPs, like swales, and requires treating the runoff flow rate produced from a rain event equal to at least 0.2 inches per hour intensity (or one of two other approximately equivalent options).

Scope of the Assessment

With respect to each of the six development case studies, three assessments were undertaken: a baseline scenario incorporating no storm water management controls; a second scenario employing conventional BMPs; and a third development scenario employing LID storm water management strategies.

To establish a baseline for each case study, annual storm water runoff volumes were estimated, as well as concentrations and mass loadings of four pollutants: (1) total suspended solids (TSS), (2) total recoverable copper (TCu), (3) total recoverable zinc (TZn), and (4) total phosphorus (TP). These baseline estimates were based on the anticipated land use and cover with no storm water management efforts.

Two sets of calculations were then conducted using the parameters defined for the six case studies.

The first group of calculations estimated the extent to which basic BMPs reduce runoff volumes and pollutant concentrations and loadings, and what impact, if any, such BMPs have on recharge rates or water retention on-site.

The second group of calculations estimated the extent to which commonly used soil-based BMPs and LID site design strategies ameliorate runoff volumes and pollutant concentrations and loadings, and the effect such techniques have on recharge rates. When evaluating LID strategies, it was presumed that EIA would be limited to three percent and runoff from EIA, NCIA, and pervious areas would be managed as indicated above. The assessment of basins, biofiltration, and low-impact design practices analyzed the expected infiltration capacity of the case study sites. It also considered related LID techniques and practices, such as source reduction strategies, that could work in concert with infiltration to serve the goals of: (1) preventing increase in annual runoff volume from the pre- to the post-developed state, (2) preventing increase in annual pollutant mass loadings between the two development states, and (3) avoiding exceedances of California Toxics Rule (CTR) acute saltwater criteria for copper and zinc.

The results of this analysis show that:

- Developments implementing no post-construction BMPs result in storm water runoff volume and pollutant loading that are substantially increased, and recharge rates that are substantially decreased, compared to pre-development conditions.

- Developments implementing basic post-construction treatment BMPs achieve reduced pollutant loading compared to developments with no BMPs, but storm water runoff volume and recharge rates are similar to developments with no BMPs.

- Developments implementing traditional basins and biofilters, and even more so low-impact post-construction BMPs, achieve significant reduction of pollutant loading and runoff volume as well as greatly enhanced recharge rates compared to both developments with no BMPs and developments with basic treatment BMPs.

- Typical development categories, ranging from single family residential to large commercial, can feasibly implement low-impact post-construction BMPs designed in compliance with the draft permit's requirements, as modified to include a lower, three percent EIA requirement.

This report covers the methods employed in the investigation, data sources, and references for both. It then presents the results, discusses their consequences, draws conclusions, and makes recommendations relative to the feasibility of utilizing low-impact development practices in Ventura County developments.

CASE STUDIES

Six case studies were selected to represent a range of urban development types considered to be representative of coastal Southern California, including Ventura County. These case studies involved: a multi-family residential complex (MFR), a relatively small-scale (23 homes) single-family residential development (Sm-SFR), a restaurant (REST), an office building (OFF), a relatively large (1000 homes) single-family residential development (Lg-SFR) and a sizeable commercial retail installation (COMM).[1]

Parking spaces were estimated to be 176 sq ft in area, which corresponds to 8 ft width by 22 ft length dimensions. Code requirements vary by jurisdiction, with the tendency now to drop below the traditional 200 sq ft average. About 180 sq ft is common, but various standards for full- and compact-car spaces, and for the mix of the two, can raise or lower the average.[2] The 176 sq ft size is considered to be a reasonable value for conventional practice.

Roadways and walkways assume a wide variety of patterns. Exclusive of the two SFR cases, simple, square parking lots with roadways around the four sides and square buildings with walkways also around the four sides were assumed. Roadways and walkways were taken to be 20 ft and 6 ft wide, respectively.

Single-family residences were assumed each to have a driveway 20 ft wide and 30 ft long. It was further assumed that each would have a sidewalk along the front of the lot, which was calculated to be 5749 sq ft in area. Assuming a square lot, the front dimension would be 76 ft. A 40-ft walkway was included within the property. Sidewalks and walkways were taken to be 4 ft wide.

Exclusive of the COMM case, the total area for all of these impervious features was subtracted from the total site area to estimate the pervious area, which was assumed to have conventional landscaping cover (grass, small herbaceous decorative plants, bushes, and a few trees). For the COMM scenario, the hypothetical total impervious cover was enlarged by 10 percent to represent the landscaping, on the belief that a typical retail commercial establishment would typically be mostly impervious.

Table 1 (page 5) summarizes the characteristics of the six case studies. The table also provides the recorded or estimated areas in each land use and cover type.

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[1] Building permit records from the City of San Marcos in San Diego County provided data on total site areas for the first four case studies, including numbers of buildings, building footprint areas (including porch and garage for Sm-SFR), and numbers of parking spaces associated with the development projects. While the building permit records made no reference to features such as roadways, walkways, and landscaping normally associated with development projects, these features were taken into account in the case studies using assumptions described herein. Larger developments were not represented in the sampling of building permits from the San Marcos database. To take larger development projects into account in the subsequent analysis, the two larger scale case studies were hypothesized. The Lg-SFR scenario scaled up all land use estimates from the Sm-SFR case in the ratio of 1000:23. The hypothetical COMM scenario consisted of a building with a 2-acre footprint and 500 parking spaces. As with the smaller-scale cases, these hypothetical developments were assumed to have roadways, walkways, and landscaping, as described herein.

[2] J. Gibbons, *Parking Lots*, NONPOINT EDUCATION FOR MUNICIPAL OFFICERS, Technical Paper No. 5 (1999) (http://nemo.uconn.edu/tools/publications/tech_papers/tech_paper_5.pdf).

Table 1. Case Study Characteristics and Land Use and Land Cover Areas

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	COMM[a]
No. buildings	11	23	1	1	1000	1
Total area (ft^2)	476,982	132,227	33,669	92,612	5,749,000	226,529
Roof area (ft^2)	184,338	34,949	3,220	7,500	1,519,522	87,120
No. parking spaces	438	-	33	37	-	500
Parking area (ft^2)	77,088	-	5808	6512	-	88,000
Access road area (ft^2)	22,212	-	6097	6456	-	23,732
Walkway area (ft^2)	33,960	10,656	1362	2078	463,289	7,084
Driveway area (ft^2)	-	13,800	-	-	600,000	-
Landscape area (ft^2)	159,384	72,822	17,182	70,066	3,166,190	20,594

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential;
REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; COMM—retail commercial

METHODS OF ANALYSIS

Annual Storm Water Runoff Volumes

Annual surface runoff volumes produced were estimated for both pre- and post-development conditions for each case study site. Runoff volume was computed as the product of annual precipitation, contributing drainage area, and a runoff coefficient (ratio of runoff produced to rainfall received). For impervious areas the following equation was used:

$$C = (0.009)\, I + 0.05$$

where I is the impervious percentage. This equation was derived by Schueler (1987) from Nationwide Urban Runoff Program data (U.S. Environmental Protection Agency 1983). With I = 100 percent for fully impervious surfaces, C is 0.95.

The basis for pervious area runoff coefficients was the Natural Resource Conservation Service's (NRCS) Urban Hydrology for Small Watersheds (NRCS 1986, as revised from the original 1975 edition). This model estimates storm event runoff as a function of precipitation and a variable representing land cover and soil, termed the curve number (CN). Larger events are forecast to produce a greater amount of runoff in relation to amount of rainfall because they more fully saturate the soil. Therefore, use of the model to estimate annual runoff requires selecting some event or group of events to represent the year. A 0.75-inch rainfall event was used in the analysis here for the relative comparison between pre- and post-development and applied to deriving a runoff coefficient for annual estimates, recognizing that smaller storms would produce less and larger storms more runoff.

To select CN for the pre-development case, an analysis performed in the area of the Cedar Fire in San Diego County was used in which CN was determined before and after the 2003 fire.[3] In the San Diego analysis, CN = 83 was estimated for the pre-existing land cover, which was generally chaparral, a vegetative cover also typical of Ventura County. As indicated below, soils are also similar in Ventura and San Diego Counties, making the parameter selection reasonable for use in both locations. For post-development landscaping, CN = 86 was selected based on tabulated data in NRCS (1986) and professional judgment.

Pre- and post-development runoff quantities were computed with these CN values and the 0.75-inch rainfall, and then divided by the rainfall to obtain runoff coefficients. The results were 0.07

[3] American Forests, *San Diego Urban Ecosystem Analysis After the Cedar Fire* (Feb. 3, 2006) (http://www.ufei.org/files/pubs/SanDiegoUrbanEcosystemAnalysis-PostCedarFire.pdf).

and 0.12, respectively. Finally, total annual runoff volumes were estimated based on an average annual precipitation in the City of Ventura of 14.71 inches.[4]

Storm Water Runoff Pollutant Discharges

Annual pollutant mass discharges were estimated as the product of annual runoff volumes produced by the various land use and cover types and pollutant concentrations typical of those areas. Again, the 0.75-inch precipitation event was used as a basis for volumes. Storm water pollutant data have typically been measured and reported for general land use types (e.g., single-family residential, commercial). However, an investigation of low-impact development practices of the type this study sought to conduct demands data on specific land coverages. The literature offers few data on this basis. Those available and used herein were assembled by a consultant to the City of Seattle for a project in which the author participated. They appear in Attachment B (Herrera Environmental Consultants, Inc. undated).

Pollutant concentrations expected to occur typically in the mixed runoff from the several land use and cover types making up a development were estimated by mass balance; i.e., the concentrations from the different areas of the sites were combined in proportion to their contribution to the total runoff.

The Effect of Conventional Treatment BMPs on Runoff Volume, Pollutant Discharges, and Recharge Rates

The first question in analyzing how BMPs reduce runoff volumes and pollutant discharges was, What BMPs are being employed in Ventura County developments under the permit now in force? This permit is open-ended and provides regulated entities with a large number of choices and few fixed requirements. These options presumably include manufactured BMPs, such as drain inlet inserts (DIIs) and continuous deflective separation (CDS) units. Developments may also select such non-proprietary devices as extended-detention basins (EDBs) and biofiltration swales and filter strips. EDBs hold water for two to three days for solids settlement before releasing whatever does not infiltrate or evaporate. Biofiltration treats runoff through various processes mediated by vegetation and soil. In a swale, runoff flows at some depth in a channel, whereas a filter strip is a broad surface over which water sheet flows. Each of these BMP types was applied to each case study, although it is not clear that these BMPs, in actuality, have been implemented consistently within Ventura County to date.

The principal basis for the analysis of BMP performance was the California Department of Transportation's (CalTrans, 2004) BMP Retrofit Pilot Program, performed in San Diego and Los Angeles Counties. One important result of the program was that BMPs with a natural surface infiltrate and evaporate (probably, mostly infiltrate) a substantial amount of runoff, even if conditions do not appear to be favorable for an infiltration basin. On average, the EDBs, swales, and filter strips lost 40, 50 and 30 percent, respectively, of the entering flow before the discharge point. DIIs and CDS units do not contact runoff with a natural surface, and therefore do not reduce runoff volume.

The CalTrans program further determined that BMP effluent concentrations were usually a function of the influent concentrations, and equations were developed for the functional

[4] Ventura County Watershed Protection District (http://www.vcwatershed.org/fws/specialmedia.htm). The City of Ventura is considered to be representative of most of the developed and developing areas in Ventura County. However, there is some variation around the county, with the maximum precipitation registered at Ojai (annual average 21.32 inches). Ojai is about 15 miles inland and lies at elevation 745 ft at the foot of the Topatopa Mountains, the orographic effect of which influences its meteorology. Ojai's higher rainfall was taken into account in the calculations, and the report notes the few instances where it affected the conclusions.

relationships in these cases. BMPs generally reduced influent concentrations proportionately more when they were high. In relatively few situations influent concentrations were constant at an "irreducible minimum" level regardless of inflow concentrations.

In analyzing the effects of BMPs on the case study runoff, the first step was to reduce the runoff volumes estimated with no BMPs by the fractions observed to be lost in the pilot study. The next task was estimating the effluent concentrations from the relationships in the CalTrans report. The final step was calculating discharge pollutant loadings as the product of the reduced volumes and predicted effluent concentrations. As before, typical pollutant concentrations in the mixed runoff were established by mass balance.

Estimating Infiltration Capacity of the Case Study Sites

Infiltrating sufficient runoff to maintain pre-development hydrologic characteristics and prevent pollutant transport is the most effective way to protect surface receiving waters. Successfully applying infiltration requires soils and hydrogeological conditions that will pass water sufficiently rapidly to avoid overly-lengthy ponding, while not allowing percolating water to reach ground-water before the soil column captures pollutants.

The study assumed that infiltration would occur in surface facilities and not in below-ground trenches. The use of trenches is certainly possible, and was judged to be an approved BMP by CalTrans after the pilot study. However, the intent of this investigation was to determine the ability of pervious areas to manage the site runoff. This was accomplished by determining the infiltration capability of the pervious areas in their original condition for each development case study, and further assessing the pervious areas' infiltration capabilities if soils were modified according to low impact development practices.

The chief basis for this aspect of the work was an assessment of infiltration capacity and benefits for Los Angeles' San Fernando Valley (Chralowicz et al. 2001). The Chralowicz study posited providing 0.1-0.5 acre for infiltration basins to serve each 5 acres of contributing drainage area. At 2-3 ft deep, it was estimated that such basins could infiltrate 0.90-1.87 acre-ft/year of runoff in San Fernando Valley conditions. Soils there are generally various loam textures with infiltration rates of approximately 0.5-2.0 inches/hour. The most prominent soils in Ventura County, at least relatively near the coast, are loams, sandy loams, loamy sands, and silty clay loams, thus making the conclusions of the San Fernando Valley study applicable for these purposes.[5] This information was used to estimate how much of each case study site's annual runoff would be infiltratable, and if the pervious portion would provide sufficient area for infiltration. For instance, if sufficient area were available, the infiltration configuration would not have to be in basin form but could be shallower and larger in surface area. This study's analyses assumed the use of bioretention areas rather than traditional infiltration basins.

Volume and Pollutant Source Reduction Strategies

As mentioned above, the essence of low-impact development is reducing runoff problems before they can develop, at their sources, or exploiting the infiltration and treatment abilities of soils and vegetation. If a site's existing infiltration and treatment capabilities are inadequate to preserve pre-development hydrology and prevent runoff from causing or contributing to violations of water quality standards, then LID-based source reduction strategies can be implemented, infiltration and treatment capabilities can be upgraded, or both.

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[5] Cabrillo Port Liquefied Natural Gas Deepwater Port Draft EIS/EIR (Oct. 2004) (http://www.cabrilloport.ene.com/files/eiseir/4.05%20%20-Agriculture%20and%20Soils.pdf).

Source reduction can be accomplished through various LID techniques. Soil can be upgraded to store runoff until it can infiltrate, evaporate, or transpire from plants through compost addition. Soil amendment, as this practice is known, is a standard LID technique.

Upgraded soils are used in bioretention cells that hold runoff and effect its transfer to the subsurface zone. This standard LID tool can be used where sufficient space is available. This study analyzed whether the six development case study sites would have sufficient space to effectively reduce runoff using bioretention cells, assuming the soils and vegetation could be amended and enhanced where necessary.

Conventional pavements can be converted to porous asphalt or concrete or replaced with concrete or plastic unit pavers or grid systems. For such approaches to be most effective, the soils must be capable of infiltrating the runoff passing through, and may require renovation.

Source reduction can be enhanced by the LID practice of water harvesting, in which water from impervious surfaces is captured and stored for reuse in irrigation or gray water systems. For example, runoff from roofs and parking lots can be harvested, with the former being somewhat easier because of the possibility of avoiding pumping to use the water and fewer pollutants. Harvesting is a standard technique for Leadership in Energy and Environmental Design (LEED) buildings.[6] Many successful systems of this type are in operation, such as the Natural Resources Defense Council offices (Santa Monica, CA), the King County Administration Building (Seattle, WA), and two buildings on the Portland State University campus (Portland, OR). This investigation examined how water harvesting could contribute to storm water management for case study sites where infiltration capacity, available space, or both appeared to be limited.

RESULTS OF THE ANALYSIS

1. "Base Case" Analysis: Development without Storm Water Controls

Comparison of Pre- and Post-Development Runoff Volumes

Table 2 (page 9) presents a comparison between the estimated runoff volumes generated by the respective case study sites in the pre- and post-development conditions, assuming implementation of no storm water controls on the developed sites. On sites dominated by impervious land cover, most of the infiltration that would recharge groundwater in the undeveloped state is expected to be lost to surface runoff after development. This greatly increased surface flow would raise peak flow rates and volumes in receiving water courses, raise flooding risk, and transport pollutants. Only the office building, the plan for which retained substantial pervious area, would lose less than half of the site's pre-development recharge.

[6] New Buildings Institute, Inc., *Advanced Buildings* (2005) (http://www.poweryourdesign.com/LEEDGuide.pdf).

Table 2. Pre- and Post-Development without BMPs: Distribution of Surface Runoff Versus Recharge to Groundwater

Annual Volume (acre-ft)	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	COMM[a]
Precipitation[b]	13.4	3.72	0.95	2.60	162	6.37
Pre-development runoff[c]	0.94	0.26	0.07	0.18	11	0.45
Pre-development recharge[d]	12.5	3.46	0.88	2.42	150	5.92
Post-development impervious runoff[c]	8.48	1.59	0.44	0.60	69	5.50
Post-development pervious runoff[c]	0.54	0.25	0.06	0.24	11	0.07
Post-development total runoff[c]	9.02	1.83	0.50	0.84	80	5.57
Post-development recharge[d]	4.39	1.88	0.45	1.76	82	0.80
Post-development recharge loss (% of pre-development recharge)	8.08 (65%)	1.57 (46%)	0.43 (49%)	0.66 (27%)	68 (45%)	5.12 (86%)

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential;
COMM—retail commercial
[b] Volume of precipitation on total project area
[c] Quantity of water discharged from the site on the surface
[d] Quantity of water infiltrating the soil; the difference between precipitation and runoff

Pollutant Concentrations and Loadings

Table 3 presents the pollutant concentrations from the literature and loadings calculated as described for the various land use and cover types represented by the case studies. Landscaped areas are expected to release the highest TSS concentration, although relatively low TSS mass loading because of the low runoff coefficient. The highest copper concentrations and loadings are expected from parking lots. Roofs, especially commercial roofs, top the list for both zinc concentrations and loadings. Landscaping would issue by far the highest phosphorus, although access roads and driveways would contribute the highest mass loadings.

Table 3. Pollutant Concentrations and Loadings for Case Study Land Use and Cover Types

Land Use	Concentrations				Loadings			
	TSS (mg/L)	TCu (mg/L)	TZn (mg/L)	TP (mg/L)	Lbs. TSS/ acre-year	Lbs. TCu/ acre-year	Lbs. TZn/ acre-year	Lbs. TP/ acre-year
Residential roof	25	0.013	0.159	0.11	79	0.041	0.503	0.348
Commercial roof	18	0.014	0.281	0.14	57	0.044	0.889	0.443
Access road/driveway	120	0.022	0.118	0.66	380	0.070	0.373	2.088
Parking	75	0.036	0.097	0.14	237	0.114	0.307	0.443
Walkway	25	0.013	0.059	0.11	79	0.041	0.187	0.348
Landscaping	213	0.013	0.059	2.04	85	0.005	0.024	0.815

The CTR acute criteria for copper and zinc are 0.0048 mg/L and 0.090 mg/L, respectively. Table 3 shows that all developed land uses are expected to discharge copper above the criterion, based on the mass balance calculations using concentrations from Table 3. Any surface release from the case study sites would violate the criterion at the point of discharge, although dilution by the receiving water would lower the concentration below the criterion at some point. Even if copper mass loadings are reduced by BMPs, any surface discharge would exceed the criterion initially, but it would be easier to dilute below that level. In contrast, runoff from some land covers would not violate the acute zinc criterion. Because of this difference, the evaluation considered whether or not the zinc criterion would be exceeded in each analysis, whereas there was no point in this analysis for copper. There are no equivalent water quality

criteria for TSS and TP; hence, their concentrations were not further analyzed in the different scenarios.

Table 4 shows the overall loadings, as well as zinc concentrations, expected to be delivered from the case study developments should they not be fitted with any BMPs. As Table 4 shows, all cases are forecast to exceed the 0.090 mg/L acute zinc criterion, and the retail commercial development does so by a wide margin. Because of its size, the large residential development dominates the mass loading emissions.

Table 4. Case Study Pollutant Concentration and Loading Estimates without BMPs

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	COMM[a]
TZn (mg/L)	0.127	0.123	0.128	0.133	0.123	0.175
Lbs. TSS/year	1321	345	125	242	15016	853
Lbs. TCu/year	0.46	0.074	0.032	0.045	3.21	0.37
Lbs. TZn/year	3.09	0.607	0.174	0.301	26.4	2.64
Lbs. TP/year	6.58	2.39	0.72	1.78	104	3.36

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; COMM—retail commercial

2. "Conventional BMP" Analysis: Effect of Basic Treatment BMPs

Effect of Basic Treatment BMPs on Post-Development Runoff Volumes

The current permit allows regulated parties to select from a range of BMPs in order to treat or infiltrate a given quantity of annual rainfall. The range includes drain inlet inserts, CDS units, and other manufactured BMPs, detention vaults, and sand filters, all of which isolate runoff from the soil; as well as basins and biofiltration BMPs built in soil and generally having vegetation. Treatment BMPs that do not permit any runoff contact with soils discharge as much storm water runoff as equivalent sites with no BMPs, and hence yield zero savings in recharge. As mentioned above, the CalTrans (2004) study found that BMPs with a natural surface can reduce runoff by substantial margins (30-50 percent for extended-detention basins and biofiltration).

With such a wide range of BMPs in use, runoff reduction ranging from 0 to 50 percent, and a lack of clearly ascertainable requirements, it is not possible to make a single estimate of how much recharge savings are afforded by maximal implementation of the current permit. We made the following assumptions regarding implementation of BMPs. Assuming natural-surface BMPs perform at the average of the three types tested by CalTrans (2004), i.e., 40 percent runoff reduction, the estimate can be bounded as shown in Table 5 (page 11). The table demonstrates that allowing free choice of BMPs without regard to their ability to direct water into the ground forfeits substantial groundwater recharge benefits when hardened-surface BMPs are selected. Use of soil-based conventional BMPs could cut recharge losses from half or e more of the full potential to about one-quarter to one-third or less, except with the highly impervious commercial development. This analysis shows the wisdom of draining impervious to pervious surfaces, even if those surfaces are not prepared in any special way. But as subsequent analyses showed, soil amendment can gain considerably greater benefits.

Table 5. Pre- and Post-Development with Conventional BMPs: Distribution of Surface Runoff Versus Recharge to Groundwater

Annual Volume (acre-ft)	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	COMM[a]
Precipitation[b]	13.4	3.72	0.95	2.60	162	6.37
Pre-development runoff[c]	0.94	0.26	0.07	0.18	11	0.45
Pre-development recharge	12.5	3.46	0.88	2.42	150	5.92
Post-development impervious runoff[c, d]	5.09-8.48	0.95-1.59	0.26-0.44	0.36-0.60	41-69	3.30-5.50
Post-development pervious runoff[c, d]	0.32-0.54	0.15-0.25	0.04-0.06	0.14-0.24	6.6-11	0.04-0.07
Post-development total runoff[c, d]	5.41-9.02	1.10-1.83	0.30-0.50	0.50-0.84	48-80	3.34-5.57
Post-development recharge[d, e]	4.39-7.99	1.88-2.62	0.45-0.65	1.76-2.10	82-114	0.80-3.03
Post-development recharge loss (% of pre-development recharge)[d, e]	4.51-8.08 (36-65%)	0.84-1.57 (24-46%)	0.23-0.43 (26-49%)	0.32-0.66 (13-27%)	36-68 (24-45%)	2.89-5.12 (49-86%)

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; COMM—retail commercial. Ranges represent 40 percent runoff volume reduction, with full site coverage by BMPs having a natural surface, to no reduction, with BMPs isolating runoff from soil.
[b] Volume of precipitation on total project area
[c] Quantity of water discharged from the site on the surface
[d] Ranging from the quantity with hardened bed BMPs to the quantity with soil-based BMPs
[e] Quantity of water infiltrating the soil; the difference between precipitation and runoff

Effect of Basic Treatment BMPs on Pollutant Discharges

Table 6 (page 12) presents estimates of zinc effluent concentrations and mass loadings of the various pollutants discharged from four types of conventional treatment BMPs. The manufactured CDS BMPs in this table, which do not expose runoff to soil or vegetation, are not expected to drop any of the concentrations sufficiently to meet the acute zinc criterion at the discharge point. The loading reduction results show the CDS units always performing below 50 percent reduction for all pollutants analyzed, and most often in the vicinity of 20 percent, with zero copper reduction.

When treated with swales or filter strips, effluents from each development case study site are expected to fall below the CTR acute zinc criterion. All but the large commercial site would meet the criterion with EDB treatment. These natural-surface BMPs, if fully implemented and well maintained, are predicted to prevent the majority of the pollutant masses generated on most of the development sites from reaching a receiving water. Only total phosphorus reduction falls below 50 percent for two case studies. Otherwise, mass loading reductions range from about 60 to above 80 percent for the EDB, swale, and filter strip. This data indicates that draining impervious to pervious surfaces, even if those surfaces are not prepared in any special way, pays water quality as well as hydrologic dividends.

Table 6. Pollutant Concentration and Loading Reduction Estimates with Conventional BMPs

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	COMM[a]
Effluent Concentrations:						
CDS TZn (mg/L)[a]	0.095	0.095	0.098	0.102	0.095	0.131
EDB TZn (mg/L)[a]	0.085	0.086	0.084	0.084	0.086	0.098
Swale TZn (mg/L)	0.055	0.054	0.055	0.056	0.054	0.068
Filter strip TZn (mg/L)	0.039	0.039	0.039	0.041	0.039	0.048
Loading Reductions:						
CDS TSS loading reduction	15.7%	19.9%	22.0%	24.0%	19.9%	16.9%
CDS TCu loading reduction	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CDS TZn loading reduction	22.7%	22.4%	22.9%	23.1%	22.4%	25.1%
CDS TP loading reduction	30.6%	41.5%	40.7%	45.9%	41.5%	20.3%
EDB TSS loading reduction	68.1%	73.7%	79.0%	81.1%	73.7%	71.7%
EDB TCu loading reduction	61.9%	55.7%	66.2%	63.0%	55.7%	66.8%
EDB TZn loading reduction	59.7%	59.6%	60.4%	61.9%	59.6%	66.6%
EDB TP loading reduction	61.9%	69.7%	69.1%	72.9%	69.7%	54.5%
Swale TSS loading reduction	68.8%	71.1%	73.1%	73.9%	71.1%	69.4%
Swale TCu loading reduction	72.5%	68.5%	78.2%	73.3%	68.5%	75.8%
Swale TZn loading reduction	78.4%	78.1%	84.3%	78.8%	78.1%	80.7%
Swale TP loading reduction	66.3%	70.7%	67.2%	76.2%	70.7%	55.0%
Filter strip TSS loading reduction	69.9%	75.4%	80.6%	82.6%	75.4%	72.3%
Filter strip TCu loading reduction	74.4%	69.1%	78.2%	75.4%	69.1%	78.7%
Filter strip TZn loading reduction	78.3%	77.9%	78.4%	78.7%	77.9%	80.9%
Filter strip TP loading reduction	48.4%	53.1%	63.7%	59.8%	53.1%	34.6%

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; COMM—retail commercial; CDS— continuous deflective separation unit; EDB—extended-detention basin

3. LID Analysis: Development According to Modified Draft Permit Provisions

(a) Hydrologic Analysis

The LID analysis was first performed according to the Draft Permit provisions under the Planning and Land Development Program (Part 4, section E). In this analysis, however, EIA was limited to three instead of five percent, under the reasoning presented in Attachment A. All runoff from NCIA was assumed to drain to vegetated surfaces, as provided in the Draft Permit.

One goal of this exercise was to identify methods that reduce runoff production in the first place. It was hypothesized that implementation of source reduction techniques could allow all of the case study sites to infiltrate substantial proportions of the developed site runoff, advancing the hydromodification mitigation objective of the Draft Permit. When runoff is dispersed into the soil instead of being rapidly collected and conveyed away, it recharges groundwater, supplementing a resource that maintains dry season stream flow and wetlands. An increased water balance can be tapped by humans for potable, irrigation, and process water supply. Additionally, runoff volume reduction would commensurately decrease pollutant mass loadings.

Accordingly, the analysis considered the practicability of more than one scenario by which the draft permit's terms could be met, as modified to reflect three percent EIA. In one option, all roof runoff is harvested and stored for some beneficial use. A second option disperses runoff into the soil via roof downspout infiltration trenches. The former option is probably best suited to cases like the large commercial and office buildings, while distribution in the soil would fit best with residences and relatively small commercial developments. The analysis was repeated with the assumptions of harvesting OFF and COMM roof runoff for some beneficial use and dispersing roof runoff from the remaining four cases in roof downspout infiltration systems.

Expected Infiltration Capacities of the Case Study Sites

The first inquiry on this subject sought to determine how much of the total annual runoff each property is expected to infiltrate. This assessment tested the feasibility of draining all but three percent of impervious area to pervious land on the sites. Based on the findings of Chralowicz et al. (2001), it was assumed that an infiltration zone of 0.1-0.5 acres in area and 2-3 ft deep would serve a drainage catchment area in the size range 0-5 acres and infiltrate 0.9-1.9 acre-ft/year. The conclusions of Chralowicz et al. (2001) were extrapolated to conservatively assume that 0.5 acre would be required to serve each additional five acres of catchment, and would infiltrate an incremental 1.4 acre-ft/year (the midpoint of the 0.9-1.9 acre-ft/year range). According to these assumptions, the following schedule of estimates applies:

Pervious Area Available for Infiltration	Catchment Served acres	Infiltration Capacity
0.5 acres	0-5 acres	1.4 acre-ft/year
1.0 acres	5-10 acres	2.8 acre-ft/year
1.5 acres	10-15 acres	4.2 acre-ft/year
(Etc.)	...	...

As a formula, infiltration capacity ≈ 2.8 x available pervious area. To apply the formula conservatively, the available area was reduced to the next lower 0.5-acre increment before multiplying by 2.8.

As shown in Table 7, five of the six sites have adequate or greater capacity to infiltrate the full annual runoff volume from NCIA and pervious areas where EIA is limited to three percent of the total site area (four at the higher Ojai rainfall). Indeed, five of the six development types have sufficient pervious area to infiltrate *all* runoff, including runoff from EIA areas. With the most representative rainfall, only the large commercial development, with little available pervious area, falls short of the needed capacity to infiltrate all rainfall, but it still has the capacity to meet the terms of the draft permit, as modified for this analysis. These results are based on infiltrating in the native soils with no soil amendment. For any development project at which infiltration-oriented BMPs are considered, it is important that infiltration potential be carefully assessed using site-specific soils and hydrogeologic data. In the event such an investigation reveals a marginal condition (e.g., hydraulic conductivity, spacing to groundwater) for infiltration basins, soils could be enhanced to produce bioretention zones to assist infiltration. Notably, the four case studies with far greater than necessary infiltration capacity would offer substantial flexibility in designing infiltration, allowing ponding at less than 2-3 ft depth.

Table 7. Infiltration and Runoff Volume With 3 Percent EIA and All NCIA Draining to Pervious Areas

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	COMM[a]
EIA runoff (acre-ft/year)	0.38	0.11	0.03	0.07	4.6	0.18
NCIA + pervious area runoff (acre-ft/year)	**8.63**	**1.73**	**0.47**	**0.76**	**75.0**	**5.39**
Total runoff (acre-ft/year)	9.01	1.84	0.50	0.83	79.6	5.57
Pervious area available for infiltration (acres)	3.66	1.67	0.39	1.61	72.7	0.47
Estimated infiltration capacity (acre-ft/year)[b]	**9.8**	**4.2**	**1.4**	**4.2**	**203**	**1.4**
Infiltration capacity [c]	> 100%[d]	> 100%	> 100%	> 100%	> 100%	~26% [d]

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; COMM—retail commercial;
[b] Based on Chralowicz et al. (2001) according to the schedule described above
[c] Compare runoff production from NCIA + pervious area (**row 3**) with estimated infiltration capacity (**row 6**)
[d] At Ojai rainfall levels, capacity would be ~78 percent at the MFR site and ~18 percent at the COMM site.

As Table 7 shows, five of the six case study sites have the capacity to infiltrate *all* runoff produced onsite by draining impervious surfaces to pervious areas. Even runoff from the area assumed to be EIA could be infiltrated in most cases based on the amount of pervious area available in typical development projects. By showing that it is possible under normal site conditions and using native soils to retain *all* runoff in typical developments, these results demonstrate that a three percent EIA requirement, which would not demand that all runoff be retained, is feasible and practicable.

Additional Source Reduction Capabilities of the Case Study Sites: Water Harvesting Example

Infiltration is one of a wide variety of LID-based source reduction techniques. Where site conditions such as soil quality or available area limit a site's infiltration capacity, other source LID measures can enhance a site's runoff retention capability. For example, soil amendment, which improves infiltration, is a standard LID technique. Water harvesting is another. Such practices can also be used where infiltration capacity is adequate, but the developer desires greater flexibility for land use on-site. Table 8 shows the added implementation flexibility created by subtracting roof runoff by harvesting it or efficiently directing it into the soil through downspout dispersion systems, further demonstrating the feasibility of meeting the draft permit's proposed requirements, as modified to include a three percent EIA standard.

Table 8. Infiltration and Runoff Volume Reduction Analysis Including Roof Runoff Harvesting or Disposal in Infiltration Trenches (Assuming 3 Percent EIA and All NCIA Draining to Pervious Areas)

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	COMM[a]
EIA runoff (acre-ft/year)	0.38	0.11	0.03	0.07	4.6	0.18
Roof runoff (acre-ft/year)	4.92	0.93	0.09	0.20	41	2.33
Other NCIA + pervious area runoff (acre-ft/year)	**3.71**	**0.79**	**0.39**	**0.56**	**35**	**3.06**
Total runoff (acre-ft/year)	9.01	1.84	0.50	0.83	79.6	5.57
Pervious area available for infiltration (acres)	3.66	1.67	0.39	1.61	72.7	0.47
Estimated infiltration capacity (acre-ft/year)[b]	**9.8**	**4.2**	**1.4**	**4.2**	**203**	**1.4**
Infiltration capacity [c]	> 100%	> 100%	> 100%	> 100%	> 100%	~45% [d]

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; COMM—retail commercial;
[b] Based on Chralowicz et al. (2001) according to the schedule described above
[c] Comparison of runoff production from NCIA + pervious area (**row 3**) with estimated infiltration capacity (**row 6**)
[d] If the higher rainfall at Ojai is assumed, capacity would be ~32 percent of the amount needed for the COMM case.

Effect of Full LID Approach on Recharge

Table 9 (page 15) shows the recharge benefits of preventing roofs from generating runoff and infiltrating as much as possible of the runoff from the remainder of the case study sites. The data show that LID methods offer significant benefits relative to the baseline (no storm water controls) in all cases. These benefits are particularly impressive in developments with relatively high site imperviousness, such as in the MFR and COMM cases. In the latter case the full LID approach (excluding the common and effective practice of soil amendment) would cut loss of the potential water resource represented by recharge and harvesting from 86 to 37 percent.

Table 9. Comparison of Water Captured Annually (in acre-ft) from Development Sites for Beneficial Use With a Full LID Approach Compared to Development With No BMPs

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	COMM[a]
Pre-development recharge[b] (acre-ft)	12.5	3.46	0.88	2.42	150	5.92
No BMPs:						
post-development recharge [b] (acre-ft)	4.39	1.88	0.45	1.76	82	0.80
post-development runoff (acre-ft)	8.08	1.57	0.43	0.66	68	5.12
post-development % recharge lost	65%	46%	49%	27%	45%	86%
Full LID approach:						
post-development runoff capture (acre-ft)[c]	12.5	3.46	0.88	2.42	150	3.73
post-development runoff (acre-ft)	0	0	0	0	0	2.19
post-development % recharge lost	0%	0%	0%	0%	0%	37%

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; COMM—retail commercial
[b] Quantity of water infiltrating the soil; the difference between precipitation and runoff
[c] Water either entirely infiltrated in BMPs and recharged to groundwater or partially harvested from roofs and partially infiltrated in BMPs. For the first five case studies, EIA was not distinguished from the remainder of the development, because these sites have the potential to capture all runoff.

(b) Water Quality Analysis

As outlined above, it was assumed that EIA discharges, as well as runoff from all pervious surfaces, are subject to treatment control. For purposes of the analysis, treatment control was assumed to be provided by conventional sand filtration. This choice is appropriate for study purposes for two reasons. First, sand filters can be installed below grade, and land above can be put to other uses. Under the Draft Permit's approach, pervious area should be reserved for receiving NCIA drainage, and using sand filters would not draw land away from that service or other site uses. A second reason for the choice is that sand filter performance data equivalent to the data used in analyzing other conventional BMPs are available from the CalTrans (2004) work. Sand filters may or may not expose water to soil, depending on whether or not they have a hard bed. This analysis assumed a hard bed, meaning that no infiltration would occur and thus there would be no additional recharge in sand filters. Performance would be even better than shown in the analytical results if sand filters were built in earth.

Pollutant Discharge Reduction Through LID Techniques

The preceding analyses demonstrated that each of the six case studies could feasibly comply with the draft permit's requirements, as modified to include a more protective three percent EIA standard. Moreover, for five of the six case studies, *all* storm water discharges could be eliminated at least under most meteorological conditions by dispersing runoff from impervious surfaces to pervious areas. Therefore, pollutant additions to receiving waters would also be eliminated. This demonstrates not only that a lower EIA (three percent) is a feasible and practicable approach to maintaining the natural hydrology of land being developed, as discussed above, but that a lower EIA is a feasible and practicable way to eliminate the discharge of pollutants that could cause or contribute to violations of water quality standards.

While the high proportion of impervious area present on the large commercial site relative to pervious area would not allow eliminating all discharge, harvesting roof water and draining NCIA to properly-prepared pervious area would substantially decrease the volume discharged. Deployment of treatment control BMPs (e.g. sand filter treatment) could cut contaminant discharges from pollutants in the remaining volume of runoff to low levels.

Table 10 presents the pollutant reductions from the untreated case achievable through the complete LID approach described above in comparison to conventional treatments (from Table 6). Assuming EIA still discharges through sand filters, pollutant loadings from the untreated condition are expected to decrease by more than 96 percent for all but the COMM case. In that challenging case loadings would still fall by at least 89 percent for TSS and the metals and by 83 percent for total phosphorus, assuming City of Ventura rainfall levels, and slightly less assuming the higher Ojai rainfall levels. Thus, the Draft Permit's basic premise of disconnecting most impervious area, supplemented by specially managing roof water, is shown by both water quality and hydrologic results to be feasible and to afford broad and significant environmental benefits.

Table 10. Pollutant Loading Reduction Estimates With a Full LID Approach Relative to Conventional BMPs

	MFR[a]	Sm-SFR[a]	REST[a]	OFF[a]	Lg-SFR[a]	COMM[a]
Conventional TSS loading reduction[b]	15.7-69.9%	19.9-75.4%	22.0-80.6%	24.0-82.6%	19.9-75.4%	16.9-72.3%
Conventional TCu loading reduction[b]	0.0-74.4%	0.0-69.1%	0.0-78.2%	0.0-75.4%	0.0-69.1%	0.0-78.7%
Conventional TZn loading reduction[b]	22.7-78.4%	22.4-78.1%	22.9-84.3%	23.1-78.8%	22.4-78.1%	25.1-80.9%
Conventional TP loading reduction[b]	30.6-66.3%	41.5-70.7%	40.7-69.1%	45.9-76.2%	41.5-70.7%	20.3-55.0%
LID TSS loading reduction[c]	99.4%	99.3%	99.5%	99.4%	99.3%	89.0% [d]
LID TCu loading reduction[c]	98.1%	96.7%	98.0%	96.2%	96.7%	90.6% [d]
LID TZn loading reduction[c]	99.1%	98.8%	98.9%	98.3%	98.8%	94.8% [d]
LID TP loading reduction[c]	98.1%	98.6%	98.8%	98.7%	98.6%	83.1%[d]

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; REST—restaurant; OFF—office building; Lg-SFR—large-scale single-family residential; COMM—retail commercial; CDS— continuous deflective separation unit; EDB—extended-detention basin; NCIA—not connected impervious area; EIA—effective (connected) impervious area
[b] Range from Table 6 represented by treatment by CDS unit, EDB, biofiltration swale, or biofiltration strip
[c] Based on directing roof runoff to downspout infiltration trenches (MFR, Sm-SFR, REST, and Lg-SFR) or harvesting it (OFF and COMM), draining other NCIA to pervious areas, and treating EIA with sand filters
[d] If the higher rainfall at Ojai is assumed, reduction estimates for TSS, TCu, TZn, and TP would be 84.0, 86.3, 92.5, and 75.5 percent, respectively.

SUMMARY AND CONCLUSIONS

This paper demonstrated that common Ventura County area residential and commercial development types subject to the Municipal NPDES Permit are likely, without storm water management, to reduce groundwater recharge from the predevelopment state by approximately half in most cases to a much higher fraction with a large ratio of impervious to pervious area. With no treatment, runoff from these developments is expected to exceed CTR acute copper and zinc criteria at the point of discharge and to deliver large pollutant mass loadings to receiving waters.

Conventional soil-based BMP solutions that promote and are component parts of low-impact development approaches, by contrast, regain about 30-50 percent of the recharge lost in development without storm water management, although commercially-manufactured filtration and hydrodynamic BMPs for storm water management give no benefits in this area. It is expected the soil-based BMPs generally would release effluent that meets the acute zinc criterion at the point of discharge, although it would still exceed the copper limit. Excepting phosphorus, it was found that these BMPs would capture and prevent the movement to receiving waters of the majority of the pollutant loadings considered in the analysis.

It was found that a three percent Effective Impervious Area standard can be met in typical developments, and that by draining all site runoff to pervious areas, runoff can be eliminated entirely in most development types. This result was reached assuming the use of native soils. Soil enhancement (typically, with compost) can further advance infiltration. Draining impervious surfaces onto the loam soils typical of Ventura County, in connection with limiting directly connected impervious area to three percent of the site total area, should eliminate storm runoff from some development types and greatly reduce it from more highly impervious types. Adding roof runoff elimination to the LID approach (by harvesting or directing it to downspout infiltration trenches) should eliminate runoff from all but mostly impervious developments. Even in the development scenario involving the highest relative proportion of impervious surface, losses of rainfall capture for beneficial uses could be reduced from more than 85 to less than 40 percent, and pollutant mass loadings would fall by 83-95 percent from the untreated scenario when draining to pervious areas was supplemented with water harvesting. These results demonstrate the basic soundness of the Draft Permit's concept to limit directly connected impervious area and drain the remainder over pervious surfaces.

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ATTACHMENT A

JUSTIFICATION OF PROPOSED EFFECTIVE IMPERVIOUS AREA LIMITATION

Summary

The literature shows that adverse impacts to the physical habitat and biological integrity of receiving waters occur as a result of the conversion of natural areas to impervious cover. These effects are observed at the lowest levels of impervious cover in associated catchments (two to three percent) and are pronounced by the point that impervious cover reaches five percent. To protect biological productivity, physical habitat, and other beneficial uses, effective impervious area should be capped at no more than three percent.

I. Impacts to physical habitat of California receiving waters observed at three percent impervious cover

Stein *et al*.[7] note that while studies from parts of the country with climates more humid than California's indicate that physical degradation of stream channels can initially be detected when watershed impervious cover approaches 10%, biological effects, which may be more difficult to detect, may occur at lower levels (CWP 2003).[8] Recent studies from both northern and southern California indicate that intermittent and ephemeral streams in California are more susceptible to the effects of hydromodification than streams from other regions of the US, with stream degradation being recognized when the associated catchment's impervious cover is as little as 3-5% (Coleman *et al*. 2005).[9] Furthermore, supplemental landscape irrigation in semi-arid regions, like California, can substantially increase the frequency of erosive flows (AQUA TERRA Consultants 2004).[10]

Coleman, *et al*.[3] report that the ephemeral/intermittent streams in southern California (northwestern Los Angeles County through southern Ventura County to central Orange County) appear to be more sensitive to changes in percent impervious cover than streams in other areas. Stream channel response can be represented using an *enlargement curve*, which relates the percent of impervious cover to a change in cross-sectional area. The data for southern California streams forms a relationship very similar in shape to the enlargement curves developed for other North American streams. However, the curve for southern California streams is above the general curve for streams in other climates. This suggests that a specific enlargement ratio is produced at a lower value of impervious surface area in southern California than in other parts of North America. Specifically, the estimated threshold of response is approximately 2-3% impervious cover, as compared to 7-10% for other portions of the U.S. It is important to note that this conclusion applies specifically to streams with a catchment drainage area less than 5 square miles.

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[7] Stein, E.D., S. Zaleski, (2005) *Managing Runoff to Protect Natural Streams: The Latest Developments on Investigation and Management of Hydromodification in California*. (Proceedings of a Special Technical Workshop Co-sponsored by California Stormwater Quality Association (CASQA), Stormwater Monitoring Coalition (SMC), University of Southern California Sea Grant (USC Sea Grant), Technical Report #475).

[8] Center for Watershed Protection (CWP), (2003) *Impacts of Impervious Cover on Aquatic Systems*. Ellicott City, MD.

[9] Coleman, D., C. MacRae, and E.D. Stein, (2005) *Effect of Increases in Peak Flows and Imperviousness on the Morphology of Southern California Streams.* Southern California Coastal Water Research Project Technical Report #450, Westminster, CA.

[10] AQUA TERRA Consultants, (2004) *Urbanization and Channel Stability Assessment in the Arroyo Simi Watershed of Ventura County CA*. FINAL REPORT. Prepared for Ventura County Watershed Protection Division, Ventura CA.

This study concludes that disconnecting impervious areas from the drainage network and adjacent impervious areas is a key approach to protecting channel stability. Utilizing this strategy can make it practical to keep the effective impervious cover (*i.e.* the amount hydrologically connected to the stream) equal to or less than the identified threshold of 2-3%.

II. Impacts to biological integrity of receiving waters observed with any conversion from natural to impervious surface

Two separate studies conducted by Horner *et al*.[11,12] in the Puget Sound region (Washington State), Montgomery County, Maryland, and Austin, Texas built a database totaling more than 650 reaches on low-order streams in watersheds ranging from no urbanization and relatively little human influence (the reference state, representing "best attainable" conditions) to highly urban (>60 percent total impervious area, "TIA"). Biological health was assessed according to the benthic index of biotic integrity (B-IBI) and, in Puget Sound, the ratio of young-of-the-year coho salmon (*Oncorhynchus kisutch*), a relatively stress-intolerant fish, to cutthroat trout (*Oncorhynchus clarki*), a more stress-tolerant species. The following discussion summarizes the results and conclusions of these two studies.

There is no single cause for the decline of water resource conditions in urbanizing watersheds. Instead, it is the cumulative effects of multiple stressors that are responsible for degraded aquatic habitat and water quality. Imperviousness, while not a perfect yardstick, appears to be a useful predictor of ecological condition. However, a range of stream conditions can be associated with any given level of imperviousness. In general, only streams that retain a significant proportion of their natural vegetative land-cover <u>and</u> have very low levels of watershed imperviousness appear to retain their natural ecological integrity. It is this change in watershed land-cover that is largely responsible for the shift in hydrologic regime from a sub-surface flow dominated system to one dominated by surface runoff.

While the decline in ecological integrity is relatively continuous and is consistent for all parameters, the impact on physical conditions appears to be more pronounced earlier in the urbanization process than chemical degradation. It is generally acknowledged, based on field research and hydrologic modeling, that it is the shift in hydrologic conditions that is the driving force behind physical changes in urban stream-wetland ecosystems.

Multiple scales of impact operate within urbanizing watersheds: landscape-level impacts, including the loss of natural forest cover and the increase in impervious surface area throughout the watershed; riparian corridor-specific impacts such as encroachment, fragmentation, and loss of native vegetation; and local impacts such as water diversions, exotic vegetation, stream channelization, streambank hardening, culvert installation, and pollution from the widespread use of pesticides and herbicides. All of these stressors contribute to the overall cumulative impact.

The researchers found that there is no clear threshold of urbanization below which there exists a "no-effect" condition. Instead, there appears to be a relatively continuous decline in almost all measures of water quality or ecological integrity. Losses of integrity occur from the lowest levels of TIA and are already pronounced by the point that TIA reaches 5 percent.

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[11] Horner, R. R., C. W. May, (2002) *The Limitations of Mitigation-Based Stormwater Management in the Pacific Northwest and the Potential of a Conservation Strategy based on Low-Impact Development Principles*. (Proceedings of the American Society of Engineers Stormwater Conference, Portland, OR).

[12] Horner, R.R., E. H. Livingston, C. W. May, J. Maxted, (2006) *BMPs, Impervious Cover, and Biological Integrity of Small Streams*. (Proceedings of the Eighth Biennial Stormwater Research and Watershed Management Conference, Tampa, FL).

Similarly, the Alliance for the Chesapeake Bay[13] reports that small-watershed studies by the Maryland Department of Natural Resources Biological Stream Survey have shown that some sensitive species are affected by even low amounts of impervious cover. In one study, no brook trout were observed in any stream whose watershed had more than 2 percent impervious cover, and brook trout were rare in any watershed with more than 0.5 percent impervious cover.

III. Ventura County's watersheds include biologically-significant water bodies

The literature discussed above is relevant to the watersheds of Ventura County, which contain rivers and streams that currently or historically support a variety of beneficial uses that may be impaired by water quality degradation and stream hydromodification as a result of storm water runoff from impervious land cover. Unlike some Southern California watersheds, Ventura County still has many natural stream systems with a high degree of natural functionality.

For instance, the Ventura River watershed in northwestern Ventura County "supports a large number of sensitive aquatic species,"[14] including steelhead trout, a federally-listed endangered species. Although "local populations of steelhead and rainbow trout have nearly been eliminated along the Ventura River" itself, the California Department of Fish and Game has "recognized the potential for the restoration of the estuary and enhancement of steelhead populations in the Ventura River."[15] Steelhead may also be present in tributaries such as San Antonio Creek.[16] Thriving rainbow trout populations exist in tributaries of the Ventura River including Matilija Creek and Coyote Creek.[17] The Ventura River either does or is projected to support the following beneficial uses: warm freshwater habitat; cold freshwater habitat; wildlife habitat; rare, threatened, or endangered species; migration of aquatic organisms; and spawning and reproduction.[18] Furthermore, the Ventura River Estuary also supports commercial fishing, shellfish harvesting, and wetland habitat.[19] The Ventura River receives municipal storm drain discharges from Ojai, San Buenaventura, and unincorporated areas of Ventura County.[20]

The Santa Clara River watershed in northern Ventura County "is the largest river system in southern California that remains in a relatively natural state."[21] Sespe Creek is one of the Santa Clara's largest tributaries, and "supports significant steelhead spawning and rearing habitat."[22] Other creeks in the Santa Clara River watershed that support steelhead are Piru Creek and Santa Paula Creek. Sespe Creek and the Santa Clara River also provide spawning habitat for the Pacific lamprey. Rainbow trout populations exist in tributaries of the Santa Clara River including Sespe Creek.[23] The creeks and the Santa Clara river do or are projected to support the following beneficial uses: warm freshwater habitat; cold freshwater habitat; wildlife habitat; preservation of biological habitats rare, threatened, or endangered species; migration of aquatic organisms; and spawning and reproduction.[24] Los Padres National Forest covers much of the Santa Clara River watershed, but increasing development in floodplain areas has been

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[13] Karl Blankenship, BAY JOURNAL,"It's a hard road ahead for meeting new sprawl goal: States will try to control growth of impervious" (July/August 2004), at http://www.bayjournal.com/article.cfm?article=66.
[14] Los Angeles Region Water Quality Control Plan (1994) p. 1-18 ("Basin Plan").
[15] Basin Plan, p. 1-16; Ventura County Environmental & Energy Resources Division, "Endangered Steelhead Trout in Ventura County: Past, Present, and Future," available at http://www.wasteless.org/Eye_articles/steelhead.htm.
[16] Ventura County Environmental & Energy Resources Division, "Steelhead Spawning in Ventura County," (2005), available at http://www.wasteless.org/Eye_articles/steehead2005.html.
[17] Ventura County Environmental & Energy Resources Division, "Endangered Steelhead Trout in Ventura County: Past, Present, and Future," available at http://www.wasteless.org/Eye_articles/steelhead.htm.
[18] Basin Plan, Table 2-1.
[19] Basin Plan, Table 2-4.
[20] Ventura County Watershed Protection District, *Report of Waste Discharge* (January 2005) at p. 3.
[21] Basin Plan, p. 1-16.
[22] Basin Plan, p. 1-16.
[23] Ventura County Environmental & Energy Resources Division, "Endangered Steelhead Trout in Ventura County: Past, Present, and Future," available at http://www.wasteless.org/Eye_articles/steelhead.htm.
[24] Basin Plan, Table 2-1.

identified as a threat to the river system's water quality.[25] Furthermore, the Santa Clara estuary supports the additional beneficial uses of shellfish harvesting and wetlands habitat.[26] The Santa Clara River receives municipal storm drain discharges from Fillmore, Oxnard, San Buenaventura, Santa Paula, and unincorporated areas of Ventura County.[27]

The Calleguas Creek watershed "empties into Mugu Lagoon, one of southern California's few remaining large wetlands."[28] It supports or is projected to support the following beneficial uses: estuarine habitat; marine habitat; wildlife habitat; preservation of biological habitats; rare, threatened, or endangered species; migration of aquatic organisms; spawning and reproduction; shellfish harvesting; and wetlands habitat.[29] Historically, Calleguas Creek drained largely agricultural areas. But this watershed has been under increasing pressure from sedimentation due to increased surface flow from municipal discharges and urban wastewaters, among other sources.[30] Increasing residential developments on steep slopes has been identified as a substantial contributing factor to the problem of accelerated erosion in the watershed (and sedimentation in the Lagoon). Calleguas Creek receives municipal storm drain discharges from Camarillo, Moorpark, Simi Valley, Thousand Oaks, and unincorporated areas of Ventura County.[31]

Ventura County's coastal streams also support a variety of beneficial uses:[32]

- Little Sycamore Canyon Creek in southern Ventura County (warm freshwater habitat; wildlife habitat; rare, threatened or endangered species; and spawning and reproduction);
- Lake Casitas tributaries (warm freshwater habitat; cold freshwater habitat; wildlife habitat; rare, threatened or endangered species; spawning and reproduction; and wetland habitat);
- Javon Canyon and Padre Juan Canyon (warm freshwater habitat; cold freshwater habitat; wildlife habitat; and spawning and reproduction); and
- Los Sauces Creek in northern Ventura County (warm freshwater habitat; cold freshwater habitat; wildlife habitat; migration of aquatic species; and spawning and reproduction).

IV. Conclusion

In order to protect the biological habitat, physical integrity, and other beneficial uses of the water bodies in Ventura County, effective impervious area should be capped at no more than three percent.

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[25] Basin Plan, pp. 1-16, 1-18.
[26] Basin Plan, Table 2-4.
[27] Ventura County Watershed Protection District, *Report of Waste Discharge* (January 2005) at p. 3.
[28] Basin Plan, p. 1-18.
[29] Basin Plan, Table 2-1.
[30] Basin Plan, pp. 1-16, 1-18.
[31] Ventura County Watershed Protection District, *Report of Waste Discharge* (January 2005) at p. 3.
[32] Basin Plan, Table 2-1.

ATTACHMENT B

POLLUTANT CONCENTRATIONS FOR URBAN SOURCE AREAS (HERRERA ENVIRONMENTAL CONSULTANTS, INC. UNDATED)

Source Area	Study	Location	Sample Size (n)	TSS (mg/L)	TCu (ug/L)	TPb (ug/L)	TZn (ug/L)	TP (mg/L)	Notes
Roofs									
Residential	Steuer, et al. 1997	MI	12	36	7	25	201	0.06	2
Residential	Bannerman, et al. 1993	WI	~48	27	15	21	149	0.15	3
Residential	Waschbusch, et al. 2000	WI	25	15	n.a.	n.a.	n.a.	0.07	3
Residential	FAR 2003	NY		*19*	*20*	*21*	*312*	*0.11*	4
Residential	Gromaire, et al. 2001	France		*29*	*37*	*493*	*3422*	*n.a.*	5
Representative Residential Roof Values				**25**	**13**	**22**	**159**	**0.11**	
Commercial	Steuer, et al. 1997	MI	12	24	20	48	215	0.09	2
Commercial	Bannerman, et al. 1993	WI	~16	15	9	9	330	0.20	3
Commercial	Waschbusch, et al. 2000	WI	25	18	n.a.	n.a.	n.a.	0.13	3
Representative Commercial Roof Values				**18**	**14**	**26**	**281**	**0.14**	
Parking Areas									
Res. Driveways	Steuer, et al. 1997	MI	12	157	34	52	148	0.35	2
Res. Driveways	Bannerman, et al. 1993	WI	~32	173	17	17	107	1.16	3
Res. Driveways	Waschbusch, et al. 2000	WI	25	34	n.a.	n.a.	n.a.	0.18	3
Driveway	FAR 2003	NY		*173*	*17*		*107*	*0.56*	4
Representative Residential Driveway Values				**120**	**22**	**27**	**118**	**0.66**	
Comm./ Inst. Park. Areas	Pitt, et al. 1995	AL	16	110	116	46	110	n.a.	1
Comm. Park. Areas	Steuer, et al. 1997	MI	12	110	22	40	178	0.2	2
Com. Park. Lot	Bannerman, et al. 1993	WI	5	58	15	22	178	0.19	3
Parking Lot	Waschbusch, et al. 2000	WI	25	51	n.a.	n.a.	n.a.	0.1	3
Parking Lot	Tiefenthaler, et al. 2001	CA	5	36	28	45	293	n.a.	6
Loading Docks	Pitt, et al. 1995	AL	3	40	22	55	55	n.a.	1
Highway Rest Areas	CalTrans 2003	CA	53	*63*	*16*	*8*	*142*	*0.47*	7
Park and Ride Facilities	CalTrans 2003	CA	179	*69*	*17*	*10*	*154*	*0.33*	7
Comm./ Res. Parking	FAR 2003	NY		*27*	*51*	*28*	*139*	*0.15*	4
Representative Parking Area/Lot Values				**75**	**36**	**26**	**97**	**0.14**	

Landscaping/Lawns									
Landscaped Areas	Pitt, et al. 1995	AL	6	33	81	24	230	n.a.	1
Landscaping	FAR 2003	NY		*37*	*94*	*29*	*263*	n.a.	4
Representative Landscaping Values				**33**	**81**	**24**	**230**	**n.a.**	
Lawns - Residential	Steuer, et al. 1997	MI	12	262	n.a.	n.a.	n.a.	2.33	2
Lawns - Residential	Bannerman, et al. 1993	WI	~30	397	13	n.a.	59	2.67	3
Lawns	Waschbusch, et al. 2000	WI	25	59	n.a.	n.a.	n.a.	0.79	3
Lawns	Waschbusch, et al. 2000	WI	25	122	n.a.	n.a.	n.a.	1.61	3
Lawns - Fertilized	USGS 2002	WI	58	n.a.	n.a.	n.a.	n.a.	2.57	3
Lawns - Non-P Fertilized	USGS 2002	WI	38	n.a.	n.a.	n.a.	n.a.	1.89	3
Lawns - Unfertilized	USGS 2002	WI	19	n.a.	n.a.	n.a.	n.a.	1.73	3
Lawns	FAR 2003	NY	3	*602*	*17*	*17*	*50*	*2.1*	4
Representative Lawn Values				**213**	**13**	**n.a.**	**59**	**2.04**	

Notes:

Representative values are weighted means of collected data. Italicized values were omitted from these calculations.

1 - Grab samples from residential, commercial/institutional, and industrial rooftops. Values represent mean of DETECTED concentrations

2 - Flow-weighted composite samples, geometric mean concentrations

3 - Geometric mean concentrations

4 - Citation appears to be erroneous - original source of data is unknown. Not used to calculate representative value

5 - Median concentrations. Not used to calculate representative values due to site location and variation from other values.

6 - Mean concentrations from simulated rainfall study

7 - Mean concentrations. Not used to calculate representative values due to transportation nature of land use.

INVESTIGATION OF THE FEASIBILITY AND BENEFITS OF LOW-IMPACT SITE DESIGN PRACTICES APPLIED TO MEET VARIOUS POTENTIAL STORMWATER RUNOFF REGULATORY STANDARDS

By

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Report to

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EXECUTIVE SUMMARY

STUDY DESIGN

A study was performed to investigate the degree to which stormwater management practices, commonly referred to as “low-impact development” methods or “green infrastructure,” can retain urban runoff and meet five possible regulatory standards that could be applied nationally. Retention is defined as preventing the conversion of precipitation to runoff discharging from a development site on the surface, from where it can enter a receiving water. Retaining runoff from impervious and pollutant generating pervious surfaces prevents the introduction of urban runoff pollutants to receiving waters as well as reduces runoff volume to prevent stream channel and habitat damage, flooding, and loss of groundwater recharge. ARCD methods were assessed for their ability to: (1-2) meet standards pertaining to retention of the runoff generated by the 85th and 95th percentile, 24-hour precipitation events; (3) retain 90 percent of the post-development runoff; and (4-5) retain the difference between the post- and pre-development runoff, both with and without a cap at the 85th percentile, 24-hour event. The study assessed five urban land use types (three residential, one retail commercial, and one infill redevelopment), each placed in four climate regions in the continental United States on two regionally common soil types.

Infiltrating bioretention was applied as an initial strategy in the analysis of each case. When the initial strategy could not fully retain post-development runoff, additional methods were applied, involving roof runoff harvesting in the most impervious development cases and roof water dispersion in those with substantial pervious area. Benefits were assessed with respect to reduction of the annual average surface runoff volume from the quantity estimated without any stormwater management practices, the associated maintenance of pre-development groundwater recharge, and water quality improvement achieved through preventing discharge to receiving waters of pollutants generated with developed land uses.

RETENTION AND POLLUTANT REDUCTION CAPABILITIES

The initial strategy of infiltrating bioretention could retain all post-development runoff and pre-existing groundwater recharge, as well as attenuate all pollutant transport, in the three residential land use development types on hydrologic soil group (HSG) B soils, in all cases, in all regions, taking a fraction of the available pervious area to do so. For the more highly impervious commercial retail and redevelopment cases, bioretention would retain about 45 percent of the runoff and pollutants generated and save about 40 percent of the pre-development recharge. Adding roof runoff management measures in these cases would approximately double retention and pollutant reduction for the retail commercial land use and raise it to 100 percent for the redevelopment. Results were generally similar with HSG C soils, although more of the pervious portion of sites was required to equal the retention seen on B soils.

For development on the D soils in all climate regions, use of roof runoff management techniques was estimated to increase runoff retention and pollutant reduction from zero to between about one-third to two-thirds of the post-development runoff generated, depending on the land use case. These strategies would offer little groundwater recharge benefit with this soil condition, but would still have the potential to significantly reduce runoff volume and pollutant loading.

ABILITY TO MEET STANDARDS

The projected ability to meet the five standards identified above was found to vary mostly in relation to soil type (B or C versus D) and the relative imperviousness of development. The ability to meet the five standards varied much less across climate regions. With B and C soils,

the methods considered were projected to meet all five standards in all but 12 of 125 evaluations. With D soils, however, only three standards could be met at all and those only occasionally. However, even on D soils, all cases for Standard 1 (retention of the 85th percentile, 24-hour precipitation event) were able to retain greater than 50 percent of the required runoff volume. Moreover, opportunities to use ARCD practices or site design principles not modeled in this analysis have the potential to further increase runoff retention volume.

Standard 3 (retain 90 percent of the average annual post-development runoff volume) would be the most environmentally protective standard. Meeting or coming as close as possible to meeting, but not exceeding, this standard was estimated to lead to 66-90 percent of total runoff retention and pollutant loading reduction on B and C soils and 37-66 percent runoff retention on D soils. Standard 2 (retain the runoff produced by the 95th percentile, 24-hour precipitation event) would yield equivalent protection on D soils and only slightly less protection with B and C soils. The outcome with this standard would also be more consistent region to region than with the alternative standard 1, based on the 85th instead of the 95th percentile precipitation event. Sites located on B or C soils were able retain the runoff produced by the 85th percentile storm in 24 of 25 cases modeled (in 18 of the 25 cases by using infiltrating bioretention alone), and were able to retain the runoff produced by the 95th percentile storm in 22 of 25 cases modeled.

Standards 4 and 5, based on the differential between pre- and post-development runoff volume, are inconsistent in retaining runoff and reducing pollutants, in that they are relatively protective where pre-development runoff is estimated to be low relative to post-development flow, but result in progressively lower retention and pollutant loading reduction as pre- and post-development volumes converge, such as in several cases on D soils. Standard 5 is especially weak in this regard. The potentially low level of retention and pollutant loading reduction renders these standards based on the change in pre- versus post-development runoff volume poor candidates for national application, at least as formulated in these terms.

In summary, standards 2 and 3 are clearly superior to the other three options from both a volume and pollutant load reduction standpoint. Standard 3 is entirely consistent from place to place in degree of environmental protection, and standard 2 does not deviate much. Analysis of the five development cases on two soil groups in each of four regions demonstrated the two standards are virtually identical in the runoff retention and pollutant loading reduction they would bring about. Of the remaining standards, standard 1 (retantion of the runoff produced by the 85th percentile storm event) remains more consistent across regions and more protective of water quality for development on D soils than either standard 4 or 5, and is preferable to those standards in this regard.

INTRODUCTION

GENERAL STUDY DESCRIPTION

Study Design

This purpose of this study was to investigate the degree to which low-impact development (LID) [1] practices can meet or exceed the requirements of various potential stormwater management facility design standards and to determine the environmental benefits that can be realized by applying these techniques. The investigation was performed by estimating the stormwater retention possible with full application of low-impact options under a range of conditions broadly representative of different regions within the United States and then determining the implications of the findings for achieving various standards and for providing benefits. Retention is defined as preventing the conversion of precipitation to surface runoff from urbanized land uses through infiltration, evapotranspiration, and/or harvesting for some water supply purpose. Retaining runoff from impervious and pollutant generating pervious surfaces prevents the introduction of urban runoff pollutants to receiving waters as well as reduces runoff volume to prevent stream channel and habitat damage, flooding, and loss of groundwater recharge. Benefits were assessed with respect to reduction of the potential developed land surface runoff volume, the associated maintenance of pre-development groundwater recharge, and water quality improvement achieved through preventing discharge to receiving waters of pollutants generated with developed land uses.

The potential regulatory standards investigated were capture and retention of, at minimum:

- Standard 1—The runoff produced by the 85th percentile, 24-hour precipitation event,[2] a standard commonly used in California;
- Standard 2—The runoff produced by the 95th percentile, 24-hour precipitation event, the standard adopted under Section 438 of the Energy Independence and Security Act;
- Standard 3—90 percent of the average annual post-development runoff volume;
- Standard 4—The difference between the post- and pre-development[3] average annual runoff volumes; and
- Standard 5—The difference between the post- and pre-development runoff volumes for all events up to and including the 85th percentile, 24-hour precipitation event.

Conditions broadly representative of the nation were selected by, first, considering the climate regions defined in USEPA's (1983) Nationwide Urban Runoff Project (NURP) report. For full analysis, climate regions 1 (Northeast-Upper Midwest), 3 (Southeast), 5 (South Central), and 6 (Southwest) were chosen as providing a wide range of climatological conditions and geographic distribution. Once the four regions were picked, a metropolitan area and a specific city in each were chosen to serve as typical models of development circumstances in the general area, as

[1] The National Research Council (NRC, 2009) renamed LID, also known as green infrastructure, as aquatic resources conservation design (ARCD), the term used henceforth in this report.

[2] The 85th percentile, 24-hour event represents the precipitation quantity in a 24-hour period not exceeded in 85 percent of all events in an extended record.

[3] In this study the pre-development state is taken as the typical land cover existing before European settlement of an area.

detailed in the Case Studies discussion below. In addition, region 7 (Pacific Northwest) was identified as an additional location to be discussed. This region is the site of a considerable amount of ARCD application in an area somewhat different climatologically than other selected regions, in having persistent winter rainfall totaling annually, in the major urban areas, intermediately among the other regions. Results of research on ARCD conducted in this region are discussed at several points in this report.

Soils and topography were the next considerations in developing broadly representative conditions. U.S. Department of Agriculture websites were the source of general soil characterizations for the study regions and specific soil survey data in and around the representative metropolitan areas. Soils generally represented some range in textural classes and associated hydraulic conductivities. For each region, a soil type predominating among those representing hydraulic conductivities relatively high and low for the region were selected to serve as a basis for the analyses. The effect of slope was also investigated but ultimately found not to affect results substantially.

Five types of urban development were selected to represent breadth in land use: (1) multi-family residential, (2) small-scale single-family residential, (3) large-scale single-family residential, (4) large-scale commercial, and (5) infill redevelopment. Building permit data from each region were consulted to determine typical distributions of site features for each (e.g., land cover by buildings, parking areas, roadways, walkways, driveways, landscaping).

Case studies thus comprised four climate regions, each with two soil conditions and five land use types, for a total of 40 permutations. For each, the ability of the site to accommodate soil- and vegetation-based ARCD practices was investigated. Runoff quantities were estimated and compared to the five potential regulatory standards. Annual mass loading discharges were estimated for four pollutants: total suspended solids (TSS), total recoverable copper (TCu) and zinc (TZn), and total phosphorus (TP). In any case where soil- and vegetation-based ARCD infiltration techniques appeared not to be able to attenuate all runoff, specific roof runoff management strategies were investigated as possible measures to achieve additional retention. Runoff quantities and pollutant discharges were recalculated based on use of these additional practices in place.

This report covers the methods employed in the investigation, data sources, and references for both. It then presents the results, discusses their consequences, draws conclusions, and makes recommendations relative to the feasibility of utilizing low-impact development practices to meet the respective potential regulatory standards.

AQUATIC RESOURCES CONSERVATION DESIGN PRACTICES

General Description

As the stormwater management field developed, it passed through several stages. First, it was thought that the key to success was to match post-development with pre-development peak flow rates, while also reducing a few common pollutants (usually, TSS) by a set percentage. Finding that these efforts generally required large ponds, but that they did not forestall impacts, stormwater managers next deduced that runoff volumes and high discharge durations would also have to decrease. Almost simultaneously, although not necessarily in concert, the idea of low-impact development arose to offer a way to achieve actual avoidance, or at least minimization, of discharge quantity and pollutant increases reaching far above pre-development levels. These methods reduce storm runoff and its contaminants by decreasing their generation

at sources, infiltrating into the soil or evaporating or transpiring[4] storm flows before they can enter surface receiving waters, and treating flow remaining on the surface through contact with vegetation and soil, or a combination of these strategies.

The National Research Council ("NRC") (2009) renamed LID as Aquatic Resources Conservation Design (ARCD) for several reasons. First, this term signifies that the principles and many of the methods apply not only to building on previously undeveloped sites, but also to redeveloping and retrofitting existing development. Second, incorporating aquatic resources conservation in the title is a direct reminder of the central reason for improving stormwater regulation and management. ARCD encompasses the complete range of practices to counteract all negative urban runoff impacts; i.e., the full suite of practices that emphasize and accomplish retention as defined above. These practices aim at decreasing surface runoff peak flow rates, volumes, and elevated flow durations, as well as avoiding or at least minimizing the introduction of pollutants to any surface runoff produced. Reducing the concentration of pollutants, together with runoff volume decrease, cuts the cumulative mass loadings (mass per unit time) of pollutants entering receiving waters over time.

The menu of ARCD practices begins with conserving, as much as possible, existing trees, other vegetation, and soils, as well as natural drainage features (e.g., depressions, dispersed sheet flows, swales). Clustering development to affect less land is a fundamental practice advancing this goal. Conserving natural features would further entail performing construction in such a way that vegetation and soils are not needlessly disturbed and soils are not compacted by heavy equipment. Using less of polluting materials, isolating contaminating materials and activities from contact with rainfall or runoff, and reducing the introduction of irrigation and other non-stormwater flows into storm drain systems are essential. Many ARCD practices fall into the category of minimizing impervious areas through decreasing building footprints and restricting the widths of streets and other pavements to the minimums necessary. Another important category of ARCD practices involves directing runoff from roofs and pavements onto pervious areas as sheet flow, where all or much of the runoff can infiltrate or evaporate in many situations.

Water can be harvested from impervious surfaces, especially roofs, and put to use for irrigation, non-potable indoor water supply. Harvesting is a standard technique for Leadership in Energy and Environmental Design (LEED) buildings (U.S. Green Building Council, 2008). Many successful systems of this type are in operation, with examples such as the Natural Resources Defense Council offices (Santa Monica, CA), the King County Administration Building (Seattle, WA), and two buildings on the Portland State University campus (Portland, OR). Harvesting is feasible at the small scale using rain barrels and at larger scales using larger collection cisterns and piping systems. These small-scale applications have been used throughout the world for centuries and are rapidly spreading in the United States today (See, e.g., Texas Water Development Board, 2005; Georgia Department of Community Affairs, 2009).

If these practices are used but runoff is still produced, ARCD offers an array of techniques to retain it on-site through infiltration and evapotranspiration (ET). The bioretention cell (rain garden) is the workhorse practice in this category, but swales conveying flow slowly, filter strips set up for sheet flows, and other modes are also important. Relatively low traffic areas can be constructed with permeable surfaces such as porous asphalt, open-graded Portland cement concrete, coarse granular materials, concrete or plastic unit pavers, or plastic grid systems to allow for infiltration.

[4] Transpiration refers to vaporization of water from plant tissue, while evaporation applies to vaporization from a liquid (e.g., pool) or solid (e.g., leaf) surface. The terms are often combined to form the compound evapotranspiration (ET).

ARCD practices should be selected and applied as close to sources as possible to stem runoff and pollutant production near the point of potential generation. However, these practices must also work well together and, in many cases, must be supplemented with strategies operating farther downstream. For example, the City of Seattle, in its "natural drainage system" retrofit initiative, built serial bioretention cells flanking relatively flat streets. "Cascades" of vegetated stepped pools created by weirs were installed along more sloping streets. In some cases the cells drain to downstream cascades. The upstream components are highly effective in attenuating most or even all runoff. Flowing at higher velocities on sloped surfaces, the cascades do not perform at such a high level, although under favorable conditions they can still infiltrate or evapotranspire the majority of the incoming runoff (Chapman 2006, Chapman and Horner 2010). Even if not as impressive statistically, cascades can actually decrease storm discharge to streams more than the cells do, because of their generally greater size. Also, the cascades extract pollutants from remnant runoff through mechanisms mediated by vegetation and soils. The success of Seattle's natural drainage systems demonstrates that well designed ARCD practices can mimic natural landscapes hydrologically, and thereby avoid raising discharge quantities.

A watershed-based program emphasizing ARCD practices would convey significant benefits beyond greatly improved stormwater management. ARCD techniques overall would advance water conservation, and infiltrative practices would increase recharge of groundwater resources. ARCD practices can be made attractive and thereby improve neighborhood aesthetics and property values. Retention of more natural vegetation can both save wildlife habitat and provide recreational opportunities. Municipalities could use the program in their general urban improvement initiatives, giving incentives to property owners to contribute to goals in that area while also protecting water resources.

A Catalogue of ARCD Practices

ARCD practices are numerous and expanding as existing configurations are applied in new ways. Table 1 presents a catalogue adapted from USEPA (2007) and NRC (2009). This catalogue contains practices that are not equally applicable in all settings; e.g., nevertheless, each category offers practices applicable in a broad variety of circumstances.

The best strategy for choosing among and implementing these practices is a decentralized, integrated one; i.e., selecting practices that fit together as a system, starting at or near sources and working through the landscape until management objectives are met. This strategy makes maximum possible use of practices in the first three categories, which prevent stormwater quantity and quality problems, and then selects among the remaining classifications in relation to the localized and overall site conditions. Source control and preservation of existing vegetation and soils obviously avoid post-development runoff quantity and pollutant increases from any portion of the site that can be so treated. Among all strategies, these best maintain natural infiltration and ET patterns and yield of materials flowing from the site. This preventive strategy is supplemented by strategies to create as little impervious cover as possible. The remaining practices then contend with the excess runoff and pollutants over pre-development levels generated by the development.

For the practices that infiltrate water, a site's soil characteristics and depth to groundwater can and should be determined through infiltration rate testing and excavation to determine the infiltration capability. Because of the often substantial variability of conditions around a site, these determinations should be made at multiple points. If the natural infiltration rate is low, generally < 0.5 inch/hour (< 1.25 cm/h, Geosyntec 2008), in many situations the soil can be amended, usually with organic compost, to apply an infiltrative practice.

In addition to soil characteristics, the position of the groundwater table is a crucial determinant of whether or not stormwater infiltration should be promoted by applying ground-based ARCD

practices. A seasonal high water table too close to the surface results in rapid saturation of a thin soil column and retarded infiltration. Ponding water longer than 72 hours can permit mosquito growth, damage vegetation, and promote clogging of the facility by microorganism growths and polysaccharide organic materials that form in the reduced-oxygen environment accompanying excessive ponding time (Mitchell and Nevo 1964, Ronner and Wong 1996). Also, storm runoff flow through a short soil column or very rapidly through a coarse-textured soil can convey contaminants to groundwater.

Evidence gathering from available performance data is that evapotranspiration (ET) can be a substantial factor in water retention (discussed below) but may be difficult to quantify at a given site without more research. A conservative approach is to design on the basis of infiltration rate, calculated to include consideration of soil amendments, if any. Together with careful investigation of soils and hydrogeologic conditions, this means of proceeding is very likely to produce facilities that retain at least as much runoff as predicted, and almost certainly more as a result of unquantified ET.

Table 1. A Catalogue of Aquatic Resources Conservation Design Practices (USEPA [2007] and NRC [2009])

Category	Definition	Examples
Source control	Minimizing pollutants or isolating them from contact with rainfall or runoff	• Substituting less for more polluting products • Segregating, covering, containing, and/or enclosing pollutant-generating materials, wastes, and activities • Avoiding or minimizing fertilizer and pesticide applications • Removing animal wastes deposited outdoors • Conserving water to reduce non-stormwater discharges
Conservation site design	Minimizing the generation of runoff by preserving open space and reducing the amount of land disturbance and impervious surface	• Clustering development • Preserving wetlands, riparian areas, forested tracts, and porous soils • Reducing pavement widths (streets, sidewalks, driveways, parking lot aisles) • Reducing building footprints
Conservation construction	Retaining vegetation and avoiding removing topsoil or compacting soil	• Minimizing site clearing • Minimizing site grading • Prohibiting heavy vehicles from driving anywhere unnecessary
Runoff harvesting	Capturing rainwater, generally from roofs, for a beneficial use	• Using storage and distribution systems (rain barrels or cisterns) for irrigation and/or indoor supply for public and private buildings
Natural runoff conveyance practices	Maintaining natural drainage patterns (e.g., depressions, natural swales) as much as possible, and designing drainage paths to increase the time before runoff leaves the site	• Emphasizing sheet instead of concentrated flow • Eliminating curb-and-gutter systems in favor of natural drainage systems • Roughening land surfaces • Creating long flow paths over landscaped areas • When flow must be concentrated, using vegetated channels with flow controls (e.g., check dams)
Practices for temporary runoff storage followed by infiltration and/or evapotranspiration[a]	Use of soil pore space and vegetative tissue to increase the opportunity for runoff to percolate to groundwater or vaporize to the atmosphere	• Bioretention cells (rain garden) • Vegetated swales (channel flow) • Vegetated filter strips (sheet flow) • Planter boxes • Tree pits • Infiltration basins • Infiltration trenches • Roof downspout surface or subsurface dispersal • Permeable pavement • Vegetated (green) roofs
ARCD landscaping[b]	Soil amendment and/or plant selection to increase storage, infiltration, and evapotranspiration	• Organic compost soil amendments • Native, drought-tolerant plantings • Reforestation • Turf conversion to meadow, shrubs, and/or trees

[a] Some of these practices are also conventional stormwater BMPs but are ARCD practices when ARCD landscaping methods are employed as necessary to maximize storage, infiltration, and evapotranspiration. The first five examples can be constructed with an impermeable liner and an underdrain connection to a storm sewer, if full retention is technically infeasible (see further discussion later). Vegetated roofs store and evapotranspire water but offer no infiltration opportunity, unless their discharge is directed to a secondary, ground-based facility.

[b] Selection of landscaping methods depends on the ARCD practice to which it applies and the stormwater management objectives, but amending soils unless they are highly infiltrative and planting several vegetation canopy layers (e.g., herbaceous growth, shrubs, and trees) are generally conducive to increasing storage, infiltration, and evapotranspiration.

Application of ARCD Practices in This Study

The investigation performed for this study first assessed the capacity of each case study site to infiltrate the full average annual post-development storm runoff volume and thereby reduce pollutant releases to zero. The report terms this initial evaluation as the "Basic ARCD Analysis". The means of infiltration was not distinguished at this level of analysis. For example, it was not specified if runoff would be distributed in sheet flow across a pervious area or channeled into a rain garden. As detailed later in the Methods of Analysis section, this analysis was limited to the estimated infiltration capacity of the case study soil type, possibly compost-amended, and the available pervious area.

Critically, there was no attempt to estimate the loss of surface runoff through ET in the Basic ARCD analysis (ET is considered, to address rooftop runoff only, as part of our "Full ARCD analysis," discussed below). In general, the estimated mean annual evapotranspiration in the Southeast is about 70 percent of the precipitation, or roughly 35 inches per year. For large areas of the Southwest, evapotranspiration is virtually equal to 100 percent of the precipitation, which is only about 10 inches per year. The ratio of estimated mean annual evapotranspiration to precipitation is least in the mountains of the Pacific Northwest and New England where evapotranspiration is about 40 percent of the precipitation (Hanson, 1991). By leaving out these substantial losses, generally 40 percent of precipitation or more, the retention estimates in this study can be considered quite conservative.

Additionally, there was no consideration of many ARCD practices in the Table 1 catalogue that could be applied in site-specific design. For example, there were no refinements of the prevailing building standards to reduce street widths or cluster buildings and reduce their footprints. Further, green roofs were not considered in this study, although they are already making a contribution to runoff reduction around the nation and reflect a significant additional opportunity to retain runoff on-site. The U.S. EPA has stated that "a 3.5-4 in. (8 -10 cm) deep green roof can retain 50% or more of the annual precipitation." (U.S. EPA, 2009a). For water quality, we did not assume any source control implementation. Thus, actual site design could take advantage of substantial additional capabilities not considered in this study.

In cases where the practices incorporated in the initial level of analysis (infiltration through bioretention) did not, according to the estimates, fully attenuate post-development pollutant discharges, specific attention was directed at ways of extracting additional water from surface discharge by managing roof runoff. This assessment is called the "Full ARCD Analysis" in the report. The options broadly divide into harvesting water for a purpose such as irrigation and/or non-potable indoor supply, or making special provisions to infiltrate or evapotranspire roof runoff even if soil conditions are limiting. Harvesting applies best to relatively large developments having sufficient demand for the collected water. While single-family residences can harvest water into rain barrels or cisterns for lawn and garden watering, these containers may be small in volume relative to runoff production; and though opportunity exists, no credit was taken for them in this study. However, even in poorly infiltrating soils, options exist to disperse house roof runoff as sheet flow for storage in vegetation and soil until evapotranspiration and some infiltration occurs.

CASE STUDIES

CLIMATE REGIONS

Basis of Selection

The Nationwide Urban Runoff Project divided the nation into nine regions based on differences in volume, intensity, and duration of precipitation and interval between precipitation events (USEPA 1983). For broad representation of the U.S. generally this study chose regions 1 (Northeast-Upper Midwest), 3 (Southeast), 5 (South Central), and 6 (Southwest) for analysis. Table 2 provides the annual precipitation statistics from the NURP compilation.

Table 2. Precipitation Statistics (Means) for Four NURP Regions Selected for Study (USEPA 1983)

Region	Volume (inch)	Intensity (inch/hour)	Duration (hours)	Interval (hours)
1—Northeast-Upper Midwest	0.26	0.051	5.8	73
3—Southeast	0.49	0.102	5.2	89
5—South Central	0.33	0.080	4.0	108
6—Southwest	0.17	0.045	3.6	277

The selected regions represent a volume differential of about a factor of three, intensity variation of approximately two times, and inter-storm interval varying by almost four times. The NURP report shows coefficients of variation (mean/standard deviation) of greater than 1.0 for all of these means, indicating an overall high degree of dispersion.

Figure 1 visually depicts variation in mean annual precipitation across the continental United States. It shows that the selected regions are overall representative of the broadly prevailing range across the nation, particularly its major urban and still urbanizing areas.

Region 7 (Pacific Northwest) was also identified for discussion of research results on ARCD, although not full analysis. It has less intense (mean 0.024 inch/hour) but much more extended (mean 20.0 hours) precipitation compared to any other region in the nation. Mean storm volume ranks with region 3 (mean 0.48 inch); but fewer storms, especially in the summer, yield overall less total annual precipitation in lowland areas holding all urban development in region 7. It was of interest because of the already occurring use of ARCD techniques in a relatively rainy part of the country.

Representative Metropolitan Areas and Cities

Once the regions were identified, a metropolitan area within each area was chosen as a basis for assigning specific precipitation and development characteristics. The areas considered were USEPA-designated Urban Areas: “An urbanized area is a land area comprising one or more places – central place(s) – and the adjacent densely settled surrounding area – urban fringe – that together have a residential population of at least 50,000 and an overall population density of at least 1,000 people per square mile” (USEPA 2007). Stormwater regulations would have the most impact in areas that are being quickly developed, redeveloped, or both. Five of the twenty fastest growing counties in the nation from 2000 to 2009 were near Atlanta, GA and five were in the state of Texas (U.S. Census Bureau 2010). These statistics factored into the decision to focus on records from these regions.

Each selected metropolitan area is generally representative of its region in precipitation and development characteristics. Each is also undergoing relatively active new development and redevelopment, offering candidate locations where a prospective stormwater standard would frequently be applied. These metropolitan areas are: region 1—Boston, MA, region 3—Atlanta, GA, region 5—Austin, TX, and region 6—San Diego, CA

Figure 1. Precipitation of the Conterminous States of the United States, National Atlas of the United States, 2011.

Finally, a city with a high rate of development (and often redevelopment) was picked in each metropolitan area for investigation of building patterns and standards. The intent was to match regional patterns of climate, soils (see discussion on physiographic data, below), and land use and land cover realistically. After substantial investigation, the conclusion was that building standards, how land is used, and the relative allocation of impervious and pervious lands do not vary in any systematic way across the nation and cannot be regionally distinguished. Therefore, the variables of interest came down to precipitation and soils.

Alpharetta, about 30 miles north of Atlanta, represents that metropolitan area. In 1981 it was a small town of approximately 3,000 residents but grew to 51,243 by 2007. During the workday, the city swells to more than 120,000 residents, workers, and visitors. Alpharetta is home to large corporations such as AT&T (3500 employees), Verizon Wireless (3000 employees), and ADP, Inc./National Account Services (2100 employees). Infill redevelopment projects are anticipated in the downtown area (City of Alpharetta, 2011).

Round Rock is a typical developing city located 15 miles to the north of Austin, TX. In 1970 there were only 2,700 residents in this town, while today the population exceeds 100,000. Round Rock is the eighth-fastest growing city in the nation and the location of several large corporate campuses.

The Town of Framingham, 20 miles west of Boston, represents the northeastern climate zone. At nearly 67,000 inhabitants, Framingham is the largest entity designated as a “town” in the Commonwealth of Massachusetts. It is home to three large corporations and overall 2200 businesses providing 45,000 jobs. Differing greatly from the representative communities in

other regions, Framingham was incorporated in 1700 and developed early in the nation's history. Today's activity includes redevelopment of brownfields and downtown revitalization, although some agricultural land still remains within the town limits (Town of Framingham, 2011).

San Marcos, representing the San Diego area and located about 35 miles north of the city, grew from a population of 17,479 in 1980 to 82,743 by 2008. Major institutions in the city include California State University San Marcos and Palomar Community College. At this stage the city is only approximately 72 percent built out, and thus new development continues (City of San Marcos, 2011).

Precipitation Data

Average monthly precipitation data were obtained from the NOAA Hourly Precipitation Data Rainfall Event Statistics[5] for one station with a long-term record in each region: Southeast—Atlanta/Hartsfield International Airport (Station #90451), South Central—Austin/Robert Mueller Municipal Airport (410428), Northeast—Boston/Logan International Airport (190770), and Southwest—San Diego/San Diego International Airport (Lindbergh Field) (47740). Atlanta receives the most precipitation, averaging about 49 inches per year, followed by Boston (47 inches/year), Austin (33 inches/year), and San Diego (10 inches/year). Figure 2 depicts precipitation variations over more than 50 years.

Values for either the 85th and 95th percentile, 24-hour storms were available in a number of state-specific resources, including the Georgia Stormwater Standards Supplement (Center for Watershed Protection 2009) and the Integrated Stormwater Management Program (North Central Texas Council of Governments 2010), as well as national publications such as an USEPA's technical guidance documents (USEPA 2009). However, few references had values for both 85th and 95th percentile storms. Therefore, these values were calculated following the methodology outlined in the USEPA's Technical Guidance on Implementing the Stormwater Runoff Requirements (USEPA 2009, page 30). Daily precipitation and temperature data from the National Climatic Data Center's TD Summary of the Day data set were collected and analyzed for the four stations lover a time period of 60 years, January 1, 1950 to January, 31 2010.

[5] National Climatic Data Center, Hourly Precipitation Data Rainfall Event Statistics (http://cdo.ncdc.noaa.gov/cgi-bin/HPD/HPDStats.pl, last accessed December 15, 2011).

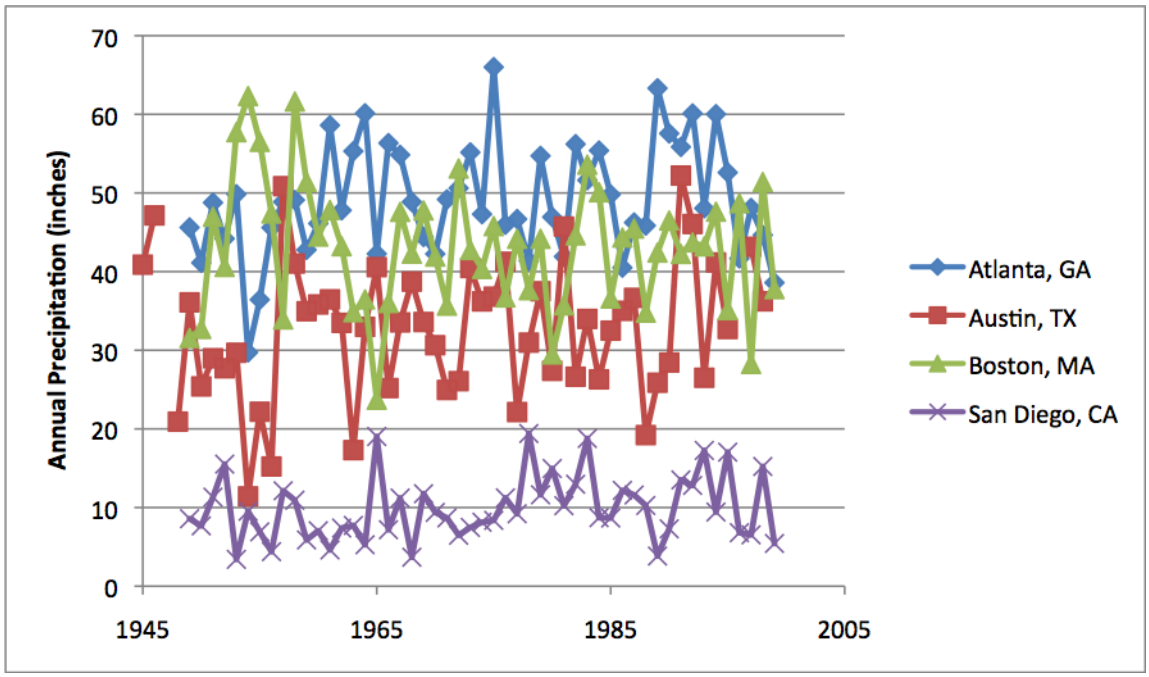

Figure 2. Average Annual Precipitation for Four Climate Regions over the Latter Part of the Twentieth Century (from NOAA Hourly Precipitation Data Rainfall Event Statistics, http://cdo.ncdc.noaa.gov/cgi-bin/HPD/HPDStats.pl)

For snowfall days, snow water equivalent (SWE) was calculated according to the guidelines provided by a National Climate Data Center's (NCDC) document, Estimating the Water Equivalent of Snow, utilizing the reported mean temperature for the day (National Climatic Data Center, accessed December 16, 2011). The NCDC tables calculate that the SWE is at most, about 10 percent of the total snowfall depth. In the methodology for determining the 85th and 95th percentile events, all days with < 0.1 inch precipitation are removed, lowering the impact of snow on the results. Snowfall had no effect in the Southwest region, a very minor effect in the Southeast and South Central, and still a relatively small effect in the Northeast, as follows: San Diego—0 snow days; Atlanta—74 of 4600 total days having ≥ 0.1 inch (1.6 percent), with a contribution ranging 0.01-0.79 inch precipitation; Austin—32 of 2418 days (1.3 percent), contributing 0.01-0.50 inch; and Boston—993 of 4783 days (20.8 percent), contributing 0.01-2.24 inch. Since snow does add to runoff that must be managed in a location like the Northeast, these snow water equivalents were left in the records. Table 3 summarizes precipitation data used in the analyses for the four regions.

Table 3. Precipitation Summary for Study Regions

Region	Average Annual Precipitation (inches)	85th Percentile, 24-Hour Event		95th Percentile, 24-Hour Event	
		Depth (inch)[a]	Fraction Covered[b]	Depth (inch)[a]	Fraction Covered[b]
Southeast	49.02	1.13	0.63	1.79	0.87
South Central	32.67	1.19	0.58	1.99	0.82
Northeast	47.03	1.07	0.81	1.72	0.89
Southwest	9.68	0.76	0.62	1.26	0.83

[a] Calculated from National Climatic Data Center's TD Summary of the Day, for all precipitation days >0.1 inch for period January 1, 1950 – December 31, 2009
[b] Fraction of total annual precipitation covered by event standard

Physiographic Data

General Methods

This section of the report covers the soils, groundwater, and topographic data underlying the analyses. Soil characteristics are largely a product of climate, geology and topography. The characteristics of most interest for this study were those controlling infiltration of surface water and percolation to an aquifer. Although there is variation within each climate region, the major soil orders can be used to identify regional characteristics. The Natural Resources Conservation Service (NRCS) website[6] describing the major soil orders and their locations was the initial source of these data. Maps generated by Miller and White (1998) gave information from the State Soil Geographic Database (STATSGO), including characteristics such as soil texture and hydrologic soil group. These resources were employed to gain a broad view of the soils in each of the four regions.

To extend the scope of the study, soils were investigated in the Upper Midwest, in addition to the Southeast, South Central, Northeast, and Southwest climate regions. Upper Midwest and Northeast soils share general similarities. Both regions also have temperate, seasonal, humid climates. While average annual precipitation is overall somewhat greater in the Northeast compared to the Upper Midwest, the two regions were deemed similar enough physiographically and climatologically to be considered together. This report henceforth groups them as the Northeast – Upper Midwest climate region.

To validate the regional patterns emerging from the general sources, custom "soil resource" reports for four cities were generated using the NRCS Web Soil Survey[7] tool. These reports collected characteristics related to infiltration rates and runoff including soil texture, hydrologic soil group, drainage classification, representative slope, and depth to water table. Using this tool requires selecting an "area of interest". This examination utilized a size of at least 8,000 acres (10,000 acres is the maximum allowed) to insure a representative sample of soil and related conditions.

Hydrologic soil group assignment is a means of generally categorizing soils according to their tendency to admit and transmit water. The hydrologic soil group (HSG) is determined with respect to the water-transmitting soil layer with the lowest saturated hydraulic conductivity and depth to any layer that is more or less water impermeable (such as a fragipan or duripan) or depth to a water table. Box 1 summarizes the characteristics of the four HSGs (NRCS 2007).

The position of the groundwater table is a crucial determinant of whether or not stormwater infiltration should be promoted by applying ground-based ARCD practices. A seasonal high water table too close to the surface results in rapid saturation of a thin soil column and retarded infiltration. Ponding water longer than 72 hours can permit mosquito growth, damage vegetation, and promote clogging of the facility by microorganism growths and polysaccharide organic materials that form in the reduced-oxygen environment accompanying excessive ponding time (Mitchell and Nevo 1964, Ronner and Wong 1996). Also, storm runoff flow through a short soil column or very rapidly through a coarse-textured soil can potentially convey contaminants to groundwater. To avoid entertaining stormwater management strategies threatening development of these problems, data on depth to groundwater was obtained from the U.S. Geological Survey's (USGS) Groundwater-Level Annual Statistics (USGS 2011).

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[6] Natural Resources Conservation Service, Distribution Maps of Dominant Soil Orders (http://soils.usda.gov/technical/classification/orders/, last accessed December 16, 2011).

[7] Natural Resources Conservation Service, 2011, Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm).

Topographic slope influences runoff production by setting incident precipitation in motion downslope, thus producing a horizontal component of velocity vector partially counteracting the tendency to penetrate the soil vertically. This study investigated that importance of that effect by considering two slopes typical of urban development sites. As discussed during the presentation of results, below, this factor did not have a large effect on the analysis.

Box 1. Summary of Hydrologic Soil Groups (NRCS 2007)

Group A—Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The saturated hydraulic conductivity of all soil layers exceeds 5.67 inches per hour. The depth to any water-impermeable layer is greater than 20 inches. The depth to the water table is greater than 24 inches. Soils deeper than 40 inches to a water-impermeable layer are in group A if the saturated hydraulic conductivity of all soil layers within 40 inches of the surface exceeds 1.42 inch per hour.[a]

Group B—Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The saturated hydraulic conductivity in the least transmissive layer between the surface and 20 inches ranges from 10.0 1.42 to 5.67 inches per hour. The depth to any water-impermeable layer is greater than 20 inches. The depth to the water table is greater than 24 inches. Soils deeper than 40 inches to a water- impermeable layer or water table are in group B if the saturated hydraulic conductivity of all soil layers within 40 inches of the surface exceeds 0.57 inch per hour but is less than 1.42 inch per hour.

Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The saturated hydraulic conductivity in the least transmissive layer between the surface and 20 inches is between 0.14 and 1.42 inch per hour. The depth to any water-impermeable layer is greater than 20 inches. The depth to the water table is greater than 24 inches. Soils deeper than 40 inches to a restriction or water table are in group C if the saturated hydraulic conductivity of all soil layers within 40 inches of the surface exceeds 0.06 inch per hour but is less than 0.57 inch per hour.

Group D—Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water-impermeable layer less than 20 inches and all soils with a water table within 24 inches of the surface are in this group, although some may have a dual classification if they can be adequately drained. For soils with a water-impermeable layer at a depth between 20 and 40 inches, the saturated hydraulic conductivity in the least transmissive soil layer is less than or equal to 0.14 inch per hour. For soils deeper than 40 inches to a restriction or water table, the saturated hydraulic conductivity of all soil layers within 40 inches of the surface is less than or equal to 0.06 inch per hour.

[a] While Group A soils are present across large areas of the country, our analysis considers only Group B, C, and D soils to provide a conservative assessment of infiltration potential in urban areas, and to account for potential issues such as soil compaction that may occur for lawn and other landscaping in urban and suburban development.

Southeast Climate Region

The major soil order found throughout the southeastern United States is Utisols, sub-order Udults. The humid climate with frequent rainfall gives the soils an udic moisture regime; soils are rarely dry for more than 45 consecutive days. Utisols are highly weathered and are deficient in calcium and other bases. Georgia is known for its red soils, which are the unhydrated iron oxides left in the weathered material. Pre-European contact, these soils supported mixed conifer and deciduous woodlands. Due to its relatively flat topography and warmer temperatures, Florida has primarily Spodosols, Alphisols and Histosols (Soil Survey Staff, NRCS 2011).

This region has a variety of soil textures, ranging from sand and sandy loam throughout Mississippi, Alabama, and Georgia; silty loam soils near the Appalachian Mountains; and some areas with significant organic materials in Florida. The major soil hydrologic groups of the region are varied as well, with C and D soils dominating the Georgia coastline and most of Florida. Group A and B soils are more prevalent in the interior parts of the region, in central Georgia and Alabama (Miller and White 1998).

A NRCS web soil survey was conducted for an area of interest (AOI) centered in Alpharetta, GA. The selected AOI did not have complete soil survey coverage, and findings were compared with another AOI of 8990.5 acres north of the city in Fulton County. In both AOIs, the leading HSG is B (86 percent of AOI), followed by group C (11 percent of AOI). Approximately 97 percent of the AOI has a sandy loam soil texture. The leading drainage classification was well drained (86 percent of AOI), followed by somewhat poorly drained (10 percent of AOI). The selected AOI was moderately steep, with approximately 70 percent of the AOI having slopes between 8 and 12 percent.

Fulton County, Georgia has four wells in the USGS record, three with depth-to-groundwater data. Two wells have only one recorded depth: site 08CC08 had a depth of 2.447 ft in 1986, and site 10DD01 had a depth of 16.131 ft in 1968. Site 10DD02 has been monitored annually from 1977-2010 and has an annual well-depth average in this time period of 6.292 ft.

South Central Climate Region

The major soil order in Texas is Mollisols, sub-order ustolls. These soils span the sub-humid and semiarid climate zones, and are common on the western Great Plains and throughout the Rocky Mountain States. These soils originally supported grasslands and (in mountainous regions) forests, and now are ranched or farmed. Houston black soils are also characteristic of the region and are important in agriculture and urban areas, occurring throughout central Texas. Dry soils in the Order Aridisols, sub-orders Argids and Calcids, are found in west Texas and large portions of New Mexico as well. These soils were formerly sparsely vegetated areas, now used for rangeland or wildlife habitat (Soil Survey Staff, NRCS 2011).

Soil characteristic maps generated by Miller & White (1998) indicate that the majority of soil types in the South Central climate region are diverse: sandy loam and clay dominate eastern Texas, clay soils are prevalent in central parts of the state and loam soils are in western Texas and New Mexico. Most soils tend to be in the C and D hydrologic groups, however B soils are found in bands in New Mexico (Miller & White, 1998).

A web soil survey was conducted for an area of interest of 8267.5 acres centered in Round Rock, TX. The leading HSG is D (68 percent of AOI), followed by group C (22 percent of AOI) and group B (10 percent). Primary soil textures are clay (33 percent), silty clay (27 percent), extremely stony clay (17 percent), and silty clay loam (10 percent). The leading drainage classification is well drained (79 percent of AOI) followed by moderately well drained (21

percent). The selected AOI is relatively flat; approximately 70 percent of the AOI has slopes under 2 percent, and 20 percent has slopes of 3-4 percent.

Travis County, Texas had three wells that were measured in 2003 and recorded by USGS (site YD-58-50-216) and 2004 (sites YD-58-50-216 and YD-58-25-907). Groundwater is very deep in each location, averaging 220 ft below the ground surface.

Northeast – Upper Midwest Climate Region

This climate region has significant variation in dominant soil orders. The Spodsols order, sub-order Orthods, dominates the northern portions (northern Minnesota, Wisconsin, Michigan, Vermont, and Maine) and is generally considered infertile without soil amendments. Inceptisols, sub-order Udepts, are also prevalent in the region, especially in New England states, through the Appalachian Mountains and northeastern Minnesota. Alfisols, sub-order Udalfs, too are prevalent in the region, extending from Minnesota east to New York. These two soils both have an udic moisture regime, and are rarely dry for more than 45 consecutive days due to the year-round precipitation in the area (Soil Survey Staff, NRCS 2011). The state soil of Massachusetts is the Paxton fine sandy loam and also extends into New Hampshire, New York and Vermont. These deep soils were formed in acid subglacial till and are derived from schist, gneiss and granite (NRCS undated).

Based on maps generated by Miller and White (1998), sandy loam and silt loam soils tend to dominate the region, with small areas of clay and silty clay soils. Hydrologic soil group B is most prevalent in the Midwestern states (Minnesota, Wisconsin, Illinois), and Group C is most common in the rest of the region, spanning from Indiana to Maine. The region primarily supported forest ecosystems before development.

A web soil survey was conducted for an area of interest centered in Framingham, MA with an AOI of 8645.6 acres. The region has relatively equal amounts of each HSG: 20 percent of the AOI in Group A, 19 percent in group B, 20 percent in Group C, and 24 percent in Group D. Soil textures represented are fine sandy loam (49 percent), muck (10 percent), loamy sand (9 percent), and moderately decomposed plant material (8 percent). The leading drainage classification is well drained (32 percent of AOI) followed by very poorly drained (16 percent), somewhat excessively drained (12 percent), and moderately well drained (11 percent). Fourteen percent of the AOI has slopes of 1 percent or less, with 18 percent at 2-5 percent, 23 percent at 6-8 percent, and another 23 percent at 8-12 percent slopes.

There are three wells in the USGS record for Middlesex County, MA including 5 years of record for an Acton well averaging 17.75 ft, 6 years for the Wakefield well with an average depth of 6.59 ft, and 11 years at the Wilmington well with an average of 8.09 ft.

Southwest Climate Region

There are multiple soil orders in California due to its variation in climate, topography and geologic history. Entisols occur in the southern parts of the state; sub-order Psamments is a frequently found sandy soil that makes productive rangeland. Order Mollisols, sub-order Xerolls, are freely drained and dry soils found in the Mediterranean climate along the coast of California. Pre-settlement ecosystems supported by these soils include oak savanna, grasslands, and chaparral. Current soils may be used as cropland or rangeland (Soil Survey Staff, NRCS 2011).

A web soil survey was conducted for an 8267.5-acre area of interest centered in San Marcos, CA. The leading HSG is D (58 percent of AOI), followed by group C (26 percent) and group B (14 percent). Soil texture include sandy loam (19 percent), coarse sandy loam (17 percent), silt loam (15 percent), very fine sandy loam (14 percent), loamy fine sand (12 percent), loam (7

percent), and clay (5 percent). The leading drainage classification is well drained (51 percent of AOI), followed by moderately well drained (34 percent). Approximately 10 percent of the AOI has slopes ≤ 5 percent, and 66 percent has slopes of 5-10 percent.

There are no groundwater records for San Diego County available on the USGS website. Data were collected from the California Department of Water Resource Water Data Library[8]. Ten wells west of San Marcos near Escondido were sampled in 1987. The depth to groundwater ranged from 2.0 to 28.1 ft for an average of 11.6 ft.

Summary of Physiographic Characteristics

Due to the large area of land encompassed in each climate region, it is difficult to select one location that is truly "representative" of the entire region. By selecting four cities that are spaced throughout the country with different climate and soil characteristics, however, this study can demonstrate the different potential for ARCD strategies in regions around the nation. Table 4 summarizes the major soils, groundwater, and topographic characteristics for these regions. Figure 3 shows the distributions of hydrologic soil groups in areas of interest investigated in the four metropolitan areas.

Table 4. Summary of Physiographic Data

Characteristic	Southeast	South Central	Northeast – Upper Midwest	Southwest
Main soil types	Sandy loam	Clay, clay loam	Sandy loam, silt loam	Sandy loam, loam
Hydrologic soil group near study site	B (GA, AL, SC)	D (TX)	C (Northeastern states)	D
Other hydrologic soil group in climate region	D (FL)	C (NM)	B (MN, WI, IL, MI)	C
Predominant pre-development land cover	Woods	Semi-arid herbaceous	Woods	Narrow-leaved chaparral
Predominant slopes	70% @ 8-12%	90% < 4%	65% < 12%	76% < 10%

LAND USE CASES

Five cases were selected to represent a range of urban development types considered to be representative of the nation. These cases involved: a multi-family residential complex (MFR), a relatively small-scale (23 homes) single-family residential development (Sm-SFR), a relatively large (1000 homes) single-family residential development (Lg-SFR), a sizeable commercial retail installation (COMM), and an urban redevelopment (REDEV).

Building permit records from the City of San Marcos in San Diego County, California provided data on total site areas for the first three cases, including numbers of buildings, building footprint areas (including porch and garage for Sm-SFR), and numbers of parking spaces associated with the development projects. Information was not as complete for cities in other regions, but what data was available indicated no substantial difference in these site features. Therefore, the San Marcos data were used for all regional case studies. This uniformity had the advantage of placing comparisons completely on the basis of the major variables of interest, climatological and soils characteristics.

[8] http://www.water.ca.gov/waterdatalibrary (last accessed December 16, 2011).

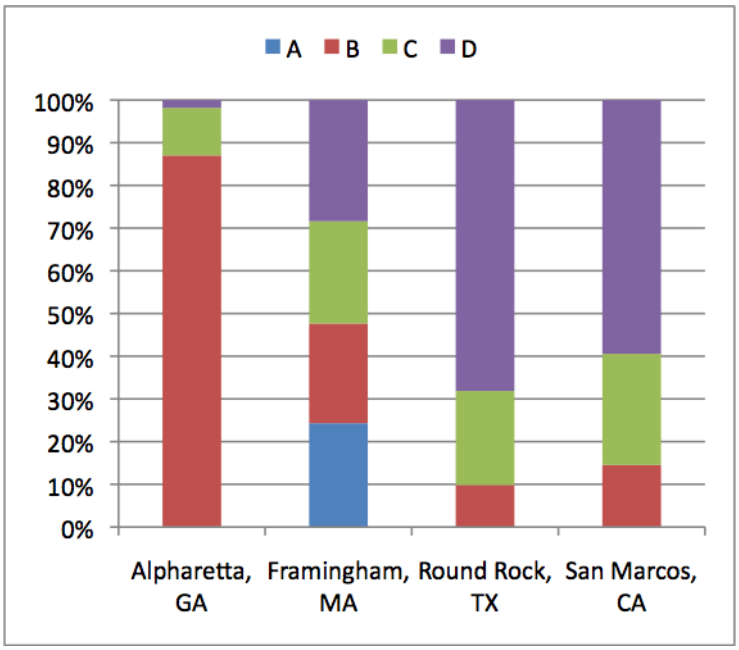


Figure 3. Distribution of Hydrologic Soil Groups in Four Study Cities

The REDEV case was taken from an actual project in Berkeley, California involving conversion of an existing structure, built originally as a corner grocery store, to apartments and addition of a new building to create a nine-unit, mixed-use, urban infill project. Space remained for a large side yard.

Larger developments were not represented in the sampling of building permits from the San Marcos database. To take larger development projects into account in the subsequent analysis, the two larger scale cases were hypothesized. The Lg-SFR scenario scaled up all land use estimates from the Sm-SFR case in the ratio of 1000:23. The hypothetical COMM scenario consisted of a building with a 2-acre footprint and 500 parking spaces. As with the smaller-scale cases, these hypothetical developments were assumed to have roadways, walkways, and landscaping, as described below.

While the building permit records made no reference to features such as roadways, walkways, and landscaping normally associated with development projects, these features were taken into account in the case studies using assumptions described herein. Parking spaces were estimated to be 176 square ft in area, which corresponds to 8 ft width by 22 ft length dimensions. Code requirements vary by jurisdiction, with the tendency now to drop below the traditional 200 square ft average. About 180 square ft is common, but various standards for full- and compact-car spaces, and for the mix of the two, can raise or lower the average (Gibbons, 2009). The 176 square ft size is considered to be a reasonable value for conventional practice.

Roadways and walkways assume a wide variety of patterns. Exclusive of the two SFR cases, simple, square parking lots with roadways around the four sides and square buildings with walkways also around the four sides were assumed. Roadways and walkways were taken to be 20 ft and 6 ft wide, respectively.

Each single-family residences (SFR) was assumed to have a lot area of 5749 square ft,, and a driveway 20 ft wide and 30 ft long. Assuming a square lot, each would have a sidewalk 76 feet by 4 feet wide, and a walkway that is 40 feet by 4 feet. .

Exclusive of the COMM case, the total area for all of these impervious features was subtracted from the total site area to estimate the pervious area, which was assumed to have conventional landscaping cover (grass, small herbaceous decorative plants, bushes, and a few trees). For the COMM scenario, an additional 10 percent was added to the building, parking lot, access road, and walkway area to represent the landscaping, on the belief that a typical retail commercial establishment would be mostly impervious.

Table 5 summarizes the characteristics of the five land use cases. The table also provides the recorded or estimated areas in each land use and cover type.

Table 5. Summary of Cases with Land Use and Land Cover Areas

	MFR[a]	Sm-SFR[a]	Lg-SFR[a]	COMM[a]	REDEV[a]
No. buildings	11	23	1000	1	2
Total area (ft^2)	476,982	132,227	5,749,000	226,529	5,451
Roof area (ft^2)	184,338	34,949	1,519,522	87,120	3,435
No. parking spaces[b]	438	-	-	500	2
Parking area (ft^2)[b]	77,088	-	-	88,000	316
Access road area (ft^2)	22,212	-	-	23,732	-
Walkway area (ft^2)	33,960	10,656	463,289	7,084	350
Driveway area (ft^2)	-	13,800	600,000	-	650
Landscape area (ft^2)	159,384	72,822	3,166,190	20,594	700

[a] MFR—multi-family residential; Sm-SFR—small-scale single-family residential; Lg-SFR—large-scale single-family residential; COMM—retail commercial; REDEV—redevelopment
[b] Uncovered

METHODS OF ANALYSIS

AVERAGE EVENT AND ANNUAL STORMWATER RUNOFF VOLUMES

Calculation Methods

Surface runoff volumes produced were estimated for both pre- and post-development conditions for each case study. The pre-development state was considered to be the predominant land cover for each region prior to European settlement.

For impervious areas, average event and annual runoff volumes were computed as the product of event or average annual precipitation, contributing drainage area, and a runoff coefficient (ratio of runoff produced to precipitation received) according to the familiar Rational Method equation. The runoff coefficient was determined from the equation C = (0.009) I + 0.05, where I is the impervious percentage. This equation was derived by Schueler (1987) from Nationwide Urban Runoff Program data (USEPA 1983). With I = 100 percent for fully impervious surfaces, C is 0.95.

The basis for pervious area runoff coefficients, for both the pre-development state and landscaped areas in developments, was the NRCS's Urban Hydrology for Small Watersheds (NRCS 1986, as revised from the original 1975 edition). This model estimates storm event runoff (R, inch) as a function of precipitation (P, inch) and a variable representing land cover and soil, termed the curve number (CN, dimensionless). CN enters the calculation via a variable S, which is the potential maximum soil moisture retention after runoff begins. The equations for English units of measurement are:

$$R = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad S = \frac{1000}{CN} - 10$$

The runoff equation is valid for P > 0.2S, which represents the initial abstraction, the amount of water retained before runoff begins by vegetative interception and infiltration (NRCS 1986). According to this model, larger events are forecast to produce a greater amount of runoff in relation to amount of precipitation, because they more fully saturate the soil. Therefore, use of the model to estimate annual runoff requires selecting some event or group of events to compute an average runoff coefficient representing the year.

Average pre- and post-development pervious area average runoff coefficients were derived by computing runoff from a series of precipitation events ranging from 0.1 inch up to the 95th percentile, 24-hour event for the respective metropolitan areas, dividing by the associated precipitation, and averaging for all event amounts > 0.2S. Average annual runoff volumes for pervious areas were estimated based on these runoff coefficients and average annual precipitation quantities recorded at the respective gauging locations.

Curve Number Selection

Pre-development curve numbers were determined from existing studies and NRCS (1986) CN tables based on pre-European settlement land cover. Before development, woods predominated in Georgia and Massachusetts. Pre-development Texas had principally arid and semi-arid range with herbaceous cover. Chaparral was the predominant land cover in the San Diego area, however, this land cover type is not listed in the NRCS tables. For that region the selection came from a study by Easterbrook (undated) on curve numbers and associated soil hydrologic groups in an investigation of mainly chaparral lands before and after wildfires in the San Diego area.

Conversion to landscaping typical of development modifies soil and water infiltration characteristics by removing topsoil and even subsoil, compacting the remaining soil, and changing the vegetative cover. For pervious landscaping after development, CN was based on 1/8-acre urban development for all building types.

To demonstrate a range of results, runoff estimates were made for two soils in each region falling in B and C, B and D, or C and D HSGs. The more infiltrative soil was assumed to be in "good" condition and the less permeable one in "poor" condition, differentiations made in the NRCS tables. Table 6 summarizes the curve numbers used in the analyses. The paragraphs following the table detail how the selections were made for each region.

Table 6. Summary of Curve Numbers for Study Regions

	Southeast		South Central		Northeast – Upper Midwest		Southwest	
Hydrologic soil group-condition	B-good	D-poor	C-good	D-poor	B-good	C-poor	C-good	D-poor
Pre-development	55	83	74	93	55	77	77	90
Post-development	85	92	90	93	85	90	91	93

The Georgia Stormwater Manual Supplement recommends that watershed managers select curve numbers proposed by the NRCS based on hydrologic soil groups A through D and hydrologic condition of the site (Center for Watershed Protection 2009). As aforementioned, the pre-European land cover of the southeastern United States was forested. A study by Dyke (2001) in Forsyth and Hall Counties northeast of Atlanta confirmed that, immediately prior to development, approximately 50 percent of urban lands were forested, with 22 percent in agricultural use.

Because the region includes B soils in the interior of Alabama and Georgia, and poorly draining D soils in Florida and along the coasts, it was decided, for the purpose of demonstrating a range of results, to base NRCS Curve number values on B soils in good condition and D soils in poor condition. The corresponding pre- and post-development curve numbers are 55 and 83 and 85 and 92, respectively.

Prior to human development, approximately 80 percent of Texas, mostly in the central part, was covered in short and tall grassland communities; the western 10 percent of the state was desert grassland; and the eastern 10 percent was forested (University of Texas 2000). McLendon (2002) conducted a study on the observed and predicted curve numbers in 107 watersheds in Texas. For rural watersheds the CNs ranged from 48 to 88. The range in Austin was 49-89 and in Dallas 60-90. The Texas Department of Transportation's (2001) Hydraulic Design Manual Section 7 lists values for pre-development curve numbers for arid and semi- arid rangelands. Based on these sources, the respective pre- and post-development CN choices were 74 (C—good soil) and 93 (D—poor soil) and 90 (C—good soil) and 93 (D—poor soil).

Before European development, most of the Northeast – Upper Midwest region was covered in mixed hardwood and coniferous forests. A recent USGS report confirms that most urban development in the region from 1973 to 2000 has converted forestland (47 percent of all changes), followed by farmland (11 percent) (Auch undated). For this study's pre-development curve number, the woods cover type, soil group B in good condition and C soil in poor condition gave corresponding curve numbers of 55 and 77, respectively. Post-development curve numbers for these soil types at 1/8-acre development size were 85 and 90 for the good B and poor C soils, respectively. These post-development curve numbers are similar to a recent study in the Aberjona River watershed, an urban catchment northwest of Boston, where the authors used an overall CN of 89 to represent the more impervious parts of the watershed (Perez-Pedini et al. 2005).

With the lack of NRCS data for chaparral, CN selection for the San Diego area was based on an analysis performed in the area of the 2003 Cedar Fire in San Diego County by Easterbrook (undated). For pre-development C soils in good condition and D soils in poor condition, the choices were 77 and 90, respectively. Post-development curve numbers were selected from Easterbrook's estimation of CN after a high-burn fire; for good C soils CN = 91, and for poor D soils CN = 93.

Effect of Slope on Curve Number

NRCS documents developing the curve number concept and associated methods did not cover the effect of land slope. Independent researchers have given some attention to the question though. Sharpley and Williams (1990) introduced the empirical equation that has been most often used to adjust CN relative to slope:

$$CN_s = 0.333(CN_w - CN)(1 - 2e^{-13.86s}) + CN$$

where CN is the curve number reported in NRCS tables for an average soil moisture condition and assumed slope ≤ 5 percent, CN_s = slope-adjusted CN, CN_w = CN in an initially wet soil condition, and s = slope (ft/ft). Ward and Trimble provided factors to adjust tabulated CN values to obtain CN_w. Carrying through the analysis in this manner demonstrated that results deviated between two assessed slopes (5 and 10 percent) by only around 2-6 percent. This small difference was considered minimal in the context of the approximations and assumptions inherent in the modeling process. While the results presentation gives some additional data on slope effects, full coverage is given only for 5 percent, the topographic basis of the NRCS model and by far the subject of its greatest application.

ESTIMATING INFILTRATION CAPACITY OF THE CASE STUDY SITES

Infiltration Rates

Infiltrating sufficient runoff to maintain pre-development hydrologic characteristics and prevent pollutant transport is the most effective way to protect surface receiving waters. Successfully applying infiltration requires soils and hydrogeological conditions that will pass water sufficiently rapidly to avoid overly-lengthy ponding, while not allowing percolating water to reach groundwater before the soil column captures pollutants.

The study assumed that infiltration would occur in surface facilities and not in below-ground trenches. The use of trenches is certainly possible. However, the intent of this investigation was to determine the ability of pervious areas to manage the site runoff, and their exclusion is consistent with the conservative approach to modeling taken in this analysis. This inquiry was accomplished by evaluating the ability of the predominant soil types identified for each region to provide an infiltration rate of at least 0.5 inch/hour, the rate often regarded in the stormwater management field as the minimum for the use of infiltration practices (e.g., Geosyntec Consultants 2008). The assessment considered soils that either would provide this rate, at a minimum, in their original condition or could be organically amended to augment soil water storage and increase infiltration, while also safeguarding groundwater. Therefore, prevailing groundwater depths were assessed in relation to runoff percolation times generally regarded as safe.

Infiltration rates were based on saturated hydraulic conductivities (obtained from Leij et al. 1996) typical of the basic soil types incorporated in the U.S. Department of Agriculture (USDA, 1987) soil textural triangle. Sand, loamy sand, sandy loam have conductivities well above 0.5 inch/hour. As Table 4 indicates, three of the four regions have a sandy loam as the dominant soil type. For such a soil in the B HSG in these regions, the infiltration rate was taken as 1.74

inch/hour (Leij et al. 1996). Other textures represented that would generally fall in the C group are mostly loam and silt loam. These soil types either have conductivities in excess of 0.5 inch/hour or, in the first author's experience, can be and have been successfully organically amended to produce such a rate and infiltrate accumulated water within 72 hours, and usually less time. The D soils in some study regions, silty clay and clay, were regarded as not amendable to reach 0.5 inch/hour conductivity to host conventional or ARCD-type facilities designed specifically for infiltration. Still, locations with these soils could distribute sheet flow over pervious areas for evapotranspiration and some infiltration at slow rates and could utilize roof downspout surface or subsurface dispersal.

Groundwater Protection Assessment

Avoidance of groundwater contamination was assessed by assuming a hydraulic conductivity generally regarded as the maximum rate for the use of infiltration practices, 2.4 inches/hour (e.g., Geosyntec Consultants 2008), and a minimum spacing to seasonal high groundwater from the bed of an infiltration facility of 4 ft. These conditions would provide a travel time of 20 hours, during which contaminant capture would occur through soil contact. This 20-hour travel time was regarded as a minimum for any soil type. For example, infiltrating on loamy sand with a hydraulic conductivity of 5.7 inches/hour would require minimum spacing from the infiltration surface to groundwater of 10 ft. This consideration did not actually become an issue for analyses in any region in this study, because all predominant soil types have infiltration rates under 2.4 inches/hour and groundwater spacings that exceed 4 ft.

Site Infiltration Capacities

Runoff volumes were estimated for the 85th and 95th percentile, 24-hour events as described previously. Bioretention cell surface area to accommodate these volumes was calculated based on a method in the City of Santa Barbara's Storm Water BMP Guidance Manual (Geosyntec Consultants 2008) (adapted from the Georgia Stormwater Manual (Atlanta Regional Commission, 2001)):

$$A = \frac{(V_{design})(l)}{(t)(k_{design})(d + l)}$$

where:

V_{design} = design volume of runoff to be infiltrated (ft3);

k_{design} = design infiltration rate (in/hr), taken as 0.5 times the typical rate for the soil type naturally or amended as a safety factor;

d = ponding depth (ft), assumed as 0.25 ft for a shallow landscape feature on the recommendation of the Georgia manual;

l = depth of planting media (ft), assumed as 4 ft on the recommendation of the Georgia manual;

t = required drawdown time (hr), taken as 48 hours.

The design variable selections are conservative in applying a safety factor to hydraulic conductivity, using minimum depths for economy and limiting site disruption, and applying a drain time lower than the maximum of 72 hours.

In considering the long-term capacity of a facility designed to infiltrate, the potential for groundwater mounding below or aside the unit is a concern. To avoid this problem a basic analysis was made using a groundwater rise equation from Zomorodi (2005):

$$\text{Rise} = 0.86\,\frac{(K_v)(W)}{(K_h - K_v)}$$

where:

Rise = mounding occurring in a year of use (ft);

K_v = vertical saturated hydraulic conductivity (ft/year);

W = bioretention cell width (ft); and

K_h = horizontal saturated hydraulic conductivity (ft/year).

This equation was solved for K_v for computation of the allowable annual infiltration rate, assuming a rise limited to 1 ft. It was assumed that the bioretention surface area would be broken up to have no more than one basin for each 5 acres of total site area, another measure safeguarding against groundwater mounding. Also assumed was a square cell (i.e., W was computed as the square root of the surface area calculated according to the equation for A above). Horizontal hydraulic conductivites for loams such as represented among the B and C soils in the study regions tend to run in the range of 10 to 1000 meters/year (0.1 to 9 ft/day. A conservative value of 3 ft/day was used in the analysis.

The yearly rate of infiltration from a bioretention cell can be expressed in terms of volume of runoff per unit infiltrating surface area, acre-ft/acre-year, which is equivalent to K_v expressed as ft/year. The K_v value avoiding groundwater monitoring was therefore used to assess maximum annual infiltration capacity by multiplying by the total available pervious surface area. However, the K_v value was capped at a rate found in a study of infiltration capacity and benefits for Los Angeles' San Fernando Valley by Chralowicz et al. (2001). The Los Angeles study posited providing 0.1-0.5 acre for infiltration basins to serve each 5 acres of contributing drainage area. At 2-3 ft deep, it was estimated that such basins could infiltrate 0.90-1.87 acre-ft/year of runoff in San Fernando Valley conditions. Three types of soils predominate in the study area: sandy loams (35 percent of the area), a clay loam (23 percent), and a silty clay loam (29 percent). The balance of 13 percent includes small amounts at both ends of the textural spectrum, a clay and loamy sands. Infiltration rates are in the approximate range of 0.5-2.0 inches/hour, within the span generally regarded as ideal for successful infiltration without threatening groundwater. Computing the ratios of the rate and basin size data of Chralowicz et al. (2001), K_v maximized at approximately 20 acre-ft of runoff/acre infiltration surface-year under the most limiting conditions of soils and basin dimensions. This value was applied in this study if calculated rates were higher, another conservative feature to obtain the most realistic projections of infiltration potential.

In some cases analyzed, the maximum annual infiltration capacity was estimated at greater than post-development runoff volume production. In these instances complete retention would be possible with excess capacity left, and only a fraction of the available pervious area would have to be devoted to bioretention. That fraction was expressed as the ratio of annual runoff production to infiltration capacity.

STORMWATER RUNOFF VOLUME AND POLLUTANT DISCHARGES

Urban Land Use Pollutant Yields

Annual pollutant mass loadings prior to application of any stormwater management practices were estimated as the product of annual runoff volumes produced by the various land use and cover types and pollutant concentrations typical of those areas. General land use types (e.g., single-family residential, commercial) have typically been the basis for measuring and reporting stormwater pollutant data. However, an investigation of ARCD practices of the type of interest in this study demands data on specific land coverages. The literature offers few data on this basis. Those available and used herein were assembled by a consultant to the City of Seattle for a project in which the author participated. They appear in Attachment A (Herrera Environmental Consultants, Inc. undated). Table 7 summarizes the representative values used in the analysis.

Table 7. Pollutant Concentrations in Runoff from Developed Land Uses (after Herrera Environmental Consultants, Inc. undated)

Land Use	Total Suspended Solids (mg/L)	Total Copper (µg/L)	Total Zinc (µg/L)	Total Phosphorus (µg/L)
Residential roof	25	13	159	110
Commercial roof	18	14	281	140
Access road/driveway	120	22	118	660
Parking	75	36	97	140
Walkway	25	13	59	110
Landscaping	213	13	59	2040

Pollutant concentrations expected to occur typically in the mixed runoff from the several land use and cover types making up a development were estimated by mass balance; i.e., the concentrations from the different areas of the sites were combined in proportion to their contribution to the total runoff.

Estimating Retention

The principal interest of this study was to estimate how much of the post-development runoff volume for the various land use cases could be retained by ARCD measures and prevented from discharging from the site on the surface. The analyses initially evaluated the runoff volume that could potentially be infiltrated by using a portion or all of the available pervious area for bioretention facilities. In some instances judicious use of the pervious area could infiltrate the full volume. In other cases use of the pervious area for as much infiltration as possible plus special management of roof runoff would fully attenuate post-development runoff.

Complete retention would, of course, exceed any ordinary regulatory standard intended to govern discharge quantity and quality. To the extent that full retention could not be expected, the study was interested in assessing the degree to which bioretention and roof runoff management could meet the specific potential standards outlined earlier. Performance was estimated in terms of volume retained versus released, the extent to which pre-development groundwater recharge would be preserved, and the pollutant loading reduction accompanying volume retention in comparison to the quantities that would enter receiving waters with no stormwater management actions. These measures expressed in equation form are:

$$\text{Runoff retention (\%)} = \frac{(\text{Volume with no practices} - \text{Volume with ARCD practices})}{\text{Volume with no practices}} x100$$

(expresses amount of the theoretical maximum post-development runoff prevented from discharging by ARCD)

$$\text{Recharge retention (\%)} = [1 - \frac{(\text{Predevelopment recharge} - \text{Postdevelopment recharge with ARCD})}{\text{Predevelopment recharge}}]x100$$

Pre-development recharge = Rainfall volume – Predevelopment runoff volume

Post-development recharge = The smaller of rainfall volume or post-development infiltration volume

$$\text{Loading reduction (\%)} = \frac{(\text{Loading with no practices} - \text{Loading with ARCD practices})}{\text{Loading with no practices}} x100$$

It should be noted that runoff retention and recharge retention express different quantities and are not equal numerically.

When infiltration alone (Basic ARCD) could not accomplish full retention, roof runoff management strategies were selected as appropriate for the land use case (Full ARCD). For the retail commercial development (COMM), roof runoff management was assumed to be accomplished by harvesting, temporarily storing, and applying water to use in the building. To this end, the assumption was made that the commercial development would be able to manage and would have capacity to store and make use of the entire roof runoff volume. While this particular assumption is, on its own, speculative, the commercial development would, as discussed in the section on Application of ARCD Practices, earlier, see a reduction in runoff as a result of evapotranspiration, and would have the option to employ ARCD site design principles to reduce impervious surface area, to install a green roof to retain runoff, or to implement any of a number of other ARCD practices designed to reduce runoff volume and pollutant loading. As a result, the overall analysis of the commercial site remains conservative in its assessment of the potential to retain runoff onsite.

In the three multi-family and single-family residential cases it was assumed that the roof water would be dispersed on or within the pervious area according to accepted and standardized practices. For example, the Washington Department of Ecology's (2005) Stormwater Management Manual for Western Washington provides design criteria for two methods: splash blocks followed by vegetated dispersion areas and gravel-filled trenches. These devices can be used wherever space is sufficient regardless of infiltration rates, as they operate by evapotranspiration and slow infiltration. Even clay can infiltrate at an approximate rate of 0.2 inch/hour or higher (Leij et al. 1996; Pitt, Chen, and Clark 2002). Care was taken to assure that pervious area already allocated to infiltration would not also be counted upon for dispersion. While dispersion was assumed for simplification of the study analyses, in reality a site designer would have the option of using rain barrels, cisterns, and/or green roofs instead of or along with ground dispersion to manage roof water. Analyses for the final case, the redevelopment scenario (REDEV), assumed dispersion and/or small-scale harvesting of roof runoff above whatever level of infiltration could be accomplished given the soil condition.

Additional Analyses When Full Retention Cannot Be Expected

Retaining runoff from impervious and pollutant generating pervious surfaces is the best stormwater management policy, because it prevents the introduction of urban runoff pollutants

to receiving waters as well as serves quantity discharge control requirements. Maintaining pre-development peak flow rates, volumes, and elevated flow durations prevents stream channel and habitat damage, flooding, and loss of groundwater recharge. When conditions were expected to render full retention technically infeasible for the study cases, estimates were made of the volume and pollutant loadings that would be discharged assuming the remaining surface runoff is released to a receiving water with and without treatment. Treatment was assumed to be provided by bioretention discharging either directly on the surface or via an underdrain. While not as environmentally beneficial as retention, such treatment is superior to conventional stormwater management practices like ponds and sand filters. It captures pollutants through a number of mechanisms as contaminants are held for a time in the facility and contact vegetation and soil, such as sedimentation, filtration by plants, and adsorption and ion exchange in soil.

The effectiveness of bioretention in removing pollutants from surface runoff was estimated according to measurements by Chapman and Horner (2010). This study was performed on a linear bioretention device located on a slope and made up of a number of cells separated by weirs (termed a “cascade”). While an estimated 74 percent of all entering runoff infiltrated or evapotranspired before discharging, the flows reaching the end in the larger storms would have less residence time in the facility than in a unit on flat ground percolating water through soil before surface discharge via an underdrain. Therefore, pollutant concentrations exiting such a unit could be less yet. On the other hand, some bioretention facilities bypass the relatively rare higher flows, affording no treatment, while the cascade was designed to convey all runoff, even beyond its water quality design storm flow, and provide some treatment. On balance between the advantage and disadvantage of the facility providing the data, the discharge concentrations are considered to be representative of bioretention.

Chapman and Horner (2010) computed volume-weighted average discharge pollutant concentrations by multiplying concentrations times flow volumes for each monitored storm, summing, and dividing by total volume. The resulting values for the contaminants considered in this study are: total suspended solids (TSS)—30 mg/L, total copper—6.3 µg/L, total zinc—47 µg/L, and total phosphorus—133 µg/L. In a few instances these concentrations are higher than those in Table 7, an expression of the observation sometimes made in stormwater management that treatment cannot reduce concentrations in relatively “clean” flows below certain minimum values. In these situations the concentrations in Table 8 were also used in computing discharge loadings; i.e., no concentration reduction was applied in estimating discharge loadings, although flow volume would still be decreased to the extent infiltration could occur.

RESULTS OF THE ANALYSIS

ASSESSMENT OF MAXIMUM ARCD CAPABILITIES

Runoff Retention and Groundwater Recharge

Basic ARCD

One goal of this exercise was to determine if ARCD practices could eliminate post-development runoff production, and the pollutants it transports, and maintain pre-development groundwater recharge. The first assessment, termed the Basic ARCD analysis in this report, was to estimate if each site's pervious area is sufficient for full infiltration if given to this purpose to the extent necessary without compromising other uses. Accordingly, shallow, unobtrusive bioretention cells (i.e., rain gardens) are envisioned, dispersed through sites at no more than one for each 5 acres. It bears reemphasis that no credit was taken for water loss through evapotranspiration in this assessment, although a substantial, but not necessarily easily quantifiable, amount would undoubtedly occur. Estimates of runoff retention are therefore conservative.

Table 8 presents comparisons, for the Southeast climate region, between estimated annual runoff volumes generated before development and then post-development with and without Basic ARCD stormwater management. The table also gives annual groundwater recharge estimates for these same conditions.

Table 8. Runoff and Groundwater Recharge Volumes with Basic ARCD: Southeast Climate Region[a]

Period	Volume (acre-ft) or Percentage Measure	MFR	Sm-SFR	Lg-SFR	COMM	REDEV
B soil						
Pre-dev.	Runoff	0.046	0.013	0.56	0.022	0.001
	Recharge	44.7	12.4	539	21.2	0.51
Post-dev.	Runoff without stormwater practices	29.5	6.85	298	18.7	0.45
	Runoff retained with Basic ARCD	29.5	6.85	298	8.30	0.21
	Runoff released with Basic ARCD	0	0	0	10.4	0.25
	Runoff retention (%)	100%	100%	100%	44%	45%
	Recharge without stormwater practices	15.3	5.55	241	2.53	0.06
	Recharge with Basic ARCD	44.7	12.4	539	8.30	0.21
	Recharge retention (%)	100%	100	100%	39%	40%
	Pervious area needed (%)[b]	36%	22%	22%	100%	100%
D soil						
Pre-dev.	Runoff	13.5	3.76	163	6.43	0.16
	Recharge	31.2	8.64	376	14.8	0.36
Post-dev.	Runoff without stormwater practices	Full ARCD needed to maximize retention on D soil				
	Runoff retained with Basic ARCD					
	Runoff released with Basic ARCD					
	Runoff retention (%)					
	Recharge without stormwater practices	11.6	4.17	181	2.12	0.05
	Recharge with Basic ARCD	Full ARCD needed to maximize retention on D soil				
	Recharge retention (%)	37%	48%	48%	14%	14%
	Pervious area needed (%)[b]	Full ARCD needed to maximize retention on D soil				

[a] Pre-dev.—pre-development; post-dev.—post-development; ARCD—aquatic resources conservation design; MFR—multi-family residential; Sm-SFR—small-scale single-family residential; Lg-SFR—large-scale single-family residential; COMM—retail commercial; REDEV—infill redevelopment; Basic ARCD—infiltrating bioretention; runoff—quantity of water discharged from the site on the surface; recharge--quantity of water infiltrating the soil

[b] Proportion of the total pervious area on the site required for bioretention to achieve given results

In all cases the majority of the infiltration that would recharge groundwater in the undeveloped state would be lost to surface runoff after development. These losses would approach 90 percent in the most impervious developments. The greatly increased surface flow would raise peak flow rates and volumes in receiving water courses, increase flooding risk, and transport pollutants.

Basic ARCD could retain all post-development runoff and pre-existing groundwater recharge in the three residential cases on the B soils, using from less than one-fourth to just over one-third of the available pervious area for bioretention cells. Taking all available pervious area for the more highly impervious COMM and REDEV cases on B soil, bioretention would retain about 45 percent of the runoff generated and save about 40 percent of the pre-development recharge. To illustrate the relatively small role that slope increase from 5 to 10 percent plays in runoff retention, full retention would still be expected in the three residential cases and for the remaining two cases (COMM and REDEV) would decrease from 44-45 percent only slightly to 40-41 percent (not shown in table).

On the D soil, infiltrating bioretention may not be technically feasible and was not relied upon for retention estimates. Without the use of additional measures in the Full ARCD category, only incidental post-development runoff would be retained; and most pre-development recharge would be lost.

Tables 9-11 are companions to Table 8 for the South Central, Northeast – Upper Midwest, and Southwest climate regions, respectively. Results for the Northeast - Upper Midwest B soil are very close to those for the Southeast B soil, as would be expected given the similar precipitation quantities and soil characteristics. In the three regions having C soils, Basic ARCD can retain all runoff for the MFR, Sm-SFR, and Lg-SFR residential cases. With these soils, except in the Southwest, achieving full retention requires more of the available pervious area than with B soils, up to 69 percent, but is still fully attainable.

The effect of lower rainfall is evident in the South Central and, especially, the Southwest regions. In the latter location, not only the residential cases but also the COMM and REDEV scenarios can achieve full runoff retention with Basic ARCD on the C soil. The residential cases need much smaller percentages of the available pervious area for bioretention than for the same cases on C and even B soils elsewhere. Applying Basic ARCD to the South Central, C soil, REDEV case results in higher runoff retention than for the B soil cases in higher rainfall regions.

The study cases demonstrated two interesting points about groundwater recharge. First, with effective infiltrating bioretention it is possible for post-development annual recharge to exceed the pre-development quantity. This phenomenon is most evident in comparing the two amounts for cases with 100 percent runoff retention on C soils, which in the natural state produce much less recharge in relation to runoff than B soils. The B soils have a recharge-to-runoff ratio of about 500, whereas that ratio is only 4-6 for the C soils studied. One reason for higher post- compared to pre-development recharge is that bioretention is set up to hold water, increasing the time for infiltration to occur, instead of letting it run off. Another is that soils, especially in the C HSG, are often improved by organic amendments to yield both more water storage capacity and higher infiltration rates than the pre-existing soils.

A related point is that the percentage of pre-development recharge retained after development can be higher with C than B soils. This situation can best be seen in cases without full runoff retention, COMM and sometimes REDEV. In terms of recharge, installing bioretention conveys a greater advantage to the C than the B soils, which already have more pore space for water storage and higher infiltration and recharge rates.

Table 9. Runoff and Groundwater Recharge Volumes with Basic ARCD: South Central Climate Region[a]

Period	Volume (acre-ft) or Percentage Measure	MFR	Sm-SFR	Lg-SFR	COMM	REDEV
C soil						
Pre-dev.	Runoff	4.10	1.14	49.4	1.95	0.05
	Recharge	25.7	7.13	310	12.2	0.29
Post-dev.	Runoff without stormwater practices	21.2	5.15	224	12.7	0.31
	Runoff retained with Basic ARCD	21.2	5.15	224	4.33	0.21
	Runoff released with Basic ARCD	0	0	0	8.32	0.10
	Runoff retention (%)	100	100	100	34	67
	Recharge without stormwater practices	8.62	3.11	135	1.51	0.03
	Recharge with Basic ARCD	29.8	8.3	359	4.33	0.21
	Recharge retention (%)	100	100	100	38	70
	Pervious area needed (%)[b]	51	23	30	100	100
D soil						
Pre-dev.	Runoff	18.5	5.14	223	8.80	0.21
	Recharge	11.3	3.13	136	5.36	0.13
Post-dev.	Runoff without stormwater practices	Full ARCD needed to maximize retention on D soil				
	Runoff retained with Basic ARCD					
	Runoff released with Basic ARCD					
	Runoff retention (%)					
	Recharge without stormwater practices	7.23	7.59	112	1.35	0.03
	Recharge with Basic ARCD	Full ARCD needed to maximize retention on D soil				
	Recharge retention (%)	64	83	83	25	24
	Pervious area needed (%)[b]	Full ARCD needed to maximize retention on D soil				

Table 10. Runoff and Groundwater Recharge Volumes with Basic ARCD: Northeast – Upper Midwest Climate Region[a]

Period	Volume (acre-ft) or Percentage Measure	MFR	Sm-SFR	Lg-SFR	COMM	REDEV
B soil						
Pre-dev.	Runoff	0.04	0.01	0.54	0.02	0.001
	Recharge	42.9	11.9	517	20.4	0.49
Post-dev.	Runoff without stormwater practices	28.3	6.68	286	18.0	0.44
	Runoff retained with Basic ARCD	28.3	6.68	286	8.53	0.21
	Runoff released with Basic ARCD	0	0	0	9.43	0.23
	Runoff retention (%)	100	100	100	48	47
	Recharge without stormwater practices	14.6	5.32	231	2.42	0.06
	Recharge with Basic ARCD	42.9	11.9	517	8.53	0.21
	Recharge retention (%)	100	100	100	42	42
	Pervious area needed (%)[b]	34	21	21	100	100
C soil						
Pre-dev.	Runoff	7.87	2.18	94.8	3.74	0.09
	Recharge	35.1	9.72	422	16.6	0.40
Post-dev.	Runoff without stormwater practices	30.5	7.42	323	18.2	0.44
	Runoff retained with Basic ARCD	30.5	7.42	323	4.57	0.21
	Runoff released with Basic ARCD	0	0	0	13.6	0.24
	Runoff retention (%)	100	100	100	25	47
	Recharge without stormwater practices	12.4	4.48	195	2.17	0.05
	Recharge with Basic ARCD	42.9	11.9	517	4.57	0.21
	Recharge retention (%)	100	100	100	27	51
	Pervious area needed (%)[b]	69	31	40	100	100

Table 11. Runoff and Groundwater Recharge Volumes with Basic ARCD: Southwest Climate Region[a]

Period	Volume (acre-ft) or Percentage Measure	MFR	Sm-SFR	Lg-SFR	COMM	REDEV
C soil						
Pre-dev.	Runoff	1.62	0.45	19.5	0.77	0.02
	Recharge	7.22	2.00	87.0	3.43	0.08
Post-dev.	Runoff without stormwater practices	6.41	1.57	68.5	3.77	0.09
	Runoff retained with Basic ARCD	6.41	1.57	68.5	3.77	0.09
	Runoff released with Basic ARCD	0	0	0	0	0
	Runoff retention (%)	100	100	100	100	100
	Recharge without stormwater practices	2.43	0.88	38.1	0.43	0.01
	Recharge with Basic ARCD	8.84	2.45	107	4.20	0.10
	Recharge retention (%)	100	100	100	100	100
	Pervious area needed (%)[b]	12	5	7	69	44
D soil						
Pre-dev.	Runoff	4.47	1.24	53.8	2.12	0.05
	Recharge	4.37	1.21	52.7	2.08	0.05
Post-dev.	Runoff without stormwater practices	Full ARCD needed to maximize retention on D soil				
	Runoff retained with Basic ARCD					
	Runoff released with Basic ARCD					
	Runoff retention (%)					
	Recharge without stormwater practices	2.14	0.77	33.3	0.40	0.01
	Recharge with Basic ARCD	Full ARCD needed to maximize retention on D soil				
	Recharge retention (%)	49	63	63	19	18
	Pervious area needed (%)[b]	Full ARCD needed to maximize retention on D soil				

Full ARCD

Infiltration is one of a wide variety of ARCD-based source reduction techniques. Where site conditions such as soil quality or available area limit a site's infiltration capacity, other ARCD measures can enhance a site's runoff retention capability. Such practices can also be used where infiltration capacity is adequate, but the developer desires greater flexibility for land use on-site. Among those techniques, this study considered special management of roof water in those cases where bioretention could not infiltrate all post-development runoff.

Specifically, water harvesting for supply of irrigation and/or non-potable indoor uses was investigated for the retail commercial development. In residential cases with insufficient capacity for infiltrative bioretention but remaining space not already devoted to infiltration, efficiently directing roof runoff into the soil through downspout dispersion systems was the method of choice. Such cases invariably occurred with HSG D soils. The Full-ARCD scenario applied to the redevelopment case was roof water dispersion, harvesting, or a combination of the two practices. Generally speaking, infiltration consumed all available pervious area in the REDEV cases on B and C soils, making roof runoff harvesting the mechanism to retain more water. With no bioretention facility on D soil, the pervious area would be available for dispersion. Of course, harvesting could be applied instead of or along with dispersion. Again, it was assumed that that the commercial and, as needed, redevelopment sites had capacity to harvest and make use of the full volume of roof runoff generated, however, the analysis remains conservative in terms of the potential for onsite retention as it does not consider the use of ARCD site design principles to reduce impervious surfaces, green roofs, and evaporation/evapotranspration from surfaces other than rooftops.

Table 12 gives Southeast climate region results with the addition of Full ARCD techniques: roof runoff management, consisting of harvesting for reuse in the COMM case, dispersion on or within pervious land for the three residential cases, and a combination of these measures for REDEV. On the B soil runoff retention would approximately double for the retail commercial

land use and reach 100 percent for the redevelopment. Groundwater recharge would not be expected to increase over the Basic ARCD case, though; because harvesting still keeps water out of the soil system.

For development on the D soil, use of roof runoff management techniques was estimated to increase runoff retention from zero to about one-third to two-thirds of the post-development runoff generated, depending on the land use case. Groundwater recharge would not materially benefit, however; because harvest does not contribute to it. Also, no recharge credit was taken for dispersion, since infiltration is restricted and loss by ET would tend to occur before infiltration. Some small amount of recharge would still be likely though. To illustrate further the small role of topography, in this D soil, Full ARCD scenario runoff retention is forecast to decrease by only 1-2 percent at a 10 percent slope compared to a 5 percent slope (not shown in table).

Table 12. Runoff and Groundwater Recharge Volumes with Full ARCD: Southeast Climate Region[a]

Period	Volume (acre-ft) or Percentage Measure	MFR	Sm-SFR	Lg-SFR	COMM	REDEV
B soil						
Pre-dev.	Runoff	0.046	0.013	0.56	0.022	0.001
	Recharge	44.7	12.4	539	21.2	0.51
Post-dev.	Runoff without stormwater practices	Complete retention possible with Basic ARCD			18.7	0.45
	Runoff retained with Full ARCD				16.1	0.45
	Runoff released with Full ARCD				2.66	0
	Runoff retention (%)				86%	100%
	Recharge without stormwater practices				2.53	0.06
	Recharge with Full ARCD				8.30	0.21
	Recharge retention (%)				39%	40%
	Pervious area needed (%)[b]				100%	100%
D soil						
Pre-dev.	Runoff	13.5	3.76	163	6.43	0.16
	Recharge	31.2	8.64	376	14.8	0.36
Post-dev.	Runoff without stormwater practices	33.1	8.23	358	19.1	0.46
	Runoff retained with Full ARCD	16.4	3.11	135	7.76	0.31
	Runoff released with Full ARCD	16.7	5.12	222	11.4	0.16
	Runoff retention (%)	50%	38%	38%	41%	66%
	Recharge without stormwater practices	11.6	4.17	181	2.12	0.05
	Recharge with Full ARCD	11.6	4.17	181	2.12	0.05
	Recharge retention (%)	37.2%	48.3%	48.3%	14.3%	13.6%
	Pervious area needed (%)[b]	100%	100%	100%	100%	100%

[a] Pre-dev.—pre-development; post-dev.—post-development; ARCD—aquatic resources conservation design; MFR—multi-family residential; Sm-SFR—small-scale single-family residential; Lg-SFR—large-scale single-family residential; COMM—retail commercial; REDEV—infill redevelopment; Full ARCD—infiltrating bioretention, roof runoff harvesting, and/or roof runoff dispersion; runoff—quantity of water discharged from the site on the surface; recharge--quantity of water infiltrating the soil

[b] Proportion of the total pervious area on the site required for bioretention to achieve given results

Tables 13-15 give data analogous to Table 12 for the South Central, Northeast – Upper Midwest, and Southwest climate regions, respectively. Results are similar to those reported for the Southeast region. Full ARCD can approximately double runoff retention from the Basic ARCD level for the COMM case and extend runoff retention to 100 percent for the redevelopment on both B and C soils. Once again, application of Full ARCD to the D soil cases increases runoff retention from zero to one-third to two-thirds of the volume produced, depending on land use case.

Table 13. Runoff and Groundwater Recharge Volumes with Full ARCD: South Central Climate Region[a]

Period	Volume (acre-ft) or Percentage Measure	MFR	Sm-SFR	Lg-SFR	COMM	REDEV
C soil						
Pre-dev.	Runoff	4.10	1.14	49.4	1.95	0.05
	Recharge	25.7	7.13	310	12.2	0.29
Post-dev.	Runoff without stormwater practices	Complete retention possible with Basic ARCD			12.7	0.31
	Runoff retained with Full ARCD				9.51	0.31
	Runoff released with Full ARCD				3.15	0
	Runoff retention (%)				75	100
	Recharge without stormwater practices				1.51	0.03
	Recharge with Full ARCD				4.33	0.21
	Recharge retention (%)				35	72
	Pervious area needed (%)[b]				100	100
D soil						
Pre-dev.	Runoff	18.5	5.14	223	8.80	0.21
	Recharge	11.3	3.13	136	5.36	0.13
Post-dev.	Runoff without stormwater practices	22.6	5.68	247	12.8	0.31
	Runoff retained with Full ARCD	11.0	2.08	90.3	5.17	0.20
	Runoff released with Full ARCD	11.6	3.60	157	7.63	0.11
	Runoff retention (%)	49	37	37	40	66
	Recharge without stormwater practices	7.23	2.59	112	1.35	0.03
	Recharge with Full ARCD	7.23	2.59	112	1.35	0.03
	Recharge retention (%)	64	83	83	25	24
	Pervious area needed (%)[b]	100	100	100	100	100

Table 14. Runoff and Groundwater Recharge Volumes with Full ARCD: Northeast – Upper Midwest Climate Region[a]

Period	Volume (acre-ft) or Percentage Measure	MFR	Sm-SFR	Lg-SFR	COMM	REDEV
B soil						
Pre-dev.	Runoff	0.04	0.01	0.54	0.02	0.001
	Recharge	42.9	11.9	51.7	20.4	0.49
Post-dev.	Runoff without stormwater practices	Complete retention possible with Basic ARCD			18.0	0.44
	Runoff retained with Full ARCD				16.0	0.44
	Runoff released with Full ARCD				2.00	0
	Runoff retention (%)				89	100
	Recharge without stormwater practices				2.42	0.06
	Recharge with Full ARCD				8.53	0.21
	Recharge retention (%)				42	43
	Pervious area needed (%)[b]				100	100
C soil						
Pre-dev.	Runoff	7.87	2.18	94.8	3.74	0.09
	Recharge	35.1	9.72	422	16.6	0.40
Post-dev.	Runoff without stormwater practices	Complete retention possible with Basic ARCD			18.2	0.44
	Runoff retained with Full ARCD				12.0	0.44
	Runoff released with Full ARCD				6.19	0
	Runoff retention (%)				66	100
	Recharge without stormwater practices				2.17	0.05
	Recharge with Full ARCD				4.57	0.21
	Recharge retention (%)				28	43
	Pervious area needed (%)[b]				100	100

Table 15. Runoff and Groundwater Recharge Volumes with Full ARCD: Southwest Climate Region[a]

Period	Volume (acre-ft) or Percentage Measure	MFR	Sm-SFR	Lg-SFR	COMM	REDEV
C soil						
Pre-dev.	Runoff	1.62	0.45	19.5	0.77	0.02
	Recharge	7.22	2.00	87.0	3.43	0.08
Post-dev.	Runoff without stormwater practices	Complete retention possible with Basic ARCD				
	Runoff retained with Full ARCD					
	Runoff released with Full ARCD					
	Runoff retention (%)					
	Recharge without *stormwater* practices					
	Recharge with Full ARCD					
	Recharge retention (%)					
	Pervious area needed (%)[b]					
D soil						
Pre-dev.	Runoff	4.47	1.24	53.8	2.12	0.05
	Recharge	4.37	1.21	52.7	2.08	0.05
Post-dev.	Runoff without stormwater practices	6.70	1.68	73.2	3.80	0.09
	Runoff retained with Full ARCD	3.25	0.62	26.8	1.53	0.06
	Runoff released with Full ARCD	3.45	1.07	46.5	2.26	0.03
	Runoff retention (%)	49	37	37	40	66
	Recharge without stormwater practices	2.14	0.77	33.3	0.40	0.01
	Recharge with Full ARCD	2.14	0.77	33.3	0.40	0.01
	Recharge retention (%)	49	63	63	19	18
	Pervious area needed (%)[b]	100	100	100	100	100

Pollutant Loading Reductions

The examination of maximum ARCD capabilities considered the reductions of annual mass loadings of four water pollutants that would accompany runoff retention. Since retention means no surface discharge, these loading reductions are, at a minimum, equal to the percentages of runoff retention. In those cases with less than full runoff retention, there is good reason to expect pollutant loading reductions higher than the percentage of runoff retained. The early runoff ("first flush"), occurring when the soils are least saturated, is more likely to be retained than later runoff. It is frequently observed that the first flush has higher pollutant concentrations than later runoff, particularly in the wash off after relatively extended dry periods.

For the B and D soil and the residential cases on C soils, the reductions were very consistent among regions:

- B and C soils, Basic ARCD, residential cases—100%;
- B soil, Basic ARCD, COMM and REDEV cases—44-45%;
- B soil, Full ARCD, COMM and REDEV cases—86-100%;
- D soil, Full ARCD, SFR and COMM cases—38-41%;
- D soil, Full ARCD, MFR case—50%; and
- D soil, Full ARCD, REDEV case—66%.

For the most highly impervious cases, COMM and REDEV, on C soils reduction was variable and dependent on precipitation. With Basic ARCD the range was from 25 to 100 percent, going from relatively high to low precipitation. Full ARCD is expected to raise the lowest reductions to 100 percent for REDEV and at least 66 percent for COMM.

Therefore, taking the greatest advantage of what ARCD offers could prevent the addition to receiving waters of all or almost all pollutant mass that would otherwise discharge from a range

of urban developments on B and C soils. With D soils, Full ARCD can accomplish loading reductions approaching or somewhat exceeding 50 percent.

ABILITY TO MEET POTENTIAL STANDARDS

General Summary

This section evaluates the ability of the Basic and Full ARCD strategies to meet each of the five potential stormwater management standards enumerated in the beginning of the report. It also examines the extent of pollutant loading reduction if the standards are just met; i.e., if runoff is retained at the minimum needed to meet the standard. It has already been demonstrated that retention of all post-development runoff and full pollutant attenuation is possible in some circumstances. Table 16 summarizes the results for all regions and cases and both ARCD strategies.

Ability to Meet Standards

The projected ability to meet the standards overall varies mostly in relation to soil type (B or C versus D) and the relative imperviousness of development, and much less across climate regions. The one exception to this generality is that implementing Basic ARCD practices on the Southwest region C soil would meet all five standards. This uniformity does not occur elsewhere on either B or C soils, and is apparently primarily a function of the relatively low precipitation in the region.

Setting aside the Southwest region, success in complying with standards is mostly comparable among the various B and C soils, with a small number of instances where a development type meets a standard on B but not on C soil. Basic ARCD methods invariably can meet all standards on B and C soils for the residential development cases (MFR and Sm- and Lg-SFR). Full ARCD practices are forecast to meet all standards for the redevelopment case on B soils but only standards 1 and 5 consistently on C soils. The combination of infiltration and roof runoff management applied to the retail commercial development allows meeting these same two standards on B soils but only the latter on both of the C soils occurring outside the Southwest region. The only standards that cannot be met on B and C soils by the ARCD methods considered are standards 2-4 for the COMM case. Therefore, of the 125 standards assessments, ARCD practices are projected to meet 113 (90.4 percent) with B and C soils.

The ability to meet these standards is much reduced on D soils. Standard 1 can be met occasionally with Full ARCD used in the redevelopment. All cases with Full ARCD comply with standard 4 on this soil where pre-development runoff is estimated to be relatively high, reflecting a low overall requirement for retention volume. Standard 5 can be met with Full ARCD with the exception of one COMM case. Standards 2 and 3 were never estimated to be met in any D soil case. All in all, with this soil 26 of the 75 scenarios (34.7 percent) are expected to meet a standard.

Table 16. Ability to Meet Potential Regulatory Standards with Basic/Full ARCD Practices

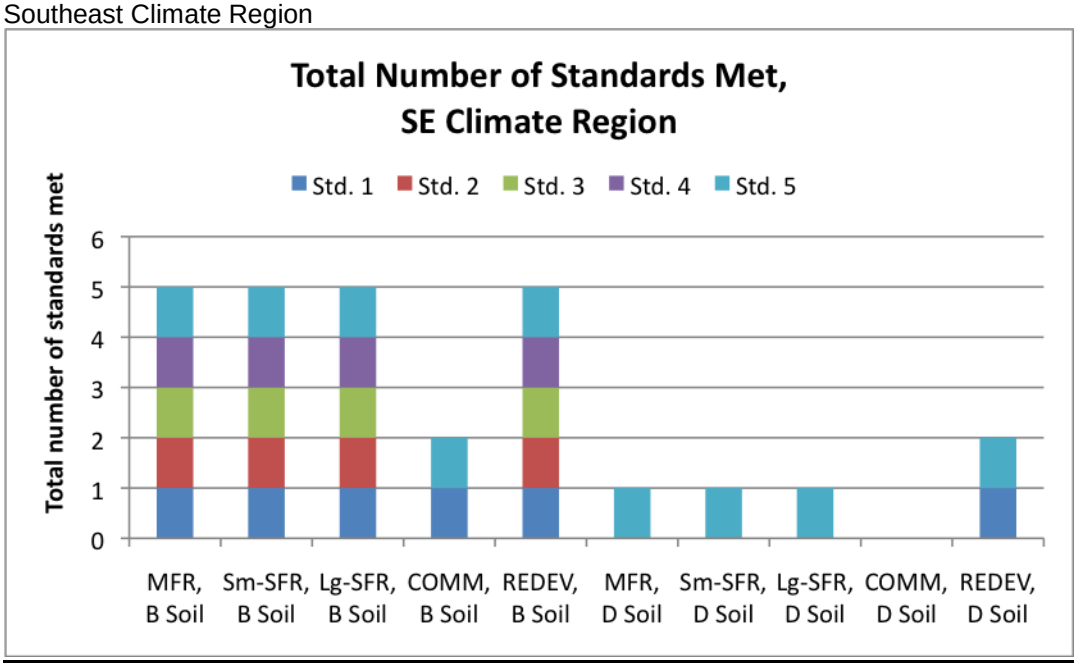
Region-Case[a]	Standards Met—Basic ARCD[b]	Standards Met—Full ARCD[b]	Runoff Retention and Pollutant Loading Reduction (%)[b, c]				
			Std. 1	Std. 2	Std. 3	Std. 4	Std. 5
SE(B)-MFR	1, 2, 3, 4, 5		63	87	90	>99	63
Sm-SFR	1, 2, 3, 4, 5		63	87	90	>99	63
Lg-SFR	1, 2, 3, 4, 5		63	87	90	>99	63
COMM		1, 5	63	86	86	86	63
REDEV		1, 2, 3, 4, 5	63	87	90	>99	63
SE(D)-MFR		5	50	50	50	50	37
Sm-SFR		5	38	38	38	38	34
Lg-SFR		5	38	38	38	38	34
COMM			41	41	41	41	41
REDEV		1, 5	63	66	66	66	42
SC(C)-MFR	1, 2, 3, 4, 5		58	82	90	81	47
Sm-SFR	1, 2, 3, 4, 5		58	82	90	78	45
Lg-SFR	1, 2, 3, 4, 5		58	82	90	78	45
COMM		1, 5	58	75	75	75	49
REDEV		1, 2, 3, 4, 5	58	82	90	84	49
SC(D)-MFR		4, 5	49	49	49	18	10
Sm-SFR		4, 5	37	37	37	10	6
Lg-SFR		4, 5	37	37	37	10	6
COMM		4, 5	40	40	40	31	18
REDEV		1, 4, 5	58	66	66	32	18
NM(B)-MFR	1, 2, 3, 4, 5		81	89	90	>99	81
Sm-SFR	1, 2, 3, 4, 5		81	89	90	>99	81
Lg-SFR	1, 2, 3, 4, 5		81	89	90	>99	81
COMM		1, 2, 5	81	89	89	89	81
REDEV		1, 2, 3, 4, 5	81	89	90	>99	81
NM(C)-MFR	1, 2, 3, 4, 5		81	89	90	74	60
Sm-SFR	1, 2, 3, 4, 5		81	89	90	71	57
Lg-SFR	1, 2, 3, 4, 5		81	89	90	71	57
COMM		5	66	66	66	66	64
REDEV		1, 2, 3, 4, 5	81	89	90	80	64
SW(C)-MFR	1, 2, 3, 4, 5		62	83	90	75	46
Sm-SFR	1, 2, 3, 4, 5		62	83	90	72	44
Lg-SFR	1, 2, 3, 4, 5		62	83	90	72	44
COMM	1, 2, 3, 4, 5		62	83	90	80	49
REDEV	1, 2, 3, 4, 5		62	83	90	80	49
SW(D)-MFR		4, 5	49	49	49	33	21
Sm-SFR		4, 5	37	37	37	27	16
Lg-SFR		4, 5	37	37	37	27	16
COMM		5	40	40	40	40	27
REDEV		1, 4, 5	62	66	66	44	28

[a] Region (hydrologic soil group)—land use; regions: SE—Southeast, SC—South-central, NM—Northeast-Upper Midwest, SW—Southwest; land uses: MFR—multi-family residential, Sm-SFR—small single-family residential, Lg-SFR--large single-family residential, COMM—retail commercial, REDEV--redevelopment

[b] Standard (Std.) 1—Retain the runoff produced by the 85th percentile, 24-hour precipitation event
Standard 2—Retain the runoff produced by the 95th percentile, 24-hour precipitation event
Standard 3—Retain 90 percent of the average annual post-development runoff volume
Standard 4—Retain the difference between the post- and pre-development average annual runoff volumes
Standard 5—Retain the difference between the post- and pre-development runoff volumes for all events up to and including the 85th percentile, 24-hour precipitation event

[c] Reduction estimated to result from meeting the standard, to the extent it can be met (fully met if so indicated in preceding columns), without treatment of remaining discharge. Where a standard can be met using Basic or Full ARCD application it is indicated in black, where a standard cannot be met using Basic or Full ARCD it is highlighted red.

Figure 4a. Ability to Meet Potential Regulatory Standards with Basic/Full ARCD Practices for Southeast Climate Region



MFR—multi-family residential, Sm-SFR—small single-family residential, Lg-SFR--large single-family residential, COMM—retail commercial, REDEV—redevelopment. Standard (Std.) 1—Retain the runoff produced by the 85th percentile, 24-hour precipitation event; Standard 2—the 95th percentile, 24-hour precipitation event; Standard 3—90 percent of the average annual post-development runoff volume; Standard 4—the difference between the post- and pre-development average annual runoff volumes; and, Standard 5—the difference between the post- and pre-development runoff volumes for all events up to and including the 85th percentile, 24-hour precipitation event

Figure 4b. Ability to Meet Potential Regulatory Standards with Basic/Full ARCD Practices for South Central Climate Region

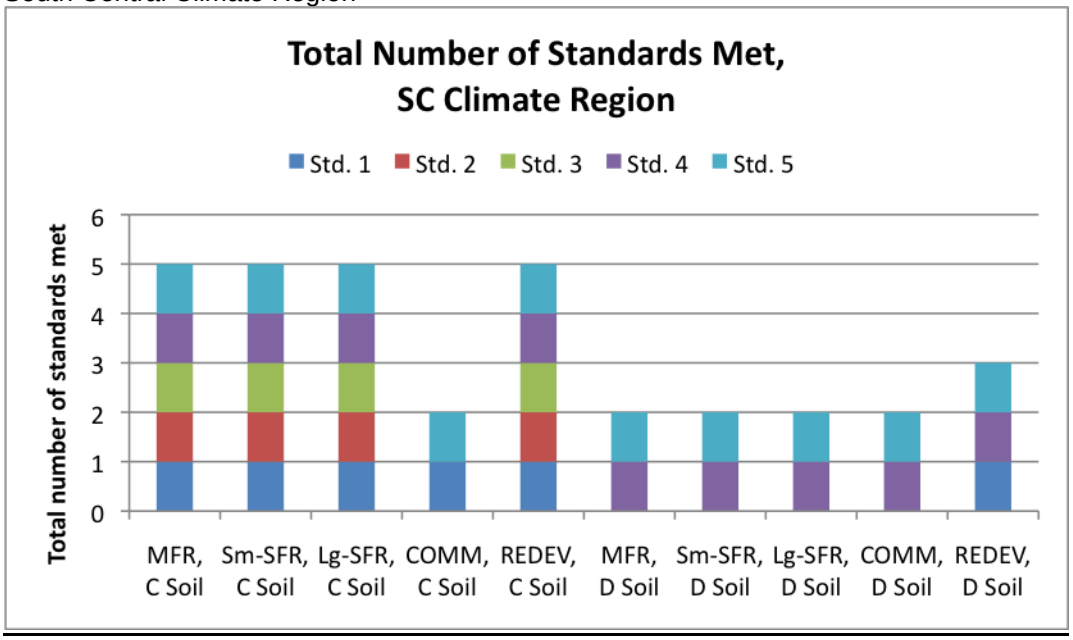


Figure 4c. Ability to Meet Potential Regulatory Standards with Basic/Full ARCD Practices for Northeast-Midwest Climate Region

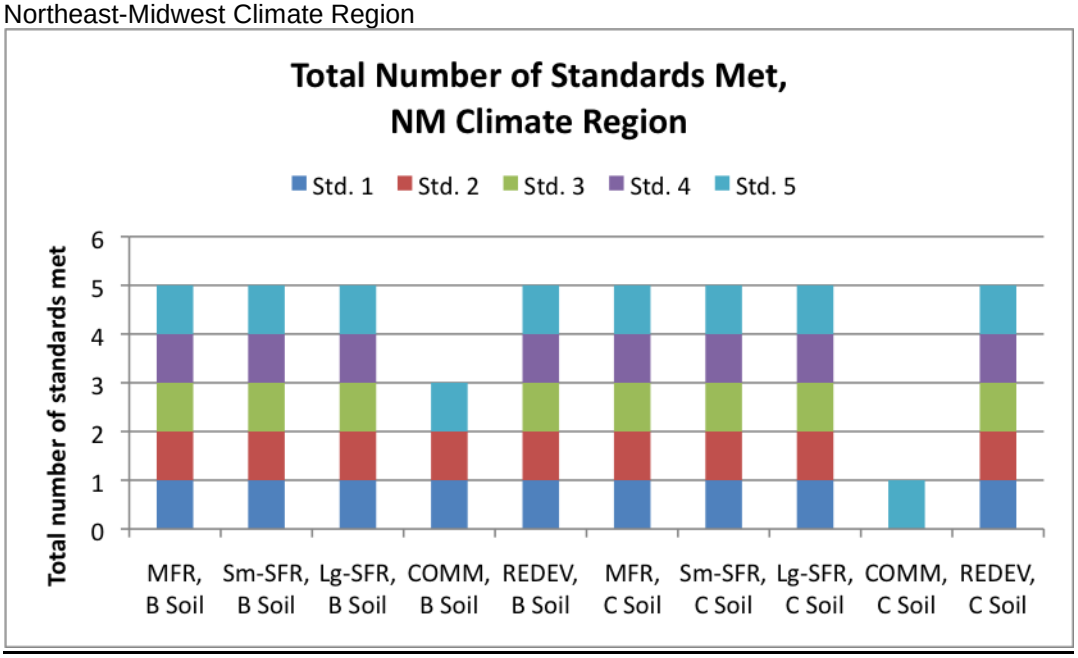


Figure 4d. Ability to Meet Potential Regulatory Standards with Basic/Full ARCD Practices for Southwest Climate Region

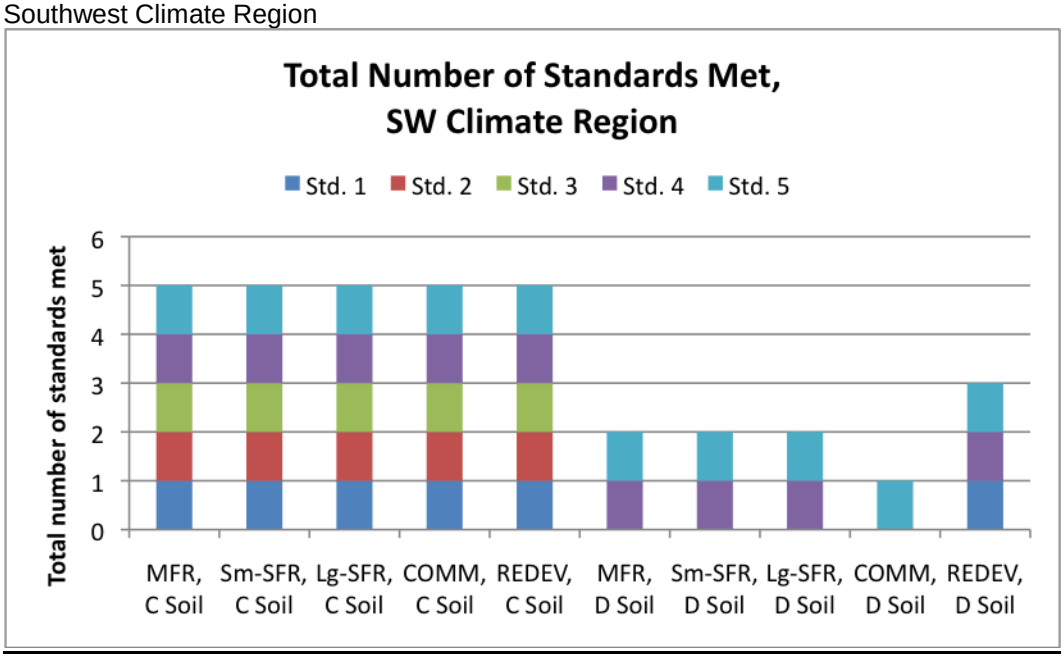
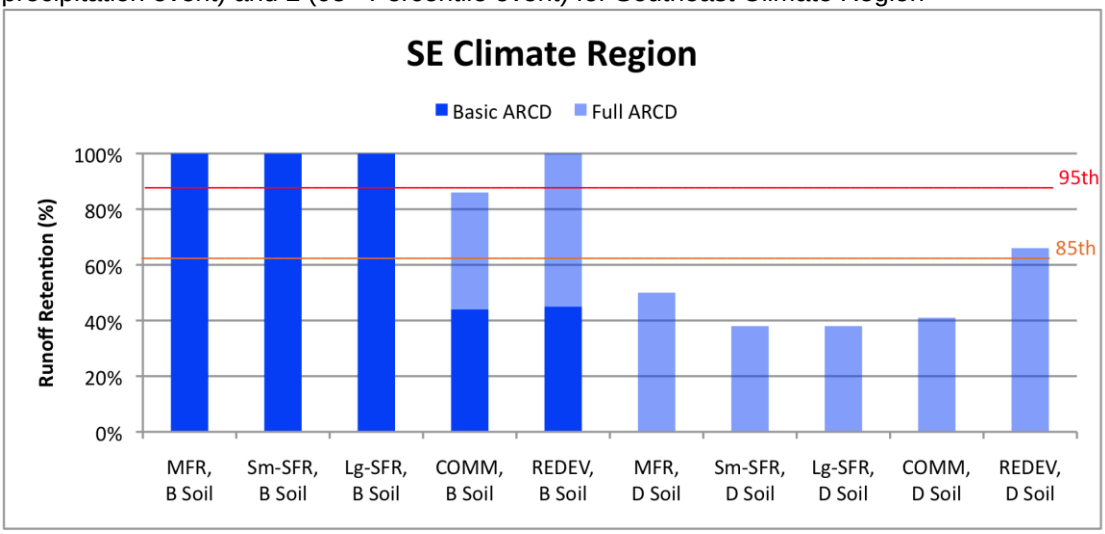


Figure 5a. Percentage of Runoff Retained Relative to Standards 1 (85th Percentile, 24-hour precipitation event) and 2 (95th Percentile event) for Southeast Climate Region



MFR—multi-family residential, Sm-SFR—small single-family residential, Lg-SFR--large single-family residential, COMM—retail commercial, REDEV—redevelopment. Standard (Std.) 1—Retain the runoff produced by the 85th percentile, 24-hour precipitation event; Standard 2—the 95th percentile, 24-hour precipitation event; Standard 3—90 percent of the average annual post-development runoff volume; Standard 4—the difference between the post- and pre-development average annual runoff volumes; and, Standard 5—the difference between the post- and pre-development runoff volumes for all events up to and including the 85th percentile, 24-hour precipitation event

Figures 5a-d show the percentage of runoff that can be retained for each development type, in each region, using either Basic or Full ARCD practices, in comparison with Standard 1 (retention of the 85th percentile, 24-hour precipitation event) and Standard 2 (retention of the 95th percentile, 24 hour event). Even where Standards 1 and 2 cannot be met in full, ARCD practices can still result in substantial compliance, and retention of significant runoff volume.

Figure 5b. Percentage of Runoff Retained Relative to Standards 1 (85th Percentile, 24-hour precipitation event) and 2 (95th Percentile event) for South Central Climate Region

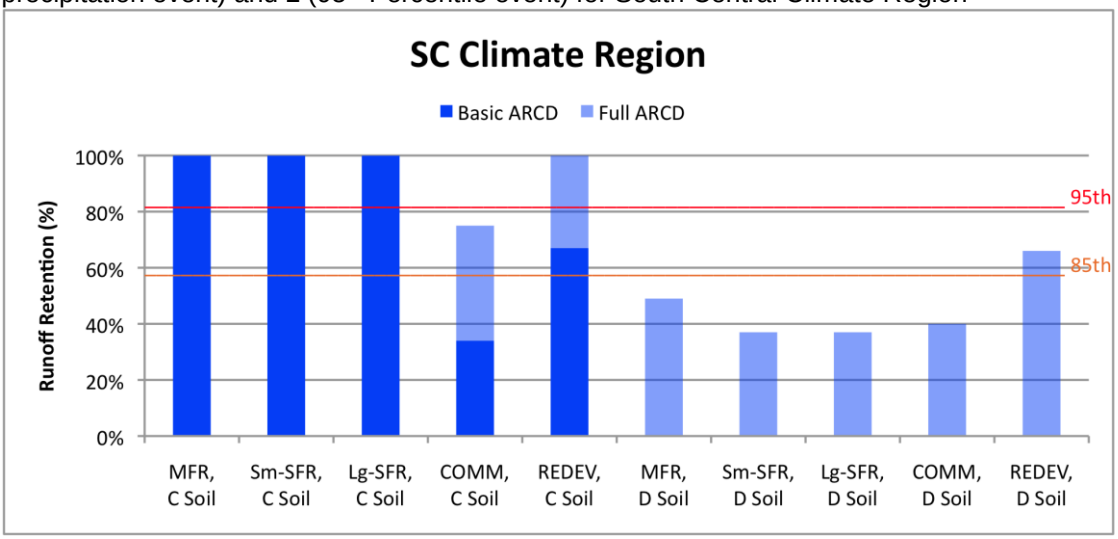


Figure 5c. Percentage of Runoff Retained Relative to Standards 1 (85th Percentile, 24-hour precipitation event) and 2 (95th Percentile event) for Northeast-Midwest Region

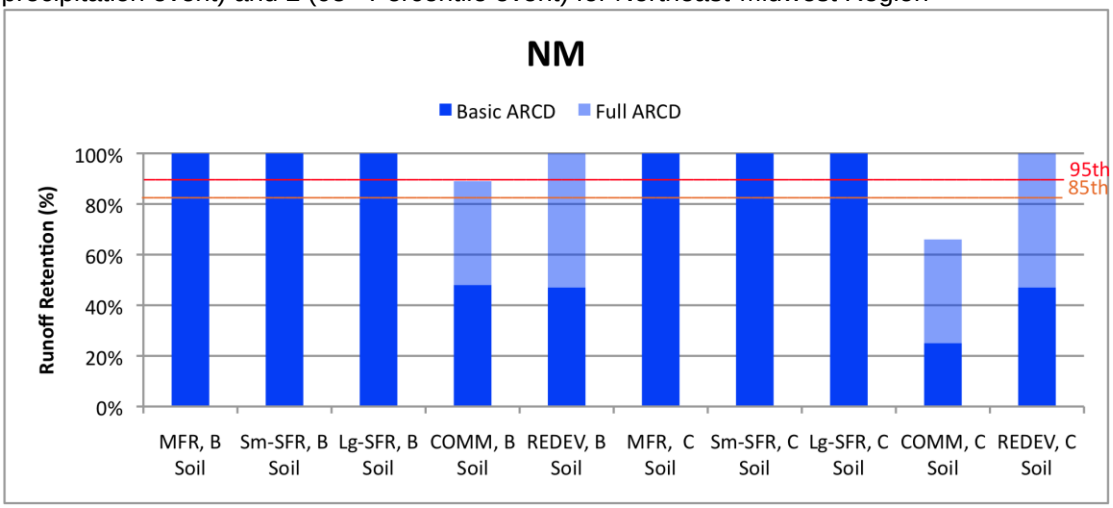
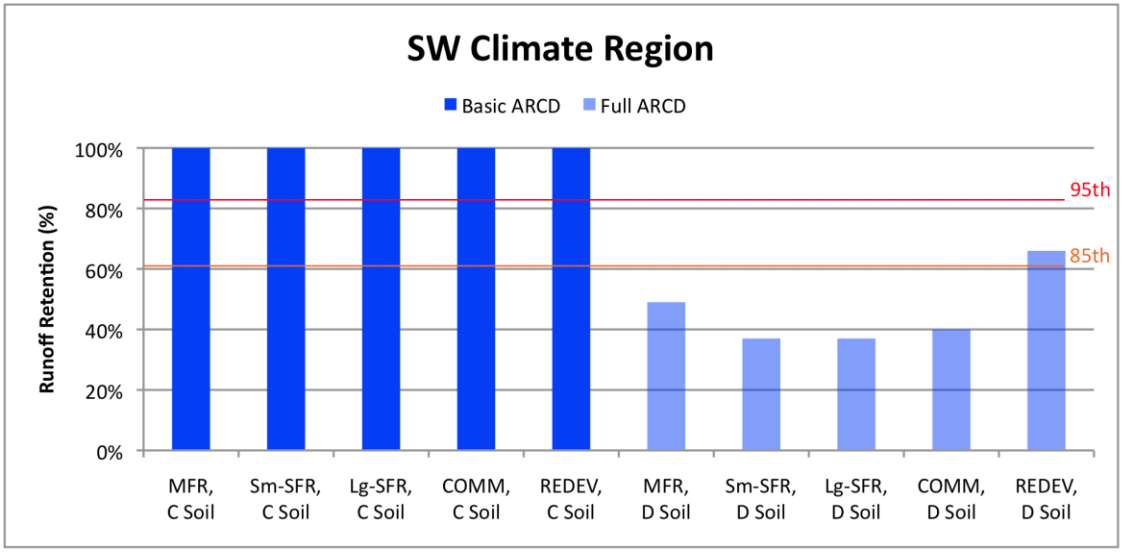


Figure 5d. Percentage of Runoff Retained Relative to Standards 1 (85th Percentile, 24-hour precipitation event) and 2 (95th Percentile event) for Southwest Region



Effectiveness of Standards in Environmental Protection

Standard 3 (retain 90 percent of the average annual post-development runoff volume) would be the most protective standard. Meeting or coming as close as possible to meeting, but not exceeding, this standard is estimated to lead to 66-90 percent runoff retention and pollutant loading reduction on B and C soils and 37-66 percent on D soil. Standard 2 (retain the runoff produced by the 95th percentile, 24-hour precipitation event) would yield only slightly less protection with B and C soils and, with D soil, retention and loading reduction equivalent to standard 3.

Standards 4 and 5, based on the differential between pre- and post-development runoff volume, are highly inconsistent in retaining runoff and reducing pollutants, in that they are relatively protective where pre-development runoff is estimated to be very low relative to post-development flow, but result in progressively lower retention and pollutant loading reduction as pre- and post-development volumes converge, such as in several cases on D soils. Standard 5 is especially weak in this regard. The potentially low level of retention and pollutant loading reduction renders these standards based on the change in pre- versus post-development runoff volume poor candidates for national application, at least as formulated in these terms.

Fully meeting standard 1 (retain the runoff produced by the 85th percentile, 24-hour precipitation event) would yield runoff retention and pollutant mass reduction ranging from 58 to 81 percent, depending on climate region. This level of inconsistency decreases the utility of this standard for widespread use. Standard 2, based on the 95th percentile event, is much better in this respect, with variability in runoff retention and loading reduction across the nation in the much narrower 82-89 percent range. However, standard 1 remains more consistent across regions, and more protective of water quality for development on D soils than either standard 4 or 5, and is preferable to those standards in this regard.

In summary, standards 2 and 3 are clearly superior to the other three options. Standard 3 is entirely consistent from place to place in degree of environmental protection, and standard 2 does not deviate much. Analysis of the five development cases on two soil groups in each of four regions demonstrated the two standards are virtually identical in the runoff retention and pollutant loading reduction they would bring about.

Management or Runoff in Excess of Standards Requirements

All of the analysis reported above assumed that any remaining runoff after the application of ARCD and meeting, or coming as close as possible to meeting a standard, would discharge with no treatment. In fact, additional treatment could further decrease pollutant loadings. Treatment without further runoff retention could be accomplished by many conventional or ARCD methods designed to lower contaminant concentrations. The most effective of the alternatives is probably bioretention discharging non-retained runoff either on the surface or through an underdrain, assumed in the analysis conducted for this study according to the methods cited above. Treatment of all remaining runoff with underdrained bioretention cells where space remains but all infiltration capacity is used can raise the pollutant removals given in Table 16 to the levels in Table 17. These estimates apply to the four pollutants considered, TSS and total copper, zinc, and phosphorus. Space would most likely be available in the three MFR and SFR cases but not the COMM and REDEV scenarios.

While there is substantial variability in these results, they demonstrate that discharging effluent of relatively consistent, high quality can be accomplished with a comprehensive ARCD strategy. This strategy would embrace, first, retaining as much urban runoff as possible and then utilizing treatment based on soil and vegetative media to capture contaminants from the remainder.

Table 17. Estimated Pollutant Loading Reduction Benefits of Bioretention Treatment of Runoff Remaining After ARCD Implemented to Meet or Approach Standards

Range of Table 16 Values (%)	Approximate Pollutant Removal Increase (%)	Total Estimated Pollutant Removal Range (%)
35-45	30-45	65-90
45-55	25-35	70-90
55-65	20-30	75-95
65-75	15->20	80->95
75-85	10->15	85->95
>85	5->10	90->95

SUMMARY AND CONCLUSIONS

STUDY DESIGN

This study was performed to investigate the degree to which low-impact development ARCD practices can meet or exceed the requirements of various potential stormwater management facility design standards and the resulting environmental benefits. The investigation was performed by estimating the stormwater retention possible with full application of ARCD practices to five land use cases in four representative climatic regions in the United States on two prominent soil types in each region. Retention is defined as preventing the conversion of precipitation to surface runoff. Retaining runoff from impervious and pollutant generating pervious surfaces prevents the introduction of urban runoff pollutants to receiving waters as well as reduces runoff volume to prevent stream channel and habitat damage, flooding, and loss of groundwater recharge. Infiltrating bioretention was first applied in the analysis of each case, a strategy termed Basic ARCD. When Basic ARCD could not fully retain post-development runoff, a Full ARCD strategy was added, involving roof runoff harvesting in the most impervious development cases and roof water dispersion in those with substantial pervious area. Benefits were assessed with respect to reduction of the annual average surface runoff volume from the quantity estimated without any stormwater management practices, and associated maintenance of pre-development groundwater recharge and water quality improvement through preventing discharge to receiving waters of pollutants generated with developed land uses.

A number of conservative assumptions were built into the analysis to ensure that the capabilities and benefits of ARCD would not be over-estimated. In summary, these assumptions are:

- No retention credit for evapotranspiration in the Basic ARCD strategy, although generally a substantial amount would occur, and consideration of evapotranspiration only for roof runoff in the Full ARCD strategy;

- Letting aside many available ARCD practices and site design principles that could be employed to reduce the runoff quantity, and the pollutants it transports, by reducing impervious surface area or directing the runoff to bioretention, harvesting, and dispersion facilities;

- The assumption of no infiltration on hydrologic soil group D soils, although some infiltration occurs at finite rates even on clay;

- Application of a safety factor to estimated infiltration rates;

- Minimum bioretention cell depths, so that these facilities would not be disruptive to site design and could be put to other uses;

- Requiring a 48-hour drawdown time for bioretention, instead of the 72-hour maximum;

- An analysis to guard against groundwater mounding under bioretention cells, with conservative assumptions for horizontal and vertical hydraulic conductivity rates; and

- An analysis demonstrating that doubling topographic slope changes results by only a few percent.

CAPABILITIES OF FULL ARCD APPLICATION

Comparison of estimated runoff production in the pre- and post-development states demonstrated that the majority of the infiltration that would recharge groundwater in the undeveloped state would be lost to surface runoff after development with no stormwater management practices. These losses would approach 90 percent in the most impervious developments. These observations apply in in all climate regions and with the full range of soil conditions.

Basic ARCD could retain all post-development runoff and pre-existing groundwater recharge, as well as attenuate all pollutant transport, in the three residential cases on B soils in the two climate regions where these soils were analyzed. Bioretention cells to accomplish this retention would use from less than one-fourth to just over one-third of the available pervious area for infiltration. Taking all available pervious area for the more highly impervious COMM and REDEV cases, bioretention would retain about 45 percent of the runoff and pollutants generated and save about 40 percent of the pre-development recharge. Adding Full ARCD measures in these cases would approximately double retention and pollutant reduction for the retail commercial land use and raise it to 100 percent for the redevelopment. Groundwater recharge would not increase, however, because the additional retention is accomplished by harvesting or dispersion.

In the three regions having C soils, Basic ARCD can again retain all runoff and reduce urban runoff pollutant mass loading to zero for the MFR and Sm-SFR and Lg-SFR residential cases, although generally requiring more of the available pervious area to do so than in B soil cases. The effect of lower rainfall is evident in the South Central and, especially, the Southwest regions. In the latter location, not only the residential cases but also the COMM and REDEV scenarios can achieve full runoff and groundwater recharge retention and pollutant loading attenuation with Basic ARCD on C soil. Full ARCD can approximately double runoff retention and pollutant removal from the Basic ARCD level for the COMM case and extend these measures to 100 percent for the redevelopment.

For development on the D soils in all climate regions, use of roof runoff management techniques was estimated to increase runoff retention and pollutant reduction from zero to between about one-third to two-thirds of the post-development runoff generated, depending on the land use case. These strategies would offer little groundwater recharge benefit with this soil condition, but would still have the potential to significantly reduce runoff volume and pollutant loading.

Therefore, taking the greatest advantage of what ARCD offers is expected to retain the great majority of post-development runoff and pre-development groundwater recharge. This strategy would also prevent the addition to receiving waters of all or almost all pollutant mass that would otherwise discharge from a range of urban developments on B and C soils. With D soils, Full ARCD can accomplish runoff retention and loading reductions approaching or somewhat exceeding 50 percent, and opportunities to use ARCD practices or site design principles not modeled in this analysis can further increase runoff retention volume.

ABILITY TO MEET STANDARDS

ARCD methods were assessed for their ability to meet five potential regulatory standards, the first two pertaining to retention of the 85th and 95th percentile, 24-hour precipitation events, the third to retain 90 percent of the post-development runoff, and the last two to retain the difference between the post- and pre-development runoff, the final standard capped at the 85th percentile, 24-hour event. The projected ability to meet the five standards varies mostly in relation to soil type (B or C versus D) and the relative imperviousness of development, and much less across climate regions, except for the relatively arid Southwest.

The only standards that cannot be fully met on B and C soils by the ARCD methods considered are standards 2-4 for the COMM case. Of the 125 standards assessments, ARCD practices are projected to meet 113 (90.4 percent) with B and C soils. The ability to meet these standards is much reduced on D soils. Only standards 1 (85th percentile, 24-hour precipitation event, and 4 and 5 (related to the difference between the post- and pre-development runoff) can be met occasionally and under limited conditions using Full ARCD methods. However, even on D soils, all cases for Standard 1 were able to retain greater than 50 percent of the required runoff volume.

Standard 3 (retain 90 percent of the average annual post-development runoff volume) would be the most environmentally protective standard. Meeting or coming as close as possible to meeting, but not exceeding, this standard was estimated to lead to 66-90 percent runoff retention and pollutant loading reduction on B and C soils and 37-66 percent on D soil. Standard 2 (retain the runoff produced by the 95th percentile, 24-hour precipitation event) would yield equivalent protection on D soils and only slightly less protection with B and C soils.

Standards 4 and 5, based on the differential between pre- and post-development runoff volume, are very inconsistent in retaining runoff and reducing pollutants. They are highly protective where pre-development runoff is estimated to be very low relative to post-development flow, and then to result in progressively lower retention and loading reduction as pre- and post-development volumes converge. Standard 5 is especially weak in this regard. This inconsistency makes these standards poor candidates for national application, at least as formulated in these terms.

Fully meeting standard 1 (retain the runoff produced by the 85th percentile, 24-hour precipitation event) would yield runoff retention and pollutant mass reduction ranging from 58 to 81 percent, depending on climate region. This level of inconsistency decreases the utility of this standard to some degree. Standard 2, based on the 95th percentile event, is much better in this respect, with variability in runoff retention and loading reduction across the nation in the much narrower 82-89 percent range. However, standard 1 remains more consistent across regions, and more protective of water quality for development on D soils than either standard 4 or 5, and is preferable to those standards in this regard.

In summary, standards 2 and 3 are clearly superior to the other three options. Standard 3 is entirely consistent from place to place in degree of environmental protection, and standard 2 does not deviate much. Analysis of the five development cases on two soil groups in each of four regions demonstrated the two standards are virtually identical in the runoff retention and pollutant loading reduction they would bring about.

All five standards are based on some stipulated runoff retention. Pollutant mass loading reduction is at least equal to the amount of retention that occurs. It is possible to decrease loadings further by treating excess runoff. Analysis showed that subjecting that runoff to bioretention treatment before discharge could reduce loadings of TSS and total copper, zinc, and phosphorus by at least two-thirds and as much as over 95 percent. This conclusion applies to all climate regions and soil types for land use cases where space is available for the additional bioretention cells. The three residential cases are in this group but not the COMM or REDEV cases, where all pervious land would have already been used for retentive or roof water dispersion practices.

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ATTACHMENT A

POLLUTANT CONCENTRATIONS FOR URBAN SOURCE AREAS (HERRERA ENVIRONMENTAL CONSULTANTS, INC. UNDATED)

Source Area	Study	Location	Sample Size (n)	TSS (mg/L)	TCu (µg/L)	TPb (µg/L)	TZn (µg/L)	TP (mg/L)	Notes
Roofs									
Residential	Steuer, et al. 1997	MI	12	36	7	25	201	0.06	2
Residential	Bannerman, et al. 1993	WI	~48	27	15	21	149	0.15	3
Residential	Waschbusch, et al. 2000	WI	25	15	n.a.	n.a.	n.a.	0.07	3
Residential	FAR 2003	NY		*19*	*20*	*21*	*312*	*0.11*	4
Residential	Gromaire, et al. 2001	France		*29*	*37*	*493*	*3422*	*n.a.*	5
Representative Residential Roof Values				**25**	**13**	**22**	**159**	**0.11**	
Commercial	Steuer, et al. 1997	MI	12	24	20	48	215	0.09	2
Commercial	Bannerman, et al. 1993	WI	~16	15	9	9	330	0.20	3
Commercial	Waschbusch, et al. 2000	WI	25	18	n.a.	n.a.	n.a.	0.13	3
Representative Commercial Roof Values				**18**	**14**	**26**	**281**	**0.14**	
Parking Areas									
Res. Driveways	Steuer, et al. 1997	MI	12	157	34	52	148	0.35	2
Res. Driveways	Bannerman, et al. 1993	WI	~32	173	17	17	107	1.16	3
Res. Driveways	Waschbusch, et al. 2000	WI	25	34	n.a.	n.a.	n.a.	0.18	3
Driveway	FAR 2003	NY		*173*	*17*		*107*	*0.56*	4
Representative Residential Driveway Values				**120**	**22**	**27**	**118**	**0.66**	
Comm./ Inst. Park. Areas	Pitt, et al. 1995	AL	16	110	116	46	110	n.a.	1
Comm. Park. Areas	Steuer, et al. 1997	MI	12	110	22	40	178	0.2	2
Com. Park. Lot	Bannerman, et al. 1993	WI	5	58	15	22	178	0.19	3
Parking Lot	Waschbusch, et al. 2000	WI	25	51	n.a.	n.a.	n.a.	0.1	3
Parking Lot	Tiefenthaler, et al. 2001	CA	5	36	28	45	293	n.a.	6
Loading Docks	Pitt, et al. 1995	AL	3	40	22	55	55	n.a.	1
Highway Rest Areas	CalTrans 2003	CA	53	*63*	*16*	*8*	*142*	*0.47*	7

Park and Ride Facilities	CalTrans 2003	CA	179	*69*	*17*	*10*	*154*	*0.33*	7
Comm./ Res. Parking	FAR 2003	NY		*27*	*51*	*28*	*139*	*0.15*	4
Representative Parking Area/Lot Values				**75**	**36**	**26**	**97**	**0.14**	
Landscaping/Lawns									
Landscaped Areas	Pitt, et al. 1995	AL	6	33	81	24	230	n.a.	1
Landscaping	FAR 2003	NY		*37*	*94*	*29*	*263*	n.a.	4
Representative Landscaping Values				**33**	**81**	**24**	**230**	**n.a.**	
Lawns - Residential	Steuer, et al. 1997	MI	12	262	n.a.	n.a.	n.a.	2.33	2
Lawns - Residential	Bannerman, et al. 1993	WI	~30	397	13	n.a.	59	2.67	3
Lawns	Waschbusch, et al. 2000	WI	25	59	n.a.	n.a.	n.a.	0.79	3
Lawns	Waschbusch, et al. 2000	WI	25	122	n.a.	n.a.	n.a.	1.61	3
Lawns - Fertilized	USGS 2002	WI	58	n.a.	n.a.	n.a.	n.a.	2.57	3
Lawns - Non-P Fertilized	USGS 2002	WI	38	n.a.	n.a.	n.a.	n.a.	1.89	3
Lawns - Unfertilized	USGS 2002	WI	19	n.a.	n.a.	n.a.	n.a.	1.73	3
Lawns	FAR 2003	NY	3	*602*	*17*	*17*	*50*	*2.1*	4
Representative Lawn Values				**213**	**13**	**n.a.**	**59**	**2.04**	

Notes:

Representative values are weighted means of collected data. Italicized values were omitted from these calculations.

1 - Grab samples from residential, commercial/institutional, and industrial rooftops. Values represent mean of DETECTED concentrations

2 - Flow-weighted composite samples, geometric mean concentrations

3 - Geometric mean concentrations

4 - Citation appears to be erroneous - original source of data is unknown. Not used to calculate representative value

5 - Median concentrations. Not used to calculate representative values due to site location and variation from other values.

6 - Mean concentrations from simulated rainfall study

7 - Mean concentrations. Not used to calculate representative values due to transportation nature of land use.

Ventura County Technical Guidance Manual for Stormwater Quality Control Measures

Manual Update 2011

Ventura Countywide Stormwater Quality Management Program

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Manual Updates: The 2011 TGM may be periodically updated to correct minor errors and unintentional omissions. Additionally, due to the evolving nature of stormwater quality management, the 2011 TGM may also be updated to incorporate new and innovative control measures. 2011 TGM users should ensure that they are referencing the most current edition by checking www.vcstormwater.org or contacting the local permitting agency.

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1 INTRODUCTION

This *Technical Guidance Manual for Stormwater Quality Measures* (2011 TGM) provides guidance for the implementation of stormwater management control measures in new development and redevelopment projects in the County of Ventura and the incorporated cities therein. These guidelines are intended to improve water quality and mitigate potential water quality impacts. These guidelines have been developed to meet the Planning and Land Development requirements contained in Part 4, Section E of the Los Angeles Regional Water Quality Control Board's (Regional Board) municipal separate storm sewer system (MS4) permit (Order R4-2010-0108) for new development and redevelopment projects.

The Planning and Land Development requirements are not implemented at the discretion of the local permitting agency; they are requirements in Order R4-2010-0108 that must be complied with. The 2011 TGM does not attempt to expand or circumvent these requirements, but rather it provides guidance on how to meet them.

When used in this Manual, the verb "shall" indicates a statement of required, mandatory, or specifically prohibited practice. Statements that are not mandatory, but are recommended practice in typical situations, with allowable deviations if engineering judgment or scientific study indicates them appropriate, are typically stated with the verb "should." In both cases specific options may be provided that are allowable modifications.

1.1 Goals

The 2011 TGM has been prepared by the Ventura Countywide Stormwater Quality Management Program to accomplish the following goals:

- Ensure that new development and redevelopment projects reduce urban runoff pollution to the "maximum extent practicable" (MEP);
- Ensure that the implementation of measures in the 2011 TGM are consistent with Regional Water Quality Control Board Order R4-2010-0108 and other state requirements;
- Provide guidance to developers, design engineers, agency engineers, and planners on the selection and implementation of appropriate stormwater management control measures; and
- Provide maintenance procedures to ensure that the selected stormwater management control measures will be properly maintained to provide effective, long-term pollution control.

1.2 Regulatory Background

In 1972, the Federal Water Pollution Control Act [later referred to as the Clean Water Act (CWA)] was amended to require National Pollutant Discharge Elimination System (NPDES) permits for the discharge of pollutants to waters of the United States from any point source. In 1987, the CWA was amended to require the United States Environmental Protection Agency (USEPA) to establish regulations permitting municipal and industrial stormwater discharges under the NPDES permit program. The USEPA published final regulations regarding stormwater discharges on November 16, 1990. The regulations require that MS4 discharges to surface waters be regulated by a NPDES permit.

The Ventura County Watershed Protection District, County of Ventura, and the cities of Camarillo, Fillmore, Moorpark, Ojai, Oxnard, Port Hueneme, San Buenaventura, Santa Paula, Simi Valley, and Thousand Oaks have joined together to form the Ventura Countywide Stormwater Quality Management Program (Program)and are named as co-permittees under a revised countywide municipal NPDES permit for stormwater discharges issued by the Regional Water Quality Control Board in 2010 (Order R4-2010-0108).

Prior to the issuance of Order R4-2010-0108, stormwater discharges from the Ventura County MS4 were covered under the countywide waste discharge requirements contained in three previous MS4 NPDES Permits (Order 09-0057, Order 00-108, and Order No. 94-082).

Under Order R4-2010-0108, the co-permittees are required to administer, implement, and enforce a Stormwater Quality Management Program (Program) to reduce pollutants in urban runoff to the MEP. The Program emphasizes all aspects of pollution control including, but not limited to, public awareness and participation, source control, regulatory restrictions, water quality monitoring, and treatment control.

For the Program to be successful, it is critical to control urban runoff pollution from new development and redevelopment projects during and after construction. Therefore, the co-permittees implemented the Planning and Land Development Program, one element within the Program, to specifically control post-construction urban runoff pollutants from new development and redevelopment projects. The goal of the Planning and Land Development Program is to minimize runoff pollution typically caused by land development and protect the beneficial uses of receiving waters by limiting effective impervious area (EIA) to no more than 5% of the project area and retaining stormwater on site. This goal can be achieved by employing a sensible combination of Site Design Principles and Techniques, Source Control Measures, Retention Best Management Practices (BMPs), Biofiltration BMPs, and Treatment Control Measures to the level required in Order R4-2010-0108.

“Site Design Principles and Techniques,” “Source Control Measures,” “Retention

BMPs," "Biofiltration BMPs," and "Treatment Control Measures," as used in the 2011 TGM refer to BMPs and features incorporated into the design of a new development or redevelopment project, which prevent and/or reduce pollutants in stormwater runoff from the project. These measures are described below:

1) ***Site Design Principles and Techniques*** are a stormwater management strategy that emphasizes conservation and use of existing site features to reduce the amount of runoff and pollutant loading that is generated from a project site.

2) ***Source Control Measures*** limit the exposure of materials and activities so that potential sources of pollutants are prevented from making contact with stormwater runoff.

3) ***Retention BMPs*** are stormwater BMPs that are designed to retain water onsite, and achieve a greater reduction in surface runoff from a project site than traditional stormwater Treatment Control Measures. The term "Retention BMPs" encompasses infiltration, rainwater harvesting[1], and evapotranspiration BMPs. Retention BMPs are preferred and shall be selected over biofiltration BMPs and Treatment Control Measures where technically feasible to do so.

4) ***Biofiltration BMPs*** are vegetated stormwater BMPs that remove pollutants by filtering stormwater through vegetation and soils.

5) ***Treatment Control Measures*** are engineered BMPs that provide a reduction of pollutant loads and concentrations in stormwater runoff.

Applicable projects (Section 1.4) must reduce Effective Impervious Area (EIA) to less than or equal to five percent (≤5%) of the total project area, unless infeasible. Impervious surfaces are rendered "ineffective" if the design storm volume is fully retained onsite using Retention BMPs. Biofiltration BMPs may be used to achieve the 5% EIA standard if Retention BMPs are technically infeasible (see Section 3.2).

The 2011 TGM contains guidance for the design and implementation of all of these types of stormwater management control measures for new development and redevelopment projects. In addition to the requirements of Order R4-2010-0108, owners and developers of some of the sites in the County may also be subject to the State of California's general permit for stormwater discharge from industrial activities (Industrial General Permit) and general permit for stormwater discharge from construction activities (Construction General Permit). The stormwater management control measures provided in the 2011 TGM may also assist the owner or developer in meeting the requirements of the State's construction and industrial permits. The stormwater management staffs of the governing co-permittee agencies are available to provide assistance regarding all of the State stormwater permit

[1] Rainwater harvesting is a BMP that stores and uses rainwater or stormwater runoff. This is consistent with the use of the term "reuse" contained in Order R4-2010-0108.

requirements.

1.3 Impacts of Land Development

The Cities and County of Ventura have separate stormwater and sanitary sewer conveyance systems. Land development typically creates an increase in impervious surfaces, which increases the amount of runoff and pollutants entering stormwater conveyance systems. Pollutants that enter the conveyance system in stormwater are typically transported directly to receiving waters (i.e. local channels, rivers, and the ocean), and are not treated in a wastewater treatment plant. Pollutants in untreated stormwater runoff from impervious surfaces that drains to streets and enters storm drains directly contribute to water pollution.

Typically, as stormwater runs over impervious surfaces (e.g., rooftops, roadways, and parking lots), it:

- Does not infiltrate or evapotranspire, which increases runoff volumes, velocities, and flow rates;
- Moves more quickly, which increases runoff velocities; and
- Entrains (i.e., accumulates) pollution and sediment, which increases nutrients, bacteria, and other pollutant concentrations in receiving waters (i.e., local channels, rivers, and the ocean).

The impacts of these alterations due to development may include:

- Increased concentrations of nutrients, toxic pollutants, and bacteria in surface receiving waters, including adjacent land and habitat (e.g., beaches) creeks, estuaries, and storm drain outlets.
- Increased flooding due to higher peak flow rates and runoff volumes produced by a storm.
- Decreased wet season groundwater recharge due to a decreased infiltration area.
- Increased dry season groundwater recharge due to outdoor irrigation with potable or reclaimed water.
- Introduction of baseflows in ephemeral streams due to surface discharge of dry weather urban runoff.
- Increased stream and channel bank instability and erosion due to increased runoff volumes, flow durations, and higher stream velocities (“hydromodification impacts”); and

- Increased stream temperature due to loss of riparian vegetation as well as runoff warmed by impervious surfaces, which decreases dissolved oxygen levels and makes streams inhospitable to some aquatic life requiring cooler temperatures for survival.

1.4 Stormwater Management Principles

Stormwater management principles such as Integrated Water Resource Management (IWRM) and Low Impact Development (LID) can be used to help mitigate the impacts of development. These principles are described below.

The emergence of LID falls under the umbrella of the over-arching concept of IWRM. IWRM is a process which promotes the coordinated development and management of water, land, and related resources. IWRM links traditional development topics such as land use, water supply, wastewater treatment/reclamation, flood control/drainage, water quality, and hydromodification management into a cohesive hydrologic system that recognizes their interdependencies and minimizes their potentially negative effects on the environment. An example of IWRM includes recharging groundwater with reclaimed wastewater to support the water supply. Another example is combining stormwater treatment, hydromodification control, and flood control in a single regional infiltration basin that recharges groundwater, incorporates recreation, and provides habitat. Another example is using Smart Growth principles to help reduce the environmental footprint while still accommodating growth.

Generally, the 2011 TGM advises to first design for the largest hydrologic controls (such as matching post development 100-year flows with pre-project 100-year flows for flood mitigation requirements), according to the appropriate City or County drainage requirements (not included in the 2011 TGM). Secondly, the 2011 TGM advises to check if flood mitigation will reduce or satisfy the stormwater management requirements (as set forth in the 2011 TGM). If it does not, then add more controls as necessary. Flood mitigation may provide the necessary sediment and pollution control, thereby reducing maintenance requirements for the stormwater management BMPs. A sequence of hydrologic controls should be considered, such as site design, flood drainage mitigation, and Retention BMPs. Biofiltration BMPs and Treatment Control Measures can be considered where the use of Retention BMPs is technically infeasible. Each of these controls will have an influence on stormwater runoff from the new development or redevelopment project.

Similar to Source Control Measures, which prevent pollutant sources from contacting stormwater runoff, Retention BMPs use techniques to infiltrate, store, use, and evaporate runoff onsite to mimic pre-development hydrology, to the extent feasible. The goal of LID is to increase groundwater recharge, enhance water quality, and prevent degradation of downstream natural drainage channels. This goal may be accomplished with creative site planning and with incorporation of localized, naturally functioning BMPs into the project. Implementation of Retention BMPs will

reduce the size of additional Hydromodification Control Measures that may be required for a new development or redevelopment project, and, in many circumstances, may be used to satisfy all stormwater management requirements.

1.5 Applicability

The following projects and associated triggers, contained in subpart 4.E.II of Order R4-2010-0108, are subject to the requirements and standards laid out in the 2011 TGM.

Note that some of the project triggers are based on *total altered surface area* and others on *impervious surface area*, which is an intentional requirement in the MS4 Permit.

New Development Projects

Development projects subject to conditioning and approval for the design and implementation of post-construction stormwater management control measures, prior to completion of the project(s), are:

1) All development projects equal to 1 acre or greater of disturbed area that adds more than 10,000 square feet of impervious surface area.

2) Industrial parks with 10,000 square feet or more of total altered surface area.

3) Commercial strip malls with 10,000 square feet or more of impervious surface area.

4) Retail gasoline outlets with 5,000 square feet or more of total altered surface area.

5) Restaurants (Standard Industrial Classification (SIC) of 5812) with 5,000 square feet or more of total altered surface area.

6) Parking lots with 5,000 square feet or more of impervious surface area, or with 25 or more parking spaces.

7) Streets, roads, highways, and freeway construction of 10,000 square feet or more of impervious surface area (see Section 2 for specific requirements).

8) Automotive service facilities (Standard Industrial Classification (SIC) of 5013, 5014, 5511, 5541, 7532-7534 and 7536-7539) of 5,000 square feet or more of total altered surface area.

9) Projects located in or directly adjacent to, or discharging directly to an Environmentally Sensitive Area (ESA), where the development will:

    a. Discharge stormwater runoff that is likely to impact a sensitive biological species or habitat; and

b. Create 2,500 square feet or more of impervious surface area.

10) Single-family hillside homes (see Section 2 for specific requirements).

Redevelopment Projects

Redevelopment projects subject to conditioning and approval for the design and implementation of post-construction stormwater management control measures, prior to completion of the project(s), are redevelopment projects in categories 1 through 10 above that meet the threshold identified below:

- Land-disturbing activity that results in the creation or addition or replacement of 5,000 square feet or more of impervious surface area on an already developed site.

Additionally:

1) Projects where redevelopment results in an alteration to more than fifty percent of impervious surfaces of a previously existing development, and the existing development was not subject to the post development stormwater quality control requirements of Board Order 00-108, shall mitigate the entire redevelopment project area.

2) Projects where redevelopment results in an alteration to more than fifty percent of impervious surfaces of a previously existing development, and the existing development was subject to the post development stormwater quality control requirements of Board Order 00-108, must mitigate only the altered portion of the redevelopment project area and not the entire project area.

3) Projects where redevelopment results in an alteration of less than fifty percent of impervious surfaces of a previously existing development must mitigate only the altered portion of the redevelopment project area and not the entire project area.

Land-disturbing activity that results in the creation or addition or replacement of less than 5,000 square feet of impervious surface area on an already developed site, or that results in a decrease in impervious area which was subject to the post-development stormwater quality control requirements of Board Order 00-108, is not subject to mitigation unless so directed by the local permitting agency.

Redevelopment does not include routine maintenance activities that are conducted to maintain the original line and grade, hydraulic capacity, or original purpose of the facility or emergency redevelopment activity required to protect public health and safety. Impervious surface replacement, such as the reconstruction of parking lots and roadways, that does not disturb additional area and maintains the original grade and alignment, is considered a routine maintenance activity. Agencies' flood control, drainage, and wet utilities projects that maintain original line and grade or hydraulic capacity are considered routine maintenance. Redevelopment also does not include the repaving of existing roads to maintain original line and grade.

Existing single-family dwelling and accessory structure projects are exempt from the redevelopment requirements unless the project creates, adds, or replaces 10,000 square feet of impervious surface area.

Effective Date

The new development and redevelopment requirements contained in Part 4, Section E of Board Order R4-2010-0108 (the "Order") shall become effective 90 calendar days after the Regional Water Quality Control Board Executive Officer approves the 2011 TGM (the "Effective Date"). After the Effective Date, all applicable projects, except those identified below, must comply with the new development and redevelopment requirements contained in Part 4, Section E of the Order.

The new development and redevelopment requirements contained in Part 4, Section E of the Order shall not apply to the projects described in paragraphs 1 through 5 below. Projects meeting the criteria listed in paragraphs 1 through 5 below shall instead continue to comply with the performance criteria set forth in the 2002 Technical Guidance Manual for Stormwater Quality Control Measures under Board Order 00-108:

1) Projects or phases of projects where the project's applications have been "deemed complete for processing" (or words of equivalent meaning), including projects with ministerial approval, by the applicable local permitting agency in accordance with the local permitting agency's applicable rules prior to the Effective Date; or

2) Projects that are the subject of an approved Development Agreement and/or an adopted Specific Plan; or an application for a Development Agreement and/or Specific Plan where the application for the Development Agreement and/or Specific Plan has been "deemed complete for processing" (or words of equivalent meaning), by the applicable local permitting agency in accordance with the local permitting agency's applicable rules, and thereafter during the term of such Development Agreement and/or Specific Plan unless earlier cancelled or terminated; or

3) All private projects in which, prior to the Effective Date, the private party has completed public improvements; commenced design, obtained financing, and/or participated in the financing of the public improvements; or which requires the private party to reimburse the local agency for public improvements upon the development of such private project; or

4) Local agency projects for which the governing body or their designee has approved initiation of the project design prior to the Effective Date; or

5) A Tentative Map or Vesting Tentative Map deemed complete or approved by the local permitting agency prior to the Effective Date, and subsequently a Revised Map is submitted, the project would be exempt from the 2011 TGM provisions if the revisions substantially conform to original map design, consistent with

Subdivision Map Act requirements. Changes must also comply with local and state law.

The intent of these guidelines is to ensure that projects for which the applications have been deemed "complete" or the applicants have worked with local permitting agency staff to develop a final, or substantially final, drainage concept and site layout that includes water quality treatment based upon the performance criteria set forth in the 2002 Technical Guidance Manual for Stormwater Quality Control Measures prior to the Effective Date, are not required to redesign their proposed projects for purposes of complying with the new development and redevelopment requirements contained in Part 4, Section E of Board Order R4-2010-0108.

In addition, any project, phase of a project, or individual lot within a larger previously-approved project, where the application for such project has been "deemed complete for processing" (or words of equivalent meaning) that does not have a final or substantially final drainage concept as determined by the local permitting agency or a site layout that includes water quality treatment must comply with the performance standards set forth in the 2011 TGM.

1.6 Organization of the 2011 TGM

The 2011 TGM is divided into seven sections and nine appendices:

Section 1	Introduction
Section 2	Stormwater Management Standards
Section 3	Site Assessment and BMP Selection
Section 4	Site Design Principles & Techniques
Section 5	Source Control Measures
Section 6	Retention BMPs, Biofiltration BMPs, and Treatment Control Measure Design
Section 7	Operation and Maintenance Planning
Appendix A	Glossary of Terms
Appendix B	Maps: Watersheds Delineation, Existing Urban Areas, Environmentally Sensitive Areas, and 85th Percentile Rainfall Depth
Appendix C	Site Soil Type and Infiltration Testing

Appendix D	BMP Performance Guidance
Appendix E	BMP Sizing Worksheets
Appendix F	Flow Splitter Design
Appendix G	Design Criteria Checklists for Stormwater Runoff BMPs
Appendix H	Stormwater Control Measure Access and Maintenance Agreements
Appendix I	Stormwater Control Measure Maintenance Plan Guidelines and Checklists

2 STORMWATER MANAGEMENT STANDARDS

2.1 Introduction

This section outlines the design process to comply with stormwater control requirements. A flowchart is presented in Figure 2-1 to illustrate a step-by-step process for incorporating these stormwater management control measures.

The selection of appropriate stormwater management control measures should be a collaborative effort between the project proponent and the local permitting agency staff. It is recommended that discussions between project planners, engineers, and local permitting agency staff regarding selection of stormwater management control measures occur very early in the design process.

2.2 Step 1: Determine Project Applicability

New development and redevelopment projects meeting the applicability criteria contained in Section 4.E.II of Order R4-2010-0108 [presented in Section 1.5 of the 2011 TGM] must include control measures specified in the 2011 TGM. These projects should be designed to meet the performance criteria described in the steps below.

Separate requirements exist for three types of projects:

- Projects located within a Redevelopment Project Area Master Plan (RPAMP);
- Single Family Hillside Homes; and
- Roadway Projects.

The requirements for these three project types are described in further detail in the substeps below. Projects that are not applicable are still subject to stormwater agency review, especially for flood drainage requirements. Stormwater management control measures may be required by the governing agency for inapplicable projects, depending on the potential discharge of pollutants in stormwater runoff, impairments in receiving water, or other special conditions that would require increased protection.

Step 1a: Determine RPAMP Eligibility

If a project is located within the boundary of a Redevelopment Project Area Master Plan (RPAMP), the stormwater management requirements in the RPAMP take precedence over the control measures and performance criteria specified in this 2011 TGM. A stormwater agency may apply to the Regional Water Quality Control Board for approval of a RPAMP in consideration of exceptional site constraints that inhibit site-by-site or project-by-project implementation of post-construction requirements.

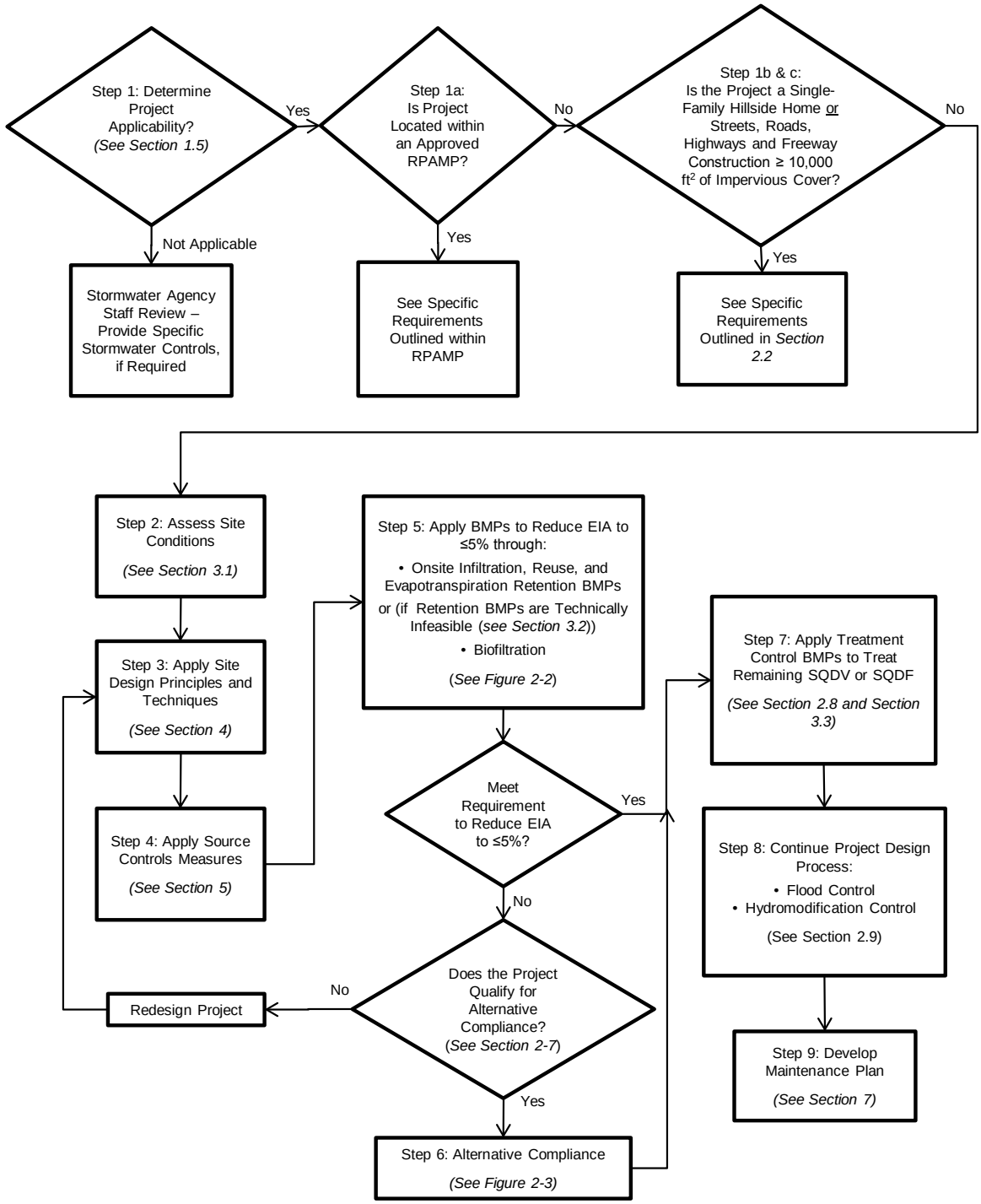


Figure 2-1: Stormwater Management Control Measures Design Decision Flowchart

Step 1b: Single-Family Hillside Homes

Single-family hillside home projects have specific requirements separate from other new development and redevelopment project categories. These requirements only apply to single-family hillside homes that disturb less than 1 acre and that add less than 10,000 square feet of impervious surface area. If the project is equal to 1 acre or greater of disturbed area that adds more than 10,000 square feet of impervious surface area, then project must comply with Steps 2 through 9.

According to Order R4-2010-0108, a hillside is defined as:

> "*Property located in an area with known erosive soil conditions, where the development will result in grading on any slope that is 20% or greater or an area designated by the Municipality under a General Plan or ordinance as a 'hillside area.'*"

The measures presented in this substep comprise the performance standard for single-family hillside home new development and redevelopment projects and apply to the entire lot (additional information on these measures may be found in Section 4 and Section 5).

Conserve Natural Areas

Each project site possesses unique topographic, hydrologic and vegetative features, some of which are more suitable for development than others. Locating development on the least sensitive portion of a site and conserving naturally vegetated areas can minimize environmental impacts in general and stormwater runoff impacts in particular.

The following measures are required and should be included in the lot layout, consistent with applicable General Plan and Local Area Plan policies and if appropriate and feasible with the given site conditions:

1) Concentrate or cluster improvements on the least-sensitive portions of the lot and leave the remaining land in a natural undisturbed state; at a minimum, sensitive portions of the lot should include areas covered under Clean Water Act Section 404 such as riparian areas and wetlands;

2) Limit clearing and grading of native vegetation on the lot to the minimum area needed to build the home, allow access, and provide fire protection; and

3) Maximize trees and other vegetation at the site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants.

Protect Slopes and Channels

Erosion of slopes and channels can be a major source of sediment and associated pollutants such as nutrients, if not properly protected and stabilized.

Slope Protection

Slope protection practices must conform to local permitting agency erosion and sediment control standards and design requirements. The post-construction design criteria described below are intended to enhance and be consistent with these local standards.

1) Slopes must be protected from erosion by safely conveying runoff from the tops of slopes.

2) Slopes must be vegetated by first considering the use of native or drought-tolerant species.

Channel Protection

The following measures should be implemented to provide erosion protection to unlined receiving streams on the lot. Activities and structures must conform to applicable permitting requirements, standards, and specifications of agencies with jurisdiction (i.e., U.S. Army Corps of Engineers, California Department of Fish and Game, or Regional Water Quality Control Board).

1) Use natural drainage systems to the maximum extent practicable, but minimize runoff discharge to the maximum extent practicable.

2) Stabilize permanent channel crossings.

3) Install energy dissipaters, such as rock riprap, at the outlets of storm drains, culverts, conduits or channels that discharge into unlined channels.

Provide Storm Drain System Stenciling and Signage

Storm drain message markers or placards are required at all storm drain inlets within the project boundary. The signs should be placed in clear sight facing anyone approaching the inlet from either side. All storm drain inlet locations must be identified on the development site map.

Some local agencies within the County have approved storm drain message placards for use. Consult local permitting agency stormwater staff to determine specific requirements for placard types and installation methods.

Divert Roof Runoff and Surface Flows to Vegetated Area(s) or Collection System(s), Unless the Diversion Would Result in Slope Instability

Diverted Roof Runoff
City of Santa Barbara

Disconnecting downspouts divert water from roof gutters to (1) vegetated pervious areas of the site in order to allow for infiltration, storage, evapotranspiration (i.e., evaporation and uptake of water by plants), and treatment, or (2) a rainwater collection system (e.g., a rain barrel or a cistern). Disconnected downspouts differ from conventional downspout systems that provide a direct connection of roof runoff to stormwater conveyance systems (storm drains), which quickly collect and convey stormwater away from the site. "Flow spreading" is a technique used to spread runoff from rooftops, sidewalks, patios, and driveways out over a vegetated pervious area, rather than concentrating and conveying the runoff directly to a stormwater conveyance system.

Dispersion methods include splash blocks, gravel-filled trenches, or other methods which serve to spread runoff over vegetated pervious areas. Sheet flow dispersion is the simplest method and can be used for any impervious or pervious surface that is graded so as to avoid concentrating flows. Because flows are already dispersed as they leave the surface, they only need to traverse through a narrow band of adjacent vegetation for the runoff to be effectively attenuated and treated.

The following requirements apply to runoff diversion:

- Vegetated flowpaths for the diverted flows should be at least 25 feet in length, measured from the diversion location to the downstream property line, structure, steep slope, stream, wetland, or impervious surface. The vegetated flowpath must be covered with well-established lawn or pasture, landscaping with well-established groundcover, or native vegetation with natural groundcover. The groundcover should be dense enough to help disperse and infiltrate flows and to prevent erosion.

- If the vegetated flowpath (measured as defined above) is less than 25 feet, a perforated stub-out connection may be used in lieu of downspout dispersion. A perforated stub-out connection is a length of perforated pipe within a gravel-filled trench that is placed between roof downspouts and a stub-out to the local drainage system. A perforated stub-out may also be used where implementation of downspout dispersion might cause erosion or flooding problems, either onsite or on adjacent lots. This provision might be

appropriate, for example, for lots where dispersed flows might pose a potential hazard for lower lying lots or adjacent offsite lots. Location of the connection should be selected to allow a maximum amount of runoff to infiltrate into the ground (ideally a dry location on the site that is relatively well drained). To facilitate maintenance, the perforated pipe portion of the system should not be located under impervious or heavily compacted (e.g., driveways and parking areas) surfaces. The use of a perforated stub-out in lieu of downspout dispersion may be determined by the Local permitting agency.

- In general, if the ground is sloped away from the foundation and there is adequate vegetation and area for effective dispersion, splash blocks will adequately disperse stormwater runoff. If the ground is fairly level, if the structure includes a basement, or if foundation drains are proposed, splash blocks with downspout extensions may be a better choice because the discharge point is moved away from the foundation. Downspout extensions may include piping to a splash block/discharge point a considerable distance from the downspout, as long as the runoff can travel through a well-vegetated area as described above.

- No erosion or flooding of downstream properties may result.

- Runoff discharged towards steep slopes or landslide hazard areas, including perforated stub-out connections, must be evaluated by a geotechnical engineer or qualified geologist. The discharge point may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and jurisdiction approval.

- For sites with septic systems, the discharge point must be down gradient of the drainfield primary and reserve areas. This requirement can be waived by the jurisdiction's permit review staff if site topography clearly prohibits flows from intersecting with the drainfield.

Step 1c: Roadway Projects

Roadway projects have specific requirements separate from other new development and redevelopment project categories. The measures presented in this substep comprise the performance standard for street, roadway, highway, and freeway projects. Section 4.E.II of Order R4-2010-0108 requires street, roadway, highway, and freeway projects that construct 10,000 square feet or more of impervious surface area, to incorporate USEPA guidance regarding *Managing Wet Weather with Green Infrastructure: Green Streets* to the maximum extent practicable.

The following requirements apply to the impervious area within the right-of-way associated with public streets, roads, highways, and freeways projects and the streets

that are part of a larger private project. These requirements do not apply to routine maintenance activities that are conducted to maintain original line and grade, hydraulic capacity, original purpose of facility, or emergency redevelopment activity required to protect public health and safety. Impervious surface replacement, such as the reconstruction of parking lots and roadways, which does not disturb additional area and maintains the original grade and alignment, is considered a routine maintenance activity. Agencies' flood control, drainage, and wet utilities projects that maintain original line and grade or hydraulic capacity are considered routine maintenance. Also, the requirements do not apply to the repaving of existing roads to maintain original line and grade.

Minimum requirements for the impervious area within the right-of-way associated with streets, roads, highways, and freeways are as follows:

1) Provide Retention BMPs or Biofiltration BMPs sized to capture and treat the Stormwater Quality Design Volume (SQDV) or the Stormwater Quality design Flow (SQDF) (see Step 7 for guidance on calculating the SQDV and SQDF).

   Additional Treatment Control Measures may be integrated into roadway projects if they are used in a treatment train approach with Retention BMPs or Biofiltration BMPs to address the pollutants of concern (see Section 3.3).

2) Projects should apply the following measures to the maximum extent practicable and as specified in the local permitting agency's codes:

   - Minimize street width to the appropriate minimum width for maintaining traffic flow and public safety;
   - Use porous pavement or pavers for low traffic roadways, on-street parking, shoulders or sidewalks; and
   - Add tree canopy by planting or preserving trees and shrubs.

2.3 Step 2: Assess Site Conditions

The next step is to collect site information that is critical for the selection and implementation of Retention BMPs, Biofiltration BMPs, and Treatment Control Measures. The following information should be documented: topography, soil type and geology, groundwater, geotechnical considerations, offsite drainage, existing utilities, and Environmentally Sensitive Areas. In addition, soil and infiltration testing should be conducted. Detailed guidance on assessing site conditions can be found in Section 3.1.

2.4 Step 3: Apply Site Design Principles and Techniques

The third step is to apply Site Design Principles & Techniques (see Section 4). The implementation of LID requires an integrated approach to site design and

stormwater management. Traditional approaches to stormwater management planning within the site planning process are not likely to achieve the LID performance standard of the MS4 Permit. The use of the site planning techniques presented in Section 4 (Site Design Principles & Techniques) will help generate a more hydrologically functional site, maximize the effectiveness of Retention BMPs, and integrate stormwater management throughout the site.

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

- Retention BMPs should be considered as early as possible in the site planning process. Hydrology should be a key principle that is integrated into the initial site assessment planning phases. Where flexibility exists, conceptual drainage plans should attempt to route water to areas suitable for Retention BMPs.

- A multidisciplinary approach at the initial phases of the project is recommended and should include planners, engineers, landscape architects, and architects.

- Individual Retention BMPs should be distributed throughout the project site as feasible and may influence the configuration of roads, buildings and other infrastructure.

- The project must demonstrate disconnection of impervious surface such that the 5% EIA requirement is achieved. If fully meeting the 5% EIA requirement using Retention BMPs is not technically feasible, the project must still utilize Retention BMPs to the maximum extent practicable.

- Flood and hydromodification control should be considered early in the design stages. Even sites with Retention BMPs will still have runoff that occurs during large storm events, but Retention facilities can have flood and hydromodification control benefits. It may be possible to simultaneously address flood and hydromodification control requirements through an integrated water resources management approach.

Perhaps the most important aspect of site planning is allowing sufficient space for Retention BMPs in areas that can physically accept runoff. A simple rule of thumb is to allow 3 to 10 percent of the tributary impervious area (depending on how well the soils drain and then allow for more area with less infiltrative soils) for infiltration BMPs and 3 to 5 percent for biofiltration in preliminary design to achieve the 5% Effective Impermeable Area (EIA) standard.

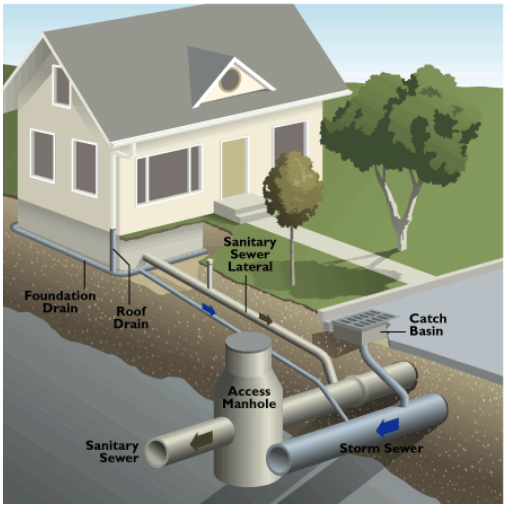
2.5 Step 4: Apply Source Control Measures

All applicable projects must implement applicable Source Control Measures. Source Control Measures are operational practices that reduce potential pollutants at the

source. They typically do not require maintenance or significant construction. Guidance on Source Control Measures can be found in Section 5.

2.6 Step 5: Apply BMPs to Reduce EIA to ≤5%

According to Order R4-2010-0108, Applicable projects must reduce Effective Impervious Area (EIA) to less than or equal to five percent (≤5%) of the total project area, unless infeasible. Impervious surfaces are rendered "ineffective" if the design storm volume is fully retained onsite using either infiltration, rainwater harvesting, and/or evapotranspiration Retention BMPs. Biofiltration BMPs may be used to achieve the 5% EIA standard if Retention BMPs are technically infeasible (see Section 3.2). This section and Figure 2-2 describe the process for reducing EIA to ≤5%. Refer to Section 2.7 if Retention BMPs and/or Biofiltration BMPs cannot feasibly be used to meet the 5% EIA standard (see Section 3.2).



Effective Impervious Area
Victoria, BC Capital Regional District

Step 5a: Calculate Allowable EIA

EIA is defined as impervious area that is hydrologically connected via sheet flow over a hardened conveyance or impervious surface without any intervening medium to mitigate flow volume. Connected impervious areas efficiently transport runoff without allowing infiltration. Often in urban areas, runoff from connected impervious surfaces is immediately directed into a stormwater conveyance system where it is further connected and efficiently transported to an outfall (stormwater conveyance system outlet). For example, in this illustration, the rooftop is directly connected via a roof drain and underground solid drain pipe to the storm drain in the street (Note that the sanitary sewer is separate from the storm sewer). The roadway drains to the storm drain through the catch basin. The roof area and roadway area would be considered EIA.

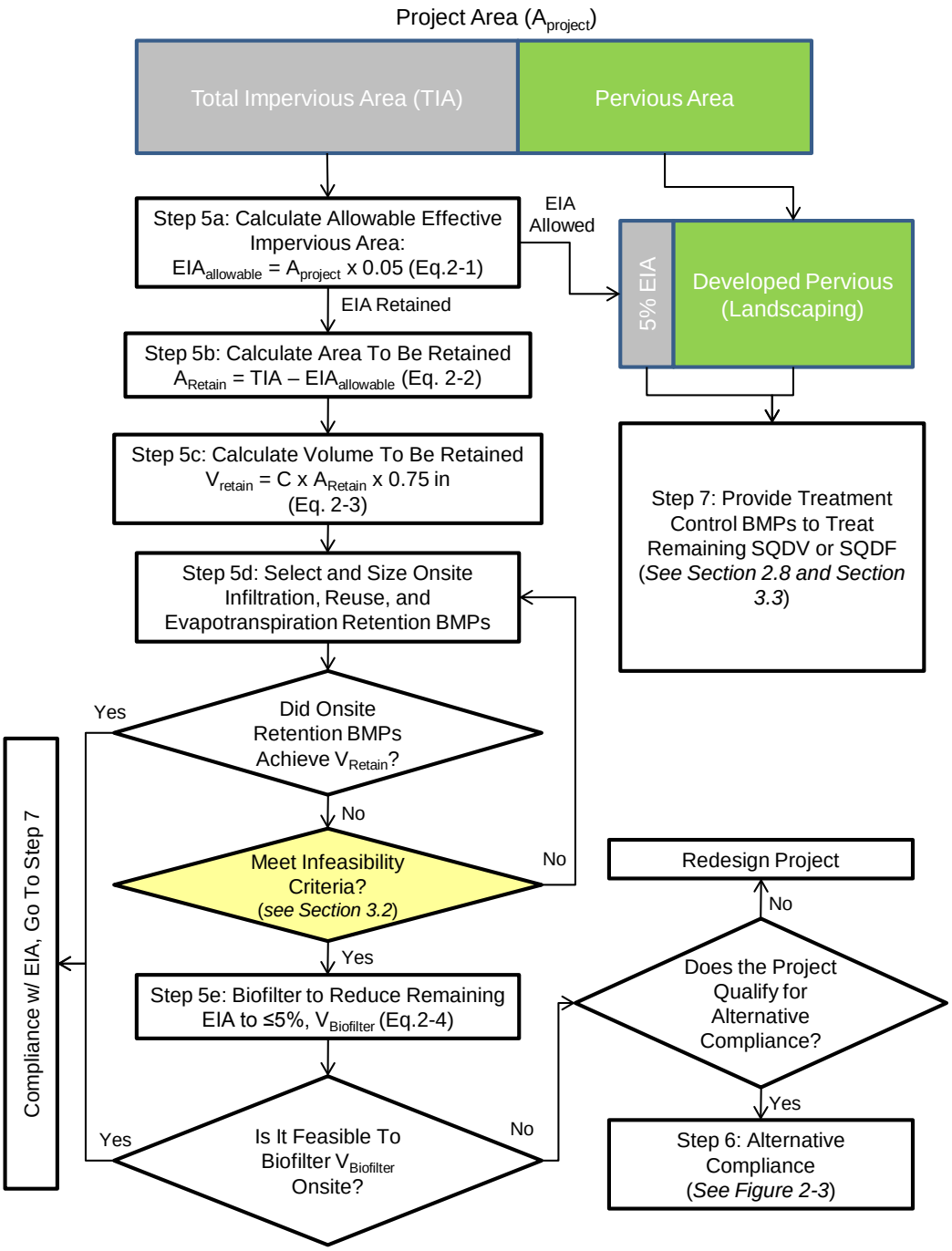


Figure 2-2: Apply BMPs to Reduce EIA to ≤5% Process Flow Chart

> "Impervious surface" is a man-made hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, compacted gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater. Open, uncovered retention/detention facilities and exposed bedrock shall not be considered as impervious surfaces for purposes of determining EIA retention volume.

The allowable EIA for a project site should be calculated as follows:

$$EIA_{allowable} = (A_{project})*(\%_{allowable}) \qquad \text{(Equation 2-1)}$$

Where:

$EIA_{allowable}$ = the maximum impervious area from which runoff can be treated and discharged offsite [and not retained onsite] (acres)

$A_{project}$ = the total project area (acres).

> "Total project area" (or "gross project area") for new development and redevelopment projects is defined as the disturbed, developed, and undisturbed portions within the project's property (or properties) boundary, at the project scale submitted for first approval. Areas proposed to be permanently dedicated for open space purposes as part of the project are explicitly included in the "total project area." Areas of land precluded from development through a restrictive covenant, conservation easement, or other recorded document for the permanent preservation of open space prior to project submittal shall not be included in the "total project area."

$\%_{allowable}$ = 5 percent

Step 5b: Calculate Impervious Area to be Retained

The impervious area from which runoff must be retained onsite is the total impervious area minus the $EIA_{allowable}$, which should be calculated as follows:

$$A_{Retain} = TIA - EIA_{allowable} = (IMP*A_{project}) - EIA_{allowable} \qquad \text{(Equation 2-2)}$$

Where:

A_{Retain} = the drainage area from which runoff must be retained (acres)

TIA = total impervious area (acres)

$EIA_{allowable}$	=	the maximum impervious area from which runoff can be treated and discharged offsite [and not retained onsite] (acres).
IMP	=	imperviousness of project area (%)/100
$A_{project}$	=	the total project area (acres)

Step 5c: Calculate the Volume to be Retained (SQDV)

All Retention BMPs used to render impervious surfaces "ineffective" should be properly sized to retain the volume of water that results from the water quality design storm. The design storm volume, referred to in the TGM as the Stormwater Quality Design Volume (SQDV) shall be calculated using the following four allowable methodologies:

1) The 85th percentile 24-hour runoff event determined as the maximized capture stormwater volume for the area using a 48 to 72-hour draw down time, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998); or

2) The volume of annual runoff based on unit basin storage water quality volume to achieve 80 percent or more volume treatment; or

3) The volume of runoff produced from a 0.75 inch storm event; or

4) Eighty (80) percent of the average annual runoff volume using an appropriate public domain continuous flow model [such as Storm Water Management Model (SWMM) or Hydrologic Engineering Center – Hydrologic Simulation Program – Fortran (HEC-HSPF)], using the local rainfall record and relevant BMP sizing and design data.

Note: Examples used throughout the 2011 TGM use the 0.75 inch storm event (Methodology #3).

EXAMPLE 2-1: EIA CALCULATION

Given: 10 acre total project area, 55% impervious, 25% landscaped, 20% undisturbed, percent allowable EIA = 5%.

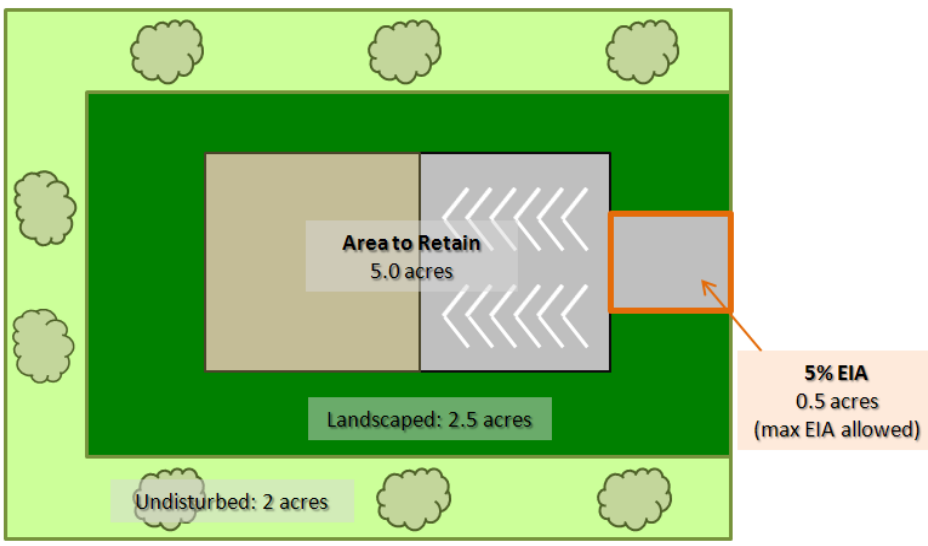
$EIA_{allowable} = 10 * 0.05 = 0.5$ acres

$A_{Retain} = (0.55*10) – 0.5 = 5.0$ acres

$A_{treatment} = (0.25*10) + 0.5 = 3.0$ acres

The maximum EIA allowed for the site is 0.5 acres, from which the generated runoff must be treated prior to discharge, in addition to the runoff from the 2.5 acres landscaped area, up to the design storm volume or flow rate. The runoff volume generated from the remaining 5 acre impervious area (A_{Retain}) must be retained onsite via infiltration, rainwater harvesting, and/or evapotranspiration Retention BMPs.

$A_{treatment}$ equals the EIA allowed for the site plus the landscaped area.



Note: graphic not to scale; for illustration purposes only

The runoff volume that is to be retained onsite should be calculated using Equation 2-3 below:

$$V_{Retain} = C*(0.75/12)*A_{retain} \qquad \text{(Equation 2-3)}$$

Where:

V_{Retain} = the stormwater quality design volume (SQDV) that must be retained onsite (ac-ft)

C	=	runoff coefficient (equals o.95 for impervious surfaces)
0.75	=	the design rainfall depth (in) [based on SQDV sizing method 3]
A_{Retain}	=	the drainage area from which runoff is retained (acres), calculated using Equation 2-2

EXAMPLE 2-2: RETENTION VOLUME CALCULATION

Given: A_{Retain} = 5.0 acres (from Example 2-1); runoff coefficient (C) = 0.95

$$V_{Retain} = 0.95*(0.75/12)*5.0 \text{ acres} = 0.3 \text{ acre-feet}$$

The project must retain at least 0.3 acre-feet of runoff from impervious surfaces using Retention BMPs.

Step 5d: Select and Size Onsite Retention BMPs to Achieve 5% EIA

The next step is to select and size Retention BMPs, based on the site assessment design, and constraints. Section 3-4 provides guidance on the selection of Retention BMPs. The project must demonstrate disconnection of impervious area such that the 5% EIA requirement is achieved.

Step 5e: Select and Size Biofiltration BMPs to Reduce EIA to ≤5%

Retention BMPs shall be used onsite to the maximum extent practicable. Pretreatment BMPs shall be provided for all infiltration BMPs and other Retention BMPs as needed (see Section 6.1).

New development and redevelopment projects that demonstrate technical infeasibility for reducing EIA to ≤5% using Retention BMPs are eligible to use Biofiltration BMPs to achieve the EIA performance standard.

The project applicant shall demonstrate technical infeasibility by submitting a site-specific analysis conducted and endorsed by a registered professional engineer, geologist, architect, and/or landscape architect. Section 3.2 discusses technical feasibility screening criteria. Projects that cannot demonstrate technical infeasibility shall meet the requirement to reduce EIA to ≤5% using Retention BMPs. Otherwise project applicants must examine other options for meeting the requirements, such as redesigning the site.

Volume-based biofiltration BMPs shall be sized to treat 1.5 times the volume not retained using Retention BMPs.

The onsite biofiltered volume ($V_{Biofilter}$), should be calculated as follows:

$$V_{Biofilter} = (V_{Retain} - V_{Achieved}) * 1.5 \qquad \text{(Equation 2-4)}$$

Where:

$V_{Biofilter}$	=	the volume that must be captured and treated in a Biofiltration BMP (ac-ft)
V_{Retain}	=	the stormwater quality design volume (SQDV) that must be retained (ac-ft) (established in Step 5c)
$V_{Achieved}$	=	the volume retained onsite using Retention BMPs (ac-ft)

EXAMPLE 2-3: BIOFILTRATION VOLUME CALCULATION

Given: V_{Retain} = 0.3 ac-ft (from Example 2-2); $V_{Achieved}$ = 0.25 ac-ft

$$V_{Biofilter} = (0.3 - 0.25) * 1.5 = 0.075 \text{ ac-ft}$$

If the project applicant has demonstrated technical infeasibility, the remaining EIA requirement may be met by biofiltering 1.5 times the remaining V_{Retain}. In this case, the Biofiltration BMP must be sized to treat 0.075 ac-ft.

If the project applicant has demonstrated technical infeasibility, the remaining EIA requirement may also be satisfied with flow-based Biofiltration BMPs. Flow-based Biofiltration BMPs shall be sized for the remaining drainage area from which runoff must be retained (A_{Retain}) using the methodology described in Section 2.8, Stormwater Quality Design Flow, with a rainfall intensity that varies with time of concentration for the catchment tributary to the flow-based Biofiltration BMP, according to Table 2-1.

Table 2-1: Flow-Based Biofiltration BMP Design Intensity for 150% Sizing

Time of Concentration, minutes	Design Intensity for 150% Sizing, in/hr
30	0.24
20	0.25
15	0.28
10	0.31
5	0.35

Time of concentration should be determined using the methodology provided in the Ventura County Hydrology Manual.

2.7 Step 6: Alternative Compliance

Certain new development and redevelopment project types are eligible for alternative compliance measures if onsite Retention BMPs and/or Biofiltration BMPs cannot feasibly be used to meet the 5% EIA standard (see Section 3.2). Such projects include:

1) Redevelopment projects (as defined in Section 1.5).

2) Infill projects. Infill projects meet the following conditions:

   a. The project is consistent with applicable general plan designation, and all applicable general plan policies, and applicable zoning designation and regulations;

   b. The proposed development occurs on a project site of no more than five acres substantially surrounded by urban uses;

   c. The project site has no value as habitat for endangered, rare, or threatened species;

   d. Approval of the project would not result in any significant effects relating to traffic, noise, air quality, or water quality; and

   e. The site can be adequately served by all required utilities and public services (modified from State Guidelines § 15332).

3) Smart Growth projects. Smart Growth projects are defined as new development and redevelopment projects that occur within existing urban areas[2] (see maps in Appendix B) designed to achieve the majority of the following principles[3]:

   a. Create a range of housing opportunities and choices;

   b. Create walkable neighborhoods;

   c. Mix land uses;

[2] Existing urban areas and corresponding maps in Appendix B are based on the cities' City Urban Restriction Boundaries (CURB) lines and in the case of the unincorporated County, the Existing Community designation. These boundaries are a growth management tool intended to channel growth and protect agricultural and open-space land. The 2011 TGM utilizes existing urban areas (as defined in Appendix B) to provide parameters around eligibility for alternative compliance in two areas: 1) Smart Growth and 2) low income housing projects.

[3] Adapted from the Smart Growth Network's Smart Growth Principles in cooperation with the U.S. Environmental Protection Agency.

d. Preserve open space, natural beauty, and critical areas;

   i. Farmland preservation may also be considered for projects occurring outside existing urban areas (as defined by the Appendix B maps).

e. Provide a variety of transportation choices;

   i. Includes transit oriented development (development located within an average 2,000 foot walk to a bus or train station).[4]

f. Strengthen and direct development towards existing communities (as defined by Appendix B maps); and

g. Take advantage of compact building design.

The City or County Planning Division in which a project is proposed will ultimately determine whether a project meets these Smart Growth criteria.

4) Pedestrian/bike trail projects:

   ✓ Located along side of a road and

   ✓ Where right-of-way width is inadequate for the implementation of Retention and/or Biofiltration BMPs.

5) Agency flood control, drainage, and wet utilities projects:

   ✓ Located within waterbody and is therefore not increasing functional impervious cover; or

   ✓ Located on top of a narrow flood control feature (such as a levee) and space is unavailable for the implementation of Retention and/or Biofiltration BMPs; or

   ✓ Where the integrity of the flood control feature (such as a dam or levee) may be compromised through Retention and/or Biofiltration BMPs (e.g., infiltration of stormwater is not appropriate in a levee).

6) Historical preservation projects:

   ✓ Where the extent of the designated preservation area restricts the amount of land available for the implementation of Retention BMPs.

[4] Calthorpe, P. (1993), "The next American metropolis: Ecology, community, and the American dream", New York: Princeton Architectural Press.

7) Low income housing projects that occur within existing urban areas (as defined by the maps provided in Appendix B):

   - ✓ Where density requirements restrict the amount of land available for the implementation of Retention BMPs and/or
   - ✓ Where project financing constraints restrict the amount of land available for the implementation of Retention BMPs.

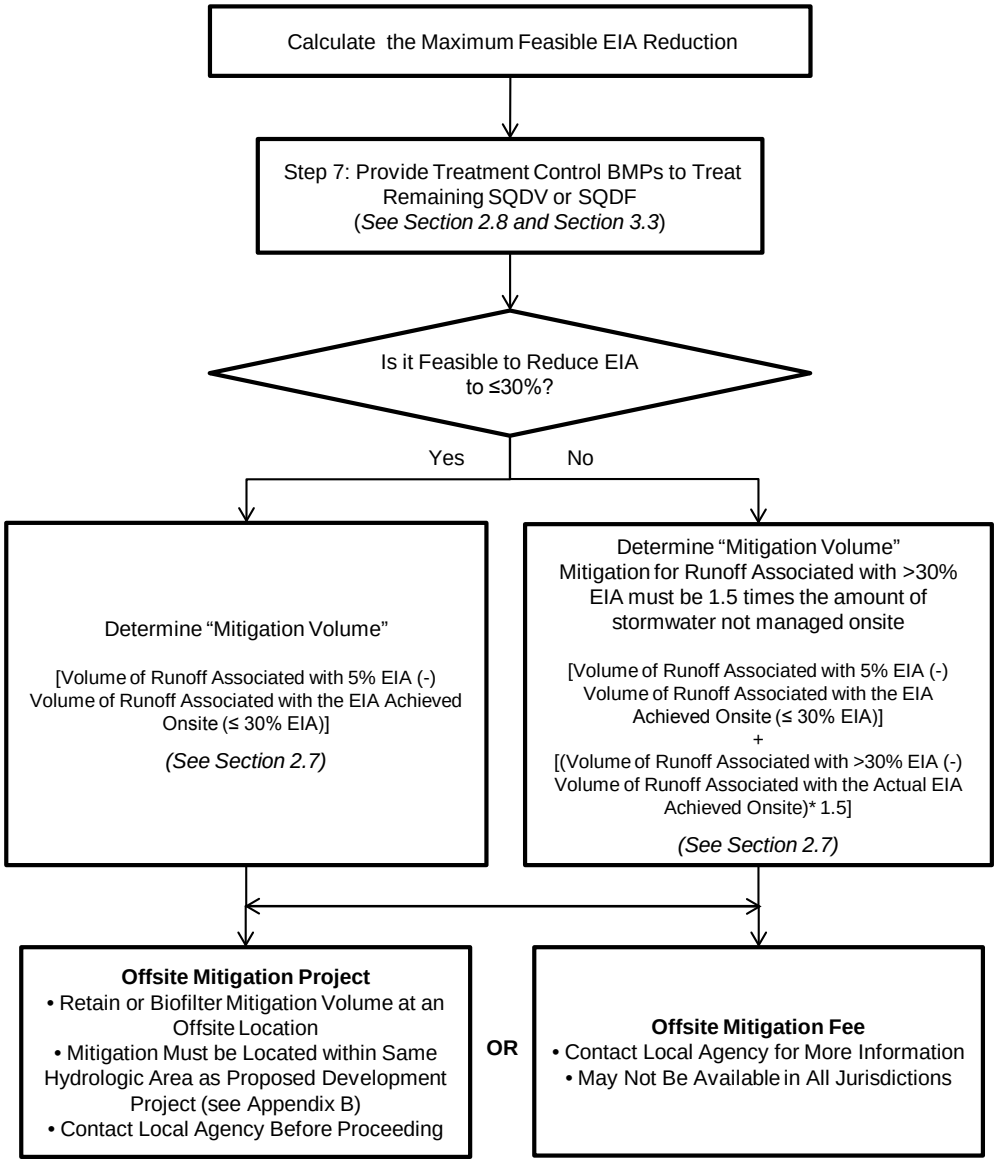


Figure 2-3: Alternative Stormwater Management Control Measures Compliance Decision Flow Chart

Projects in these categories must demonstrate that full compliance with the 5% EIA standard using Retention BMPs and Biofiltration BMPs is infeasible prior to moving to the alternative compliance flowchart (Figure 2-3) and selecting an offsite mitigation alternative. Section 3.2 provides infeasibility criteria.

Stormwater runoff from impervious surfaces and developed pervious surfaces that is not fully retained onsite (up to the SQDV) shall be mitigated using Treatment Control Measures [Chapter 6] selected per the BMP selection process outlined in Section 3.3, in addition to offsite alternative compliance measures.

Alternative compliance may be met through two options:

- Offsite mitigation project; or
- Offsite mitigation fee.

In either case, the Project applicant must contact the local approval agency before proceeding with Alternative Compliance.

Mitigation Volume

Projects requesting alternative compliance must demonstration that EIA has been reduced to the maximum extent practicable. Additionally, the SQDV or SQDF from all directly connected impervious area and the developed pervious project area must be captured and treated within the project site.

Alternative compliance options will be based on the "mitigation volume." The mitigation volume is the difference between the volume of runoff associated with 5% EIA and the volume of runoff associated with the actual EIA achieved onsite less than or equal to 30% (≤30%) EIA. The offsite mitigation requirement for EIA in excess of 30% (>30%) is 1.5 times the amount of stormwater not managed onsite.

Projects Feasible to Reduce EIA to ≤ 30%

1) Determine the volume of runoff that is retained and biofiltered onsite ($V_{Ret/Bio}$), using Equation 2-5 below:

$$V_{Ret/Bio} = (V_{Achieved} + (V_{Biofiltered}/1.5)) \qquad \text{(Equation 2-5)}$$

Where:

$V_{Ret/Bio}$ = the total volume of runoff retained and/or biofiltered onsite using Retention and Biofiltration BMPs

$V_{Achieved}$ = the runoff volume retained onsite using Retention BMPs as calculated in Equation 2-4

$V_{Biofiltered}$ = the runoff volume biofiltered onsite

2) Determine the Mitigation Volume ($V_{Mitigation}$), using Equation 2-6 below:

$$V_{Mitigation} = V_{Retain} - V_{Ret/Bio} \quad \text{(Equation 2-6)}$$

Where:

$V_{Mitigation}$ = the volume of runoff that must be mitigated offsite

V_{Retain} = the SQDV that must be retained onsite per the 5% EIA requirement calculated in Equation 2-3

$V_{Ret/Bio}$ = the total volume of runoff retained and/or biofiltered onsite using Retention and Biofiltration BMPs calculated in Equation 2-5

EXAMPLE 2-4: ≤30% EIA OFFSITE MITIGATION VOLUME CALCULATION

Given: V_{Retain} = 0.3 ac-ft (from Example 2-2); $V_{Retained}$ = 0.25 ac-ft; $V_{Biofiltered}$ = 0.06 ac-ft

1) Calculate volume of runoff retained and biofiltered onsite ($V_{Ret/Bio}$).

$V_{Ret/BioBio}$ = 0.25 + (0.06/1.5) = 0.29 ac-ft [See Equation 2-5]

2) Calculate Mitigation Volume: ($V_{Mitigation}$):

$V_{Mitigation}$ = 0.3– 0.29 = 0.01 acre-feet [See Equation 2-6]

The required offsite mitigation volume is 0.01 ac-ft.

In addition, the SQDV or SQDF from the EIA (0.5 acres) and the developed pervious area (10 acres *25% = 2.5 acres) must be captured and treated in an approved Treatment Control Measure.

SQDV (acre-feet) = C*(0.75/12)*3 acres

OR

SQDF (cfs) = C* 0.20 in/hr * 3 acres

Note: Per Order R4-2010-0108, several options exist to determine the SQDV and SQDF. Examples used throughout the 2011 TGM use the 0.75 inch storm event (SQDV Methodology #3) for the SQDV and 0.2 inches per hour intensity for the SQDF (SQDF Methodology #1). For these examples, the 10-acre project site is assumed to be in a location where the 85th percentile storm event is equal to 0.75 inches.

Projects with EIA > 30%

For the scenario where the effective impervious area of the project is greater than 30% due to infeasibility, the runoff volume associated with the effective impervious area up to 30% must be mitigated offsite at a one-to-one ratio and the runoff volume associated with the effective impervious area greater than 30% must be mitigated off-site at 1.5 times the volume.

1) Determine the area of the impervious portion of the drainage area from which runoff is retained or biofiltered at 30% EIA ($A_{30\%EIA}$), using Equation 2-7 below:

$$A_{30\%EIA} = (IMP*A_{project}) - (30\%*A_{project}) \quad \text{(Equation 2-7)}$$

Where:

$A_{30\%EIA}$	=	the impervious portion of the drainage area from which runoff would have been retained or biofiltered at 30% EIA (acres)
IMP	=	total imperviousness of project area (%)/100
$A_{project}$	=	the total project area (acres)

2) Determine the total volume that would have been retained or biofiltered onsite at 30% EIA ($V_{30\%EIA}$), using Equation 2-8 below:

$$V_{30\%EIA} = C*(0.75/12)*A_{30\%EIA} \qquad \text{(Equation 2-8)}$$

Where:

$V_{30\%EIA}$	=	the stormwater quality design volume (SQDV) retained or biofiltered at 30% EIA (note: for the purposes of this calculation, the biofiltered volume does not include the 1.5 multiplier)
C	=	runoff coefficient [equals o.95 for impervious surfaces]
0.75	=	the design rainfall depth (in) [based on SQDV sizing method 3]
$A_{30\%EIA}$	=	the impervious area from which runoff would have been retained or biofiltered at 30% EIA (acres) [See Equation 2-7]

3) Determine the impervious area from which runoff is actually retained ($A_{ActualEIA}$). This is the total amount of impervious area that drains to properly sized Retention or Biofiltration BMPs.

$$A_{ActualEIA} = (IMP*A_{project}) - (EIA\%*A_{project}) \qquad \text{(Equation 2-9)}$$

Where:

$A_{ActualEIA}$	=	the impervious portion of the drainage area from which runoff is retained or biofiltered using the actual EIA achieved on-site (acres)
IMP	=	total imperviousness of project area (%)/100
$A_{project}$	=	the total project area (acres)
EIA%	=	percent EIA actually achieved on-site

4) Determine the volume that is actually retained onsite ($V_{ActualEIA}$), using Equation 2-10 below:

$$V_{ActualEIA} = C*(0.75/12)*A_{AcutalEIA} \quad \text{(Equation 2-10)}$$

Where:

$V_{AcutalEIA}$	=	the stormwater quality design volume (SQDV) that is retained and/or biofiltered onsite C = runoff coefficient [equals o.95 for impervious surfaces]
0.75	=	the design rainfall depth (in) [based on SQDV sizing method 3]
$A_{ActualEIA}$	=	the area associated with the Actual EIA achieved onsite, (i.e., the area from which runoff is retained or biofiltered (acres) [See # 3 above]

Determine the Mitigation Volume for 30% EIA using Equation 2-11 below:

$$V_{Mitigation30\%} = V_{Retain} - V_{30\%EIA} \quad \text{(Equation 2-11)}$$

Where:

$V_{Mitigation30\%}$	=	the mitigation volume for Project site with 30% EIA
V_{Retain}	=	the SQDV that must be retained onsite per the 5% EIA requirement, calculated using Equation 2-3
$V_{30\%EIA}$	=	the runoff that would have been retained and/or biofiltered at 30% EIA (note: for the purposes of this calculation, the biofiltered volume does not include the 1.5 multiplier), calculated using Equation 2-8

Determine the Mitigation Volume for >30% (EIA $V_{Mitigation>30\%}$), using Equation 2-12 below:

$$V_{Mitigation>30\%} = (V_{30\%EIA} - V_{ActualEIA})*1.5 \quad \text{(Equation 2-12)}$$

Where:

$V_{Mitigation>30\%}$	=	the mitigation volume for >30% EIA
$V_{30\%EIA}$	=	the stormwater quality design volume (SQDV) retained or biofiltered at 30% EIA (note: for the

purposes of this calculation, the biofiltered volume does not include the 1.5 multiplier)

$V_{ActualEIA}$ = the stormwater quality design volume (SQDV) that is actually retained and/or biofiltered onsite, calculated using Equation 2-9

Determine the Total Mitigation Volume ($V_{MitigationTotal}$), using Equation 2-13 below:

$$V_{MitigationTotal} = V_{Mitigation>30\%} + V_{Mitigation30\%} \quad \text{(Equation 2-13)}$$

Where:

$V_{MitigationTotal}$ = the total mitigation volume for 30% EIA

$V_{Mitigation>30\%}$ = the mitigation volume for >30% EIA, calculated using Equation 2-11

$V_{Mitigation30\%}$ = the mitigation volume for 30% EIA calculated using Equation 2-10.

EXAMPLE 2-5: >30% EIA OFFSITE MITIGATION CALCULATION

Given: 40% EIA; 10 acre total project area, 55% impervious, 25% landscaped, 20% undisturbed; runoff coefficient (C) = 0.95; V_{Retain} = 0.3 ac-ft

1) Determine impervious area retained or biofiltered onsite at 30% EIA
   $A_{30\%EIA}$ = ((55/100)*10) – ((30/100)*10) = 2.5 acres [See Equation 2-7]

2) Determine the volume that is retained or biofiltered onsite at 30% EIA
   $V_{30\%EIA}$ = 0.95*(0.75/12)*2.5 = 0.15 ac-ft [See Equation 2-8]

3) Determine the impervious area from which runoff is actually retained
   $A_{ActualEIA}$ = ((55/100)*10) – ((40/100)*10) = 1.5 acres [See Equation 2-9]

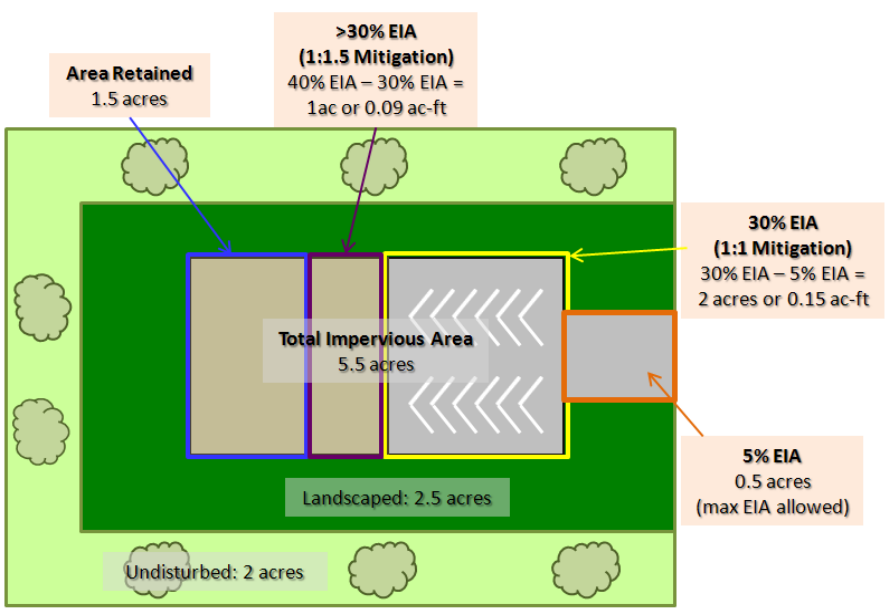
4) Determine the volume that is actually retained or biofiltered onsite
   $V_{ActualEIA}$ = 0.95*(0.75/12)*1.5 = 0.09 ac-ft [See Equation 2-10]

5) Determine Mitigation Volume for 30% EIA
   $V_{Mitigation30\%}$ = 0.3 – 0.15 = 0.15 ac-ft [See Equation 2-11]

6) Determine Mitigation Volume for >30%
   $V_{Mitigation>30\%}$ = (0.15-0.09) *1.5 = 0.09 ac-ft [See Equation 2-12]

7) Determine the Total Mitigation Volume
   $V_{MitigationTotal}$ = 0.15 + 0.09 = 0.24 ac-ft [See Equation 2-13]

The required offsite mitigation volume is 0.24 ac-ft



Selecting Offsite Mitigation Projects

Project applicants may identify offsite mitigation projects. Project applicants are responsible for completing offsite mitigation projects that will achieve equivalent volume and pollutant load reduction using Retention and/or Biofiltration BMPs sized for the mitigation volume. Offsite mitigation projects must adhere to the following criteria:

- Offsite mitigation projects must be located within the same hydrologic area (see map in Appendix B)
- Offsite mitigation projects must be completed as soon as possible and at the latest, within 4 years of the certificate of occupancy for the original project.

Examples of Offsite Mitigation Projects

Mitigation projects should target urbanized areas that were developed without stormwater mitigation. All projects must be approved by the local permitting agency and must adhere to the BMP Selection Criteria presented in Section 3.3 of the 2011 TGM. Potential project types may include:

- Convert a convex parking lot landscaped island into a depressed bioretention area designed to retain parking lot runoff.
- Convert a traditionally-paved parking lot into porous pavement.
- Modify an existing detention pond into a retention pond.
- Install bioretention in bump-outs, in parkways, or in roadway medians.
- Install bioretention in sidewalk areas to infiltrate roof, sidewalk, and/or roadway runoff. Sidewalks must be wide enough to permit foot traffic around bioretention area.
- Incorporate infiltration BMPs into landscaped areas that collect runoff from impervious surfaces.
- Regional BMPs.

Offsite Mitigation Fee

In some cases, Alternative Compliance may be achieved through an Offsite Mitigation Fee. A list of offsite mitigation projects available for funding will be identified by the Approval Agencies. Applicants should contact their local Approval Agency for more information. The Offsite Mitigation Fee may not be available in all jurisdictions.

2.8 Step 7: Apply Treatment Control Measures

Stormwater runoff from EIA and developed pervious surfaces shall be mitigated using Retention BMPs, Biofiltration BMPs, or Treatment Control Measures [Chapter 6] selected per the BMP selection process outlined in Section 3.3. Biofiltration BMPs and Treatment Control Measures may be sized to meet the Stormwater Quality Design Volume (SQDV) or the Stormwater Quality Design Flow (SQDF). Treatment Control Measures should be designed in adherence with the guidance provided in Section 6 of the 2011 TGM in order to assure a level of pollutant removal comparable to those listed in Attachment "C" of Order R4-2010-0108 (also provided in Appendix D.1).

Projects that are eligible for Offsite Mitigation must still provide treatment for all impervious surfaces and developed pervious areas using Treatment Control Measures sized to meet the SQDV or SQDF on site. Treatment Control Measures must be selected per the BMP selection process outlined in Section 3.3.

Stormwater Quality Design Volume (SQDV)

Volume-based Treatment Control Measures must be sized to capture and treat the runoff volume from the water quality design storm. The SQDV shall be calculated using the following four allowable methodologies:

1) The 85th percentile 24-hour runoff event determined as the maximized capture stormwater volume for the area using a 48 to 72-hour draw down time, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998); or

2) The volume of annual runoff based on unit basin storage water quality volume to achieve 80 percent or more volume treatment; or

3) The volume of runoff produced from a 0.75 inch storm event; or

4) Eighty (80) percent of the average annual runoff volume using an appropriate public domain continuous flow model [such as Storm Water Management Model (SWMM) or Hydrologic Engineering Center – Hydrologic Simulation Program – Fortran (HEC-HSPF)], using the local rainfall record and relevant BMP sizing and design data.

The allowable design storm calculation methodology for Treatment Control Measures, per Order R4-2010-0108, is determined by the total project disturbed land area, as summarized in Table 2-2 below.

Table 2-2: Allowed Design Storm Methodology Based on Project Size

Project Size (Disturbed Land Area[1])	Allowed Design Storm Methodology
Less than 5 acres	(1), (2), (3), or (4)
5 acres - 50 acres	(1), (2), or (4)
More than 50 acres	(4)

[1] "Disturbed Area" means any area that is altered as a result of land disturbance, such as clearing, grading, grubbing, stockpiling or excavation.

Instructions for calculating the SQDV based on method (3), the volume of runoff produced from a 0.75 inch storm event, are provided below. Instructions for calculating the SQDV for methods (1), (2), and (4) are provided in Appendix E. Note that Biofiltration BMPs must be sized to treat 1.5 times the volume not retained using Retention BMPs as indicated in Step 5e.

Calculation Procedure

1) Determine the area from which runoff must be retained or captured and treated ($A_{project}$).

2) Determine the runoff coefficient (C), using Equation 2-13 below:

$$C = 0.95*imp + C_p\,(1\text{-}imp) \qquad \text{(Equation 2-13)}$$

Where:

C	=	runoff coefficient (equals o.95 for impervious surfaces)
imp	=	impervious fraction of watershed
C_p	=	pervious runoff coefficient, determined based on soil type using table below [see Ventura County Hydrology Manual (2006)]:

Table 2-3: Ventura Soil Type Pervious Runoff Coefficients

Ventura Soil Type (Soil Number)	C_p value
1	0.15
2	0.10
3	0.10
4	0.05
5	0.05
6	0
7	0

3) Determine the stormwater runoff design volume (SQDV), using Equation 2-14 below:

$$SQDV = C*(0.75/12)* A_{project} \qquad \text{(Equation 2-14)}$$

Where:

SQDV	=	the stormwater quality design volume (acre-feet)
C	=	runoff coefficient, calculated by Equation 2-13
0.75	=	the design rainfall depth (in) [based on sizing method (3)]Atrib
$A_{project}$	=	drainage area of the tributary catchment (acres)

Stormwater Quality Design Flow (SQDF)

For the purposes of the 2011 TGM, instructions for calculating the SQDF based on method (1), the flow of runoff produced from a rainfall event equal to at least 0.2 inches per hour intensity, are provided below. Instructions for calculating the SQDF for methods (2), and (3) are provided in Appendix E. Note that flow-based Biofiltration BMPs used to achieve 5% EIA must be sized per the design intensity specified in Table 2-1.

Calculation Procedure

1) Determine the drainage area from which the flow-based BMP will be receiving runoff ($A_{project}$).

2) Calculate the runoff coefficient (C), using Equation 2-13.

3) Calculate the SQDF using Equation 2-15 below:

$$SQDF = C*I*A_{project} \quad \text{(Equation 2-15)}$$

Where:

SQDF	=	flow in cubic feet per second (cfs)
C	=	runoff coefficient, calculated by Equation 2-13 above
I	=	average rainfall intensity (inches/hour) for a duration equal to the time of concentration of the watershed [equal to 0.2 in/hr for method (1); see also Table 2-1:]
$A_{project}$	=	drainage area of the tributary catchment (acres)

2.9 Step 8: Continue Project Design Process: Flood Control and Hydromodification Requirements

The project applicant should continue with the design process to address additional requirements including flood control and hydromodification control criteria.

Step 8a: Flood Control Requirements

Applicants shall comply with Ventura County and local approval agency regulations on floodplain and floodway management.

Step 8b: Hydromodification (Flow/Volume/Duration) Control Criteria

Projects meeting the applicability criteria contained in Section 4.E.II of Order R4-2010-0108 (presented in Section 1.5 of the 2011 TGM) are required to implement hydrologic control measures to prevent accelerated erosion and to protect stream habitat in downstream natural drainage systems. Natural drainage systems are defined as unlined or unimproved (not engineered) creeks, streams, rivers and their tributaries.

Exemptions

The following new development and redevelopment projects are exempt from the hydromodification control criteria:

1) Single-family structures, unless such projects disturb one acre or more of land or create, add, or replace 10,000 square feet or more of impervious surface area.

2) All projects that disturb less than one acre.

3) Projects that are replacement, maintenance, or repair of an Agency's existing flood control facility, storm drain, or transportation network.

4) Redevelopment projects in existing urban areas [see maps in Appendix B] that do not increase the effective impervious area or decrease the infiltration capacity of pervious areas compared to the pre-developed condition.

5) Projects that have any increased discharge directly or via a storm drain to a sump, lake, area under tidal influence, into a waterway that has a 100-year peak flow (Q100) of 25,000 cubic feet per second (cfs) or more, or other receiving water that is not susceptible to hydromodification impacts.

6) Projects that discharge directly or via a storm drain into concrete or improved (not natural) channels (e.g., rip rap, sackcrete, etc.), which, in turn, discharge into receiving water that is not susceptible to hydromodification impacts (as in #5 above).

Hydromodification Control Measures

The purpose of Hydromodification Control Measures is to minimize changes in post-development stormwater runoff discharge rates, velocities, and durations by maintaining within a certain tolerance, the project's pre-developed stormwater runoff flow rates and durations.

Hydromodification Control Measures may include onsite, subregional, or regional Hydromodification Control Measures, Retention BMPs, or stream restoration measures. Preference must be given to onsite Retention BMPs and Hydromodification Control Measures. In-stream restoration measures may not adversely affect the beneficial uses of natural drainage systems.

The Southern California Stormwater Monitoring Coalition (SMC) is developing a regional methodology to eliminate or mitigate the adverse impacts of hydromodification as a result of urbanization, including hydromodification assessment and management tools. The Program will develop and implement watershed-specific Hydromodification Control Plans (HCPs) after the completion of the SMC study. Until the completion of the HCPs, the Interim Hydromodification Control Criteria, described below, apply to applicable, non-exempt new development and redevelopment projects.

Interim Hydromodification Control Criteria

1) Projects disturbing less than 50 acres must comply with the Stormwater Management Standards contained in the 2011 TGM (i.e., a combination of Retention BMPs, Biofiltration BMPs, and/or Treatment Control Measures).

2) Projects disturbing 50 acres or greater must develop and implement a Hydromodification Analysis Study (HAS) that demonstrates that post development conditions are expected to approximate the pre-developed erosive

effect of sediment transporting flows in receiving waters. The HAS must lead to the incorporation of project design features intended to approximate, to the extent feasible, an Erosion Potential value of 1, or any alternative value that can be shown to be protective of the natural drainage systems from erosion, incision, and sedimentation that can occur as a result of flow increases from impervious surfaces and damage stream habitat in natural drainage systems. The methodology for calculating Erosion Potential is provided in Appendix E of Order R4-2010-0108. Project proponents must work with their local permitting authority to ensure that the HAS is correctly prepared.

2.10 Step 9: Develop Maintenance Plan

The Ventura Countywide Stormwater Quality Management Program (Program) requires the submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of any stormwater control that requires maintenance including Site Design Principles and Techniques (Section 4); Source Control Measures (Section 5; and Retention BMPs, Biofiltration BMPs, and Treatment Control Measures (Section 6). Maintenance Plans must include guidelines for how and when inspection and maintenance should occur for each control. Section 7 and Appendices H and I provide additional information and guidance on compliance with maintenance requirements.

3 SITE ASSESSMENT AND BMP SELECTION

3.1 Assessing Site Conditions and Other Constraints

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

Site Conditions

Topography

The site's topography should be assessed to evaluate surface drainage and topographic high and low points, as well as to identify the presence of steep slopes that qualify as Hillside Locations. All of these conditions have an impact on what type of Retention BMPs, Biofiltration BMPs, and Treatment Control Measures will be most beneficial for a given project site. Stormwater infiltration is more effective on level or gently sloping sites. Flows on slopes steeper than 15% may runoff as surface flows, rather than infiltrate into the ground. On hillsides, infiltrated runoff may daylight or resurface a short distance downslope, which could cause slope instability depending on the soil or geologic conditions. See the Geotechnical Considerations section below.

Soil Type and Geology

The site's soil types and geologic conditions should be determined to evaluate the site's ability to infiltrate stormwater and to identify suitable, as well as unsuitable, locations for infiltration-based BMPs (e.g., infiltration basins and trenches, bioretention without an underdrain, permeable pavement, and drywells). Using the Soil Survey completed by the Soil Conservation Service (SCS) (now identified as the Natural Resource Conservation Service [NRCS]) of the U. S. Department of Agriculture in April 1970, soils in Ventura County were grouped into seven hydrologically homogeneous families [see Ventura County Hydrology Manual (2006); also see Appendix B]. Two families were assigned to each of the NRCS Hydrologic Soil Groups A, B, and C; while only one family was considered appropriate for NRCS Hydrologic Soil Group D [for further information, see http://soils.usda.gov/]:

- Group A soils are typically sands, loamy sands, or sandy loams. Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep and well to excessively drained sands or

gravels and have a high rate of water transmission. Ventura County soil numbers 6 and 7 are Group A soils.

- Group B soils are typically silty loams or loams. They have a moderate infiltration rate when thoroughly wetted and consist chiefly of moderately deep to deep and moderately well to well drained soils with moderately fine to moderately coarse texture. Ventura County soil numbers 4 and 5 are Group B soils.

- Group C soils are typically sandy clay loams. They have low infiltration rates when thoroughly wetted, consist chiefly of soils with a layer that impedes downward movement of water, and/or have moderately fine to fine soil structure. Ventura County soil numbers 2 and 3 are Group C soils.

- Group D soils are typically clay loams, silty clay loams, sandy clays, silty clays, or clays. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with high swelling potential, permanent high water table, claypan or clay layer at or near the surface, and/or shallow soils over nearly impervious material. Ventura County soil number 1 is a Group D soil.

Infiltration-based BMPs should be feasible in areas mapped with Ventura County Soil Numbers 4 through 7. If site-specific data is available, then soils with infiltration rates of 0.5 in/hr or greater are considered feasible for infiltration. Infiltration-based BMPs should not be designed for sites mapped with Ventura County Soil Numbers 1 through 3 (unless site specific testing is performed and shows an infiltration rate greater than 0.5 in/hr) or with site-specific infiltration rates less than 0.5 in/hr.

Locations where soils are mapped with Ventura Hydrology Manual Soil Number 3, or where a site-specific analyses show that the soils have an infiltration rate of 0.3 to 0.5 inches per hour, and no other infiltration-related infeasibility criteria apply, shall use a Bioinfiltration BMP (or Rainwater Harvesting). Bioinfiltration is an adaption of the Bioretention with an Underdrain BMP in which the underdrain is raised above the gravel storage layer in order to promote infiltration but allow release of biotreated runoff to the storm drain when infiltration capacity is reached.

Early identification of soil types throughout the project footprint can reduce the number of test pit investigations and infiltration tests needed. Early identification reduces the number of potential test sites to locations with those that are most likely to be amenable to infiltration. Guidance for conducting test pit investigations and infiltration tests is provided in Appendix C.

Project applicants should review available geologic or geotechnical reports on local geology to identify relevant features such as depth to bedrock, rock type, lithology, faults, and hydrostratigraphic or confining units. These geologic investigations may also identify shallow water tables and past groundwater issues that are important for BMP design (see below).

Groundwater Considerations

Site groundwater conditions should be considered prior to Retention BMP, Biofiltration BMP, and Treatment Control Measure siting, selection, sizing, and design. The depth to groundwater beneath the project during the wet season may preclude infiltration, since five feet of separation to the seasonal high ground water level and mounded groundwater level is required. Depth to seasonal high groundwater level shall be estimated as the average of the annual minima (i.e., the shallowest recorded measurements in each water year, defined as October 1 through September 30) for all years on record. If groundwater level data are not available or not considered to be representative, seasonal high groundwater depth can be determined by redoximorphic analytical methods combined with temporary groundwater monitoring for November 1 through April 1 at the proposed project site.

In areas with known groundwater pollution, infiltration may need to be avoided, as it could contribute to the movement or dispersion of groundwater contamination. Areas with known groundwater impacts include sites listed by the Los Angeles Regional Water Quality Control Board's Leaking Underground Storage Tanks (LUST) program and Site Cleanup Program (SCP). The California State Water Resources Control Board maintains a database of registered contaminated sites through their 'Geotracker' Program. Registered contaminated sites can be identified in the project vicinity when the site address is typed into the "map cleanup sites" field.

Mobilization of groundwater contaminants may also be of concern where contamination from natural sources is prevalent (e.g., marine sediments, selenium rich groundwater, to the extent that data is available). Infiltration on sites with contaminated soils or groundwater that could be mobilized or exacerbated by infiltration is not allowed, unless a site-specific analysis determines the infiltration would be beneficial. A site-specific analysis may be conducted where groundwater pollutant mobilization is a concern to allow for infiltration-based BMPs.

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

Where soils have very high infiltration rates, groundwater quality may be impacted by infiltration BMPs. Prior to the use of infiltration basins and subsurface infiltration BMPs in areas with high infiltration rates, consult with the local

regulatory agencies to identify if unconfined aquifers are located beneath the project to determine the appropriateness of infiltration-based BMPs. In areas underlain by unconfined aquifers with designated beneficial groundwater uses (e.g. drinking water supply), the application of infiltration BMPs should be limited to those that provide significant pretreatment to ensure groundwater is protected from pollutants of concern.

Geotechnical Considerations

Water infiltration can cause geotechnical issues, including: (1) settlement through collapsible soil, (2) expansive soil movement, (3) slope instability, and (4) increased liquefaction hazard. Stormwater infiltration temporarily raises the groundwater level near the infiltration facility, such that the potential geotechnical conditions are likely to be of greatest significance near the infiltration area and decrease with distance. A geotechnical investigation should be performed for the infiltration facility to identify potential geotechnical issues and geological hazards that may result from infiltration.

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

Collapsible Soil

Typically, collapsible soil is observed in sediments that are loosely deposited, separated by coatings or particles of clay or carbonate, and subject to saturation. Stormwater infiltration will result in a temporary rise in the groundwater elevation. This rise in groundwater could change the soil structure by dissolving or deteriorating the intergranular contacts between the sand particles, resulting in a sudden collapse, referred to as hydrocollapse. This collapse phenomenon generally occurs during the first saturation episode after deposition of the soil, and repeated cycles of saturation are not likely to result in additional collapse. It is important to evaluate the potential for hydrocollapse during the geotechnical investigation.

The magnitude of hydrocollapse is proportional to the thickness of the soil column where infiltration is occurring. In most instances, the magnitude of hydrocollapse will be small. Regardless, the geotechnical engineer should evaluate the potential effects of hydrocollapse from large infiltration facilities on nearby structures and roadways. Typically, a network of surface settlement monuments is installed around the infiltration site, along adjacent roadways, and in neighboring developments to evaluate if hydrocollapse has occurred. These monuments are typically monitored

prior to infiltrating stormwater, monthly during the first year of operation of the facility, then yearly thereafter for a period of approximately five years.

Expansive Soil

Expansive soil is generally defined as soil or rock material that has a potential for shrinking or swelling under changing moisture conditions. Expansive soils contain clay minerals that expand in volume when water is introduced and shrink when the water is removed or the material is dried. When expansive soil is present near the ground surface, a rise in groundwater from infiltration activities can introduce moisture and cause these soils to swell. Conversely, as the groundwater surface falls after infiltration, these soils will shrink in response to the loss of moisture in the soil structure. The effects of expansive soil movement (swelling and shrinking) will be greatest on near surface structures such as shallow foundations, roadways, and concrete walks. Basements or below-grade parking structures can also be affected as additional loads are applied to the basement walls from the large swelling pressures generated by soil expansion. A geotechnical investigation should identify if expandable materials are present near the proposed infiltration facility, and if they are, evaluate if the infiltration will result in wetting of these materials. See Appendix B, Map B-14 (expansive soil potential map).

Slopes

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

Liquefaction

Seismically-induced soil liquefaction is a phenomenon in which saturated granular materials, typically possessing low to medium density, undergo matrix rearrangement, develop high pore water pressure, and lose shear strength due to cyclic ground motions induced by earthquakes. This rearrangement and strength loss is followed by a reduction in bulk volume. Manifestation of soil liquefaction can include loss of bearing capacity for foundations, surface settlements, and tilting in level ground. Soil liquefaction can also result in instabilities and lateral spreading in embankments and areas of sloping ground.

Saturation of the subsurface soils above the existing groundwater table may occur as a result of stormwater infiltration. A groundwater mounding analysis should also

evaluate the duration of mounding, as a lengthy duration or long-term rise in groundwater will need to be considered in the evaluation of liquefaction. If the granular soils are sufficiently dense, it is unlikely that liquefaction will be of concern, regardless of the groundwater mounding. If analyses indicate that the potential for liquefaction may be increased from stormwater infiltration, then the analyses will need to evaluate the liquefaction-induced settlement of structures, lateral spreading, and other surface manifestations. See Appendix B, Map B-14 (liquefaction potential map).

Managing Offsite Drainage

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

Existing Utilities

Existing utility lines that are onsite will limit the possible locations of certain BMPs. For example, infiltration BMPs should not be located near utility lines where the increased amount of water could damage the utilities. Stormwater should be directed away from existing underground utilities. Project designs that require the relocation of existing utilities should be avoided, if possible.

Environmentally Sensitive Areas

The presence of Environmentally Sensitive Areas (ESAs) may limit the siting of certain BMPs. ESA's are typically delineated by and fall under the regulatory oversight of state or federal agencies such as the U.S. Army Corp of Engineers (USACE), California Department of Fish and Game, U.S. Fish and Wildlife Service, or the California Environmental Protection Agency. BMPs should be selected and sited to avoid adversely affecting an ESA. The Ventura County ESA map (ESA as defined in Order R4-2010-0108) is provided in Appendix B or may be obtained from the local permitting authority.

3.2 Technical Feasibility Screening

To use biofiltration BMPs and alternative compliance measures, the project applicant should demonstrate that compliance with the requirement to reduce EIA to ≤5% using Retention BMPs is technically infeasible by submitting a site-specific hydrologic and/or design analysis conducted and endorsed by a registered professional engineer and/or geologist. Projects seeking to use alternative compliance measures must demonstrate EIA has been reduced to the maximum

extent practicable. Project applicants should contact their local Approval Agency to determine if additional infeasibility criteria apply. Technical infeasibility may result from conditions including the following:

1) Locations where seasonal high groundwater or mounded groundwater beneath an infiltration BMP is within 5 feet of the bottom of the infiltration BMP.

2) Locations on the project site where soils are mapped with Ventura Hydrology Manual Soil Numbers 1-2 or site-specific analyses show that the soils have an infiltration rate less than 0.3 inches per hour. Locations where soils are mapped with Ventura Hydrology Manual Soil Number 3, or where a site-specific analyses show that the soils have an infiltration rate of 0.3 to 0.5 inches per hour, and no other infiltration-related infeasibility criteria apply, shall use a Bioinfiltration BMP or Rainwater Harvesting (if feasible) to achieve the 5% EIA requirement.

3) Locations on the project site within 100 feet of a groundwater well used for drinking water, non-potable wells, drain fields, and springs; locations less than 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project; and locations less than eight feet from building foundations or an alternative setback established by the geotechnical expert for the project.

4) Locations where pollutant mobilization is a documented concern, unless a site-specific analysis determines that infiltration would not be detrimental. Portions of brownfield development sites may be eligible for alternative compliance where pollutant mobilization is a concern.

5) Locations with potential geotechnical hazards established by the geotechnical professional for the project.

6) Projects with high-risk areas such as service/gas stations, truck stops, and heavy industrial sites, unless a site-specific evaluation demonstrates that:

   - Treatment is provided to address pollutants of concern, and/or

   - High risks areas are isolated from stormwater runoff or infiltration areas with little chance of spill migration.

7) Locations where reduction of surface runoff may potentially impair beneficial uses of the receiving water as documented in a site-specific study (e.g., California Environmental Quality Act (CEQA) analysis) or watershed plan.

8) Location where an increase in infiltration over natural conditions could potentially cause impairments to downstream beneficial uses, such as change of seasonality of ephemeral washes, as confirmed through a site-specific study.

9) Green roofs are not required to be considered for all project locations and types; this evapotranspiration BMP is considered optional subject to the approval of the permitting authority.

10) Projects that do not provide sufficient demand for harvested stormwater such that the system provides 80% capture with a 72 hour drawdown time considering all "allowable and reliable demand."

    a. Allowable and reliable demand is defined as the rate of use of harvested water under average wet season conditions (November through March), from sources meeting the following criteria:

        - The use is permitted by building codes and health codes without requiring disinfection and fine filtration.

        - The use is reliable on a seasonal basis, such that the lowest weekly demand on an average annual basis is no less than 2/7th of the wet season average. *Intent: Under worst-case conditions, the demand should still be sufficient to use the entire tank volume within a week.*

        - Where a reliable use is present on the site that is not permitted by building codes and/or health codes, a variance has been sought to allow use without disinfection and fine filtration.

        - The use does not conflict with mandatory use of reclaimed water. It is assumed that uses do not conflict unless water balance calculations are provided to demonstrate the contrary.

        - The estimated use rates are consistent with requirements for low water use landscaping requirements under local and statewide ordinance (including California Assembly Bill 1881).

11) BMPs that are not allowable per current federal, state or local codes are considered infeasible. Local codes will be updated by mid-2012 as required in Order R4-2010-0108 (Provision III.D).

12) The following project types where the density and/or nature of the project would create significant difficulty for compliance with the requirement to reduce EIA to ≤5%:

    a. Redevelopment projects (as defined in Section1.5).

    b. Infill projects that meet the following conditions:

        i. The project is consistent with applicable general plan designation, and all applicable general plan policies, and applicable zoning designation and regulations;

ii. The proposed development occurs on a project site of no more than five acres substantially surrounded by urban uses;

iii. The project site has no value as habitat for endangered, rare, or threatened species;

iv. Approval of the project would not result in any significant effects relating to traffic, noise, air quality, or water quality; and

v. The site can be adequately served by all required utilities and public services (modified from State Guidelines § 15332).

c. Smart Growth projects, which are defined as new development and redevelopment projects that occur within existing urban areas (see maps in Appendix B) designed to achieve the majority of the following principles :

i. Create a range of housing opportunities and choices;

ii. Create walkable neighborhoods;

iii. Mix land uses;

iv. Preserve open space, natural beauty, and critical areas;

1. Farmland preservation may also be considered for projects occurring outside existing urban areas (as defined by the Appendix B maps).

v. Provide a variety of transportation choices;

vi. Includes transit oriented development (development located within an average 2,000 foot walk to a bus or train station).

vii. Strengthen and direct development towards existing communities (as defined by Appendix B maps); and

viii. Take advantage of compact building design.

The City or County Planning Division in which a project is proposed will ultimately determine whether a project meets these Smart Growth criteria.

13) Pedestrian/bike trail projects:

- ✓ Located along side of a road and
- ✓ Where right-of-way width is inadequate for the implementation of Retention and/or Biofiltration BMPs.

14) Agency flood control, drainage, and wet utilities projects:

- ✓ Located within waterbody and is therefore not increasing functional impervious cover; or
- ✓ Located on top of a narrow flood control feature (such as a levee) and space is unavailable for the implementation of Retention and/or Biofiltration BMPs; or
- ✓ Where the integrity of the flood control feature (such as a dam or levee) may be compromised through Retention and/or Biofiltration BMPs (e.g., infiltration of stormwater is not appropriate in a levee).

15) Historical preservation projects:

- ✓ Where the extent of the designated preservation area restricts the amount of land available for the implementation of Retention BMPs.

16) Low income housing projects that occur within existing urban areas (as defined by the maps provided in Appendix B):

- ✓ Where density requirements restrict the amount of land available for the implementation of Retention BMPs and/or
- ✓ Where project financing constraints restrict the amount of land available for the implementation of Retention BMPs.

Determining Maximum Volume Feasibly Infiltrated and/or Biofiltered

Site conditions and constraints may make it infeasible to fully retain stormwater to achieve ≤ 5% EIA using Retention BMPs. In such cases, stormwater runoff must be retained to the maximum extent practicable and then the remaining volume must be multiplied by 1.5 and biofiltered to the maximum extent practicable. If SQDV still remains, it may be addressed in an alternative compliance program. This section provides narrative and numeric criteria for determining the "maximized" volume for Infiltration BMPs and Biofiltration BMPs. The term "maximized" refers to the volume that is determined, on a case-by-case basis, to be consistent with the maximum extent practicable standard.

Criteria for Maximizing Infiltration Volume

Volume can be considered to be maximized in infiltration BMPs when all of the following conditions are met, or when adjustments to the site/BMP plan to meet any one of these criteria results in achievement of the ≤5% EIA performance standard:

1) BMPs are designed to the maximum depth allowed by design standards, but are not required to exceed the depth that infiltrates within 48 hours at the design percolation rate. *Explanation: Deeper BMPs provide more volume per footprint*

area, therefore it is more feasible to retain stormwater in deeper BMPs than shallower BMPs. However, because of the nature of sequential storms in Southern California, the volume provided in excess of that which drains within 48 hours provides significantly diminishing value.

2) All practicable methods are employed to enhance the design percolation rate, including:

   - Use of soil amendments to native soil below infiltration BMPs, and
   - Provision of pretreatment to reduce the allowable factor of safety, and
   - Additional site investigation to reduce uncertainty in infiltration rate and allow the use of a lower factor of safety.

3) Good site practices have been integrated to provide the maximum pervious area feasible for infiltration BMPs, and infiltration BMPs have been configured to make use of this area. Table 3-1 provides recommended percentages of a site, by project type, that should be feasible to dedicate to infiltration BMPs (where technically feasible) within pervious areas. If the project has not provided this portion of the project site for infiltration BMPs (where technically feasible), an attempt should be made to improve site design to provide more pervious area until it is either infeasible to provide more pervious area or EIA is reduced to ≤5%. The minimum percent of parking lot pavement area considered feasible to dedicate to permeable pavement (where technically feasible) is 20%; this does not apply to parking lots that anticipate heavy truck traffic such as truck stops and heavy industrial areas. The criteria provided in Table 3-1 are guidance; each project will be individually evaluated by the local permitting authority to determine if good site practices have been integrated into the project to provide the maximum pervious area feasible for siting infiltration BMPs.

Criteria for Maximizing Biofiltration Volume

Biofiltration BMPs can be used downstream of a Retention BMP that has been "maximized" (e.g., a planter box treating overflow from a cistern) or can be designed to provide both "maximized" retention and "maximized" biofiltration in the same BMP (e.g., a bioretention area with an underdrain, where retention volume is provided in a gravel layer or other subsurface reservoir below the underdrain).

Volume can be considered to be maximized in Biofiltration BMPs when all of the following conditions are met, or when adjustments to the site design and BMP plan to meet any one of these criteria results in achievement of the ≤5% EIA performance standard:

1) Drain time and/or treatment rate of the Biofiltration BMP is consistent with design guidance contained in Section 6 of the 2011 TGM.

2) Good site practices have been integrated to provide the maximum area feasible for Biofiltration BMPs, and BMPs have been configured to make use of this area. Table 3-1 provides recommended percentages of a site that are feasible to be dedicated to Biofiltration BMPs by project type. If the project has not provided these portions of the project site for siting Biofiltration BMPs, an attempt should be made to improve site design to provide more area until it is either infeasible to provide more area or EIA is reduced to ≤5%. The criteria provided in Table 3-1 are guidance; each project will be individually evaluated by the local permitting authority to determine if good site practices have been integrated into the project to provide the maximum pervious area feasible for siting Biofiltration BMPs.

If a Biofiltration BMP also includes a retention component (e.g., storage volume in a swale in amended soil below the surface discharge elevation or storage below the underdrain of a bioretention area), the maximized retention volume is determined as the volume of water that can be infiltrated or evapotranspired within 48 hours after the Biofiltration BMP has emptied. This criterion should be used to establish the depth of the retention layer (i.e., the depth of amended soil below the swale or the size of the storage below underdrains in the bioretention area).

Table 3-1: Recommended Criteria for Percent of Site Feasible to Dedicate to BMPs

Project Type		Percent of Site[1]
New Development	SF/MF Residential < 7 du/ac	10
	SF/MF Residential 7 – 18 du/ac	7
	SF/MF Residential > 18 du/ac	5
	Mixed Use, Commercial, Institutional/Industrial w/ FAR < 1.0	10
	Mixed Use, Commercial, Institutional/Industrial w/ FAR 1.0 – 2.0	7
	Mixed Use, Commercial, Institutional/Industrial w/ FAR > 2.0	5
	Podium (parking under > 75% of project)	3
	Projects with zoning allowing development to lot lines	2
	Transit Oriented Development	5
	Parking	5

Project Type		Percent of Site[1]
Redevelopment	SF/MF Residential < 7 du/ac	5
	SF/MF Residential 7 – 18 du/ac	4
	SF/MF Residential > 18 du/ac	3
	Mixed Use, Commercial, Institutional/Industrial w/ FAR < 1.0	5
	Mixed Use, Commercial, Institutional/Industrial w/ FAR 1.0 – 2.0	4
	Mixed Use, Commercial, Institutional/Industrial w/ FAR > 2.0	3
	Podium (parking under > 75% of project)	2
	Projects with zoning allowing development to lot lines	1
	Transit Oriented Development	3
	Projects in Historic Districts	3

Key: SF = Single Family, MF = Multi Family, du/ac = dwelling units per acre, FAR = Floor Area Ratio = ratio of gross floor area of building to gross lot area.

[1] If subsurface BMPs are used, dedicated area may have other surface land uses which do not structurally impact the subsurface BMP (see INF-6: Proprietary Infiltration).

3.3 Treatment Control Measure Selection Guidance

Treatment Control Measure selection criteria contained in Order R4-2010-0108 include the following:

- Treatment Control Measures shall be selected based on the primary class of pollutants likely to be discharged from the project (e.g., metals from an auto repair shop).
- For projects that discharge to an impaired waterbody and whose discharges contain the pollutant causing impairment, the project shall select Treatment Control Measures from the top three performing BMP categories, or alternative BMPs that are designed to meet or exceed the performance of the highest performing BMP, for the pollutant causing impairment.

Primary Class of Pollutants

Pollutants in stormwater runoff are typically related to land use activities, which means that the proposed project's site uses provide some indication of the pollutants that will be generated in the site's runoff. Table 3-2 identifies pollutants of concern based on typical land use activities that may be present on a project site.

Table 3-2: Land Uses and Associated Pollutants

Class of Pollutant	Potential Land Use and Activities Sources
Sediment (TSS and Turbidity)	Streets, driveways, roads, landscaped areas, construction activities, soil erosion (channels and slopes)
Nutrients	Landscape fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents
Metals/Metalloids	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, metal surfaces, combustion processes
Pesticides	Landscaped areas, roadsides, utility right-of-ways
Organic Materials/ Oxygen Demanding Substances	Landscaped areas, animal wastes, industrial wastes
Oil and Grease/ Organics Associated with Petroleum	Roads, driveways, parking lots, vehicle maintenance areas, gas stations, automobile emissions, restaurants
Bacteria and Viruses	Lawns, roads, leaky sanitary sewer lines, sanitary sewer cross-connections, animal waste (domestic and wild), septic systems, homeless encampments, sediments/biofilms in stormwater conveyance system
Trash and Debris (Gross Solids and Floatables)	Commercial areas, roadways, schools, trash receptacles/storage/disposal

Adapted from US EPA, 1999 (Preliminary Data Summary of Urban Stormwater BMPs)

Impaired Waterbodies

When designated beneficial uses of a particular receiving water body are being compromised by water quality for a specific or multiple pollutants, Section 303(d) of the CWA requires identifying and listing that water body as "impaired".

Table 3-3 below lists the categories of pollutants and specific pollutants that are included on the 2010 303(d) list for Ventura County. Project proponents should consult the most recent 303(d) list to identify whether the project's receiving waterbody is listed as impaired. The most recent 303(d) list is located on the State Water Resources Control Board website (click on water issues/programs/water quality assessment).

Table 3-3: Ventura County 2010 303(d)-listed Water Quality Pollutants

Class of Pollutant	Specific Pollutants		
Sediment (TSS and Turbidity)	Sedimentation/Siltation		
Nutrients	Ammonia Nitrate and Nitrite Nitrate Nitrogen	Organic Enrichment/ Low Dissolved Oxygen	Algae Eutrophic
Metals/Metalloids	Boron Copper Copper, Dissolved	Lead Mercury Nickel	Selenium Zinc
Pesticides	ChemA (tissue) Chlordane Chlordane (tissue & sediment) Chlordane (tissue) Chlorpyrifos Chlorpyrifos (tissue) DDT DDT (sediment) DDT (tissue & sediment)	DDT (tissue) Diazinon Dieldrin Dieldrin (tissue) Organophosphorous Pesticides Toxaphene Toxaphene (tissue & sediment) Toxaphene (tissue)	
Trash and Debris (Gross Solids and Floatables)	Trash and Debris		
Other Organics	PCBs		
Bacteria and Viruses	Coliform Bacteria	Indicator Bacteria	
Salinity	Chloride		
Toxicity	Sediment Toxicity	Toxicity	
Miscellaneous	pH	Scum/Foam - unnatural	Sulfates

Once the classes of pollutants likely to be discharged from the project have been identified for projects that do not discharge to an impaired waterbody, any Treatment Control Measures listed in Table 3-4 that addresses the primary pollutant class may be selected. If more than one pollutant class is identified, then sediment shall be the primary pollutant class.

For projects that discharge to an impaired waterbody and whose discharges contain the pollutant causing impairment, the project shall select Treatment Control Measures from the top three BMPs listed for that class of pollutant in Table 3-4, or alternative BMPs that are designed to meet or exceed the performance of the highest performing Treatment Control Measure, for the pollutant causing impairment. Many receiving water impairments are due to legacy pollutants from past land use activities (e.g., DDT from historical farming or PCBs from historical industrial activities), where the primary sources are contaminated soils and sediment. For these pollutants, site clean-up, erosion and sediment controls during construction, slope

stabilization measures, and placement of impervious surfaces will address the legacy pollutants.

Table 3-4: Treatment Control Measures for Addressing Pollutants of Concern

Class of Pollutant	Recommended BMPs (in Order of Performance)
Sediment	1. Retention BMPs (Infiltration, Rainwater Harvesting, and Evapotranspiration BMPs) 2. Any of the following BMPs(equivalent performance): a. Biofiltration BMPs b. Wet Detention Basin c. Constructed Wetland d. Sand Filter/Cartridge Media Filter 3. Dry Extended Detention Basin
Metals / Metalloids	1. Retention BMPs (Infiltration, Rainwater Harvesting, and Evapotranspiration BMPs) 2. Any of the following BMPs (equivalent performance): a. Constructed Wetland b. Biofiltration BMPs c. Wet Detention Basin d. Sand Filter/Cartridge Media Filter 3. Dry Extended Detention Basin
Nutrients[1]	1. Retention BMPs (Infiltration, Rainwater Harvesting, and Evapotranspiration BMPs) 2. Any of the following BMPs (equivalent performance): a. Bioinfiltration b. Wet Detention Basin c. Constructed Wetland 3. Any of the following BMPs (equivalent performance): a. Biofiltration BMPs 4. Any of the following (equivalent performance): a. Sand Filter/Cartridge Media Filter b. Dry Extended Detention Basin
Pesticides[2]	1. Source controls, erosion controls 2. Retention BMPs (Infiltration, Rainwater Harvesting, and Evapotranspiration BMPs) 3. Any of the following BMPs (equivalent performance): a. Biofiltration BMPs b. Wet Detention Basin c. Constructed Wetland d. Sand Filter/Cartridge Media Filter 4. Dry Extended Detention Basin

Class of Pollutant	Recommended BMPs (in Order of Performance)
Pathogens	1. Retention BMPs (Infiltration, Rainwater Harvesting, and Evapotranspiration BMPs) 2. Any of the following BMPs (equivalent performance): a. Bioretention with Underdrain b. Wet Detention Basins c. Proprietary Biofiltration 3. Sand Filter/Cartridge Media Filter
Trash and Debris	1. Gross Solids Removal BMPs (should be combined with a Retention BMP, Biofiltration BMP, or Treatment Control Measure) 2. Any Retention BMP, Biofiltration BMP, or Treatment Control Measure designed to incorporate a trash capture device (e.g., a trash screen)

[1]Performance is based on removal of nitrogen compounds. For performance of BMPs in removing phosphorous, see sediment pollutant class as they are largely associated with particulates.
[2]Performance data is not available for this pollutant class, but as they are largely associated with particulates, BMP selection should be similar to the sediment pollutant class.

An analysis of Biofiltration BMP and Treatment Control Measure performance from the ASCE International Stormwater BMP Database [1999-2008] is provided in Appendix D. These performance data summaries are occasionally revised. Updated analyses of Biofiltration BMP and Treatment Control Measure performance may be found on the ASCE International Stormwater BMP Database website. The 2011 TGM assumes that BMPs adhering to the design guidance provided in Section 6 will have a level of pollutant removal performance comparable to those listed in Attachment C in Order R4-2010-0108 (also provided in Appendix D.1).

Proprietary BMPs should meet or exceed the performance standards listed in Attachment C in Order R4-2010-0108 and provided in Appendix D.

The data contained in the Stormwater BMP Database indicate that wet detention basins, constructed wetlands, sand filters, and biofilters are among the best performing BMPs for the typical pollutants of concern in urban runoff. This conclusion is consistent with the treatment processes typically provided by these BMP types (e.g., filtration, sedimentation, adsorption, and biological processes).

Wet detention basins (wetponds) and constructed wetlands are attractive solutions both from a treatment process and observed performance perspective. However, these systems require significant base flow to maintain their permanent pools and to avoid creating stagnant conditions and vector concerns. Therefore, these BMPs are often infeasible in locations where water conservation during dry weather is a significant concern. If a regional Treatment Control Measure is desired, infiltration basins and dry extended detention basins may be more feasible in Ventura County. However, these BMPs may need additional treatment train components (e.g., pre- or post-treatment) to adequately address the entire list of pollutants of concern and provide reliable and consistent performance, in addition to significant space

requirements. BMP designs for each pollutant category that incorporate dense vegetation and promote extended contact with or filtration through soils are encouraged, consistent with the BMP selection prioritization requirements in Order R4-2010-0108.

Consideration of Site-Specific Conditions

Ultimately, Retention BMPs, Biofiltration BMPs, and Treatment Control Measures have to be constructed at a physical location and site-specific conditions should be considered during the BMP selection process. Site constraints such as steep slopes, poor draining soils, high ground water tables, unstable or contaminated soils and several other factors can preclude the implementation of certain kinds of Retention BMPs, Biofiltration BMPs, and Treatment Control Measures or design options. Therefore, site-specific conditions must be considered when selecting specific BMPs or Treatment Control Measures to implement. Once candidate BMPs or Treatment Control Measures have been chosen, the selection process should consider the site assessment results for soil characteristics, slopes, groundwater proximity, etc. Table 3-5 below provides general guidance for designers regarding site limitations for the different Retention BMPs, Biofiltration BMPs, and Treatment Control Measures.

Table 3-6 below provides general guidance for designers regarding capital and operation costs for the different Retention BMPs, Biofiltration BMPs, and Treatment Control Measures. BMP costs can also be estimated using the Water Environment Research Foundation (WERF) BMP and LID Whole Life Cost Models. These models are set of spreadsheet tools that help users identify and combine capital costs and ongoing maintenance expenditures in order to estimate whole life costs for stormwater management. The models provide a framework for calculating capital and long-term maintenance costs of individual Retention BMPs, Biofiltration BMPs, and Treatment Control Measures. Models are included for retention ponds, extended detention basins, vegetated swales, permeable pavement, green roofs, large commercial cisterns, and bioretention. Online PDF of user's guide and spreadsheet tools are located here: http://www.werf.org/AM/Template.cfm?Section=Research_Profile&Template=/CustomSource/Research/PublicationProfile.cfm&id=SW2R08.

Table 3-5: BMP Site Suitability Considerations

Important Note to Users: This table should be used to provide general BMP comparisons only and should not replace an evaluation performed by a qualified water quality professional.

BMP	Site Suitability Considerations			
	Tributary Area (Acres) [1]	Site Slope (%)	Depth to Seasonally High or Mounded Groundwater (ft)	Soil Number
Infiltration BMPs: INF-1: Infiltration Basin INF-2: Infiltration Trench INF-3: Bioretention INF-4: Drywell INF-6: Proprietary Infiltration	< 5	< 7[2]	> 5	Not suitable in Soil Numbers 1, 2, and 3 unless percolation testing shows the infiltration rate is greater than 0.5 in/hr
INF-5: Permeable Pavement	< 5	< 5[2,5]	> 2 with underdrains; > 5 without underdrains	Underdrains should be provided for Soil Numbers 1, 2, and 3
ET-1: Green Roof	Equal to roof tributary area	N/A	N/A	N/A
BIO-1: Bioretention with Underdrain	< 5	< 15; planter boxes are generally more suitable for steep slopes[2,3]	> 2 with underdrains; > 5 without underdrains	Underdrains should be provided for Soil Numbers 1, 2, and 3
BIO-2: Planter Box	< 1	< 15[4]	> 2	Any
BIO-3: Vegetated Swale	< 5	< 10 site slope; 0.5 to 6 longitudinal slope of swale [2,3]	> 2 with underdrains; > 5 without underdrains	Any[3]

BMP	Site Suitability Considerations			
	Tributary Area (Acres) [1]	Site Slope (%)	Depth to Seasonally High or Mounded Groundwater (ft)	Soil Number
BIO-4: Vegetated Filter Strip	< 2	< 4 site slope; 2 to 6 longitudinal slope of strip[2]	> 2	Any
BIO-5: Proprietary Biotreatment Devices	The site suitability requirements for specific proprietary devices must be provided by the manufacturer and should be verified by independent sources or assessed by a qualified water quality professional.			
TCM-4: Sand Filter	< 10	< 15[4]	> 2	Any
TCM-5: Cartridge Media Filters	The site suitability requirements for specific proprietary devices must be provided by the manufacturer and should be verified by independent sources or assessed by a qualified water quality professional.			
PT-1: Hydrodynamic Devices	The site suitability requirements for specific proprietary devices must be provided by the manufacturer and should be verified by independent sources or assessed by a qualified water quality professional.			
PT-2: Catch Basin Inserts				

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here should be used as a general guideline only. Tributary areas can be larger or smaller as appropriate.

[2] If site slope exceeds that specified or if the system is within 200 ft from the top of a hazardous slope or landslide area (on the uphill side), a geotechnical investigation analysis and report addressing slope stability shall be prepared by a licensed civil engineer. In addition, for swales, if the longitudinal slope exceeds 6%, check dams should be provided.

[3] If system is located within 50 feet of a sensitive steep slope (on the uphill side), within 10 feet from a structure, has a longitudinal slope less than 1.5% (swales), or has poorly drained soils (e.g., silts and clays), underdrains should be incorporated.

[4] If system is fully contained, includes an underdrain system, and overflows to a stormwater conveyance system, then slopes can exceed 15%.

[5] If a gravel base is used for storage of runoff: (1) slopes should be restricted to 0.5% (steeper grades reduce storage capacity) and (2) underdrains should be used if within 50 feet of a sensitive steep slope.

[6] Setbacks apply to systems without underdrains.

Table 3-6: BMP Cost Considerations

BMP Type	Relative Expense[4] (cost/ac-ft[1] or cost/cfs[2])	Construction Costs (per cubic feet)[3,4]	Typical Cost[3]		Annual Maintenance Cost (% of Construction)[3,4]	Notes
			($/BMP)	Application		
Infiltration Trench	Not included	$4- $50	$45,000	5-ac Commercial Site (65% Impervious)	5%-20%	
Infiltration Basin	$	$1.30 - $18	$15,000	5-ac Commercial Site (65% Impervious)	1% -10%	
Bioretention	Not included	$3- $5.30	$60,000	5-ac Commercial Site (65% Impervious)	5%- 7%	Cost of plants varies. Maintenance costs comparable to cost of typical landscaping.
Swale	$$	$0.25-$0.50	$3,500	5-ac Residential Site (35% Impervious)	5%- 7%	
Filter Strip	$$	$0.00- $1.30	$0- $9,000	5-ac Residential Site (35% Impervious)	$350/ acre/ year (about $0.01/square foot/ year)	
Extended Detention Basin	$$$	$0.50- $1.00	Not included		3 to 6%	Costs vary widely. One 0.3 ac-ft basin was recorded to have cost $160,000[5] $3,132 Annual maintenance costs for per Caltrans[5]
Wet Ponds	$$$	$0.50- $1.00	Not included		3 to 6%	$17,000 Annual maintenance costs for one Caltrans pond[5]
Constructed Wetland	$$$$	$0.60 – $1.25	$125,000	50-Acre Residential Site (35% Impervious)	2%	
Sand Filter	$$$$	$3 - $6	$35,000- $70,000	5-Acre Commercial Site (65% Impervious)		

[1] Volume based BMPs

[2] Flow based BMPs

[3] EPA, 1999. Preliminary Data Summary of Urban Storm Water Best Management Practices. Part D, Cost and Benefits Analysis. http://water.epa.gov/scitech/wastetech/guide/stormwater/index.cfm#report

[4] CASQA, 2003. New Development and Redevelopment Handbook

[5] Figures from Caltrans studies cited in CASQA BMP Handbook.

4 SITE DESIGN PRINCIPLES AND TECHNIQUES

4.1 Introduction

The primary objective of the Site Design Principles and Techniques is to reduce the hydrologic and water quality impacts associated with land development. The benefits derived from this approach include**:**

- Reduced size of downstream Treatment Control Measures and conveyance systems;
- Reduced pollutant loading to onsite Treatment Control Measures and receiving streams; and
- Reduced hydraulic impact on receiving streams.

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

- Site planning;
- Protect and restore natural areas;
- Minimize land disturbance;
- Minimize impervious cover;
- Apply Low Impact Development best management practices (LID BMPs) at various scales: and
- Implement Integrated Water Resource Management Practices.

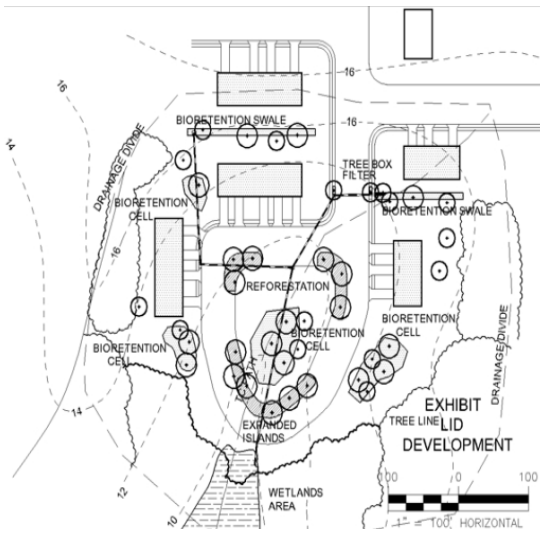
The Site Design Principles and Techniques described in this section are required to be considered for all new development and redevelopment projects subject to conditioning and approval for the design and implementation of post-construction stormwater management control measures (as defined in Section 1.5). They are not required if the project proponent demonstrates to the satisfaction of the City or County that the particular measures are not applicable to the proposed project, or the project site conditions make it infeasible to implement the site design control measure in question. The applicability of specific controls outlined within this section should be confirmed with the local government.

Detailed descriptions and design criteria for each of the Site Design Principles and Techniques are presented in the following section.

4.2 Site Planning

Purpose

LID requires a holistic approach to site design and stormwater management. As such, planners, developers, architects, and engineers should reconsider conventional approaches to stormwater management. The use of site planning techniques presented here will generate a more hydrologically functional site, help to maximize the effectiveness of Retention BMPs, and integrate stormwater management throughout the site.



LID BMPs Integrated within Site Planning Process

Low Impact Development Center, Inc.

Design Criteria

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

1) Retention BMPs should be considered as early as possible in the site planning process. Hydrology should be an organizing principle that is integrated into the initial site assessment planning phases.

2) Project applicants should anticipate and plan for the space requirements of Retention and Biofiltration BMPs. Table 4-1 provides general rules of thumb for BMP space requirements.

3) Site planning should use a multidisciplinary approach that includes planners, engineers, landscape architects, and architects at the initial phases of the project.

4) Individual Retention BMPs should be distributed throughout the project site and may influence the configuration of roads, buildings, and other infrastructure.

5) The project must demonstrate disconnection of impervious surface such that the 5% EIA requirement is achieved. If fully meeting the 5% EIA requirement using Retention BMPs is not technically feasible, the project must still utilize Retention BMPs to the maximum extent practicable.

6) Consider flood control early in the design stages. Even sites with Retention BMPs will still have runoff that occurs during large storm events. Look for opportunities to simultaneously address flood control requirements and the requirement to reduce EIA to ≤5% presented in Section 2.

7) Consider the use of alternative building materials instead of conventional materials for new construction and renovation. Several studies have indicated that metal used as roofing material, flashing, or gutters can leach metals into the environment. Avoid the use of roofing, gutters, and trim made of copper and galvanized (zinc) roofs, gutters, chain link fences and siding.

8) Consider 2010 Green Building Code requirements during the site planning stages.

Table 4-1: Rule of Thumb Space Requirements for BMPs[5]

BMP Type	% of Contributing Drainage Area
Infiltration	3 to 10
Rainwater Harvesting (Cistern)	0 to 10
Evapotranspiration (Green Roof)	1 to 1 ratio of impervious cover treated
Biofiltration	3 to 5
Dry Extended Detention Basin	1 to 3
Wet Detention Basin	1 to 3
Sand Filters	0 to 5
Cartridge Media Filter	0 to 5

[5] Modified from Schueler, T., D. Hirschman, M. Novotney, and J. Zielinski. 2007. Urban Stormwater Retrofit Practices. Manual 3 in the Urban Subwatershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

4.3 Protect and Restore Natural Areas

Purpose

Each project site possesses unique topographic, hydrologic and vegetative features, some of which are more suitable for development than others. Sensitive areas that should be protected and/or restored include streams and their buffers, floodplains, wetlands, steep slopes, and high permeability soils. Additionally, slopes can be a major source of sediment and should be properly protected and stabilized.

Locating development on the least sensitive portion of a site and conserving naturally vegetated areas can minimize environmental impacts in general and stormwater runoff impacts in particular.

Stream Buffer

Larry Walker Associates

Design Criteria

If applicable and feasible for the given site conditions, the following site design features or elements are required and should be included in the project site layout, consistent with applicable General Plan and Local Area Plan policies:

1) Identify and cordon off streams and their buffers, floodplains, wetlands, and steep slopes.

2) Reserve areas with high permeability soils for either open space or Infiltration BMPs.

3) Incorporate existing trees into site layout.

4) Identify areas that may be restored or revegetated either during or post-construction.

5) Identify and avoid and/or stabilize areas susceptible to erosion and sediment loss.

6) Concentrate or cluster development on the least-sensitive portions of a site, while leaving the remaining land in a natural undisturbed state.

7) Slopes must be protected from erosion by safely conveying runoff from the tops of slopes.

   - Slopes should be vegetated by first considering use of native or drought-tolerant species.

- Slope protection practices must conform to local permitting agency erosion and sediment control standards and design standards. The design criteria described in this section are intended to enhance and be consistent with these local standards.

8) Limit clearing and grading of native vegetation at the project site to the minimum amount needed to build lots, allow access, and provide fire protection.

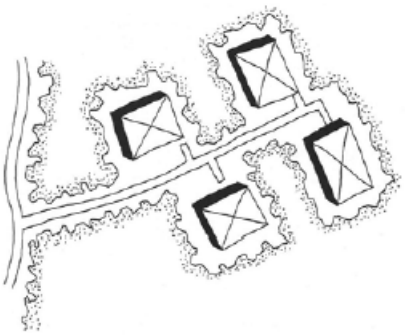
9) Maintain existing topography and existing drainage divides to encourage dispersed flow.

10) Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants.

11) Promote natural vegetation by using parking lot islands and other landscaped areas. Integrate vegetated BMPs within parking lot islands and landscaped areas.

4.4 Minimize Land Disturbance

Purpose



Minimized Clearing and Grading

Greenfield et al., 1991

This control works to protect water quality by preserving some of the natural hydrologic function of the site. By designing a site layout to preserve the natural hydrology and drainageways on the site, it reduces the need for grading the disturbance of vegetation and soils (GSMM, 2001). By siting buildings and impervious surfaces away from steep slopes, drainageways, and floodplains, it limits the amount of grading, clearing and distance and reduces the hydrologic impact. This site design principle has most applicability in greenfield settings, but opportunities may exist in redevelopment and infill projects.

Existing soils may contain organic material and soil biota that are ideal for storing and infiltrating stormwater. Clearing, grading, and heavy equipment can remove and compact existing soils and, therefore, limit their infiltrative capacity. The design criteria presented below are not intended to supersede compaction requirements associated with building codes.

Design Criteria

1) Delineate and flag the development envelope for the site. Delineating and flagging the development envelope includes a clear indication of the development envelope on the site plan and physical demarcation in the field which can be accomplished using temporary orange construction fencing or flagging. The development envelope can be established by identifying the minimum area needed to build lots; allow access and provide fire protection; and protect and buffer sensitive features such as streams, floodplains, steep slopes and wetlands. Concentrate buildings and paved areas on the least permeable soils, with the least intact habitats.

2) Plan clearing and grading to minimize the compaction of infiltrative soils.

3) Restrict equipment access and storage of construction equipment to the development envelope.

4) Restrict storage of construction equipment within the development envelope.

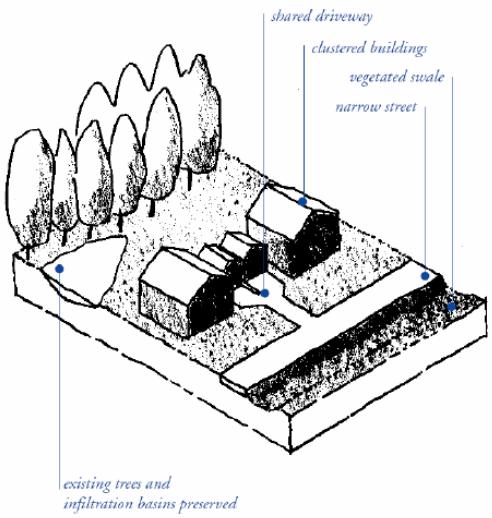
5) Avoid the removal of existing trees and valuable vegetation, as feasible.

6) Consider soil amendments to restore permeability and organic content especially for infill and redevelopment projects to avoid soil disturbance.

4.5 Minimize Impervious Cover

Purpose

The potential for the discharge of pollutants in stormwater runoff from a project site increases as the percentage of impervious area within the project site increases because impervious areas increase the volume and rate of runoff flow. Pollutants deposited on impervious areas tend to be easily mobilized and transported by surface water runoff. Minimizing impervious area through site design is an important means of minimizing stormwater pollutants of concern. In addition to the environmental and aesthetic benefits, a highly pervious site may allow reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs. Reducing impervious area is the most cost effective way of minimizing the effective impervious area (EIA) requirement.



Impervious Cover Minimization

BASMAA, Start at the Source

Design Criteria

Local permitting agency building and fire codes and ordinances determine some aspects of site design. These design strategies are intended to enhance and be consistent with these local codes and ordinances. Minimizing impervious surfaces at every possible opportunity requires integration of many small strategies. Suggested strategies for minimizing impervious surfaces through site design include the following:

1) Use minimum allowable roadway cross sections, driveway lengths, and parking stall widths and lengths.

2) Minimize or eliminate the use of curbs and gutters, and maximize the use of Retention BMPs, where slope and density permit.

3) Use two-track/ribbon alleyways/driveways or shared driveways.

4) Include landscape islands in cul-de-sac streets. Consider alternatives to cul-de-sacs to increase connectivity.

5) Reduce the footprints of building and parking lots. Building footprints may be reduced by building taller.

6) Use permeable pavement to accommodate overflow parking (if overflow parking is needed).

7) Cluster buildings and paved areas to maximize pervious area.

8) Maximize tree preservation or tree planting.

9) Avoid compacting or paving over soils with high infiltration rates (see Minimize Land Disturbance).

10) Use pervious pavement materials where appropriate, such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobbles.

11) Use grass-lined channels or surface swales to convey runoff instead of paved gutters (see Vegetated Swale in Section 6).

12) Build more compactly in infill and redevelopment site to avoid disturbing natural and agricultural lands. Per capita impacts can be significantly reduced by building more compactly in infill and redevelopment areas.

4.6 Apply LID at Various Scales

Purpose

LID is a decentralized approach to stormwater management that works to mimic the natural hydrology of the site by retaining rainfall onsite. In order to realize the full benefits of water quality protection and runoff volume reduction, LID should be integrated and considered at the regional and watershed scale and the site scale.

Design Criteria

Regional/Watershed

1) Consider Density: Low density development has a greater water resource impact than compact growth on a watershed scale. Higher density development uses less land and produces less impervious cover per capita than low density development (USEPA, 2006). Developments should consider higher densities, but should still adhere to density levels as specified within local zoning requirements.

2) Identify and Preserve Contiguous Open Space: Large contiguous areas of open space can act as a flood control, have an ecological benefit, serve as a buffer for streams and rivers, and provide recreational opportunities (EPA, 2004). Applicants should look for opportunities to link open space preservation with regional open space preservation efforts (such as Save Open Space and Agricultural Resources).

3) Make use of Previously Developed Sites: Redevelopment of existing sites replace impervious cover with impervious cover, reduces the need for greenfield development, and makes use of existing infrastructure.

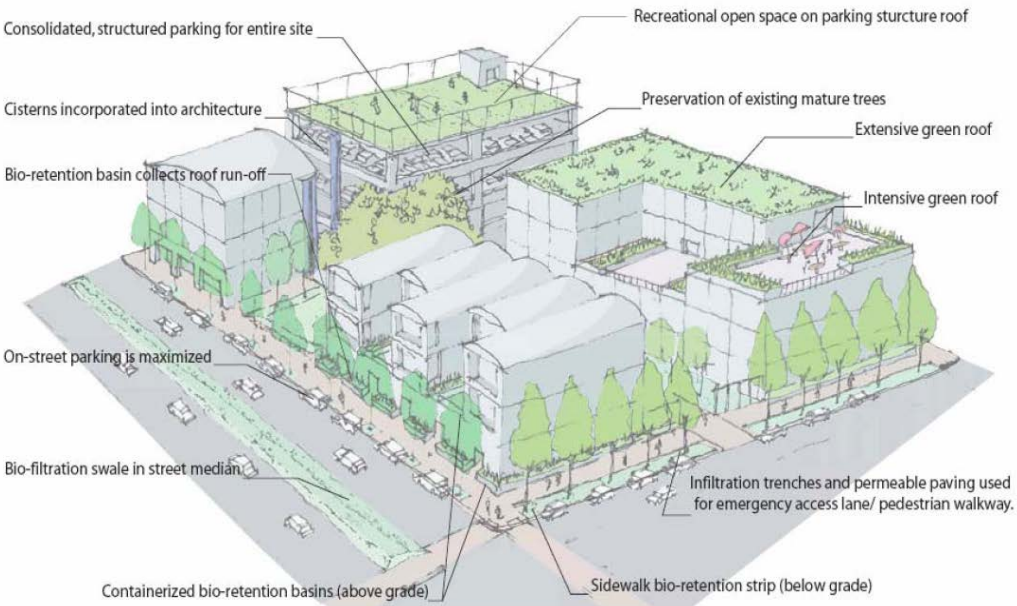
4) Locate Compact Development within Close Proximity to Mass Transit: This maximizes transportation choices, reduces the number of automobile trips, and lessens the water quality impacts associated with transportation and low-density sprawl.

Site

The following design criteria should be considered at the site level in addition to the principles and techniques discussed earlier in this section (e.g., Minimize Impervious Cover).

1) Maintain and Restore Natural Flowpaths for Runoff: Site buildings and impervious surfaces away from steep slopes, drainageways, and floodplains to reduce the amount of necessary clearing and grading and maintain the pre-development hydrology's time of concentration.

2) Maximize Use of Existing Impervious Cover: Assess and take advantage of opportunities to use existing impervious surfaces at the site level to reduce runoff at a watershed scale.



LID BMPs Considered at Various Scales

C. Anderson, Sustainable Urbanism

3) Design Public Spaces and Common Areas to Minimize Stormwater Runoff: Public spaces and common areas can serve as community gathering places but are often composed of impervious cover (e.g., courtyards primarily made up of concrete) (EPA, 2004). Design public spaces and common areas to accommodate both people and stormwater management.

4) Compact Project Design: Compact project design reduces the amount of impervious cover per capita, increases walkability, and decreases water quality impacts associated with transportation. Concentrating development on one portion of the site reduces the amount of lawn, provides more opportunities to preserve open space, and maintains and restores natural flow paths. Additionally, compact design can reduce street and driveway length and as a result, can help to reduce the imperviousness associated with development.

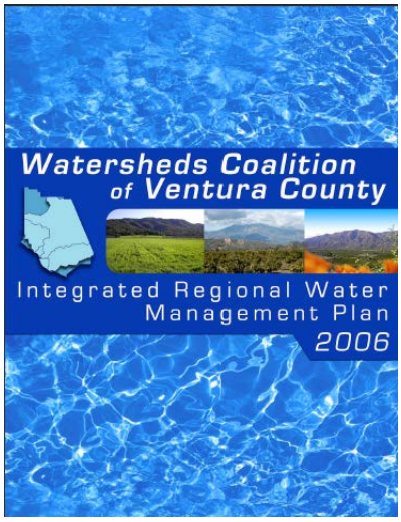
5) Encourage Use of Multiple Modes of Transportation: In addition to density and compact design, additional aspects of site design may encourage the use of multiple modes of transportation:

- Bicycle and pedestrian-friendly streets;
- Well connected sidewalks and streets; and
- Mixed uses that encourage walking.

4.7 Implement Integrated Water Resource Management Practices

Purpose

Integrated Water Resource Management (IWRM) is a process which promotes the coordinated development and management of water, land, and related resources. Order R4-2010-0108 promotes the use of IWRM to help guide the selection of BMPs that conserve water, recharge groundwater, provide recreational opportunities and serve as multiple purpose parks and preserve open space.



Integrated Regional Water Management Plan

Ventura County

Many of the concepts of IWRM are documented in the County's Integrated Regional Water Management Plan (IRWMP). The IRWMP is the product of an intensive stakeholder process and addresses multiple water resource management goals including improved water supply reliability, water recycling, water conservation, recreation and access, flood control, wetlands enhancement and creation, and environmental and habitat protection (Watershed Coalition of Ventura County, 2006).

Design Criteria

The goals of the 2011 TGM and the new development and redevelopment requirements contained within Order R4-2010-0108, complement the goals of the IRWMP. Development projects should strive to select BMPs that meet the following multiple objectives (Watershed Coalition of Ventura County, 2006):

1) Conserve and Augment Water Supplies: Identify and evaluate the opportunities to recharge groundwater and increase water use efficiency. This can be accomplished through infiltration of stormwater runoff and selection of drought-tolerant landscaping.

2) Protect People, Property and the Environment from Adverse Flooding Impacts: Identify opportunities to utilize BMPs that provide both water quality and water quantity benefits. Provide and maintain setbacks from streams and rivers.

3) Protect and Restore Habitat and Ecosystems in Watersheds: Implement the practices identified in Protect and Restore Natural Areas to integrate habitat and stormwater goals. Landscaping selection for stormwater management practices may also further encourage and attract wildlife.

4) Provide Water-related Recreational, Public Access and Educational Opportunities: Integrate recreation and stormwater management by creating multi-functional BMPs and designing courtyards and open spaces that accommodate both people and stormwater runoff. Consider providing educational signs for BMPs located in public spaces, where appropriate.

5 SOURCE CONTROL MEASURES

5.1 Introduction

Source Control Measures are low-technology practices designed to prevent pollutants from contacting stormwater runoff and prevent discharge of contaminated runoff to the storm drainage system. This section addresses site-specific, structural-type Source Control Measures consisting of specific design features or elements. Non-structural type Source Control Measures; such as good housekeeping and employee training, are not included in the 2011 TGM. The project applicant can consult the California Industrial Best Management Practice Manual for this type of practice (SWQTF, 1993). The governing stormwater agency may require additional Source Control Measures not included in the 2011 TGM for specific pollutants, activities, or land uses.

This section describes control measures for specific types of sites or activities that have been identified as potential significant sources of pollutants in stormwater. Each of the measures specified in this section should be implemented in conjunction with appropriate non-structural Source Control Measures to optimize pollution prevention.

The measures addressed in this section apply to both stormwater and non-stormwater discharges. Non-stormwater discharges are the discharge of any substance, such as process wastewater, to the storm drainage system or water body that is not composed entirely of stormwater. Stormwater that is mixed or commingled with other non-stormwater flows is considered non-stormwater. Discharges of stormwater and non-stormwater to the storm drainage system or a water body may be subject to local, state, or federal permitting prior to discharge. The appropriate agency should be contacted prior to any discharge. Discuss the matter with the stormwater staff if you are uncertain as to which agency should be contacted.

Some of the measures presented in this section require connection to the sanitary sewer system. It is prohibited to connect and discharge to the sanitary sewer system without prior approval or obtaining the required permits. Contact the stormwater staff of the governing agency about obtaining sanitary sewer permits within Ventura County. Discharges of certain types of flows to the sanitary sewer system may be cost prohibitive. The designer is urged to contact the appropriate agency prior to completing site and equipment design of the facility.

5.2 Description

Table 5-1 summarizes site-specific Source Control Measures and associated design features specified for various sites and activities. Fact Sheets are presented in this section for each source control measure. These sheets include design criteria

established by the Approval Agencies to ensure effective implementation of the required Source Control Measures:

Table 5-1: Summary of Site-Specific Source Control Measure Design Features

Site-Specific Source Control Measure [1]	DESIGN FEATURE OR ELEMENT						
	Signs, placards, stencils	Surfacing (compatible, impervious)	Covers, screens	Grading/berming to prevent run-on	Grading/berming to provide secondary containment	Sanitary sewer connection	Emergency Storm Drain Seal
Storm Drain Message and Signage (S-1)	X						
Outdoor Material Storage Area Design (S-2)		X	X	X	X		X
Outdoor Trash Storage and Waste Handling Area Design (S-3)		X	X	X		X	
Outdoor Loading/Unloading Dock Area Design (S-4)		X	X	X	X		
Outdoor Repair/Maintenance Bay Design (S-5)		X	X	X	X		X
Outdoor Vehicle/Equipment/ Accessory Washing Area Design (S-6)		X	X	X	X	X	X
Fueling Area Design (S-7)		X	X	X	X		X
Parking Lot Design [2]							

1 Refer to Fact Sheets in Section 6 for detailed information and design criteria and Appendix E for BMP sizing worksheets

2 Requirements for proper design of parking lots are covered by requirements for General Site Design Principles and Techniques (see Section 4) and Treatment Control Measures (see Section 6).

5.3 Site-Specific Source Control Measures

S-1: Storm Drain Message and Signage

Purpose

Waste materials dumped into storm drain inlets can have severe impacts on receiving and ground waters. Posting notices regarding discharge prohibitions at storm drain inlets can prevent waste dumping. This Fact Sheet contains details on the installation of storm drain messages at storm drain inlets located in new or redeveloped commercial, industrial, and residential sites.

Design Criteria

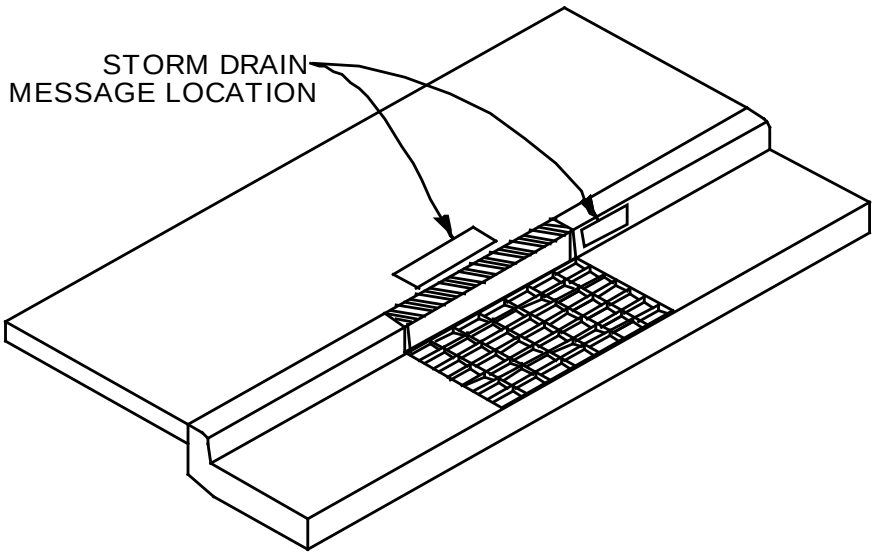
Storm drain messages have become a popular method of alerting the public to the effects of and the prohibitions against waste disposal into the storm drain system. The signs are typically stenciled or affixed near the storm drain inlet. The message simply informs the public that dumping of wastes into storm drain inlets is prohibited and/or the drain discharges to a receiving water.

Storm drain message markers or placards are required at all storm drain inlets within the boundary of the development project. The marker should be placed in clear sight facing anyone approaching the inlet from either side (see Figure 5-1). All storm drain inlet locations must be identified on the development site map.

Some local agencies within the County have approved storm drain message placards for use. Signs with language and/or graphical icons, which prohibit illegal dumping, should be posted at designated public access points along channels and streams within a project area. Consult local permitting agency stormwater staff to determine specific requirements for placard types and installation methods.

Maintenance Requirements

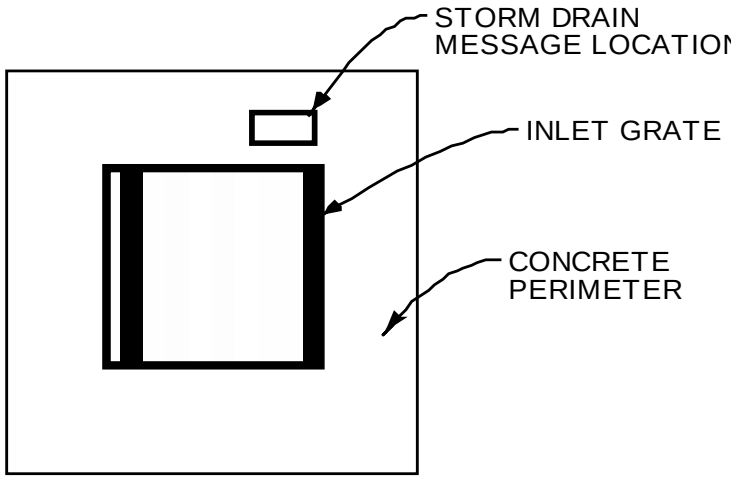
Legibility of markers and signs should be maintained. If required by the agency with jurisdiction over the project, the owner/operator or homeowner's association shall enter into a Maintenance Agreement with the agency or record a deed restriction upon the property title to maintain the legibility of placards and signs.



CURB TYPE INLET

NOTES:

1. **STORM DRAIN MESSAGE SHALL BE APPLIED IN SUCH A WAY AS TO PROVIDE A CLEAR, LEGIBLE IMAGE.**
2. **STORM DRAIN MESSAGE SHALL BE PERMANENTLY APPLIED DURING THE CONSTRUCTION OF THE CURB AND GUTTER USING A METHOD APPROVED BY THE LOCAL AGENCY.**



AREA TYPE INLET

Figure 5-1: Storm Drain Message Location

S-2: Outdoor Material Storage Area Design

Purpose

Materials that are stored outdoors could become sources of pollutants in stormwater runoff if not handled or stored properly. Materials could be in the form of raw products, by-products, finished products, and waste products. The type of pollutants associated with the materials will vary depending on the type of commercial or industrial activity.

Some materials are more of a concern than others. Toxic and hazardous materials must be prevented from coming in contact with stormwater. Non-toxic or non-hazardous materials do not have to be prevented from stormwater contact, but cannot be allowed to runoff with the stormwater. These materials may have toxic effects on receiving waters. Accumulated material on an impervious surface could result in significant debris and sediment being discharged with stormwater runoff causing a significant impact on the rivers or streams that receive the runoff.

Materials may be stored in a variety of ways, including bulk piles, containers, shelving, stacking, and tanks. Stormwater contamination may be prevented by eliminating the possibility of stormwater contact with the material storage areas either through diversion, cover, or capture of the stormwater. Control measures may also include minimizing the storage area. Control measures are site-specific and must meet local permitting agency requirements.

Design Criteria

Design requirements for material storage areas are governed by Building and Fire Codes and by current City or County ordinances and zoning requirements. Source Control Measures described in the Fact Sheet are intended to enhance and be consistent with these code and ordinance requirements. The following design features should be incorporated into the design of a material storage area when storing materials outside could contribute significant pollutants to the storm drain.

Table 5-2: Design Criteria for Outdoor Material Storage Area Design

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Covers	• Install a cover that extends beyond the storage area, or use a manufactured storage shed for small containers.
Grading/Containment	• Minimize the storage area. • Slope the storage area towards a dead-end sump to contain spills. • Grade or berm storage areas to prevent run-on from surrounding areas. • Direct runoff from downspouts/roofs away from storage areas.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

S-3: Outdoor Trash Storage Area Design

Purpose

Stormwater runoff from areas where trash is stored or disposed of can be polluted. In addition, loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or creeks. Waste handling operations may be sources of stormwater pollution and include dumpsters, litter control, and waste piles. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff associated with trash storage and handling.

Design Criteria

Design requirements for waste handling areas are governed by Building and Fire Codes, and by current local permitting agency ordinances and zoning requirements. The design criteria described in the Fact Sheet are meant to enhance and be consistent with these code and ordinance requirements. Hazardous waste should be handled in accordance with legal requirements established in Title 22, California Code of Regulations.

Wastes from commercial and industrial sites are typically hauled by either public or commercial carriers that may have design or access requirements for waste storage areas. The design criteria listed below are recommendations and are not intended to be in conflict with requirements established by the waste hauler. The waste hauler

should be contacted prior to the design of your site trash collection area to obtain established and accepted guidelines for designing trash collection areas. Conflicts or issues should be discussed with the local permitting agency.

The following trash storage area design controls were developed to enhance the local permitting agency codes and ordinances and should be implemented depending on the type of waste and the type of containment.

Table 5-3: Design Criteria for Outdoor Trash Storage Areas

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Screens/Covers	• Install a screen or wall around trash storage area to prevent offsite transport of loose trash. • Use lined bins or dumpsters to reduce leaking of liquid wastes. • Use water-proof lids on bins/dumpsters or provide a roof to cover enclosure (local permitting agency discretion) to prevent rainfall from entering containers.
Grading/Contouring	• Berm or grade the waste handling area to prevent run-on of stormwater. • Do not locate storm drains in immediate vicinity of the trash storage area.
Signs	• Post signs on all dumpsters informing users that hazardous materials are not to be disposed of therein.

Maintenance Requirements

The owner/operator must maintain the integrity of structural elements that are subject to damage (e.g. screens, covers and signs). Maintenance Agreements between the local permitting agency and the owner/operator may be required. Some agencies will require maintenance deed restrictions to be recorded of the property title. If required by the local permitting agency, Maintenance Agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved. Refer to Appendix G and H for further guidance regarding Maintenance Plan Agreements.

S-4: Outdoor Loading/Unloading Dock Area Design

Purpose

Materials spilled, leaked, or lost during loading or unloading may collect on impervious surfaces or in the soil and be carried away by runoff or when the area is cleaned. Rainfall may also wash pollutants from machinery used to load or unload materials. Depressed loading docks (truck wells) are contained areas that can accumulate stormwater runoff. Discharge of spills or contaminated stormwater to

the storm drain system is prohibited. This Fact Sheet contains details on specific measures recommended to prevent or reduce pollutants in stormwater runoff from outdoor loading or unloading areas.

Design Criteria

Design requirements for outdoor loading and unloading of materials are governed by Building and Fire Codes, and by current local permitting agency ordinances and zoning requirements. Source Control Measures described in this Fact Sheet are meant to enhance and be consistent with these code and ordinance requirements. Companies may have their own design or access requirements for loading docks. The design criteria listed below are not intended to be in conflict with requirements established by individual companies. Conflicts or issues should be discussed with the local permitting agency.

The following design criteria should be followed when developing construction plans for material loading and unloading areas:

Table 5-4: Design Criteria for Outdoor Loading/ Unloading Areas

Source Control Design Feature	Design Criteria
Surfacing	• Construct floor surfaces with materials that are compatible with materials being handled in the loading/unloading area.
Covers	• Cover loading/unloading areas to a distance of at least 3 feet beyond the loading dock or install a seal or door skirt to be used for all material transfers between the trailer and the building.
Grading/Contouring	• Grade or berm storage the areas to prevent run-on from surrounding areas. • Direct runoff from downspouts/roofs away from loading areas.
Emergency Storm Drain Seal	• Do not locate storm drains in the loading dock area. Direct connections to storm drains from depressed loading docks are prohibited. • Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces, such as depressed loading docks. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

S-5: Outdoor Repair/Maintenance Bay Design

Purpose

Activities that can contaminate stormwater include engine repair, service, and parking (i.e. leaking engines or parts). Oil and grease, solvents, car battery acid, coolant and gasoline from the repair/maintenance bays can severely impact stormwater if allowed to come into contact with stormwater runoff. This Fact Sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment maintenance and repair areas.

Design Criteria

Design requirements for vehicle maintenance and repair areas are governed by Building and Fire Codes, and by current local permitting agency ordinances, and zoning requirements. The design criteria described in this Fact Sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment maintenance, and repair. All wash water, hazardous and toxic wastes must be prevented from entering the storm drainage system.

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

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

S-6: Outdoor Vehicle/Equipment/Accessory Washing Area Design

Purpose

Washing vehicles and equipment in areas where wash water flows onto the ground can pollute stormwater. Wash waters are not allowed in the storm drain system. They can contain high concentrations of oil and grease, solvents, phosphates and high suspended solids loads. Sources of washing contamination include outside vehicle/equipment cleaning or wash water discharge to the ground. This Fact Sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment washing areas.

Design Criteria

Design requirements for vehicle maintenance and repair areas are governed by Building and Fire Codes, and by current local permitting agency ordinances, and zoning requirements. The design criteria described in this Fact Sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment washing areas. All hazardous and toxic wastes must be prevented from entering the storm drain system.

Source Control Design Feature	Design Criteria
Surfacing	• Construct the vehicle/equipment wash area floors with Portland cement concrete.
Covers	• Provide a cover that extends over the entire wash area.
Grading/ Contouring	• Berm or grade the maintenance/repair area to prevent run-on and runoff of stormwater or runoff of spills. • Grade or berm the wash area to contain the wash water within the covered area and direct the wash water to treatment and recycle or pretreatment and proper connection to the sanitary sewer system. Obtain approval from the governing agency before discharging to the sanitary sewer. • Direct runoff from downspouts/roofs away from wash areas. • Do not locate storm drains in the immediate vicinity of the wash area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

S-7: Fueling Area Design

Purpose

Spills at vehicle and equipment fueling areas can be a significant source of pollution because fuels contain toxic materials and heavy metals that are not easily removed by stormwater treatment devices. When stormwater mixes with fuel spilled or leaked onto the ground, it becomes polluted by petroleum-based materials that are harmful to humans, fish, and wildlife. This could occur at large industrial sites or at small commercial sites such as gas stations and convenience stores. This Fact Sheet contains details on specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment fueling areas, including retail gas stations.

Design Criteria

Design requirements for fueling areas are governed by Building and Fire Codes and by current local permitting agency ordinances and zoning requirements. The design requirements described in this Fact Sheet are meant to enhance and be consistent with these code and ordinance requirements.

Source Control Design Feature	Design Criteria
Surfacing	• Fuel dispensing areas must be paved with Portland cement concrete. The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assemble may be operated plus 1 foot, whichever is less. The paving around the fuel dispensing area may exceed the minimum dimensions of the "fuel dispensing area" stated above. • Use asphalt sealant to protect asphalt paved areas surrounding the fueling area.
Covers	• The fuel dispensing area must be covered [1], and the cover's minimum dimensions must be equal to or greater than the area within the grade break or the fuel dispensing area, as defined above. The cover must not drain onto the fuel dispensing area.
Grading/ Contouring	• The fuel dispensing area should have a 2% to 4% slope to prevent ponding and must be separated from the rest of the site by a grade break that prevents run-on of stormwater to the extent practicable. • Grade the fueling area to drain toward a dead-end sump. • Direct runoff from downspouts/roofs away from fueling areas. • Do not locate storm drains in the immediate vicinity of the fueling area.

Source Control Design Feature	Design Criteria
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

1. If fueling large equipment or vehicles that would prohibit the use of covers or roofs, the fueling island should be designed to sufficiently accommodate the larger vehicles and equipment and to prevent run-on and runoff of stormwater. Grade to direct stormwater to a dead-end sump.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

S-8: Proof of Control Measure Maintenance

Purpose

Continued effectiveness of control measures specified in the 2011 TGM depends on diligent ongoing inspection and maintenance. To ensure that such maintenance is provided, the local permitting agency will require both a Maintenance Agreement and a Maintenance Plan from the owner/operator of stormwater control measures.

Maintenance Agreement

Onsite Treatment Control Measures are to be maintained by the owner/operator. Maintenance Agreements between the governing agency and the owner/operator may be required. A Maintenance Agreement with the governing agency must be executed by the owner/operator before occupancy of the project is approved. A sample Maintenance Agreement form is provided in Appendix H.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the governing agency's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

Additional guidelines for Maintenance Plans are provided in Appendix I.

6 STORMWATER BMP DESIGN

6.1 Introduction

Retention BMPs, Biofiltration BMPs, and Treatment Control Measures are required to augment Site Design Principles and Techniques and Source Control Measures to reduce pollution from stormwater discharges to the maximum extent practicable. Retention BMPs are engineered facilities that are designed to retain surface runoff on the project site. Biofiltration BMPs are vegetated stormwater BMPs that remove pollutants by filtering stormwater through vegetation and soils. Treatment Control Measures are engineered BMPs that provide a reduction of pollutant loads and concentrations in stormwater runoff. The type(s) of Retention BMPs and Biofiltration BMPs to be implemented depends on site suitability factors discussed in this chapter. The type of Treatment Control Measure(s) to be implemented at a site depends on a number of factors including: type of pollutants in the stormwater runoff, quantity of stormwater runoff to be treated, project site conditions, receiving water conditions, and state industrial permit requirements, where applicable. Land requirements and costs to design, construct, and maintain Treatment Control Measures vary by type.

Unlike flood control measures that are designed to handle peak flows, stormwater Retention BMPs, Biofiltration BMPs, and Treatment Control Measures are designed to retain or treat the more frequent, lower-flow storm events, or the first flush runoff from larger storm events (typically referred to as the first flush events). Small, frequent storm events represent most of the total average annual rainfall for the area. It's the volume from such small events, referred to as the Stormwater Quality Design Volume (SQDV), that is targeted for retention onsite in Retention BMPs. Biofiltration BMPs and Treatment Control Measures can be sized to capture either the SQDV or the Stormwater Quality Design Flow (SQDF). Calculation methods for the SQDV and the SQDF are presented in Section 2 and Appendix E.

6.2 General Considerations

Retention BMPs, Biofiltration BMPs, and Treatment Control Measures are designed to remove pollutants contained in stormwater runoff. The pollutants of concern, depending on the watershed, may include trash, debris, and sediment; metals such as copper, lead, and zinc; nutrients such as nitrogen and phosphorous; certain bacteria and viruses; mineral salts such as chloride; and organic chemicals such as petroleum hydrocarbons and pesticides. Pollutant removal methods include sedimentation/settling, filtration, plant uptake, ion exchange, adsorption, and microbially-mediated decomposition. Floatable pollutants such as oil, debris, and scum can be removed with separator structures. Retention BMPs, Biofiltration BMPs, and some Treatment Control Measures are also designed to reduce runoff volume, thereby reducing pollutant loading to receiving waters. Retention BMP,

Biofiltration BMPs, and Treatment Control Measure types and common terms used in stormwater treatment are discussed below.

Maintenance Responsibility

Unless otherwise agreed to by the governing stormwater agency, the landowner, site operator, or homeowner's association is responsible for the operation and maintenance of the Retention BMPs, Biofiltration BMPs, and Treatment Control Measures. Failure to properly operate and maintain the measures could result in reduced treatment of stormwater runoff or a concentrated loading of pollutants to the storm drain system. To protect against failure, a Maintenance Plan must be developed and implemented for all Retention BMPs, Biofiltration BMPs, and Treatment Control Measures. Guidelines for maintenance plans are provided in Appendix I of the 2011 TGM. The Plan must be made available at the agency's request. In addition, a maintenance agreement with the governing agency may be required. The example maintenance agreements are included in Appendix H.

In addition to maintenance, the governing agency may require water quality monitoring agreements for any of the Retention BMPs, Biofiltration BMPs, or Treatment Control Measures recommended in the 2011 TGM. Monitoring may be conducted by the site operator, the agency, or both. Monitoring may be required for a period of time to help the agency evaluate the effectiveness of Retention BMPs, Biofiltration BMPs, and Treatment Control Measures in reducing pollutants in stormwater runoff.

Pretreatment

Pretreatment must be provided for filtration and infiltration facilities and other facilities whose function could be adversely affected by sediment or other pollutants. Pretreatment may also be provided for water quality detention basins and other Treatment Control Measures to facilitate the routine removal of sediment, trash, and debris, and to increase the longevity of the downstream BMPs.

Pretreatment may be provided by presettling basins or forebays (small detention basins), vegetated swales, filter strips, and hydrodynamic separators. Source control activities, described in Chapter 5, minimize the introduction of pollutants into stormwater runoff and also help to protect filtration and infiltration facilities. Effort should be made early in the site planning stages to minimize runoff from impervious areas by grading toward landscaped areas, disconnecting downspouts, and using pervious conveyances prior to discharging to the storm drain system. These site design practices can reduce the size and maintenance burden of downstream, end-of-pipe BMPs.

Oil/Water Separation

Oil/water separators remove floating oil from the water surface. There are two general types of separators: American Petroleum Institute (API) separators and

coalescing plate (CP) separators. Both types use physical mechanisms to remove high concentrations of floating and dispersed oil. Oil/water separators are not suitable for the relatively low concentrations of petroleum hydrocarbons present in typical urban runoff, and should only be used in locations where higher concentrations of oil are expected to occur, such as retail fuel facilities, high volume roads, and petroleum-related industrial facilities. Oil/water separators must be located off-line from the primary conveyance system, as they function at low flow conditions and will wash out in high flow conditions. Other oil control devices/facilities that may be used for pretreatment of slightly elevated concentrations of oil (i.e., typical of high use commercial parking lots) include catch basin inserts, hydrodynamic devices, and linear sand filters. Oil control devices/facilities should always be placed upstream of other treatment facilities and as close to the oil source as possible.

Infiltration

Infiltration refers to the use of the filtration, adsorption, and biological decomposition properties of soils to remove pollutants prior to the intentional routing of runoff to the subsurface for groundwater recharge. Infiltration BMPs are a type of Retention BMP and include infiltration basins, infiltration trenches, bioretention without an underdrain, dry wells, permeable pavement, and proprietary infiltration devices. Infiltration can provide multiple benefits including pollutant removal, hydromodification control, groundwater recharge, and flood control. However, conditions that can limit the use of infiltration include soil properties and potential adverse impacts on groundwater quality. A geotechnical investigation must be conducted when evaluating infiltration to determine the suitability of the site soil in adequately addressing groundwater protection. This may include an in-situ percolation test, per the guidance provided in Appendix C, and the determination of minimum depth to groundwater. The minimum separation to seasonal high groundwater or estimated mounded groundwater is five feet. Depth to seasonal high groundwater level shall be estimated as the average of the annual minima (i.e., the shallowest recorded measurements in each water year, defined as October 1 through September 30) for all years on record. If groundwater level data are not available or not considered to be representative, seasonal high groundwater depth can be determined by redoximorphic analytical methods combined with temporary groundwater monitoring for November 1 through April 1 at the proposed project site.

Soils should have sufficient organic content and sorption capacity to remove certain pollutants, but must be coarse enough to infiltrate runoff in a reasonable amount of time (e.g., < 72 hours for above-ground ponded water to prevent vector breeding). Examples of suitable soils are silty and sandy loams. Coarser soils, such as gravelly sands, have limited organic content and high permeability and therefore present a potential risk to groundwater from certain pollutants, especially in areas of shallow groundwater. Prior to the use of infiltration BMPs, consult with the local permitting agency to identify if vulnerable unconfined aquifers are located beneath the project to determine the appropriateness of these BMPs. In an area identified as an unconfined

aquifer, the application of infiltration BMPs should include significant pretreatment to ensure groundwater is protected from pollutants of concern.

Infiltration BMPs should not be placed in high-risk areas such as at or near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk. Infiltration BMPs may be placed in high-risk areas if a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.

In addition, infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project. Adequate spacing (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback from building foundations at least eight feet or have an alternative setback established by the geotechnical expert for the project.

Infiltration is not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines the infiltration would not be detrimental. A site-specific analysis shall be prepared where pollutant mobilization (e.g., naturally-derived groundwater pollutants) is a concern. Projects must consider the potential for mobilization of groundwater contamination from natural sources as a result of stormwater infiltration (e.g., marine sediments, selenium-rich groundwater) to the extent that data is available.

Incidental infiltration that occurs in other types of Biofiltration BMPs and Treatment Control Measures, such as dry extended detention basins, vegetation swales, filter strips, and bioretention areas with underdrains, pose little risk to groundwater quality as treatment is provided in the BMP prior to infiltration.

Biofiltration BMPs

Biofiltration BMPs use vegetation and soils or other filtration media for runoff treatment. As runoff passes through the vegetation and filtration media, the combined effects of filtration, adsorption, and biological uptake remove pollutants. In biofiltration BMPs, pore spaces and organic material in the soils help to retain water in the form of soil moisture and to promote the pollutant adsorption (e.g., dissolved metals and petroleum hydrocarbons) into the soil matrix. Plants use soil moisture, promote the drying of the soil through transpiration, and uptake pollutants in their roots and leaves. Plants with extensive root systems also help to maintain filtration rates. Vegetation also decreases the velocity of flow and allows for particulates to settle.

Treatment Control Measures

Filtration

Various media, such as sand, perlite, zeolite, compost, and activated carbon, can be used in filtration BMPs to effectively remove total suspended solids (TSS) and associated pollutants such as organics (hydrocarbons and pesticides) and particulate metals. Filtration systems can be configured in the form of horizontal beds, trenches, or lastly, cartridge systems in underground vaults or catch basins.

Wetpools

A wetpool is a permanent pool of water incorporated into a wetpond or stormwater wetland BMP. Wetpools provide runoff treatment by allowing settling of particulates (sedimentation) by biological uptake and by vegetative filtration (if vegetation is present). Wetpool BMPs may be single-purpose facilities, providing only runoff treatment, or they may also provide flow control by providing additional detention storage with the use of a multi-stage outlet structure. If combined with detention, the wetpool volume can often be stacked under the detention volume with little further loss of development area.

"On-line" and "Off-line" Facilities

The location and configuration of control facilities can vary depending on the desired function. For example, drop structures or grade control may be located in a drainage channel so as to stabilize a channel for hydromodification control purposes. Such facilities are referred to as "in-stream" controls. Retention BMPs, Biofiltration BMPs, and Treatment Control Measures may not be located in-stream. Retention BMPs, Biofiltration BMPs, and Treatment Control Measures cannot be located in Waters of the US, but rather must be located upland to retain or treat runoff prior to discharge into Waters of the US.

If a Retention BMP, Biofiltration BMP, or Treatment Control Measure facility is designed such that all the runoff passes through the facility, the facility is called an "on-line" system. However, care must be taken to limit the resuspension of previously captured pollutants or damage to BMP performance during high flows. If, on the other hand, the facility only receives flows less than or equal to the stormwater quality design flow (SQDF), the facility is called an "off-line" system. Off-line systems therefore require a flow splitter or equivalent device. Generally treatment performance is better for off-line facilities because a larger percentage of the runoff is treated. Figure 6-1 illustrates the difference between on-line, off-line, and in-stream controls.

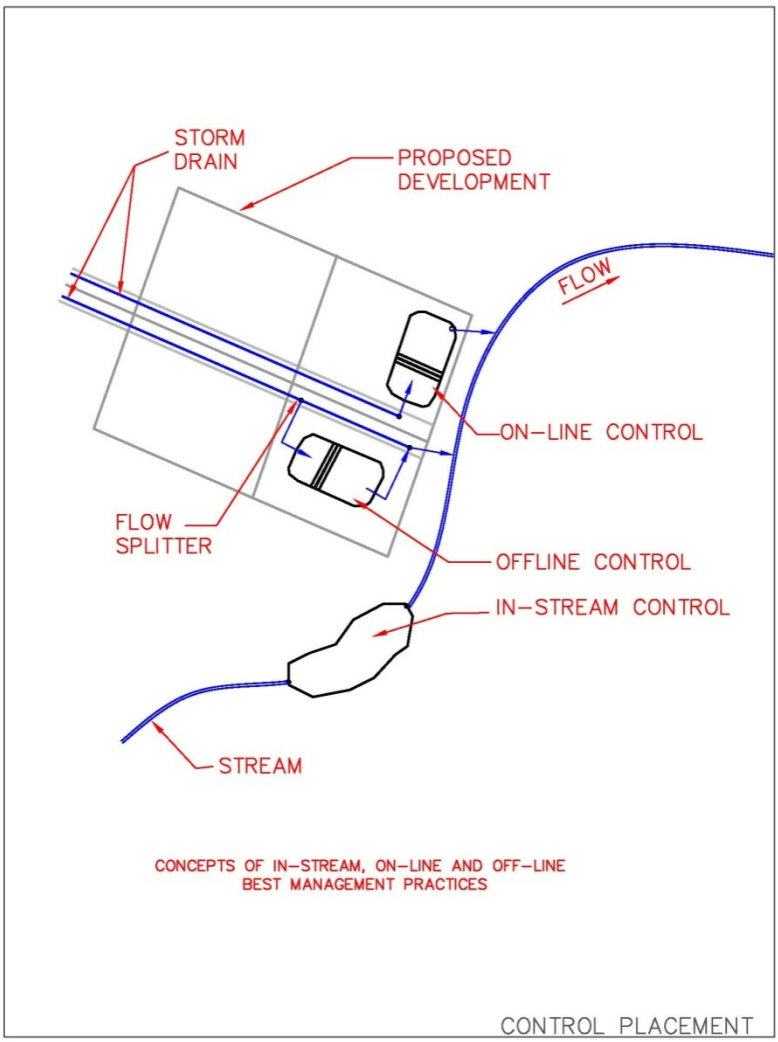


Figure 6-1: Differences between On-line, Off-line, and In-stream Control Measures

6.3 Retention BMP, Biofiltration BMP, and Treatment Control Measure Fact Sheets

This section provides fact sheets with recommended criteria for the design and implementation of Retention BMPs, Biofiltration BMPs, and Treatment Control Measures. The siting, design, and maintenance requirements in the fact sheets are intended to ensure optimal performance of the measures. Alternative designs may be approved by the local permitting authority based on site specific conditions if equivalent pollutant removal performance is provided.

The 2011 TGM also contains calculation worksheets to aid in the design of these BMPs in Appendix E. New BMPs that are equivalent to those included in the 2011 TGM are acceptable based on approval of the local permitting agency.

Fact sheets are provided for the Retention BMPs, Biofiltration BMPs, and Treatment Control Measures listed below:

Retention BMPs

Infiltration BMPs

INF-1: Infiltration Basin
INF-2: Infiltration Trench
INF-3: Bioretention
INF-4: Drywell
INF-5: Permeable Pavement
INF-6: Proprietary Infiltration

Rainwater Harvesting BMPs

RWH-1: Rainwater Harvesting

Evapotranspiration BMPs

ET-1: Green Roof
ET-2: Hydrologic Source Controls

Biofiltration BMPs

BIO-1: Bioretention with Underdrain
BIO-2: Planter Box
BIO-3: Vegetated Swale
BIO-4: Vegetated Filter Strip
BIO-5: Proprietary Biotreatment

Treatment Control Measures

TCM-1: Dry Extended Detention Basin
TCM-2: Wet Detention Basin
TCM-3: Constructed Wetland
TCM-4: Sand Filter (if vegetated, this is considered a Biofiltration BMP)
TCM-5: Cartridge Media Filter

Pretreatment/Gross Solids Removal BMPs

PT-1: Hydrodynamic Device
PT-2: Catch Basin Insert

INF-1: Infiltration Basin

An infiltration basin consists of an earthen basin constructed in naturally pervious soils (Type A or B soils) with a flat bottom and provided with an inlet structure to dissipate energy of incoming flow and an emergency spillway to control excess flows. An optional relief underdrain may be provided to drain the basin if standing water conditions occur. A forebay settling basin or separate Treatment Control Measure must be provided as pretreatment. An infiltration basin functions by retaining the SQDV in the basin and allowing the retained runoff to percolate into the underlying native soils over a specified period of time. The bottoms of infiltration basins are typically vegetated with dry-land grasses or irrigated turf grass. A typical layout of an infiltration basin system is shown in Figure 6-2.

Infiltration Basin in a Fresno, CA Park, Before and After a Rain Event

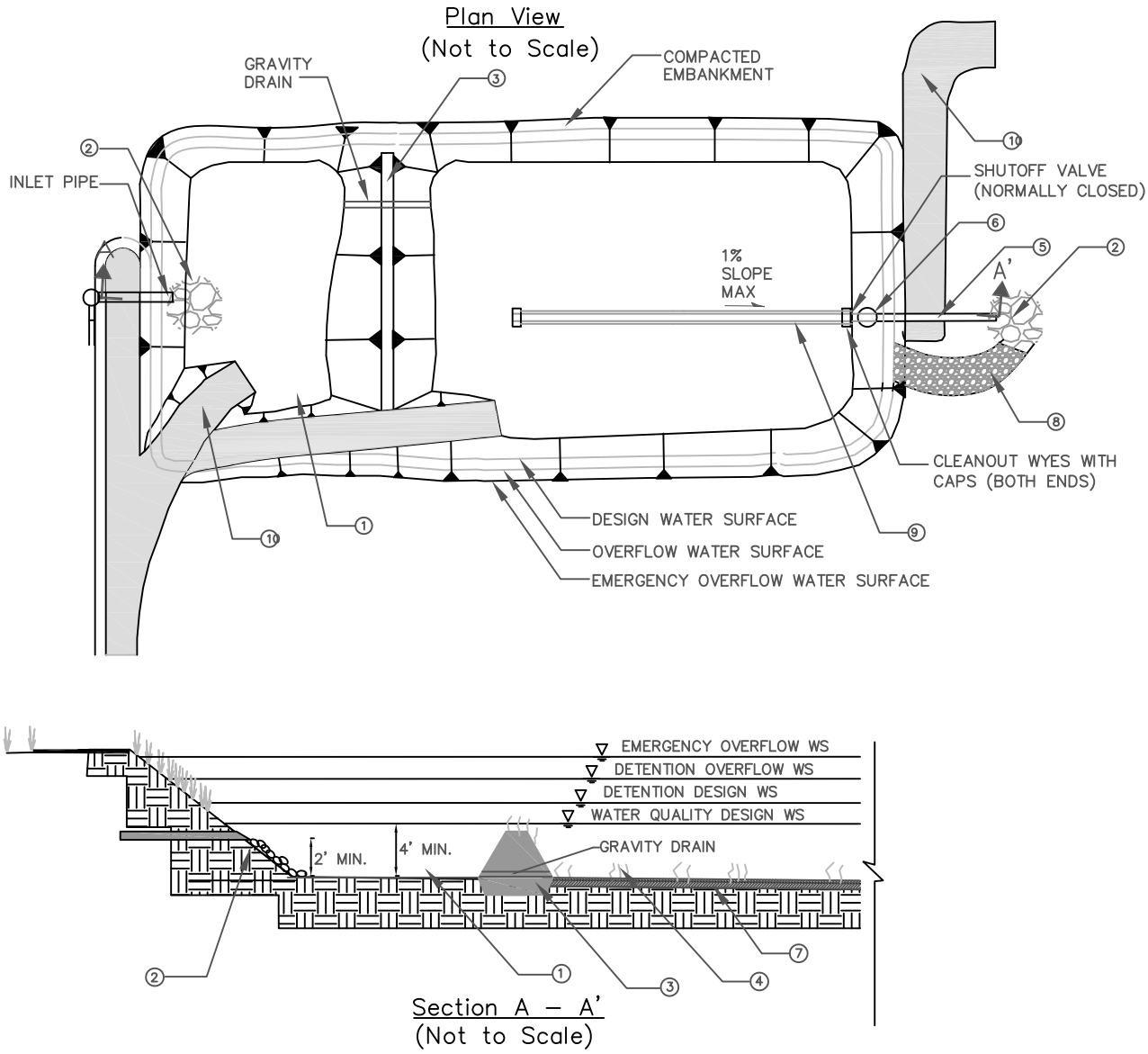
Photo Credit: Geosyntec Consultants

Application

- Mixed-use and commercial
- Roads and parking lots
- Parks and open spaces
- Single and multi-family residential
- Can integrate with parks

Routine Maintenance

- Removal trash, debris, and sediment at inlet and outlets
- Wet weather inspection to ensure drain time
- Remove weeds
- Inspect for mosquito breeding



NOTES:

1. UPSTREAM PRETREATMENT SHALL BE PROVIDED. SEDIMENT FOREBAY WITH VOLUME EQUAL TO 25% OF TOTAL INFILTRATION BASIN VOLUME MAY BE USED IN LIEU OF UPSTREAM PRETREATMENT. DEPTH SHALL BE 4' MIN TO 8' MAX PLUS AN ADDITIONAL 1 FOOT MIN SEDIMENT STORAGE DEPTH.
2. RIP RAP APRON OR OTHER ENERGY DISSIPATION.
3. EXTEND EARTHEN BERM ACROSS ENTIRE WIDTH OF THE INFILTRATION BASIN.
4. INFILTRATION BASIN BOTTOM AND SIDE SLOPES SHALL BE PLANTED WITH DROUGHT TOLERANT VEGETATION. DEEP ROOTED VEGETATION PREFERRED FOR BASIN BOTTOM. NO TOPSOIL SHALL BE ADDED TO INFILTRATION BASIN BED.
5. SIZE OUTLET PIPE TO PASS 100–YEAR PEAK FLOW FOR ON–LINE INFILTRATION BASINS AND WATER QUALITY PEAK FLOW FOR OFF–LINE INFILTRATION BASINS.
6. WATER QUALITY OUTLET STRUCTURE. SEE FIGURE 7–2 AND FIGURE 7–3 FOR DETAILS.
7. OVER EXCAVATE BASIN BOTTOM 1 FOOT. RE–PLACE EXCAVATED MATERIAL UNIFORMLY WITHOUT COMPACTION. AMENDING EXCAVATED MATERIAL WITH 2" – 4" OF COARSE SAND IS RECOMMENDED FOR SOILS WITH BORDER LINE INFILTRATION CAPACITY.
8. INSTALL EMERGENCY OVERFLOW SPILLWAY AS NEEDED. SEE FIGURE 2–4 FOR DETAILS
9. INSTALL OPTIONAL 6" MINIMUM DIAMETER PERFORATED PIPE UNDERDRAIN. INSTALL AT 0.5% MINIMUM SLOPE.
10. MAINTENANCE RAMP SHOULD PROVIDE ACCESS TO BOTH THE FIRST CELL AND MAIN BASIN.

Geosyntec consultants

Figure 6-2: Infiltration Basin

Limitations

The following limitations should be considered before choosing to use an infiltration basin:

- Native soil infiltration rate - permeability of soils at the infiltration basin location must be at least 0.5 inches per hour.
- Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration basin and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.
- Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.
- Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback at least eight feet from building foundations or have an alternative setback established by the geotechnical expert for the project.
- Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer to ensure groundwater is protected for pollutants of concern.
- Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater, where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines the infiltration would be beneficial.
- High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at or near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.
- High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

Additional Control Functions

Infiltration basins can be designed for flow control by providing storage capacity in excess of that provided by infiltration and incorporating outlet controls. The additional storage and outlet structure should be provided per the requirements outlined in the Dry Extended Detention Basins section of the 2011 TGM. Note that the selected outlet structure should not be designed to drain the design volume intended for infiltration and should be similar to outlet structures that maintain a permanent pool (see Section 6.10.2 – Wet Retention Basins).

Multi-Use Opportunities

Infiltration basins may be integrated into the design of a park or playfield. Recreational multi-use facilities should be inspected after every storm and may require a greater maintenance frequency than dedicated infiltration basins to ensure aesthetics and public safety are not compromised. Any planned multi-use facility must obtain approval by the affected City and County departments.

Design Criteria

The main challenge associated with infiltration basins is preventing system clogging and subsequent infiltration inhibition. Infiltration basins should be designed according to the requirements listed in Table 6-1 and outlined in the section below. Detailed design procedures and an example are included in Appendix E.

Table 6-1: Infiltration Basin Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2.3 and Appendix E for calculating SQDV
Design drawdown time	hr	12 - 72 (See Appendix D, Section D.2)
Bottom basin Elevation	feet	5 feet above seasonally high groundwater table or mounded groundwater
Setbacks	feet	100 feet from wells, fields, and springs; 20 feet downslope of 100 feet upslope of foundations; Geotechnical expert should establish the setback requirement from building foundations that must be ≥ 8 ft.
Pretreatment	-	Sedimentation forebay or any Treatment Control Measure shall be provided as pretreatment for all tributary surfaces other than roofs.

Design Parameter	Unit	Design Criteria
Design percolation rate (P_{design})	in/hr	Measured percolation rate must be corrected based onsite suitability assessment and design related considerations described in this fact sheet.
Facility geometry	-	Forebay (if applicable): 25% of facility volume; flat bottom slope
Freeboard (minimum)	ft	1.0
Inlet/ Outlet erosion control	-	Energy dissipater to reduce velocity
Overflow device	-	Required if system is on-line

Geotechnical Considerations

An extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of infiltration facilities, due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity.. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration facility. See Appendix C for guidance on infiltration testing.

The project designer must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil engineer that sufficiently permeable soils exist onsite to allow the construction of a properly functioning infiltration facility.

1) Infiltration facilities require a minimum soil infiltration rate of 0.5 inches/hour. Pretreatment is required in all instances.

2) Groundwater separation must be at least 5 feet from the basin bottom to the measured Seasonal High Groundwater Elevation or estimated high groundwater mounding elevation. Groundwater levels measurements must be made during the time when water level is expected to be at a maximum (i.e., toward the end of the wet season).

3) Potential BMP sites with a slope greater than 25% (4:1) should be excluded. A geotechnical analysis and report addressing slope stability are required if located within 50 feet of slopes greater than 15%.

Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report should:

- State whether the site is suitable for the proposed infiltration basin;

- Recommend a design percolation rate (see "*Step 2: Determine The Design Percolation Rate*" below);
- Identify the seasonally high depth to groundwater table surface elevation;
- Provide a good understanding of how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water; and
- If a geotechnical investigation and report are required, the report should:
  - Provide a written opinion by a professional civil engineer describing whether the infiltration basin will compromise slope stability; and
  - Identify potential impacts to nearby structural foundations.

Setbacks

1) Infiltration facilities shall be setback a minimum of 100 feet from proposed or existing potable wells, non-potable wells, septic drain fields, and springs.
2) Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.
3) The geotechnical expert shall establish the setback requirement from building foundations that must be ≥ 8 ft.

Pretreatment

Pretreatment is required for infiltration basins in order to reduce the sediment load entering the facility and maintain the infiltration rate of the facility. Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice; easing the long-term maintenance burden. Pretreatment is important for most all structural stormwater BMPs, but it is particularly important for infiltration BMPs. To ensure that pretreatment mechanisms are effective, designers should incorporate sediment reduction practices. Sediment reduction BMPs may include vegetated swales, vegetated filter strips, sedimentation basins or forebays, sedimentation manholes and hydrodynamic separation devices. The use of at least two pretreatment devices is highly recommended for infiltration basins.

For design specification of selected pretreatment devices, refer to:

- BIO-3: Vegetated swales
- BIO-4: Vegetated filter strips
- TCM-4: Sand filters

- TCM-5: Cartridge media filters
- PT-1: Hydrodynamic separation device

Sizing Criteria

As with sand filters, infiltration facilities can be sized using one of two methods: a simple sizing method or a routing modeling method. With either method the SQDV volume must be completely infiltrated within 12 to 72 hours (see Appendix D, Section D.2 for a discussion on drawdown time and BMP performance). The simple sizing procedures provided below can be used for either infiltration basins or infiltration trenches (see INF-2: Infiltration Trench). For the routing modeling method, refer to TCM-4 Sand Filters.

Step 1: Calculate the Design Volume

Infiltration facilities shall be sized to capture and infiltrate the SQDV volume (see Section 2 and Appendix E) with a 12 to 72 hour drawdown time (see Appendix D, Section D.2).

Step 2: Determine the Design Percolation Rate

The percolation rate will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the infiltrative layer. Monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For infiltration trenches, the design percolation rate discussed here is the percolation rate of the underlying soils and not the percolation rate of the filter media bed (refer to the "Geometry and Sizing" section of INF-2 for the recommended composition of the filter media bed for infiltration trenches).

Considerations for Design Percolation Rate Corrections

Suitability assessment related considerations include (Table 6-2):

- Soil assessment methods – the site assessment extent (e.g., number of borings, test pits, etc.) and the measurement method used to estimate the short-term infiltration rate.
- Predominant soil texture/percent fines – soil texture and the percent fines can greatly influence the potential for clogging.
- Site soil variability – site with spatially heterogeneous soils (vertically or horizontally), as determined from site investigations, are more difficult to estimate average properties resulting in a higher level of uncertainty associated with initial estimates.

- Depth to seasonal high groundwater/impervious layer – groundwater mounding may become an issue during excessively wet conditions where shallow aquifers or shallow clay lenses are present.

Table 6-2: Suitability Assessment Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Assessment methods	Use of soil survey maps or simple texture analysis to estimate short-term infiltration rates	Direct measurement of ≥ 20 percent of infiltration area with localized infiltration measurement methods (e.g., infiltrometer)	Direct measurement of ≥ 50 percent of infiltration area with localized infiltration measurement methods or Use of extensive test pit infiltration measurement methods
Ventura Hydrology Manual soil number (measured infiltration rate)	3 (f = 0.5 – 0.64)	4 or 5 (f = 0.65 –0.91)	6 or 7 (f = 0.92 or higher)
Site soil variability	Highly variable soils indicated from site assessment or limited soil borings collected during site assessment	Soil borings/test pits indicate moderately homogeneous soils	Multiple soil borings/test pits indicate relatively homogeneous soils
Depth to groundwater/ impervious layer	<10 ft below facility bottom	10-30 ft below facility bottom	>30 below facility bottom

Localized infiltration testing refers to methods such as the double ring infiltrometer test (ASTM D3385-88), which measure infiltration rates over an area less than 10 sq-ft and do not attempt to account for soil heterogeneity. Extensive infiltration testing refers to methods that include excavating a significant portion of the proposed infiltration area, filling the excavation with water, and monitoring drawdown. In all cases, testing should be conducted in the area of the proposed BMP where, based on geotechnical data, soils appear least likely to support infiltration.

Design related considerations include (Table 6-3):

- Size of area tributary to facility – all things being equal, both physical and economic risk factors related to infiltration facilities increase with an increase in the tributary area served. Therefore facilities serving larger tributary areas should use more restrictive adjustment factors.

- Level of pretreatment/expected influent sediment loads – credit should be given for good pretreatment by allowing less restrictive factors to account for the reduced probability of clogging from high sediment loading. Also, facilities designed to capture runoff from relatively clean surfaces such as rooftops are likely to see low sediment loads and therefore should be allowed to apply less restrictive safety factors.

- Redundancy – facilities that consist of multiple subsystems operating in parallel such that parts of the system remains functional when other parts fail and/or bypass, should be rewarded for the built-in redundancy with less restrictive correction and safety factors. For example, if bypass flows would be at least partially treated by another BMP, the risk of discharging untreated runoff in the event of clogging the primary facility is reduced. A bioretention facility that overflows to a landscaped area is another example. Compaction during construction – proper construction oversight is needed during construction to ensure that the bottoms of infiltration facility are not overly compacted. Facilities that do not commit to proper construction practices and oversight should have to use more restrictive correction and safety factors.

Table 6-3: Design Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Tributary area size	Greater than 10 acres.	Greater than 2 acres but less than 10 acres.	2 acres or less.
Level of pre-treatment/ expected influent sediment loads	Pre-treatment from gross solids removal devices only, such as hydrodynamic separators, racks and screens, AND tributary area includes landscaped areas, steep slopes, high traffic areas, or any other areas expected to produce high sediment, trash, or debris loads.	Good pre-treatment with BMPs that mitigate coarse sediments such as vegetated swales AND influent sediment loads from the tributary area are expected to be relatively low (e.g., low traffic, mild slopes, disconnected impervious areas, etc.).	Excellent pre-treatment with BMPs that mitigate fine sediments such as bioretention or media filtration OR sedimentation or facility only treats runoff from relatively clean surfaces, such as rooftops.
Redundancy of treatment	No redundancy in BMP treatment train.	Medium redundancy, other BMPs available in treatment train to maintain at least 50% of function of facility in event of failure.	High redundancy, multiple components capable of operating independently and in parallel, maintaining at least 90% of facility functionality in event of failure.
Compaction during construction	Construction of facility on a compacted site or elevated probability of unintended/ indirect compaction.	Medium probability of unintended/ indirect compaction.	Heavy equipment actively prohibited from infiltration areas during construction and low probability of unintended/ indirect compaction.

Adjust the measured short-term infiltration rate using a weighted average of several safety factors using the worksheet shown in Table 6-4 below. The design percolation rate would be determined as follows:

- For each consideration shown in Table 6-2 and Table 6-3 above, determine whether the consideration is a high, medium, or low concern.
- For all high concerns, assign a factor value of 3, for medium concerns, assign a factor value of 2, and for low concerns assign a factor value of 1.
- Multiply each of the factors by the corresponding weight to get a product.

- Sum the products within each factor category to obtain a safety factor for each.
- Multiply the two safety factors together to get the final combined safety factor. If the combined safety factor is less than 2, then use 2 as the safety factor.
- Divide the measured short-term infiltration rate by the combined safety factor to obtain the adjusted design percolation rate for use in sizing the infiltration facility.

Table 6-4: Infiltration Facility Safety Factor Determination Worksheet

Factor Category		Factor Description	Assigned Weight (w)	Factor Value (v)	Product (p) p = w x v
A	Suitability Assessment	Soil assessment methods	0.25		
		Predominant soil texture	0.25		
		Site soil variability	0.25		
		Depth to groundwater / impervious layer	0.25		
		Suitability Assessment Safety Factor, $S_A = \Sigma p$			
B	Design	Tributary area size	0.25		
		Level of pre-treatment/ expected sediment loads	0.25		
		Redundancy	0.25		
		Compaction during construction	0.25		
		Design Safety Factor, $S_B = \Sigma p$			
Combined Safety Factor = S_A x S_B					

Note: The minimum combined adjustment factor shall not be less than 2.0 and the maximum combined adjustment factor shall not exceed 9.

Step 3: Calculate the surface area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus (for infiltration trenches) the void spaces based on the computed porosity of the filter media (normally about 32%).

1) Determine the maximum depth of runoff that can be infiltrated within the required drain time (d_{max}) as follows:

$$d_{\max} = \frac{P_{design}}{12} t \qquad \text{(Equation 6-1)}$$

Where:

d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)
P_{design}	=	design percolation rate of underlying soils (in/hr)
t	=	required drain time (hrs)

2) Choose the ponding depth (d_p) and/or trench depth (d_t) such that:

$$d_{\max} \geq d_p \quad \text{For Infiltration Basins} \qquad \text{(Equation 6-2)}$$

$$d_{\max} \geq n_t d_t + d_p \quad \text{For Infiltration Trenches} \qquad \text{(Equation 6-3)}$$

Where:

d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)
d_p	=	ponding depth (ft)
n_t	=	trench fill aggregate porosity (unitless)
d_t	=	depth of trench fill (ft)

3) Calculate infiltrating surface area (filter bottom area) required:

$$A = \frac{SQDV}{((TP_{design}/12) + d_p)} \quad \text{For Infiltration Basins} \qquad \text{(Equation 6-4)}$$

$$A = \frac{SQDV}{((TP_{design}/12) + n_t d_t + d_p)} \quad \text{For Infiltration Trenches} \qquad \text{(Equation 6-5)}$$

Where:

$SQDV$	=	stormwater quality design volume (ft^3)
n_t	=	trench fill aggregate porosity (unitless)
P_{design}	=	design percolation rate (in/hr)
d_p	=	ponding depth (ft)
d_t	=	depth of trench fill (ft)
T	=	fill time (time to fill to max ponding depth with water) (hrs) [use 2 hours for most designs]

Geometry and Sizing

1) Infiltration basins should be designed and constructed with the flattest bottom slope possible to promote uniform ponding and infiltration across the facility.

2) A sediment forebay is required unless adequate pretreatment is provided in a separate pretreatment unit (e.g., vegetated swale, filter strip, hydrodynamic device) to reduce sediment loads entering the infiltration basin. The sediment forebay, if present, should have a volume equal to 25% of the total infiltration basin volume.

3) The forebay should be designed with a minimum length to width ratio of 2:1 and should completely drain to the main basin through an 8-inch minimum low-flow outlet within 10 minutes.

4) All inlets should enter the sediment forebay. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets.

5) Design embankments to conform to requirements of the State of California Division of Safety of Dams, if the basin dimensions cause it to fall under that agency's jurisdiction.

Drainage

1) The bottom of the infiltration bed should be native soil, over-excavated to at least one foot in depth, and replaced uniformly without compaction. Amending the excavated soil with 2-4 inches (~15-30%) of coarse sand is recommended.

2) The hydraulic conductivity of the subsurface layers should be sufficient to ensure a maximum 72-hr drawdown time. An observation well shall be incorporated to allow observation of drain time.

3) For infiltration basins, an underdrain should be installed within the bottom layer to provide drainage in case of standing water. The underdrain should be operated by opening a valve, which should be closed during normal operation. Cleanouts should be provided for the underdrain. See Sand Filter Section VEG-8 for specifications for underdrains.

Emergency Overflow

1) There should be an overflow route for stormwater flows that overtop the facility or in case the infiltration facility becomes clogged.

2) The overflow channel should be able to safely convey flows from the peak design storm to the downstream stormwater conveyance system or other acceptable discharge point.

3) Spillway and overflow structures should be designed in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.

Vegetation

1) A thick mat of drought tolerant grass should be established on the basin floor and side-slopes following construction. Grasses can help prevent erosion and increase evapotranspiration and their roots discourage compaction helping to maintain the surface infiltration rates. Additionally, the active growing vegetation can help break up surface layers that accumulate fine particulates.

2) Grass may need to be irrigated during establishment.

3) For infiltration basins, landscaping of the area surrounding the basin should adhere to the following criteria so as not to hinder maintenance operations:

    a. No trees or shrubs may be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, should not be used within 50 feet of pipes.

    b. Prohibited non-native plant species will not be permitted. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

Maintenance Access

1) Maintenance access road(s) shall be provided to the drainage structures associated with the basin (e.g., inlet, emergency overflow, or bypass structures). Manhole and catch basin lids should be in or at the edge of the access road.

2) An access ramp to the basin bottom is required to facilitate the entry of sediment removal and vegetation maintenance equipment without compaction of the basin bottom and side slopes.

Construction Considerations

To preserve and avoid the loss of infiltration capacity, the following construction guidelines are specified:

1) The entire area draining to the facility should be stabilized before construction begins. If this is impossible, a diversion berm should be placed around the perimeter of the infiltration site to prevent sediment entrance during construction.

2) Infiltration basins should not be hydraulically connected to the stormwater conveyance system until all contributing tributary areas are stabilized as shown on the Contract Plans and to the satisfaction of the Engineer. Infiltration basins should not be used as sediment control facilities.

3) Compaction of the subgrade with heavy equipment should be minimized to the maximum extent possible. If the use of heavy equipment on the base of the facility cannot be avoided, the infiltrative capacity should be restored by tilling or aerating prior to placing the infiltrative bed.

4) The exposed soils should be inspected by a civil engineer after excavation to confirm that soil conditions are suitable.

Operations and Maintenance

Infiltration facility maintenance should include frequent inspections to ensure that surface ponding infiltrates into the subsurface completely within the design infiltration time after a storm (see Appendix I for an infiltration BMP inspection and maintenance checklist).

Maintenance and regular inspections are of primary importance if infiltration BMPs are to continue to function as originally designed. A specific maintenance plan shall be formulated specifically for each facility outlining the schedule and scope of maintenance operations, as well as the data handling and reporting requirements. The following are general maintenance requirements:

1) Regular inspection should determine if the pretreatment sediment removal BMPs require routine maintenance.

2) If water is noticed in the basin more than 72 hours after a major storm the infiltration facility may be clogged. Maintenance activities triggered by a potentially clogged facility include:

    a. Check for debris/sediment accumulation, rake surface, and remove sediment (if any) and evaluate potential sources of sediment and debris (e.g., embankment erosion, channel scour, overhanging trees, etc). If suspected upland sources are outside of the immediate jurisdiction, additional pretreatment operations (e.g., trash racks, vegetated swales, etc.) may be necessary.

    b. For basins, removal of the top layer of native soil may be required to restore infiltrative capacity.

    c. Any debris or algae growth located on top of the infiltration facility should be removed and disposed of properly.

    d. Facilities shall be inspected annually. Trash and debris should be removed as needed, but at least annually prior to the beginning of the wet season.

3) Site vegetation should be maintained as frequently as necessary to maintain the aesthetic appearance of the site, and as follows:

   a. Vegetation, large shrubs, or trees that limit access or interfere with basin operation should be pruned or removed.

   b. Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.

   c. Grass should be mowed to 4" - 9" high and grass clippings should be removed.

   d. Fallen leaves and debris from deciduous plant foliage should be raked and removed.

   e. Invasive vegetation, such as Alligatorweed (Alternanthera philoxeroides), Halogeton (Halogeton glomeratus), Spotted Knapweed (Centaurea maculosa), Giant Reed (Arundo donax), Castor Bean (Ricinus communis), Perennial Pepperweed (Lepidium latifolium), and Yellow Starthistle (Centaurea solstitalis) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 25% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

   f. Dead vegetation should be removed if it exceeds 10% of area coverage. Vegetation should be replaced immediately to maintain cover density and control erosion where soils are exposed.

4) For infiltration basins, sediment build-up exceeding 50% of the forebay capacity should be removed. Sediment from the remainder of the basin should be removed when 6 inches of sediment accumulates. Sediments should be tested for toxic substance accumulation in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed. If toxic substances are encountered at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, the sediment should be disposed of in a hazardous waste landfill and the source of the contaminated sediments should be investigated and mitigated to the extent possible.

5) Following sediment removal activities, replanting and/or reseeding of vegetation may be required for reestablishment.

INF-2: Infiltration Trench

Infiltration trenches are long, narrow, gravel-filled trenches, often vegetated, that infiltrate stormwater runoff from small drainage areas. Infiltration trenches may include a shallow depression at the surface, but the majority of runoff is stored in the void space within the gravel and infiltrates through the sides and the bottom of the trench.

Rural Highway Infiltration Trench

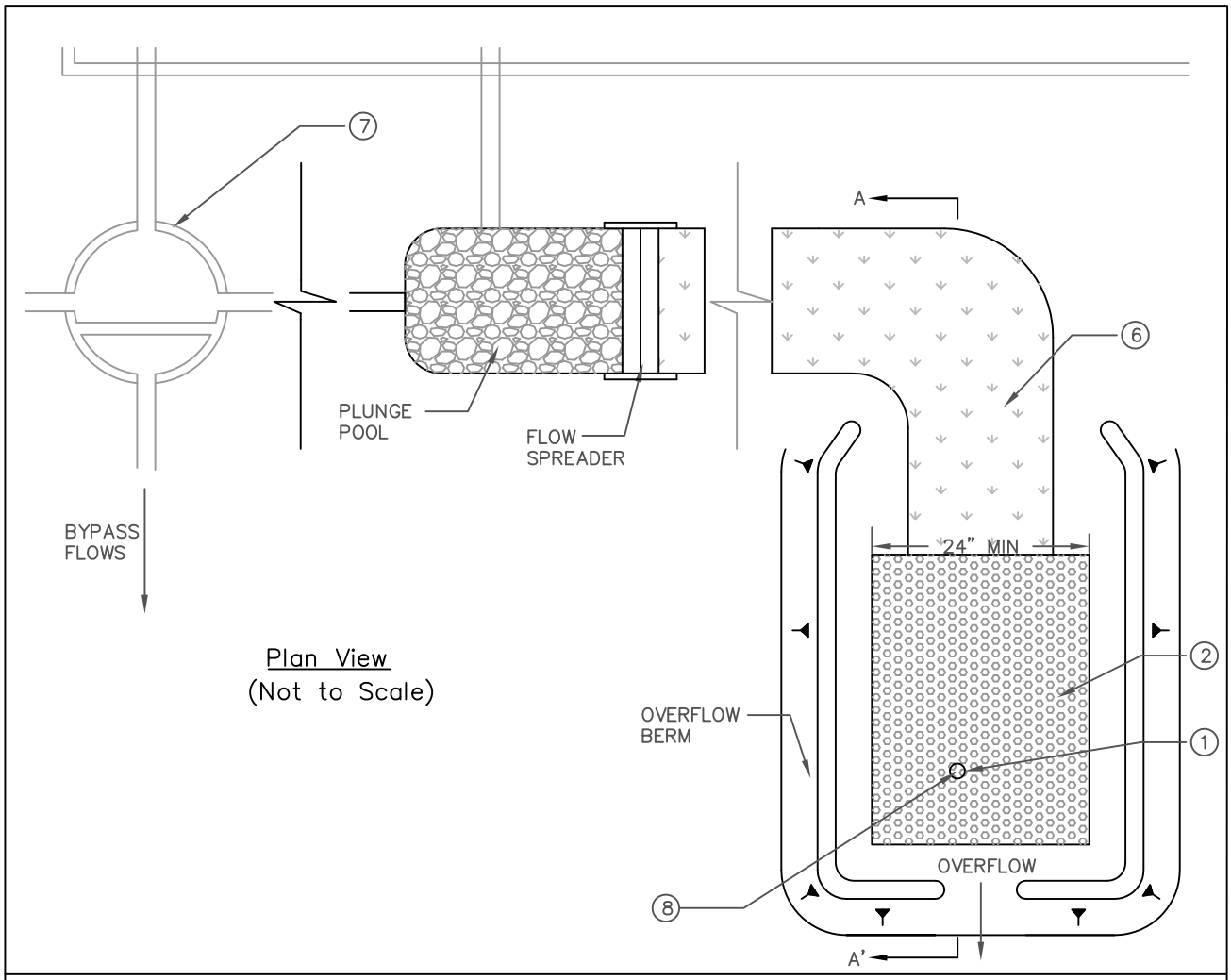
http://stormwater.wordpress.com/2007/05/23/infiltration--trenches/

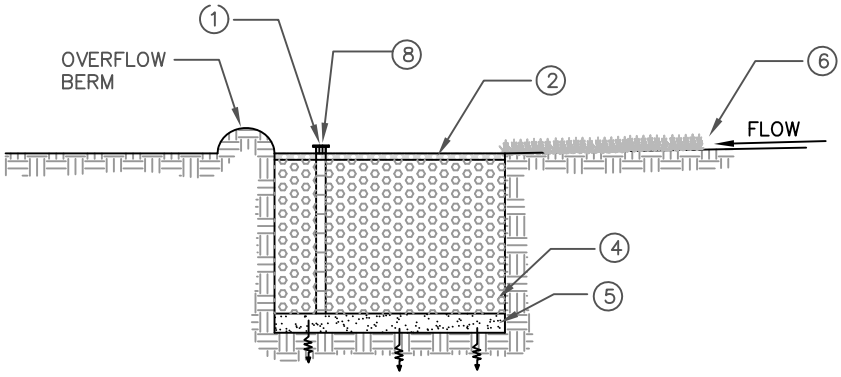
Application

- Open areas adjacent to parking lots, driveways, and buildings
- Roadway medians and shoulders

Routine Maintenance

- Removal trash, debris, and sediment at inlet and outlets
- Wet weather inspection to ensure drain time
- Remove weeds
- Inspect for mosquito breeding





Section A – A'
(Not to Scale)

NOTES:

1. OBSERVATION WELL WITH LOCKABLE ABOVE-GROUND CAP.
2. 2" PEA GRAVEL FILTER LAYER.
3. MINIMUM 10' ABOVE SEASONAL HIGH GROUNDWATER TABLE AND 3' ABOVE BEDROCK.
4. 3' – 5' DEEP TRENCH FILLED WITH 2" – 6" DIAMETER CLEAN STONE WITH 30% – 40% VOIDS.
5. 6" DEEP SAND FILTER LAYER (OR FABRIC EQUIVALENT).
6. RUNOFF FILTERS THROUGH GRASS FILTER STRIP OR VEGETATED SWALE.
7. OPTIONAL FLOW CONTROL DEVICE FOR OFF-LINE CONFIGURATIONS.

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Figure 6-3: Infiltration Trench

Limitations

The following limitations should be considered before choosing to use an infiltration trench:

- Native soil infiltration rate – soil permeability at the infiltration trench location must be at least 0.5 inches per hour.
- Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration trench and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.
- Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.
- Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields and springs. Infiltration BMPs must be setback from building foundations at least eight feet or an alternative setback established by the geotechnical expert for the project.
- Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer to ensure groundwater is protected for pollutants of concern.
    - Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines that infiltration would be beneficial.
- High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at or near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.
- High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

Design Criteria

The main challenge associated with infiltration trenches is preventing system clogging and subsequent infiltration inhibition. Infiltration trenches should be designed according to the requirements listed in Table 6-5 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-5: Infiltration Trench Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix E for calculating SQDV.
Design drawdown time	hr	12 – 72, see Appendix D, Section D.2
Trench bottom elevation	feet	5 feet from seasonally high groundwater table
Setbacks	feet	100 feet from wells, fields, springs Geotechnical expert should establish the setback requirement from building foundations that must be ≥ 8 ft Do not locate under tree drip-lines
Pretreatment	-	BIO-3: Vegetated Swale, BIO-4: Filter Strip, proprietary device, or sedimentation forebay, for all surfaces other than roofs
Design percolation rate, (P_{design})	in/hr	Measured percolation rate must be corrected based onsite suitability assessment and design related considerations described in this fact sheet
Maximum depth of facility (d_{max})	feet	8.0; Defined by the design infiltration rate and the design drawdown time (includes ponding depth and depth of media)
Surface area of facility (A)	square feet	Based on depth of ponding (if applicable) and depth of trench media
Facility geometry	-	Minimum 24 inches wide and maximum 5 feet deep; max 3% bottom slope
Filter media diameter	inches	1 – 3 (gravel); prefabricated media may also be used
Trench lining material	-	Geotextile fabric
Overflow device	-	Required if system is on-line

Geotechnical Considerations

An extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of infiltration facilities due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration facility. See Appendix C for guidance on infiltration testing.

The project designer must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil engineer that sufficiently permeable soils exist onsite to allow the construction of a properly functioning infiltration facility.

1) Infiltration facilities require a minimum soil infiltration rate of 0.5 inches/hour. If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated in an upstream BMP prior to infiltration to protect groundwater quality. Pretreatment for coarse sediment removal is required in all instances.

2) Groundwater separation must be at least 5 feet from the trench bottom to the measured season high groundwater elevation or estimated high groundwater mounding elevation. Groundwater level measurements must be made during the time when water level is expected to be at a maximum (i.e., toward the end of the wet season).

3) Sites with a slope greater than 25% (4:1) should be excluded. A geotechnical analysis and report addressing slope stability are required if located on slopes greater than 15%.

Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report should:

- State whether the site is suitable for the proposed infiltration trench;
- Recommend a design infiltration rate (see the Step 2 of sizing methodology section, “Determine the design percolation rate,” in the Infiltration Basin fact sheet above);
- Identify the seasonally high depth to groundwater table surface elevation.
- Provide a good understanding of how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water; and
- If a geotechnical investigation and report are required, the report should:
    - Provide a written opinion by a professional civil engineer describing whether the infiltration trench will compromise slope stability; and

- Identify potential impacts to nearby structural foundations.

Setbacks

1) Infiltration facilities shall be setback a minimum of 100 feet from proposed or existing potable wells, non-potable wells, septic drain fields, and springs.

2) Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

3) Infiltration BMPs must be setback from building foundations at least eight feet or an alternative setback established by the geotechnical expert for the project.

Pretreatment

Pretreatment is required for infiltration trenches in order to reduce the sediment load entering the facility and maintain the infiltration rate of the facility. Pretreatment refers to design features that provide settling of large particles before runoff reaches a management practice; easing the long-term maintenance burden. Pretreatment is important for most all structural stormwater BMPs, but it is particularly important for infiltration BMPs. To ensure that pretreatment mechanisms are effective, designers should incorporate sediment reduction practices. Sediment reduction BMPs may include vegetated swales, vegetated filter strips, sedimentation basins or forebays, sedimentation manholes and hydrodynamic separation devices.

For design specification of selected pre-treatment devices, refer to:

- VEG-3: Vegetated swales
- VEG-4: Vegetated filter strips
- TCM-4: Sand filters
- TCM-5: Cartridge media filters
- PT-1: Hydrodynamic separation device

Sizing Criteria

See Sizing Criteria section in the INF-1: Infiltration Basin fact sheet.

Geometry and Sizing

1) Infiltration trenches should be at least 2 feet wide and 3 to 5 feet deep.

2) The longitudinal slope of the trench should not exceed 3%.

3) The filter bed media layers should have the following composition and thickness:

a. Top layer – If stormwater runoff enters the top of the trench via sheet flow at the ground surface, then the top 2 inches should be pea gravel with a thin 2 to 4 inch layer of pure sand and 2 inch layer of chocking stone (e.g., #8) to capture sediment before entering the trench. If stormwater runoff enters the trench from an underground pipe, pretreatment prior to entry into the trench is required.

b. Middle layer (3 to 5 feet of washed, 1.5 to 3 inch gravel). Void space should be in the range of 30 percent to 40 percent.

c. Bottom layer (6 inches of clean, washed sand to encourage drainage and prevent compaction of the native soil while the stone aggregate is added).

4) One or more observation wells should be installed, depending on trench length, to check for water level, drawdown time, and evidence of clogging. A typical observation well consists of a slotted PVC well screen, 4 to 6 inches in diameter, capped with a lockable, above-ground lid.

Drainage

1) The bottom of the infiltration bed must be native soil, over-excavated to at least one foot in depth and replaced uniformly without compaction. Amending the excavated soil with 2 to 4 inches (~15% to 30%) of coarse sand is recommended.

2) The hydraulic conductivity of the subsurface layers should be sufficient to ensure the design drawdown time. An observation well should be incorporated to allow observation of drain time.

Emergency Overflow

1) There must be an overflow route for stormwater flows that overtop the facility or in case the infiltration facility becomes clogged.

2) The overflow channel must be able to safely convey flows from the peak design storm to the downstream stormwater conveyance system or other acceptable discharge point.

Vegetation

1) Trees and other large vegetation should be planted away from trenches such that drip lines do not overhang infiltration beds.

Maintenance Access

1) The facility and outlet structures must all be safely accessible during wet and dry weather conditions.

2) An access road along the length of the trench is required, unless the trench is located along an existing road or parking lot that can be safely used for maintenance access.

3) If the infiltration trench becomes plugged and fails, then access is needed to excavate the facility to remove and replace the top layer or the filter bed media, as well as to increase all dimensions of the facility by 2 inches to provide a fresh surface for infiltration. To prevent damage and compaction, access must be able to accommodate a backhoe working at "arms length".

Construction Considerations

To preserve and avoid the loss of infiltration capacity, the following construction guidelines are specified:

1) The entire area draining to the facility must be stabilized before construction begins. If this is impossible, a diversion berm should be placed around the perimeter of the infiltration site to prevent sediment entering during construction.

2) Infiltration trenches should not be hydraulically connected to the stormwater conveyance system until all contributing tributary areas are stabilized as shown on the Contract Plans and to the satisfaction of the Engineer. Infiltration trenches should not be used as sediment control facilities.

3) Compaction of the subgrade with heavy equipment should be minimized to the maximum extent possible. If the use of heavy equipment on the base of the facility cannot be avoided, the infiltrative capacity should be restored by tilling or aerating prior to placing the infiltrative bed.

4) The exposed soils should be inspected by a civil engineer after excavation to confirm that soil conditions are suitable.

Operations and Maintenance

Infiltration facility maintenance should include frequent inspections to ensure that water infiltrates into the subsurface completely within the design drawdown time after a storm.

Maintenance and regular inspections are of primary importance if infiltration trenches are to continue to function as originally designed. A specific maintenance plan shall be developed specific to each facility outlining the schedule and scope of maintenance operations, as well as the documentation and reporting requirements. The following are general maintenance requirements:

1) Regular inspection should determine if the sediment pretreatment structures require preventative maintenance. Inspect a minimum of twice a year, before and after the rainy season, after large storms, or more frequently if needed.

2) If water is noticed in the observation well of the infiltration trench more than 72 hours after a major storm, the infiltration trench may be clogged. Maintenance activities triggered by a potentially clogged facility include:

a. For trenches, assess the condition of the top aggregate layer for sediment buildup and crusting. Remove top layer of pea gravel and replace. If slow draining conditions persist, entire trench may need to be excavated and replaced.

3) Any debris or algae growth located on top of the infiltration facility should be removed and disposed of properly.

4) Inspect a minimum of twice a year, before and after the rainy season, after large storms, or more frequently if needed.

5) Clean when loss of infiltrative capacity is observed. If drawdown time is observed to have increased significantly over the design drawdown time, removal of sediment may be necessary. This is an expensive maintenance activity and the need for it can be minimized through prevention of upstream erosion.

6) Mow as appropriate for vegetative cover species.

7) Monitor health of vegetation and replace as necessary.

8) Control mosquitoes as necessary.

9) Remove litter and debris from trench area as required.

INF-3: Bioretention

Bioretention stormwater treatment facilities are landscaped shallow depressions that capture and filter stormwater runoff. These facilities function as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, and plantings. An optional gravel layer can be added below the planting soil to provide additional storage volume for infiltration. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. For areas with low permeability native soils or steep slopes, see section INF-7: Bioinfiltration or BIO-1: Bioretention with Underdrain for relevant design specifications.

Bioretention in Parkway and parking lots

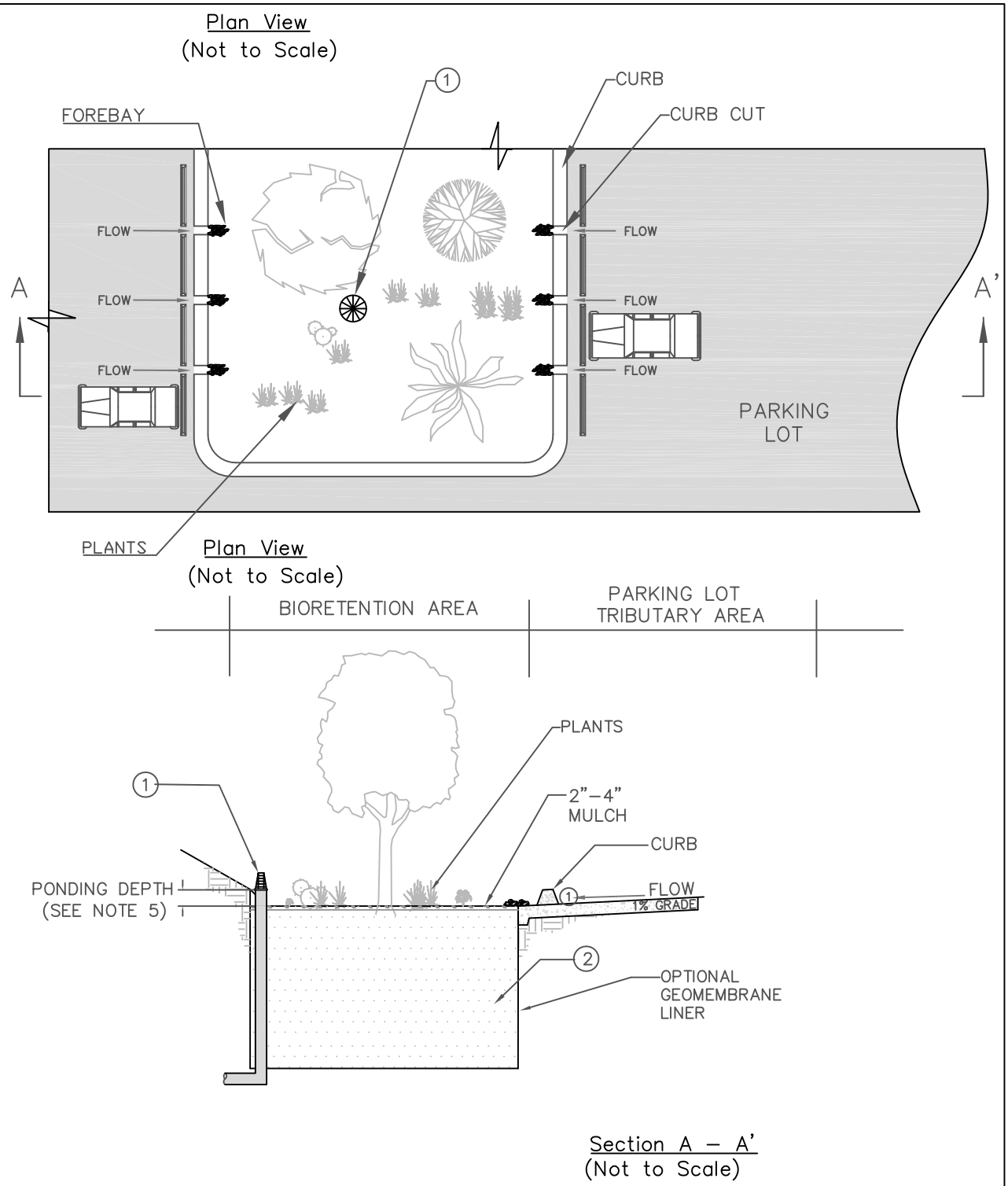
Photo Credits: Geosyntec Consultants

Application

- Commercial, residential, mixed use, institutional, and recreational uses
- Parking lot islands, traffic circles
- Road parkways & medians

Preventative Maintenance

- Repair small eroded areas
- Remove trash and debris and rake surface soils
- Remove accumulated fine sediments, dead leaves and trash
- Remove weeds and prune back excess plant growth
- Remove sediment and debris accumulation near inlet and outlet structures
- Periodically observe function under wet weather conditions



NOTES:

① OVERFLOW DEVICE: VERTICAL RISER OR EQUIVALENT.

② 2' MIN PLANTING MIX; 3' PREFERRED.

③ PONDING DEPTH 18" WITH FENCE; 6" WITHOUT FENCE.

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Figure 6-4: Bioretention

Limitations

The following limitations should be considered before choosing to use bioretention:

1) Native soil infiltration rate - soil permeability at the bioretention location must be at least 0.5 inches per hour.

2) Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration trench and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.

3) Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

4) Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback from building foundations at least eight feet or have an alternative setback established by the geotechnical expert for the project.

5) Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer to ensure groundwater is protected for pollutants of concern.

6) Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines that infiltration would be beneficial.

7) High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at or near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.

8) High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

9) Vertical relief and proximity to storm drain - site must have adequate relief between the land surface and storm drain to permit vertical percolation through the soil media and collection.

Design Criteria

Bioretention should be designed according to the requirements listed in Table 6-6 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-6: Bioretention Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix E for calculating SQDV.
Forebay	-	Forebay should be provided for all tributary surfaces that contain landscaped areas. Forebays should be designed to prevent standing water during dry weather and should be planted with a plant palette that is tolerant of wet conditions.
Maximum drawdown time of water ponded on surface	hours	48
Maximum drawdown time of surface ponding plus subsurface pores	hours	96 (72 preferred)
Maximum ponding depth	inches	18
Minimum thickness of amended soil	feet	2 (3 preferred)
Minimum thickness of stabilized mulch	inches	2 to 3
Planting mix composition	-	60 to 80% fine sand, 20 to 40% compost
Overflow device	-	Required

Sizing Criteria

Bioretention facilities can be sized using one of two methods: a simple sizing method or a routing modeling method. With either method the SQDV volume must be completely infiltrated within 96 hours (including subsurface pore space), and surface ponding must be infiltrated within 48 hours. The simple sizing procedure is provided below. For the routing modeling method, refer to TCM-4 Sand Filters.

Step 1: Calculate the Design Volume

Bioretention facilities shall be sized to capture and infiltrate the SQDV volume (see Section 2.3 and Appendix E).

Step 2: Determine the Design Percolation Rate

The percolation rate through the BMP and to the subsurface will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the infiltration layer. Monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For bioretention facilities, the design percolation rate discussed here is the adjusted percolation rate of the underlying soils and not the percolation rate of the filter media bed.

Considerations for Design Percolation Rate Corrections

Suitability assessment-related considerations include (Table 6-7):

- Soil assessment methods – the site assessment extent (e.g., number of borings, test pits, etc.) and the measurement method used to estimate the short-term infiltration rate.
- Predominant soil texture/percent fines – soil texture and the percent of fines can greatly influence the potential for clogging.
- Site soil variability – site with spatially heterogeneous soils (vertically or horizontally) as determined from site investigations are more difficult to estimate average properties, resulting in a higher level of uncertainty associated with initial estimates.
- Depth to seasonal high groundwater/impervious layer – groundwater mounding may become an issue during excessively wet conditions where shallow aquifers or shallow clay lenses are present.

Localized infiltration testing refers to methods such as the double ring infiltrometer test (ASTM D3385-88), which measure infiltration rates over an area less than 10 sq-ft and do not attempt to account for soil heterogeneity. Extensive infiltration testing refers to methods that include excavating a significant portion of the proposed infiltration area, filling the excavation with water, and monitoring drawdown. In all cases, testing should be conducted in the area of the proposed BMP where, based on geotechnical data, soils appear least likely to support infiltration.

Table 6-7: Suitability Assessment Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Assessment methods	Use of soil survey maps or simple texture analysis to estimate short-term infiltration rates	Direct measurement of ≥ 20 percent of infiltration area with localized infiltration measurement methods (e.g., infiltrometer)	Direct measurement of ≥ 50 percent of infiltration area with localized infiltration measurement methods or Use of extensive test pit infiltration measurement methods
Ventura Hydrology Manual soil number (measured infiltration rate)	3 (f = 0.5 – 0.64)	4 or 5 (f = 0.65 – 0.91)	6 or 7 (f = 0.92 or higher)
Site soil variability	Highly variable soils indicated from site assessment or limited soil borings collected during site assessment	Soil borings/test pits indicate moderately homogeneous soils	Multiple soil borings/test pits indicate relatively homogeneous soils
Depth to groundwater/ impervious layer	<10 ft below facility bottom	10-30 ft below facility bottom	>30 below facility bottom

Design related considerations include:

- Size of area tributary to facility – all things being equal, both physical and economic risk factors related to infiltration facilities increase with an increase in the tributary area served. Therefore facilities serving larger tributary areas should use more restrictive adjustment factors.

- Level of pretreatment/expected influent sediment loads – credit should be given for good pretreatment by allowing less restrictive factors to account for the reduced probability of clogging from high sediment loading. Also, facilities designed to capture runoff from relatively clean surfaces such as rooftops are likely to see low sediment loads and therefore should be allowed to apply less restrictive safety factors.

- Redundancy – facilities that consist of multiple subsystems operating in parallel such that parts of the system remain functional when other parts fail and/or bypass should be rewarded for the built-in redundancy with less restrictive

correction and safety factors. For example, if bypass flows would be at least partially treated in another BMP, the risk of discharging untreated runoff in the event of clogging the primary facility is reduced. A bioretention facility that overflows to a landscaped area is another example.

- Compaction during construction – proper construction oversight is needed during construction to ensure that the bottoms of bioretention facility are not overly compacted. Facilities that do not commit to proper construction practices and oversight should have to use more restrictive correction and safety factors.

Table 6-8: Design Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Tributary area size	Greater than 10 acres.	Greater than 2 acres but less than 10 acres.	2 acres or less.
Level of pre-treatment/ expected influent sediment loads	Pre-treatment from gross solids removal devices only, such as hydrodynamic separators, racks and screens, AND tributary area includes landscaped areas, steep slopes, high traffic areas, or any other areas expected to produce high sediment, trash, or debris loads.	Good pre-treatment with BMPs that mitigate coarse sediments such as vegetated swales AND influent sediment loads from the tributary area are expected to be relatively low (e.g., low traffic, mild slopes, disconnected impervious areas, etc.).	Excellent pre-treatment with BMPs that mitigate fine sediments such as bioretention or media filtration OR sedimentation or facility only treats runoff from relatively clean surfaces, such as rooftops.
Redundancy of treatment	No redundancy in BMP treatment train.	Medium redundancy, other BMPs available in treatment train to maintain at least 50% of function of facility in event of failure.	High redundancy, multiple components capable of operating independently and in parallel, maintaining at least 90% of facility functionality in event of failure.
Compaction during construction	Construction of facility on a compacted site or elevated probability of unintended/ indirect compaction.	Medium probability of unintended/ indirect compaction.	Heavy equipment actively prohibited from infiltration areas during construction and low probability of unintended/ indirect compaction.

Adjust the measured short-term infiltration rate using a weighted average of several safety factors using the worksheet shown in Table 6-9 below. The design percolation rate would be determined as follows:

- For each consideration shown in Tables 6-7 and 6-8 above, determine whether the consideration is a high, medium, or low concern.
- For all high concerns assign a factor value of 3, for medium concerns assign a factor value of 2, and for low concerns assign a factor value of 1.
- Multiply each of the factors by the corresponding weight to get a product.
- Sum the products within each factor category to obtain a safety factor for each.
- Multiply the two safety factors together to get the final combined safety factor. If the combined safety factor is less than 2, then use 2 as the safety factor.
- Divide the measured short-term infiltration rate by the combined safety factor to obtain the adjusted design percolation rate for use in sizing the infiltration facility.

Table 6-9: Infiltration Facility Safety Factor Determination Worksheet

Factor Category		Factor Description	Assigned Weight (w)	Factor Value (v)	Product (p) p = w x v
A	Suitability Assessment	Soil assessment methods	0.25		
		Predominant soil texture	0.25		
		Site soil variability	0.25		
		Depth to groundwater / impervious layer	0.25		
		Suitability Assessment Safety Factor, $S_A = \Sigma p$			
B	Design	Tributary area size	0.25		
		Level of pre-treatment/ expected sediment loads	0.25		
		Redundancy	0.25		
		Compaction during construction	0.25		
		Design Safety Factor, $S_B = \Sigma p$			
		Combined Safety Factor = S_A x S_B			

Note: The minimum combined adjustment factor shall not be less than 2.0 and the maximum combined adjustment factor shall not exceed 9.

Step 3: Calculate the surface area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus the void spaces in the media, based on the computed porosity of the filter media and optional aggregate layer.

1) Determine the maximum depth of surface ponding that can be infiltrated within the required surface drain time (48 hr), (d_{max}), as follows:

$$d_{\max} = \frac{P_{design} \times t_{ponding}}{12\frac{in}{ft}} \qquad \text{(Equation 6-6)}$$

Where:

$t_{ponding}$	=	required drain time of surface ponding (48 hrs)
P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)
d_{max}	=	the maximum depth of surface ponding water that can be infiltrated within the required drain time (ft), calculated using Equation 6-6

2) Choose surface ponding depth (d_p) such that:

$$d_p \le d_{\max} \qquad \text{(Equation 6-7)}$$

Where:

d_p	=	selected surface ponding depth (ft)
d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)

Choose thickness(es) of amended media and optional gravel storage layer and calculate total effective storage depth of the bioretention area ($d_{effective}$), as follows:

$$d_{effective} \le (d_p + n^*_{media} l_{media} + n_{gravel} l_{gravel}) \qquad \text{(Equation 6-8)}$$

Where:

$d_{effective}$	=	total equivalent depth of water stored in bioretention area (ft), including surface ponding and volume available in pore spaces of media and gravel layers
d_p	=	surface ponding depth (ft), chosen using Equation 6-7
n^*_{media}	=	available porosity of amended soil media (ft/ft), approximately 0.25 ft/ft accounting for antecedent moisture conditions. This represents the volume of

available pore space as a fraction of the total soil volume; sometimes has units of (ft^3/ft^3) or described as a percentage.

l_{media} = thickness of amended soil media layer (ft), minimum 2 ft

n_{gravel} = porosity of optional gravel layer (ft/ft), approximately 0.40 ft/ft

l_{gravel} = thickness of optional gravel layer (ft)

3) Check that entire effective depth (surface plus subsurface storage), $d_{effective}$, infiltrates in no greater than 96 hours as follows:

$$t_{total} = \frac{d_{effective}}{P_{design}} \times 12 \frac{in}{ft} \leq 96\ hr \qquad \text{(Equation 6-9)}$$

Where:

$d_{effective}$ = total equivalent depth of water stored in bioretention area (ft), calculated using Equation 6-8

P_{design} = design percolation rate of underlying soils (in/hr) (see Step 2, above)

If $t_{total} > 96$ hrs, then reduce surface ponding depth and/or amended media thickness and/or gravel thickness and return to 1).

If $t_{total} \leq 96$ hrs, then proceed to 5).

4) Calculate required infiltrating surface area, (A_{req}):

$$A_{req} = \frac{SQDV}{d_{effective}} \qquad \text{(Equation 6-10)}$$

Where:

A_{req} = required infiltrating area (ft^2). Should be calculated at the contour corresponding to the mid ponding depth (i.e., $0.5 \times d_p$ from the bottom of the facility).

$SQDV$ = stormwater quality design volume (ft^3)

$d_{effective}$ = total equivalent depth of water stored in bioretention area (ft), calculated using Equation 6-8

5) Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is calculated at the contour corresponding to the mid ponding depth (i.e., $0.5 \times d_p$ from the bottom of the facility).

Geometry

1) Bioretention areas shall be sized to capture and treat the stormwater quality design volume (See Section 2 and Appendix E for calculating SQDV) with an 18-inch maximum ponding depth. *The intention is that ponding depth be limited to a depth that will allow for a health vegetation layer.*

2) Minimum planting soil depth should be 2 feet, although 3 feet is preferred. *The intention is that the minimum planting soil depth should provide a beneficial root zone for the chosen plant palette and adequate water storage for the SQDV.*

3) A gravel storage layer below the bioretention soil media to promote infiltration into the native soil is optional.

4) Bioretention should be designed to drain below the planting soil in less than 48 hours and completely drain in less than 96 hours. *The intention is that soils must be allowed to dry out periodically in order to restore hydraulic capacity needed to receive flows from subsequent storms, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and to provide proper soil conditions for biodegradation and retention of pollutants.*

Flow Entrance and Energy Dissipation

The following types of flow entrance can be used for bioretention cells:

1) Dispersed, low velocity flow across a landscape area. Dispersed flow may not be possible given space limitations or if the facility is controlling roadway or parking lot flows where curbs are mandatory.

2) Dispersed flow across pavement or gravel and past wheel stops for parking areas.

3) Curb cuts for roadside or parking lot areas: curb cuts should include rock or other erosion protection material in the channel entrance to dissipate energy. Flow entrance should drop 2 to 3 inches from curb line and it should provide a settling area and periodic sediment removal of coarse material before flow dissipates to the remainder of the cell.

4) Pipe flow entrance: Piped entrances, such as roof downspouts, should include rock, splash blocks, or other appropriate measures at the entrance to dissipate energy and disperse flows.

Woody plants (trees, shrubs, etc.) can restrict or concentrate flows and can be damaged by erosion around the root ball and should not be placed directly in the entrance flow path.

Overflow

An overflow device is required at the 18-inch ponding depth. The following, or equivalent should be provided:

1) A vertical PVC pipe (SDR 35) to act as an overflow riser.

2) The overflow riser(s) should be 6 inches or greater in diameter, so it can be cleaned without damage to the pipe.

The inlet to the riser should be at the ponding depth (18 inches for fenced bioretention areas and 6 inches for areas that are not fenced), and be capped with a spider cap to exclude floating mulch and debris. Spider caps should be screwed in or glued, i.e., not removable.

Hydraulic Restriction Layers

Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mils.

Planting/Storage Media

1) The planting media placed in the cell should achieve a long-term, in-place infiltration rate of at least 1 inch per hour. Higher infiltration rates are permissible. If the design long-term, in-place infiltration rate of the soil exceeds 12 inches per hour, documentation should be provided to demonstrate that the media will adequately address pollutants of concern at a higher flowrate. Bioretention soil shall also support vigorous plant growth.

2) Planting media should consist of 60 to 80% fine sand and 20 to 40% compost.

3) Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size should be non-plastic. Sand for bioretention should be analyzed by an accredited lab using #200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation (Note: all sands complying with ASTM C33 for fine aggregate comply with the gradation requirements below):

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

Note: the gradation of the sand component of the media is believed to be a major factor in the hydraulic conductivity of the media mix. If the desired hydraulic conductivity of the media cannot be achieved within the specified proportions of sand and compost (#2), then it may be necessary to utilize sand at the coarser end of the range specified in above ("minimum" column).

4) Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.
- Organic matter: 35-75% dry weight basis.
- Carbon and Nitrogen Ratio: 15:1 < C:N < 25:1
- Maturity/Stability: shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 F) upon delivery or rewetting is not acceptable.
- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
  - NH4:NH3 < 3
  - Ammonium < 500 ppm, dry weight basis
  - Seed Germination > 80% of control
  - Plant trials > 80% of control

- Solvita® > 5 index value

- Nutrient content:
  - Total Nitrogen content 0.9% or above preferred
  - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm
- pH between 6.5 and 8 (may vary with plant palette)

Compost for bioretention should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1 inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	2	10

Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested.

Note: the gradation of compost used in bioretention media is believed to play an important role in the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range ("minimum" column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity.

In addition, a coarser compost mix provides more heterogeneity of the bioretention media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

5) The bioretention area should be covered with 2 to 4 inches (average 3 inches) of mulch at the start and an additional placement of 1 to 2 inches of mulch should be added annually. *The intention is that to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity*.

Plants

1) Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 96 hours.

2) It is recommended that a minimum of three types of tree, shrubs, and/or herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species.

3) Native plant species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent practicable.

Operations and Maintenance

Bioretention areas require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, bioretention maintenance requirements are typical landscape care procedures and include:

1) Watering: Plants should be drought-tolerant. Watering may be required during prolonged dry periods after plants are established.

2) Erosion control: Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred (see Appendix I for a bioretention inspection and maintenance checklist). Properly designed facilities with appropriate flow velocities should not have erosion problems, except perhaps in extreme events. If erosion problems occur, the following should be reassessed: (1) flow velocities and gradients within the cell, and (2) flow dissipation and erosion protection strategies in the pretreatment area and flow entrance. If sediment is deposited in the bioretention area, immediately determine the source within the contributing area, stabilize, and remove excess surface deposits.

3) Plant material: Depending on aesthetic requirements, occasional pruning and removing of dead plant material may be necessary. Replace all dead plants and if specific plants have a high mortality rate, assess the cause and, if necessary, replace with more appropriate species. Periodic weeding is necessary until plants are established. The weeding schedule should become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants excluded.

4) Nutrients and pesticides: The soil mix and plants should be selected for optimum fertility, plant establishment, and growth. Nutrient and pesticide inputs should not be required and may degrade the pollutant processing capability of the bioretention area, as well as contribute pollutant loads to receiving waters. By design, bioretention facilities are located in areas where phosphorous and nitrogen levels are often elevated and these should not be limiting nutrients. If in question, have soil analyzed for fertility.

5) Mulch: Replace mulch annually in bioretention facilities where heavy metal deposition is likely (e.g., contributing areas that include industrial and auto dealer/repair parking lots and roads). In residential lots or other areas where metal

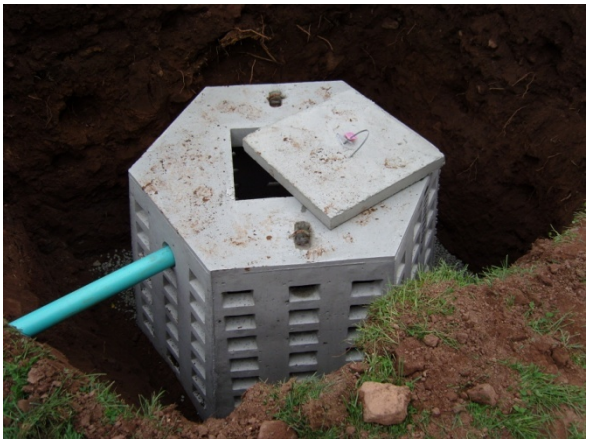
deposition is not a concern, replace or add mulch as needed to maintain a 2 to 3 inch depth at least once every two years.

6) Soil: Soil mixes for bioretention facilities are designed to maintain long-term fertility and pollutant processing capability. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in bioretention systems. Replacing mulch in bioretention facilities where heavy metal deposition is likely provides an additional level of protection for prolonged performance. If in question, have soil analyzed for fertility and pollutant levels.

INF-4: Drywell

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

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



Drywell installation

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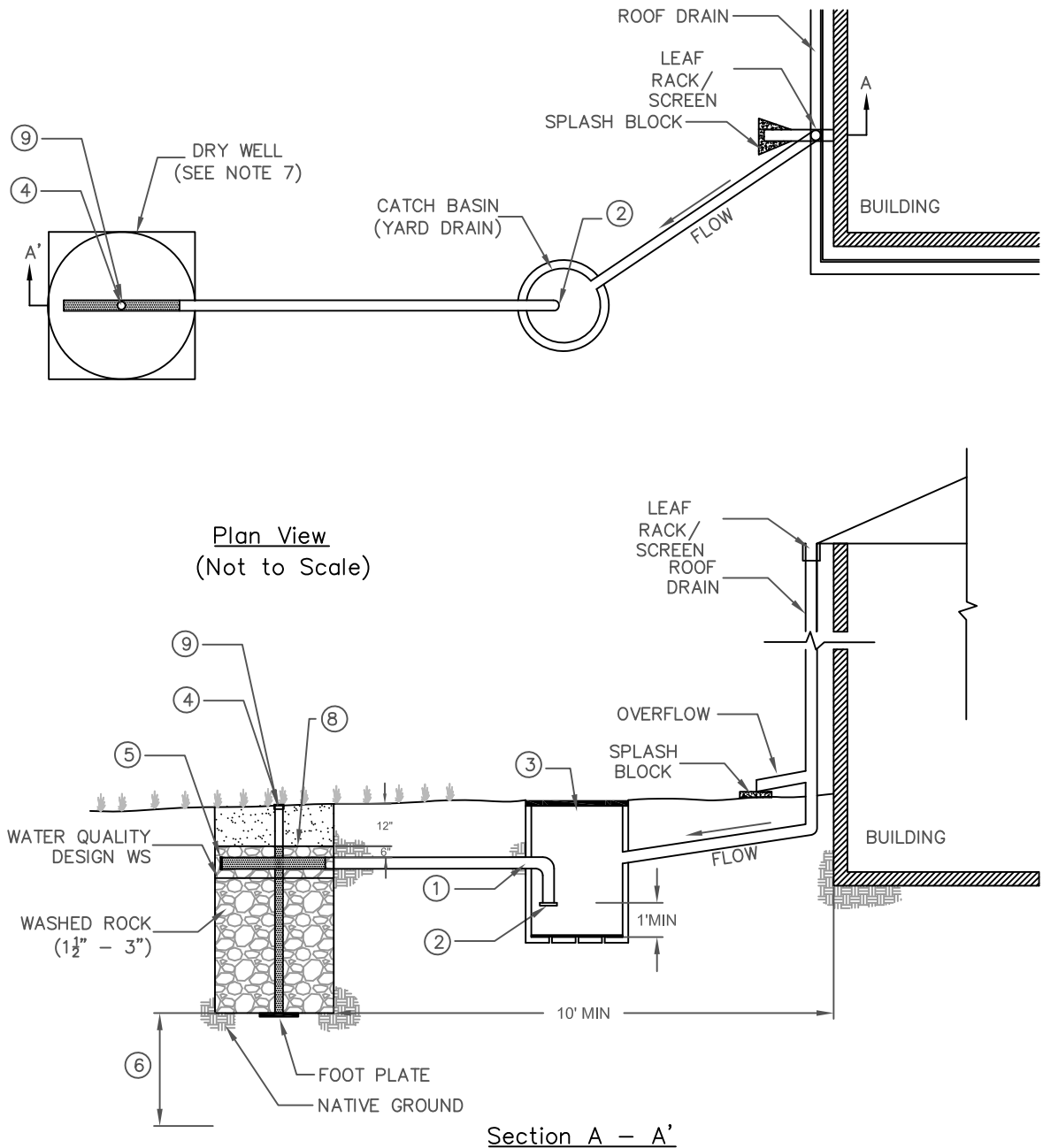
Application

- Infiltration of roof runoff

Preventative Maintenance

- Remove trash, debris, and sediment at inlet and outlets
- Wet weather inspection to ensure drain time
- Inspect for mosquito breeding



NOTES:

1. MINIMUM 4" – 6" DIAMETER PVC PIPE. INSTALL AT FLAT SLOPE.
2. INSTALL FINE MESH SCREEN AT INLET TO DRY WELL. SET INLET ELEVATION AT 1' MINIMUM ABOVE CATCH BASIN BOTTOM.
3. CATCH BASIN (YARD DRAIN) INSTALLED WITH A SOLID LID FLUSH WITH GROUND SURFACE.
4. 4–6" VERTICAL PERFORATED PVC INSPECTION WELL WITH SCREW LID (NUT DOWN) FLUSH WITH GROUND SURFACE.
5. CAP END OF 4–6" HORZONTAL PERFORATED PVC DISPERSION PIPE.
6. MINIMUM 10' ABOVE SEASONAL HIGH GROUNDWATER TABLE AND 3' ABOVE BEDROCK.
7. DRY WELL CONFIGURATION MAY VARY (E.G. PRE–FAB MAY BE CIRCULAR).
8. CHOKING STONE LAYER SHALL BE PLACED ON TOP OF THE DRY WELL TO SEPARATE IT FROM THE TOPSOIL AND PREVENT CLOGGING.

Geosyntec consultants

Figure 6-5: Drywell

Limitations

The following limitations shall be considered before choosing to use a dry well:

- Native soil infiltration rate – soil permeability at the infiltration basin location must be at least 0.5 inches per hour.
- Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration basin and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.
- Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.
- Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback from building foundations at least eight feet or have an alternative setback established by the geotechnical expert for the project.
- Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer, to ensure groundwater is protected from pollutants of concern.
- Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines the infiltration would be beneficial.
- High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at or near service/gas stations, truck stops, and heavy industrial sites due to groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.
- High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.
- Dry wells cannot receive untreated stormwater runoff, except rooftop runoff. Pretreatment of runoff from other surfaces is necessary to prevent premature failure that results from clogging with fine sediment, and to prevent potential groundwater contamination due to nutrients, salts, and hydrocarbons.

- Infiltration structures cannot be used to treat runoff from portions of the site that are not stabilized.
- Rehabilitation of failed dry wells requires complete reconstruction.

Design Criteria

The main challenge associated with drywells, as with infiltration trenches, is the prevention of system clogging and subsequent infiltration inhibition. Drywells should be designed according to the requirements listed in Table 6-10 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-10: Infiltration BMP Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix E for calculating SQDV.
Design drawdown time	hour	12
Pretreatment	-	BIO-3: Vegetated Swale, BIO-4: Filter Strip, proprietary device, or equivalent.
Design percolation rate (k_{design})	in/hr	Shall be corrected for testing method, potential for clogging and compaction over time, and facility geometry.
Maximum depth of facility (d_{max})	feet	Defined by the design infiltration rate and the design drawdown time (includes depth of media).
Surface area of facility (A)	ft^2	Based on depth of dry well media.
Facility geometry	-	Geometry varies; max 10 feet deep; flat bottom slope.
Filter media diameter	inches	1.5 – 3 (gravel); prefabricated media may also be used
Overflow device	-	Required if system is on-line

Geotechnical Considerations

An extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of infiltration facilities, due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration facility. See Appendix C for guidance on infiltration testing.

The project designer must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil engineer that sufficiently permeable soils exist on site to allow the construction of a properly functioning infiltration facility.

1) Infiltration facilities require a minimum soil infiltration rate of 0.5 inches/hour. If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully-treated in an upstream BMP prior to infiltration to protect groundwater quality. Pretreatment for coarse sediment removal is required in all instances.

2) Groundwater separation must be at least 5 feet from the basin bottom to the measured season high groundwater elevation or estimated high groundwater mounding elevation. Measurements of groundwater levels must be made during the time when water level is expected to be at a maximum (i.e., toward the end of the wet season).

3) Sites with a slope greater than 25% (4:1) should be excluded. A geotechnical analysis and report addressing slope stability are required if located on slopes greater than 15%.

Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report should:

- State whether the site is suitable for the proposed drywell;
- Recommend a design infiltration rate (see the Step 2 of sizing methodology section, "Determine the design percolation rate," in the INF-1: Infiltration Basin fact sheet above);
- Identify the seasonal high depth to groundwater table surface elevation;
- Provide a good understanding of how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water; and
- If a geotechnical investigation and report are required, the report should:
  - Provide a written opinion by a professional civil engineer describing whether the drywell will compromise slope stability; and
  - Identify potential impacts to nearby structural foundations.

Setbacks

1) Infiltration facilities shall be setback a minimum of 100 feet from proposed or existing potable wells, non-potable wells, septic drain fields, and springs.

2) Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

3) Infiltration BMPs must be setback from building foundations at least eight feet or have an alternative setback established by the geotechnical expert for the project.

Pretreatment

- A removable filter with a screened bottom should be installed in the roof leader below the surcharge pipe in order to screen out leaves and other debris.

- Though roofs are generally not a significant source of runoff pollution, they can still be source of particulates and organic matter. Measures such as roof gutter guards, roof leader clean-out with sump, or an intermediate sump box can provide pretreatment for dry wells by minimizing the amount of sediment and other particulates that may enter it.

Sizing Criteria

See Sizing Criteria section in the INF-1: Infiltration Basin fact sheet.

Geometry and Sizing

1) Dry well configurations vary, but generally they have length and width dimensions closer to square than infiltration trenches. Pre-fabricated dry-wells are often circular. The surface area of the dry well must be large enough to infiltrate the storage volume in 12 hours based on the maximum depth allowable (d_{max}).

2) The filter bed media layers are the same as for infiltration trenches unless prefabricated dry wells and/or media are used. The porosity of gravel media systems is generally 30 to 40% and is 80 to 95% for prefabricated media systems.

3) If a dry well receives runoff from an underground pipe (i.e., runoff does not enter the top of the dry well from the ground surface), a fine mesh screen should be installed at the inlet. The inlet elevation should be 18 inches below the ground surface (i.e., below 12 inches of surface soil and 6 inches of dry well media).

4) An observation well should be installed to check for water levels, drawdown time, and evidence of clogging. A typical observation well consists of a slotted PVC well screen, 4 to 6 inches in diameter, capped with a lockable, above-ground lid.

Drainage

1) The bottom of infiltration bed must be native soil, over-excavated to at least one foot in depth and replaced uniformly without compaction. Amending the excavated soil with 2 to 4 inches (~15% to 30%) of coarse sand is recommended.

2) The hydraulic conductivity of the subsurface layers should be sufficient to ensure a maximum 12 hr drawdown time. An observation well should be incorporated to allow observation of drain time.

Emergency Overflow

1) There must be an overflow route for stormwater flows that overtop the facility or in case the infiltration facility becomes clogged.

2) The overflow channel must be able to safely convey flows from the peak design storm to the downstream stormwater conveyance system or other acceptable discharge point.

Vegetation

1) Drywells should be kept free of vegetation.

2) Trees and other large vegetation should be planted away from drywells such that drip lines do not overhang infiltration beds.

Maintenance Access

1) The facility and outlet structures must all be safely accessible during wet and dry weather conditions.

2) Maintenance access is required.

3) If the drywell becomes plugged and fails, then access is needed to excavate the facility to remove and replace the top layer and the filter bed media of the structure. To prevent damage and compaction, access must be able to accommodate a backhoe working at “arms length”.

Construction Considerations

To preserve and avoid the loss of infiltration capacity, the following construction guidelines should be specified:

1) The entire area draining to the facility must be stabilized before construction begins. If this is impossible, a diversion berm should be placed around the perimeter of the infiltration site to prevent sediment entering during construction.

2) Drywells should not be hydraulically connected to the stormwater conveyance system until all contributing tributary areas are stabilized as shown on the Contract Plans and to the satisfaction of the Engineer. Drywells should not be used as sediment control facilities.

3) Compaction of the subgrade with heavy equipment should be minimized to the maximum extent possible. If the use of heavy equipment on the base of the facility

cannot be avoided, the infiltration capacity should be restored by tilling or aerating prior to placing the infiltrative bed.

4) The exposed soils should be inspected by a civil engineer after excavation to confirm that soil conditions are suitable.

Operations and Maintenance

Drywell maintenance should be performed frequently to ensure that water infiltrates into the subsurface completely within the recommended infiltration time (or drain time if a drywell receives runoff from an underground pipe) of 72 hours or less after a storm.

Maintenance and regular inspections are important for the proper function of drywells. A specific maintenance plan shall be developed specifically for each facility outlining the schedule and scope of maintenance operations, documentation, and reporting requirements.

INF-5: Permeable Pavement

Permeable pavements contain small voids that allow water to pass through to a stone base. They come in a variety of forms; they may be a modular paving system (concrete pavers, grass-pave, or gravel-pave) or a poured-in-place solution (porous concrete or permeable asphalt). All permeable pavements with a stone reservoir base treat stormwater and remove sediments and metals to some degree. While conventional pavement result in increased rates and volumes of surface runoff, porous pavements when properly constructed and maintained, allow some of the stormwater to percolate through the pavement and enter the soil below. This facilitates groundwater recharge while providing the structural and functional features needed for the roadway, parking lot, or sidewalk. The paving surface, subgrade, and installation requirements of permeable pavements are more complex than those for conventional asphalt or concrete surfaces. For porous pavements to function properly over an expected life span of 15 to 20 years, they must be properly sited and carefully designed and installed, as well as periodically maintained. Failure to protect paved areas from construction-related sediment loads can result in their premature clogging and failure. Note that the 2011 TGM does not provide specific instructions on how to design and construct pavement.

Permeable pavement applications

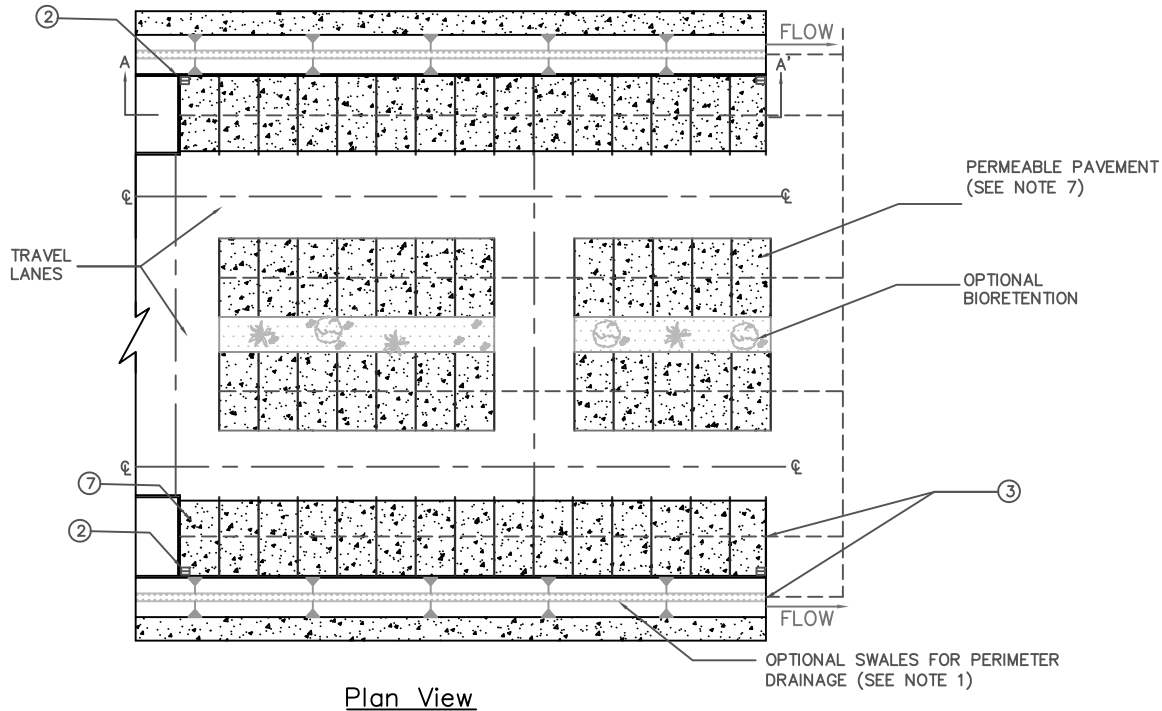
Photo Credits: 1. Geosyntec Consultants; 2. EPA Stormwater Manaaement

Application

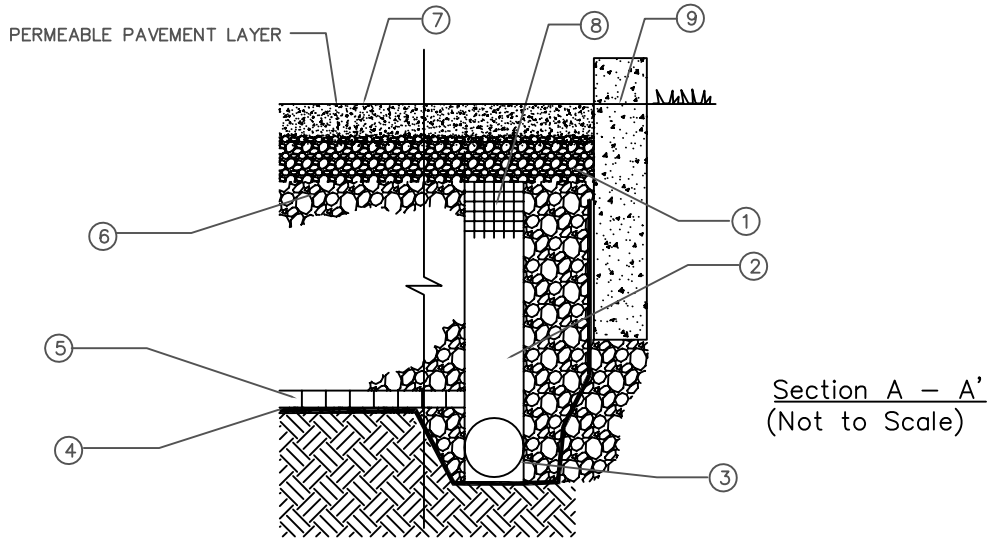
- Parking lots
- Driveways
- Sidewalks and walkways
- Outdoor athletic courts

Preventative Maintenance

- Trash removal
- Post-rain inspections
- Vacuum sweeping
- Vegetation inspection and removal



Plan View
(Not to Scale)



Section A – A'
(Not to Scale)

NOTES:

1. BEDDING COURSE SHALL BE 1½" TO 3" MIN THICKNESS (TYP NO. 8 AGGREGATE).
2. OPTIONAL OVERFLOW PIPE(S) SHALL BE PROVIDED IF OVERFLOWS ARE NOT MANAGED VIA PERIMETER DRAINAGE TO SWALES, BIORETENTION OR STORM WATER CONVEYANCE SYSTEM INLETS.
3. CONNECT OUTFALL PIPES TO DOWNSTREAM STORMWATER CONVEYANCE SYSTEM. OUTFALL PIPES SHALL BE SLOPED TOWARDS COLLECTION SYSTEM.
4. SOIL SUBGRADE SHALL HAVE ZERO SLOPE.
5. INSTALL GEOTEXTILE OR CHOKING LAYER ON BOTTOM & SIDES OF OPEN–GRADED BASE FOR FULL AND PARTIAL INFILTRATION, OR AN IMPERMEABLE LINER FOR NO INFILTRATION.
6. OPEN–GRADED BASE. THICKNESS AND GRADATION VARIES WITH DESIGN. TYP. NO. 57 AGGREGATE OR 4" THICK NO. 57 OVER NO. 2 STONE SUBASE. THICKNESS OF SUB–BASE VARIES WITH DESIGN.
7. PERMEABLE PAVEMENT INFILTRATIVE LAYER
8. OPTIONAL RIGID PLASTIC SCREEN FASTENED OVER OVERFLOW INLETS.
9. CURB/EDGE RESTRAINT WITH CUT–OUTS FOR OVERFLOW DRAINAGE TO PERIMETER BMPS, STORMWATER CONVEYANCE SYSTEM INLETS OR OPTIONAL OVERFLOW PIPES.
10. PARTIAL EXFILTRATION THROUGH THE SOIL. PERFORATED PIPES DRAIN EXCESS RUNOFF THAT CAN NOT BE ABSORBED BY SLOW–DRAINING SOIL.

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Figure 6-6: Permeable Pavement

Limitations

The following describes limitations for the use of permeable pavement.

- Native soil infiltration rate - permeability of soils at the BMP location must be at least 0.5 inches per hour.
- Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration trench and the seasonal high groundwater level or mounded groundwater level, bedrock, or other infiltration barrier to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.
- Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.
- Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback from building foundations at least eight feet or an alternative setback established by the geotechnical expert for the project.
- Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer, to ensure groundwater is protected for pollutants of concern.
- Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines the infiltration would be beneficial.
- High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at or near a service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas that have little chance of spill migration.
- High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.
- Permeable pavement cannot receive untreated stormwater runoff from other surfaces. Pretreatment of run-on from other surfaces is necessary to prevent premature failure that results from clogging with fine sediment.

- Permeable pavement cannot be used to treat runoff from portions of the site that are not stabilized.

Design Criteria

Permeable pavement should be designed according to the requirements listed in Table 6-11 and outlined in the section below.

Table 6-11: Permeable Pavements Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater Quality Design Volume (SQDV)	acre-feet	See Section 2 and Appendix E for calculating SQDV.
Pretreatment	-	Runoff from pervious areas should be minimized but, if provided, BIO-3: Vegetated Swale or BIO-4: Filter Strip should be provided for all runoff from offsite sources that are not directly adjacent to the permeable pavement.
Drawdown time of gravel drainage layer	hrs	12 - 72
Porous Pavement Infill		ASTM C-33 sand or equivalent
Minimum depth to bedrock	ft	2 (without underdrains)
Minimum depth to seasonal high water table	ft	2 (with underdrains); 10 (without underdrains)
Infiltration rate of subsoil	in/hr	1.0 (minimum without an underdrain)
Overflow device	-	Required

Geotechnical Considerations

An extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of infiltration facilities, due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration facility. See Appendix C for guidance on infiltration testing.

The project designer must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil engineer that sufficiently permeable soils exist onsite to allow the construction of a properly functioning infiltration facility.

1) Infiltration facilities require a minimum native soil infiltration rate of 0.5 inches/hour. If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated in an upstream BMP prior to infiltration to protect groundwater quality.

Pretreatment for removing coarse sediment present in runoff from the tributary area is required in all instances.

2) Groundwater separation must be at least 5 feet from the basin bottom to the measured season high groundwater elevation or estimated high groundwater mounding elevation. Groundwater levels measurements must be made during the time when the water level is expected to be at a maximum (i.e., toward the end of the wet season).

3) Sites with a slope greater than 25% (4:1) should be excluded. A geotechnical analysis and report addressing slope stability are required if located on slopes greater than 15%.

Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report should:

- State whether the site is suitable for the proposed permeable pavement;
- Recommend a design infiltration rate (see the Step 2 of sizing methodology section, "Determine the design percolation rate," in the Infiltration Basin fact sheet above);
- Identify the seasonal high depth to groundwater table surface elevation;
- Provide a good understanding of how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water; and
- If a geotechnical investigation and report are required, the report should:
  - Provide a written opinion by a professional civil engineer describing whether the infiltration trench will compromise slope stability; and
  - Identify potential impacts to nearby structural foundations.

Setbacks

1) Infiltration facilities shall be setback a minimum of 100 feet from proposed or existing potable wells, non-potable wells, septic drain fields, and springs.

2) Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

3) Infiltration BMPs must be setback from building foundations at least eight feet or have an alternative setback established by the geotechnical expert for the project.

Pretreatment

1) Depending on how and where permeable pavements will be used, pretreatment of the runoff entering the permeable pavement may be necessary. This is particularly important when the permeable pavement will be accepting run-on from pervious areas or areas that are not completely stabilized. If this is the case, then the run-on should be treated prior to contacting the permeable pavement. Without adequate pretreatment, the life of the permeable pavement may be significantly decreased.

2) If sheet flow is conveyed to the permeable pavement over stabilized grassed areas, the site must be graded in such a way that minimizes erosive conditions.

Sizing Criteria

Permeable pavement must be designed to meet Ventura County codes and/or applicable local permitting authority codes. These sizing criteria are meant to provide guidance for runoff volume storage only.

Step 1: Calculate the Design Volume

Infiltration facilities shall be sized to capture and infiltrate the SQDV volume (see Section 2 and Appendix E) with a 12 to 72 hour drawdown time (see Appendix D, Section D.2).

Step 2: Determine the Design Percolation Rate

The percolation rate will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the infiltration layer. Monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For infiltration trenches, the design percolation rate discussed here is the percolation rate of the underlying soils and not the percolation rate of the filter media bed (refer to the "Geometry and Sizing" section of INF-2 for the recommended composition of the filter media bed for infiltration trenches).

Considerations for Design Percolation Rate Corrections

Suitability assessment related considerations include (Table 6-12):

- Soil assessment methods – the site assessment extent (e.g., number of borings, test pits, etc.) and the measurement method used to estimate the short-term infiltration rate.

- Predominant soil texture/percent fines – soil texture and the percent of fines can greatly influence the potential for clogging.

- Site soil variability – site with spatially heterogeneous soils (vertically or horizontally) as determined from site investigations are more difficult to estimate

average properties resulting in a higher level of uncertainty associated with initial estimates.

- Depth to seasonal high groundwater/impervious layer – groundwater mounding may become an issue during excessively wet conditions where shallow aquifers or shallow clay lenses are present.

Table 6-12: Suitability Assessment Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Assessment methods	Use of soil survey maps or simple texture analysis to estimate short-term infiltration rates	Direct measurement of ≥ 20 percent of infiltration area with localized infiltration measurement methods (e.g., infiltrometer)	Direct measurement of ≥ 50 percent of infiltration area with localized infiltration measurement methods or Use of extensive test pit infiltration measurement methods
Ventura Hydrology Manual soil number (measured infiltration rate)	3 (f = 0.5 – 0.64)	4 or 5 (f = 0.65 – 0.91)	6 or 7 (f = 0.92 or higher)
Site soil variability	Highly variable soils indicated from site assessment or limited soil borings collected during site assessment	Soil borings/test pits indicate moderately homogeneous soils	Multiple soil borings/test pits indicate relatively homogeneous soils
Depth to groundwater/ impervious layer	<10 ft below facility bottom	10-30 ft below facility bottom	>30 below facility bottom

Localized infiltration testing refers to methods such as the double ring infiltrometer test (ASTM D3385-88) which measure infiltration rates over an area less than 10 sq-ft and do not attempt to account for soil heterogeneity. Extensive infiltration testing refers to methods that include excavating a significant portion of the proposed infiltration area, filling the excavation with water, and monitoring drawdown. In all cases, testing should be conducted in the area of the proposed BMP where, based on geotechnical data, soils appear least likely to support infiltration.

Design related considerations include (Table 6-13):

- Size of area tributary to facility – all things being equal, both physical and economic risk factors related to infiltration facilities increase with an increase in the tributary area served. Therefore facilities serving larger tributary areas should use more restrictive adjustment factors.

- Level of pretreatment/expected influent sediment loads – credit should be given for good pretreatment by allowing less restrictive factors to account for the reduced probability of clogging from high sediment loading. Also facilities designed to capture runoff from relatively clean surfaces such as rooftops are likely to see low sediment loads and therefore should be allowed to apply less restrictive safety factors.

- Redundancy – facilities that consist of multiple subsystems operating in parallel such that parts of the system remains functional when other parts fail and/or bypass should be rewarded for the built-in redundancy with less restrictive correction and safety factors. For example, if bypass flows would be at least partially treated in another BMP, the risk of discharging untreated runoff in the event of clogging the primary facility is reduced. A bioretention facility that overflows to a landscaped area is another example.

Compaction during construction – proper construction oversight is needed during construction to ensure that the bottom of the infiltration facility are not overly compacted. Facilities that do not commit to proper construction practices and oversight should have to use more restrictive correction and safety factors.

Table 6-13: Design Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Tributary area size	Greater than 10 acres.	Greater than 2 acres but less than 10 acres.	2 acres or less.
Level of pre-treatment/ expected influent sediment loads	Pre-treatment from gross solids removal devices only, such as hydrodynamic separators, racks and screens AND tributary area includes landscaped areas, steep slopes, high traffic areas, or any other areas expected to produce high sediment, trash, or debris loads.	Good pre-treatment with BMPs that mitigate coarse sediments such as vegetated swales AND influent sediment loads from the tributary area are expected to be relatively low (e.g., low traffic, mild slopes, disconnected impervious areas, etc.).	Excellent pre-treatment with BMPs that mitigate fine sediments such as bioretention or media filtration OR sedimentation or facility only treats runoff from relatively clean surfaces, such as rooftops.
Redundancy of treatment	No redundancy in BMP treatment train.	Medium redundancy, other BMPs available in treatment train to maintain at least 50% of function of facility in event of failure.	High redundancy, multiple components capable of operating independently and in parallel, maintaining at least 90% of facility functionality in event of failure.
Compaction during construction	Construction of facility on a compacted site or elevated probability of unintended/ indirect compaction.	Medium probability of unintended/ indirect compaction.	Heavy equipment actively prohibited from infiltration areas during construction and low probability of unintended/ indirect compaction.

Adjust the measured short-term infiltration rate using a weighted average of several safety factors, using the worksheet shown in Table 6-14 below. The design percolation rate would be determined as follows:

- For each consideration shown in Table 6-12 and Table 6-13 above, determine whether the consideration is a high, medium, or low concern.
- For all high concerns assign a factor value of 3, for medium concerns assign a factor value of 2, and for low concerns assign a factor value of 1.
- Multiply each of the factors by the corresponding weight to get a product.

- Sum the products within each factor category to obtain a safety factor for each.
- Multiply the two safety factors together to get the final combined safety factor. If the combined safety factor is less than 2, then use 2 as the safety factor.
- Divide the measured short term infiltration rate by the combined safety factor to obtain the adjusted design percolation rate for use in sizing the infiltration facility.

Table 6-14: Infiltration Facility Safety Factor Determination Worksheet

Factor Category		Factor Description	Assigned Weight (w)	Factor Value (v)	Product (p) p = w x v
A	Suitability Assessment	Soil assessment methods	0.25		
		Predominant soil texture	0.25		
		Site soil variability	0.25		
		Depth to groundwater / impervious layer	0.25		
		Suitability Assessment Safety Factor, $S_A = \Sigma p$			
B	Design	Tributary area size	0.25		
		Level of pre-treatment/ expected sediment loads	0.25		
		Redundancy	0.25		
		Compaction during construction	0.25		
		Design Safety Factor, $S_B = \Sigma p$			
Combined Safety Factor = S_A x S_B					

Note: The minimum combined adjustment factor shall not be less than 2.0 and the maximum combined adjustment factor shall not exceed 9.

Step 3: Determine the Gravel Drainage Layer Depth

Permeable pavement (including the base layers) should be designed to drain in less than 72 hours. The basis for this is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate sub soil oxygen levels for healthy soil biota, and to provide proper soil conditions for biodegradation and retention of pollutants.

1) Calculate the maximum depth of runoff (d_{max}) that can be infiltrated within the drawdown time:

$$d_{\max} = \frac{P_{design} \bullet t}{12} \qquad \text{(Equation 6-11)}$$

Where:

d_{max} = maximum depth that can be infiltrated (ft)

P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)
t	=	drawdown time (12-72 hours) (hr)

2) Select the gravel drainage layer depth, (l), such that:

$$d_{\max} \geq n \times l \qquad \text{(Equation 6-12)}$$

Where:

d_{max}	=	maximum depth that can be infiltrated (ft) (see 1) above)
n	=	gravel drainage layer porosity(unitless)(generally about 40% or 0.40 for gravel)
l	=	gravel drainage layer depth (ft)

Step 4: Determine infiltrating surface area

3) Calculate infiltrating surface area for permeable pavement (A):

$$A = \frac{SQDV}{\frac{TP_{design}}{12} + nl} \qquad \text{(Equation 6-13)}$$

Where:

P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)
n	=	gravel drainage layer porosity(unitless)[about 40% or 0.40 for gravel]
l	=	depth of gravel drainage layer (ft)
T	=	time to fill the gravel drainage layer with water (use 2 hours for most designs) (hr)

Geometry and Size

1) Permeable pavement shall be sized to capture and treat the stormwater quality design volume (SQDV).

2) Pavement design options include:

a. Full or partial infiltration – A design for full infiltration uses an open graded base for maximum infiltration and storage of stormwater. The water infiltrates directly into the base and through the soil. Pipes may provide drainage in overflow conditions. Partial infiltration does not rely completely on infiltration through the soil to dispose all of the captured runoff. Some of the water may infiltrate into the soil and the remainder drained by pipes.

b. No infiltration – No infiltration is desirable when the soil has low permeability and low strength, or there are other site limitations. An underdrain should be provided if the depth to bedrock is less than 2 feet or the depth to the water table is less than 10 feet. By storing water for a time in the base and then slowly releasing it through pipes, the design behaves like an underground detention pond. In other cases, the soil of the sub-base may be compacted and stabilized to render improved support for vehicular loads. This practice reduces infiltration into the soil to nearly zero. The "no infiltration" option requires the use of geotextile and bedding between the pavement and the open graded base.

3) If permeable pavement is located on a site with a slope greater than 2%, the permeable pavement area should be terraced to prevent lateral flow through the subsurface. Permeable pavement cannot be located on a site with a slope greater than 5%.

4) Porous pavement systems generally consist of at least four different layers of material:

a. The top or wearing layer consists of either asphalt or concrete with a greater than normal percentage of voids (typically 12 to 20 percent in the case of asphalt). The wearing layer may also be comprised of lattice-type pavers (either hollow concrete blocks or paving stones made from solid conventional concrete or stone), which are set in a bedding material (sand, pea-sized gravel or turf grass).

b. Below the wearing layer, a stone reservoir layer or a thick layer of aggregate (e.g., 2 inch stone) provides the bulk of the water storage capacity for a porous pavement system. In the pavement design, it is important to ensure that this reservoir layer retains its load bearing capacity under saturated conditions, because it may take several days for complete drainage to occur.

c. Typically, porous pavement designs include two (or more) transition layers that can be constructed from 1 to 2 inch diameter stone. One transition layer separates the top wearing layer from the underlying stone reservoir layer. Another transition layer is used to separate the stone reservoir from the undisturbed subgrade soil. Some designs also add a geotextile layer to this bottom layer or some combination of stones and geotextiles.

d. Porous asphalt pavement, for example, consists of open grade asphalt mixture ranging in depth from 2 to 4 inches with 16 percent voids. The thickness selected depends on bearing strength and pavement design requirements. This layer sits on a 2 to 4 inch transition layer located over a stone reservoir. The bottom layer completes the transition to the underlying undisturbed soil using a combination transition/filter fabric layer.

e. The depth of each layer should be determined by a licensed civil engineer based on analyses of the hydrology, hydraulics, and structural requirements of the site.

5) Modular paving stones are also used to create porous pavements. These pavements can be constructed in situ by pouring concrete into special frames or by using preformed blocks. The top layer of these porous pavements consists of conventional concrete, with the intervening void areas filled with either turf or sand. A transition or bedding layer is used to make the transition to the reservoir layer. These lattice-type pavers or hollow concrete blocks are often used in conjunction with turf grasses and are used in low-traffic parking lots, lanes, or driveways. Porous pavements using paving stones have similar construction, but can be designed to have a much higher load bearing capacity, and therefore have more widespread applicability. Construction guidelines and design specifications are available from the manufacturers of these products.

6) Permeable pavement (including the base layers) should be designed to drain in less than 72 hours. The basis for this is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate subsoil oxygen levels for healthy soil biota, and to provide proper soil conditions for biodegradation and retention of pollutants.

7) The percolation rate will decline as the surface becomes occluded and particulates accumulate in the infiltration layer. It is important that adequate conservatism is incorporated in the selection of design percolation rates.

Overflow

An overflow mechanism is required. Two options are provided:

Option 1: Perimeter control

Flows in excess of the design capacity of the permeable pavement system will require an overflow system connected to a downstream conveyance or other stormwater runoff BMP. In addition, if the pavement becomes clogged and infiltration decreases to the point that there is ponding, runoff will migrate off of the pavement via overland flow instead of infiltrating into the subsurface gravel layer. There are several options for handling overflow using perimeter controls such as:

1) Perimeter vegetated swale.

2) Perimeter bioretention.

3) Storm drain inlets.

4) Rock filled trench that funnels flow around pavement and into the subsurface gravel layer.

Option 2: Overflow pipe(s)

1) A vertical pipe should be connected to the underdrain.

2) The diameter, location, and quantity may vary with design and should be determined by a licensed civil engineer.

3) The pipe should be located away from vehicular traffic.

4) The piping system may incorporate an observational and/or cleanout well.

5) The top of the overflow pipe should be covered with a screen fastened over the overflow inlet.

Construction Considerations

1) Permeable pavement should be laid close to level and the bottom of the base layers must be level to ensure uniform infiltration.

2) Permeable pavement surfaces should not be used to store site materials, unless the surface is well protected from accidental spillage or other contamination.

3) To prevent/minimize soil compaction in the area of the permeable pavement installation, use light equipment with tracks or oversized tires.

4) Divert stormwater from the area as needed (before and during installation).

5) The pavement should be the last installation done at a development site. Landscaping should be completed and adjacent areas stabilized, before pavement installation to minimize the risk of clogging.

6) Vehicular traffic should be prohibited for at least 2 days after installation.

Operations and Maintenance

Permeable pavement mainly requires vacuuming and management of adjacent areas to limit sediment contamination and prevent clogging by fine sediment particles. Therefore, little special training is needed for maintenance crews. The following maintenance concerns and maintenance activities shall be considered and provided:

1) Trash tends to accumulate in paved areas, particularly in parking lots and along roadways. The need for litter removal should be determined through periodic inspection.

2) Regularly (e.g., monthly for a few months after initial installation, then quarterly) inspect pavement for pools of standing water after rain events, this could indicate surface clogging.

3) Actively (3 to 4 times per year, or more frequently depending onsite conditions) vacuum sweep the pavement to reduce the risk of clogging by frequently removing fine sediments before they can clog the pavement and subsurface layers. This also helps to prolong the functional period of the pavement.

4) Inspect for vegetation growth on pavement and remove when present.

5) Inspect for missing sand/gravel in spaces between pavers and replace as needed.

6) Activities that lead to ruts or depressions on the surface should be prevented or the integrity of the pavement should be restored by patching or repaving. Examples are vehicle tracks and utility maintenance.

7) Spot clogging of porous concrete may be remedied by drilling 0.5 inch holes every few feet in the concrete.

8) Interlocking pavers that are damaged should be replaced.

9) Maintain landscaped areas and reseed bare areas.

INF-6: Proprietary Infiltration

A number of vendors offer proprietary infiltration products that allow for similar or enhanced rates of infiltration and subsurface storage while offering durable prefrabricated structures. There are many varieties of proprietary infiltration BMPs.

Proprietary Infiltration BMPs

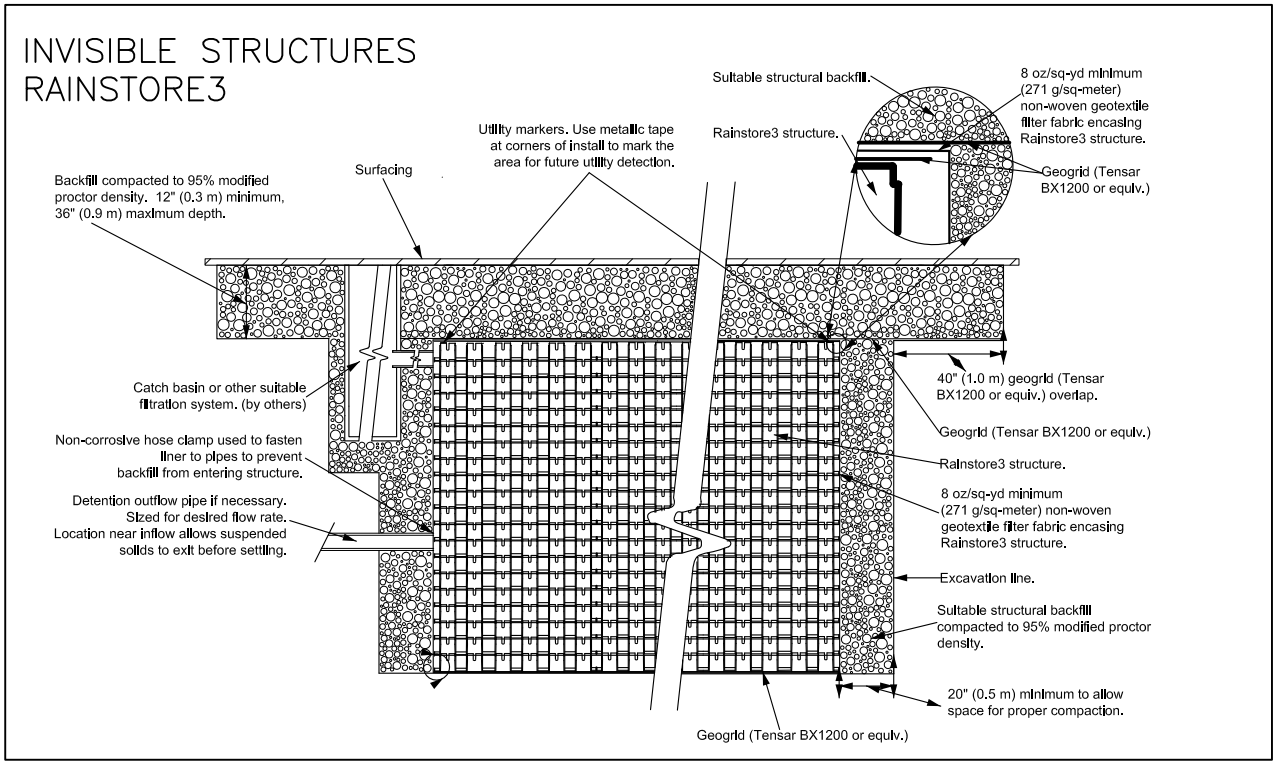
Photo Credits: 1. & 2. Contech Stormwater Solutions, Inc.

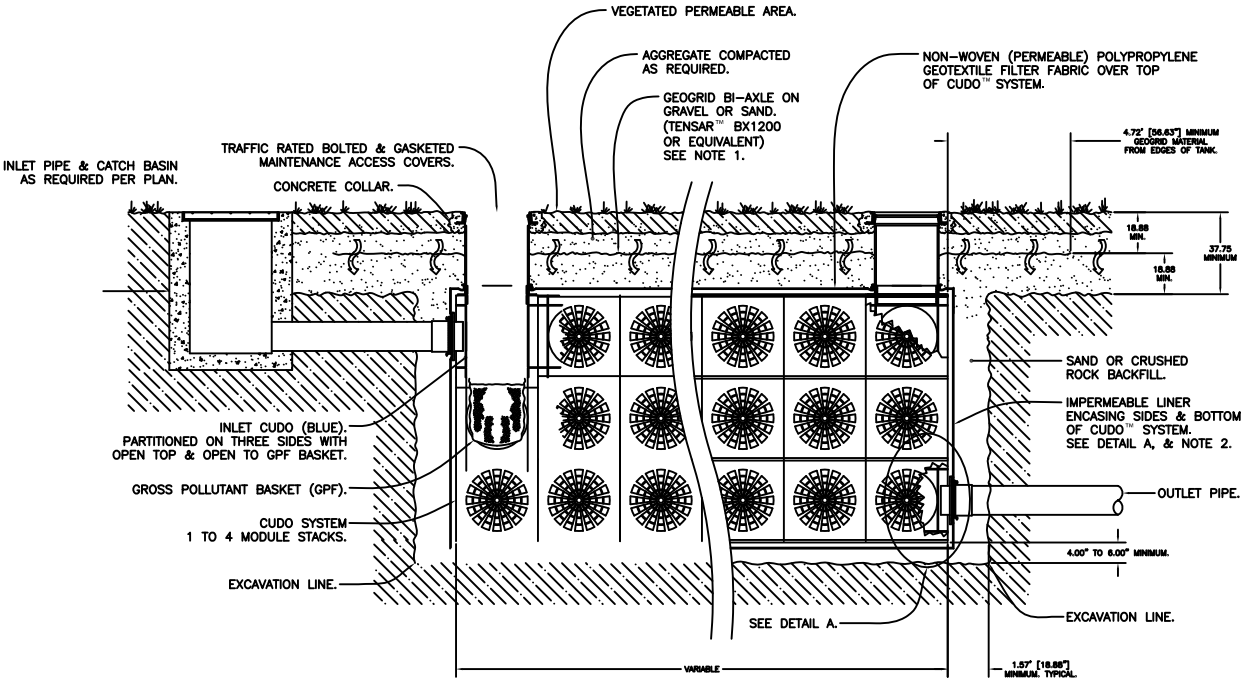
Application

- Mixed-use and commercial
- Roads and parking lots
- Parks and open spaces
- Single and multi-family residential

Routine Maintenance

- Removal trash, debris, and sediment at inlet and outlets
- Wet weather inspection to ensure drain time
- Inspect for mosquito breeding





SECTION / CUTAWAY VIEW
SCALE: NONE

CUDO Stormwater Products, Inc.
P.O. Box 497 Occidental, CA 95465
Ph. (877) 876-3345 Fax (707) 876-3346

Geosyntec consultants

Figure 6-7: Proprietary Infiltration BMPs

Limitations

The following limitations shall be considered before choosing to use an infiltration BMP:

- Native soil infiltration rate - soil permeability of the infiltration basin location must be at least 0.5 inches per hour.
- Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration basin and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.
- Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.
- Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields and springs. Infiltration BMPs must be setback from building foundations at least eight feet or have an alternative setback established by the geotechnical expert for the project.
- Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer, to ensure groundwater is protected for pollutants of concern.
- Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines the infiltration would be beneficial.
- High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at or near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration
- High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

Table 6-15: Proprietary Infiltration Manufacturer Websites

Device	Manufacturer	Website
A-2000™	Contech® Construction Products Inc.	www.contech-cpi.com/stormwater/13
ChamberMaxx™	Contech® Construction Products Inc.	www.contech-cpi.com/stormwater/13
CON/SPAN Vaults™	Contech® Construction Products Inc.	www.contech-cpi.com/stormwater/13
CON/Storm™	Contech® Construction Products Inc.	www.contech-cpi.com/stormwater/13
Perforated Corrugated Metal Pipe (CMP)	Contech® Construction Products Inc.	www.contech-cpi.com/stormwater/13
Drywell StormFilter	Contech® Construction Products Inc.	www.contech-cpi.com/stormwater/13
CUDO® Water Storage System	KriStar Enterprises Inc.	www.kristar.com
D-Raintank® Matrix Tank Modules	Atlantis®	www.atlantis-america.com
EcoRain™ Modular Rain Tank	EcoRain Systems Inc.	www.ecorain.com
Landmax®	Hancor®	www.hancor.com
Landsaver™	Hancor®	www.hancor.com
Precast Concrete Dry Well	Jensen Precast®	www.jensenprecast.com
Rainstore[3]	Invisible Structures Inc.	www.invisiblestructures.com
StormChambers™	Hydrologic Solutions, Inc.	www.hydrologicsolutions.com
Stormtech® SC-740 and SC-310 Chambers	StormTech LLC	www.stormtech.com
StormTrap®	StormTrap	www.stormtrap.com
Triton Chambers™	Triton Stormwater Solutions	www.tritonsws.com

Geotechnical Considerations

An extensive geotechnical site investigation must be undertaken early in the site planning process to verify site suitability for the installation of infiltration facilities, due to the potential to contaminate groundwater, cause slope instability, impact surrounding structures, and have insufficient infiltration capacity. Soil infiltration rates and the water table depth should be evaluated to ensure that conditions are satisfactory for proper operation of an infiltration facility. See Appendix C for guidance on infiltration testing.

The project designer must demonstrate through infiltration testing, soil logs, and the written opinion of a licensed civil engineer that sufficiently permeable soils exist onsite to allow the construction of a properly functioning infiltration facility.

1) Infiltration facilities require a minimum soil infiltration rate of 0.5 inches/hour. If infiltration rates exceed 2.4 inches/hour such that pollutant removal may not be adequate to protect groundwater quality, then the runoff should be fully treated in an upstream BMP prior to infiltration to protect groundwater quality. Pretreatment for coarse sediment removal is required in all instances.

2) Groundwater separation must be at least 5 feet from the basin bottom to the measured season high groundwater elevation or estimated high groundwater mounding elevation. Measurements of groundwater levels must be made during the time when water level is expected to be at a maximum (i.e., toward the end of the wet season).

3) Sites with a slope greater than 25% (4:1) should be excluded. A geotechnical analysis and report addressing slope stability are required if located on slopes greater than 15%.

Soil Assessment and Site Geotechnical Investigation Reports

The soil assessment report should:

- State whether the site is suitable for the proposed proprietary infiltration BMP.;
- Recommend a design infiltration rate (see the Step 2 of sizing methodology section, "Determine the design percolation rate," in the Infiltration Basin fact sheet above);
- Identify the seasonal high depth to groundwater table surface elevation;
- Provide a good understanding of how the stormwater runoff will move in the soil (horizontally or vertically) and if there are any geological conditions that could inhibit the movement of water; and
- If a geotechnical investigation and report are required, the report should:
  - Provide a written opinion by a professional civil engineer describing whether the infiltration trench will compromise slope stability; and
  - Identify potential impacts to nearby structural foundations.

Setbacks

1) Infiltration facilities shall be setback a minimum of 100 feet from proposed or existing potable wells, non-potable wells, septic drain fields, and springs.

2) Infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

3) Infiltration BMPs must be setback from building foundations at least eight feet or have an alternative setback established by the geotechnical expert for the project.

Pretreatment

Pretreatment is required for proprietary infiltration BMPs in order to reduce the sediment load entering the facility and maintain the infiltration rate of the facility. Pretreatment refers to design features that provide settling of sediment particles before runoff reaches a management practice. This eases the long-term maintenance burden and likelihood of failure. Pretreatment is important for most stormwater treatment BMPs, but it is particularly important for infiltration BMPs. To ensure that pretreatment mechanisms are effective, designers should incorporate sediment reduction practices. Sediment reduction BMPs may include vegetated swales, vegetated filter strips, sedimentation basins, sedimentation manholes and hydrodynamic separation devices. The use of at least two pretreatment devices is highly recommended for infiltration BMPs.

Sizing

1) Proprietary infiltration BMPs shall be sized to capture and treat the stormwater quality design volume (SQDV). See Section 2 and Appendix E for calculating for further detail.

2) The percolation rate will decline as the surface becomes occluded and particulates accumulate in the infiltrative layer. It is important that adequate conservatism is incorporated in the selection of design percolation rates.

3) For the sizing guidelines, refer to the manufacturer's website.

Operations and Maintenance

See vendor's website for maintenance requirements.

INF-7: Bioinfiltration

Bioinfiltration facilities are designed for partial infiltration of runoff and partial biotreatment. These facilities are similar to bioretention devices with underdrains, but the underdrain is raised above the gravel sump to facilitate infiltration. These facilities can be used in areas where there are no hazards associated with infiltration, but infiltration of the full DCV may not be feasible due to low infiltration rates (Soil Type 3) or high depths of fill. These facilities may not result in retention of the DCV but they can be used to meet the MEP standards.

Bioretention in Parkway and parking lots

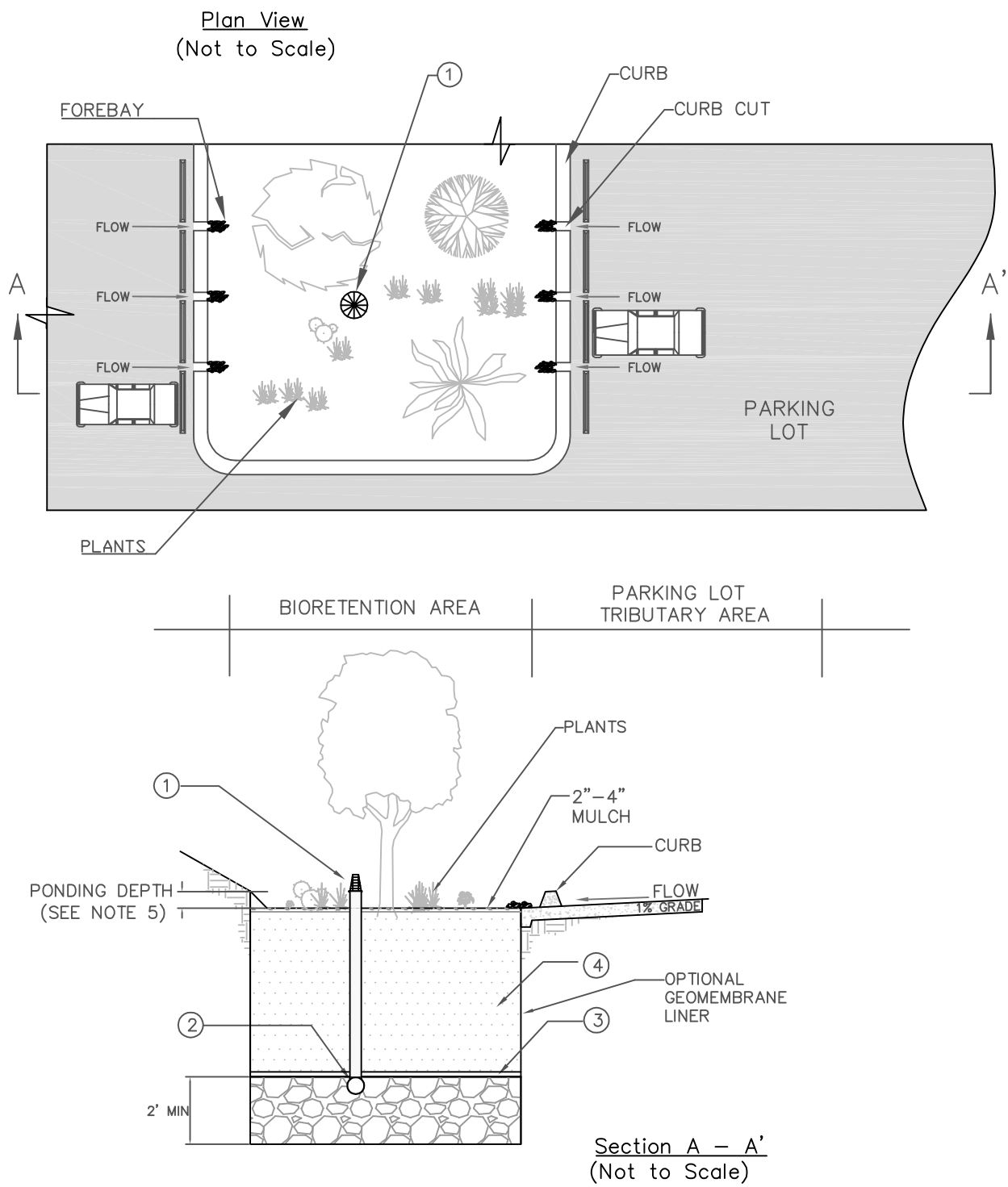
Photo Credits: Geosyntec Consultants

Application

- Commercial, residential, mixed use, institutional, and recreational uses
- Parking lot islands, traffic circles
- Road parkways & medians

Preventative Maintenance

- Repair small eroded areas
- Remove trash and debris and rake surface soils
- Remove accumulated fine sediments, dead leaves and trash
- Remove weeds and prune back excess plant growth
- Remove sediment and debris accumulation near inlet and outlet structures
- Periodically observe function under wet weather conditions



NOTES:

① OVERFLOW DEVICE: VERTICAL RISER OR EQUIVALENT.
② PERFORATED 6" MIN PVC PIPE UNDERDRAIN.
③ OPTIONAL CHOKING GRAVEL LAYER.
④ 2' MIN PLANTING MIX; 3' PREFERRED.
⑤ PONDING DEPTH 18" WITH FENCE; 6" WITHOUT FENCE.
⑥ 2' MIN GRAVEL LAYER DEPTH.

Geosyntec consultants

Figure 6-8: Bioinfiltration

Limitations

The following limitations should be considered before choosing to use bioinfiltration:

1) Native soil infiltration rate - soil permeability at the bioinfiltration location must be no less than 0.3 inches per hour.

2) Depth to groundwater, bedrock, or low permeability soil layer – 5 feet vertical separation is required between the bottom of the infiltration trench and the seasonal high groundwater level or mounded groundwater level, bedrock, or other barrier to infiltration to ensure that the facility will completely drain between storms and that infiltrating water will receive adequate treatment though the soils before it reaches the groundwater.

3) Slope stability - infiltration BMPs must be sited at least 50 feet away from slopes steeper than 15 percent or an alternative setback established by the geotechnical expert for the project.

4) Setbacks - a minimum setback (100 feet or more) must be provided between infiltration BMPs and potable wells, non-potable wells, drain fields, and springs. Infiltration BMPs must be setback from building foundations at least eight feet or have an alternative setback established by the geotechnical expert for the project.

5) Groundwater contamination - the application of infiltration BMPs should include significant pretreatment in an area identified as an unconfined aquifer to ensure groundwater is protected for pollutants of concern.

6) Contaminated soils or groundwater plumes - infiltration BMPs are not allowed at locations with contaminated soils or groundwater where the pollutants could be mobilized or exacerbated by infiltration, unless a site-specific analysis determines that infiltration would be beneficial.

7) High pollutant land uses - infiltration BMPs should not be placed in high-risk areas such as at or near service/gas stations, truck stops, and heavy industrial sites due to the groundwater contamination risk unless a site-specific evaluation demonstrates that sufficient pretreatment is provided to address pollutants of concern, high risks areas are isolated from stormwater runoff, or infiltration areas have little chance of spill migration.

8) High sediment loading rates – infiltration BMPs may clog quickly if sediment loads are high (e.g., unstabilized site) or if flows are not adequately pretreated.

9) Vertical relief and proximity to storm drain - site must have adequate relief between the land surface and storm drain to permit vertical percolation through the soil media and collection.

Design Criteria

Bioinfiltration should be designed according to the requirements listed in Table 6-16 and outlined in the section below.

Table 6-16: Bioretention Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix E for calculating SQDV.
Forebay	-	Forebay should be provided for all tributary surfaces that contain landscaped areas. Forebays should be designed to prevent standing water during dry weather and should be planted with a plant palette that is tolerant of wet conditions.
Maximum drawdown time of water ponded on surface	hours	48
Maximum drawdown time of surface ponding plus subsurface pores	hours	96 (72 preferred)
Maximum ponding depth	inches	18
Minimum thickness of amended soil	feet	2 (3 preferred)
Minimum thickness of stabilized mulch	inches	2 to 4
Planting mix composition	-	60 to 80% fine sand, 20 to 40% compost
Underdrain sizing	-	Underdrain should be installed below the choking stone; 6 inch minimum diameter; 0.5% minimum slope; slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent); spacing shall be determined to provide capacity for maximum rate filtered through amended media
Minimum thickness of gravel layer	feet	2
Overflow device	-	Required

Sizing Criteria

Bioinfiltration facilities can be sized using one of two methods: a simple sizing method or a routing modeling method. With either method the SQDV volume must be completely infiltrated within 96 hours (including subsurface pore space), and surface ponding must be infiltrated within 48 hours. The simple sizing procedure is provided below. For the routing modeling method, refer to TCM-4 Sand Filters.

Step 1: Calculate the Design Volume

Bioinfiltration facilities shall be sized to capture and partially infiltrate and partially biotreat the SQDV volume (see Section 2.3 and Appendix E).

Step 2: Determine the Design Percolation Rate

The percolation rate through the BMP and to the subsurface will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the infiltration layer. Monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For bioinfiltration facilities, the design percolation rate discussed here is the adjusted percolation rate of the underlying soils and not the percolation rate of the filter media bed. The measured short-term infiltration rate should be adjusted using a factor of safety of 2.0.

Step 3: Calculate the surface area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus the void spaces in the media, based on the computed porosity of the filter media and optional aggregate layer.

1) Determine the maximum depth of surface ponding that can be infiltrated within the required surface drain time (48 hr), (d_{max}), as follows:

$$d_{\max} = \frac{P_{design} \times t_{ponding}}{12\frac{in}{ft}} \qquad \text{(Equation 6-14)}$$

Where:

$t_{ponding}$	=	required drain time of surface ponding (48 hrs)
P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)

d_{max} = the maximum depth of surface ponding water that can be infiltrated within the required drain time (ft), calculated using Equation 6-14

2) Choose surface ponding depth (d_p) such that:

$$d_p \leq d_{\max} \qquad \text{(Equation 6-15)}$$

Where:

d_p = selected surface ponding depth (ft)

d_{max} = the maximum depth of water that can be infiltrated within the required drain time (ft)

Choose thickness(es) of amended media and aggregate layer(s) and calculate total effective storage depth of the bioinfiltration area ($d_{effective}$), as follows:

$$d_{effective} \leq (d_p + n^*_{media} l_{media} + n_{gravel} l_{gravel}) \qquad \text{(Equation 6-16)}$$

Where:

$d_{effective}$ = total equivalent depth of water stored in bioinfiltration area (ft), including surface ponding and volume available in pore spaces of media and gravel layers

d_p = surface ponding depth (ft), chosen using Equation 6=15

n^*_{media} = available porosity of amended soil media (ft/ft), approximately 0.25 ft/ft accounting for antecedent moisture conditions. This represents the volume of available pore space as a fraction of the total soil volume; sometimes has units of (ft^3/ft^3) or described as a percentage.

l_{media} = thickness of amended soil media layer (ft), minimum 2 ft

n_{gravel} = porosity of gravel layer (ft/ft), approximately 0.40 ft/ft

l_{gravel} = thickness of gravel layer (ft), minimum 2 ft

3) Check that entire effective depth (surface plus subsurface storage), $d_{effective}$, infiltrates in no greater than 96 hours as follows:

$$t_{total} = \frac{d_{effective}}{P_{design}} \times 12 \frac{in}{ft} \leq 96\ hr \qquad \text{(Equation 6-17)}$$

Where:

$d_{effective}$ = total equivalent depth of water stored in bioinfiltration area (ft), calculated using Equation 6-16

P_{design} = design percolation rate of underlying soils (in/hr) (see Step 2, above)

If $t_{total} > 96$ hrs, then reduce surface ponding depth and/or amended media thickness and/or gravel thickness and return to 1).

If $t_{total} \leq 96$ hrs, then proceed to 5).

4) Calculate required infiltrating surface area, (A_{req}):

$$A_{req} = \frac{SQDV}{d_{effective}} \qquad \text{(Equation 6-18)}$$

Where:

A_{req} = required infiltrating area (ft^2). Should be calculated at the contour corresponding to the mid ponding depth (i.e., $0.5 \times d_p$ from the bottom of the facility).

$SQDV$ = stormwater quality design volume (ft^3)

$d_{effective}$ = total equivalent depth of water stored in bioinfiltration area (ft), calculated using Equation 6-16

5) Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is calculated at the contour corresponding to the mid ponding depth (i.e., $0.5 \times d_p$ from the bottom of the facility).

Geometry

1) Minimum planting soil depth should be 2 feet, although 3 feet is preferred.

   The intention is that the minimum planting soil depth should provide a beneficial root zone for the chosen plant palette and adequate water storage for the stormwater quality design volume. A deeper soil depth will provide a smaller surface area footprint.

2) Minimum gravel layer depth is 2 feet.

The intention is that the gravel sump provides partial retention of captured water.

3) Bioinfiltration should be designed to drain below the planting soil in less than 48 hours and completely drain from the gravel layer in 96 hours (both starting from the end of inflow).

   The intention is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and to provide proper soil conditions for biodegradation and retention of pollutants.

Flow Entrance and Energy Dissipation

The following types of flow entrance can be used for bioinfiltration cells:

1) Dispersed, low velocity flow across a landscape area. Dispersed flow may not be possible given space limitations or if the facility is controlling roadway or parking lot flows where curbs are mandatory.

2) Dispersed flow across pavement or gravel and past wheel stops for parking areas.

3) Curb cuts for roadside or parking lot areas: curb cuts should include rock or other erosion protection material in the channel entrance to dissipate energy. Flow entrance should drop 2 to 3 inches from curb line and it should provide a settling area and periodic sediment removal of coarse material before flow dissipates to the remainder of the cell.

4) Pipe flow entrance: Piped entrances, such as roof downspouts, should include rock, splash blocks, or other appropriate measures at the entrance to dissipate energy and disperse flows.

Woody plants (trees, shrubs, etc.) can restrict or concentrate flows and can be damaged by erosion around the root ball and should not be placed directly in the entrance flow path.

Underdrains

Underdrains should meet the following criteria:

1) 6-inch minimum diameter.

2) Underdrains should be made of slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent). *The intention is that compared to round-hole perforated pipe, slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.*

3) Slotted pipe should have 2 to 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inches and should have a length of 1 to 1.25 inches. Slots should be longitudinally spaced such that the pipe has a minimum of one square inch of slot per lineal foot of pipe and should be placed with slots facing the bottom of the pipe.

4) Underdrains should be sloped at a minimum of 0.5%.

5) Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter should be connected to the underdrain every 100 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts should be connected to the perforated underdrain with the appropriate manufactured connections. The wells/cleanouts should extend 6 inches above the top elevation of the bioinfiltration facility mulch, and should be capped with a lockable screw cap. The ends of the underdrain pipes not terminating in an observation well/cleanout should also be capped.

Gravel Layer

1) The following aggregate should be used for the gravel layer below the underdrain pipe. Place the underdrain below the choking stone, within the top 6 inches of the gravel layer.

Sieve size	Percent Passing
¾ inch	100
¼ inch	30-60
US No. 8	20-50
US No. 50	3-12
US No. 200	0-1

2) At the option of the designer/geotechnical engineer, a geotextile fabric may be placed between the planting media and the gravel layer. If a geotextile fabric is used, it should meet a minimum permittivity rate of 75 gal/min/ft^2, should not impede the infiltration rate of the soil medium, and should meet the following minimum materials requirements.

Geotextile Property	Value	Test Method
Trapezoidal Tear (lbs)	40 (min)	ASTM D4533
Permeability (cm/sec)	0.2 (min)	ASTM D4491
AOS (sieve size)	#60 - #70 (min)	ASTM D4751
Ultraviolet resistance	70% or greater	ASTM D4355

Preferably, aggregate (choking stone) should be used in place of filter fabric to reduce the potential for clogging. This aggregate layer should consist of 2 to 4 inches

of washed sand underlain with 2 inches of choking stone (Typically #8 or #89 washed).

3) Bioinfiltration facilities have the added benefit of enhanced nitrogen removal due to the elevated underdrain. This allows for a fluctuating anaerobic/aerobic zone below the drain pipe. *The intention is that denitrification within the anaerobic/anoxic zone is facilitated by microbes using forms of nitrogen (NO_2 and NO_3) instead of oxygen for respiration.*

4) The underdrain should drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to another bioinfiltration cell as part of a connected treatment system, to a storm drain, daylight to a vegetated dispersion area using an effective flow dispersion device, or to a storage facility for harvesting.

Overflow

An overflow device is required at the 18-inch ponding depth. The following, or equivalent should be provided:

1) A vertical PVC pipe (SDR 35) to act as an overflow riser.

2) The overflow riser(s) should be 6 inches or greater in diameter, so it can be cleaned without damage to the pipe.

The inlet to the riser should be at the ponding depth (18 inches for fenced bioinfiltration areas and 6 inches for areas that are not fenced), and be capped with a spider cap to exclude floating mulch and debris. Spider caps should be screwed in or glued, i.e., not removable.

Hydraulic Restriction Layers

Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mils.

Planting/Storage Media

1) The planting media placed in the cell should achieve a long-term, in-place infiltration rate of at least 1 inch per hour. Higher infiltration rates are permissible. If the design long-term, in-place infiltration rate of the soil exceeds 12 inches per hour, documentation should be provided to demonstrate that the media will adequately address pollutants of concern at a higher flowrate. Bioinfiltration soil shall also support vigorous plant growth.

2) Planting media should consist of 60 to 80% fine sand and 20 to 40% compost.

3) Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size should be non-plastic. Sand for bioinfiltration should be analyzed by an accredited lab using #200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation (Note: all sands complying with ASTM C33 for fine aggregate comply with the gradation requirements below):

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

Note: the gradation of the sand component of the media is believed to be a major factor in the hydraulic conductivity of the media mix. If the desired hydraulic conductivity of the media cannot be achieved within the specified proportions of sand and compost (#2), then it may be necessary to utilize sand at the coarser end of the range specified in above ("minimum" column).

4) Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.
- Organic matter: 35-75% dry weight basis.
- Carbon and Nitrogen Ratio: 15:1 < C:N < 25:1
- Maturity/Stability: shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 F) upon delivery or rewetting is not acceptable.

- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
  - NH4:NH3 < 3
  - Ammonium < 500 ppm, dry weight basis
  - Seed Germination > 80% of control
  - Plant trials > 80% of control
  - e. Solvita® > 5 index value
- Nutrient content:
  - Total Nitrogen content 0.9% or above preferred
  - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm
- pH between 6.5 and 8 (may vary with plant palette)

Compost for bioinfiltration should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1 inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	2	10

Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested.

Note: the gradation of compost used in bioinfiltration media is believed to play an important role in the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range ("minimum" column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity.

In addition, a coarser compost mix provides more heterogeneity of the bioinfiltration media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

5) The bioinfiltration area should be covered with 2 to 4 inches (average 3 inches) of mulch at the start and an additional placement of 1 to 2 inches of mulch should be added annually. *The intention is that to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity*.

Planting/Storage Media Design for Nutrient Sensitive Receiving Waters

1) Where the BMP discharges to receiving waters with nutrient impairments or nutrient TMDLs, the planting media placed in the cell should be designed with the specific goal of minimizing the potential for initial and long term leaching of nutrients from the media.

2) In general, the potential for leaching of nutrients can be minimized by:

    a. Utilizing stable, aged compost (as required of media mixes under all conditions).

    b. Utilizing other sources of organic matter, as appropriate, that are safe, non-toxic, and have lower potential for nutrient leaching than compost.

    c. Reducing the content of compost or other organic material in the media mix to the minimum amount necessary to support vigorous plant growth and healthy biological processes.

3) A landscape architect should be consulted to assist in the design of planting/storage media to balance the interests of plant establishment, water retention capacity (irrigation demand), and the potential for nutrient leaching. The following practices should be considered in developing the media mix design:

    a. The actual nutrient content and organic content of the selected compost source should be considered when specifying the proportions of compost and sand. The compost specification allows a range of organic content over approximately a factor of 2 and nutrient content may vary more widely. Therefore determining the actual organic content and nutrient content of the compost expected to be supplied is important in determining the proportion to be used for amendment.

    b. A commitment to periodic soil testing for nutrient content and a commitment to adaptive management of nutrient levels can help reduce the amount of organic amendment that must be provided initially. Generally, nutrients can be added planting areas through the addition of organic mulch, but cannot be removed.

    c. Plant palettes and the associated planting mix should be designed with native plants where possible. Native plants generally have a broader tolerance for nutrient content, and can be longer lived in leaner/lower nutrient soils. An additional benefit of lower nutrient levels is that native plants will generally have less competition from weeds.

d. Nutrients are better retained in soils with higher cation exchange capacity (CEC). CEC can be increased through selection of organic material with naturally high CEC, such as peat, and/or selection of inorganic material with high CEC such as some sands or engineered minerals (e.g., low P-index sands, zeolites, rhyolites, etc). Including higher CEC materials would tend to reduce the net leaching of nutrients.

e. Soil structure can be more important than nutrient content in plant survival and biologic health of the system. If a good soil structure can be created with very low amounts of compost, plants survivability should still be provided. Soil structure is loosely defined as the ability of the soil to conduct and store water and nutrients as well as the degree of aeration of the soil. While soil structure generally develops with time, planting/storage media can be designed to promote earlier development of soil structure. Soil structure is enhanced by the use of amendments with high hummus content (as found in well-aged organic material). In addition, soil structure can be enhanced through the use of compost/organic material with a distribution of particle sizes (i.e., a more heterogeneous mix). Finally, inorganic amendments such as polymer beads may be useful for promoting aeration and moisture retention associated with a good soil structure. An example of engineered soil to promote soil structure can be found here:

http://www.hort.cornell.edu/uhi/outreach/pdfs/custructuralsoilwebpdf.pdf

f. Younger plants are generally more tolerant of lower nutrient levels and tend to help develop soil structure as they grow. Starting plants from smaller transplants can help reduce the need for organic amendments and improve soil structure. The project should be able to accept a plant mortality rate that is somewhat higher than starting from larger plants and providing high organic content.

g. With these considerations, it is anticipated that less than 10 percent compost amendment could be used, while still balancing plant survivability and water retention.

Plants

1) Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 96 hours.

2) It is recommended that a minimum of three types of tree, shrubs, and/or herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species.

3) Native plant species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent practicable.

Operations and Maintenance

Bioinfiltration areas require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, bioinfiltration maintenance requirements are typical landscape care procedures and include:

1) Watering: Plants should be drought-tolerant. Watering may be required during prolonged dry periods after plants are established.

2) Erosion control: Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred (see Appendix I for a bioinfiltration inspection and maintenance checklist). Properly designed facilities with appropriate flow velocities should not have erosion problems, except perhaps in extreme events. If erosion problems occur, the following should be reassessed: (1) flow velocities and gradients within the cell, and (2) flow dissipation and erosion protection strategies in the pretreatment area and flow entrance. If sediment is deposited in the bioinfiltration area, immediately determine the source within the contributing area, stabilize, and remove excess surface deposits.

3) Plant material: Depending on aesthetic requirements, occasional pruning and removing of dead plant material may be necessary. Replace all dead plants and if specific plants have a high mortality rate, assess the cause and, if necessary, replace with more appropriate species. Periodic weeding is necessary until plants are established. The weeding schedule should become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants excluded.

4) Nutrients and pesticides: The soil mix and plants should be selected for optimum fertility, plant establishment, and growth. Nutrient and pesticide inputs should not be required and may degrade the pollutant processing capability of the bioinfiltration area, as well as contribute pollutant loads to receiving waters. By design, bioinfiltration facilities are located in areas where phosphorous and nitrogen levels are often elevated and these should not be limiting nutrients. If in question, have soil analyzed for fertility.

5) Mulch: Replace mulch annually in bioinfiltration facilities where heavy metal deposition is likely (e.g., contributing areas that include industrial and auto dealer/repair parking lots and roads). In residential lots or other areas where metal deposition is not a concern, replace or add mulch as needed to maintain a 2 to 3 inch depth at least once every two years.

6) Soil: Soil mixes for bioinfiltration facilities are designed to maintain long-term fertility and pollutant processing capability. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental

concern for at least 20 years in bioinfiltration systems. Replacing mulch in bioinfiltration facilities where heavy metal deposition is likely provides an additional level of protection for prolonged performance. If in question, have soil analyzed for fertility and pollutant levels.

RWH-1: Rainwater Harvesting

Rainwater harvesting BMPs capture and store stormwater runoff for later use. These BMPs are engineered to store a specified volume of water with no surface discharge until this volume is exceeded. Storage facilities that can be used to harvest rainwater include cisterns (above ground tanks), open storage reservoirs (e.g., ponds and lakes), and underground storage devices (tanks, vaults, pipes, arch spans, and proprietary storage systems). Uses of captured water may potentially include irrigation demand, indoor non-potable demand, industrial process water demand, or other demands. Rainwater harvesting systems typically include several components: (1) methods to divert runoff to the storage device, (2) an overflow for when the storage device is full, and (3) a distribution system to get the water to where it is intended to be used. Harvesting systems typically include pretreatment to remove large sediment and vegetative debris. Systems used for internal uses may require an additional level of treatment prior to use.

Cistern

Photo Credit: MetaEfficient

Application

- Any type of land use, provided adequate water demand

Preventative Maintenance

- Debris and sediment removal
- After-rain inspections

Limitations

Rainwater harvesting may be used to meet all of the 5% EIA requirement if reliable demand is available. Rainwater harvesting is not required to be used if the available demands do not meet the volume required for 80% capture using a 72 hour drawdown time.

Design Criteria

Specific considerations for cistern rainwater harvesting systems include:

- Cisterns should include screens on gutters and downspouts to remove vegetative debris and sediment from the runoff prior to entering the cistern.
- Above-ground cisterns should be secured in place.
- Above-ground cisterns should not be located on uneven or sloped surfaces; if installed on a sloped surface, the base where the cistern will be installed should be leveled and designed for the weight of the filled cistern prior to installation.
- Child-resistant covers and mosquito screens should be placed on all water entry holes.
- A first flush diverter may be installed so that initial runoff bypasses the cistern. Where a first flush diverter is used, the diverted flows must be directed to a pervious area so that no runoff is produced or another form of treatment must be provided for this flow.
- Above-ground cisterns should be installed in a location with easy access for maintenance or replacement.

Specific considerations for underground detention include:

- Access entry covers (36” diameter minimum) should be locking and within 50 feet of all areas of the detention tank.
- In cases where the detention facility provides sediment containment, the facility should be laid flat and there should be at least ½ foot of dead storage within the tank or vault.
- Outlet structures should be designed using the 100-year storm as overflow and should be easily accessible for maintenance activities.
- For detention facilities beneath roads and parking areas, structural requirements should meet H20 load requirements.
- In cases where groundwater may cause flotation, these forces should be counteracted with backfill, anchors, or other measures.

- Underground detention facilities should be installed on consolidated and stable native soil; if the facility is constructed in fill slopes, a geotechnical analysis should be performed to ensure stability.

General considerations include:

- In cases where there is non-potable indoor demand, proper pretreatment measures should be installed such as pre-filtration, cartridge filtration, and/or disinfection (which can also be provided between the cistern and point of use).
- Plumbing systems should be installed in accordance with the current California Building and Plumbing Codes (CBC – part of California Code of Regulations, Title 24).
- Underground detention facilities can be incorporated into a treatment train to provide initial or supplemental storage to other detention storage facilities and/or infiltration BMPs.
- Treatment of the captured rainwater (i.e. disinfection) may be required depending on the end use of the water.

Rainwater harvesting uses include:

- Harvested rainwater can be used for irrigation and other non-potable uses (if local, State, and Federal ordinances allow). The use of captured stormwater allows a reduced demand on the potable water supply. Cross-contamination should be prevented when make-up water is required for rainwater use demand by providing a backflow prevention system on the potable water supply line and/or an air gap.
- Irrigation Use
  - Subsurface (or drip) irrigation should not require disinfection pretreatment prior to use; other irrigation types, such as spray irrigation, may require additional pre-treatment prior to use
  - Selecting native and/or drought tolerant plants for landscaped area will reduce irrigation demand; however, they are still recommended for use.
- Domestic Use
  - Domestic uses may include toilet flushing and clothes washing (if local, State, and Federal ordinances allow).
  - Pretreatment requirements per local, State, or Federal codes and ordinances may apply.
- Other Non-Potable Uses

- Other potential non-potable uses may include vehicle/equipment washing, evaporative cooling, industrial processes, and dilution water for recycled water systems.

Sizing Criteria

The effectiveness of rainwater harvesting (RWH) systems is a function of tributary area, storage volume, demand patterns and magnitudes, and operational regime. If either of the latter two factors are too complex, simple design criteria metrics are not possible. The rainwater harvesting design criteria provided in this Fact Sheet are intended for the evaluation of systems that have relatively simple demand regimes and passive operation. If the answer to any of the following complexity screening questions is yes, a site-specific evaluation of rainwater harvesting effectiveness should be completed using a continuous simulation model with a long-term precipitation record.

Complexity Screening Questions:

- Does the proposed system have seasonally-varying demand other than irrigation?
- Will the system be operated by advanced control systems or otherwise actively controlled?
- Does the operational regime call for the system be shut down at any time during the rainy season?

Effectiveness of a harvesting system for retaining the SQDV depends on the cistern's effective storage capacity (i.e., the volume available for storage at the beginning of each event). Therefore, the required storage volume varies based on precipitation and demand. Using the following sizing charts, cisterns should be sized to achieve 80 percent capture efficiency. These nomographs are based on continuous simulation performed in EPA SWMM using precipitation and ET records representative of lowland regions (Oxnard Airport Precipitation Gauge, El Rio Spreading Grounds ET station) and mountainous regions (Ojai-Stewart Canyon Precipitation Gauge, Matilja ET Station) of the County.

Instructions for determining required cistern volume and demand are provided below:

Step 1: Determine Required Rainwater Harvesting Design Volume (RWHDV)

Note that a rainwater harvesting system sized for 80% capture runoff (as determined by continuous modeling), which can draw down in 72 hours is required to meet the 5% EIA standard. If the demand required to draw a tank sized for these parameters is not available, rainwater harvesting is not mandated for use. Partial capture of runoff is allowable if rainwater harvesting is desired for use. Sizing instructions for partial capture are included in Step 3.

1) Determine the design storm required for 80% capture with a 72 hour drawdown time by selecting the project region (lowland or mountainous), then determining where the 72 hour drawdown curve intersects the 80% capture line. Pivot down from this intersection to the x axis to read the design storm, d_{design}.

2) Determine the required rainwater harvesting system volume using the following equation:

$$RWHDV = C*(d_{design}/12)*A_{retain} \qquad \text{(Equation 6-19)}$$

Where:

RWHDV	=	rainwater harvesting design volume (acre-ft)
C	=	runoff coefficient, calculated using Appendix E and the site imperviousness
d_{design}	=	design storm required for 80% capture with a 72 hour drawdown time, estimated as described in 1) (inches)
A_{retain}	=	the drainage area from which runoff must be retained (acres)

Step 2: Determine the Required Daily Demand to Achieve 80% Capture

1) The required daily demand to achieve 80% capture of runoff can be calculated as follows:

$$Demand = [RWHDV/(72/24)] * (325{,}851) \qquad \text{(Equation 6-20)}$$

Where:

Demand	=	required project daily demand to draw down rainwater harvesting system sized for 80% capture in 72 hours (gallons)
RWHDV	=	rainwater harvesting design volume (acre-ft), from Step 1 above

If the project daily demand is less than the Demand calculated, the project is not required to utilize rainwater harvesting. If rainwater harvesting is desired for use for partial retention, if a longer drawdown time is desired, or if a predetermined daily demand is to be used, refer to Steps 3 and 4 below.

Step 3: Determine RWHDV for Partial Retention or a Longer Drawdown Time

1) Calculate RWHDV for selected combination of % capture and drawdown time using nomographs and the following equation:

$$RWHDV = C*(d_{design}/12)*A_{retain} \quad \text{(Equation 6-21)}$$

Where:

RWHDV	=	rainwater harvesting design volume (acre-ft)
C	=	runoff coefficient, calculated using Appendix E and the site imperviousness
d_{design}	=	design storm required for selected % capture and drawdown time (inches)
A_{retain}	=	the drainage area from which runoff must be retained (acres)

2) Determine the required daily demand for the selected capture efficiency and/or drawdown time:

$$Demand = [RWHDV/(t_{drawdown}/24)] * (325{,}851) \quad \text{(Equation 6-22)}$$

Where:

Demand	=	required project daily demand to draw down rainwater harvesting system sized for 80% capture in 72 hours (gallons)
RWHDV	=	rainwater harvesting design volume (acre-ft), from 1) above
$t_{drawdown}$	=	selected drawdown time (hours)

Step 4: Determine RWHDV for a Predetermined Daily Demand

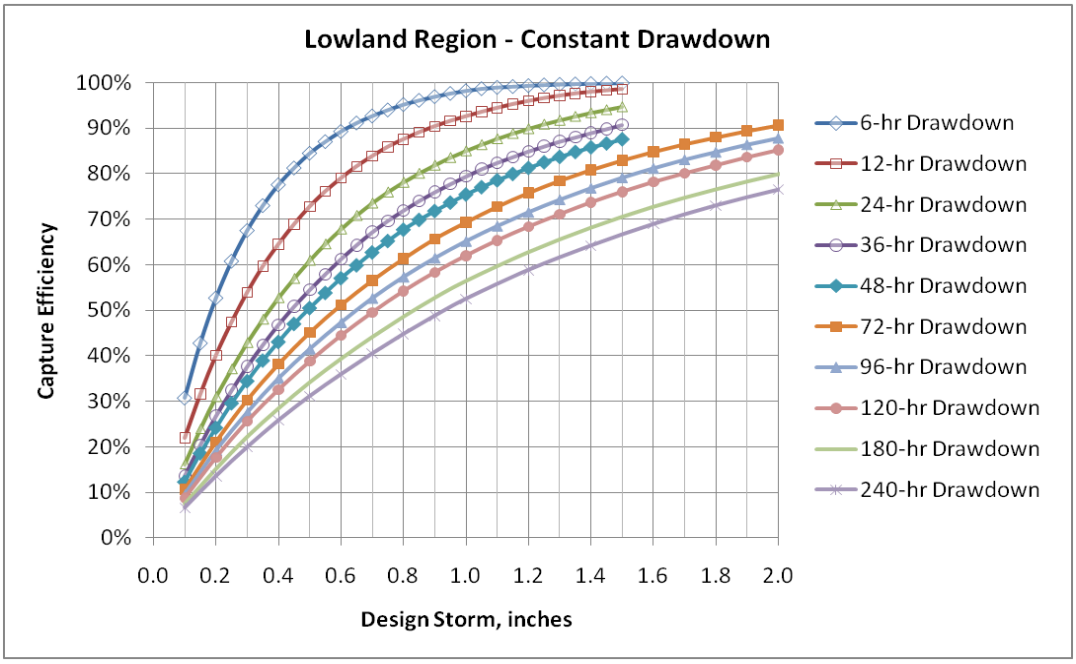
1) Determine the daily demand requirement in acre-feet (1 acre-foot = 325,851 gallons).

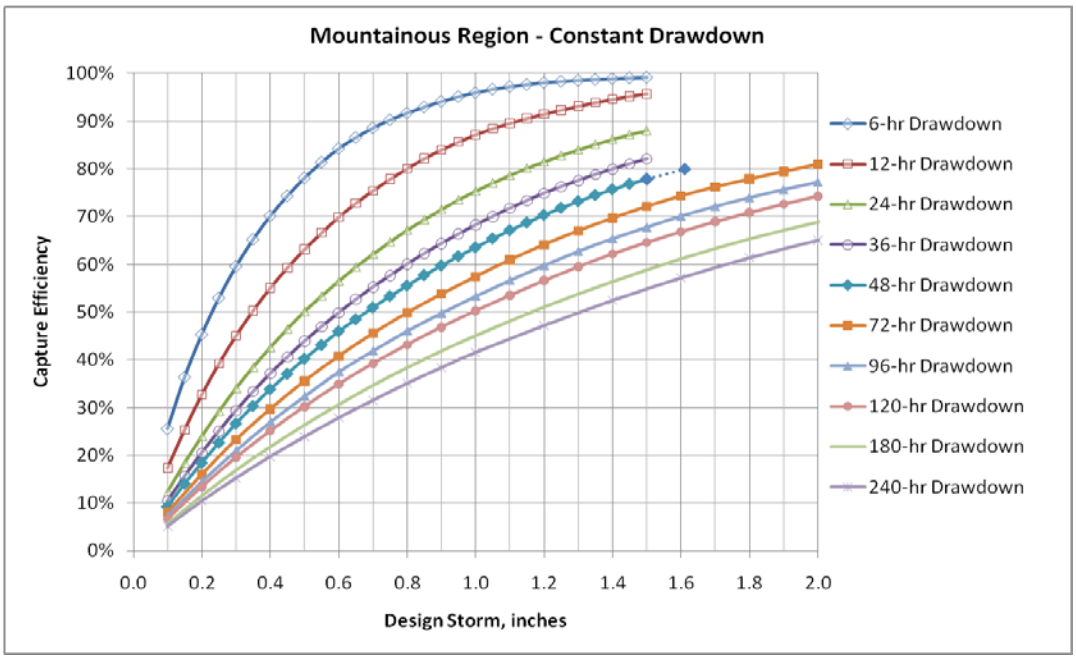
2) Calculate the required RWHDV for the desired drawdown time using the following equation:

$$RWHDV = Demand *(t_{drawdown}/24) \quad \text{(Equation 6-23)}$$

Where:

Demand	=	required project daily demand (acre-feet)
RWHDV	=	rainwater harvesting design volume (acre-ft)
$t_{drawdown}$	=	selected drawdown time (hours)


Lowland Region - Constant Drawdown
Capture Efficiency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Design Storm, inches
6-hr Drawdown
12-hr Drawdown
24-hr Drawdown
36-hr Drawdown
48-hr Drawdown
72-hr Drawdown
96-hr Drawdown
120-hr Drawdown
180-hr Drawdown
240-hr Drawdown


Mountainous Region - Constant Drawdown
Capture Efficiency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Design Storm, inches
6-hr Drawdown
12-hr Drawdown
24-hr Drawdown
36-hr Drawdown
48-hr Drawdown
72-hr Drawdown
96-hr Drawdown
120-hr Drawdown
180-hr Drawdown
240-hr Drawdown

Operations and Maintenance

1) Inspect storage facilities, associated pipes, and valve connections for leaks.
2) Clean gutters and filters of debris that has accumulated and is obstructing flow into the storage facility.
3) Clean and remove accumulated sediment annually.
4) Check cisterns for stability and anchor if necessary.
5) If the storage device is underground, ensure that a manhole is accessible, operational, and secure.

ET-1: Green Roof

Green roofs (also known as eco-roofs and vegetated roof covers) are roofing systems that layer a soil/vegetative cover over a waterproofing membrane. Green roofs rely on highly porous media and moisture retention layers to store intercepted precipitation and to support vegetation that can reduce the volume of stormwater runoff via evapotranspiration. There are two types of green roofing systems: extensive, which is a light-weight system; and intensive, which is a heavier system that allows for larger plants but requires additional structural support.

Green Roof Examples

Photo Credits:

1. Milwaukee Department of Environmental Sustainability;

2. Geosyntec Consultants

Application

- Building roofs
- Outdoor eating area roofs
- Parking structure or turnaround roofs

Preventative Maintenance

- Weeding and pruning
- Leaf and debris removal
- Regular membrane inspection
- Drain cleanout

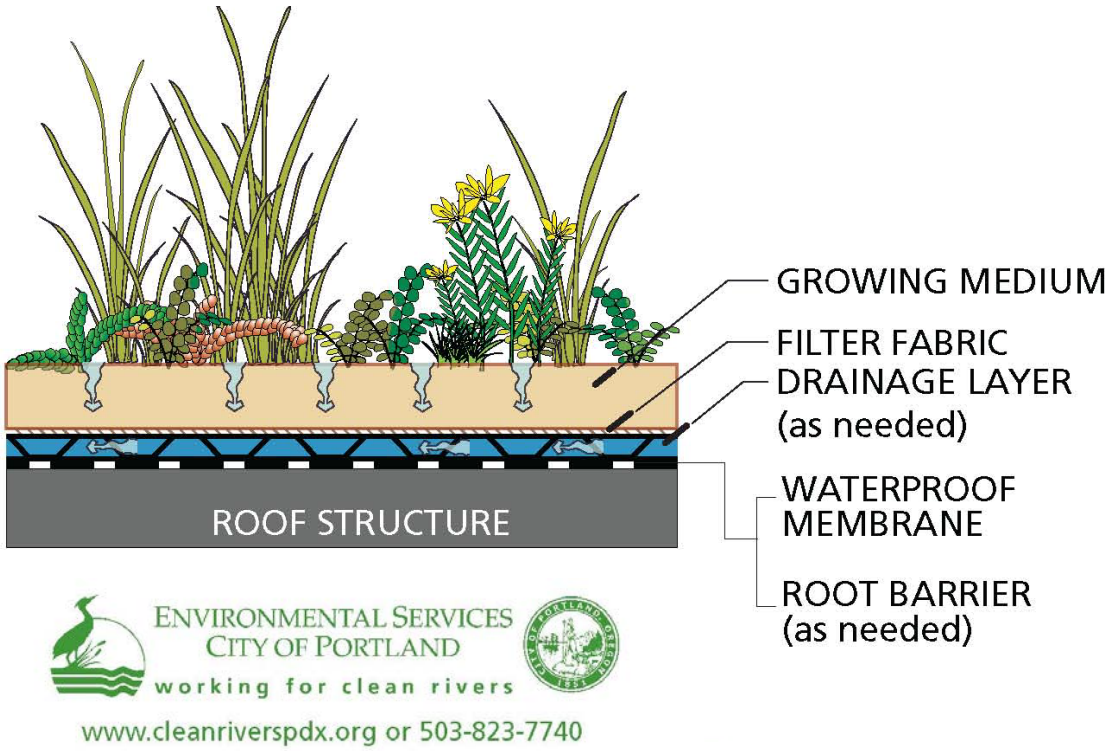


Exhibit A: Green Roof Schematic Courtesy of Portland, OR Environmental Services Department

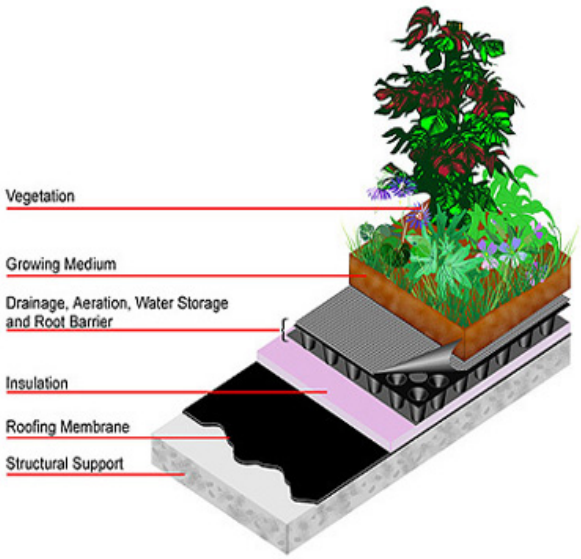


Exhibit B: Green Roof Schematic Courtesy of American Wick

Geosyntec consultants

Figure 6-9: Green Roofs

Limitations

The following describes additional site suitability recommendations and limitations for green roofs.

- Typically not used for steep roofs (>25%); and
- Structural roof support must be sufficient to support additional roof weight.

Design Criteria

Green roofs should be designed according to the requirements listed in Table 6-17 and outlined in the section below.

Table 6-17: Green Roof Design Criteria

Design Parameter	Unit	Design Criteria
Soil depth range	inch	2 – 6
Saturated soil weight	lbs. / sq. ft.	10 – 25
Maximum roof slope	%	25
Minimum roof slope	--	Flat
Vegetation type	--	Varies (see vegetation section below)
Vegetation height	--	Varies (see vegetation section below)

Sizing

Green roofs may provide quantifiable reduction in volume. However, they are not explicitly sized to meet the water quality treatment requirements. Rather, the volume reduction is accounted for implicitly in sizing calculations for the treatment BMPs for the remainder of the site by assuming that the roof area is pervious rather than impervious when calculating a runoff coefficient for the site.

Green Roof Components

Structural Support

The first requirement that must be met before installing a green roof is the structural support of the roof. The roof must be able to support the additional weight of the soil, water, and vegetation. A licensed structural engineer should be consulted to determine the proposed structural support during the design phase.

Waterproof Roofing Membrane

Waterproof roofing membrane is an integral part of a green roofing system. The waterproof membrane prevents the roof runoff from penetrating and damaging the roofing material. There are many materials available for this purpose and come in various forms (i.e., rolls, sheets, liquid) and exhibit different characteristics (e.g., flexibility, strength, etc.). Depending on the type of membrane chosen a root barrier may be required to prevent roots from compromising the integrity of the membrane.

Drainage Layer

Depending on the design of the roof, a drainage layer may be required to convey the excess runoff from of the roof. If a drainage layer is needed, there are numerous options including a gravel layer (which may require additional structural support), and many styles and types of plastic drainage layers.

Soil Considerations

The soil layer is an important factor in the construction and operation of green roofs. The soil layer must have excellent drainage, not be too heavy when saturated, and be adequately fertile as a growing medium for plants. Many companies sell their own proprietary soil mixes. However, a simple mix of ¼ topsoil, ¼ compost, and the remainder pumice perlite may be used for many applications. Other soil amendments may be substituted for the compost and the pumice perlite. The soil mix used should not contain any clay.

Vegetation

Green roofs must be vegetated in order to provide adequate treatment of runoff via filtration and evapotranspiration. Vegetation, when chosen and maintained appropriately, also improves the aesthetics of a site. Green roofs should be vegetated with a mix of erosion-resistant plant species that effectively bind the soil and can withstand the extreme environment of rooftops. A diverse selection of low growing plants that thrive under the specific site, climatic, and watering conditions should be identified. A mixture of drought-tolerant, self-sustaining (perennial or self-sowing without need for fertilizers, herbicides, and or pesticides) is most effective in the Ventura County region. Plants selected should also be low maintenance and able to withstand heat, cold, and high winds. Native or adapted sedum/succulent plants are preferred because they generally require less fertilizer, limited maintenance, and are more drought resistant than exotic plants. When appropriate, green roofs may be planted with larger plants. However, this depends on structural support and soil depth.

The following provides additional vegetation guidance for green roofs.

1) For extensive roofs, trees or shrubs may be used as long as the increased soil depth required may be supported.

2) Irrigation is required if the seed is planted in spring or summer. The use of a permanent smart (self-regulating) irrigation system or other watering system, may help provide maximal water quality performance. Drought-tolerant plants should be specified to minimize irrigation requirements. For projects seeking "High Performance Building" recognition, ASHRAE Standard 189.1 states that potable water cannot be used for irrigating green roofs after they are established.

3) Locate the green roof vegetation in an area without excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants should be used.

4) A relevant plant list should be provided by a landscape professional and used as a guide to support project-specific planting recommendations, including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth.

Drain

1) There must be a drain pipe (gutter) to convey runoff (both overflow and underdrain flow, if appropriate) safely from the roof to another basic or stormwater runoff BMP, a pervious area, or the stormwater conveyance system.

Construction Considerations

1) Building structure must be adequate to hold the additional weight of the soil, retained water, and plants.

2) Plants should be selected carefully to minimize maintenance and function properly.

Operations and Maintenance

1) During the establishment period, green roofs may need irrigation and occasional light fertilization until the plants have fully established themselves. Once healthy and fully established, properly selected climate-appropriate plants will no longer need irrigation except during extreme drought.

2) Weeding during the establishment period may be required to ensure proper establishment of the desired vegetation. Once established and assuming proper selection of vegetation, the vegetation should not require any preventative maintenance.

3) The roofing membrane should be inspected routinely, as it is a crucial element of the green roof. In addition, preventative inspection of the drainage paths is required to ensure that there are no clogs in the system. If a green roof is not properly draining, the moisture in the system may cause the roof to leak and/or the plants to drown or rot. Leaks in the roof may occur not only due to improper drainage, but also if the incorrect combination of waterproofing barrier, root barrier, and drainage systems

are selected. Leak inspections in the roofing system are advised, especially in locations prone to leaks, such as at all joints.

4) Inspect green roofs for erosion or damage to vegetation after every storm greater than 0.75 inches and at the end of the wet season to schedule summer maintenance and in the fall to ensure readiness for winter. Additional inspection after periods of heavy runoff is recommended. Green roofs should be checked for debris, litter, and signs of clogging.

5) Replanting and/or reseeding of vegetation may be required for reestablishment.

6) Vegetation should be healthy and dense enough to provide filtering while protecting underlying soils from erosion.

7) Fallen leaves and debris from deciduous plant foliage should be removed.

8) Invasive vegetation, such as Alligatorweed (*Alternanthera philoxeroides*), Halogeton (*Halogeton glomeratus*), Spotted Knapweed (*Centaurea maculosa*), Giant Reed (*Arundo donax*), Castor Bean (*Ricinus communis*), Perennial Pepperweed (*Lepidium latifolium*), and Yellow Starthistle (*Centaurea solstitalis*) should be removed and replaced with non-invasive species. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

9) Dead vegetation should be removed if greater than 10% of the area coverage. Vegetation should be replaced and established before the wet season to maintain cover density and control erosion where soils are exposed.

ET-2: Hydrologic Source Control BMPs

Hydrologic source control (HSC) BMPs are simple BMPs that are highly integrated with the site design to reduce runoff volume. The practices described in this fact sheet include impervious area dispersion, street trees, and rain barrels.

Application

- Building roofs
- Sidewalks and patios
- Landscaping hardscapes

Preventative Maintenance

- Weeding and pruning
- Leaf and debris removal

Hydrologic Source Control Examples

Photo Credits:

1. http://www.auburn.edu/projects/sustainability/website/newsletter/0910.php;

2. Geosyntec Consultants;

3. toronto.ca/environment/water.htm

Accounting for Hydrologic Source Controls in Hydrologic Calculations

The effects of HSC BMPs are accounted for in hydrologic calculations as an adjustment to the storm depth used in the SQDV calculations described in Section 2. Runoff volume calculations are performed exactly as described in Section 2, with the exception that the storm depth used in the calculation is adjusted prior to the calculation. Adjustments are based on the type and magnitude of HSC BMPs employed for the drainage area per guidance outlined in this Fact Sheet.

EXAMPLE 6.1: ACCOUNTING FOR HSCS IN HYDROLOGIC CALCULATIONS

Given:

- A drainage area consists of a 1 acre building roof surrounded by 0.25 acres of landscaping (80 percent composite imperviousness);
- The drainage from the roof is spread uniformly over the entire pervious area via splash pads and level spreaders;
- Soils are moderately well drained and have a shallow slope;
- For the purpose of this example, assume the hydrologic source control adjustment for this configuration of disconnected downspouts is 0.3 inches. For an actual project, hydrologic source control adjustment would be calculated based on instructions in this section; and
- The unadjusted design storm depth at the project site is 0.75 inches.

Result:

1) The designer uses 0.75 inches – 0.3 inches = 0.45 inches in the calculation of SQDV.

Impervious Area Dispersion

Impervious area dispersion refers to the practice of routing runoff from impervious areas, such as rooftops, walkways, and patios, onto the surface of adjacent pervious areas. Runoff is dispersed uniformly via splash block or dispersion trench and soaks into the ground as it moves slowly across the surface of the pervious area. Minor ponding may occur, but it is not the intent of this practice to actively promote localized on-lot infiltration, which should be designed as an infiltration BMP (see INF-1 through INF-6 above).

Design Considerations

1) Not likely to result in net increased infiltration over existing condition for previously pervious sites, but has potential to result in some geotechnical hazards associated with infiltration.

2) Significant pervious area should be available, at a ratio of at least 1 part pervious area capable of receiving flow to 5 parts impervious.

3) Pervious area receiving flow should have a slope ≤ 2 percent and path lengths of ≥ 10 feet per 1000 sf of impervious area.

4) Overflow from the pervious area up to the SQDV should be directed to a Retention BMP, Biofiltration BMP, or Treatment Control Measure. Larger flows should be directed to the storm drain system.

5) Soils in the pervious area should be preserved in their natural condition or improved with soil amendments (see Soil Amendments below).

6) Impervious area disconnection is an HSC that may be used as the first element in any treatment train.

7) The use of impervious area disconnection reduces the sizing requirement for downstream Retention BMPs, Biofiltration BMPs, and/or Treatment Control Measures.

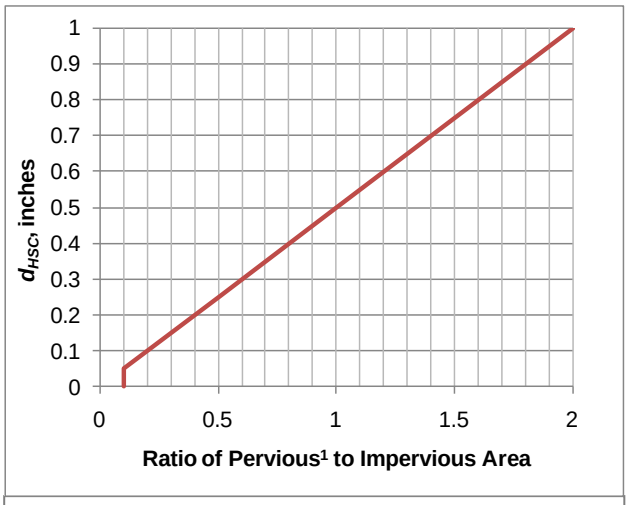
Calculating HSC Retention Volume

1) The retention volume provided by downspout dispersion is a function of the ratio of impervious to pervious area.

2) Determine flow patterns in pervious area and estimate footprint of pervious area receiving dispersed flow. Calculate the ratio of pervious to impervious area.

3) Check soil conditions using the checklist below; amend if necessary.

4) Look up the storm retention depth (d_{HSC}), from the chart to the right.



[1] Pervious area used in calculation should only include the pervious area receiving flow, not pervious area receiving only direct rainfall or upslope pervious drainage.

5) The max d_{HSC} is equal to the design storm depth for the project site.

Soil Condition Checklist

1) Soil should have a maximum slope of 2 percent.

2) Landscaping should be well-established.

3) Amended soils should consist of: 60 to 70% sand, 15 to 25% compost, 10 to 20% clean topsoil. The organic content of the soil mixture should be 8 to 12%; the pH range should be 5.5 to 7.5.

Additional References

- SMC LID Manual (pp 131): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- City of Portland Bureau of Environmental Services. 2010. How to manage stormwater – Disconnect Downspouts: http://www.portlandonline.com/bes/index.cfm?c=43081&a=177702
- Seattle Public Utility: http://www.cityofseattle.org/util/stellent/groups/public/@spu/@usm/documents/webcontent/spu01_006395.pdf
- Thurston County, Washington State (pp 10): http://www.co.thurston.wa.us/wwm/Engineering_Standards/Drainage_Manual/PDFs/DG-5%20Roof%20Runoff%20Control.pdf

Amended Soils

A soil amendment is any material added to the upper layer of soil especially in the vicinity of the root zone soil to improve its physical properties, such as the water retention, permeability, water infiltration, drainage, aeration and structure. The goal is to provide a better environment for roots. To do its work, an amendment should be thoroughly mixed into the soil. If it is merely buried, its effectiveness is reduced and it will interfere with water and air movement and root growth.

Amending a soil is different from mulching, although many mulches also are used as amendments. A mulch is left on the soil surface. Its purpose is to reduce evaporation and runoff, inhibit weed growth, and create an attractive appearance. Mulches also moderate soil temperature, helping to warm soils in the spring and cool them in the summer. Mulches may be incorporated into the soil as amendments after they have decomposed to the point that they no longer serve their purpose.

Organic amendments, such as compost, increase soil organic matter content and offer many benefits. Organic matter improves soil aeration, water infiltration, and both water- and nutrient-holding capacity. Many organic amendments contain plant nutrients and act as organic fertilizers. Organic matter also is an important energy source for bacteria, fungi and earthworms that live in the soil.

Design Considerations

1) Landscaped and other developed pervious areas can be amended to improve evapotranspiration and soil moisture storage capacity.

2) Landscape and other developed pervious areas can be amended to increase infiltration rates in cases where the limiting infiltration horizon exists near the surface of the soil column.

3) Soil amendments are common components of several Retention BMPs, Biofiltration BMPs, and Treatment Control Measures, including infiltration basins, bioretention, vegetated swales, filter strips, planter boxes, green roofs, dry extended detention basins, wet retention basins, and constructed treatment wetlands.

4) Compost, soil conditioners, and fertilizers should be rototilled into the native soil to a minimum depth of 6 inches; 12 inches preferred.

5) All soil amendments shall be free of sticks, glass, plastic, metal, debris larger than 1 inch, and other deleterious material.

6) Compost shall meet criteria listed in the guidelines for planting and storage media.

Calculating HSC Retention Volume

No retention credit is given for amended soils alone. Amended soils should be used to increase the retention volume of Retention BMPs, Biofiltration BMPs, and Treatment Control Measures.

Additional References

- San Diego County LID Handbook Appendix 4 (Factsheet 30): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

- Colorado State University Extension website: http://www.ext.colostate.edu/pubs/garden/07235.html

Street Trees

By intercepting rainfall, trees can provide several aesthetic and stormwater benefits including peak flow control, increased infiltration and evapotranspiration, and runoff temperature reduction. The volume of precipitation intercepted by the canopy reduces the treatment volume required for downstream treatment BMPs. Shading reduces the heat island effect as well as the temperature of adjacent impervious surfaces over which stormwater flows, and thus reduces the heat transferred to the downstream waterbody. Tree roots also strengthen the soil structure and provide infiltrative pathways, simultaneously reducing erosion potential and enhancing infiltration.

Design Considerations

1) Street trees can be incorporated along sidewalks, streets, parking lots, or driveways.

2) Street trees can be used in combination with bioretention systems along medians or in traffic calming bays.

3) There should be sufficient space available to accommodate both the tree canopy and the root system.

4) The mature tree canopy, height, and root system should not interfere with subsurface utilities, overhead powerlines, buildings and foundations, or other existing or planned structures.

5) Depending on space constraints, a 20 to 30 foot canopy (at maturity) is recommended for stormwater mitigation.

6) Native, drought-tolerant species should be selected in order to minimize irrigation requirements and improve the long-term viability of the tree.

7) Trees should not impede pedestrian or vehicle sight lines.

8) Planting locations should receive adequate sunlight and wind protection. Other environmental factors should be considered prior to planting.

9) Soils should be preserved in their natural condition (if appropriate for planting) or restored via soil amendments. If necessary, a landscape architect should be consulted.

Calculating HSC Retention Volume

1) The retention volume provided by streets trees via canopy interception is dependent on the tree species, time of the year, and maturity.

2) To compute the retention credit, the expected impervious area covered by the full tree canopy after 4 years of growth should be computed (IA_{HSC}). The maximum retention depth credit for canopy interception (d_{HSC}) is 0.05 inches.

Additional References

- California Stormwater BMP Handbook: http://www.cabmphandbooks.com/Documents/Development/Section_3.pdf
- City of Los Angeles, Street Tree Division - Street Tree Selection Guide: http://bss.lacity.org/UrbanForestryDivision/StreetTreeSelectionGuide.htm
- Portland Stormwater Management Manual: http://www.portlandonline.com/bes/index.cfm?c=35122&a=55791
- San Diego County LID Handbook Fact Sheets: http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

Residential Rain Barrels

Rain barrels are above ground storage vessels that capture runoff from roof downspouts during rain events and detain that runoff for later use for irrigating landscaped areas.

Design Considerations

1) If detained water will be used for irrigation, sufficient vegetated areas and other impervious surfaces should be present in the drainage area.

2) Storage capacity and sufficient area for overflow dispersion should be accounted for.

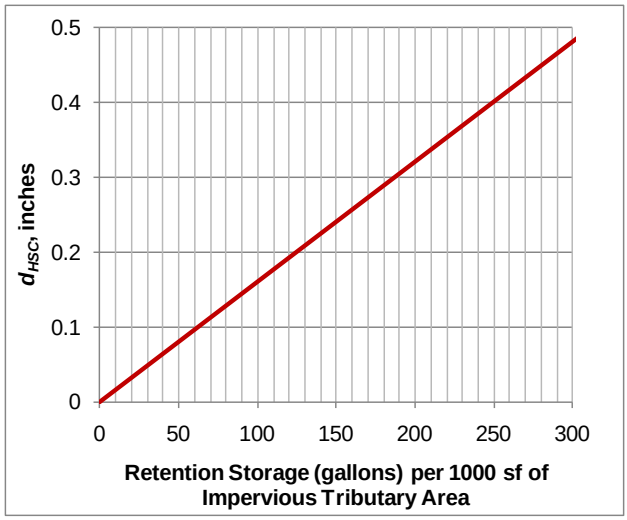
3) Screens on gutters and downspouts to remove sediment and particles as the water enters the barrel or cistern should be provided.

4) Removable child-resistant covers and mosquito screening should be provided to prevent unwanted access.

5) Above-ground barrels should be secured in place.

6) Above-ground barrels should not be located on uneven or sloped surfaces. If installed on a sloped surface, the base where the rain barrel will be installed should be leveled prior to installation.

7) Overflow dispersion should occur greater than 5 feet from building foundations.



8) Dispersion should not cause geotechnical hazards related to slope stability.

9) Effective energy dissipation and uniform flow spreading methods should be employed to prevent erosion and facilitate dispersion.

10) Placement should allow easy access for regular maintenance.

Calculating HSC Retention Volume

1) The retention volume provided by rain barrels that are not actively managed can be computed as 50% of the total storage volume (e.g., 22.5 gallons for each 55 gallon barrel).

2) If the rain barrel is actively managed, then it should be treated as a cistern (see RWH-1).

3) Estimate the average retention volume per 1000 square feet impervious tributary area provided by rain barrels.

4) Look up the storm retention depth (d_{HSC}), from the chart to the right.

5) The max d_{HSC} is equal to the design storm depth for the project site.

Additional References

- Santa Barbara BMP Guidance Manual, Chapter 6: http://www.santabarbaraca.gov/NR/rdonlyres/91D1FA75-C185-491E-A882-49EE17789DF8/0/Manual_071008_Final.pdf
- County of Los Angeles LID Standards Manual: http://dpw.lacounty.gov/wmd/LA_County_LID_Manual.pdf
- SMC LID Manual (pp 114): http://www.lowimpactdevelopment.org/guest75/pub/All_Projects/SoCal_LID_Manual/SoCalLID_Manual_FINAL_040910.pdf
- San Diego County LID Handbook Appendix 4 (Factsheet 26): http://www.sdcounty.ca.gov/dplu/docs/LID-Appendices.pdf

BIO-1: Bioretention with Underdrain

Bioretention stormwater treatment facilities are landscaped shallow depressions that capture and filter stormwater runoff. These facilities function as a soil and plant based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, and plantings. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. Bioretention with an underdrain is a treatment control measures that can be used for areas with low permeability native soils or steep slopes. Bioretention may be designed without an underdrain to serve as a retention BMP in areas of high soil permeability (see INF-3 Bioretention) or partial retention/ partial biofiltration BMP (see INF-7: Bioinfiltration).

Bioretention in Parking Lots

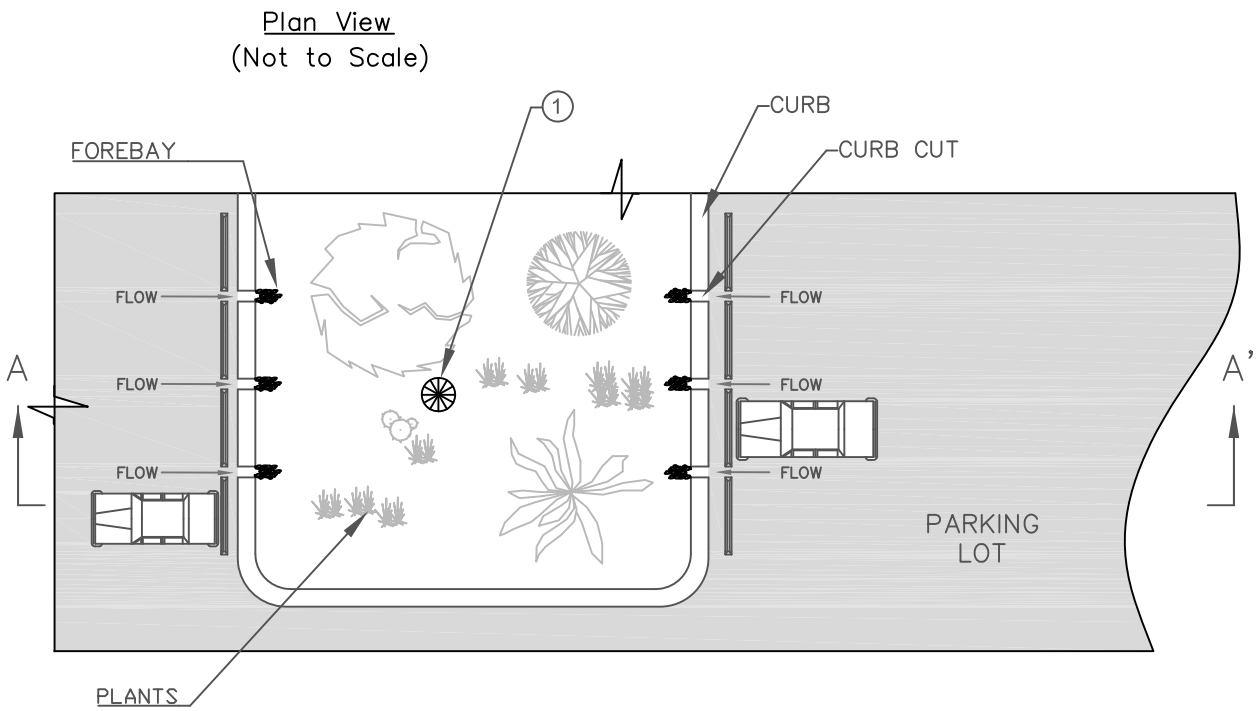
Photo Credits: Geosyntec Consultants

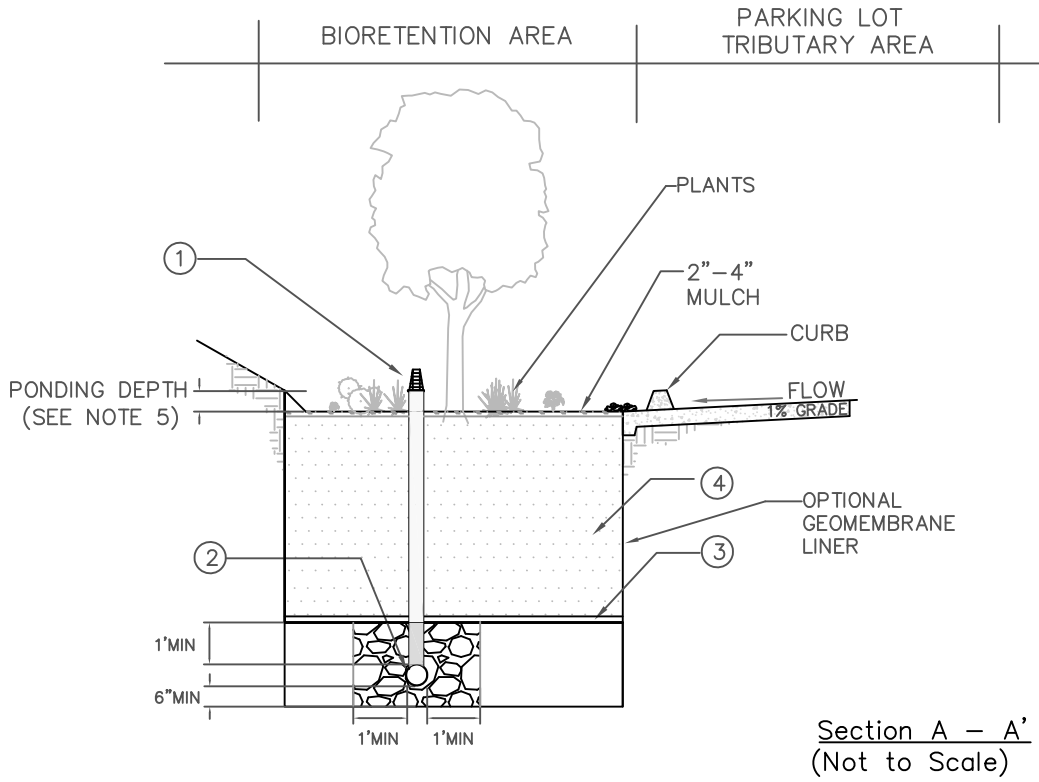
Application

- Parking lots
- Roadway parkways and medians
- School entrances, courtyards, and walkways
- Playgrounds and sports fields

Preventative Maintenance

- Repair small eroded areas
- Remove trash and debris and rake surface soils
- Remove accumulated fine sediments, dead leaves, and trash
- Remove weeds and prune back excess plant growth
- Remove sediment and debris accumulation near inlet and outlet structures
- Periodically observe function under wet weather conditions





NOTES:

① OVERFLOW DEVICE: VERTICAL RISER OR EQUIVALENT.
② PERFORATED 6" MIN PVC PIPE UNDERDRAIN.
③ OPTIONAL CHOKING GRAVEL LAYER.
④ 2' MIN PLANTING MIX; 3' PREFERRED.
⑤ PONDING DEPTH 18" WITH FENCE; 6" WITHOUT FENCE.

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Figure 6-10: Bioretention with Underdrain

Limitations

1) Vertical relief and proximity to storm drain - site must have adequate relief between land surface and storm drain to permit vertical percolation through the soil media and collection and conveyance in underdrain to storm drain system.

2) Depth to groundwater - shallow groundwater table may not permit complete drawdown between storms.

Design Criteria

Bioretention with an underdrain should be designed according to the requirements listed in Table 6-18 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-18: Bioretention with an Underdrain Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix E for calculating SQDV.
Forebay	-	Forebay should be provided for all tributary surfaces that contain landscaped areas. Forebays should be designed to prevent standing water during dry weather and should be planted with a plant palette that is tolerant of wet conditions.
Maximum drawdown time of water ponded on surface	hours	72
Maximum drawdown time of surface ponding plus subsurface pores	hours	96 (72 preferred)
Maximum ponding depth	inches	18 inches
Minimum thickness of amended soils layer	feet	2 (3 preferred)
Minimum thickness of stabilized mulch	inches	2 to 4
Planting mix composition	-	60 to 80% fine sand, 20 to 40% compost
Underdrain sizing	-	6 inch minimum diameter; 0.5% minimum slope; slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent); spacing shall be determined to provide

Design Parameter	Unit	Design Criteria
		capacity for maximum rate filtered through amended media
Gravel layer	-	A gravel bed should be provided around underdrain. Underdrain should have at least 1 foot of gravel installed to the sides and on top of the underdrain, and at least 0.5 feet of gravel installed below underdrain.
Overflow device	-	Required

Sizing Criteria

Bioretention facilities with underdrains shall be designed to capture and treat the SQDV. However because these systems commonly have a relatively high amended soil infiltration rate and shallow depth, these systems are typically capable of filtering a significant portion of the SQDV during a storm event. Therefore, a simplified routing approach is described in the following steps that accounts for the portion of the SQDV that is filtered during the storm event.

Step 1: Calculate the Design Volume

Bioretention facilities shall be sized to capture and biofilter the SQDV (see Section 2.3 and Appendix E).

Step 2: Determine the Design Percolation Rate

Sizing is based on the design saturated hydraulic conductivity (K_{sat}) of the amended soil layer. A target K_{sat} of 5 inches per hour is recommended for non-proprietary amended soil media. The media K_{sat} will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the amended soil layer. A factor of safety of 2.0 should be applied such that the resulting recommended design K_{sat} is 2.5 inches per hour. This value should be used for sizing unless sufficient rationale is provided to justify a higher design K_{sat}.

Step 3: Calculate the surface area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus the void spaces in the media, based on the computed porosity of the filter media and aggregate layer.

1) Select a surface ponding depth (d_p) that satisfies geometric criteria and is congruent with the constraints of the site. Selecting a deeper ponding depth (18 inches maximum) generally yields a smaller footprint, however, it requires greater consideration for public safety, energy dissipation, and plant selection.

2) Compute time for selected ponding depth to filter through media:

$$t_{ponding} = \frac{d_p}{K_{design}} 12 \frac{in}{ft}$$ (Equation 6-24)

Where:

$t_{ponding}$	=	required drain time of surface ponding (≤ 72 hrs)
d_p	=	selected surface ponding water depth (ft)
K_{design}	=	media design saturated hydraulic conductivity (in/hr) (see Step 2, above)

If $t_{ponding}$ exceeds 72 hours, return to (1) and reduce surface ponding or increase media K_{design}. Otherwise, proceed to next step.

Note: In nearly all cases, $t_{ponding}$ will not approach 72 hours unless a low K_{design} is specified.

3) Compute depth of water that may be filtered during the design storm event as follows:

$$d_{filtered} = Minimum\left[\frac{K_{design} \times T_{routing}}{12 \, in/ft}, d_p\right]$$ (Equation 6-25)

Where:

$d_{filtered}$	=	depth of water that may be considered to be filtered during the design storm event (ft) for routing calculations; this value should not exceed the surface ponding depth (d_p)
K_{design}	=	design saturated hydraulic conductivity (in/hr) (see Step 2, above)
$T_{routing}$	=	storm duration that may be assumed for routing calculations; this should be assumed to be 3 hours unless rationale for an alternative assumption is provided
d_p	=	selected surface ponding water depth (ft)

The intention is that routing is important in the appropriate sizing of bioretention with underdrains. However, the depth of water considered to be filtered during the storm should be limited to the maximum ponding depth. This

results in designs that are robust to account for a variety of storm depths and durations. This limitation is for sizing calculations only. In reality, the depth that is filtered during a storm will vary based on storm depth, duration, and intensity. This TGM does not intend to limit the amount that may actually be filtered.

4) Calculate required infiltrating surface area (filter bottom area):

$$A_{req} = \frac{SQDV}{d_p + d_{filtered}} \qquad \text{(Equation 6-26)}$$

Where:

A_{req}	=	required infiltrating area (ft^2). Should be calculated at the contour corresponding to the mid ponding depth (i.e., $0.5 \times d_p$ from the bottom of the facility)
$SQDV$	=	stormwater quality design volume (ft^3)
d_p	=	selected surface ponding water depth (ft)
$d_{filtered}$	=	depth of water that can be considered to be filtered during the design storm event (ft) for routing calculations (See Equation 6-15)

5) Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is calculated at the contour corresponding to the mid ponding depth (i.e., $0.5 \times d_p$ from the bottom of the facility).

Geometry

1) Minimum planting soil depth should be 2 feet, although 3 feet is preferred.

   The intention is that the minimum planting soil depth should provide a beneficial root zone for the chosen plant palette and adequate water storage for the stormwater quality design volume. A deeper soil depth will provide a smaller surface area footprint.

2) Bioretention should be designed to drain below the planting soil in less than 72 hours and completely drain from the underdrain in 96 hours (both starting from the end of inflow).

   The intention is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate soil oxygen levels for healthy soil biota and vegetation, and to provide proper soil conditions for biodegradation and retention of pollutants.

Flow Entrance and Energy Dissipation

The following types of flow entrance can be used for bioretention cells:

1) Dispersed, low velocity flow across a landscape area. Dispersed flow may not be possible given space limitations or if the facility is controlling roadway or parking lot flows where curbs are mandatory.

2) Dispersed flow across pavement or gravel and past wheel stops for parking areas.

3) Curb cuts for roadside or parking lot areas: Curb cuts should include rock or other erosion protection material in the channel entrance to dissipate energy. Flow entrance should drop 2 to 3 inches from curb line and provide an area for settling and periodic removal of sediment and coarse material before flow dissipates to the remainder of the cell.

4) Pipe flow entrance: Piped entrances, such as roof downspouts, should include rock, splash blocks, or other appropriate measures at the entrance to dissipate energy and disperse flows.

5) Woody plants (trees, shrubs, etc.) can restrict or concentrate flows and can be damaged by erosion around the root ball and should not be placed directly in the entrance flow path.

Underdrains

Underdrains should meet the following criteria:

1) 6-inch minimum diameter.

2) Underdrains should be made of slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent). *The intention is that compared to round-hole perforated pipe, slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.*

3) Slotted pipe should have 2 to 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inches and should have a length of 1 to 1.25 inches. Slots should be longitudinally spaced such that the pipe has a minimum of one square inch of slot per lineal foot of pipe and should be placed with slots facing the bottom of the pipe.

4) Underdrains should be sloped at a minimum of 0.5%.

5) Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter should be connected to the underdrain every 100 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts should be connected to the perforated underdrain with the appropriate manufactured connections. The wells/cleanouts should extend 6 inches above the top

elevation of the bioretention facility mulch, and should be capped with a lockable screw cap. The ends of the underdrain pipes not terminating in an observation well/cleanout should also be capped.

6) The following aggregate should be used to provide a gravel blanket and bedding for the underdrain pipe. Place the underdrain on a bed of washed aggregate at a minimum thickness of 6 inches and cover it with the same aggregate to provide a 1 foot minimum depth around the top and sides of the slotted pipe.

Sieve size	Percent Passing
¾ inch	100
¼ inch	30-60
US No. 8	20-50
US No. 50	3-12
US No. 200	0-1

7) At the option of the designer/geotechnical engineer, a geotextile fabric may be placed between the planting media and the drain rock. If a geotextile fabric is used, it should meet a minimum permittivity rate of 75 gal/min/ft^2, should not impede the infiltration rate of the soil medium, and should meet the following minimum materials requirements.

Geotextile Property	Value	Test Method
Trapezoidal Tear (lbs)	40 (min)	ASTM D4533
Permeability (cm/sec)	0.2 (min)	ASTM D4491
AOS (sieve size)	#60 - #70 (min)	ASTM D4751
Ultraviolet resistance	70% or greater	ASTM D4355

Preferably, aggregate should be used in place of filter fabric to reduce the potential for clogging. This aggregate layer should consist of 2 to 4 inches of washed sand underlain with 2 inches of choking stone (Typically #8 or #89 washed).

8) For bioretention facilities enhanced to remove address nitrogen as the primary pollutant class, the underdrain should be elevated from the bottom of the bioretention facility by at least 6 inches within the gravel blanket to create a fluctuating anaerobic/aerobic zone below the drain pipe. *The intention is that denitrification within the anaerobic/anoxic zone is facilitated by microbes using forms of nitrogen (NO_2 and NO_3) instead of oxygen for respiration.*

An alternative enhanced nitrogen removal design is to include an internal water storage layer by adding a 90-degree elbow to the underdrain to raise the outlet. This design feature provides additional storage in the media. The bioretention facility must have at least 30 inches of planting media. The top of the elbow should be at

least 12 inches below the top of the planting media, and in poorly draining soils, should preferably be 18 to 24 inches below the top of the planting media. The top of the water storage layer should not be less than 12 inches from the bottom of the planting media layer. (For more information, see Urban Waterways publication).

9) The underdrain should drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to another bioretention cell as part of a connected treatment system, to a storm drain, daylight to a vegetated dispersion area using an effective flow dispersion device, or to a storage facility for rainwater harvesting.

Overflow

An overflow device is required at the maximum ponding depth. The following, or equivalent, should be provided:

1) A vertical PVC pipe (SDR 35) should be connected to the underdrain.

2) The overflow riser(s) should be 6 inches or greater in diameter, so it can be cleaned without damage to the pipe. The vertical pipe will provide access to cleaning the underdrains.

3) The inlet to the riser should be at the ponding depth (maximum 18 inches for fenced bioretention areas and 6 inches for areas that are not fenced), and be capped with a spider cap to exclude floating mulch and debris. Spider caps should be screwed in or glued (i.e., not removable).

Hydraulic Restriction Layers

Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mils.

Planting/Storage Media

1) The planting media placed in the cell should achieve a long-term, in-place infiltration rate of at least 1 inch per hour. Higher infiltration rates are permissible. If the design long-term, in-place infiltration rate of the soil exceeds 12 inches per hour, documentation should be provided to demonstrate that the media will adequately address pollutants of concern at a higher flowrate. Bioretention soil shall also support vigorous plant growth.

2) Planting media should consist of 60 to 80% fine sand and 20 to 40% compost.

3) Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size should be non-plastic. Sand for bioretention should be analyzed by an accredited lab using

#200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation (Note: all sands complying with ASTM C33 for fine aggregate comply with the gradation requirements below):

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

Note: the gradation of the sand component of the media is believed to be a major factor in the hydraulic conductivity of the media mix. If the desired hydraulic conductivity of the media cannot be achieved within the specified proportions of sand and compost (#2), then it may be necessary to utilize sand at the coarser end of the range specified in above ("minimum" column).

4) Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.
- Organic matter: 35-75% dry weight basis.
- Carbon and Nitrogen Ratio: 15:1 < C:N < 25:1
- Maturity/Stability: shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 F) upon delivery or rewetting is not acceptable.
- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
  - NH4:NH3 < 3
  - Ammonium < 500 ppm, dry weight basis

  - Seed Germination > 80% of control
  - Plant trials > 80% of control
  - Solvita® > 5 index value
- Nutrient content:
  - Total Nitrogen content 0.9% or above preferred
  - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm
- pH between 6.5 and 8 (may vary with plant palette)

Compost for bioretention should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1 inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	2	10

Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested.

Note: the gradation of compost used in bioretention media is believed to play an important role in the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range ("minimum" column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity.

In addition, a coarser compost mix provides more heterogeneity of the bioretention media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

5) The bioretention area should be covered with 2 to 4 inches (average 3 inches) of mulch at the start and an additional placement of 1 to 2 inches of mulch should be added annually. *The intention is that to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity*.

Plants

Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 96 hours.

It is recommended that a minimum of three types of tree, shrubs, and/or herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species.

Native plant species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent practicable.

Operations and Maintenance

Bioretention areas require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, bioretention maintenance requirements are typical landscape care procedures and include:

1) Watering: Plants should be selected to be drought-tolerant and not require watering after establishment (2 to 3 years). Watering may be required during prolonged dry periods after plants are established.

2) Erosion control: Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred (see Appendix I for a bioretention inspection and maintenance checklist). Properly designed facilities with appropriate flow velocities should not have erosion problems except perhaps in extreme events. If erosion problems occur, the following should be reassessed: (1) flow velocities and gradients within the cell, and (2) flow dissipation and erosion protection strategies in the pretreatment area and flow entrance. If sediment is deposited in the bioretention area, immediately determine the source within the contributing area, stabilize, and remove excess surface deposits.

3) Plant material: Depending on aesthetic requirements, occasional pruning and removing of dead plant material may be necessary. Replace all dead plants and if specific plants have a high mortality rate, assess the cause and, if necessary, replace with more appropriate species. Periodic weeding is necessary until plants are established. The weeding schedule should become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants have been excluded.

4) Nutrient and pesticides: The soil mix and plants are selected for optimum fertility, plant establishment, and growth. Nutrient and pesticide inputs should not be required and may degrade the pollutant processing capability of the bioretention area, as well as contribute pollutant loads to receiving waters. By design, bioretention facilities are located in areas where phosphorous and nitrogen levels are often

elevated and these should not be limiting nutrients. If in question, have soil analyzed for fertility.

5) Mulch: Replace mulch annually in bioretention facilities where high trash, sediment load, and heavy metal deposition is likely (e.g., heavy metal contributing areas include industrial and auto dealer/repair parking lots and roads). In residential lots or other areas where metal deposition is not a concern, replace or add mulch as needed to maintain a 2 to 3 inch depth at least once every two years.

6) Soil: Soil mixes for bioretention facilities are designed to maintain long-term fertility and pollutant processing capability. Replacing mulch in bioretention facilities where high trash, sediment load, and heavy metal deposition are likely provides an additional level of protection for prolonged performance. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in bioretention systems. However, the saturated hydraulic conductivity should be assessed at least annually to ensure that the design water quality event is being treated. If in question, have soil analyzed for fertility and pollutant levels.

BIO-2: Planter Box

Planter boxes are bioretention treatment control measures that are completely contained within an impermeable structure with an underdrain (they do not infiltrate). These facilities function as a soil and plant based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. The facilities normally consist of a ponding area, mulch layer, planting soils, plantings, and an underdrain within the planter box. As stormwater passes down through the planting soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants. Planter boxes are comprised of a variety of materials, usually chosen to be the same material as the adjacent building or sidewalk.

Planter boxes may be placed adjacent to or near buildings, other structures, or sidewalks. Planter boxes can be used directly adjacent to buildings beneath downspouts as long as the boxes are properly lined on the building side and the overflow outlet discharges away from the building to ensure water does not percolate into footings or foundations. They can also be placed further away from buildings by conveying roof runoff in shallow engineered open conveyances, shallow pipes, or other innovative drainage structures.

Planter boxes extending along a building wall

Photo Credit: Geosyntec Consultants

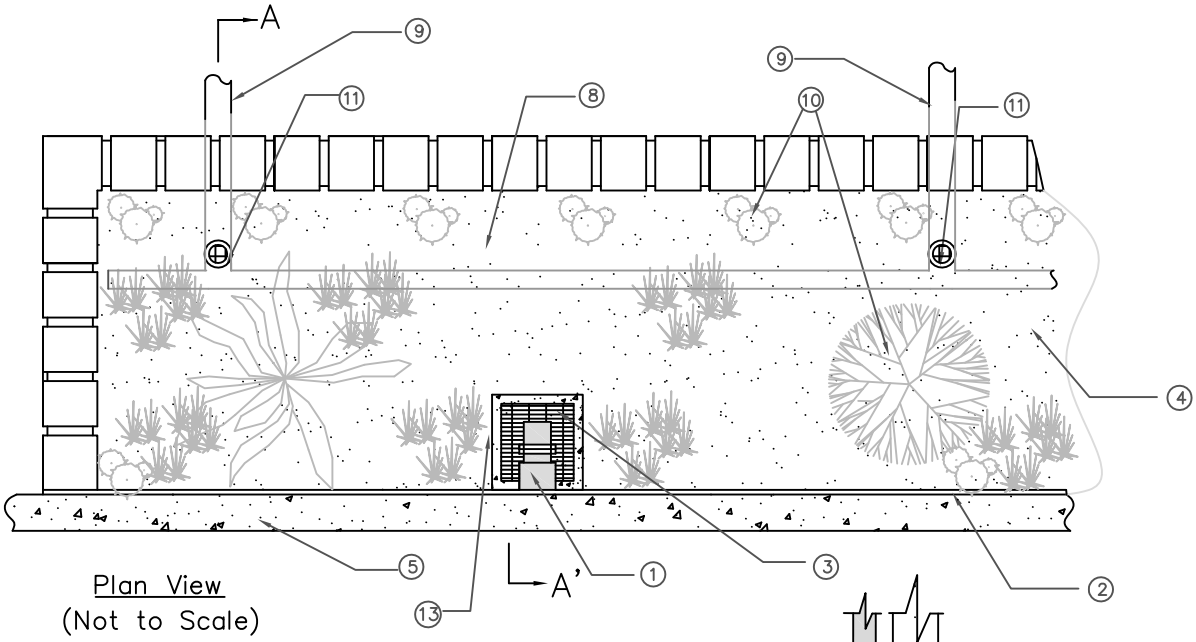
Application

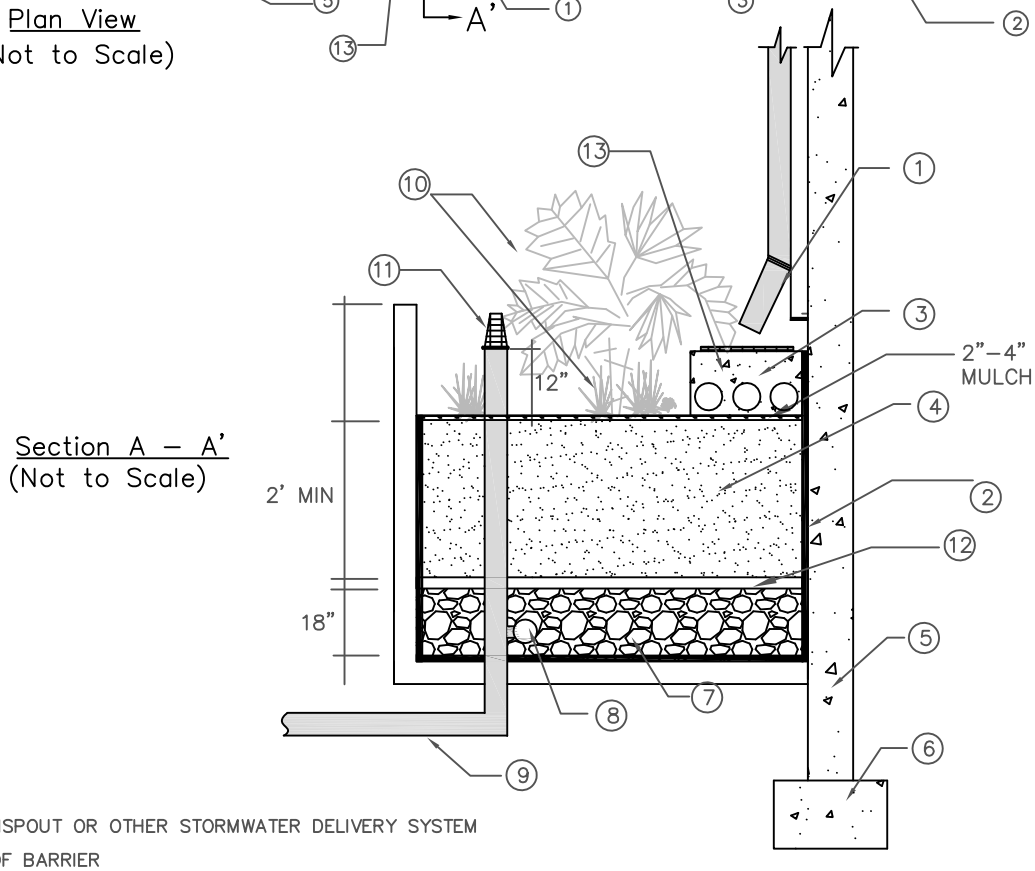
- Areas adjacent to buildings and sidewalks
- Building entrances, courtyards, and walkways

Preventative Maintenance

- Repair small eroded areas
- Remove trash and debris and rake surface soils
- Remove accumulated fine sediments, dead leaves, and trash
- Remove weeds and prune back excess plant growth
- Remove sediment and debris accumulation near inlet and outlet structures

  Periodically observe function under wet weather conditions





NOTES:

1. ROOF DOWNSPOUT OR OTHER STORMWATER DELIVERY SYSTEM
2. WATERPROOF BARRIER
3. SHALLOW ENERGY DISSIPATOR BASIN DISPERSES FLOW AT SOIL SURFACE
4. SOIL MIX (SEE PLANTING MEDIA SECTION)
5. BUILDING
6. FOUNDATION. INSTALL FOUNDATION DRAINS AS NEEDED
7. GRAVEL BEDDING (SEE UNDERDRAIN)
8. PERFORATED PIPE SHALL RUN ENTIRE LENGTH OF PLANTER
9. CONNECTION TO DOWNSTREAM CONVEYANCE SYSTEM
10. PLANTS
11. SET OVERFLOW 2" BELOW THE TOP OF THE PLANTER
12. OPTIONAL CHOKING GRAVEL LAYER

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Figure 6-11: Planter Box

Limitations

The applicability of stormwater planter boxes is limited by the following site characteristics:

1) The tributary area (area draining to the planter box area) should be less than 15,000 ft^2.

2) Groundwater levels should be at least 2 ft lower than the bottom of the planter box.

3) Site must have adequate vertical relief between land surface and the stormwater conveyance system to permit connection of the underdrain to the stormwater conveyance system.

4) Planter boxes should not be located in areas with excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants should be used.

Design Criteria

Planter boxes should be designed according to the requirements listed in Table 6-19 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-19: Planter Box Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix E for calculating SQDV.
Drawdown time of planting soil	hours	12
Maximum ponding depth	inches	12
Minimum soil depth	feet	2; 3 preferred
Stabilized mulch depth	inches	2 to 3
Planting soil composition	-	60 to 70% sand, 30 to 40% compost
Underdrain	-	6 inch minimum diameter; 0.5% minimum slope; slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent)
Overflow device	-	Required

Sizing Criteria

See Sizing Criteria section in the BIO-1: Bioretention with underdrains fact sheet.

Geometry and Size

1) Planter boxes areas should be sized to capture and treat the SQDV with a 12 inch maximum ponding depth. The mulch layer should be included as part of the ponding depth.

2) Minimum soil depth should be 2 feet, although 3 feet is preferred. *The intention is that a minimum soil depth should provide a beneficial root zone for the chosen plant palette and adequate water storage for the SQDV. A deeper planting soil depth will provide a smaller surface area footprint.*

3) Planter boxes should be designed to drain to below the planting soil depth in less than 48 hours. *The intention is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, prevent long periods of saturation for plant health, maintain adequate soil oxygen levels for healthy soil biota and vegetation, reduce potential for vector breeding, and provide proper soil conditions for biodegradation and retention of pollutants.*

4) Any planter box shape configuration is possible as long as other design criteria are met.

5) The distance between the downspouts and the overflow outlet should be maximized. *The intention is to increase the opportunity for stormwater retention and filtration.*

6) Off-line configurations should be considered to minimize the possibility of scouring and resuspension of previously captured pollutants during large storms.

Structural Materials

1) Planter boxes should be constructed out of stone, concrete, brick, recycled plastic, or other permanent materials. Pressure-treated wood or other materials that may leach pollutants (e.g., arsenic, copper, zinc, etc.) should not be allowed.

2) The structure should be adequately sealed or a waterproof membrane installed to ensure water only exits the structure via the underdrain.

Flow Entrance and Energy Dissipation

The following types of flow entrance can be used for planter boxes:

1) Pipe flow entrance: Piped entrances, such as roof downspouts, should include rock, splash blocks, or other appropriate measures at the entrance to dissipate energy and disperse flows.

2) Woody plants (e.g., trees, shrubs, etc.) can restrict or concentrate flows and can be damaged by erosion around the root ball and should not be placed directly in the entrance flow path.

Underdrains

Underdrains are required and should meet the following criteria:

1) 6-inch minimum diameter.

2) Underdrains should be made of slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent). *The intention is that in comparison to round-hole perforated pipe, slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.*

3) Slotted pipe should have 2 to 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inch and should have a length of 1 to 1.25 inches. Slots should be longitudinally spaced such that the pipe has a minimum of one square inch opening per lineal foot and should face down.

4) Underdrains should be sloped at a minimum of 0.5%.

5) Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter should be connected to the underdrain every 100 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts should be connected to the perforated underdrain with the appropriate manufactured connections. The wells/cleanouts should extend 6 inches above the top elevation of the bioretention facility mulch, and should be capped with a lockable screw cap. The ends of underdrain pipes not terminating in an observation well/cleanout should also be capped.

6) The following aggregate should be used to provide a gravel blanket and bedding for the underdrain pipe. Place the underdrain on a bed of washed aggregate at a minimum thickness of 6 inches and cover it with the same aggregate to provide a 1 foot minimum depth around the top and sides of the slotted pipe.

Sieve size	Percent Passing
¾ inch	100
¼ inch	30-60
US No. 8	20-50
US No. 50	3-12
US No. 200	0-1

7) At the option of the designer/geotechnical engineer, a geotextile fabric may be placed between the planting media and the drain rock. If a geotextile fabric is used, it should

meet a minimum permittivity rate of 75 gal/min/ft^2, should not impede the infiltration rate of the soil medium, and should meet the following minimum materials requirements.

Geotextile Property	Value	Test Method
Trapezoidal Tear (lbs)	40 (min)	ASTM D4533
Permeability (cm/sec)	0.2 (min)	ASTM D4491
AOS (sieve size)	#60 - #70 (min)	ASTM D4751
Ultraviolet resistance	70% or greater	ASTM D4355

Preferably, aggregate should be used in place of filter fabric to reduce the potential for clogging. This aggregate layer should consist of 2 to 4 inches of washed sand underlain with 2 inches of choking stone (Typically #8 or #89 washed).

8) The underdrain should be elevated from the bottom of the bioretention facility by 6 inches within the gravel blanket to create a fluctuating anaerobic/aerobic zone below the drain pipe. *The intention is that denitrification within the anaerobic/anoxic zone is facilitated by microbes using forms of nitrogen (NO_2 and NO_3) instead of oxygen for respiration.*

9) The underdrain must drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to another bioretention cell as part of a connected treatment system, to a storm drain, daylight to a vegetated dispersion area using an effective flow dispersion device, or to a storage facility for rainwater harvesting.

Overflow

An overflow device is required to be set at 2 inches below the top of the planter and no more than 12 inches above the soil surface. The most common option is a vertical riser, described below.

Vertical riser

1) A vertical PVC pipe (SDR 35) should be connected to the underdrain.

2) The overflow riser(s) should be 6 inches or greater in diameter, so it can be cleaned without damage to the pipe. The vertical pipe will provide access to cleaning the underdrains.

3) The inlet to the riser should be a maximum of 12 inches above the planting soil, and be capped with a spider cap. Spider caps should be screwed in or glued (i.e., not removable).

Hydraulic Restriction Layers

A waterproof barrier should be provided to restrict moisture away from foundations. Geomembrane liners should have a minimum thickness of 30 mils. Equivalent waterproofing measures may be used.

Planting/Storage Media

1) The planting media placed in the cell should achieve a long-term, in-place infiltration rate of at least 1 inch per hour. Higher infiltration rates are permissible. If the design long-term, in-place infiltration rate of the soil exceeds 12 inches per hour, documentation should be provided to demonstrate that the media will adequately address pollutants of concern at a higher flowrate. Planter box soil shall also support vigorous plant growth.

2) Planting media should consist of 60 to 80% fine sand and 20 to 40% compost.

3) Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material. All aggregate passing the No. 200 sieve size should be non-plastic. Sand for the planter box should be analyzed by an accredited lab using #200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation (Note: all sands complying with ASTM C33 for fine aggregate comply with the gradation requirements below):

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
3/8 inch	100	100
#4	90	100
#8	70	100
#16	40	95
#30	15	70
#40	5	55
#100	0	15
#200	0	5

Note: the gradation of the sand component of the media is believed to be a major factor in the hydraulic conductivity of the media mix. If the desired hydraulic conductivity of the media cannot be achieved within the specified proportions of sand and compost (#2), then it may be necessary to utilize sand at the coarser end of the range specified in above ("minimum" column).

4) Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal

of Testing Assurance (STA) Program (a compost testing and information disclosure program). Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.
- Organic matter: 35-75% dry weight basis.
- Carbon and Nitrogen Ratio: 15:1 < C:N < 25:1
- Maturity/Stability: shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 F) upon delivery or rewetting is not acceptable.
- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
    - NH4:NH3 < 3
    - Ammonium < 500 ppm, dry weight basis
    - Seed Germination > 80% of control
    - Plant trials > 80% of control
    - Solvita® > 5 index value
- Nutrient content:
    - Total Nitrogen content 0.9% or above preferred
    - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm
- pH between 6.5 and 8 (may vary with plant palette)

Compost for planter box should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1 inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	2	10

Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested.

Note: the gradation of compost used in planter box media is believed to play an important role in the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range ("minimum" column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity.

In addition, a coarser compost mix provides more heterogeneity of the planter box media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

5) The planter box should be covered with 2 to 4 inches (average 3 inches) of mulch at the start and an additional placement of 1 to 2 inches of mulch should be added annually. *The intention is that to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity*.

Plants

1) Plant materials should be tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 96 hours.

2) It is recommended that a minimum of three types of tree, shrubs, and/or herbaceous groundcover species be incorporated to protect against facility failure due to disease and insect infestations of a single species.

3) Native plant species and/or hardy cultivars that are not invasive and do not require chemical inputs should be used to the maximum extent practicable.

4) Plants should be selected carefully to minimize maintenance and function properly.

Operations and Maintenance

Planter boxes require annual plant, soil, and mulch layer maintenance to ensure optimum infiltration, storage, and pollutant removal capabilities. In general, planter box maintenance requirements are typical of landscape care procedures and include:

1) Watering: Plants should be selected to be drought-tolerant and do not require watering after establishment (2 to 3 years). Watering may be required during prolonged dry periods after plants are established.

2) Erosion control: Inspect flow entrances, ponding area, and surface overflow areas periodically, and replace soil, plant material, and/or mulch layer in areas if erosion has occurred (see Appendix I for an inspection and maintenance checklist). Properly designed facilities with appropriate flow velocities should not have erosion problems

except perhaps in extreme events. If erosion problems occur, the following should be reassessed: (1) flow velocities and gradients within the cell, and (2) flow dissipation and erosion protection strategies in the flow entrance. If sediment is deposited in the planter box, immediately determine the source within the contributing area, stabilize, and remove excess surface deposits.

3) Plant material: Depending on aesthetic requirements, occasional pruning and removing of dead plant material may be necessary. Replace all dead plants and if specific plants have a high mortality rate, assess the cause and, if necessary, replace with more appropriate species. Periodic weeding is necessary until plants are established. The weeding schedule should become less frequent if the appropriate plant species and planting density have been used and, as a result, undesirable plants have been excluded.

4) Nutrients and pesticides: The soil mix and plants are selected for optimum fertility, plant establishment, and growth. Nutrient and pesticide inputs should not be required and may degrade the pollutant processing capability of the planter box area, as well as contribute pollutant loads to receiving waters. By design, planter boxes are located in areas where phosphorous and nitrogen levels are often elevated and these should not be limiting nutrients. If in question, have soil analyzed for fertility.

5) Mulch: Replace mulch annually in planter boxes where high trash, sediment load, and heavy metal deposition is likely (e.g., heavy metal contributing areas include industrial, auto dealer/repair, parking lots, and roads). In residential lots or other areas where metal deposition is not a concern, replace or add mulch as needed to maintain a 2 to 3 inch depth at least once every two years.

6) Soil: Soil mixes for planter boxes are designed to maintain long-term fertility and pollutant processing capability. Replacing mulch in planter boxes where high trash, sediment load, and heavy metal deposition are likely provides an additional level of protection for prolonged performance. Estimates from metal attenuation research suggest that metal accumulation should not present an environmental concern for at least 20 years in planter boxes. However, the saturated hydraulic conductivity should be assessed at least annually to ensure that the design water quality event is being treated. If in question, have soil analyzed for fertility and pollutant levels.

BIO-3: Vegetated Swale

Vegetated swales are open, shallow channels with low-lying vegetation covering the side slopes and bottom that collect and slowly convey runoff to downstream discharge points. Vegetated swales provide pollutant removal through settling and filtration in the vegetation (usually grasses) lining the channels, provide the opportunity for stormwater volume reduction through infiltration and evapotranspiration, reduce the flow velocity, and conveying stormwater runoff. An effective vegetated swale achieves uniform sheet flow through a densely vegetated area for a period of several minutes. The vegetation in the swale can vary depending on its location and is the choice of the designer, depending on the design criteria outlined in this section.

Vegetated swale captures flow from a residential street

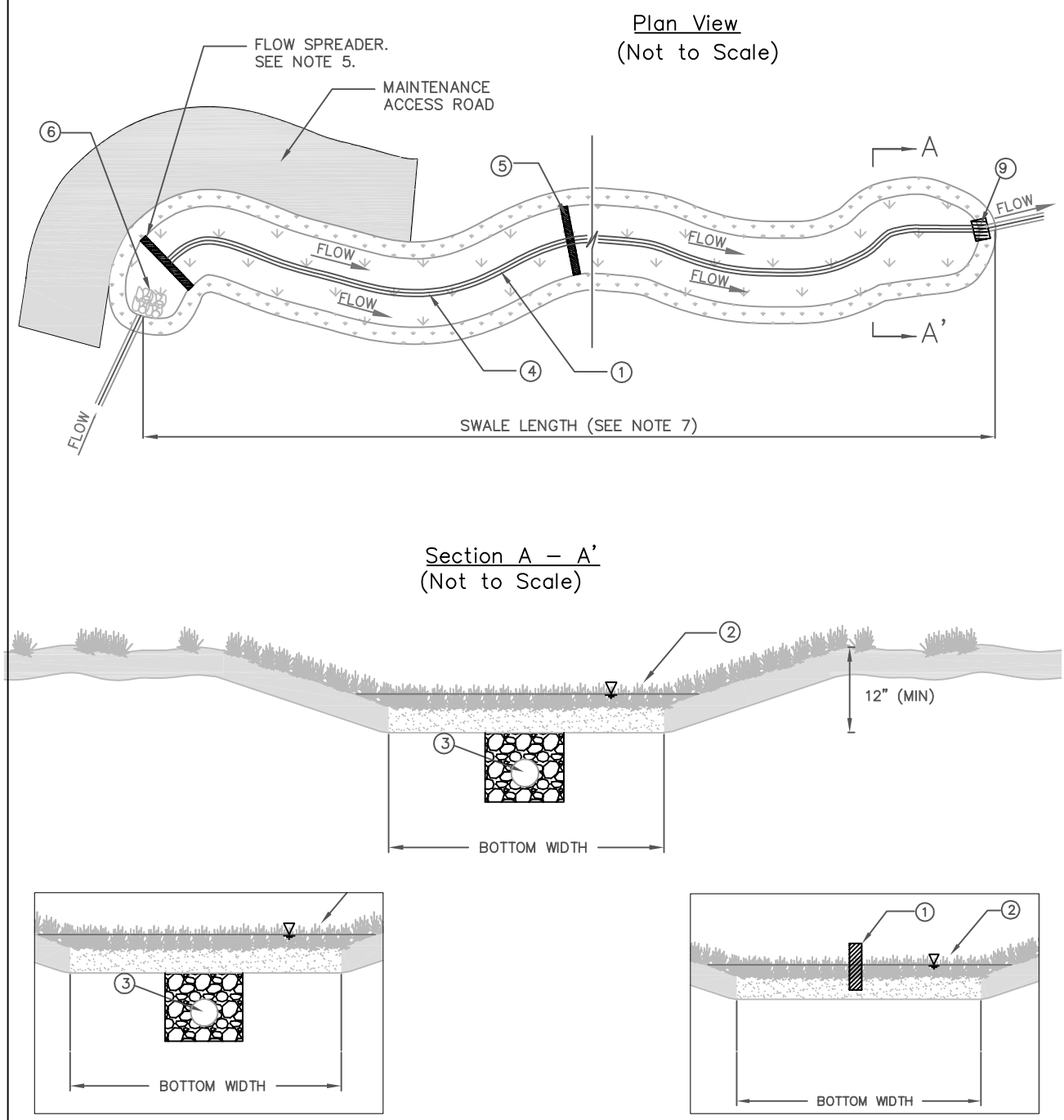
Photo Credit: Geosyntec Consultants

Application

- Open areas adjacent to parking lots
- Open spaces adjacent to athletic fields
- Roadway medians and shoulders

Preventative Maintenance

- Remove excess sediment, trash, and debris
- Clean and reset flow spreaders
- Mow regularly
- Remove sediment and debris build-up near inlets and outlets
- Repair minor erosion and scouring



NOTES:

1. SWALE DIVIDER REQUIRED FOR BOTTOM WIDTHS > 10'. MINIMUM REQUIRED BOTTOM WIDTH IS 2' EXCLUDING WIDTH OF LOW FLOW CHANNEL. MAXIMUM BOTTOM WIDTH WITH DIVIDER IS 16'.
2. DEPTH OF FLOW FOR WATER QUALITY TREATMENT MUST NOT EXCEED TWO–THIRDS OF VEGETATION HEIGHT OR NOT GREATER THAN 2" FOR FREQUENTLY MOWED TURF.
3. IF AN UNDERDRAIN IS REQUIRED, IT MUST CONSIST OF AN AT LEAST 6" DIAMETER PERFORATED PIPE IN COARSE AGGREGATE BED CONNECTED TO STORM DRAIN. GRAVEL BED MUST EXTEND 6" BELOW AND 12" TO THE SIDE AND TOP OF THE PIPE.
4. IF NO UNDERDRAIN, LOW FLOW DRAIN SHALL EXTEND ENTIRE LENGTH OF SWALE AND SHALL HAVE A DEPTH OF 6" MINIMUM AND WIDTH NO MORE THAN 5% SWALE BOTTOM WIDTH. ANCHORED PLATE FLOW SPREADER IF USED, SHALL HAVE V–NOTCHES (MAX TOP WIDTH = 5% OF SWALE WIDTH) OR HOLES TO ALLOW PREFERENTIAL EXIT OF LOW FLOWS.
5. INSTALL CHECK DAMS OR GRADE CONTROL STRUCTURES FOR SLOPES > 2% AT 50' MAXIMUM SPACING TO ACHIEVE A MAXIMUM EFFECTIVE LONGITUDINAL SLOPE OF 2%. FLOW SPREADERS SHALL BE PROVIDED AT INLET AND AT THE BASE OF EACH CHECK DAM.
6. INSTALL ENERGY DISSIPATOR AT THE INLET OF VEGETATED SWALE.
7. SWALE LENGTH SHALL LENGTH REQUIRED TO PROVIDE 7 MINUTES RESIDENCE TIME.
8. INSTALL APPROPRIATE OUTLET STRUCTURE. ACCOMODATE LOW FLOW CHANNEL AND/OR UNDERDRAIN (IF PRESENT).
9. AMEND SOILS WITH 2" OF COMPOST TILLED INTO 6" OF NATIVE SOIL UNLESS NATIVE SOIL ORGANIC CONTENT > 10%.

Geosyntec consultants

Figure 6-12: Vegetated Swale

Limitations

1) Compatibility with flood control - swales should not interfere with flood control functions of existing conveyance and detention structures.

2) Vegetation - select vegetation appropriately based on irrigation requirements and exposure (shady versus sunny areas). A thick vegetative cover is needed for vegetated swales to function properly. Native and drought tolerant plants are recommended.

3) Drainage area - each vegetated swale can treat a relatively small drainage area. Large areas should be divided and treated using multiple swales.

Design Criteria

Vegetated swales should be designed according to the requirements listed in Table 6-20 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-20: Vegetated Swale Filter Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design flow rate (SQDF)	cfs	See Section 2 and Appendix E for calculating SQDF.
Swale Geometry	-	Trapezoidal
Minimum bottom width	feet	2
Maximum bottom width	feet	10; if greater than 10 must use swale dividers; with dividers, max is 16
Minimum length	feet	sufficient length to provide minimum contact time
Minimum slope in flow direction	%	0.2 (provide underdrains for slopes less < 0.5%)
Maximum slope in flow direction	%	2.0 (provide grade-control checks for slopes > 2.0)
Maximum flow velocity	ft/sec	1.0 (water quality treatment); 3.0 (flood conveyance)
Maximum depth of flow for water quality treatment	inches	3 to 5 (1 inch below top of grass)
Minimum residence (contact) time	minutes	7 (provide sufficient length to yield minimum residence time)
Vegetation type	--	Varies (see vegetation section below); Native and drought tolerant plants are recommended
Vegetation height	inches	4 to 6 (trim or mow to maintain height)

Sizing Criteria

The flow capacity of a vegetated swale is a function of the longitudinal slope (parallel to flow), the resistance to flow (i.e. Manning's roughness), and the cross sectional area. The cross section is normally approximately trapezoidal and the area is a function of the bottom width and side slopes. The flow capacity of vegetated swales should be such that the SQDF will not exceed a flow depth of 2/3 the height of the vegetation within the swale or 4 inches at the SQDF. Once design criteria have been selected, the resulting flow depth for the SQDF is checked. If the depth restriction is exceeded, swale parameters (e.g. longitudinal slope, width) are adjusted to reduce the flow depth.

Procedures for sizing vegetated swales are summarized below. A vegetated swale sizing worksheet and example are also provided.

Step 1: Select design flows

The swale sizing is based on the SQDF (see Section 2 and Appendix E).

Step 2: Calculate swale bottom width

The swale bottom width (b) is calculated based on Manning's equation for open-channel flow. This equation can be used to calculate discharges (Q) as follows:

$$Q = \frac{1.49AR^{0.67}S^{0.5}}{n} \qquad \text{(Equation 6-27)}$$

Where:

Q	=	flow rate (cfs)
n	=	Manning's roughness coefficient (unitless)
A	=	cross-sectional area of flow (ft2)
R	=	hydraulic radius (ft) = area divided by wetted perimeter
S	=	longitudinal slope (ft/ft)

For shallow flow depths in swales, channel side slopes are ignored in the calculation of bottom width. Use the following equation (a simplified form of Manning's formula) to estimate the swale bottom width (b):

$$b = \frac{SQDF * n_{wq}}{1.49y^{0.67}s^{0.5}} \qquad \text{(Equation 6-28)}$$

Where:

b	=	bottom width of swale (ft)

$SQDF$	=	stormwater quality design flow (cfs)
n_{wq}	=	Manning's roughness coefficient for shallow flow conditions = 0.2 (unitless)
y	=	design flow depth (ft)
s	=	longitudinal slope (along direction of flow) (ft/ft)

Proceed to Step 3 if the bottom width is calculated to be between 2 and 10 feet. A minimum 2-foot bottom width is required. Therefore, if the calculated bottom width is less than 2 feet, increase the width to 2 feet and recalculate the design flow depth y using the Equation 6-18, where $SQDF$, n_{wq}, and s are the same values as used above, but b = 2 feet.

The maximum allowable bottom width is 10 feet. Therefore, if the calculated bottom width exceeds 10 feet, then one of the following steps is necessary to reduce the design bottom width:

1) Increase the longitudinal slope (s) to a maximum of 2 feet in 100 feet (0.02 feet per foot).

2) Increase the design flow depth (y) to a maximum of 4 inches.

3) Place a divider lengthwise along the swale bottom (Figure 6-11) at least three-quarters of the swale length (beginning at the inlet), without compromising the design flow depth and swale lateral slope requirements. The swale width can be increased to an absolute maximum of 16 feet if a divider is provided.

Step 3: Determine design flow velocity

To calculate the design flow velocity (V_{wq}) through the swale, use the flow continuity equation:

$$V_{wq} = SQDF/A_{wq} \qquad \text{(Equation 6-29)}$$

Where:

V_{wq}	=	design flow velocity (fps)
$SQDF$	=	stormwater quality design flow (cfs)
A_{wq}	=	$by + Zy^2$ = cross-sectional area (ft^2) of flow at design depth, where Z = side slope length per unit height (e.g., Z = 3 if side slopes are 3H:1V)

If the design flow velocity exceeds 1 foot per second, go back to Step 2 and modify one or more of the design parameters (longitudinal slope, bottom width, or flow depth) to

reduce the design flow velocity to 1 foot per second or less. If the design flow velocity is calculated to be less than 1 foot per second, proceed to Step 4. *Note: It is desirable to have the design velocity as low as possible, both to improve treatment effectiveness and to reduce swale length requirements.*

Step 4: Calculate swale length

Use the following equation to determine the necessary swale length (L) to achieve a hydraulic residence time of at least 7 minutes:

$$L = 60 t_{hr} V_{wq} \qquad \text{(Equation 6-30)}$$

Where:

L	=	minimum allowable swale length (ft)
t_{hr}	=	hydraulic residence time (min)
V_{wq}	=	design flow velocity (fps), calculated by Equation 6-19

If there is adequate space on the site to accommodate a larger swale, consider using a greater length to increase the hydraulic residence time and improve the swale's pollutant removal capability. If the calculated length is too long for the site, or if it would cause layout problems, such as encroachment into shaded areas, proceed to Step 5 to further modify the layout. If the swale length can be accommodated on the site (meandering may help), proceed to Step 6.

Step 5: Adjust swale layout to fit on site

If the swale length calculated in Step 4 is too long for the site, the length can be reduced (to a minimum of 100 feet) by increasing the bottom width up to a maximum of 16 feet, as long as the 10 minute retention time is retained. However, the length cannot be increased in order to reduce the bottom width because Manning's depth-velocity-flow rate relationships would not be preserved. If the bottom width is increased to greater than 10 feet, a low flow dividing berm is needed to split the swale cross section in half to prevent channelization.

Length can be adjusted by calculating the top area of the swale and providing an equivalent top area with the adjusted dimensions.

1) Calculate the swale treatment top area (A_{top}), based on the swale length calculated in Step 4:

$$A_{top} = (b_i + b_{slope}) L_i \qquad \text{(Equation 6-31)}$$

Where:

A_{top}	=	top area (ft^2) at the design treatment depth
b_i	=	bottom width (ft), calculated in Step 2 using Equation 6-18
b_{slope}	=	the additional top width (ft) above the side slope for the design water depth (for 3:1 side slopes and a 4-inch water depth, b_{slope} = 2 feet)
L_i	=	initial length (ft) calculated in Step 4 using Equation 6-30

2) Use the swale top area and a reduced swale length (L_f) to increase the bottom width, using the following equation:

$$L_f = A_{top} / (b_f + b_{slope}) \qquad \text{(Equation 6-32)}$$

Where:

L_f	=	reduced swale length (ft)
b_f	=	increased bottom width (ft)

3) Recalculate V_{wq} according to Step 3 using the revised cross-sectional area A_{wq} based on the increased bottom width (b_f). Revise the design as necessary if the design flow velocity exceeds 1 foot per second.

4) Recalculate to ensure that the 10 minute retention time is retained.

Step 6: Provide conveyance capacity for flows higher than SQDF

Vegetated swales may be designed as flow-through channels that convey flows higher than the SQDF, or they may be designed to incorporate a high-flow bypass upstream of the swale inlet. A high-flow bypass usually results in a smaller swale size. If a high-flow bypass is provided, this step is not needed. If no high-flow bypass is provided, proceed with the procedure below. A flow splitter structure design is described in Appendix F.

1) Check the swale size to determine whether the swale can convey the flood control design storm peak flow (Refer to Ventura County Hydrology Manual, revised 2006).

2) The peak flow velocity of the flood control design storm (see Ventura County Hydrology Manual revised 2006) should be less than 3.0 feet per second. If this velocity exceeds 3.0 feet per second, return to Step 2 and increase the bottom width or flatten the longitudinal slope as necessary to reduce the flood control design storm peak flow velocity to 3.0 feet per second or less. If the longitudinal slope is flattened, the swale bottom width must be recalculated (Step 2) and must meet all design criteria.

Geometry and Size

1) In general, a trapezoidal channel shape should be assumed for sizing calculations above, but a more naturalistic channel cross-section is preferred.

2) Swales designed for water quality treatment purposes only are usually fairly shallow, generally less than 1 ft. Therefore, a side slope of 2:1 (H:V) can be used and is acceptable.

3) Swales shall be greater than 100 feet in length. The vegetated swale can be shorter than 100 feet if it is used for pretreatment only (i.e., prior to infiltration). Length can be increased by meandering the swale.

4) The minimum swale bottom width shall be 2 feet to allow for ease of mowing.

5) The maximum swale bottom width shall be limited to 10 feet, unless a swale divider is provided, then the maximum bottom width can be a maximum of 16 feet wide. The swale width is calculated without the swale diving berm. *The intention is that experience shows that when the width exceeds about 10 feet, it is difficult to keep the water from concentrating in low flow channels. It is also difficult to construct the bottom level without sloping to one side. Vegetated swales are best constructed by leveling the bottom after excavating. A single-width pass with a front-end loader produces a better result than a multiple-width pass.*

6) Swales that are required to convey flood flow as well as the SQDF should be sized to convey the flood control design storm and include a provision of freeboard as required by the local approval authority.

7) Gradual meandering bends in the swale are desirable for aesthetic purposes and to promote slower flow.

Bottom Slope

1) The longitudinal slope (along the direction of flow) should be between 1% and 6%.

2) If longitudinal slopes are less than 1.5% and the soils are poorly drained (e.g., silts and clays), then underdrains should be provided. A soils report to verify soils properties should be provided for swales less than 1.5%.

3) If longitudinal slope exceeds 2%, check dams with vertical drops of 12 inches or less should be provided to achieve a bottom slope of 2% or less between the drop structures.

4) The lateral (horizontal) slope at the bottom of the swale should be zero (flat) to discourage channeling.

Water Depth and Dry Weather Flow Drain

1) Water depth should not exceed 4 inches (or 2/3 of the expected vegetation height), except for frequently mowed turf swales, in which the depth should not exceed 2 inches.

2) The swale length must provide a minimum hydraulic residence time of 7 minutes.

3) A low flow drain should be provided if the potential for dry weather flows exists. The low flow drain should extend the entire length of the swale. The drain should have a minimum depth of 6 inches, and a width no more than 5% of the calculated swale bottom width. The width of the drain should be in addition to the required bottom width. The flow spreader at the swale inlet should have v-notches (maximum top width = 5% of swale width) or holes to allow preferential exit of low flows into the drain, if applicable. If an underdrain or gravel drainage layer is installed as discussed below, the low flow drain should be omitted.

Swale Inflow and Design Capacity

1) Whenever possible, inflow should be directed towards the upstream end of the swale and should, at a minimum, occur evenly over the length of the swale. Swale inflow design should provide for positive drainage into the swale to function on the long-term with minimal maintenance.

2) On-line vegetated swales should be designed to convey flow rates up to the post-development peak stormwater runoff discharge rate (flow rate) for the 100-yr 24-hour storm event, with appropriate freeboard (see Ventura County Hydrology Manual, revised 2006).

3) Off-line vegetated swales should be designed to convey the flow-based SQDF by using a flow diversion structure (e.g., flow splitter) which diverts the SQDF to the off-line vegetated swale designed to handle SQDF. Freeboard for off-line swales is not required, but should be provided if space is available. Flow splitter design specifications are described in Appendix F.

Energy Dissipation

1) Vegetated swales may be designed either on-line or off-line. If the facility is on-line, velocities should be maintained below the maximum design flow velocity of 3 feet per second to prevent scour and resuspension of deposited sediments.

2) The maximum flow velocity under the stormwater quality design flow rate should not exceed 1.0 foot per second. *The intention is that this maximum SQDV promotes settling and keeps vegetation upright.*

3) This velocity limitation combined with a maximum depth of 4 inches and bottom width of 10 feet results in a recommended maximum flow capacity of about 3.3 cfs,

after accounting for the side slopes. The contributory drainage area to each swale is limited so as not to exceed this recommended maximum flow capacity.

4) The maximum flow velocity during the 100-yr 24-hr storm event should not exceed 3.0 foot per second. This can be accomplished by:

    a. Splitting roadside swales near high points in the road so that flows drain in opposite directions, mimicking flow patterns on the road surface.

    b. Limiting tributary areas to long swales by diverting flows throughout the length of the swale at regular intervals, to the downstream stormwater conveyance system.

5) A flow spreader (see "Flow Spreaders" below) should be used at the inlet so that the entrance velocity is quickly dissipated and the flow is uniformly distributed across the whole swale. Energy dissipation controls should be constructed of sound materials such as stones, concrete, or proprietary devices that are rated to withstand the energy of the influent flows.

6) If check dams are used to reduce the longitudinal slope, a flow spreader should be provided at the toe of each vertical drop, with specifications described below.

7) If flow is to be introduced through curb cuts, place pavement approximately one inch above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging.

Flow Spreaders

1) An anchored plate flow spreader or similar device should be provided at the inlet to the swale. Equivalent methods for spreading flows evenly throughout the width of the swale are acceptable.

2) The top surface of the flow spreader plate should be level, projecting a minimum of 2 inches above the ground surface of the water quality facility, or v-notched with notches 6 to 10 inches on center and 1 to 4 inches deep (use shallower notches with closer spacing).

3) A flow spreader plate should extend horizontally beyond the bottom width of the facility to prevent water from eroding the side slope. The plate should have a row of horizontal perforations at its base to prevent ponding for long durations. The horizontal extent should be such that the bank is protected for all flows up to the 100-yr 24-hr storm event (on-line swales) or the maximum flow that will enter the water quality facility (off-line swales).

4) Flow spreader plates should be securely fixed in place.

5) Flow spreader plates may be made of either concrete, stainless steel, or other durable material.

6) Anchor posts should be 4-inch square concrete, tubular stainless steel, or other material resistant to decay.

Check Dams

If check dams are required, they can be designed using a number of different materials, including riprap, earthen berms, or removal stop logs. Where vegetated swales parallel urban streets, the check dam can double as a crossing walk so that pedestrians have a pathway from the parked car to the building.

Check dams must be placed as to achieve the desired slope (1 to 6%) at a maximum of 50 feet apart. Check dams should be no higher than 12 inches. If riprap is used, the material should consist of well-graded stone consisting of a mixture of rock sizes. The following is an example of an acceptable gradation:

Particle Size	% Passing
24 inch	100
15 inch	75
9 inch	50
4 inch	10

Underdrains

If underdrains (not to be confused with a dry weather flow drain) are required, then they should meet the following criteria:

1) Underdrains should be made of slotted, polyvinyl chloride (PVC) pipe (PVC SDR 35 or approved equivalent). *The intention is that in comparison to round-hole perforated pipe, slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.*

2) Slotted pipe should have 2 to 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots should be 0.04 to 0.1 inch and should have a length of 1 to 1.25 inches. Slots should be longitudinally spaced such that the pipe has a minimum of one square inch of opening per linear foot of pipe.

3) Underdrains should be sloped at a minimum of 0.5%.

4) The underdrain pipe should be 6 inches or greater in diameter, so it can be cleaned without damage to the pipe. Clean-out risers with diameters equal to the underdrain pipe should be placed at the terminal ends of the underdrain and can be incorporated into the flow spreader and outlet structure to minimize maintenance obstacles in the swale. Intermediate clean-out risers may also be placed in the check dams or grade control structures. The cleanout risers should be capped with a lockable screw cap.

5) The underdrain should be placed parallel to the swale bottom and backfilled and underbedded with six inches of drain rock. The following coarse aggregate should be used to provide a gravel blanket and bedding for the underdrain pipe to provide a 1 foot minimum depth around the top and sides of the slotted pipe.

Sieve size	Percent Passing
¾ inch	100
¼ inch	30-60
US No. 8	20-50
US No. 50	3-12
US No. 200	0-1

6) At the option of the designer/geotechnical engineer, the drain rock may be wrapped in a geotextile fabric meeting the following minimum materials requirements. If a geotextile fabric is used, it should pass 75 gal/min/ft^2, should not impede the infiltration rate of the soil medium, and should meet the following minimum materials requirements.

Geotextile Property	Value	Test Method
Trapezoidal Tear (lbs)	40 (min)	ASTM D4533
Permeability (cm/sec)	0.2 (min)	ASTM D4491
AOS (sieve size)	#60 - #70 (min)	ASTM D4751
Ultraviolet resistance	70% or greater	ASTM D4355

Preferably, aggregate should be used in place of geotextile fabric to reduce the potential for clogging. This aggregate layer should consist of 2 to 4 inches of washed sand underlain with 2 inches of choking stone (Typically #8 or #89 washed).

7) The underdrain should drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to another bioretention cell as part of a connected treatment system, daylight to a vegetated dispersion area using an effective flow dispersion device, stored for rainwater harvesting, or to a storm drain.

Gravel Drainage Layer

To increase volume reduction and if soil conditions allow (infiltration rate > 0.5 in/hr), omit the low flow drain or underdrain and install an appropriately sized gravel drainage layer (typically a washed 57 stone) beneath the swale to achieve desired volume reduction goals. Where slopes are greater than 1%, the gravel drainage layer should be installed in combination with check dams (e.g., drop structures) to slow the flow in the swale and allow for infiltration into the gravel drainage layer and then into the subsurface. The base of the drainage layer should have zero slope. The drawdown time in the gravel drainage layer should not exceed 72 hours. The soil and gravel layers should

be separated with a geotextile filter fabric or a thin, 2 to 4 inch layer of pure sand and a thin layer (nominally two inches) of choking stone (such as #8). Sizing of the gravel drainage layer is based on volume reduction requirements.

Swale Divider

1) If a swale divider is used, the divider should be constructed of a firm material that will resist weathering and not erode, such as concrete, plastic, or compacted soil seeded with grass. Treated timber should not be used. Selection of divider material should take into account maintenance activities, such as mowing.

2) The divider should have a minimum height of 1 inch greater than the stormwater quality design water depth.

3) Earthen berms should be no steeper than 2H:1V.

4) Material other than earth should be embedded to a depth sufficient to be stable.

Soils

Swale soils should be amended with 2 inches of compost, unless the organic content is already greater than 10%. The compost should be mixed into the native soils to a depth of 6 inches to prevent soil layering and washout of compost. The compost will contain no sawdust, green or under-composted material, or any other toxic or harmful substance. It should contain no un-sterilized manure, which can lead to high levels of pathogen indictors (coliform bacteria) in the runoff.

Vegetation

Swales must be vegetated in order to provide adequate treatment of runoff via filtration. Vegetation, when chosen and maintained appropriately, also improves the aesthetics of a site. It is important to maximize water contact with vegetation and the soil surface.

1) The swale area should be appropriately vegetated with a mix of erosion-resistant plant species that effectively bind the soil. A diverse selection of low growing plants that thrive under the specific site, climatic, and watering conditions should be specified. A mixture of dry-area and wet-area grass species that can continue to grow through silt deposits is most effective. Native or adapted grasses are preferred because they generally require less fertilizer, limited maintenance, and are more drought-resistant than exotic plants. When appropriate, swales that are integrated within a project may use turf or other more intensive landscaping, while swales that are located on the project perimeter, within a park, or close to an open space area are encouraged to be planted with a more naturalistic plant palette.

2) Trees or shrubs may be used in the landscape as long as they do not over-shade the turf.

3) Above the design treatment elevation, a typical lawn mix or landscape plants can be used provided they do not shade the swale vegetation.

4) Irrigation is required if the seed is planted in the spring or summer. Use of a permanent irrigation system may help provide maximal water quality performance. Drought-tolerant grasses should be specified to minimize irrigation requirements.

5) Vegetative cover should be at least 4 inches in height, ideally 6 inches. Swale water depth should ideally be 2/3 of the height of the shortest plant species.

6) Locate the swale in an area without excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants should be used.

7) Locate the swale away from large trees that may drop excessive leaves or needles, which may smother the grass or impede the flow through the swale. Landscape planter beds should be designed and located so that soil does not erode from the beds and enter a nearby swale.

Maintenance Access

1) Access to the swale inlet and outlet should be safely provided, with ample room for maintenance and operational activities.

Operations and Maintenance

1) Inspect vegetated swales for erosion or damage to vegetation after every storm greater than 0.75 inches for on-line swales and at least twice annually for off-line swales, preferably at the end of the wet season to schedule summer maintenance and in the fall to ensure readiness for winter. Additional inspection after periods of heavy runoff is recommended. Each swale should be checked for debris and litter and areas of sediment accumulation (see Appendix I for a vegetated swale inspection and maintenance checklist).

2) Swale inlets (curb cuts or pipes) should maintain a calm flow of water entering the swale. Remove sediment as needed at the inlet, if vegetation growth is inhibited in greater than 10% of the swale or if the sediment is blocking even distribution and entry of the water. Following sediment removal activities, replanting and/or reseeding of vegetation may be required for reestablishment.

3) Flow spreaders should provide even dispersion of flows across the swale. Sediments and debris should be removed from the flow spreader if blocking flows. Splash pads should be repaired if needed to prevent erosion. Spreader level should be checked and releveled if necessary.

4) Side slopes should be maintained to prevent erosion that introduces sediment into the swale. Slopes should be stabilized and planted using appropriate erosion control measures when native soil is exposed or erosion channels are formed.

5) Swales should drain within 48 hours of the end of a storm. Till the swale if compaction or clogging occurs and revegetate. If a perforated underdrain pipe is present, it should be cleaned if necessary.

6) Vegetation should be healthy and dense enough to provide filtering, while protecting underlying soils from erosion:

   - Mulch should be replenished as needed to ensure survival of vegetation.
   - Vegetation, large shrubs or trees that interfere with landscape swale operation should be pruned.
   - Fallen leaves and debris from deciduous plant foliage should be removed.
   - Grassy swales should be mowed to 4 to 6 inches height. Grass clippings should be removed.
   - Invasive vegetation, such as Alligatorweed (*Alternanthera philoxeroides*), Halogeton (*Halogeton glomeratus*), Spotted Knapweed (*Centaurea maculosa*), Giant Reed (*Arundo donax*), Castor Bean (*Ricinus communis*), Perennial Pepperweed (*Lepidium latifolium*), and Yellow Starthistle (*Centaurea solstitalis*) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 10% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.
   - Dead vegetation should be removed if greater than 10% of area coverage or when swale function is impaired. Vegetation should be replaced and established before the wet season to maintain cover density and control erosion where soils are exposed.

7) Check dams (if present) should control and distribute flow across the swale. Causes for altered water flow and/or channelization should be identified and obstructions cleared. Check dams and swale should be repaired if damaged.

8) The vegetated swale should be well maintained. Trash and debris, sediment, visual contamination (e.g., oils), noxious or nuisance weeds, should all be removed.

BIO-4: Vegetated Filter Strip

Filter strips are vegetated areas designed to treat sheet flow runoff from adjacent impervious surfaces or intensive landscaped areas such as golf courses. Filter strips decrease runoff velocity, filter out total suspended solids and associated pollutants, and provide some infiltration into underlying soils. While some assimilation of dissolved constituents may occur, filter strips are generally more effective in trapping sediment and particulate-bound metals, nutrients, and pesticides. Filter strips are more effective when the runoff passes through the vegetation and thatch layer in the form of shallow, uniform flow. Biological and chemical processes may help break down pesticides, uptake metals, and use nutrients that are trapped in the filter.

Vegetated filter strip captures runoff from freeway

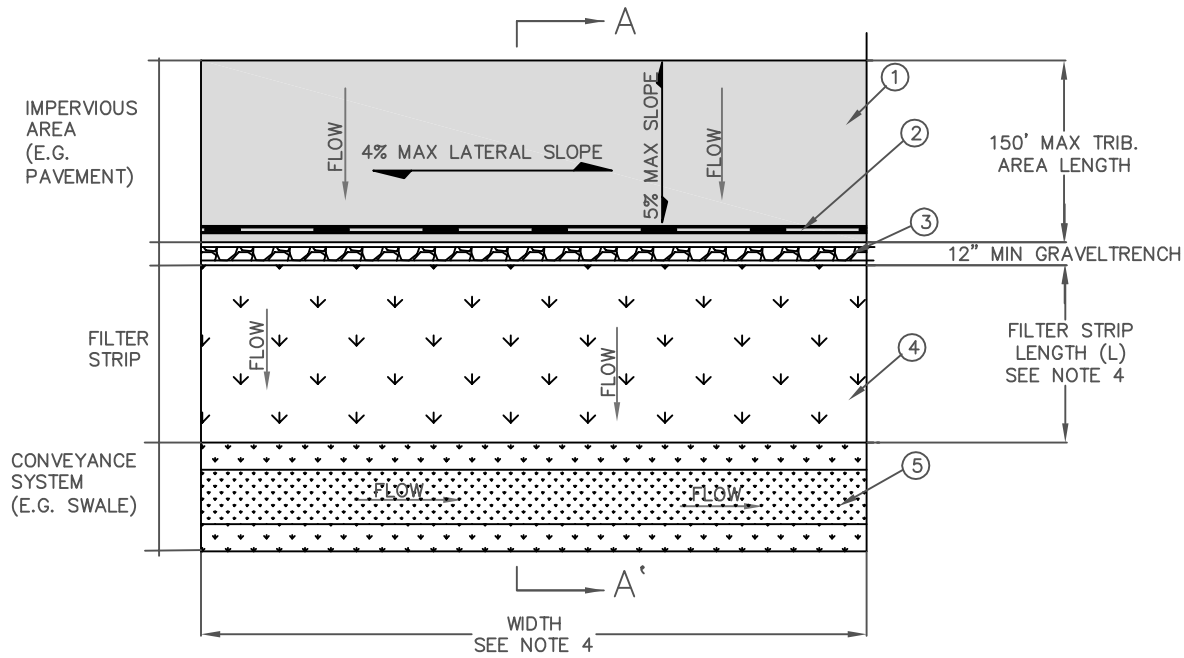
Photo Credit: Washington Department of Transportation

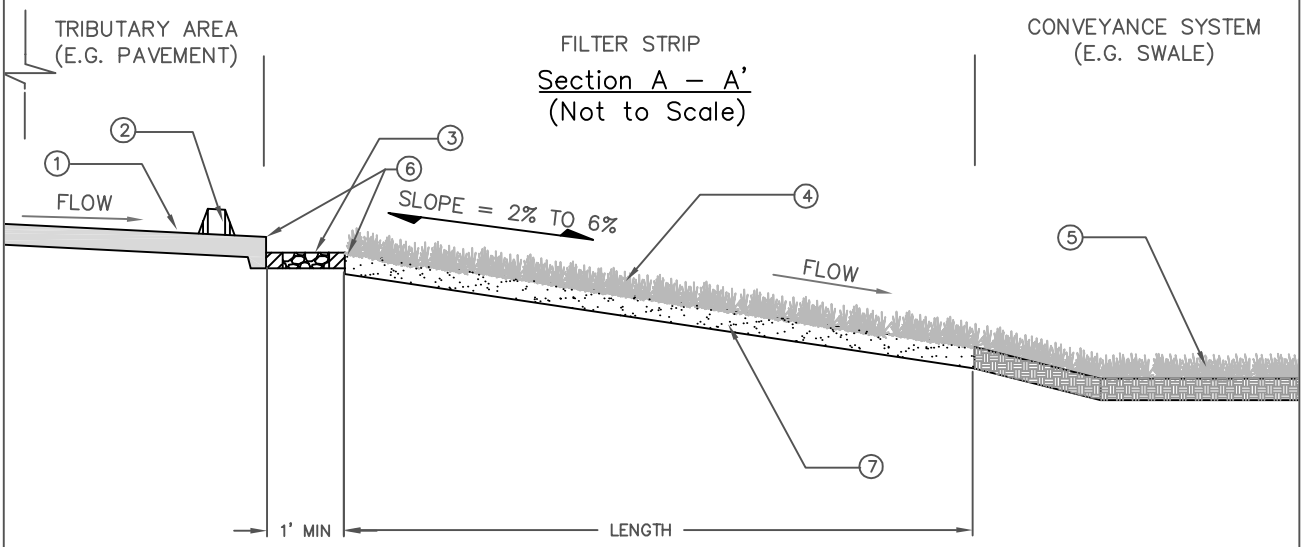
Applications

- Areas adjacent to parking lots and driveways
- Road medians and shoulders

Preventative Maintenance

- Remove excess sediment
- Stabilize/repair minor erosion and scouring
- Remove trash and debris
- Mow regularly





NOTES:

1. MAXIMUM LENGTH OF IMPERVIOUS TRIBUTARY AREA (PER UNIT WIDTH OF FILTER STRIP) SHALL BE 150'.
2. OPTIONAL NOTCHED CURB SPREADERS MAY BE USED IN CONJUNCTION WITH GRAVEL FLOW SPREADER.
3. GRAVEL FLOW SPREADER 6" DEEP BY 12" WIDE MIN SHALL BE PROVIDED.
4. VEGETATED FILTER STRIP SURFACE. SLOPE SHALL BE BETWEEN 2–4%. LENGTH OF STRIP MUST BE BETWEEN 15' AND 150'. WIDTH MUST BE EQUAL OR GREATER THAN THE WIDTH OF THE TRIBUTARY AREA.
5. INSTALL SWALE OR OTHER CONVEYANCE SYSTEM DOWNSTREAM OF FILTER STRIP.
6. TOP OF FILTER STRIP SHALL BE >1" BELOW TOP OF ADJACENT PAVEMENT.
7. AMEND SOILS WITH 2" OF COMPOST TILLED INTO 6" OF NATIVE SOIL UNLESS NATIVE SOIL ORGANIC CONTENT > 10%.

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Figure 6-13: Vegetated Filter Strip

Limitations

The following describes limitations for vegetated filter strips:

- High flow velocity - steep terrain and/or large tributary area may cause concentrated, erosive flows.
- Sheet flow - shallow, evenly-distributed flow across the entire width of the filter strip is required. Filter strips are designed to treat small areas. The maximum flow path from a contributing impervious surface should not exceed 150 feet. Flows should enter as sheet flow and not exceed a depth of 1 inch.
- Shallow grades – a limited site slope may cause ponding.
- Availability of pervious area adjacent to impervious area - filter strips require sheet flow from impervious areas.

Design Criteria

The main challenge associated with filter strips is maintaining sheet flow, which is critical to the performance of this BMP. If flows are concentrated, then little or no treatment of stormwater runoff is achieved and erosive rilling is likely. The use of a flow spreading device (e.g., gravel trench or level spreader) to deliver shallow, evenly-distributed sheet flow to the strip is required. Vegetated filter strips should be designed according to the requirements listed in Table 6-21 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-21: Vegetated Filter Strip Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design flow (SQDF)	cfs	See Section 2 and Appendix E for calculating SQDF.
Maximum design flow depth	inches	1
Design residence time	minutes	7
Design flow velocity	ft/sec	< 1 ft/sec
Minimum length in flow direction	feet	15 (25 preferred); If sized for pretreatment only, filter strip can be a minimum of 4.
Maximum length (parallel to flow) of tributary area per unit width (perpendicular to flow) of filter strip	feet	150
Minimum slope in flow direction	%	2

Design Parameter	Unit	Design Criteria
Maximum slope in flow direction	%	4
Maximum lateral slope	%	4
Vegetation	-	Turf grass (irrigated) or approved equal
Minimum grass height	inches	2
Maximum grass height	inches	4 (typical) or as required to prevent shading
Elevation of flow spreader	inches	> 1 inch below the pavement surface

Sizing Criteria

The flow capacity of a vegetated filter strips (filter strips) is a function of the longitudinal slope (parallel to flow), the resistance to flow (e.g., Manning's roughness), and the width and length of the filter strip. The slope should be shallow enough to ensure that the depth of water will not exceed 1 inch over the filter strip. Similarly, the flow velocity should be less than 1 ft/sec. Procedures for sizing filter strips are summarized below. A filter strip sizing example is also provided.

Step 1: Calculate the design flow rate

The design flow is calculated based on the SQDF (see Section 2).

Step 2: Calculate the minimum width

Determine the minimum width (W_{min}), perpendicular to flow, allowable for the filter strip and design for that width or larger.

$$Wmin = (SQDF) / (qa,min) \qquad \text{(Equation 6-33)}$$

Where

W_{min} = minimum width of filter strip (and tributary area)

$SQDF$ = design flow (cfs)

$q_{a,min}$ = minimum linear unit application rate, 0.005 cfs/ft

Step 3: Calculate the design flow depth

The design flow depth (d_f) is calculated based on the width and the slope, parallel to the flow path, using a modified Manning's equation as follows:

$$d_f = 12 \times [SQDF * n_{wq} / 1.49 W_{trib} s^{0.5}]^{0.6} \qquad \text{(Equation 6-34)}$$

Where:

d_f	=	design flow depth (inches)
$SQDF$	=	design flow (cfs)
W	=	width of strip (perpendicular to flow = width of impervious surface contributing area (ft))
s	=	slope (ft/ft) of strip parallel to flow, average over the whole width
n_{wq}	=	Manning's roughness coefficient (0.25-0.30)

If d_f is greater than 1 inch (0.083 ft), then a shallower slope is required, or a filter strip cannot be used.

Step 4: Calculate the design velocity

The design flow velocity (V_{wq}) is based on the design flow, design flow depth, and width of the strip:

$$Vwq = SQDF / (df\ W) \qquad \text{(Equation 6-35)}$$

Where:

$d_{f,ft}$	=	design flow depth (ft) ($d_f/12$)
$SQDF$	=	stormwater quality design flow (cfs)
W	=	width of strip (perpendicular to flow = width of impervious surface contributing area (ft))

Step 5: Calculate the desired length of the filter strip

Determine the required length (L) to achieve a desired minimum residence time of 7 minutes using:

$$L = 60 t_{hr} * V_{wq} \qquad \text{(Equation 6-36)}$$

Where:

L	=	minimum allowable strip length (ft)
t_{hr}	=	hydraulic residence time (min)
V_{wq}	=	design flow velocity (fps) calculated by Equation 6-35

Geometry and Size

1) The width of the filter strip shall extend across the full width of the tributary area. The upstream boundary of the filter should be located contiguous to the developed tributary area.

2) The length (in direction of flow) should be between 15 and 150 feet. A minimum length of 25 feet is preferred. Filter strips used for pretreatment shall be at least 4 feet long (in direction of flow).

3) Filter strips shall be designed on slopes (parallel to the direction of flow) between 2% and 4%; steeper slopes tend to result in concentrated flow. Slopes less than 2% could pond runoff, and in poorly permeable soils, create a mosquito breeding habitat.

4) The lateral slope of strip (parallel to the edge of the pavement, perpendicular to the direction of flow) should be 4% or less.

5) Grading should be even: a filter strip with uneven grading perpendicular to the flow path will develop flow channels over time.

6) The top of the strip should be installed 2 to 5 inches below the adjacent pavement to allow for vegetation and sediment accumulation at the edge of the strip. A beveled transition is acceptable and may be required per roadside design specifications.

7) Both the top and toe of the slope should be as flat as possible to encourage sheet flow and prevent channeling and erosion. For engineered filter strips, the facility surface should be graded flat prior to placement of vegetation.

Energy Dissipation / Level Spreading

Runoff entering a filter strip must not be concentrated. A flow spreader should be installed at the edge of the pavement to uniformly distribute the flow along the entire width of the filter strip.

1) At a minimum, a gravel flow spreader (gravel-filled trench) should be placed between the impervious area contributing flows and the filter strip, and meet the following requirements:

    a. The gravel flow spreader should be a minimum of 6 inches deep and should be 12 inches wide.

    b. The gravel should be a minimum of 1 inch below the pavement surface. *The intention is that this allows sediment from the paved surface to be accommodated without blocking drainage onto the strip.*

2) The gravel flow spreader should be a minimum of 6 inches deep and should be 12 inches wide.

a. Where the ground surface is not level, the gravel spreader must be installed so that the bottom of the gravel trench and the outlet lip are level.

b. Along roadways, gravel flow spreaders must be placed and designed in accordance with County road design specifications for compacted road shoulders.

3) Curb ports and interrupted curbs may only be used in conjunction with a gravel spreader to better ensure that water sheet flows onto the strip, provided:

a. Curb ports use fabricated openings that allow concrete curbing to be poured or extruded while still providing an opening through the curb to admit water to the filter strip. Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width of the treatment area. Openings or gaps in the curb should be at regular intervals but at least every 6 feet. The width of each opening should be a minimum of 11 inches.

b. At a minimum, gaps should be every 6 feet to allow distribution of flows into the treatment facility before they become too concentrated. The opening should be a minimum of 11 inches. Approximately 15 percent or more of the curb section length should be in open ports, and as a general rule, no opening should discharge more than 10 percent of the overall flow entering the facility.

4) Energy dissipaters are needed in a filter strips if sudden slope drops occur, such as locations where flows in a filter strip pass over a rockery or retaining wall aligned perpendicular to the direction of flow. Adequate energy dissipation at the base of a drop section can be provided by a riprap pad.

Access

1) Access should be provided at the upper edge of a filter strip to enable maintenance of the inflow spreader throughout the strip width and allow access for mowing equipment.

Water Depth and Velocity

1) The design water depth shall not exceed 1 inch.

2) Runoff flow velocities should not exceed approximately 1 foot per second across the filter strip surface.

Soils

Filter strip soils should be amended with 2 inches of compost, unless the organic content is already greater than 10%. The compost should be mixed into the native soils to a depth of 6 inches to prevent soil layering and washout of compost. The compost will contain no sawdust, green or under-composted material, or any other toxic or harmful substance. It

should contain no un-sterilized manure which can lead to high levels of potentially pathogenic bacteria in the runoff.

Vegetation

Filter strips must be uniformly graded and densely vegetated with erosion-resistant grasses that effectively bind the soil. Native or adapted grasses are preferred because they generally require less fertilizer and are more drought-resistant than exotic plants. The following vegetation guidelines should be followed for filter strips:

1) Sod (turf) can be used instead of grass seed, as long as there is complete coverage.

2) Irrigation should be provided to establish the grasses.

3) Grasses or turf should be maintained at a height of 2 to 4 inches. Regular mowing is often required to maintain the turf grass cover.

4) Trees or shrubs should not be used in abundance because they shade the turf and impede sheet flow.

Operations and Maintenance

Filter strips mainly require vegetation management. Therefore little special training is needed for maintenance crews. Typical maintenance activities and frequencies include:

1) Inspect strips at least twice annually for erosion or damage to vegetation, preferably at the end of the wet season to schedule summer maintenance and in the fall to ensure the strip is ready for winter. However, additional inspection after periods of heavy runoff is most desirable. The strip should be checked for debris and litter and areas of sediment accumulation (see Appendix I for a vegetated filter strip inspection and maintenance checklist).

2) Mow as frequently as necessary (at least twice a year) for safety and aesthetics or to suppress weeds and woody vegetation.

3) Trash tends to accumulate in strip areas, particularly along roadways. The need for litter removal should be determined through periodic inspection. Litter should always be removed prior to mowing.

4) Regularly inspect vegetated buffer strips for pools of standing water. Vegetated filter strips can become a nuisance due to mosquito breeding in level spreaders (unless designed to dewater completely in less than 72 hours), in pools of standing water if obstructions develop (e.g. debris accumulation, invasive vegetation), and/or if proper drainage slopes are not implemented and maintained.

5) Activities that lead to ruts or depressions on the surface of the filter strip should be prevented or the integrity of the strip should be restored by leveling and reseeding. Examples are vehicle tracks, utility maintenance, and pedestrian (short-cut) tracks.

6) Vegetation should be healthy and dense enough to provide filtering, while protecting underlying soils from erosion:

- Mulch should be replenished as needed to ensure survival of vegetation.
- Vegetation, large shrubs or trees that interfere with landscape swale operation should be pruned.
- Fallen leaves and debris from deciduous plant foliage should be removed.
- Filter strips should be mowed to 4 to 6 inches height. Grass clippings should be removed.
- Invasive vegetation, such as Alligatorweed (*Alternanthera philoxeroides*), Halogeton (*Halogeton glomeratus*), Spotted Knapweed (*Centaurea maculosa*), Giant Reed (*Arundo donax*), Castor Bean (*Ricinus communis*), Perennial Pepperweed (*Lepidium latifolium*), and Yellow Starthistle (*Centaurea solstitalis*) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 10% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.
- Dead vegetation should be removed if greater than 10% of area coverage or when filter strip function is impaired. Vegetation should be replaced and established before the wet season to maintain cover density and control erosion where soils are exposed.

BIO-5: Proprietary Biotreatment

Proprietary biotreatment devices are manufactured treatment BMPs that incorporate plants, soil, and microbes engineered to provide treatment at higher flow rates or volumes and with smaller footprints than their non-proprietary counterparts. Incoming flows are typically pretreated to remove larger particles/debris, filtered through a planting media (mulch, compost, soil, and plants), collected by an underdrain, and delivered to the stormwater conveyance system.

Proprietary Biotreatment Examples

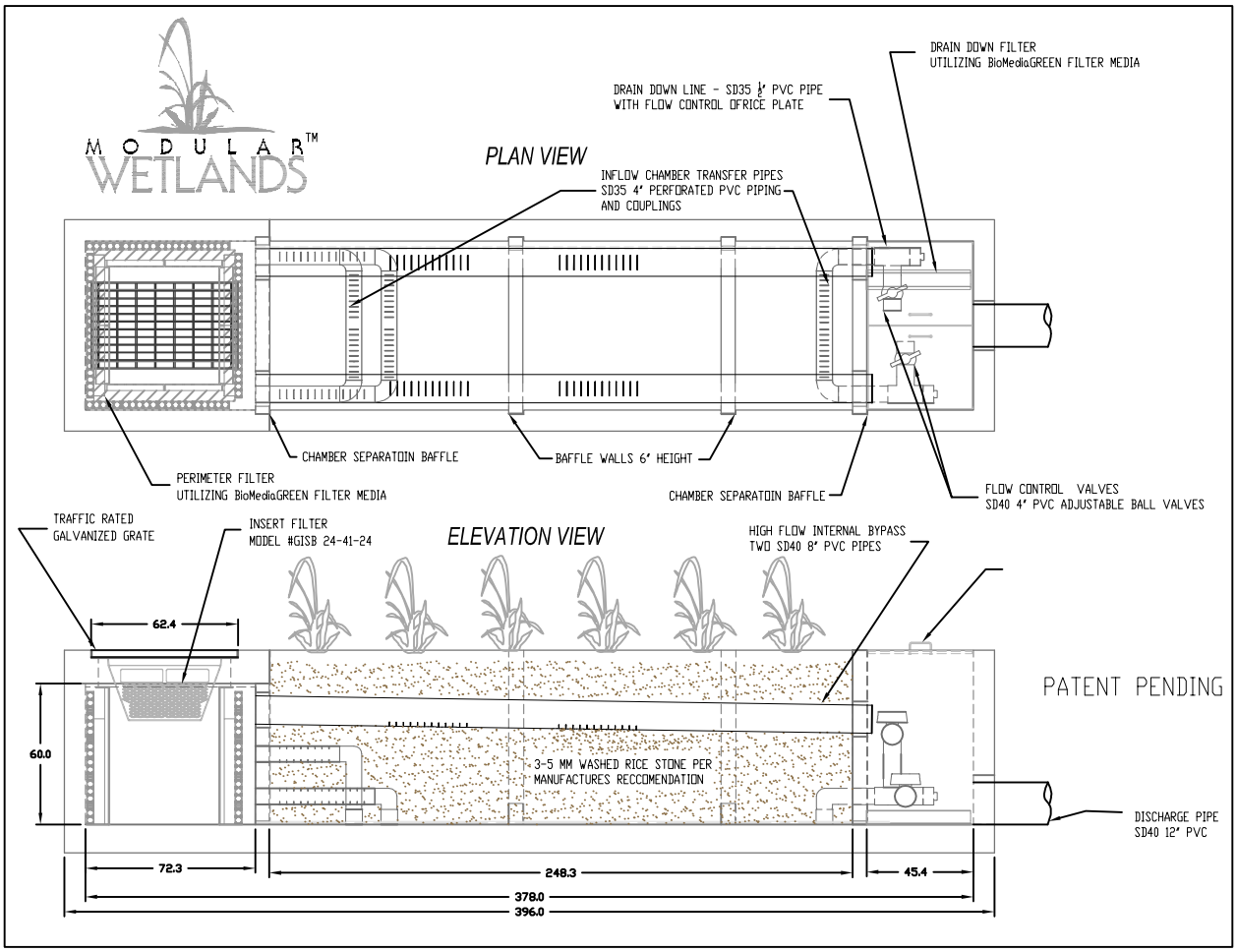
Photo Credits: 1. Filterra®; 2. Stormtreat™

Application

- Parking lot islands
- Pickup/drop off turnarounds
- Roadway curbs

Maintenance

- Filter media replacement
- Sediment, trash, and debris removal
- Mulch replacement
- Vegetation upkeep and replacement



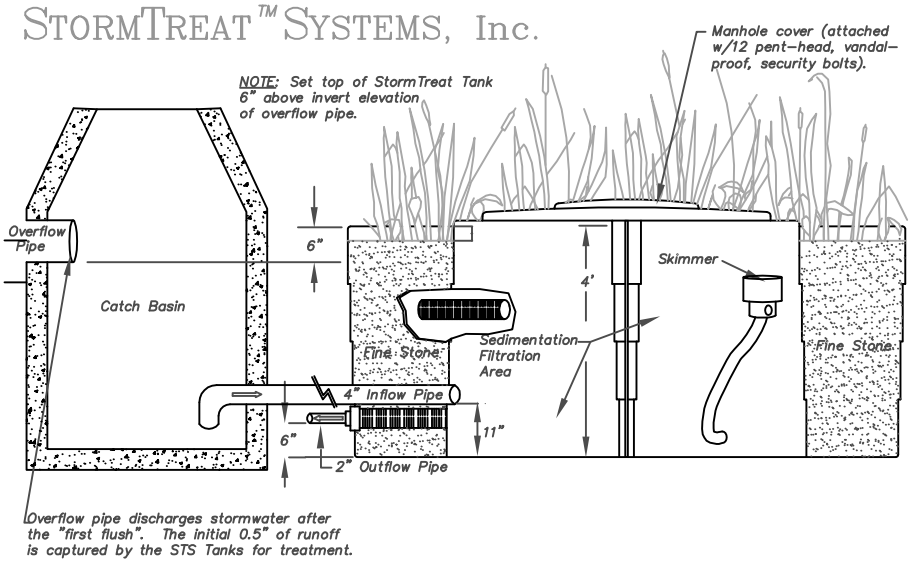


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Figure 6-14: Biotreatment Device

Table 6-22: Proprietary Biotreatment Device Manufacturer Websites

Device	Manufacturer	Website
DeepRoot® Silva Cell	DeepRoot® Urban Landscape Products	www.deeproot.com
Filterra®	Filterra® Bioretention Systems	www.filterra.com
Modular Wetlands (MWS-LINEAR)	Modular Wetlands Systems Inc.	www.modularwetlands.com
StormTreat™	StormTreat Systems Inc.	www.stormtreat.com
UrbanGreen BioFilter	Contech® Construction Products Inc.	www.contech-cpi.com/stormwater/13

Design Criteria

As proprietary biotreatment BMP vendors are constantly updating and expanding their product lines, refer to the specific vendor for the latest design and sizing guidance.

TCM-1: Dry Extended Detention Basin

Dry extended detention (ED) basins are basins whose outlets have been designed to detain the SQDV for 36 to 48 hours to allow sediment particles and associated pollutants to settle and be removed. Dry ED basins do not have a permanent pool. They are designed to drain completely between storm events. They can also be used to provide hydromodification and/or flood control by modifying the outlet control structure and providing additional detention storage. The slopes, bottom, and forebay of dry ED basins are typically vegetated. Without the addition of a sand filter beneath the basin, considerable stormwater volume reduction can still occur, depending on the infiltration capacity of the subsoil.

Extended Detention Basin Application

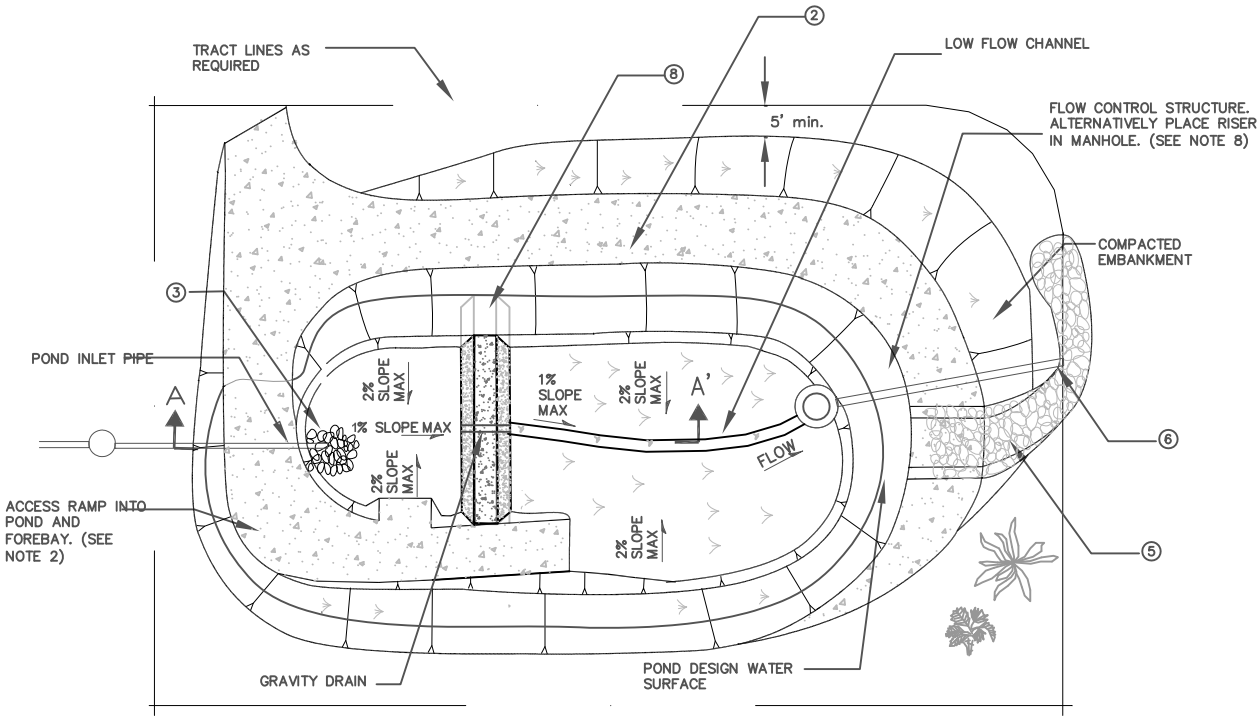
Photo Credit: Geosyntec Consultants

Application

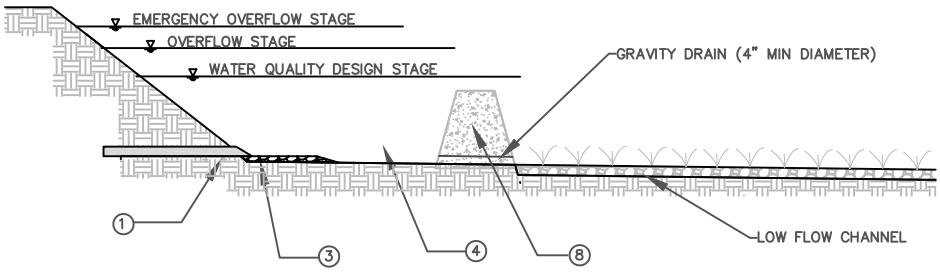
- Adjacent to parking lots
- Road medians and shoulders
- Within open areas or play fields

Preventative Maintenance

- Remove trash and debris, minor sediment accumulation, and obstructions near inlet and outlet structures
- Replace top 2 to 4 inch of sand
- Mow or weed surface of filter



Plan View
(Not to Scale)



Section A – A'
(Not to Scale)

NOTES:

1. INLET PIPE SHALL BE DESIGNED AND LOCATED SO THAT NON-EROSIVE VELOCITIES OCCUR IN THE FOREBAY
2. MAINTENANCE RAMP SHOULD PROVIDE ACCESS TO BOTH THE FOREBAY AND MAIN BASIN.
3. RIP RAP APRON OR OTHER INLET ENERGY DISSIPATION SHALL BE PROVIDED SUCH THAT VELOCITIES IN THE FOREBAY ARE < 4 FT/S.
4. SEDIMENT FOREBAY SHOULD BE SIZED TO PROVIDE 5–15% OF THE TOTAL BASIN VOLUME.
5. EMERGENCY SPILLWAY MUST BE SIZED TO PASS 100-YEAR PEAK FLOW FOR ON-LINE BASINS, AND WATER QUALITY DESIGN FLOW FOR OFF-LINE BASINS.
6. OUTLET PIPE. ENERGY DISSIPATION SHALL BE PROVIDED UNLESS DISCHARGE IS TO PIPE OR HARDENED CHANNEL.
7. OUTLET STRUCTURE SHOULD BE SIZED TO DRAIN WATER QUALITY VOLUME IN 36 – 48 HOURS (SEE FIGURE 2-2 FOR PERFORATED RISER DETAILS). ALTERNATIVELY PLACE RISER STRUCTURE IN A MANHOLE (SEE FIGURE 2-3).
8. INSTALL EARTHEN BERM OR EQUIVALENT. TOP OF BERM SHALL BE 2' MINIMUM BELOW DESIGN WATER QUALITY STAGE. BERM SHALL BE KEYED INTO EMBANKMENT A MINIMUM OF 1' ON BOTH SIDES.

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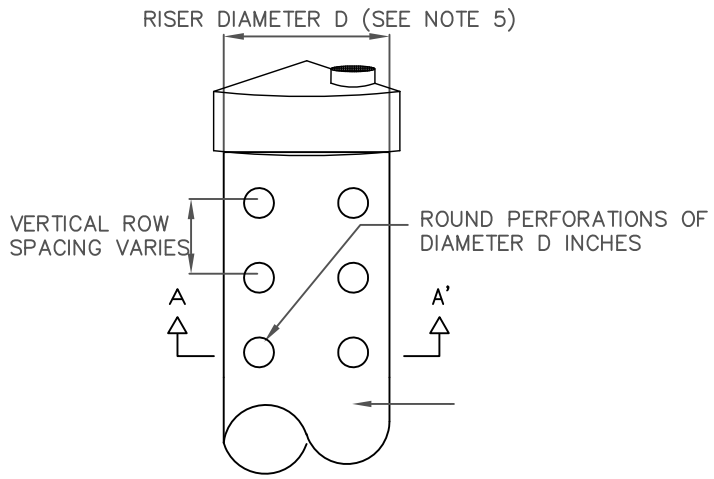
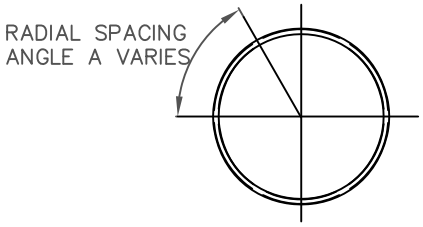
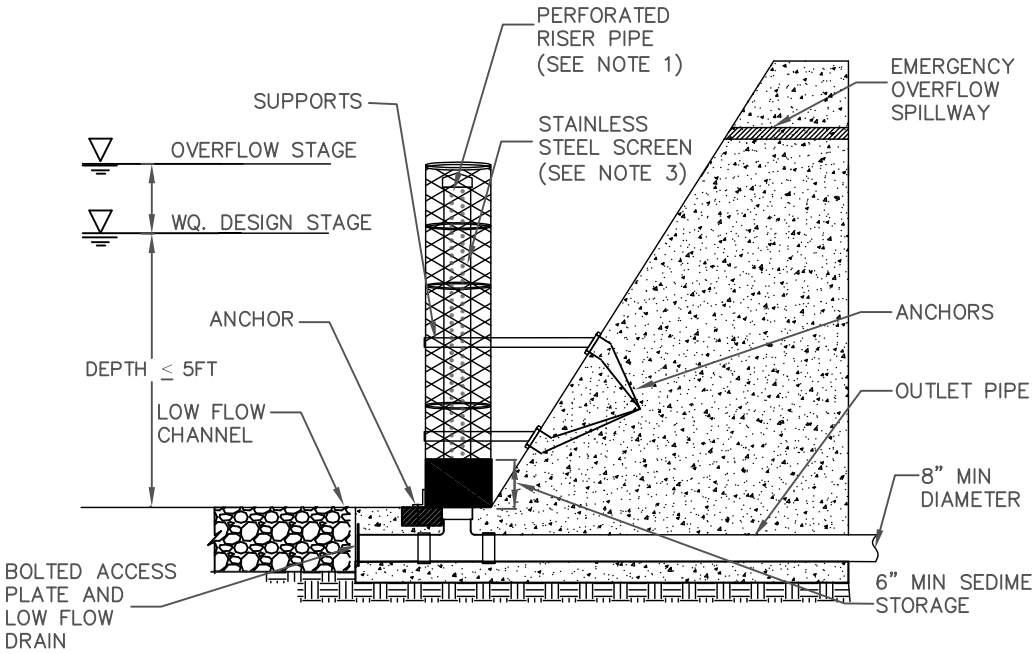
Figure 6-15: Extended Detention Basin



Perforated Riser Detail
(Not to Scale)



Section A – A'
(Not to Scale)



Perforated Riser Outlet Structure
(Not to Scale)

NOTES:

1. RISER PIPE SHALL BE SIZED TO PROVIDE 36 TO 48–HOUR FULL BRIM DRAW DOWN TIME.
2. TOTAL OUTLET CAPACITY: 100–YEAR PEAK FLOW FOR ON–LINE BASINS AND WATER QUALITY DESIGN FLOW FOR OFF–LINE BASINS.
3. SCREEN OPENINGS SHALL BE AT LEAST ¼" AND SHALL NOT EXCEED THE DIAMETER OF THE PERFORATIONS ON THE RISER.
4. RISER PIPE PERFORATION DIAMETER SHALL BE NO LESS THAN ½" AND NO MORE THAN 2"
5. MINIMUM PIPE DIAMETER (D) IS 2'
6. RISER PIPE MATERIAL IS CMP

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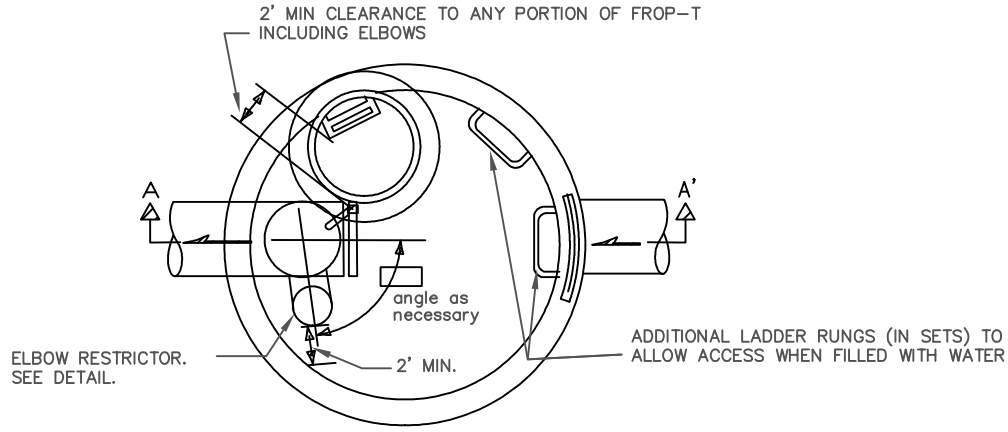
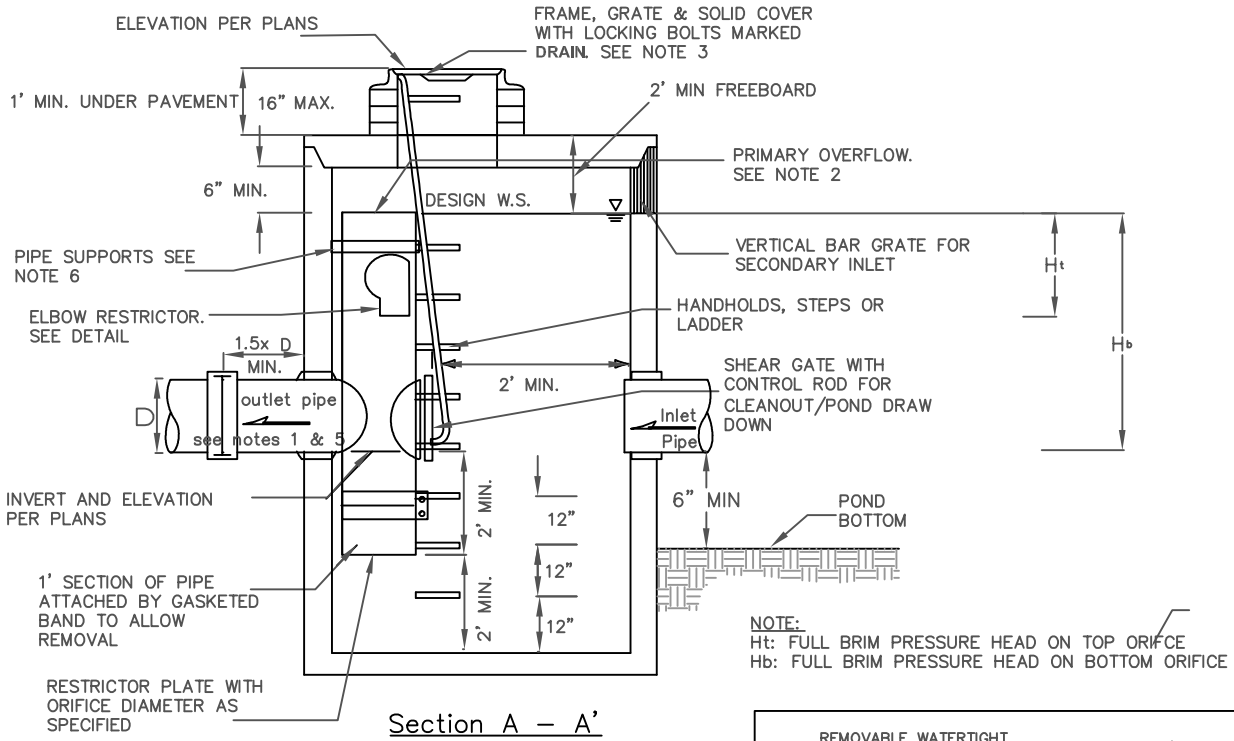
Figure 6-16: Perforated Riser Outlet

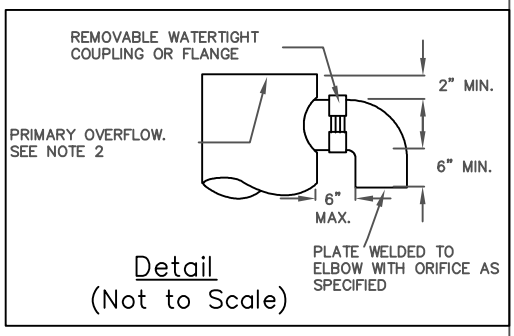


Plan View
(Not to Scale)



NOTE:
Ht: FULL BRIM PRESSURE HEAD ON TOP ORIFCE
Hb: FULL BRIM PRESSURE HEAD ON BOTTOM ORIFICE

Section A – A'
(Not to Scale)



Detail
(Not to Scale)

NOTES:

1. USE A MINIMUM OF A 54" DIA TYPE 2 CATCH BASIN
2. OUTLET CAPACITY: 100-YEAR PEAK FLOW FOR ON-LINE BASINS.
3. METAL PARTS: CORROSION RESISTANT. NON-GALVANIZED PARTS PERFERRED. GALVANIZED PIPE PARTS TO HAVE ASPHALT TREATMENT.
4. FRAME AND LADDER OR STEPS OFFSET SO:
   A. CLEANOUT GATE IS VISIBLE FROM TOP.
   B. CLIMB-DOWN SPACE IS CLEAR OF RISER AND
   C. FRAME IS CLEAR OF CURB.
5. IF METAL OUTLET PIPE CONNECTS TO CEMENT CONCRETE PIPE: OUTLET PIPE TO HAVE SMOOTH O.D. EQUAL TO CONCRETE PIPE I.D. LESS ¼"
6. PROVIDE AT LEAST ONE 3 X .090 GAGE SUPPORT BRACKET ANCHORED TO CONCRETE WALL. (MAXIMUM 3' VERTICAL SPACING)
7. LOCATE ADDITIONAL LADDER RUNGS IN STRUCTURES USED AS ACCESS TO TANKS OR VAULTS TO ALLOW ACCESS WHEN CATCH BASIN IS FILLED WITH WATER

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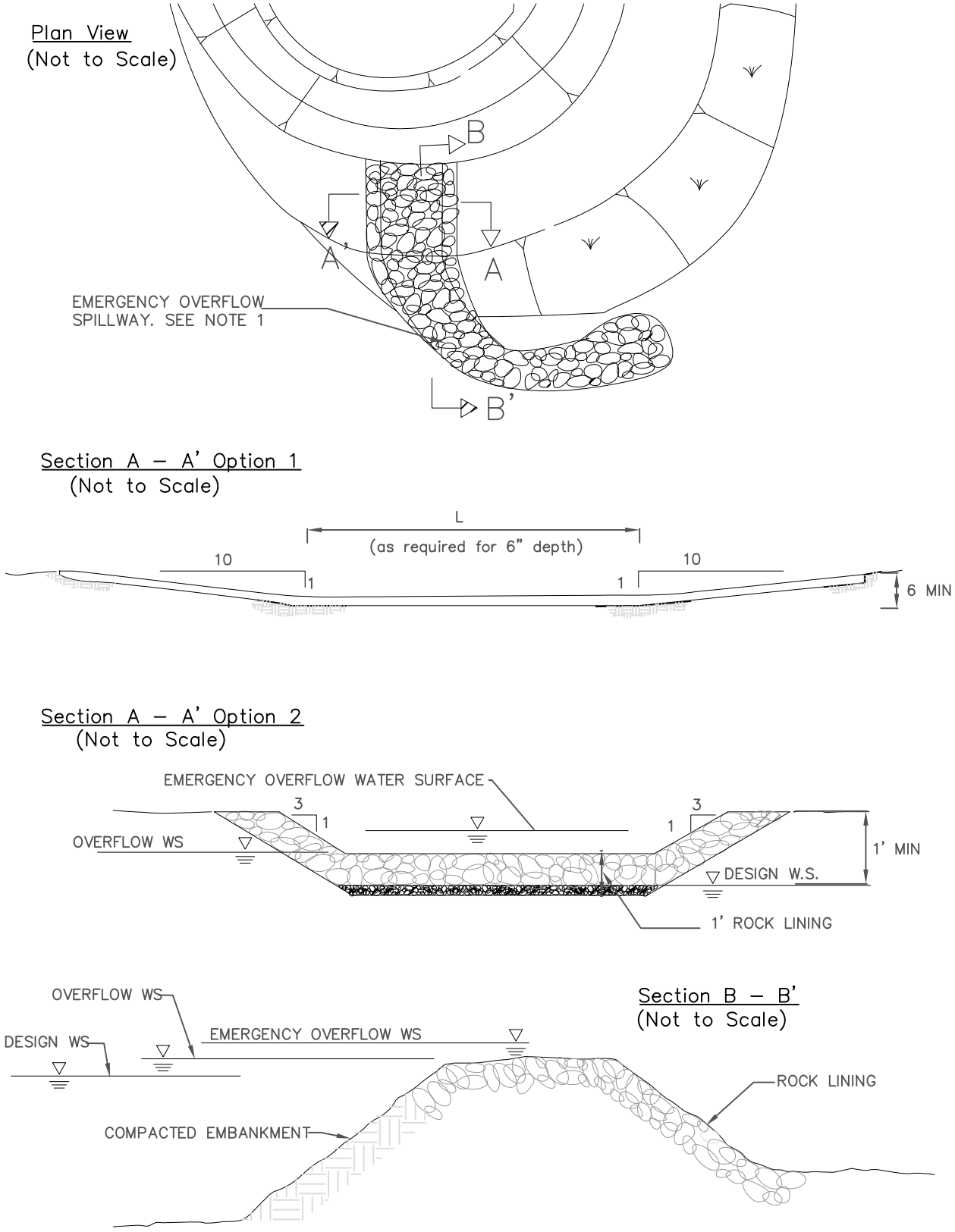
Figure 6-17: Multiple Orifice Outlet



NOTES:

1. ALTERNATIVE SPILLWAY DESIGNS BASED ON THE CALIFORNIA DEPARTMENT OF WATER RESOURCES' GUIDELINES FOR THE DESIGN AND CONSTRUCTION OF SMALL EMBANKMENT DAMS OR AT THE DISCRETION OF THE DEPARTMENT

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Figure 6-18: Spillway

Limitations

Limitations for dry extended detention basins include:

- Surface space availability - typically 0.5 to 2.0 percent of the total tributary development area required.
- Depth to groundwater - bottom of basin should be 2 feet higher than the seasonal high water table elevation.
- Steep slopes - basins placed above slopes greater than 15 percent or within 200 feet from the top of a hazardous slope or landslide area require a geotechnical investigation.
- Compatibility with flood control - basins must not interfere with flood control functions of existing conveyance and detention structures.

Design Criteria

Dry extended detention basins should be designed according to the requirements listed in Table 6-23 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-23: Dry Extended Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume (SQDV)	acre-feet	See Section 2 and Appendix E for calculating SQDV
Drawdown time for SQDV	hours	Top 50%: 12 hrs (minimum); Bottom 50%: 36 hrs
Basin Design Volume	acre-ft	1.2 * SQDV
Forebay basin size	acre-feet	5 to 15% of SQDV
Maximum forebay drain time	min	45
Low–flow channel depth	inches	9
Low-flow channel flow capacity		2*forebay outlet rate
Freeboard (minimum)	inches	12
Flow path length to width ratio	L:W	2:1, larger preferred; can be achieved using internal berms
Longitudinal slope	percentage	1 (forebay) and 0-2 (main basin)
Low flow channel geometry	feet	depth of 0.5 and width of 1
Minimum outflow device diameter	inches	18

Sizing Criteria

Dry extended detention (ED) basins are basins designed such that the SQDV is detained for 48 hours. This allows sediment particles and associated pollutants to settle and be removed from the stormwater. Procedures for sizing extended detention basins are summarized below. A sizing example is also provided.

Step 1: Calculate the design volume

Dry extended detention facilities shall be sized to capture and treat the SQDV (see Section E.1).

Step 2: Calculate the volume of the active basin

The total basin volume should be increased an additional 20% above the SQDV to account for sediment accumulation, at a minimum. If the basin is designed only for water quality treatment then the basin volume would be 120% of the SQDV. Freeboard is in additional to the total basin volume. Calculate the volume of the active basin (ft^2) (V_a):

$$V_a = 1.20*SQDV \qquad \text{(Equation 6-37)}$$

Step 3: Determine detention basin location and preliminary geometry based on site constraints

Based on site constraints, determine the basin geometry (area and length) and the storage available by developing an elevation-storage relationship for the basin. The cross-sectional geometry across the width of the basin should be approximately trapezoidal. Shallow side slopes are necessary if the basin is designed to have recreational uses during dry weather conditions.

1) Calculate the width of the basin footprint (W_{tot}) as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}} \qquad \text{(Equation 6-38)}$$

Where:

A_{tot} = total surface area of the basin footprint (ft^2)

L_{tot} = total length of the basin footprint (ft)

2) Calculate the length of the active volume surface area including the internal berm but excluding the freeboard, ($L_{av\text{-}tot}$):

$$L_{av-tot} = L_{tot} - 2Zd_{fb} \qquad \text{(Equation 6-39)}$$

Where:

Z = interior side slope as length per unit height (H:V)

d_{fb} = freeboard depth (ft)

3) Calculate the width of the active volume surface area including the internal berm but excluding freeboard (ft), ($W_{av\text{-}tot}$):

$$W_{av-tot} = W_{tot} - 2Zd_{fb} \quad \text{(Equation 6-40)}$$

4) Calculate the total active volume surface area including the internal berm and excluding freeboard, ($A_{av\text{-}tot}$):

$$A_{av-tot} = L_{av-tot} \times W_{av-tot} \quad \text{(Equation 6-41)}$$

5) Calculate the area of the berm, (A_{berm}):

$$A_{berm} = W_{berm} \times L_{berm} \quad \text{(Equation 6-4243)}$$

Where:

W_{berm} = width of the internal berm

L_{berm} = length of the internal berm (= width excluding freeboard, $W_{av\text{-}tot}$)

6) Calculate the surface area excluding the internal berm and freeboard, A_{av}:

$$A_{av} = A_{av=tot} - A_{berm} \quad \text{(Equation 6-44)}$$

Step 4: Determine Dimensions of Forebay

The forebay should be sized to at least 5 to 15% of the basin active volume (V_a). Calculate the active volume of the forebay, (V_1):

$$V_1 = \frac{V_a \times \%V_1}{100} \quad \text{(Equation 6-45)}$$

Where:

$\%V_1$ = percent of V_a in forebay (%)

V_a = total active volume (ft^3)

7) Calculate the surface area for the active volume of forebay (A_1):

$$A_1 = \frac{V_1}{d_1} \quad \text{(Equation 6-46)}$$

Where:

d_1 = average depth for the forebay (ft)

8) Calculate the length of forebay, (L_1):

$$L_1 = \frac{A_1}{W_1} \qquad \text{(Equation 6-47)}$$

Where:

W_1 = width of forebay (ft)

Step 5: Determine Dimensions of Cell 2

Cell 2 will consist of the remainder of the basin's active volume.

1) Calculate the active volume of Cell 2, (V_2):

$$V_2 = V_a - V_1 \qquad \text{(Equation 6-48)}$$

Where:

V_a = total basin active volume (ft^3)

V_1 = volume of forebay (ft^3)

2) Calculate the surface area, A_2, for the active volume of Cell 2:

$$A_2 = A_{av} - A_1 \qquad \text{(Equation 6-49)}$$

Where:

A_{av} = basin surface area excluding berm and freeboard (ft^2)

A_1 = surface area of forebay (ft^2)

3) Calculate the average depth (d_2) for the active volume of Cell 2:

$$d_2 = \frac{V_2}{A_2} \qquad \text{(Equation 6-50)}$$

4) Calculate the length of Cell 2, (L_2):

$$L_2 = \frac{A_2}{W_2} \qquad \text{(Equation 6-51)}$$

Where:

W_2 = width of Cell 2 (ft)

5) Verify that the length-to-width ratio of Cell 2 at half of d_2 is at least 1.5:1 with ≥2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the basin should be chosen. Calculate the length-to width (LW_{mid2}) ratio of Cell 2 at half of d_2 follows:

$$LW_{mid2} = \frac{L_{mid2}}{W_{mid2}} \qquad \text{(Equation 6-52)}$$

Where:

W_{mid2} = $W_2 - Zd_2$ (Equation 6-53)

L_{mid2} = $L_2 - Zd_2$ (Equation 6-54)

W_{mid2} = width of Cell 2 at half of d_2 (ft)

L_{mid2} = length of Cell 2 at half of d_2 (ft)

Z = interior side slope as length per unit height (H:V)

d_2 = cell 2 average depth (ft)

Step 6: Ensure Design Requirements and Site Constraints are achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or alternative treatment BMP.

Step 7: Size Outlet Structure

The total drawdown time for the basin should be 48 hours. The outlet structure should be designed to release the bottom 50% of the detention volume (half-full to empty) over 36 hours, and the top half (full to half-full) in 12 hours. A primary overflow should be sized to pass the peak flow rate from the developed capital design storm. See Section 6 for outlet structure sizing methodologies.

Step 8: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak stormwater runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency

spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Sizing and Geometry

1) The total basin volume should be increased an additional 20% of the SQDV to account for sediment accumulation, at a minimum. If the basin is designed only for water quality treatment then the basin volume would be 120% of the SQDV. Freeboard is in addition to the total basin volume.

2) The minimum freeboard should be at least 1 foot above the emergency overflow water surface for dry extended detention basins.

3) The minimum flow-path length to width ratio at half basin height should be a minimum of 3:1 (L:W) and can be achieved using internal berms or other means to prevent short-circuiting. Intent: a long flow length will improve fine sediment removal.

4) The cross-sectional geometry across the width of the basin should be approximately trapezoidal. Shallow side slopes are necessary if the basin is designed to have recreational uses during dry weather conditions.

5) All dry ED basins should be free draining and a low flow channel should be provided. A low flow channel is a narrow, shallow trench filled with pea gravel and encased with filter fabric that runs the length of the basin to drain dry weather flows. The low flow channel should be of sufficient size considering the natural characteristics of the soil and have a positive-draining gradient flowing toward the outlet structure (typically 1 ft wide by 6 inches deep). If infiltration rates of subsurface soils are insufficient, the low flow channel should tie into perforated pipe at the outlet structure. If a sand filter or planting media is provided beneath the dry ED basin for increased volume reduction, it may be designed to take the place of the low flow channel.

6) The basin bottom should have a 1% longitudinal slope (direction of flow) in the forebay, and may range from 0 to 2% longitudinal slope in the main basin. The bottom of the basin should slope 2% toward the center low flow channel.

7) A basin should be large enough to allow for equipment access via a graded ramp.

Soils Considerations

1) The slopes of the detention basin should be analyzed for slope stability using rapid drawdown conditions and should meet the minimum standards set by the Ventura County Flood Control District. A 1.5 static factor of safety should be used. Seismic analysis is not required due to the temporary storage of water in the basin.

2) The infiltration capability of the dry ED basin can be enhanced by incorporating soil amendments.

Energy Dissipation

1) Energy dissipation controls constructed of sound materials such as stones, concrete, or proprietary devices that are rated to withstand the energy of the influent flow should be installed at the inlet to the sediment forebay. Flow velocity into the basin forebay should be controlled to 4 feet per second (ft/sec) or less.

2) Energy dissipation controls must also be used at the outlet/spillway from the detention basin unless the basin discharges to a storm drain or hardened channel.

Sediment Forebay

As untreated stormwater enters the dry ED basin, it passes through a sediment forebay for coarse solids removal. The forebay may be constructed using an internal berm constructed out of earthen embankment material, grouted riprap, stop logs, or other structurally sound material.

1) The basin should be sized so that 5 to 15% of the total basin volume is in the forebay and 85 to 95% of the total basin volume is in the main portion of the basin.

2) A gravity drain outlet from the forebay (2 inch minimum diameter) should extend the entire width of the internal berm and be designed to completely drain to the main basin within 10 minutes.

3) The forebay outlet should be offset (horizontally) from the inflow streamline to prevent short-circuiting.

4) Permanent steel post depth markers should be placed in the forebay to define sediment removal limits at 50% of the forebay sediment storage depth.

Vegetation

Vegetation within the dry ED basin provides erosion protection from wind and water and biofiltration of stormwater. The local permitting authority should review and approve any proposed basin landscape plan prior to implementation and following guidelines should be followed:

1) The bottom and slopes of the dry ED basin should be vegetated. A mix of erosion-resistant plant species that effectively bind the soil should be used on the slopes and a diverse selection of plants that thrive under the specific site, climatic, and watering conditions should be specified for the basin bottom. The basin bottom should not be planted with trees, shrubs, or other large woody plants that may interfere with sediment removal activities. The basin should be free of floating objects. Only native perennial grasses, forbs, or similar vegetation that can be replaced via seeding should be used on the basin bottom.

    a. Landscaping outside of the basin is required for all dry ED basins and should adhere to the following criteria so as not to hinder maintenance operations:

b. No trees or shrubs may be planted within 15 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, should not be used within 50 feet of pipes or manmade structures. Weeping willow (Salix babylonica) should not be planted in or near detention basins.

2) Prohibited non-native plant species will not be permitted. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website- or the California Invasive Plant Council website at www.cal-ipc.org.

3) A plant list provided by a landscape professional should be used as a guide only and should not replace project-specific planting recommendations, including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth.

Sand Filter or Planting Media Layer

For increasing the volume reduction capability of a dry ED basin, an appropriately sized sand filter or planting media layer can be placed beneath the dry ED basin to achieve desired volume reduction goals if soil and slope conditions allow (i.e., infiltration rate greater than 0.5 in/hr but less than 2.4 in/hr; site slope less than 15%). The drawdown time of the sand filter or planting media layer should be less than 72 hours. The base of the sand filter or planting media layer should be level (i.e., zero slope). If a sand filter/planting media layer is provided over the length of the basin, it can take the place of the low-flow channel so long as it is designed to adequately infiltrate dry weather flows. Sizing of the sand filter and planting media layer for dry ED basins is the same as for sand filters and bioretention areas, respectively. The depth of water in the dry ED basin should not exceed 6 feet.

Outlet Structure and Drawdown Time

A drawdown time of 36 to 48 hours shall be provided for the SQDV. This drawdown time is for the volume in the basin above the sand filter layer (if provided) and serves the purpose of water quality treatment. An outflow device should be designed to release the bottom 50% of the detention volume (half-full to empty) over 24 to 32 hours, and the top half (full to half-full) in 12 to 16 hours. *The intention is that the drawdown schemes that detain low flows for longer periods than high flows have the following advantages over outlets that drain the basin evenly:*

- Greater flood control capabilities
- Enhanced treatment of low flows which make up the bulk of incoming flows.

Additional storage, detention, and outlet control is required to achieve pre-development stormwater runoff discharge rates for hydromodification control. The outlet structure

can be designed to achieve flow control for meeting the multiple objectives of water quality and flow attenuation.

The outflow device (i.e., outlet pipe) should be oversized (18 inch minimum diameter). There are two options that can be used for the outlet structure:

1) Uniformly perforated riser structures.

2) Multiple orifice structures (orifice plate).

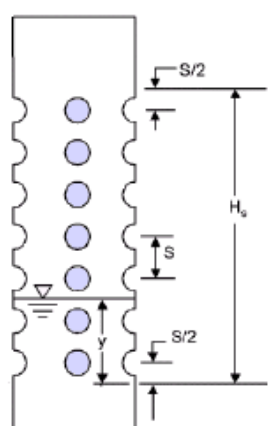
The outlet structure can be placed in the basin with a debris screen (Figure 6-15) or housed in a standard manhole (Figure 6-16). If a multiple orifice structure is used, an orifice restriction (if necessary) should be used to limit orifice outflow to the maximum discharge rates allowable for achieving the desired water quality and flow control objectives. Orifice restriction plates should be removable for emergency situations. A removable trash rack should be provided at the outlet.

Note that a primary overflow (typically a riser pipe connected to the outlet works) should be sized to pass flows larger than the stormwater quality design storm (if the ED basin is sized only for water quality) or to pass flows larger than the peak flow rate of the maximum design storm to be detained in the basin (e.g., 100-yr, 24-hr). The primary overflow is intended to protect against overtopping or breaching of a basin embankment.

Perforated Risers Outlet Sizing Methodology

The following attributes influence the perforated riser outlet sizing calculations**:**

- Shape of the basin (e.g., trapezoidal)
- Depth and volume of the basin
- Elevation / depth of first row of holes
- Elevation / depth of last row of holes
- Size of perforations
- Number of rows or perforations and number of perforations per row
- Desired drawdown time (e.g., 16 hour and 32 hour draw down for top half and bottom half respectively, 48 hour total drawdown time for the stormwater quality design volume)



Perforated Riser Outlet

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The governing rate of discharge from a perforated riser structure can be calculated using Equation 6-44 below:

$$Q = C_p \frac{2A_p}{3H_s}\sqrt{2g}H^{3/2}$$

(Equation 6-55)

Where:

Q	=	riser flow discharge (cfs)
C_p	=	discharge coefficient for perforations (use 0.61)
A_p	=	cross-sectional area of all the holes (ft^2)
s	=	center to center vertical spacing between perforations (ft)
H_s	=	distance from s/2 below the lowest row of holes to s/2 above the top row of holes (McEnroe 1988).
H	=	effective head on the orifice (measured from center of orifice to water surface)

For the iterative computations needed to size the perforations in the riser and determine the riser height, a simplified version of Equation 6-44 may be used as shown below in Equation 6-45 and Equation 6-46:

$$Q = kH^{3/2}$$

(Equation 6-56)

Where:

H	=	effective head on the orifice (measured from center of orifice to water surface)

$$k = C_p \frac{2A_p}{3H_s}\sqrt{2g}$$

(Equation 6-57)

Where:

C_p	=	discharge coefficient for perforations (use 0.61)
A_p	=	cross-sectional area of all the holes (ft^2)
s	=	center to center vertical spacing between perforations (ft)

H_s	=	distance from s/2 below the lowest row of holes to s/2 above the top row of holes.
g	=	32.17 ft/sec^2

Uniformly perforated riser designs are defined by the depth or elevation of the first row of perforations, the length of the perforated section of pipe, and the size or diameter of each perforation.

Multiple Orifice Outlet Sizing Methodology

The following attributes influence multiple orifice outlet sizing calculations**:**

- Shape of the basin (e.g., trapezoidal)
- Depth and volume of the basin
- Elevation of each orifice
- Desired draw-down time (e.g., 16 hour and 32 hour draw down times for top half and bottom half respectively, 48 hour drawdown time for stormwater quality design volume)

The rate of discharge from a single orifice can be calculated using Equation 6-22.

$$Q = CA(2gH)^{0.5} \qquad \text{(Equation 6-58)}$$

Where:

Q	=	orifice flow discharge
C	=	discharge coefficient
A	=	cross-sectional area of orifice or pipe (ft2)
g	=	acceleration due to gravity (32.2 ft/s2)
H	=	effective head on the orifice (measured from center of orifice to water surface)

Multiple orifice designs are defined by the depth (or elevation) and the size (or diameter) of each orifice. The steps needed to size a dual orifice outlet are outlined in Appendix E; multiple orifices may be provided and sized using a similar approach.

Emergency Spillway

An emergency overflow spillway in addition to the primary overflow outlet (as described above) is required. The emergency spillway should be sized for flows greater than the

peak 100-year 24-hour storm if the basin is designed on-line or, if the basin is designed on-line, the spillway should be sized for flows greater than the basin design volume (e.g., stormwater quality design volume). The spillway should provide for adequate energy dissipation downstream. The spillway should allow for at least 12 inches of freeboard above the emergency overflow water surface elevation if the basin is on-line. If the basin is on-line, 2 feet of freeboard is preferable.

Spillways shall meet the California Department of Water Resources, Division of Safety of Dams Guidelines for the Design and Construction of Small Embankment Dams (http://damsafety.water.ca.gov/docs/GuidelinesSmallDams.pdf). *Intent: Emergency overflow spillways are intended to control the location of basin overtopping and safely direct overflows back into the downstream conveyance system or other acceptable discharge point.*

On-line Basins

1) On-line basins must have an emergency overflow spillway to prevent overtopping of walls or berms should blockage of the primary outlet occur based on a downstream risk assessment.

2) The overflow spillway must be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm.

3) The minimum freeboard should be 1 foot (but preferably at least 2 feet) above the maximum water surface elevation over the emergency spillway.

Off-line Basins

1) Off-line basins must have either an emergency overflow spillway or an emergency overflow riser. The emergency overflow must be designed to pass the 100-yr 24-hr post-development peak stormwater runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

2) The emergency overflow spillway shall be armored to withstand the energy of the spillway flows.

3) The minimum freeboard should be 1 foot above the maximum water surface elevation over the emergency spillway.

Side Slopes

1) Interior side slopes above the stormwater quality design depth and up to the emergency overflow water surface steeper than 4:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

2) Exterior side slopes steeper than 2:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

3) For any slope (interior or exterior) greater than 2:1 (H:V), a geotechnical investigation and report must be submitted and approved by the local permitting authority.

4) Landscaped slopes should be no greater than 3:1 (H:V) to allow for maintenance.

5) Basin walls may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete, (b) a fence is provided along the top of the wall (see fencing below) or further back, and (c) the design is stamped by a licensed civil engineer and approved by the Local permitting authority.

Embankments

1) Earthworks and berm embankments should be performed in accordance with the latest edition of the "Greenbook Standard Specifications for Public Works Construction".

2) Embankments are earthen slopes or berms used for detaining or redirecting the flow of water.

3) Top of berm separating forebay and main basin should be 2 feet minimum below the stormwater quality design water surface and should be keyed into embankment a minimum of 1 foot on both sides.

4) Typically, the top width of berm embankments are at least 20 feet, but narrower embankments may be plausible if approved by the civil engineer and the Local permitting authority.

5) Basin berm embankments should be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil engineer) free of loose surface soil materials, roots, and other organic debris.

6) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

7) Basin berm embankments greater than 4 feet in height should be constructed by excavating a key equal to 50% of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed civil engineer.

8) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

9) Low growing native or non-invasive perennial grasses should be planted on downstream embankment slopes. See vegetation section below.

Fencing

1) Safety is provided either by fencing of the facility or by managing the contours of the basin to eliminate drop-offs and other hazards.

2) If fences are required, fences should be designed and constructed in accordance with relevant standards and should typically be located at or above the overflow water surface elevation. Shrubs (approved, California-adapted species) can be used to hide the fencing. See vegetation section above.

Right-of-Way

1) Dry extended detention basins and associated access roads to be maintained by a public agency should be dedicated in fee or in an easement to the public agency with appropriate access.

Maintenance Access

1) Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement with the Local permitting authority is required to ensure adequate performance and allow emergency access to the facilities.

2) Maintenance access road(s) should be provided to the control structure and other drainage structures associated with the basin (e.g., inlet, emergency overflow or bypass structures). Manhole and catch basin lids should be in or at the edge of the access road.

3) A ramp into the basin should be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp should extend to the basin bottom to avoid damage to vegetation planted on the basin slope.

4) All access ramps and roads should be provided in accordance with the current policies of the Ventura County Flood Control District or local approval authority.

Construction Considerations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited.

Operations and Maintenance

Maintenance is of primary importance if extended detention basins are to continue to function as originally designed. A maintenance agreement must be developed with the local approval authority to ensure adequate performance and allow emergency access. Maintenance of the basin is the responsibility of the development, unless otherwise agreed upon.

A specific maintenance plan shall be formulated for each facility outlining the schedule and scope of maintenance operations, as well as the data handling and reporting requirements. The following are general maintenance requirements:

1) The basin should be inspected semiannually or more frequently, and inspections after major storm events are encouraged (see Appendix I for guidance on facility maintenance inspections). Trash and debris should be removed as needed, but at least annually prior to the beginning of the wet season (see Appendix I for dry extended detention basin inspection and maintenance checklist).

2) Site vegetation should be maintained as follows:

   - Vegetation, large shrubs, or trees that limit access or interfere with basin operation should be pruned or removed.
   - Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.
   - Grass should be mowed to 4 to 9 inch high and grass clippings should be removed.
   - Fallen leaves and debris from deciduous plant foliage should be raked and removed.
   - Invasive vegetation, such as Alligatorweed (Alternanthera philoxeroides), Halogeton (Halogeton glomeratus), Spotted Knapweed (Centaurea maculosa), Giant Reed (Arundo donax), Castor Bean (Ricinus communis), Perennial Pepperweed (Lepidium latifolium), and Yellow Starthistle (Centaurea solstitalis) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 25% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.
   - Dead vegetation should be removed if it exceeds 10% of area coverage. Vegetation should be replaced immediately to maintain cover density and control erosion where soils are exposed.
   - No herbicides or other chemicals should be used to control vegetation.

3) Sediment buildup exceeding 50% of the forebay capacity should be removed. Sediment from the remainder of the basin should be removed when 6 inches of sediment accumulates. Sediments should be tested for toxic substance accumulation in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed. If toxic substances are encountered at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations,

the sediment must be disposed of in a hazardous waste landfill. It is recommended to clean the forebay frequently to reduce frequency of main basin cleaning.

4) Remove sediment from basin when accumulation reaches 25% of original design depth. Cleaning is recommended to occur in early spring to allow vegetation to reestablish.

5) Repair erosion to banks and bottom of basin as required.

6) Following sediment removal activities, replanting, and/or reseeding of vegetation may be required for reestablishment.

7) Control vectors as needed.

TCM-2: Wet Detention Basin

Wet detention basins are constructed, naturalistic ponds with a permanent or seasonal pool of water (also called a "wet pool" or "dead storage"). Aquascape facilities, such as artificial lakes, are a special form of wet pool facility that can incorporate innovative design elements to allow them to function as a stormwater treatment facility in addition to an aesthetic water feature. Wetponds require base flows to exceed or match losses through evaporation and/or infiltration and they must be designed with the outlet positioned and/or operated in such a way as to maintain a permanent pool. Wetponds can be designed to provide extended detention of incoming flows using the volume above the permanent pool surface.

Wet Detention Basin

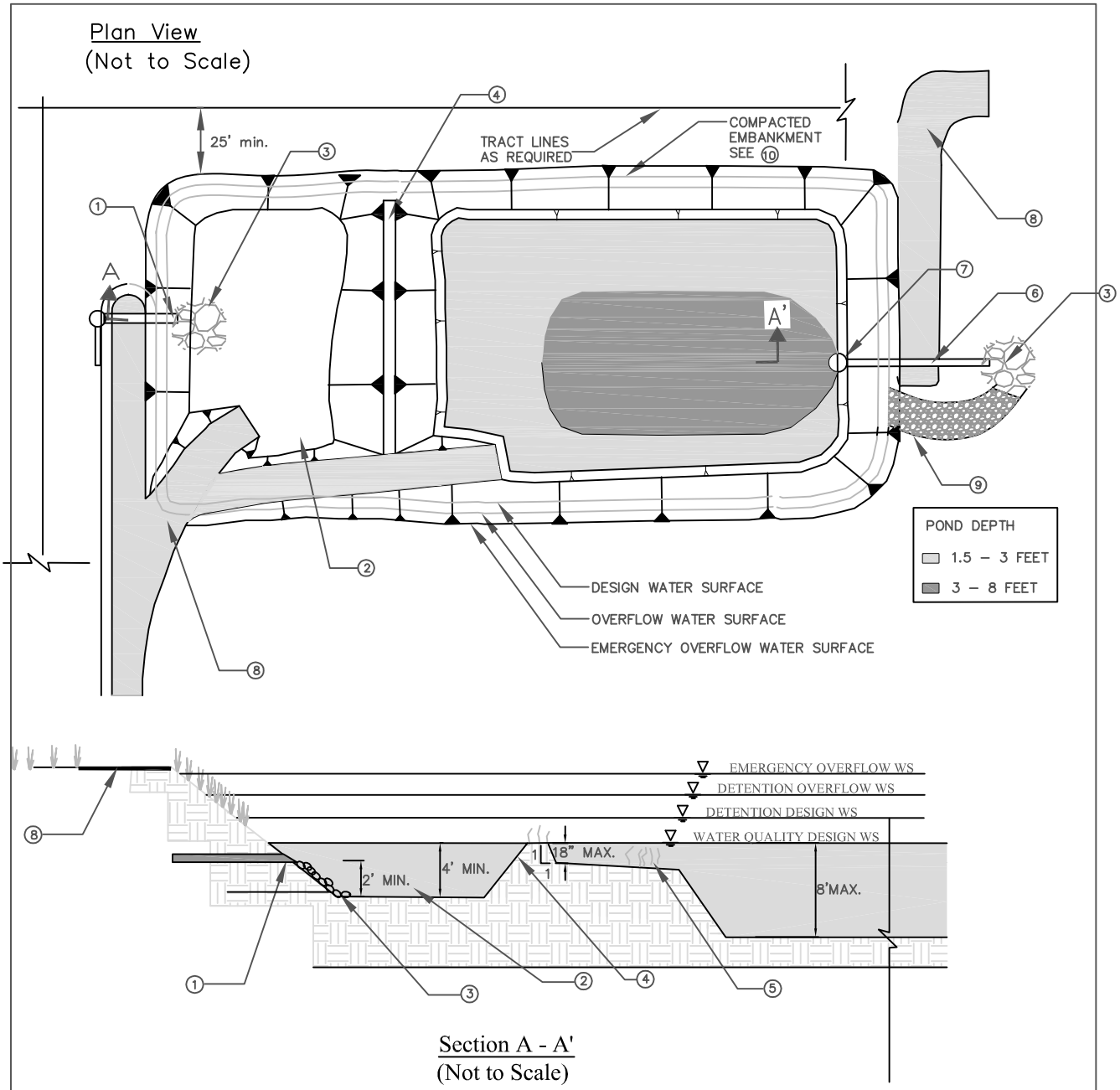
Photo Credit: Geosyntec Consultants

Application

- Regional detention & treatment
- Roads, highways, parking lots, commercial, residential
- Parks, open spaces, and golf courses

Preventative Maintenance

- inspected at a minimum annually and inspections after major storm events
- Pruned or remove vegetation, large shrubs, or trees that limit access or interfere with basin operation
- Remove sediment buildup at inlets and outlets



NOTES:

1. INLET PIPE SHOULD BE SUBMERGED WITH A MINIMUM OF 2' DISTANCE FROM THE BOTTOM
2. FIRST CELL VOLUME SHALL EQUAL 25% TO 35% OF TOTAL WETPOND VOLUME. DEPTH SHALL BE 4' MIN TO 8' MAX PLUS AN ADDITIONAL 1' MIN SEDIMENT STORAGE DEPTH.
3. RIP RAP APRON OR OTHER ENERGY DISSIPATION.
4. BERM SHALL EXTEND ACROSS ENTIRE WIDTH OF THE WETPOND.
5. EMERGENT VEGETATION SHALL BE PLANTED IN REGIONS OF THE POND THAT ARE 3' DEEP OR LESS.
6. SIZE OUTLET PIPE TO PASS 100-YEAR PEAK FLOW FOR ON-LINE PONDS AND WATER QUALITY PEAK FLOW FOR OFF-LINE PONDS.
7. WATER QUALITY OUTLET STRUCTURE. SEE FIGURE 8-2 AND FIGURE 8-3 FOR DETAILS.
8. MAINTENANCE ACCESS ROAD SHOULD PROVIDE ACCESS TO BOTH THE FIRST CELL AND MAIN BASIN.
9. INSTALL EMERGENCY OVERFLOW SPILLWAY AS NEEDED. SEE FIGURE 2-4 FOR DETAILS

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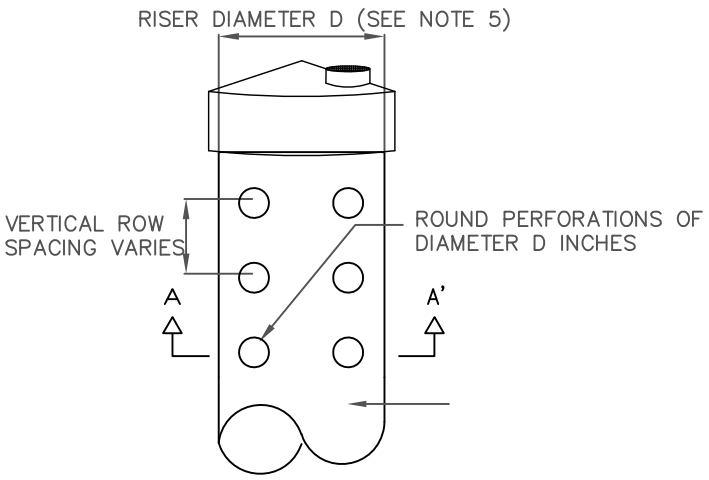
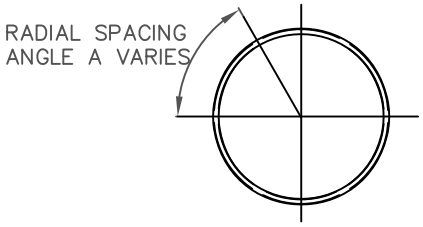
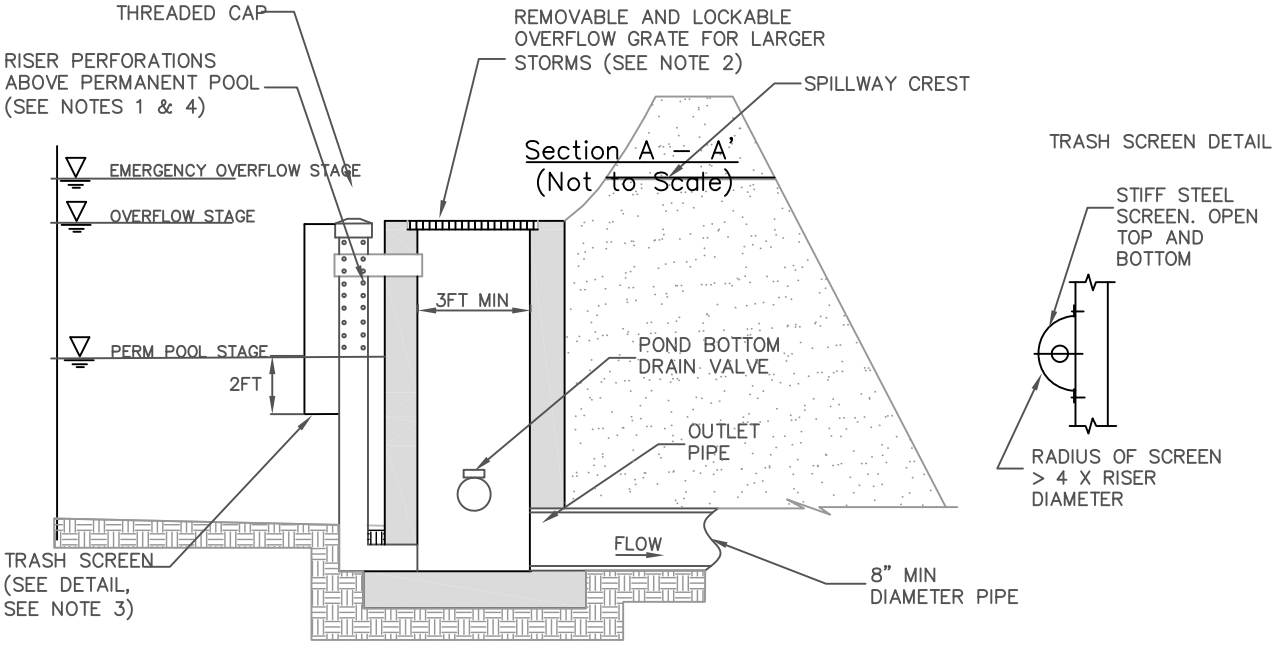
Figure 6-19: Wet Detention Basin



Perforated Riser Detail
(Not to Scale)



Section A – A'
(Not to Scale)



Perforated Riser Outlet Structure
(Not to Scale)

NOTES:

1. RISER PIPE SHALL BE SIZED TO PROVIDE 36 TO 48–HOUR FULL BRIM DRAW DOWN TIME.
2. TOTAL OUTLET CAPACITY: 100–YEAR PEAK FLOW FOR ON–LINE BASINS AND WATER QUALITY DESIGN FLOW FOR OFF–LINE BASINS.
3. SCREEN OPENINGS SHALL BE AT LEAST ¼" AND SHALL NOT EXCEED THE DIAMETER OF THE PERFORATIONS ON THE RISER.
4. RISER PIPE PERFORATION DIAMETER SHALL BE NO LESS THAN ½" AND NO MORE THAN 2"
5. MINIMUM PIPE DIAMETER (D) IS 2'
6. RISER PIPE MATERIAL IS CMP

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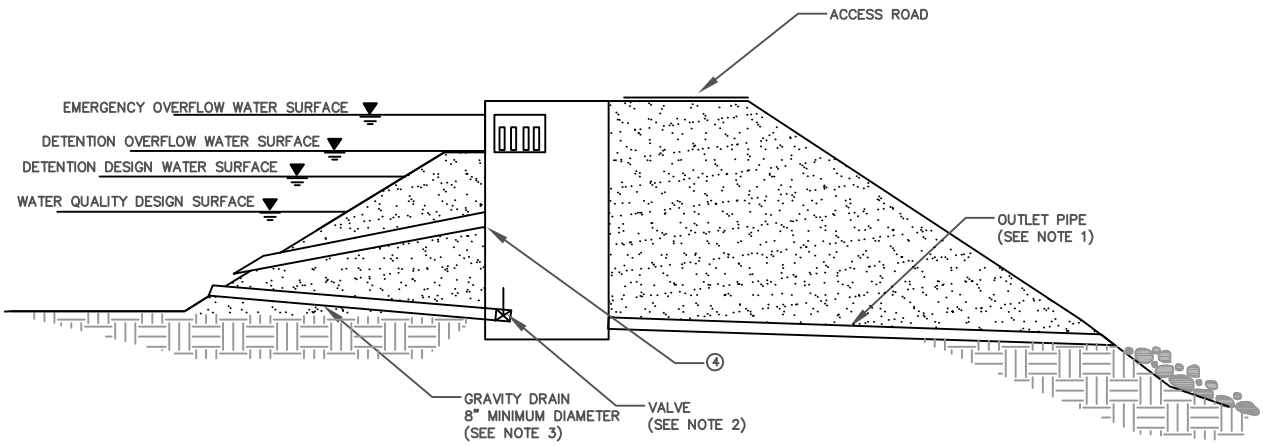
Figure 6-20: Riser Outlet



Inverted Pipe Outlet Structure
(Not to Scale)

NOTES:

1. SIZE OUTLET PIPE SYSTEM TO PASS 100-YEAR FLOW FOR ON-LINE PONDS AND WATER QUALITY PEAK FLOW FOR OFF-LINE PONDS.
2. VALVE MAY BE LOCATED INSIDE MANHOLE OR OUTSIDE WITH APPROVED OPERATIONAL ACCESS
3. INVERT OF DRAIN SHALL BE 6" MINIMUM BELOW TOP OF INTERNAL BERM. LOWER PLACEMENT IS DESIRABLE. INVERT SHALL BE 6" MINIMUM ABOVE BOTTOM OF POND.
4. OUTLET PIPE INVERT SHALL BE AT WETPOOL WATER SURFACE ELEVATION

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Figure 6-21: Inverted Pipe Outlet

Limitations

Limitations for wet detention basins include:

- Wet detention basins typically are used for treating areas larger than 10 acres and less than 10 square miles. They are especially applicable for regional water quality treatment and flow control.
- Off-line wet detention basins must not interfere with flood control functions of existing conveyance and detention structures.
- If wet detention basins are located in areas with site slopes greater than 15% or within 200 feet of a hazardous steep slope or mapped landslide area (on the uphill side), a geotechnical investigation and report must be provided to ensure that the basin does not compromise the stability of the site slope or surrounding slopes.
- Wet detention basins require a regular source of base flow if water levels are to be maintained. If base flow is insufficient during summer months, supplemental water may be necessary to maintain water levels.

Design Criteria

The main challenge associated with wet detention basins is maintaining desired water levels. A wet detention basin should be designed according to the requirements listed in Table 6-24 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-24: Wet Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume, SQDV	acre-ft	See Section 2 and Appendix E for calculating SQDV.
Permanent Pool Volume		SQDV
Forebay Volume		5 to 10% of SQDV
Maximum Forebay Drain Time	min	45
Depth without sediment storage	feet	0.5-12 (littoral zone, 25-40% permanent pool) 4 (first cell minimum) 8 (any cell maximum) Deeper zone: 4-8 feet average; 12 feet maximum depth
Maximum residence time	Days	7 (dry weather)
Freeboard (minimum)	inches	12

Flow path length to width ratio	L:W	2:1 (larger preferred)
Side slope (maximum)	H:V	4:1 (H:V) Interior and 3:1 (H:V) Exterior
Longitudinal slope	percentage	1 (forebay) and 0-2 (main basin)
Vegetation Type	--	Varies see vegetation section below
Vegetation Height	--	Varies see vegetation section below
Buffer zone (minimum)	feet	25
Minimum outflow device diameter	inches	18

Sizing Criteria

Wet Detention basins may be designed with or without extended detention above the permanent pool. The extended detention portion of the wet detention basin above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see VEG-5: Dry Extended Detention Basin). If there is no extended detention provided, wet detention basins shall be sized to provide a minimum wet pool volume equal to the stormwater quality design volume plus an additional 5% for sediment accumulation. If extended detention is provided above the permanent pool, the sizing is dependent of the functionality of the basin; the basin may function as water quality treatment only or water quality plus peak flow attenuation.

If the basin is designed for water quality treatment only, then the permanent pool volume should be a minimum of 10 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) should make up the remaining 90 percent. If extended detention is provided above the permanent pool and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume should be equal to the water quality treatment volume, and the surcharge volume should be sized to attenuate peak flows in order to meet the peak runoff discharge requirements. The extended detention portion of the wet detention basin above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see VEG-5: Dry Extended Detention Basin).

Step 1: Calculate the design volume

Wet detention basins shall be sized with a permanent pool volume equal to the SQDV volume (see Section 2 and Appendix E).

Step 2: Determine the active design volume for the wet detention basin without extended detention

The active volume of the wet detention basin, V_a, shall be equal to the SQFV plus an additional 5% for sediment accumulation.

$$V_a = 1.05 \times SQDV \qquad \text{(Equation 6-59)}$$

Step 3: Determine pond location and preliminary geometry based on site constraints

Based on site constraints, determine the pond geometry and the storage available by developing an elevation-storage relationship for the pond. Note that a more natural geometry may be used and is in many cases recommended; the preliminary basin geometry calculations should be used for sizing purposes only.

1) Calculate the width of the pond footprint, W_{tot}, as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}} \qquad \text{(Equation 6-60)}$$

Where:

A_{tot} = total surface area of the pond footprint (ft^2)

L_{tot} = total length of the pond footprint (ft)

1) Calculate the length of the active volume surface area including the internal berm but excluding the freeboard, $L_{av\text{-}tot}$:

$$L_{av-tot} = L_{tot} - 2Zd_{fb} \qquad \text{(Equation 6-61)}$$

Where:

Z = interior side slope as length per unit height

d_{fb} = freeboard depth

2) Calculate the width of the active volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot}$:

$$W_{av-tot} = W_{tot} - 2Zd_{fb} \qquad \text{(Equation 6-62)}$$

3) Calculate the total active volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot}$:

$$A_{av-tot} = L_{av-tot} \times W_{av-tot} \qquad \text{(Equation 6-63)}$$

4) Calculate the area of the berm, A_{berm}:

$$A_{berm} = W_{berm} \times L_{berm} \qquad \text{(Equation 6-64)}$$

Where:

W_{berm} = width of the internal berm

L_{berm} = length of the internal berm

5) Calculate the active volume surface area excluding the internal berm and freeboard, A_{wq}:

$$A_{wq} = A_{wq\ =\ tot} - A_{berm} \qquad \text{(Equation 6-65)}$$

Step 4: Determine Dimensions of Forebay

The wet detention basin should be divided into two cells separated by a berm or baffle. The forebay should contain between 5 and 10 percent of the total volume. The berm or baffle volume should not count as part of the total volume. Calculate the active volume of forebay, V_1:

$$V_1 = \frac{V_a \times \%V_1}{100} \qquad \text{(Equation 6-66)}$$

Where:

$\%V_1$ = percent of SQDV in forebay (%)

1) Calculate the surface area for the active volume of forebay, A_1:

$$A_1 = \frac{V_1}{d_1} \qquad \text{(Equation 6-67)}$$

Where:

d_1 = average depth fo rhte active volume of forebay (ft)

1) Calculate the length of forebay, L_1. Note, inlet and outlet should be configured to maximize the residence time.

$$L_1 = \frac{A_1}{W_1} \qquad \text{(Equation 6-68)}$$

Where:

W_1 = width of forebay (ft), $W_1 = W_{av\text{-}tot} = L_{berm}$

Step 5: Determine Dimensions of Cell 2

Cell 2 will consist of the remainder of the basin's active volume.

1) Calculate the active volume of Cell 2, V_2:

$$V_2 = V_a - V_1 \qquad \text{(Equation 6-69)}$$

2) The minimum wetpool surface area includes 0.3 acres of wetpool per acre-foot of permanent wetpool volume. Calculate A_{min2}:

$$A_{min2} = (V_2 \times 0.3 \frac{acres}{acre-feet}) \quad \text{(Equation 6-70)}$$

3) Calculate the actual wetpool surface area, A_2:

$$A_2 = A_{av} - A_1 \quad \text{(Equation 6-71)}$$

Verify that A_2 is greater than A_{min2}. If A_2 is less than A_{min2}, then modify input parameters to increase A_2 until it is greater than A_{min2}. If site constraints limit this criterion, then another site for the pond should be chosen.

4) Calculate the top length of Cell 2, L_2:

$$L_2 = \frac{A_2}{W_2} \quad \text{(Equation 6-72)}$$

Where:

W_2 = width of Cell 2 (ft), $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$

5) Verify that the length-to-width ratio of Cell 2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen.

$$LW_2 = \frac{L_2}{W_2} \quad \text{(Equation 6-73)}$$

6) Calculate the emergent vegetation surface area, A_{ev}:

$$A_{ev} = \frac{A_2 \bullet \%A_{ev}}{100} \quad \text{(Equation 6-74)}$$

Where:

$\%A_{ev}$ = percent of surface area that will be planted with emergent vegetation

7) Calculate the volume of the emergent vegetation shallow zone (1.5 – 3 ft), V_{ev}:

$$V_{ev} = A_{ev} \bullet d_{ev} \quad \text{(Equation 6-75)}$$

Where:

d_{ev} = average depth of the emergent vegetation shallow zone (1.5 – 3 ft)

8) Calculate the length of the emergent vegetation shallow zone, L_{ev}:

$$L_{ev} = \frac{A_{ev}}{W_{ev}} \qquad \text{(Equation 6-76)}$$

Where:

W_{ev} = width of the emergent vegetation shallow zone (ft), $W_{ev} = W_2$

9) Calculate the volume of the deep zone, V_{deep}:

$$V_{deep} = V_2 - V_{ev} \qquad \text{(Equation 6-77)}$$

10) Calculate the surface area of the deep (>3 ft) zone, A_{deep}:

$$A_{deep} = A_2 - A_{ev} \qquad \text{(Equation 6-78)}$$

11) Calculate the average depth of the deep zone (4-8 ft), d_{deep}:

$$d_{deep} = \frac{V_{deep}}{A_{deep}} \qquad \text{(Equation 6-79)}$$

12) Calculate length of the deep zone, L_{deep}:

$$L_{deep} = \frac{A_{deep}}{W_{deep}} \qquad \text{(Equation 6-80)}$$

Where:

W_{deep} = width of the deep zone (ft), $W_{deep} = W_2$

Step 6: Ensure design requirements and site constraints are achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location for the BMP.

Step 7: Size Outlet Structure

For extended detention wet detention basin, outlet structures should be designed to provide 12 to 48 hour emptying time for the water quality volume above the permanent pool.

The basin outlet pipe should be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

Step 8: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the water quality design storm. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Sizing and Geometry

1) If there is no extended detention provided, wet detention basins shall be sized to provide a minimum wet pool volume equal to the stormwater quality design volume plus an additional 5% for sediment accumulation. If extended detention is provided above the permanent pool and the basin is designed for water quality treatment only, then the permanent pool volume should be a minimum of 10 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) should make up the remaining 90 percent. If extended detention is provided above the permanent pool and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume shall be equal to the water quality treatment volume and the surcharge volume should be sized to attenuate peak flows to meet the peak runoff discharge requirements. The extended detention portion of the wet detention basin above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see TCM-1: Dry Extended Detention Basin).

2) The wet detention basin should be divided into two cells separated by a berm or baffle. The first cell should contain between 25 to 35 percent of the total volume. The berm or baffle volume should not count as part of the total volume. Intent: The full-length berm or baffle reduces short-circuiting and promotes plug flow.

3) Wet detention basins with wetpool volumes less than or equal to 4,000 cubic feet may be single-celled (i.e., no baffle or berm is required).

4) Sediment storage should be provided in the first cell. The sediment storage should have a minimum depth of 1 foot. This volume should not be included as part of the required water quality volume.

5) The minimum depth of the first cell should be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell. Average depth should be between 4 feet and 8 feet.

6) For wet detention basin depths in excess of 6 feet, some form of recirculation should be provided, such as a fountain or aerator, to prevent stratification, stagnation and low dissolved oxygen conditions.

7) The edge of the basin should slope from the surface of the permanent pool to a depth of 12 to 18 inches at a slope of 1:1 or greater. If soil conditions will not support a 1:1 (H:V) slope then the steepest slope that can be supported should be used or a shallow retaining wall constructed (18 inch max). Beyond the edge of the basin, a bench sloped at 4:1 (H:V) maximum should extend into the basin to a depth of at least 3 feet. A steeper slope may be used beyond the 3 foot depth to a maximum of 8 feet. Intent: steep slopes at water's edge will minimize very shallow areas that can support mosquitoes.

8) At least 25% of the basin area should be deeper than 3 feet to prevent the growth of emergent vegetation across the entire basin. If greater than 50% of the wet pool area is in excess of 6 feet deep, some form of recirculation should be provided, such as a fountain or aerator, to prevent stratification, stagnation and low dissolved oxygen conditions.

9) A wet detention basin should have a surface area of not less than 0.3 acres for each acre-foot of permanent pool volume. In addition, extra area needed to provide a design that meets all other provisions of this section should be provided. Additional surface area in excess of the minimum may be provided. There is no maximum surface area provided that all provisions of this section are met.

10) Inlets and outlets should be placed to maximize the flowpath through the facility. The flowpath length-to-width ratio should be a minimum of 1.5:1, but a flowpath length-to-width ratio of 2:1 or greater is preferred. The flowpath length is defined as the distance from the inlet to the outlet, as measured at mid-depth. The width at mid-depth can be found as follows: width = (average top width + average bottom width)/2. Intent: a long flowpath length will improve fine sediment removal.

11) All inlets should enter the first cell. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets.

12) The minimum freeboard should be 1 foot above the maximum water surface elevation (2 feet preferred) for on-line basins and 1 foot above the maximum water surface elevation for on-line basins.

13) The maximum residence time for dry weather flows should be 7 days. Intent: Vector control.

Internal Berms and Baffles

1) A berm or baffle should extend across the full width of the wet detention basin and be keyed into the basin side slopes. If the berm embankments are greater than 4 feet in height, the berm should be constructed by excavating a key equal to 50% of the embankment cross-sectional height and width. This requirement may be waived if recommended by a licensed civil engineer for the specific site conditions. The geotechnical investigation must consider the situation in which one of the two cells is empty while the other remains full of water.

2) The top of the berm should extend to the permanent pool surface or be one foot below the permanent pool surface to discourage public access. If the top of the berm is at the water permanent pool surface, the side slopes should be 4H:1V. Berm side slopes may be steeper (up to 3:1) if the berm is submerged one foot.

3) If good vegetation cover is not established on the berm, erosion control measures should be used to prevent erosion of the berm back-slope when the basin is initially filled.

4) The interior berm or baffle may be a retaining wall provided that the design is prepared and stamped by a licensed civil engineer. If a baffle or retaining wall is used, it should be submerged one foot below the permanent pool surface to discourage access by pedestrians.

5) Internal earthen berms 6 feet high or less should have a minimum top width 6 feet or as recommended by a civil engineer.

Water Supply

1) Water balance calculations should be provided to demonstrate that adequate water supply will be present to maintain a pool of water during a drought year when precipitation is 50% of average for the site. Water balance calculations should include evapotranspiration, infiltration, precipitation, spillway discharge, and dry weather flow (where appropriate).

2) Where water balance indicates that losses will exceed inputs, a source of water should be provided to maintain the basin water surface elevation throughout the year. The water supply should be of sufficient quantity and quality to not have an adverse impact on the wet detention basin water quality. Water that meets drinking water standards should be assumed to be of sufficient quality.

3) Wet detention basin may be designed as seasonal ponds where the water balance and water supply conditions make it infeasible to sustain a permanent wet detention basin.

Soils Considerations

Wet detention basin implementation in areas with high permeability soils requires liners to increase the chances of maintaining a permanent pool in the basin. Liners can be either synthetic materials or imported lower permeability soils (i.e., clays). The water balance assessment should determine whether a liner is required.

If low permeability soils are used for the liner, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with 3 parts native soil) should be placed over the liner. If a synthetic material is used, a soil depth of 2 feet is recommended to prevent damage to the liner during planting.

Buffer Zone

A minimum of 25 feet buffer should be provided around the top perimeter of the wet detention basin. The portion of the access road outside of the maximum water level may be included as part of the buffer.

Stormwater Quality Design Features

1) Wet detention basins that are located in publicly-accessible or highly visible locations should include design features that will improve and maintain the quality of water within the BMP at a level suitable for the proposed location and uses of the surrounding area. Typical design features include aeration, pumped circulation, filters, biofilters, and other facilities that operate year-round to remove pollutants and nutrients. Stormwater quality design features will result in higher quality water in the BMP and lower discharges of pollutants downstream.

2) Wet detention basins in publicly-accessible or highly visible locations should have a maintenance plan that includes regular collection and removal of trash from the area within and surrounding the BMP.

3) If fencing is required for wet detention basins in publicly-accessible or highly visible locations, the fence can be designed to be aesthetically incorporated into the site and Shrubs (approved, California-adapted species) can be used to hide the fencing. See vegetation section below.

Energy Dissipation

1) The inlet to the wet detention basin should be submerged with the inlet pipe invert a minimum of two feet from the basin bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1 foot, if possible. Intent: The inlet is submerged to dissipate energy of the incoming flow. The distance from the bottom is set to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

2) Energy dissipation controls should also be used at the outlet from the wet detention basin unless the basin discharges to a stormwater conveyance system or hardened channel.

Vegetation

A plan should be prepared that indicates how aquatic, temporarily submerged areas (extended detention wet detention basins) and terrestrial areas will be stabilized with vegetation.

1) If the second cell of the wet detention basin is 3 feet or shallower, the bottom area should be planted with emergent wetland vegetation.

2) Emergent aquatic vegetation should be planted to cover 25-75% of the area of the permanent pool.

3) Outside of the basin, native vegetation adapted for site conditions should be used in non-irrigated sites.

4) The area surrounding a wet detention basin should be landscaped to minimize erosion and should adhere to the following criteria so as not to hinder maintenance operations:

5) No trees or shrubs may be planted within 15 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, should not be used within 50 feet of pipes or manmade structures. Weeping willow (Salix babylonica) should not be planted in or near detention basins.

6) Prohibited non-native plant species will not be permitted. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website- or the California Invasive Plant Council website at www.cal-ipc.org.

7) A landscape professional should provide recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth.

Outlet Structure

1) An outlet pipe and outlet structure should be provided. The outlet pipe may be a perforated standpipe strapped to a manhole or placed in an embankment, suitable for extended detention, or may be back-sloped to a catch basin with a grated opening (jail house window) or manhole with a cone grate (birdcage). The grate or birdcage openings provide an overflow route should the basin outlet pipe become clogged.

2) For extended detention wet detention basin, outlet structures should be designed to provide 12 to 48 hour emptying time for the water quality volume above the permanent pool.

3) The basin outlet pipe should be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

Emergency Spillway

An emergency overflow spillway in addition to the primary overflow outlet (as described above) is required. The emergency spillway should be sized for flows greater than the peak 100-year 24-hour storm if the basin is designed on-line or, if the basin is designed off-line, the spillway should be sized for flows greater than the basin design volume (e.g., stormwater quality design volume). The spillway provide for adequate energy dissipation

downstream. The spillway should allow for at least 12 inches of freeboard above the emergency overflow water surface elevation if the basin is on-line. If the basin is -line, 2 feet of freeboard is preferable.

Spillways shall meet the California Department of Water Resources, Division of Safety of Dams Guidelines for the Design and Construction of Small Embankment Dams (http://damsafety.water.ca.gov/docs/GuidelinesSmallDams.pdf). *Intent: Emergency overflow spillways are intended to control the location of basin overtopping and safely direct overflows back into the downstream conveyance system or other acceptable discharge point.*

On-line Basins

1) On-line basins must have an emergency overflow spillway to prevent overtopping of walls or berms should blockage of the primary outlet occur based on a downstream risk assessment.

2) The overflow spillway must be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm.

3) The minimum freeboard should be 1 foot (but preferably at least 2 feet) above the maximum water surface elevation over the emergency spillway.

Off-line Basins

1) Off-line basins must have either an emergency overflow spillway or an emergency overflow riser. The emergency overflow must be designed to pass flows greater than the basin design volume (e.g., stormwater quality design volume) directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, an emergency overflow riser, in addition to the spillway should be provided. See Appendix E for basin/pond outlet sizing worksheets.

2) The emergency overflow spillway should be armored to withstand the energy of the spillway flows. The spillway should be constructed of grouted rip-rap.

3) The minimum freeboard should be 1 foot above the maximum water surface elevation over the emergency spillway.

Side Slopes

1) Interior side slopes above the stormwater quality design depth and up to the emergency overflow water surface steeper than 4:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

2) Exterior side slopes steeper than 2:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

3) For any slope (interior or exterior) greater than 2:1 (H:V), a geotechnical investigation and report must be submitted and approved by the local permitting authority.

4) Landscaped slopes should be no steeper than 3:1 (H:V) to allow for maintenance.

5) Basin walls may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete, (b) a fence is provided along the top of the wall (see fencing below) or further back, and (c) the design is stamped by a licensed civil engineer.

Embankments

1) Earthworks and berm embankments should be performed in accordance with the latest edition of the "Greenbook Standard Specifications for Public Works Construction".

2) Embankments are earthen slopes or berms used for detaining or redirecting the flow of water.

3) Top of berm should be 2 feet minimum below the stormwater quality design water surface and should be keyed into embankment a minimum of 1 foot on both sides.

4) Typically, the top width of berm embankments are at least 20 feet, but narrower embankments may be plausible if approved by the civil engineer and the Local permitting authority.

5) Basin berm embankments should be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil engineer) free of loose surface soil materials, roots, and other organic debris.

6) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

7) Basin berm embankments greater than 4 feet in height should be constructed by excavating a key equal to 50% of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed civil engineer.

8) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

9) Low growing native or non-invasive perennial grasses should be planted on downstream embankment slopes. See vegetation section below.

Fencing

Safety is provided either by fencing of the facility or by managing the contours of the basin to eliminate drop-offs and other hazards.

1) If fences are required, fences should be designed and constructed in accordance with current and relevant policies and typically are required to be located at or above the overflow water surface elevation. Shrubs (approved, California-adapted species) can be used to hide the fencing. See vegetation section above.

Right-of-Way

2) Wet detention basins and associated access roads to be maintained by a public agency should be dedicated in fee or in an easement to the public agency with appropriate access.

Maintenance Access

1) Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement is required to ensure adequate performance and allow emergency access to the facilities.

2) Maintenance access road(s) should be provided to the control structure and other drainage structures associated with the basin (e.g., inlet, emergency overflow or bypass structures). Manhole and catch basin lids should be in or at the edge of the access road.

3) A ramp into the basin should be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp should extend to the basin bottom to avoid damage to vegetation planted on the basin slope.

4) All access ramps and roads should be provided in accordance with the current policies of the Flood Control District.

Vector Control

1) A Mosquito Management Plan or Service Contract should be approved or waived by the local Vector Control District for any facility that maintains a pool of water for 72 hours or more.

Operations and Maintenance

General Requirements

Maintenance is of primary importance if extended detention basins are to continue to function as originally designed. A maintenance agreement must be developed with the Flood Control District to ensure adequate performance and allow the County emergency access. Maintenance of the basin is the responsibility of the development, unless otherwise agreed upon.

A specific maintenance plan shall be formulated for each facility outlining the schedule and scope of maintenance operations, as well as the data handling and reporting requirements. The following are general maintenance requirements:

1) The basin should be inspected annually and inspections after major storm events are encouraged (see Appendix I for guidance on facility maintenance inspections). Trash and debris should be removed as needed, but at least annually prior to the beginning of the wet season (see Appendix I for dry extended detention basin inspection and maintenance checklist).

2) Site vegetation should be maintained as follows:

3) Vegetation, large shrubs, or trees that limit access or interfere with basin operation should be pruned or removed.

4) Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.

5) Grass should be mowed to 4”-9” high and grass clippings should be removed.

6) Fallen leaves and debris from deciduous plant foliage should be raked and removed.

7) Invasive vegetation, such as Alligatorweed (Alternanthera philoxeroides), Halogeton (Halogeton glomeratus), Spotted Knapweed (Centaurea maculosa), Giant Reed (Arundo donax), Castor Bean (Ricinus communis), Perennial Pepperweed (Lepidium latifolium), and Yellow Starthistle (Centaurea solstitalis) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 25% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

8) Dead vegetation should be removed if it exceeds 10% of area coverage. Vegetation should be replaced immediately to maintain cover density and control erosion where soils are exposed.

9) No herbicides or other chemicals should be used to control vegetation.

10) Sediment buildup exceeding 50% of the forebay capacity should be removed. Sediment from the remainder of the basin should be removed when 6 inches of sediment accumulates. Sediments should be tested for toxic substance accumulation in compliance with current disposal requirements if land uses in the catchment include commercial or industrial zones, or if visual or olfactory indications of pollution are noticed. If toxic substances are encountered at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, the sediment must be disposed of in a hazardous waste landfill.

11) Following sediment removal activities, replanting, and/or reseeding of vegetation may be required for reestablishment.

Construction Considerations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited. The use of galvanized fencing is permitted if in accordance with the Fencing requirement above.

TCM-3: Constructed Wetland

A constructed treatment wetland is a system consisting of a sediment forebay and one or more permanent micro-pools with aquatic vegetation covering a significant portion of the basin. Constructed treatment wetlands typically include components such as an inlet with energy dissipation, a sediment forebay for settling out coarse solids and to facilitate maintenance, a base with shallow sections (1 to 2 feet deep) planted with emergent vegetation, deeper areas or micro pools (3 to 5 feet deep), and a water quality outlet structure. The interactions between the incoming stormwater runoff, aquatic vegetation, wetland soils, and the associated physical, chemical, and biological unit processes are a fundamental part of constructed treatment wetlands.

Constructed Wetlands

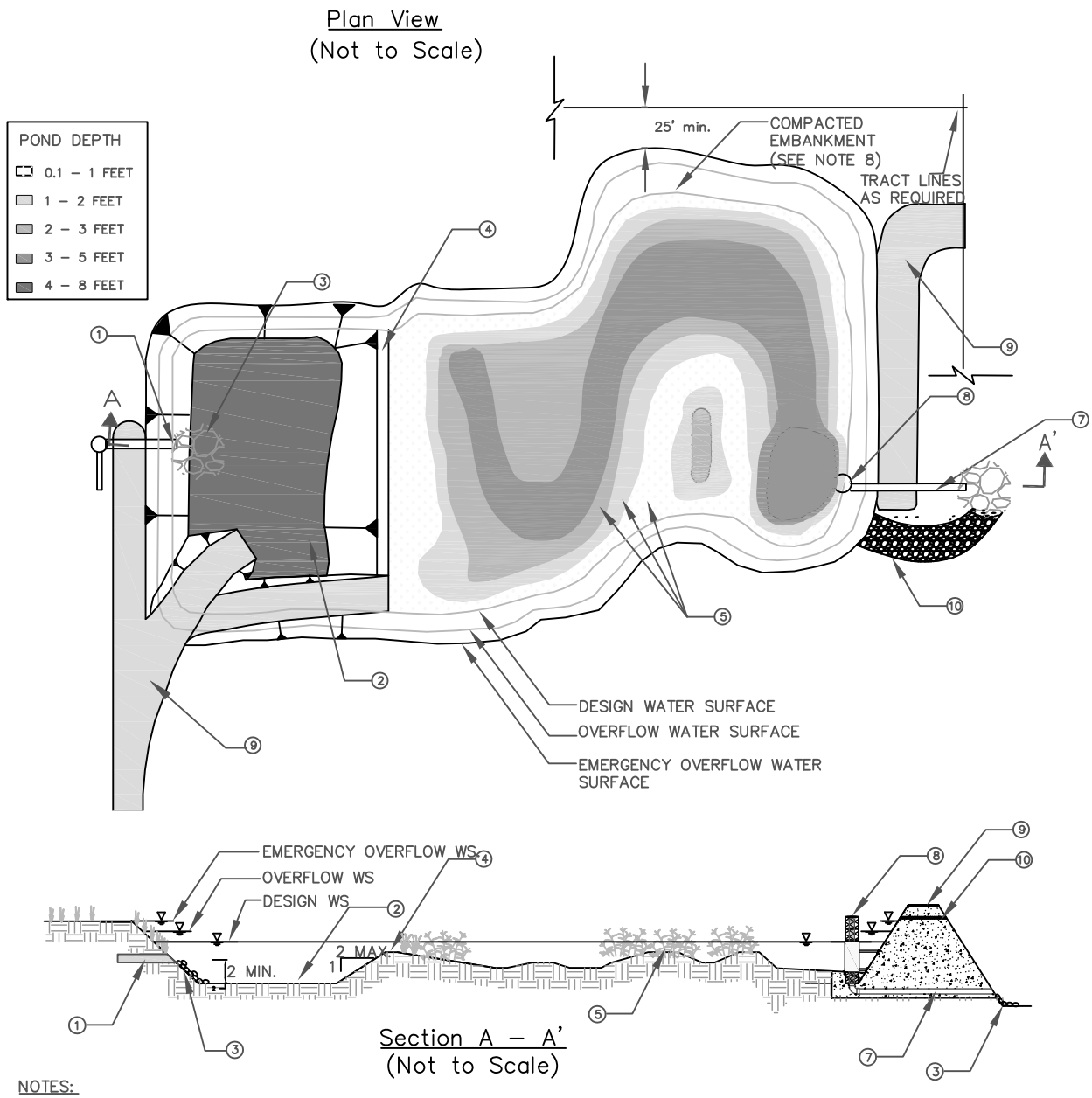
Photo Credits: Geosyntec Consultants

Application

- Regional detention & treatment
- Roads, highways, parking lots, commercial, residential
- Parks, open spaces, and golf courses

Preventative Maintenance

- inspected at a minimum annually and inspections after major storm events
- Pruned or remove vegetation, large shrubs, or trees that limit access or interfere with basin operation
- Remove sediment buildup at inlets and outlets



NOTES:

1. INLET PIPE SHOULD BE SUBMERGED WITH A MINIMUM OF 2' DISTANCE FROM THE BOTTOM
2. SEDIMENT FOREBAY. FORE BAY VOLUME SHALL EQUAL 10% TO 20% OF TOTAL WETLAND VOLUME. FOREBAY DEPTH SHALL BE 4' MIN TO 8' MAX PLUS AN ADDITIONAL 1' MIN SEDIMENT STORAGE DEPTH.
3. RIP RAP APRON OR OTHER INLET ENERGY DISSIPATION.
4. BERM AT DESIGN WATER SURFACE ELEVATION OR SUBMERGED 1' BELOW DESIGN WATER SURFACE ELEVAVTION. EXTEND BERM ACROSS ENTIRE WIDTH OF THE WETLAND.
5. WETLAND VEGETATION. PLANTING SCHEME MUST BE DESIGNED BY A WETLAND ECOLOGIST.
6. EMBANKMENT SIDE SLOPES SHALL BE NO STEEPER THAN 2H:1V OUTSIDE AND 3H:1V INSIDE
7. SIZE OUTLET PIPE TO PASS 100–YEAR PEAK FLOW FOR ONLINE AND WATER QUALTIY PEAK FLOW FOR OFFLINE BASINS.
8. WATER QUALITY OUTLET STRUCTURE. SEE FIGURE 7–2 AND FIGURE 7–3 FOR DETAILS.
9. MAINTENANCE RAMP SHOULD PROVIDE ACCESS TO BOTH THE FOREBAY AND MAIN BASIN.
10. INSTALL EMERGENGY OVERFLOW SPILWAY AS NEEDED. SEE FIGURE 2–4 FOR DETAILS

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Figure 6-22: Constructed Wetland

Limitations

- In theory, there are no limitations on the tributary area size draining to a constructed treatment wetland; however, constructed treatment wetlands usually require considerable land area. Typically, treatment wetlands capture runoff from tributary areas larger than 10 acres and less than 10 square miles. Smaller "pocket" wetlands can be feasible in areas where space is restricted.
- If the constructed treatment wetland is not used for flow control, the wetland must not interfere with flood control functions of existing conveyance and detention structures.
- Constructed treatment wetlands should not be permitted in areas with site slopes greater than 7% or within 200 feet (on the uphill side) of a steep slope hazard area or a mapped landslide area unless a geotechnical investigation and report is completed by a licensed civil engineer.
- Constructed treatment wetlands require a regular source of water (base flow) to maintain wetland vegetation and associated treatment processes. If adequate base flow is not available year-round, supplemental water may be needed during the summer months to maintain adequate base flow.

Design Criteria

The main challenge associated with constructed treatment wetlands is maintaining base flow to support vegetation. Constructed wetlands should be designed according to the requirements listed in Table 6-25 and outlined in the section below. Constructed wetland BMP sizing worksheets are presented in Appendix E.

Table 6-25: Constructed Wetland Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume, SQDV	acre-feet	See Section 2 and Appendix E for calculating SQDV.
Permanent pool volume	%	75% of SQDV
Drawdown time for extended detention (over permanent pool)	hours	48 ; 12 for 50% SQDV (minimum)
Sediment forebay volume	%	30 to 50% of permanent pool surface area
Depth of sediment forebay	feet	2-4 (1 foot of sediment storage required)
Wetland zone volume	%	50-70% of permanent pool surface area
Depth of wetland basin	feet	0.5 to 1.0 (30 to 50% should be 0.5 feet deep)

Design Parameter	Unit	Design Criteria
Wetland (littoral zone) bottom slope	%	10 maximum
Maximum residence time	Days	7 (dry weather)
Freeboard (minimum)	inches	12
Flow path length to width ratio	L:W	2:1, larger preferred
Side slope (maximum)	H:V	4:1 Interior; 3:1 Exterior
Vegetation Type	--	Varies see vegetation section below
Vegetation Height	--	Varies see vegetation section below
Buffer zone (minimum)	feet	25
Minimum outflow device diameter	inches	18

Sizing

In most cases, the constructed treatment wetland permanent pool should be sized to be greater than or equal to the stormwater quality design volume. If extended detention is provided above the permanent pool and the wetland is designed for water quality treatment only, then the permanent pool volume should be a minimum of 80 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) should make up the remaining 20 percent and provide at least 12 hours of detention. If extended detention is provided and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume should be equal to the water quality treatment volume and the surcharge volume should be sized to attenuate peak flows to meet the peak runoff discharge requirements. The extended detention portion of the wetland above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see VEG-5: Dry Extended Detention Basin).

Step 1: Calculate the design volume

Constructed wetlands shall be sized to be greater than or equal to the SQDV volume (see Section 2 and Appendix E).

Step 2: Determine the Wetland Location, Wetland Type and Preliminary Geometry Based on Site Constraints

Based on site constraints, determine the wetland geometry and the storage available by developing an elevation-storage relationship for the wetland. The equations provided

below assume a trapezoidal geometry for cell 1 (Forebay) and cell 2, and assumes that the wetland does not have extended detention.

1) Calculate the width of the wetland footprint, W_{tot}, as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}} \qquad \text{(Equation 6-81)}$$

Where:

A_{tot} = total surface area of the wetland footprint (ft^2)

L_{tot} = total length of the wetland footprint (ft)

2) Calculate the length of the water quality volume surface area including the internal berm but excluding the freeboard, $L_{wq\text{-}tot}$:

$$L_{wq-tot} = L_{tot} - 2Zd_{fb} \qquad \text{(Equation 6-82)}$$

Where:

Z = interior side slope as length per unit height

d_{fb} = freeboard depth

3) Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{wq\text{-}tot}$:

$$W_{wq-tot} = W_{tot} - 2Zd_{fb} \qquad \text{(Equation 6-83)}$$

4) Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{wq\text{-}tot}$:

$$A_{wq-tot} = L_{wq-tot} \times W_{wq-tot} \qquad \text{(Equation 6-84)}$$

5) Calculate the area of the berm, A_{berm}:

$$A_{berm} = W_{berm} \times L_{berm} \qquad \text{(Equation 6-85)}$$

Where:

W_{berm} = width of the internal berm

L_{berm} = length of the internal berm

6) Calculate the water quality surface area excluding the internal berm and freeboard, A_{wq}:

$$A_{wq} = A_{wq\ =\ tot} - A_{berm}$$ (Equation 6-86)

Step 3: Determine Dimensions of Forebay

30-50% of the SQDV is required to be within the active volume of forebay.

1) Calculate the active volume of forebay, V_1:

$$V_1 = \frac{SQDV \times \%V_1}{100}$$ (Equation 6-87)

Where:

$\%V_1$ = percent of SQDV in forebay (%)

2) Calculate the surface area for the active volume of forebay, A_1:

$$A_1 = \frac{V_1}{d_1}$$ (Equation 6-88)

Where:

d_1 = average depth fo rhte active volume of forebay (2 -4 ft) (ft)

3) Calculate the length of forebay, L_1. Note, inlet and outlet should be configured to maximize the residence time.

$$L_1 = \frac{A_1}{W_1}$$ (Equation 6-89)

Where:

W_1 = width of forebay (ft), $W_1 = W_{av\text{-}tot} = L_{berm}$

Step 4: Determine Dimensions of Cell 2

Cell 2 will consist of the remainder of the basin's active volume.

1) Calculate the active volume of Cell 2, V_2:

$$V_2 = SQDV - V_1$$ (Equation 6-90)

2) Calculate the surface area of Cell 2, A_2:

$$A_2 = A_{wq} - A_1$$ (Equation 6-91)

3) Calculate the top length of Cell 2, L_2:

$$L_2 = \frac{A_2}{W_2} \qquad \text{(Equation 6-92)}$$

Where:

W_2 = width of Cell 2 (ft), $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$

4) Verify that the length-to-width ratio of Cell 2, LW_2, is at least 3:1 with ≥ 4:1 preferred. If the length-to-width ratio is less than 3:1, modify input parameters until a ratio of at least 3:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen.

$$LW_2 = \frac{L_2}{W_2} \qquad \text{(Equation 6-93)}$$

5) Calculate the very shallow zone surface area, A_{vs}:

$$A_{vs} = \frac{A_2 \bullet \%A_{vs}}{100} \qquad \text{(Equation 6-94)}$$

Where:

$\%A_{vs}$ = percent of surface area of very shallow zone

6) Calculate the volume of the shallow zone, V_{vs}:

$$V_{vs} = A_{vs} \bullet d_{vs} \qquad \text{(Equation 6-95)}$$

Where:

d_{vs} = average depth of the very shallow zone (0.1 – 1 ft)

7) Calculate the length of the very shallow zone, L_{vs}:

$$L_{vs} = \frac{A_{vs}}{W_{vs}} \qquad \text{(Equation 6-96)}$$

Where:

W_{vs} = width of the very shallow zone (ft), $W_{vs} = W_2$

8) Calculate the surface area of the shallow zone, A_s:

$$A_s = \frac{A_2 \bullet \%A_s}{100} \qquad \text{(Equation 6-97)}$$

Where:

$\%A_s$ = percent of surface area of shallow zone

9) Calculate the volume of the shallow zone, V_s:

$$V_s = A_s \bullet d_s \qquad \text{(Equation 6-98)}$$

Where:

d_s = average depth of shallow zone (1 - 3 ft)

10) Calculate length of the shallow zone, L_s:

$$L_s = \frac{A_s}{W_s} \qquad \text{(Equation 6-99)}$$

Where:

W_s = width of the shallow zone (ft), $W_s = W_2$

11) Calculate the surface area of the deep zone, A_{deep}:

$$A_{deep} = A_2 - A_{vs} - A_s \qquad \text{(Equation 6-100)}$$

12) Calculate the volume of the deep zone, V_{deep}:

$$V_{deep} = V_2 - V_{vs} - V_s \qquad \text{(Equation 6-101)}$$

13) Calculate the average depth of the deep zone (3-5 ft), d_{deep}:

$$d_{deep} = \frac{V_{deep}}{A_{deep}} \qquad \text{(Equation 6-102)}$$

14) Calculate length of the deep zone, L_{deep}:

$$L_{deep} = \frac{A_{deep}}{W_{deep}} \qquad \text{(Equation 6-103)}$$

Where:

W_{deep} = width of the deep zone (ft), $W_{deep} = W_2$

Step 5: Ensure design requirements and site constraints are achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or alternative treatment BMP.

Step 6: Size Outlet Structure

For wetlands with detention, the outlet structures should be designed to provide 12 hours emptying time for the water quality volume or the required detention necessary for achieving the peak runoff discharge requirements if the extended detention is designed for flow attenuation.

The wetland outlet pipe should be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for on-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

Step 7: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Sizing and Geometry

In most cases, the constructed treatment wetland permanent pool should be sized to be greater than or equal to the stormwater quality design volume. If extended detention is provided above the permanent pool and the wetland is designed for water quality treatment only, then the permanent pool volume should be a minimum of 80 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) should make up the remaining 20 percent and provide at least 12 hours of detention. If extended detention is provided and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume should be equal to the water quality treatment volume and the surcharge volume should be sized to attenuate peak flows to meet the peak runoff discharge requirements. A constructed treatment wetland design worksheets are presented in Appendix E. The extended detention portion of the wetland above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see TCM-1: Dry Extended Detention Basin).

1) Constructed treatment wetlands should consist of at least two cells including a sediment forebay and a wetland basin.

2) The sediment forebay must contain between 10 and 20 percent of the total basin volume.

3) The depth of the sediment forebay should be between 4 and 8 feet.

4) One foot of sediment storage should be provided in the sediment forebay.

5) The "berm" separating the two basins should be uniform in cross-section and shaped such that its downstream side gradually slopes to the main wetland basin.

6) The top of berm should be either at the stormwater quality design water surface or submerged 1 foot below the stormwater quality design water surface, as with wet retention basins. Correspondingly, the side slopes of the berm should meet the following criteria:

   a. If the type of the berm is at the stormwater quality design water surface, the berm side slopes should be no steeper than 4H:1V.

   b. If the top of berm is submerged 1 foot, the upstream side slope may be a max of 3H:1V.

7) The constructed treatment wetlands should be designed with a "naturalistic" shape and a range of depths intermixed throughout the wetland basin to a maximum of 5 feet.

Depth Range (feet)	Percent by Area
0.1 to 1	15
1 to 3	55
3 to 5	30

8) The flowpath length-to-width ratio should be a minimum of 2:1, but preferably at least 4:1 or greater. *Intent: a high flow path length to width ratio will maximize fine sediment removal.*

9) The minimum freeboard should be 1 foot above the maximum water surface elevation for on-line basins (2 feet preferable) and 1 foot above the maximum water surface elevation for on-line basins.

10) Wetland pools should be designed such that the residence time for dry weather flows is no greater than 7 days. *Intent: Minimize vector and stagnation issues.*

Water Supply

Water balance calculations should be provided to demonstrate that adequate water supply will be present to maintain a permanent pool of water during a drought year when precipitation is 50% of average for the site. Water balance calculations should include evapotranspiration, infiltration, precipitation, spillway discharge, and dry weather flow (where appropriate).

Where water balance indicates that losses will exceed inputs, a source of water should be provided to maintain the wetland water surface elevation throughout the year. The water supply should be of sufficient quantity and quality to not have an adverse impact on the

wetland water quality. Water that meets drinking water standards should be assumed to be of sufficient quality.

Soils Considerations

1) Implementation of constructed treatment wetlands in areas with high permeability soils (>0.1 in/hr) requires liners to increase the chances of maintaining permanent pools and/or micro-pools in the basin. Liners can be either synthetic materials or imported lower permeability soils (i.e., clays). The water balance assessment should determine whether a liner is required. The following conditions can be used as a guideline.

2) The wetland basin should retain water for at least 10 months of the year.

3) The sediment forebay should retain at least 3 feet of water year-round.

4) Many wetland plants can adapt to periods of summer drought, so a limited drought period is allowed in the wetland basin. This may allow for a soil liner rather than a geosynthetic liner. The sediment forebay should retain water year-round for presettling to be effective.

5) If low permeability soils are used for the liner, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with 3 parts native soil) should be placed over the liner (see soil amendment Section 5.10). If a synthetic material is used, a soil depth of 2 feet is recommended to prevent damage to the liner during planting.

Buffer Zone

A minimum of 25 feet buffer should be provided around the top perimeter of the constructed treatment wetlands.

Energy Dissipation

1) The inlet to the constructed treatment wetland should be submerged with the inlet pipe invert a minimum of two feet from the cell bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1 foot, if possible. *Intent: the inlet is submerged to dissipate energy of the incoming flow. The distance from the bottom is set to minimize resuspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.*

2) Energy dissipation controls must also be used at the outlet/spillway from the constructed treatment wetlands unless the wetland discharges to a stormwater conveyance system or hardened channel.

Vegetation

1) The wetland cell(s) should be planted with emergent wetland plants following the recommendations of a wetlands specialist.

2) Landscaping outside of the basin is required for all constructed wetlands and should adhere to the following criteria so as not to hinder maintenance operations:

    a. No trees or shrubs may be planted within 15 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, should not be used within 50 feet of pipes or manmade structures. Weeping willow (*Salix babylonica*) should not be planted in or near detention basins.

    b. Prohibited non-native plant species will not be permitted. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

3) Project-specific planting recommendations should be provided by a wetland ecologist or a qualified landscape professional including recommendations on appropriate plants, fertilizer, mulching applications, and irrigation requirements (if any) to ensure healthy vegetation growth.

Outlet Structure

An outlet pipe and outlet structure should be provided. The outlet pipe may be a perforated standpipe strapped to a manhole or placed in an embankment, suitable for extended detention, or may be back-sloped to a catch basin with a grated opening (jail house window) or manhole with a cone grate (birdcage). The grate or birdcage openings provide an overflow route should the basin outlet pipe become clogged. The outlet should be protected from clogging by a skimmer shield that starts at the bottom of the permanent pool and extends above the SQDV depth. A trash rack is also required.

For wetlands with detention, the outlet structures should be designed to provide 12 hours emptying time for the water quality volume or the required detention necessary for achieving the peak runoff discharge requirements if the extended detention is designed for flow attenuation.

The wetland outlet pipe should be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for on-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

See the dry extended detention section (see ST-1: Dry Extended Detention Basin) and Appendix E for further detail on outlet sizing.

Emergency Spillway

An emergency overflow spillway in addition to the primary overflow outlet (as described above) is required. The emergency spillway should be sized for flows greater than the peak 100-year 24-hour storm if the basin is designed on-line or, if the basin is designed on-line, the spillway should be sized for flows greater than the basin design volume (e.g., stormwater quality design volume). The spillway provide for adequate energy dissipation downstream. The spillway should allow for at least 12 inches of freeboard above the emergency overflow water surface elevation if the basin is on-line. If the basin is on-line, 2 feet of freeboard is preferable.

Spillways shall meet the California Department of Water Resources, Division of Safety of Dams Guidelines for the Design and Construction of Small Embankment Dams (http://damsafety.water.ca.gov/docs/GuidelinesSmallDams.pdf). *Intent: Emergency overflow spillways are intended to control the location of basin overtopping and safely direct overflows back into the downstream conveyance system or other acceptable discharge point.*

On-line Basins

1) On-line basins must have an emergency overflow spillway to prevent overtopping of walls or berms should blockage of the primary outlet occur based on a downstream risk assessment.

2) The overflow spillway must be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm.

3) The minimum freeboard should be 1 foot (but preferably at least 2 feet) above the maximum water surface elevation over the emergency spillway.

Off-line Basins

1) Off-line basins must have either an emergency overflow spillway or an emergency overflow riser. The emergency overflow must be designed to pass the 100-yr 24-hr post-development peak stormwater runoff discharge rate (see Appendix E for further detail) directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, an emergency overflow riser, *in addition* to the spillway should be provided.

2) The emergency overflow spillway should be armored to withstand the energy of the spillway flows. The spillway should be constructed of grouted rip-rap.

3) The minimum freeboard should be 1 foot above the maximum water surface elevation over the emergency spillway.

Side Slopes

1) Interior side slopes above the stormwater quality design depth and up to the emergency overflow water surface steeper than 4:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

2) Exterior side slopes steeper than 2:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

3) For any slope (interior or exterior) greater than 2:1 (H:V), a geotechnical investigation and report must be submitted and approved by the local permitting authority.

4) Landscaped slopes should be no steeper than 3:1 (H:V) to allow for maintenance.

5) Basin walls may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete, (b) a fence is provided along the top of the wall (see fencing below) or further back, and (c) the design is stamped by a licensed civil engineer and approved by the local permitting authority.

Embankments

1) Earthworks and berm embankments should be performed in accordance with the latest edition of the "Greenbook Standard Specifications for Public Works Construction".

2) Embankments are earthen slopes or berms used for detaining or redirecting the flow of water.

3) Top of berm should be 2 feet minimum below the stormwater quality design water surface and should be keyed into embankment a minimum of 1 foot on both sides.

4) Typically, the top width of berm embankments are at least 20 feet, but narrower embankments may be plausible if approved by the civil engineer and the local permitting authority.

5) Basin berm embankments should be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed civil engineer) free of loose surface soil materials, roots, and other organic debris.

6) Basin berm embankments greater than 4 feet in height should be constructed by excavating a key equal to 50% of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed civil engineer.

7) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

8) Low growing native or non-invasive perennial grasses should be planted on downstream embankment slopes. See vegetation section below.

Fencing

Safety is provided either by fencing of the facility or by managing the contours of the basin to eliminate drop-offs and other hazards.

1) Provide fencing in accordance with the local permitting agency's requirements Perimeter fencing (minimum height of 42 inches) should be required on all basins exceeding two feet in depth or where interior side slopes are steeper than 6:1 (H:V).

2) If fences are required, fences should be designed and constructed in accordance with current policies of the local permitting agency and should be located at or above the overflow water surface elevation. Shrubs (approved, California-adapted species) can be used to hide the fencing. See vegetation section above.

Right-of-Way

1) Constructed treatment wetlands and associated access roads to be maintained by a public agency should be dedicated in fee or in an easement to the public agency with appropriate access.

Maintenance Access

1) Ownership of the basin and maintenance thereof is the responsibility of the developer/applicant. A maintenance agreement is required to ensure adequate performance and allow emergency access to the facilities.

2) Maintenance access road(s) should be provided to the control structure and other drainage structures associated with the basin (e.g., inlet, emergency overflow or bypass structures). Manhole and catch basin lids should be in or at the edge of the access road.

3) An access ramp into the basin should be constructed near the basin outlet. An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp should extend to the basin bottom to avoid damage to vegetation planted on the basin slope.

4) All access ramps and roads should be provided in accordance with the current policies of the Flood Control District.

Vector Control

1) A Mosquito Management Plan or Service Contract should be approved or waived by the local Vector Control District for any facility that maintains a pool of water for 72 hours or more.

Construction Considerations

The use of treated wood or galvanized metal anywhere inside the facility is prohibited. The use of galvanized fencing is permitted if in accordance with the Fencing requirement above.

Operations and Maintenance

Maintenance is of primary importance if constructed treatment wetlands basins are to continue to function as originally designed. A specific maintenance plan shall be formulated for each facility outlining the schedule and scope of maintenance operations, as well as the data handling and reporting requirements. The following are general maintenance requirements:

1) The constructed treatment wetlands basin should be inspected twice annually or more frequently, and inspections after major storm events are encouraged (see Appendix I for a constructed treatment wetland inspection and maintenance checklist). Trash and debris should be removed as needed, but at least annually prior to the beginning of the wet season.

2) Site vegetation should be maintained as frequently as necessary to maintain the aesthetic appearance of the site and to prevent clogging of outlets, creation of dead volumes, and barriers to mosquito fish to access pooled areas, and as follows:

3) Vegetation, large shrubs, or trees that limit access or interfere with basin operation should be pruned or removed.

4) Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.

5) Invasive vegetation, such as Alligatorweed (*Alternanthera philoxeroides*), Halogeton (*Halogeton* glomeratus), Spotted Knapweed (*Centaurea maculosa*), Giant Reed (*Arundo donax*), Castor Bean (*Ricinus communis*), Perennial Pepperweed (*Lepidium latifolium*), and Yellow Starthistle (*Centaurea solstitalis*) should be removed and replaced with non-invasive species. Invasive species should never contribute more than 25% of the vegetated area. For more information on invasive weeds, including biology and control of listed weeds, look at the encycloweedia located at the California Department of Food and Agriculture website or the California Invasive Plant Council website at www.cal-ipc.org.

6) Dead vegetation should be removed if it exceeds 10% of area coverage. This does not include seasonal die-back where roots would grow back later in colder areas. Vegetation should be replaced immediately to maintain cover density and control erosion where soils are exposed.

7) Sediment buildup exceeding 6 inches over the storage capacity in the first cell should be removed. Sediments should be tested for toxic substance accumulation in compliance with current disposal requirements if land uses in the catchment include

commercial or industrial zones, or if visual or olfactory indications of pollution are noticed. If toxic substances are encountered at concentrations exceeding thresholds of Title 22, Section 66261 of the California Code of Regulations, the sediment must be disposed of in a hazardous waste landfill. Clean forebay every two years at a minimum, to avoid accumulation in main wetland area. Environmental regulations and permits may be involved with the removal of wetland deposits. When the main wetland area needs to be cleaned, it is suggested that the main area be cleaned one half at a time with at least one growing season in between cleanings. This will help to preserve the vegetation and enable the wetland to recover more quickly from the cleaning.

8) Repair erosion to banks and bottom as required.

9) Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.

10) Following sediment removal activities, replanting, and/or reseeding of vegetation may be required for reestablishment.

TCM-4: Sand Filters

Sand filters operate much like bioretention facilities; however, instead of filtering stormwater through engineered soils, stormwater is filtered through a constructed sand bed with an underdrain system. Runoff enters the filter and spreads over the surface. As flows increase, water backs up on the surface of the filter where it is held until it can percolate through the sand. The treatment pathway is vertical (downward through the sand) to a perforated underdrain system that is connected to the downstream storm drainage system or to an infiltration facility. As stormwater passes through the sand, pollutants are trapped in the small pore spaces between sand grains or are adsorbed to the sand surface.

Sand filters connected to impervious surfaces

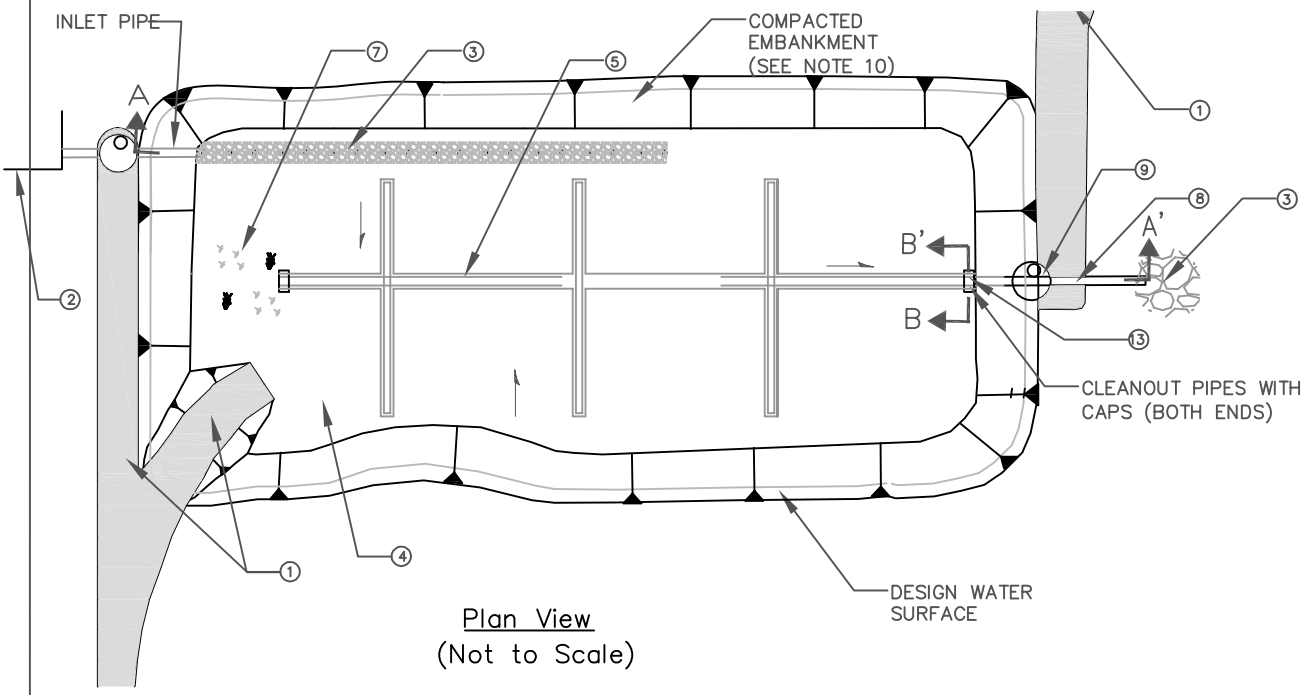
Photo Credits: Geosyntec Consultants

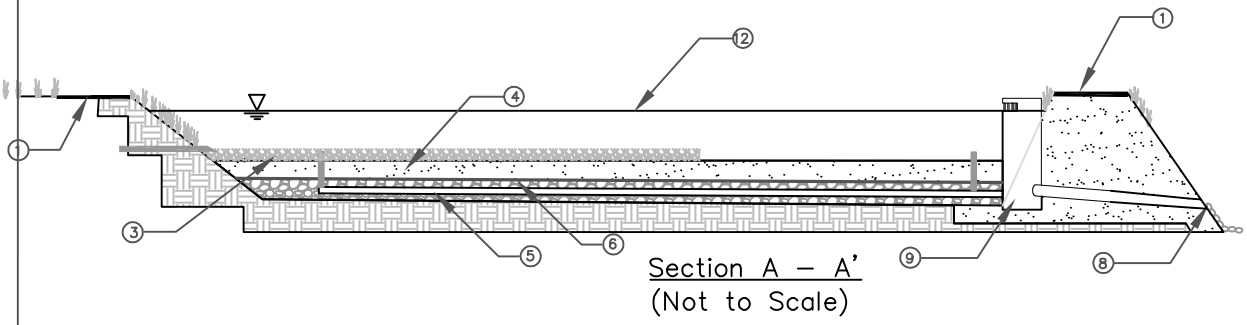
Application

- Adjacent to parking lots
- Road medians and shoulders
- Within open areas or play fields

Preventative Maintenance

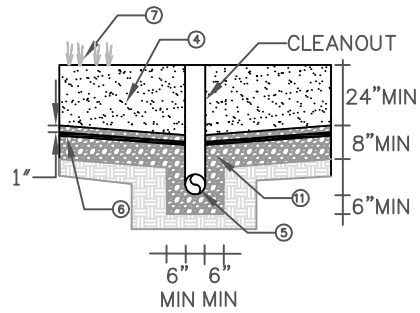
- Remove trash and debris, minor sediment accumulation, and obstructions near inlet and outlet structures
- Replace top 2” – 4” of sand
- Mow or weed surface of filter





NOTES:

1. INSTALL MAINTENANCE ACCESS ROAD AND RAMP TO BOTTOM OF SAND FILTER.
2. UPSTREAM PRETREATMENT SHALL BE PROVIDED. IN THE ABSENCE OF PRETREATMENT, INCLUDE SEDIMENT FOREBAY WITH VOLUME EQUAL TO 10–20% OF TOTAL SAND FILTER VOLUME.
3. FLOW SPREADER TO EVENLY DISTRIBUTE FLOWS ALONG AT LEAST 20% OF PERIMETER.
4. FILTER BED SHALL BE A 24" MINIMUM SAND LAYER ON TOP OF 8" MINIMUM GRAVEL OR DRAIN ROCK BACKFILL.
5. 6" MINIMUM DIAMETER PERFORATED PIPE UNDERDRAIN SURROUNDED BY GRAVEL BEDDING. INSTALL AT 0.5% MINIMUM SLOPE
6. INSTALL GEOTEXTILE FABRIC OVERLAIN BY 1" OF DRAIN ROCK OR TRANSITIONALLY GRADED AGGREGRATE BETWEEN SAND AND GRAVEL LAYER.
7. VEGETATION MAY BE PLANTED ON TOP OF FILTER BED. NO TOP SOIL SHALL BE ADDED TO FILTER BED.
8. SIZE OUTLET PIPE STRUCTURE TO PASS WATER QUALITY DESIGN STORM AND INCLUDE AN EMERGENCY OVERFLOW.
9. EMERGENCY OVERFLOW STRUCTURE.
10. ¾" – 1½" WASHED DRAIN ROCK OR GRAVEL LAYER.
11. DESIGN WATER SURFACE. 6' MAX PONDING DEPTH.



Section B – B'
(Not to Scale)

Geosyntec consultants

Figure 6-23: Sand Filter

Limitations

Limitations for sand filters include:

- The sand filter should be located away from trees producing leaf litter or areas contributing significant eroded sediment to prevent clogging.
- Sand filters are should not be used in areas where heavy sediment loads are expected or in tributary areas that are not fully stabilized; high sediment loading rates may cause premature clogging of the filter. Pretreatment is essential.
- Site must have adequate relief between land surface and stormwater conveyance system to permit vertical percolation through the sand filter and collection and conveyance in the underdrain to stormwater conveyance system; four feet of elevation difference is recommended between the inlet and outlet of the filter.
- Not applicable in areas of high groundwater.
- Does not provide quantity control.

Design Criteria

The main challenge associated with sand filters is maintaining the filtration capacity, which is critical to the performance of this BMP. If flows entering the sand filter have high sediment concentrations, clogging of the sand filter is likely. Contribution of eroded soils or leaf litter may also reduce the infiltration and associated treatment capacity of the structure. Sand filters should be designed according to the requirements listed in Table 6-26 and outlined in the section below. BMP sizing worksheets are presented in Appendix E.

Table 6-26: Sand Filter Design Criteria

Design Parameter	Unit	Design Criteria
Stormwater quality design volume, SQDV	acre-feet	See Section 2 and Appendix E for calculating SQDV.
Max depth at SQDV	feet	3
Freeboard (minimum)	feet	1
Length to width ratio	L:W	2:1 (larger preferred)
Filter bed depth	inches	18 inches sand; 9 inches gravel
Max ponding depth above filter bed	feet	6
Drawdown time	Hours	?

Design Parameter	Unit	Design Criteria
Hydraulic conductivity of sand, k	in/hr	1 (equal to 2 ft/day)
Underdrains		6 inch minimum diameter; 0.5% minimum slope
Side slopes	H:V	4:1 (H:V) interior and 3:1 (H:V) exterior, unless stabilization has been approved by a licensed geotechnical engineer; or vertical concrete walls

Pretreatment

Pretreatment must be provided for sand filters in order to reduce the sediment load entering the filter. Pretreatment refers to design features that provide settling of large particles before runoff reaches the filter, easing the long-term maintenance burden. To ensure that pretreatment mechanisms are effective, designers shall incorporate pretreatment such as a biofiltration BMP, proprietary device, or sedimentation forebay. BMPs that are described in the 2011 TGM that may serve this purpose include:

For design specification of selected pre-treatment devices, refer to:

- VEG-3: Vegetated swale
- VEG-4: Vegetated filter strip
- PROP-1: Hydrodynamic separation device

Sizing Criteria

Background

Sand filter design is based on Darcy's law:

$$Q = KiA \qquad \text{(Equation 6-104)}$$

Where:

Q = water quality design flow (cfs)

K = hydraulic conductivity (fps)

A = surface area perpendicular to the direction of flow (ft^2)

i = hydraulic gradient (ft/ft) for a constant head and constant media depth, computed as follows:

$$i = \frac{h+l}{l} \qquad \text{(Equation 6-105)}$$

Where:

h	=	average depth of water above the filter (ft), defined for this design as $d/2$
d	=	maximum storage depth above the filter (ft)
l	=	thickness of sand media (ft)

Darcy's law underlies both the simple and the routing methods of design. The filtration rate V, or more correctly, $1/V$, is the direct input in the sand filter design. The relationship between the filtration rate V and hydraulic conductivity K is revealed by equating Darcy's law and the equation of continuity, $Q = VA$. Specifically:

$Q = KiA$ and $Q = VA$

So, $VA = KiA$

Or: $V = Ki$ (Equation 6-106)

Where,

V	=	filtration rate (ft/s)

Note that $V \neq K$. That is, the filtration rate is not the same as the hydraulic conductivity, but they do have the same units (distance per time). K can be equated to V by dividing V by the hydraulic gradient i, which is defined above.

The hydraulic conductivity K does not change with head nor is it dependent on the thickness of the media, only on the characteristics of the media and the fluid. A design hydraulic conductivity of 1 inch per hour (2 feet per day) used in this simple sizing method is based on bench-scale tests of conditioned rather than clean sand (KCSWDM, 2005) and represents the average sand bed condition as silt is captured and held in the sand bed.

Unlike the hydraulic conductivity, the filtration rate V changes with head and media thickness, although the media thickness is constant in the sand filter design.

Simple Sizing Method

The simple sizing method does not route flows through the filter. It determines the size of the filter based on the simple assumption that inflow is immediately discharged through the filter as if there were no storage volume. An adjustment factor (0.7) is applied to compensate for the greater filter size resulting from this method. Even with the adjustment factor, the simple method generally produces a larger filter size than the routing method.

Step 1: Determine the water quality design volume

Sand filters should be sized to capture and treat the stormwater quality design volume (see Section E.1).

Step 2: Determine maximum storage depth of water

Determine the maximum water storage depth (d) above the sand filter. This depth is defined as the depth at which water begins to overflow the reservoir pond, and it depends on the site topography and hydraulic constraints. The depth is chosen by the designer, but should be 6 feet or less.

Step 3: Calculate the sand filter area

Determine the sand filter area using the following equation:

$$A_{sf} = \frac{V_{wq} RL}{Kt(h+L)} \qquad \text{(Equation 6-107)}$$

Where,

A_{sf}	=	surface area of the sand filter bed (ft^2)
V_{wq}	=	water quality design volume (ft^3)
R	=	routing adjustment factor (use $R = 0.7$)
L	=	sand bed depth (ft)
K_{des}	=	design hydraulic conductivity of media (use 2 ft/day)
t	=	drawdown time (use 1 day)
h	=	average depth of water above the filter (ft), [use (d/2) with d from Step 2]

Routing Method

A continuous runoff model, such as US EPA's Stormwater Management Model (SWMM) Model, can be used to optimally size a sand filter. A continuous simulation model consists of three components: a representative long term period of rainfall data (≈ 20 years or greater) as the primary model input; a model component representing the tributary area to the sand filter that takes into account the amount of impervious area, soil types of the pervious area, vegetation, evapotranspiration, etc.; and a component that simulates the sand filter. Using this method, the filter should be sized to capture and treat the WQ design volume from the post-development tributary area.

The continuous simulation model routes predicted tributary runoff to the sand filter, where treatment is simulated as a function of the infiltrative (flow) capacity of the sand filter and the available storage volume above the sand filter. In a continuous runoff model such as SWMM, the physical parameters of the sand filter are represented with stage-storage-discharge relationships. Due to the computational power of ordinary desktop computers, long-term continuous simulations generally take only minutes to run. This allows the modeler to run several simulations for a range of sand filter sizes, varying either the surface area of the filter (and resulting flow capacity) or the storage capacity above the sand filter, or both. Sufficient continuous model simulations should be completed so that results encompass the WQ design volume capture goal.

Model results should be plotted for both varying storage depths above the filter and for varying filter surface area (and resulting flow capacity) while keeping all other parameters constant. The resulting relationship of percent capture as a function of sand filter flow and storage capacity can be used to optimally size a sand filter based on site conditions and restraints.

In addition to continuous simulation modeling, routing spreadsheets and/or other forms of routing modeling that incorporate rainfall-runoff relationships and infiltrative (flow) capacities of sand filters may be used to size facilities. Alternative sizing methodologies should be prepared with good engineering practices.

Sizing and Geometry

1) Sand filters shall be sized to capture and filter the Stormwater quality design volume, SQDV (See Section 2 and Appendix E for further detail).

2) Sand filters may be designed in any geometric configuration, but rectangular with a 2:1 length-to-width ratio or greater is preferred.

3) Filter bed depth must be at least 24 inches, but 36 inches is preferred.

4) Depth of water storage over the filter bed should be 6 feet maximum. Minimum freeboard is one foot.

5) Sand filters should be placed off-line to prevent scouring of the filter bed by high flows. The overflow structure must be designed to pass the stormwater quality design storm.

Sand Specification

Ideally the effective diameter of the sand, d_{10} (the diameter corresponding to the sieve size that passes 10% of sand grains), should be just small enough to ensure a good quality effluent while preventing penetration of stormwater particles to such a depth that they cannot be removed by surface scraping (~2-3 inches). This effective diameter usually lies in the range 0.20-0.35 mm. In addition, the coefficient of uniformity, Cu = d_{60}/d_{10}, should be less than 3.

The sand in a filter should consist of medium sand with few fines meeting ASTM C 33 size gradation (by weight) or equivalent as given in the table below.

U.S. Sieve Size	Percent Passing
3/8 inch	100
U.S. No. 4	95 to 100
U.S. No. 8	80 to 100
U.S. No. 16	50 to 85
U.S. No. 30	25 to 60
U.S. No. 50	5 to 30
U.S. No. 100	Less than 10

Finally, the silica (SiO_2) content of the sand should be greater than 95% by weight.

Underdrain

1) There are several underdrain system options which can be used in the design of a sand filter:

    a. A central underdrain collection pipe with lateral collection pipes in an 8 inch minimum gravel backfill or drain rock bed.

    b. Longitudinal pipes in an 8 inch minimum gravel backfill or drain rock bed, with a collection pipe at the outfall.

    c. Small sand filters may use a single underdrain pipe in an 8 inch minimum gravel backfill or drain rock bed.

2) All underdrain pipes and connectors should be 6 inches or greater so they can be cleaned without damage to the pipe. Clean-out risers with diameters equal to the underdrain pipe should be placed at the terminal ends of all pipes and extend to the surface of the filter. A valve box should be provided for access to the cleanouts and the cleanout assembly should be water tight to prevent short circuiting of the sand filter.

3) The underdrain pipe should be sized and perforated as to ensure free draining of the sand filter bed. Round perforations should be at least 1/2-inch in diameter and the pipe should be laid with holes downward.

4) The maximum perpendicular distance between any two lateral collection pipes or from the edge of the filter and the collection pipes should be 9 feet.

5) All pipes should be placed with a minimum slope of 0.5%.

6) The invert of the underdrain outlet should be above the seasonal high groundwater level.

7) At least 8 inches of gravel backfill should be maintained over all underdrain piping, and at least 6 inches should be maintained on both side and beneath the pipe to prevent damage by heavy equipment during maintenance. Either drain rock or gravel backfill may be used between pipes.

8) The bottom gravel layer should have a diameter at least 2X the size of the openings into the drainage system. The grains should be hard, preferably rounded, with a specific gravity of at least 2.5, and free of clay, debris and organic impurities.

9) Either a geotextile fabric or a two-inch transition gradation layer (preferred) should be placed between the sand layer and the drain rock or gravel backfill layer. If a geotextile is used, one inch of drain rock or gravel backfill should be place above the fabric. This allows for a transitional zone between sand and gravel and may reduce pooling of water at the liner interface. The geotextile should meet the following minimum materials requirements.

Geotextile Property	Value	Test Method
Trapezoidal Tear (lbs)	40 (min)	ASTM D4533
Permeability (cm/sec)	0.2 (min)	ASTM D4491
AOS (sieve size)	#60 - #70 (min)	ASTM D4751
Ultraviolet resistance	70% or greater	ASTM D4355

Flow Spreader

1) A flow spreader should be installed at the inlet along one side of the filter to evenly distribute incoming runoff across the filter and to prevent erosion of the filter surface.

    a. If the sand filter is curved or an irregular shape, a flow spreader should be provided for a minimum of 20 percent of the filter perimeter.

    b. If the length-to-width ratio of the filter is 2:1 or greater, a flow spreader should be located on the longer side and for a minimum length of 20 percent of the facility perimeter.

    c. In other situations, use good engineering judgment in positioning the spreader.

2) Erosion protection should be provided along the first foot of the sand bed adjacent to the flow spreader. Geotextile weighted with sand bags at 15-foot intervals may be used. Quarry spalls may also be used.

Vegetation

1) The use of vegetation in sand filters is optional. However, no top soil should be added to the sand filter bed because the fine-grained materials (silt and clay) would reduce the hydraulic capacity of the filter.

2) Growing grass or other vegetation requires the selection of species that can tolerate the demanding environment of a sand filter bed. Plants not receiving sufficient dry weather flows should be able to withstand long periods of drought during summer periods, followed by periods of saturation during storm events. A horticultural specialist should be consulted for advice on species selection.

3) A sod grown in sand may be used on the sand surface as long as there is no clay in the sand substrate and the particle size gradation of the substrate meets the sand filter specifications. No other sod should be used due to the high clay content in most sod soils.

4) To prevent uses that could compact and damage the filter surface, permanent structures are not permitted on sand filters (e.g. playground equipment).

Emergency Overflow Structure

Sand filters may only be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged. The overflow structure must be able to safely convey flows from the stormwater quality design storm to the downstream conveyance system or other acceptable discharge point.

Side Slopes

1) Interior side slopes above the stormwater quality design depth and up to the emergency overflow water surface steeper than 4:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

2) Exterior side slopes steeper than 2:1 (H:V) should be stabilized to prevent erosion with a method approved by the local permitting authority.

3) For any slope (interior or exterior) greater than 2:1 (H:V), a geotechnical investigation and report must be submitted and approved by the local permitting authority.

4) Pond walls may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete, (b) a fence, which prevents access, is provided along the top of the wall or further back, and (c) the design is stamped by a licensed civil engineer and approved by the County.

Embankments

1) Embankments (earthen slopes or berms) may be used for detaining or redirecting the flow of water.

2) The minimum top width of all berm embankments should be 20 feet, or as approved by the geotechnical engineer.

3) Basin berm embankments should be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a licensed geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.

4) Earthworks should be in accordance with Section 300-6 of the Standard Specifications for Public Works Construction, most recent edition.

5) Basin berm embankments greater than 4 feet in height should be constructed by excavating a key equal to 50% of the berm embankment cross-sectional height and width. This requirement may be waived if specifically recommended by a licensed geotechnical engineer.

6) The berm embankment should be constructed of compacted soil (95% minimum dry density, modified proctor method per ASTM D1557), placed in 6-inch lifts.

Maintenance Access

Maintenance access road(s) shall be provided to the control structure and other drainage structures associated with the basin (e.g., inlet, emergency overflow or bypass structures). Manhole and catch basin lids should be in or at the edge of the access road.

An access ramp is required for removal of sediment with a backhoe or loader and truck. The ramp should extend to the bottom of the sand filter.

Landscaping Outside of the Facility

A sand filter can add aesthetics to a site and should be incorporated into a project's landscape design. Interior side slopes may be stepped with flat areas to provide informal seating with a game or play area below. Perennial beds may be planted above the overflow water surface elevation. Large shrubs and trees are not recommended, however, as shading limits evaporation and falling leaves can clog the filter surface. If a sand filter area is intended for recreational uses, such as a volleyball area, the interior side slopes of the filter embankment should be no steeper than 3:1 and may be stepped.

1) No trees or shrubs may be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways, flow spreaders, or earthen embankments. Species with roots that seek water, such as willow or poplar, should not be used within 50 feet of pipes or manmade structures.

2) Prohibited non-native plant species will not be permitted. For more information on invasive weeds, including biology and control of listed weeds, look at the

encycloweedia located at the California Department of Food and Agriculture website at or the California Invasive Plant Council website at www.cal-ipc.org.

Operations and Maintenance

Sand filters are subject to clogging by fine sediment, oil and grease, and other debris (e.g., trash and organic matter such as leaves). Filters and pretreatment facilities should be inspected every 6 months during the first year of operation. Inspection should also occur immediately following a storm event to assess the filtration capacity of the filter. Once the filter is performing as designed, the frequency of inspection may be reduced to once per year.

Most of the maintenance should be concentrated on the pretreatment practices, such as buffer strips and swales upstream of the trench to ensure that sediment does not reach the infiltration trench. Regular inspection should determine if the sediment removal structures require preventative maintenance.

Inspect basin a minimum of twice a year, before and after the rainy season, after large storm events, or more frequently if needed. Some important items to check for include: differential settlement, cracking; erosion, leakage, or tree growth on the embankment; the condition of the riprap in the inlet, outlet and pilot channels; sediment accumulation in the basin; and the vigor and density of the vegetation on the basin side slopes and floor. Correct observed problems as necessary.

- Remove litter and debris from banks and basin bottom as required.
- Repair erosion to banks and bottom as required.
- Check infiltration rate of sand bed twice annually, once after significant rainfall.
- Scarify top 3 to 5 inches of filters surface by raking once annually or as required to restore infiltration rate of the filter.
- Clean forebay every two years at a minimum, to avoid accumulation in main basin.
- Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed. Correct observed problems as necessary.

TCM-5: Cartridge Media Filter

Cartridge media filters are manufactured devices that typically consist of a series of cylindrical vertical filters contained in a catch basin, manhole, or vault that provide treatment through filtration and sedimentation. The manhole or vault may be divided into multiple chambers where the first chamber acts as a pre-settling basin for removal of coarse sediment while another chamber acts as the filter bay and houses the filter cartridges.

Cartridge Media Filters

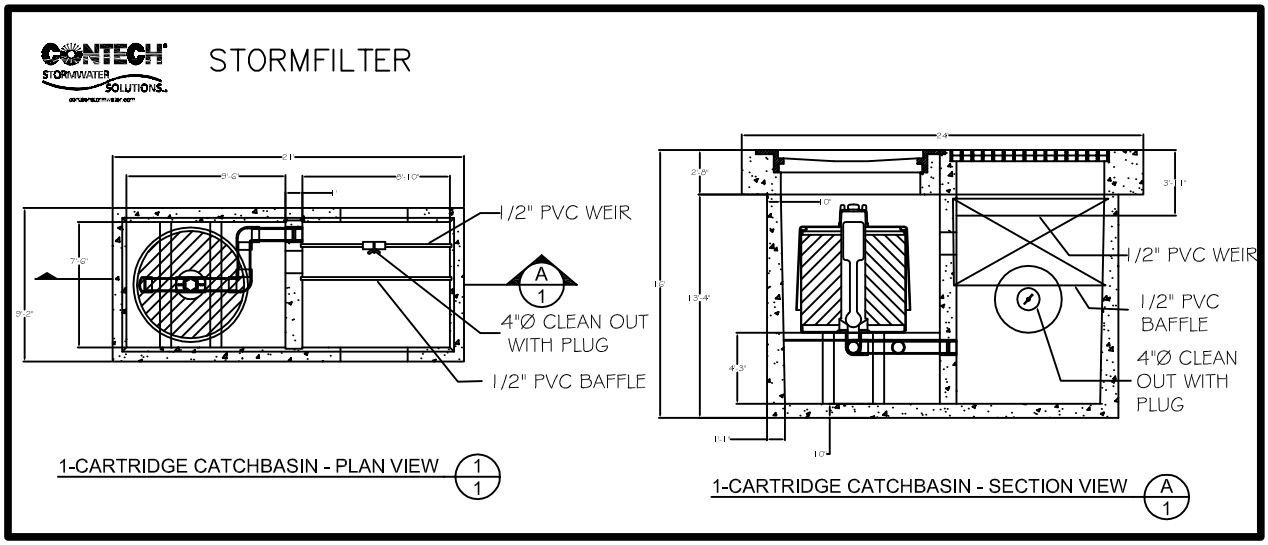
Photo Credits: Contech Stormwater Solutions, Inc.

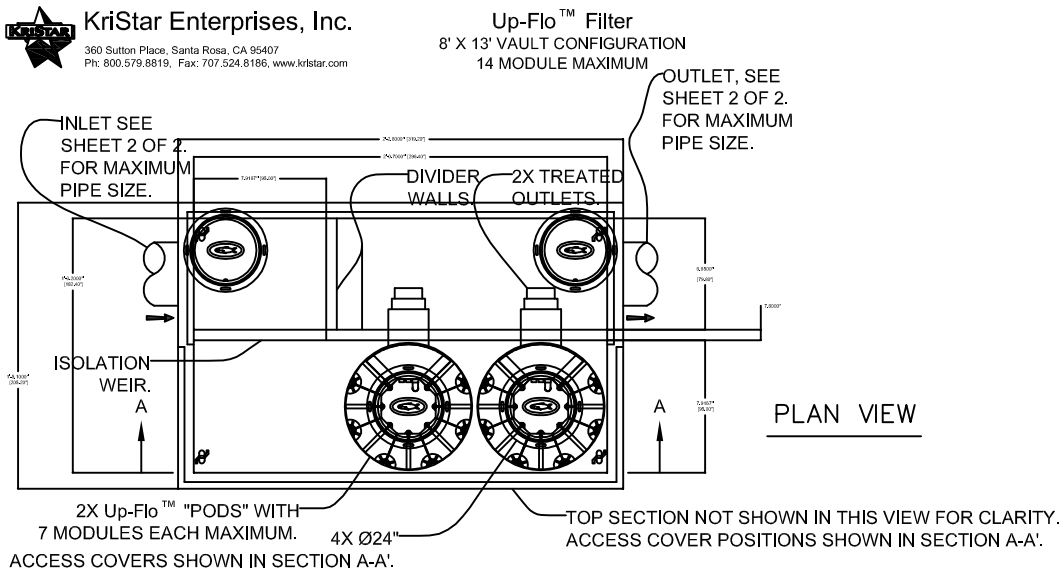
Application

- Parking lots
- Roadways
- Playgrounds
- Outdoor eating areas

Preventative Maintenance

- Filter media replacement
- Solids removal from vault, manhole, or catch basin
- Inspect for inlet and outlet for clogging





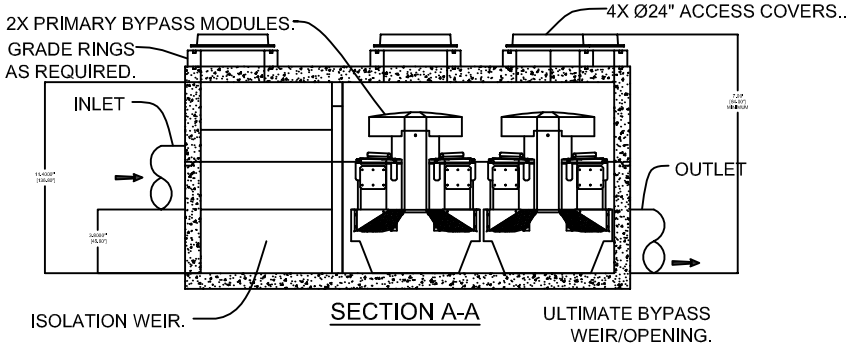


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Figure 6-24: Cartridge Media Filter

Table 6-27: Proprietary Cartridge Media Filter Manufacturer Websites

Device	Manufacturer	Website
BaySaver BayFilter	Baysaver Technologies Inc.	www.baysaver.com
ConTech StormFilter™	Contech® Construction Products Inc.	www.contech-cpi.com
CrystalStream	CrystalStream Technologies	www.crystalstream.com
KriStar Fossil Tee™ (media filter)	KriStar Enterprises Inc.	www.kristar.com
KriStar Up-Flo™ Filter and Perk™ Filter	KriStar Enterprises Inc.	www.kristar.com

Limitations

As with all filtration systems, use in catchments that have significant areas of non-stabilized soils can lead to premature clogging.

Design Criteria

1) Cartridge media filter BMP vendors are constantly updating and expanding their product lines, so refer to the latest design guidance from each of the vendors.

2) Selected filter media should target pollutants of concern. A combination of media is often recommended to maximize pollutant removal. Perlite is effective for removing TSS and oil and grease. Zeolite removes soluble metals, ammonium, and some organics. Vendors also offer proprietary medias (such as leaf compost or activated carbon) that are designed to remove soluble metals, organics, and other pollutants.

3) Manufacturers try to distinguish their products through innovative designs that aim at providing self cleaning and draining, uniformly loaded, and clog resistant cartridges that functional properly over a wide range of hydraulic loadings and pollutant concentrations.

4) All stormwater vaults containing cartridge filters that have standing water for longer than 72 hours can become a breeding area for mosquitoes. The selected BMP should have a system to completely drain the vault, such as weep holes in the bottom of the vault.

Sizing

1) Cartridge media filters should be sized to capture and treat the stormwater quality design flow rate.

2) Proprietary cartridge media filter devices, like most proprietary BMPs, and auxiliary components such as media, screens, baffles, and sumps are selected based onsite-specific conditions such as the loading that is expected and the desired frequency of maintenance. Sizing of proprietary devices is reduced to a simple process whereby a model can simply be selected from a table or a chart based on a few known quantities

(tributary area, location, design flow rate, etc). Most of the manufacturers either size the devices for potential clients or offer calculators on their websites that simplify the design process. For the latest sizing guidelines, refer to the manufacturer's website.

PT-1: Hydrodynamic Separation Device

Hydrodynamic separation devices (alternatively, swirl concentrators) are devices that remove trash, debris, and coarse sediment from incoming flows using screening, gravity settling, and centrifugal forces generated by forcing the influent into a circular motion. By having the water move in a circular fashion, rather than a straight line, it is possible to obtain significant removal of suspended sediments and attached pollutants with less space as compared to wet vaults and other settling devices. Hydrodynamic devices were originally developed for combined sewer overflows (CSOs), where they were used primarily to remove coarse inorganic solids. Hydrodynamic separation has been adapted for stormwater treatment by several manufacturers and is currently used to remove trash, debris, and other coarse solids down to sand-sized particles. Several types of hydrodynamic separation devices are also designed to remove floating oils and grease using sorbent media.

Hydrodynamic Separation

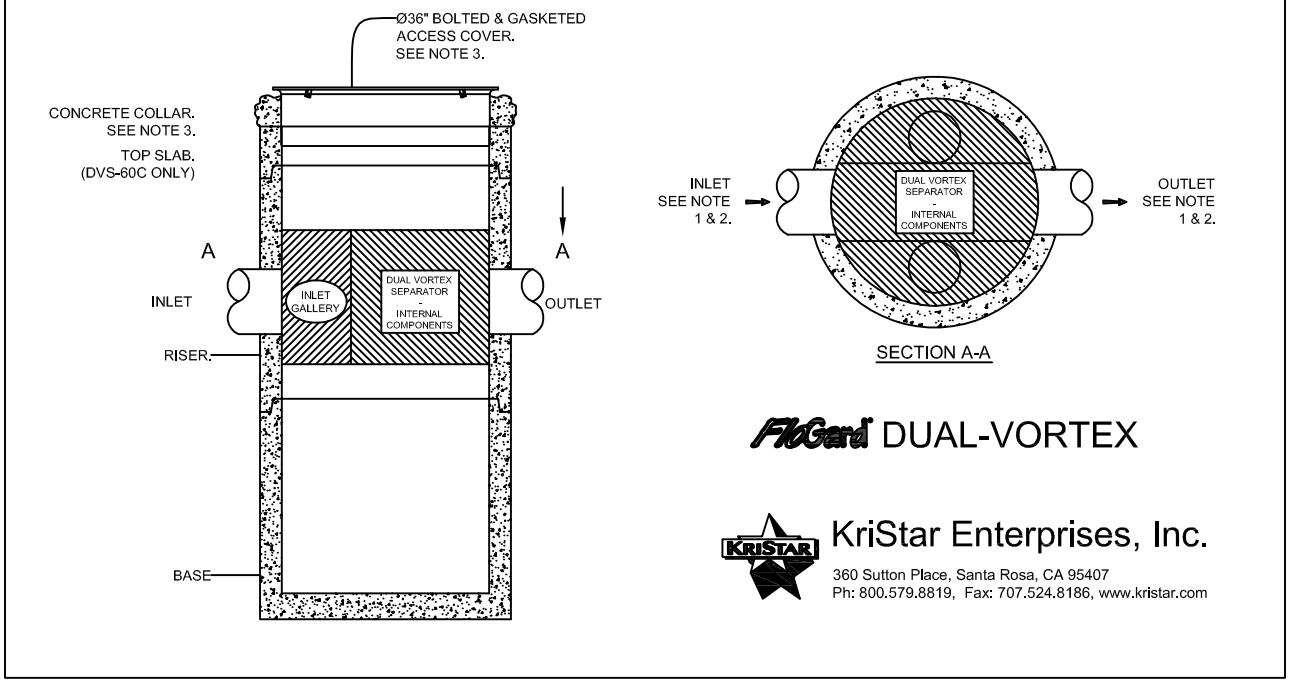
Photo Credits: 1. Contech Stormwater Solutions, Inc.; 2. Dave Weller, FedCo Construction

Application

- Parking lots
- Areas adjacent to parking lots
- Areas adjacent to buildings
- Road medians and shoulders

Preventative Maintenance

- Sediment, trash and debris removal
- Vector control



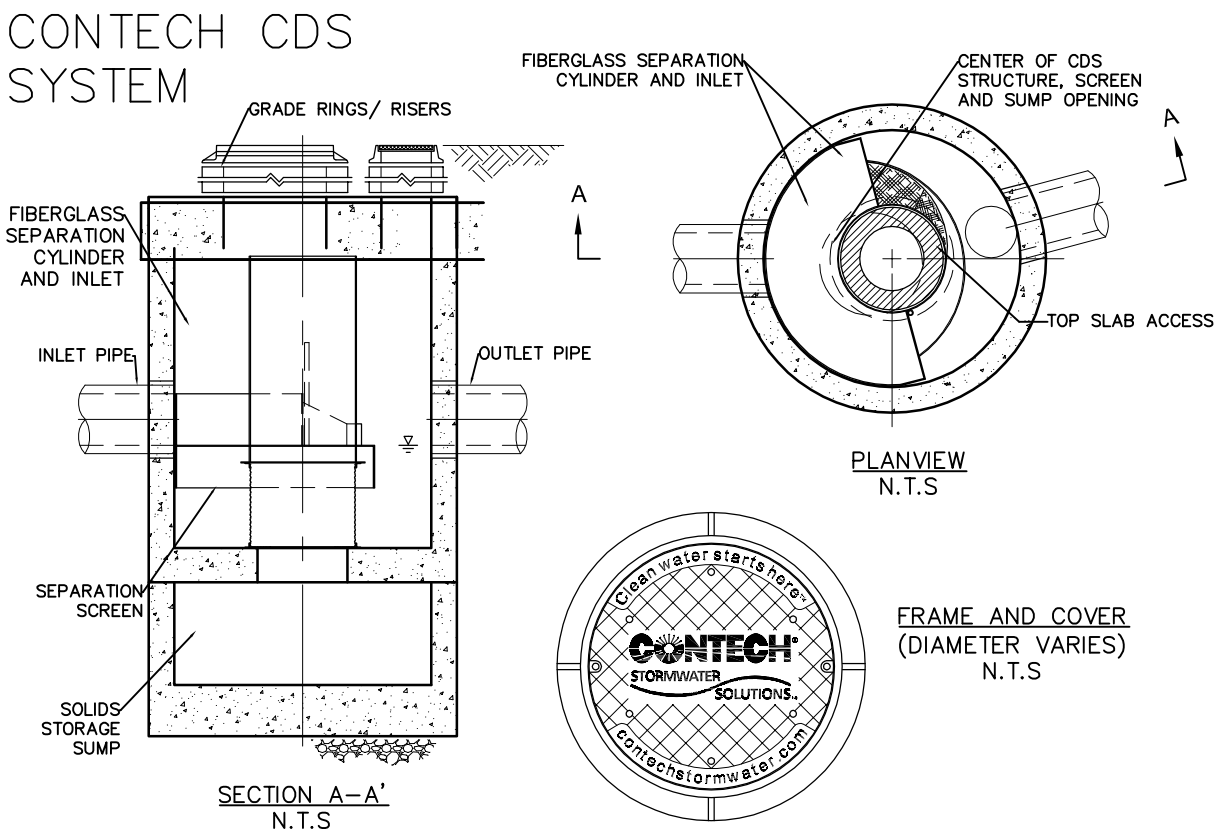


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Figure 6-25: Hydrodynamic Separation

Table 6-28: Proprietary Hydrodynamic Device Manufacturer Websites

Device	Manufacturer	Website
Rinker In-Line Stormceptor®	Rinker Materials™	www.rinkerstormceptor.com
FloGard® Dual-Vortex Hydrodynamic Separator	KriStar Enterprises Inc.	www.kristar.com
Contech® CDS[a]™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® Vortechs™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® VorSentry™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® VorSentry™ HS	Contech® Construction Products Inc.	www.contech-cpi.com
BaySaver BaySeparator	Baysaver Technologies Inc.	www.baysaver.com

Limitations

Hydrodynamic separation devices are effective for the removal of course sediment, trash, and debris, and are useful as pretreatment in combination with other BMP types that target smaller particle sizes.

Hydrodynamic devices represent a wide range of device types that have different unit processes and design elements (e.g., storage versus flow-through designs, inclusion of media filtration, etc.) that vary significantly within the category. These design features likely have significant effects on BMP performance; therefore, generalized performance data for hydrodynamic devices is not practical.

Design Criteria

Proprietary hydrodynamic device BMP vendors are constantly updating and expanding their product lines, so refer to the latest design guidance from each of the vendors. General guidelines on the performance, sizing, operations and maintenance of proprietary devices are provided by the vendors.

Sizing

Hydrodynamic devices shall be sized to capture and treat the stormwater quality design flow rate and to completely drain within 72 hours.

Sizing of proprietary devices is reduced to a simple process whereby a model can simply be selected from a table or a chart based on a few known quantities (tributary area, location, design flow rate, design volume, etc). A few of the manufacturers either size the devices for potential clients or offer calculators on their websites that simplify the design process even further and lessens the possibility of using obsolete design information. For the latest sizing guidelines, refer to the manufacturer's website.

The hydrodynamic separators listed in Table 6-28 are designed to have a permanent pool of water stored within the system. Various methods of vector control are available to prevent mosquito breeding including manhole cover screens and the use of mosquito dunks. In many designs, oil and grease is stored at the water surface and provides a deterrent to mosquito breeding.

Operations and Maintenance

Hydrodynamic devices should be inspected every 6 months during the first year of operation. Inspection should also occur immediately following a storm event to assess the function of the device. Once the device is performing as designed, the frequency of inspection may be reduced to once per year.

PT-2: Catch Basin Insert

Catch basin inserts are manufactured filters or fabric placed in a drop inlet to remove sediment and debris and may include sorbent media (oil absorbent pouches) to remove floating oils and grease. Catch basin inserts are selected specifically based upon the orientation of the inlet.

Catch Basin Inserts

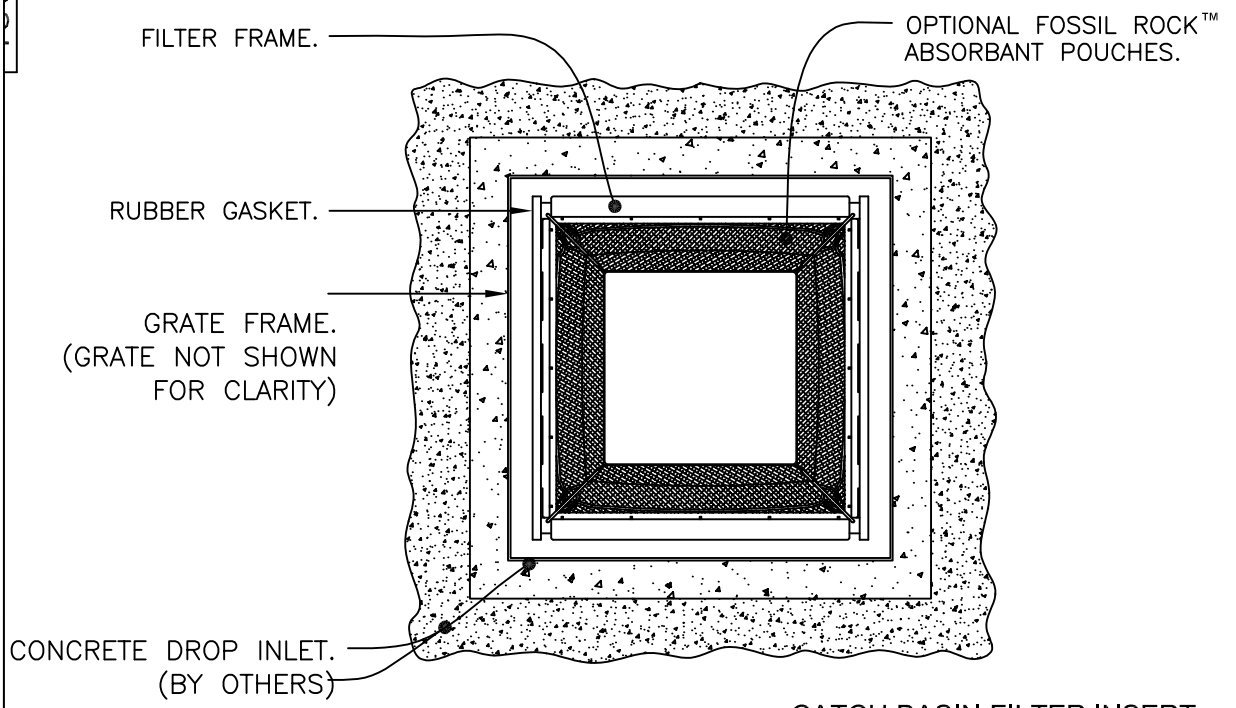
Photo Credits: 1. KriStar; 2. Aquashield

Application

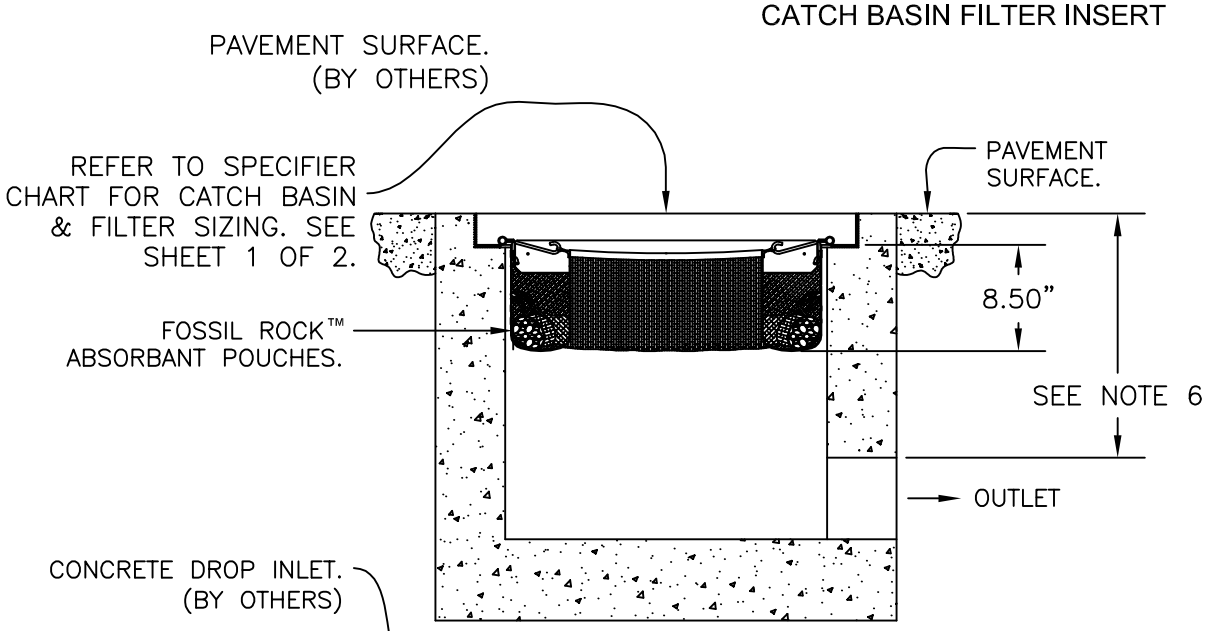
- Parking lots
- Roads
- Athletic courts
- Outdoor food areas

Preventative Maintenance

- After storm inspection
- Sediment removal
- Trash removal
- Filter/sorbent media replacement



CATCH BASIN FILTER INSERT



SECTION VIEW

KriStar Enterprises, Inc.
360 Sutton Place, Santa Rosa, CA 95407
Ph: 800.579.8819, Fax: 707.524.8186, www.kristar.com

FloGard®

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Figure 6-26: Catch Basin

Table 6-29: Proprietary Catch Basin Insert Manufacturer Websites

Device	Manufacturer	Website
AbTech Industries Ultra-Urban Filter™	AbTech Industries	www.abtechindustries.com
Aquashield Aqua-Guardian™ Catch Basin Insert	Aquashield™ Inc.	www.aquashieldinc.com
Bowhead StreamGuard™	Aquashield™ Inc.	www.aquashieldinc.com
Contech® Triton Catch Basin Filter™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® Triton Curb Inlet Filter™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® Triton Basin StormFilter™	Contech® Construction Products Inc.	www.contech-cpi.com
Contech® Curb Inlet StormFilter™	Contech® Construction Products Inc.	www.contech-cpi.com
Curb Inlet Basket	SunTree Technologies Inc.	www.suntreetech.com
Curb Inlet Grates	EcoSense International™	www.ecosenseinternational.org
Grate Inlet Skimmer Box	SunTree Technologies Inc.	www.suntreetech.com
Hydro-Kleen™ Filtration System	Hydro Compliance Management Inc.	Not available
KriStar FloGard+PLUS®	KriStar Enterprises Inc.	www.kristar.com
KriStar FloGard®	KriStar Enterprises Inc.	www.kristar.com
KriStar FloGard LoPro Matrix Filter®	KriStar Enterprises Inc.	www.kristar.com
Nyloplast Storm-PURE Catch Basin Insert	Nyloplast Engineered Surface Drainage Products	www.nyloplast-us.com
StormBasin®	FabCo® Industries Inc.	www.fabco-industries.com
Stormdrain Solutions Interceptor	FabCo® Industries Inc.	www.fabco-industries.com
Stormdrain Solutions Inceptor®	Stormdrain Solutions	www.stormdrains.com
StormPod®	FabCo® Industries Inc.	www.fabco-industries.com
Stormwater Filtration Systems	EcoSense International™	www.ecosenseinternational.org
Ultra-CurbGuard®	UltraTech International Inc.	www.spillcontainment.com
Ultra-DrainGuard®	UltraTech International Inc.	www.spillcontainment.com
Ultra-GrateGuard®	UltraTech International Inc.	www.spillcontainment.com
Ultra-GutterGuard®	UltraTech International Inc.	www.spillcontainment.com
Ultra-InletGuard®	UltraTech International Inc.	www.spillcontainment.com

Limitations

Catch basin inserts come in such a wide range of configurations that it is practically impossible to generalize the expected performance. Inserts should mainly be used for catching coarse sediments and floatable trash, and are effective as pretreatment in combination with other types of structures that are recognized as water quality treatment BMPs. Trash and large objects can greatly reduce the effectiveness of catch basin inserts with respect to sediment and hydrocarbon capture. Frequent

maintenance and the use of screens and grates to keep trash out may decrease the likelihood of clogging and prevent obstruction and bypass of incoming flows.

Design Criteria

Catch basin inserts shall be sized to capture and treat the stormwater quality design flow rate.

Operations and Maintenance

1) Trash, debris, and sediment around insert grate and inside chamber requiring trash to be cleared.

2) Repair filter media if damaged or severely clogged.

3) Inspection of catch basin insert after each storm greater than 0.2 inches is recommended.

7 MAINTENANCE PLAN

This chapter identifies the basic information that should be included in a maintenance plan. Refer to Fact Sheets for individual control measures in Chapter 6 regarding device-specific maintenance requirements.

7.1 Site Map

1) Provide a site map showing boundaries of the site, acreage and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site. Distinguish between soft and hard surfaces on the map.

2) Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.

3) With legend, show locations of expected sources of pollution generation (outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, wash-racks, etc). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.

4) With legend, indicate types and locations of stormwater management control measures which will be built to permanently control stormwater pollution. Distinguish between pollution prevention, treatment, sewer diversion, and containment devices.

7.2 Baseline Descriptions

1) List the property owners and persons responsible for operation and maintenance of the stormwater management control measures onsite. Include phone numbers and addresses.

2) Identify the intended method of providing financing for operation, inspection, routine maintenance and upkeep of stormwater control measures.

3) List all permanent stormwater control measures. Provide a brief description of stormwater management control measures selected and if appropriate, facts sheets or additional information.

4) As appropriate for each stormwater control measure provide:

    a. A written description and check list of all maintenance and waste disposal activities that will be performed. Distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance. For example, maintenance requirements for vegetation in a constructed wetland may be more intensive during the first few years until the vegetation is established. The post-establishment maintenance

plan should address maintenance needs (e.g., pruning, irrigation, weeding) for a larger, more stable system. Include maintenance performance procedures for facility components that require relatively unique maintenance knowledge, such as specific plant removal / replacement, landscape features, or constructed wetland maintenance. These procedures should provide enough detail for a person unfamiliar with maintenance to perform the activity, or identify the specific skills or knowledge necessary to perform and document the maintenance.

b. A description of site inspection procedures and documentation system, including record-keeping and retention requirements.

c. An inspection and maintenance schedule, preferably in the form of a table or matrix, for each activity for all facility components. The schedule should demonstrate how it will satisfy the specified level of performance, and how the maintenance / inspection activities relate to storm events and seasonal issues.

d. Identification of the equipment and materials required to perform the maintenance.

5) As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain. Identify housekeeping BMPs that reduce maintenance of Treatment Control Measures. These procedures are listed based on facility operations and can be found in the Ventura County Industrial/Commercial Clean Business Program document.

7.3 Spill Plan

1) Provide emergency notification procedures (phone and agency/persons to contact)

2) As appropriate for site, provide emergency containment and cleaning procedures.

3) Note downstream receiving water bodies or wetlands which may be affected by spills or chronic untreated discharges.

4) As appropriate, create an emergency sampling procedure for spills. (Emergency sampling can protect the property owner from erroneous liability for down-stream receiving area clean-ups).

7.4 Facility Changes

Operational or facility changes which significantly affect the character or quantity of pollutants discharging into the stormwater management control measures will require modifications to the Maintenance Plan and/or additional stormwater control measures.

7.5 Training

1) Identify appropriate persons to be trained and assure proper training.

2) Training to include:

   a. Good housekeeping procedures defined in the plan.

   b. Proper maintenance of all pollution mitigation devices.

   c. Identification and cleanup procedures for spills and overflows.

   d. Large-scale spill or hazardous material response.

   e. Safety concerns when maintaining devices and cleaning spills.

7.6 Basic Inspection and Maintenance Activities

1) Create and maintain onsite, a log for inspector names, dates and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.

2) Once annually, perform testing of any mechanical or electrical devices prior to wet weather.

3) Report any significant changes in stormwater management control measures to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.

4) Note any significant maintenance requirements due to spills or unexpected discharges.

5) As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater management control measures are performing as designed and approved.

6) Assure unauthorized low-flow discharges from the property do not by-pass stormwater control measures.

7) Perform an annual assessment of each pollution generation operation and its associated stormwater management control measures to determine if any part of the pollution reduction train can be improved.

7.7 Revisions of Pollution Mitigation Measures

If future correction or modification of past stormwater management control measures or procedures is required, the owner shall obtain approval from the governing stormwater

agency prior to commencing any work. Corrective measures or modifications shall not cause discharges to bypass or otherwise impede existing stormwater control measures.

7.8 Monitoring & Reporting Program

1) The governing stormwater agency may require a Monitoring & Reporting Program to assure the stormwater management control measures approved for the site are performing according to design.

2) If required by local permitting agency, the Maintenance Plan shall include performance testing and reporting protocols.

APPENDIX A : ACRONYMS AND GLOSSARY OF TERMS

A.1 Acronyms and Abbreviations

303(d)	303(d) List of Impaired Water Bodies
API	American Petroleum Institute (oil/water separator type)
BMP	Best Management Practice
CEQA	California Environmental Quality Act
CP	Coalescing Plate (oil/water separator type)
CTR	California Toxics Rule
CWA	Clean Water Act
CDFG	California Department of Fish and Game
EIA	Effective Impervious Area
EMC	Event Mean Concentration
ESA	Environmentally Sensitive Area
LID	Low Impact Development
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
RPAMP	Redevelopment Project Area Master Plan
SQDV	Stormwater Quality Design Volume
SQDF	Stormwater Quality Design Flow
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
WERF	Water Environment Research Foundation

A.2 Glossary

Automotive Repair Shop: A facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.

Backfill: Earth or engineered material used to refill a trench or an excavation.

Berm: An earthen mound used to direct the flow of runoff around or through a structure.

Best Management Practice (BMP): Any program, technology, process, siting criteria, operational methods or measures, or engineered systems, which when implemented prevent, control, remove, or reduce pollution.

Best Management Practices (BMPs): Includes schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the United States. BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Biofiltration: The simultaneous process of filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater that takes place when runoff flows over and through vegetated areas.

Bioretention Facility: A facility that utilizes soil infiltration and both woody and herbaceous plants to remove pollutants from stormwater runoff. Runoff is typically captured and infiltrated or released over a period of 24 to 48 hours.

Blue Roof: A roof that is designed to store rainwater, typically in a cistern-type device.

Brown Roof: A type of green roof which focuses on biodiversity and locally-sourced material.

Buffer Strip or Zone: Strip of erosion-resistant vegetation over which stormwater runoff is directed.

Capacity: The capacity of a stormwater drainage facility is the flow volume or rate that the facility (e.g., pipe, basin, vault, swale, ditch, drywell, etc.) is designed to safely contain, receive, convey, reduce pollutants from, or infiltrate stormwater to meet a specific performance standard. There are different performance standards for pollution reduction, flow control, conveyance, and destination/ disposal, depending on location.

Catch Basin: Box-like underground concrete structure with openings in curbs and gutters designed to collect runoff from streets and pavements.

Check Dam: Small temporary barrier, grade control structure, or dam constructed across a swale, drainage ditch, or area of concentrated flow with the intent to slow or stop runoff.

Clean Water Act (CWA): (33 U.S.C. 1251 et seq.) requirement of the National Pollutant Discharge Elimination System (NPDES) program are defined under Sections 307, 402, 318 and 405 of the CWA.

Commercial Development: Any development on private land that is not heavy industrial or residential. The category includes, but is not limited to: hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, multi-apartment buildings, car wash facilities, mini-malls and other business complexes, shopping malls, hotels, office buildings, public warehouses and other light industrial complexes.

Conduit: Any channel or pipe for directing the flow of water.

Construction General Permit: A NPDES permit issued by the State Water Resources Control Board (SWRCB) for the discharge of stormwater associated with construction activity from soil disturbance of five (5) acres or more.

Control Device: A device used to hold back or direct a calculated amount of stormwater to or from a stormwater management facility. Typical control structures include vaults or manholes fitted with baffles, weirs, or orifices.

Conveyance System: Any channel or pipe for collecting and directing the Stormwater.

Culvert: A covered channel or a large diameter pipe that crosses under a road, sidewalk, etc.

Dead-end Sump: A below surface collection chamber for small drainage areas that is not connected to the public storm drainage system. Accumulated water in the chamber must be pumped and disposed in accordance with all applicable laws.

Designated Public Access Points: Any pedestrian, bicycle, equestrian, or vehicular point of access to jurisdictional channels in the area of Ventura County subject to permit requirements.

Detention: The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of runoff at reduced peak flow rates.

Detention Facility: A facility designed to receive and hold stormwater and release it at a slower rate, usually over a number of hours. The full volume of stormwater that enters the facility is eventually released.

Detention Tank, Vault, or Oversized Pipe: A structural subsurface facility used to provide flow control for a particular drainage basin.

Development: any construction, rehabilitation, redevelopment or reconstruction of any public or private residential project (whether single-family, multi-unit or planned unit development); industrial, commercial, retail and any other non-residential projects, including public agency projects; or mass grading for future construction.

Directly Adjacent: Situated within 200 feet of the contiguous zone required for the continued maintenance, function, and structural stability of the environmentally sensitive area.

Directly Connected Impervious Area (DCIA): The area covered by a building, impermeable pavement, and/ or other impervious surfaces, which drains directly into the storm drain without first flowing across permeable land area (e.g. turf buffers).

Directly Discharging: Outflow from a drainage conveyance system that is composed entirely or predominantly of flows from the subject, property, development, subdivision, or industrial facility, and not commingled with the flows from adjacent lands.

Discharge: A release or flow of Stormwater or other substance from a conveyance system or storage container.

Disturbed Area: Any area that is altered as a result of land disturbance, such as: clearing, grading, grubbing, stockpiling and excavation.

Drainage Basin: A specific area that contributes stormwater runoff to a particular point of interest, such as a stormwater management facility, drainageway, wetland, river, or pipe.

Effective Impervious Area (EIA): That portion of the surface area that is hydrologically connected via sheet flow over a hardened conveyance or impervious surface without any intervening medium to mitigate flow volume.

Environmentally Sensitive Area (ESA): An area "in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which would be easily disturbed or degraded by human activities and developments" (California Public Resources Code § 30107.5). Areas subject to stormwater mitigation requirements are: 303(d) listed water bodies in all reaches that are unimproved, all California Coastal Commission's *Environmentally Sensitive Habitat Areas* as delineated on maps in Local Coastal Plans, and Regional Water Quality Control Board's Basin Plan Rare, Threatened or Endangered Species (RARE) and Preservation of Biological Habitats (BIOL) designated waterbodies. The California Department of Fish and Game's (CDFG) *Significant Natural Areas* map will be considered for inclusion as the department field-verifies the designated locations. Watershed restoration projects will be considered for inclusion as the department field verifies the designated locations.

Erosion: The wearing a way of land surface by wind or water. Erosion occurs naturally from weather or runoff, but can be intensified by land-clearing practices relating to farming; residential, commercial, or industrial development; road building; or timber cutting.

Excavation: The process of removing earth, stone, or other materials, usually by digging.

Existing Urban Area: Existing urban areas and corresponding maps in Appendix B are based on the cities' City Urban Restriction Boundaries (CURB) lines and the Existing Community designation in the unincorporated County. These boundaries are a growth management tool intended to channel growth and protect agricultural and open-space land. The 2011 TGM utilizes existing urban areas (as defined in Appendix B) to provide parameters around eligibility for alternative compliance in two areas: 1) Smart Growth and 2) low income housing projects.

Extended Detention Basin: A surface vegetated basin used to provide flow control for a particular drainage basin. Stormwater temporarily fills the extended detention basin during large storm events and is slowly released over a number of hours, reducing peak flow rates.

Facility: Is a collection of industrial process discharging stormwater associated with industrial activity within the property boundary or operational unit.

Filter Fabric: Geotextile of relatively small mesh or pore size that is used to: (a) allow water to pass through while keeping sediment out (permeable); or (b) prevent both runoff and sediment from passing through (impermeable).

Filter Strip: A gently sloping, densely grassed area used to filter, slow, and infiltrate stormwater.

Flow Control Facility: Any structure or drainage device that is designed, constructed, and maintained to collect, retain, infiltrate, or detain surface water runoff during and after a storm event for the purpose of controlling post-development quantity leaving the site.

Flow Control: The practice of limiting the release of peak flow rates, flow durations, and volumes from a site. Flow control is intended to protect downstream properties, infrastructure, and natural resources from the increased stormwater runoff flow rates and volumes resulting from development.

Grading: The cutting and/or filling of the land surface to a desired shape or elevation.

Green Roof: A roofing system that layers a soil/vegetative cover over a waterproofing membrane. Green roofs rely on highly porous media and moisture retention layers to store intercepted precipitation and to support vegetation that can reduce the volume of stormwater runoff via evapotranspiration

Hazardous Substance: (1) Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive; (2) Any substance named by EPA to be reported if a designated quantity of the substance is spilled in the waters of the United States or if otherwise emitted into the environment.

Hazardous Waste: By-products of society that can pose a substantial or potential hazard to human health or the environment when improperly managed. Possesses at least one of four characteristics (flammable, corrosivity, reactivity, or toxicity), or appears on special EPA lists.

Hillside: Property located in an area with known erosive soil conditions, where the development contemplates grading on any natural slope that is 25 percent or greater.

Hydrodynamic Separation: Flow-through structures with a settling or separation unit to remove sediments and other pollutants in which no outside power source is required, because the energy of the flowing water allows the sediments to efficiently separate. Depending on the type of unit, this separation may be by means of swirl action or indirect filtration.

Illegal Discharges: Any discharge to a municipal separate storm sewer that is not composed entirely of stormwater except discharges authorized by an NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and discharges resulting from fire fighting activities.

Impervious Surface / Area: A hard surface area which either prevents or retards the entry of water into the predevelopment soil mantle. A hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under predevelopment conditions. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, (impermeable) concrete or asphalt paving, gravel roads, packed earthen materials, and oiled macadam or other surfaces which similarly impede the natural infiltration of storm water.

Industrial General Permit: A NPDES permit issued by the State Water Resources Control Board for the discharge of Stormwater associated with industrial activity.

Infiltration: The downward entry of water into the surface of the soil.

Infiltration Trench: A linear excavation, backfilled with gravel, used to filter pollutants and infiltrate storm water.

Integrated Pest Management Plan (IPMP): A balanced approach to pest management which incorporates the many aspects of plant health care in ways that mitigate harmful environmental impacts and protect human health.

Inlet: An entrance into a ditch, storm sewer, or other waterway.

Legacy Pollutants: Pollutants that are no longer in production but remain in site soils and groundwater and still have the potential to cause ecological and water quality impacts.

Material Storage Areas: On site locations where raw materials, products, final products, by-products, or waste materials are stored.

Maximum Extent Practicable (MEP): The technology-based permit requirement established by Congress in CWA section 402(p)(3)(B)(iii) that municipal dischargers of stormwater must meet. Technology-based requirements, including MEP, establish a level of pollutant control that is derived from available technology or other controls. MEP requires municipal dischargers to perform at maximum level that is practicable. Compliance with MEP may be achieved by emphasizing pollution prevention and source control BMPs in combination with structural and treatment methods where appropriate. The MEP approach is an ever evolving and advancing concept, which considers technical and economic feasibility.

Municipal Separate Storm Sewer System (MS4) Permit: : A NPDES permit issued by the Regional Water Quality Control Board for the discharge of Stormwater from Municipal Separate Storm Sewer Systems.

New Development: Land disturbing activities; structural development, including construction or installation of a building or structure, creation and replacement of impervious surfaces; and land subdivision.

Non-Stormwater Discharge: Any discharge to municipal separate storm drain that is not composed entirely of stormwater. Discharges containing process wastewater, non-contact cooling water, or sanitary wastewater are non-stormwater discharges.

Non-Structural Source Control Measure: Low technology, low cost activities, procedures or management practices designed to prevent pollutants associated with site functions and activities from being discharged with Stormwater runoff. Examples include good housekeeping practices, employee training, standard operating practices, inventory control measures, etc.

Notice of Intent (NOI): A formal notice to State Water Resources Control Board submitted by the owner/developer that a construction project is about to begin. The NOI provides information on the owner, location, type of project, and certifies that the permittee will comply with the conditions of the construction general permit.

NPDES Permit: An authorization, license, or equivalent control document issued by EPA or an approved State agency to implement the requirements of the NPDES program.

Operations and Maintenance (O&M): The continuing activities required to keep storm water management facilities and their components functioning in accordance with design objectives.

Outfall: The point where stormwater discharges from a pipe, channel, ditch, or other conveyance to a waterway.

Parking Lot: Land area or facility for the temporary parking or storage of motor vehicles used personally, for business or for commerce with an impervious surface area of 5,000 square feet or more, or with 25 or more parking spaces.

Permeability: A property of soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Pervious Surface/Area: A surface or area with a surface (i.e., soil, loose rock, permeable pavement, etc.) that allows water to infiltrate (soak) into the ground.

Planter Box: A structural facility filled with topsoil and gravel and planted with vegetation. The planter is completely sealed, and a perforated collection pipe is placed under the soil and gravel, along with an overflow provision, and directed to an acceptable destination point. The storm water planter receives runoff from impervious surfaces, which is filtered and retained for a period of time.

Pollutant: An elemental or physical material that can be mobilized or dissolved by water or air and creates a negative impact to human health and/ or the environment. Pollutants include suspended solids (sediment), heavy metals (such as lead, copper, zinc, and cadmium), nutrients (such as nitrogen and phosphorus), bacteria and viruses, organics (such as oil, grease, hydrocarbons, pesticides, and fertilizers), floatable debris, and increased temperature.

Pollutants of Concern: constituents that have exceeded Basin Plan Objectives, and California Toxics Rule chronic or acute objectives during monitoring at mass emission, receiving water, and land use stations.

Pollution Reduction: The practice of filtering, retaining, or detaining surface water runoff during and after a storm event for the purpose of maintaining or improving surface and/or groundwater quality.

Precipitation: Any form of rain or snow.

Predevelopment: The existing land use condition prior to the proposed development activity.

Practicable: Available and capable of being done, after taking into consideration existing technology, legal issues, and logistics in light of overall project purpose.

Pre-developed Condition: the native vegetation and soils that existed at a site prior to first development. The pre-developed condition may be assumed to be the

typical vegetation, soil, and stormwater runoff characteristics of open space areas in coastal Southern California unless reasonable historic information is provided that the area was atypical.

Pre-project Condition: the condition of the site at the time of the proposed project.

Pretreatment: Treatment of wastewater before it is discharged to a wastewater collection system.

Process Wastewater: Wastewater that has been used in one or more industrial processes.

Project: development, redevelopment, and land disturbing activities. The term is not limited to "project" as defined under CEQA (Reference: California Public Resources Code § 21065).

Public Facility: A street, right-of-way, park, sewer, drainage, storm water management, or other facility that is either currently owned by the City/County or will be conveyed to the City/County for maintenance responsibility after construction.

Rainwater Harvesting: Rainwater harvesting is a BMP that stores and uses rainwater or stormwater runoff. This is consistent with the use of the term "reuse" contained in Order R4-2010-0108.

Receiving Stream: (for purposes of this Manual only) any natural or man-made surface water body that receives and conveys stormwater runoff.

Redevelopment: Land-disturbing activity that results in the creation, addition, or replacement of 5,000 square feet or more of impervious surface area on an already developed site. Redevelopment includes, but is not limited to: the expansion of a building footprint; addition or replacement of a structure; replacement of impervious surface area that is not part of a routine maintenance activity; and land disturbing activities related to structural or impervious surfaces. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility, nor does it include emergency construction activities required to immediately protect public health and safety. Note: redevelopment as defined here is not the same as a "Redevelopment Project" as defined by California redevelopment law.

Redevelopment Project Area Master Plan (RPAMP): A plan submitted to the Regional Water Board for approval by a Permittee or a coalition of Permittees to establish standards for redevelopment projects within Redevelopment Project Areas, in consideration of exceptional site constraints that inhibit site-by-site or project-by-project implementation of post-construction requirements. See Section 4.E.IV.3 of Order R4-2010-0108.

Restaurant: A stand-alone facility that sells prepared foods and/or drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and/or drinks for immediate consumption (SIC code 5812).

Retail Gasoline Outlet: Any facility engaged in selling gasoline and lubricating oils.

Retention Facility: A facility designed to receive and hold stormwater runoff. Rather than storing and releasing the entire runoff volume, retention facilities permanently retain a portion of the water on-site, where it infiltrates, evaporates, or is absorbed by surrounding vegetation. In this way, the full volume of storm water that enters the facility is not released off-site.

Retrofit: Retrofit projects implement structural treatment BMPs as a stand-alone project, without other site improvements. The BMP sizing requirements of this Technical Guidance Manual do not apply to retrofit projects.

Runoff: Water originating from rainfall and other precipitations (e.g., sprinkler irrigation) that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes, wetlands, and shallow groundwater.

Runon: Stormwater surface flow or other surface flow which enters property other than that where it originated.

Secondary Containment: Structures, usually dikes or berms, surrounding tanks or other storage containers and designed to catch spilled material from the storage containers.

Sedimentation: The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.

Sediments: Soil, sand, and minerals washed from land into water usually after rain, that accumulate in reservoirs, rivers, and harbors, destroying aquatic animal habitat and clouding the water so that adequate sunlight might not reach aquatic plants.

Site: land or water area where any “facility” or “activity” is physically located or conducted including adjacent land used in connection with the facility or activity.

Source Control BMP or Measure: Any schedules of activities, structural devices, prohibitions of practices, maintenance procedures, managerial practices or operational practices that aim to prevent Stormwater pollution by reducing the potential for contamination at the source of pollution.

Source Control BMPs: Operational practices or design features that prevent pollution by reducing potential pollutants at the source.

Spill Guard: A device used to prevent spills of liquid materials from storage containers.

Spill Prevention Control and Countermeasures Plan (SPCC): Plan consisting of structures, such as curbing, and action plans to prevent and respond to spills of hazardous substances as defined in the Clean Water Act.

Storm Drains: Above and below ground structures for transporting stormwater to streams or outfalls for flood control purposes.

Storm Drain System: Network of above and below-ground structures for transporting stormwater to streams or outfalls.

Storm Event: A rainfall event that produces more than 0.1 inch of precipitation and is separated from the previous storm event by at least 72 hours of dry weather.

Stormwater Discharge Associated with Industrial Activity: Discharge from any conveyance which is used for collecting and conveying stormwater which is related to manufacturing processing or raw materials storage areas at an industrial plant [see 40 CFR 122.26(b)(14)].

Stormwater: Stormwater runoff, snow-melt runoff, surface runoff, and drainage, excluding infiltration and irrigation tailwater.

Structural BMP or Control Measure: Any structural facility designed and constructed to mitigate the adverse impacts of stormwater and urban runoff pollution (e.g. canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

Total Project Area: Total project area (or “gross project area”) for new development and redevelopment projects is the disturbed, developed, and undisturbed portions within the project’s property (or properties) boundary, at the project scale submitted for first approval. Areas proposed to be permanently dedicated for open space purposes as part of the project are explicitly included in the "total project area." Areas of land precluded from development through a restrictive covenant, conservation easement, or other recorded document for the permanent preservation of open space prior to project submittal shall not be included in the "total project area."

Total Suspended Solids (TSS): Matter suspended in stormwater excluding litter, debris, and other gross solids exceeding 1 millimeter in diameter.

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

Treatment: The application of engineered systems that use physical, chemical, or biological processes to remove pollutants. Such processes include, but are not limited to, filtration, gravity settling, media adsorption, biodegradation, biological uptake, chemical oxidation and UV radiation.

Tributary Area: The area from which all runoff produced flows to the same specific discharge point.

Vegetated Facilities: Stormwater management facilities that rely on plantings to enhance their performance. Plantings can provide wildlife habitat and enhance many facility functions, including infiltration, pollutant removal, water cooling, flow calming, and prevention of erosion.

Vegetated Swale: A long and narrow, trapezoidal or semicircular channel, planted with a variety of trees, shrubs, and grasses or with a dense mix of grasses. Stormwater runoff from impervious surfaces is directed through the swale, where it is slowed and in some cases infiltrated, allowing pollutants to settle out. Check dams are often used to create small ponded areas to facilitate infiltration.

APPENDIX B : MAPS

NOTES:

1. Contact the local permitting authority for more detailed maps.
2. Existing Urban Area maps are current as of 11/2/10.

Legend

- River
- Lake
- National Forest
- 10-Digit Hydrologic Unit Boundary

Existing Urban Area

- Camarillo
- Fillmore
- Moorpark
- Oxnard
- Santa Paula
- Simi Valley
- Thousand Oaks
- Port Hueneme
- Ventura
- Ojai
- Urban County
- Non-Urban County
- Adjacent County

10 5 0 10 Miles

Hydrologic Areas

Ventura County, CA

Geosyntec consultants

Oakland Office | April 2010

Figure **B-1**

P:\GIS\Ventura_County_Manual\Projects\B-1_Ventura_County_Watersheds_MS4_Urban_Areas_042910.mxd, WHL, September 1, 2010

Legend

- BIOL Designated Waterbody
- 303(d) Listed Waterbody
- Environmentally Sensitive Habitat Areas
- Lake
- National Forest

Existing Urban Area

- Camarillo
- Fillmore
- Moorpark
- Oxnard
- Santa Paula
- Simi Valley
- Thousand Oaks
- Port Hueneme
- Ventura
- Ojai
- Urban County
- Non-Urban County
- Adjacent County

10 5 0 10 Miles

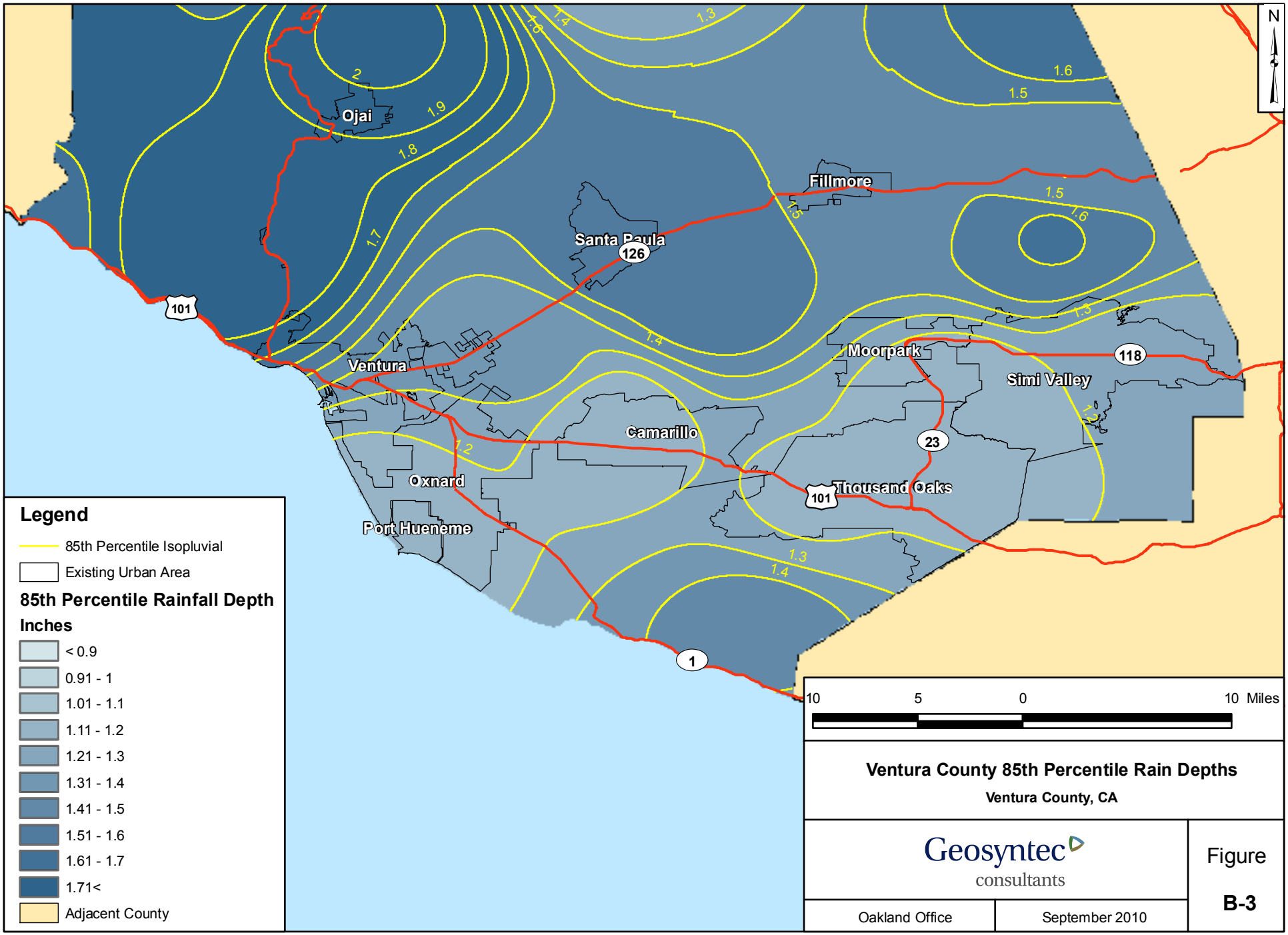
Environmentally Sensitive Areas
Ventura County, CA

Geosyntec consultants

Oakland Office | April 2010

Figure **B-2**

B-2_Ventura_County_ESA_042910.mxd, WHL, September 1, 2010



Ventura County 85th Percentile Rain Depths

Ventura County, CA

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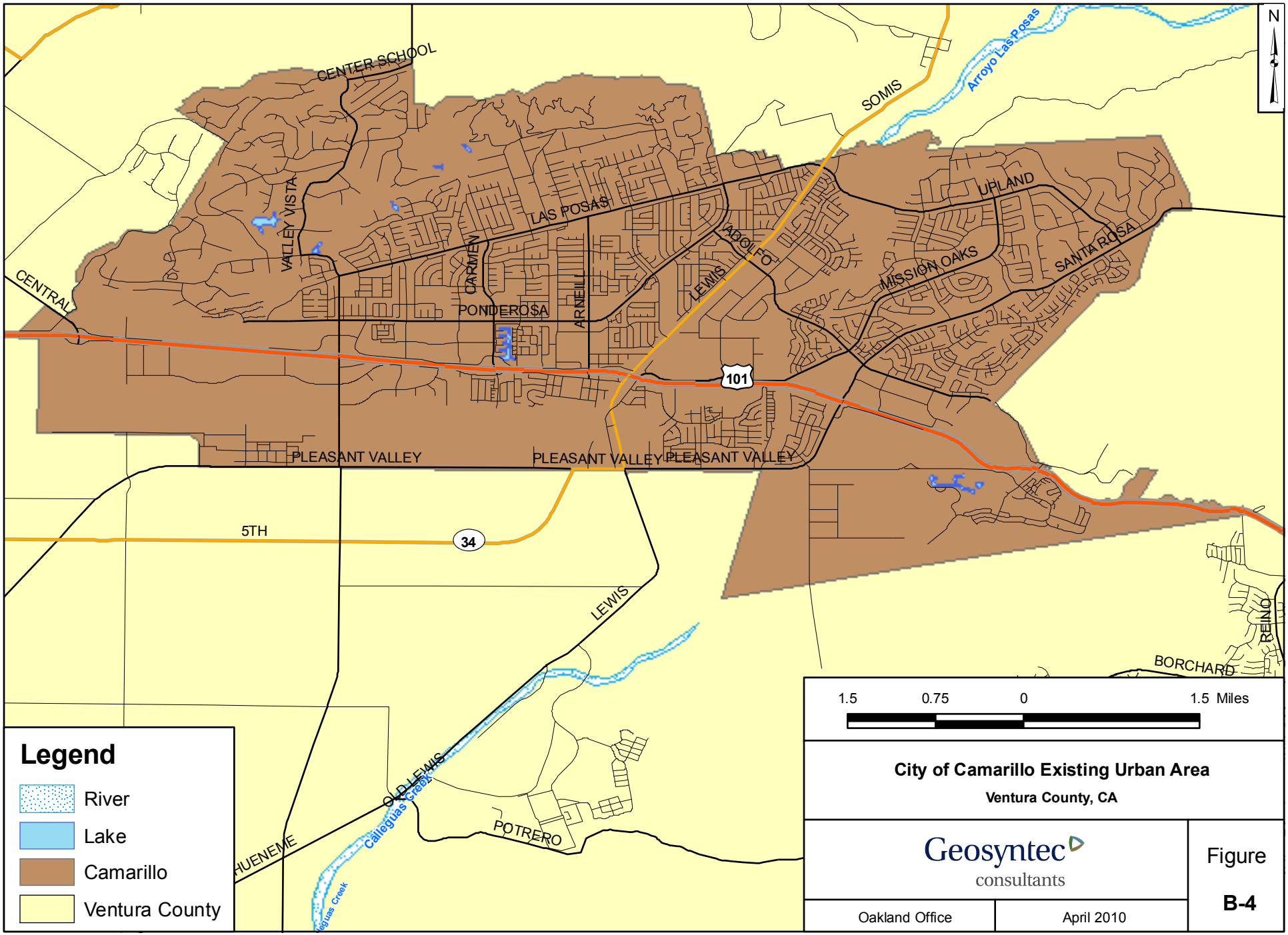
Figure **B-3**

P:\GIS\Ventura_County_Manual\Projects\B-3_Ventura_County_85th_Isopluvials_092010.mxd, WHL, September 20, 2010



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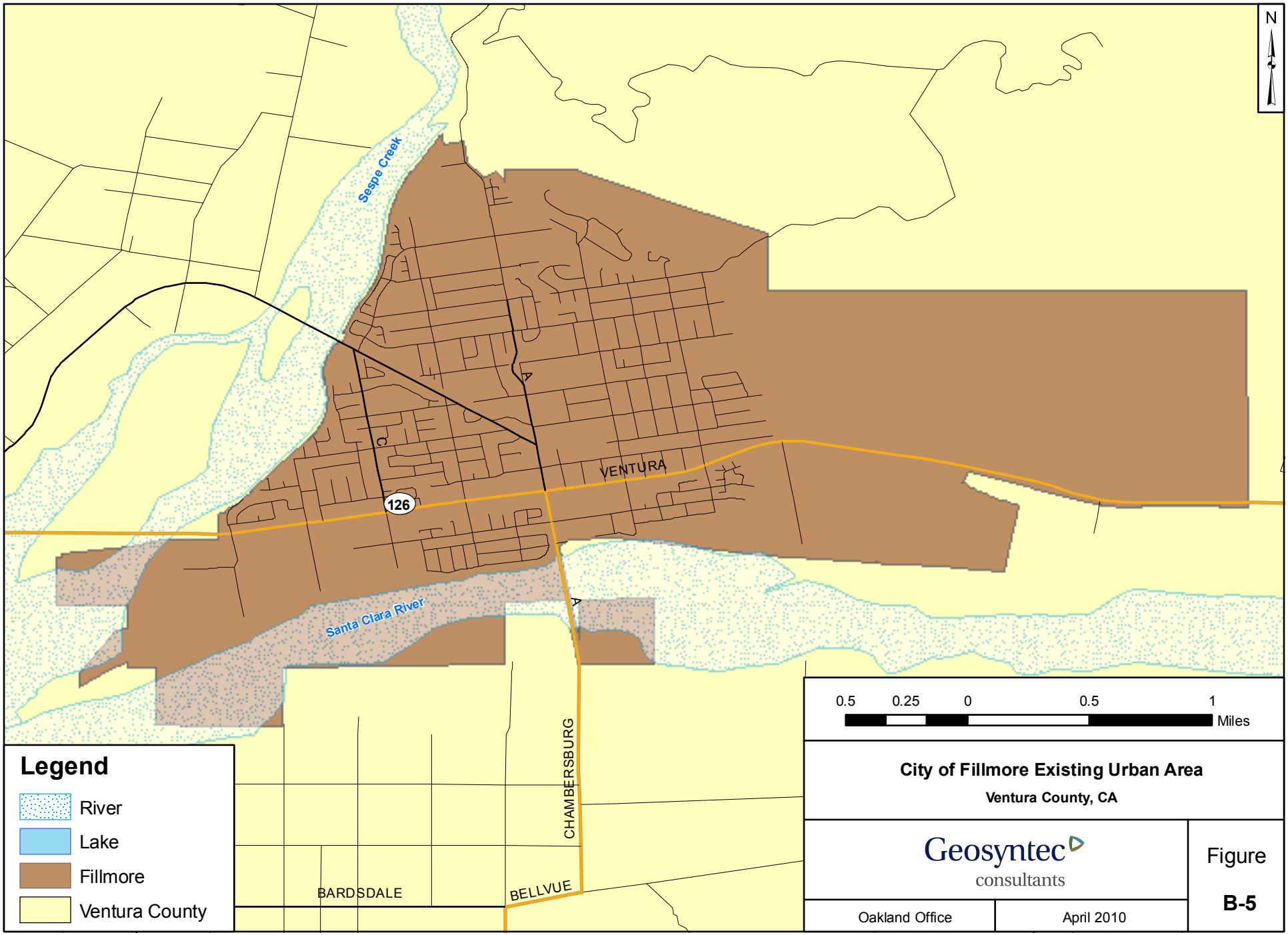

City of Fillmore Existing Urban Area

Ventura County, CA

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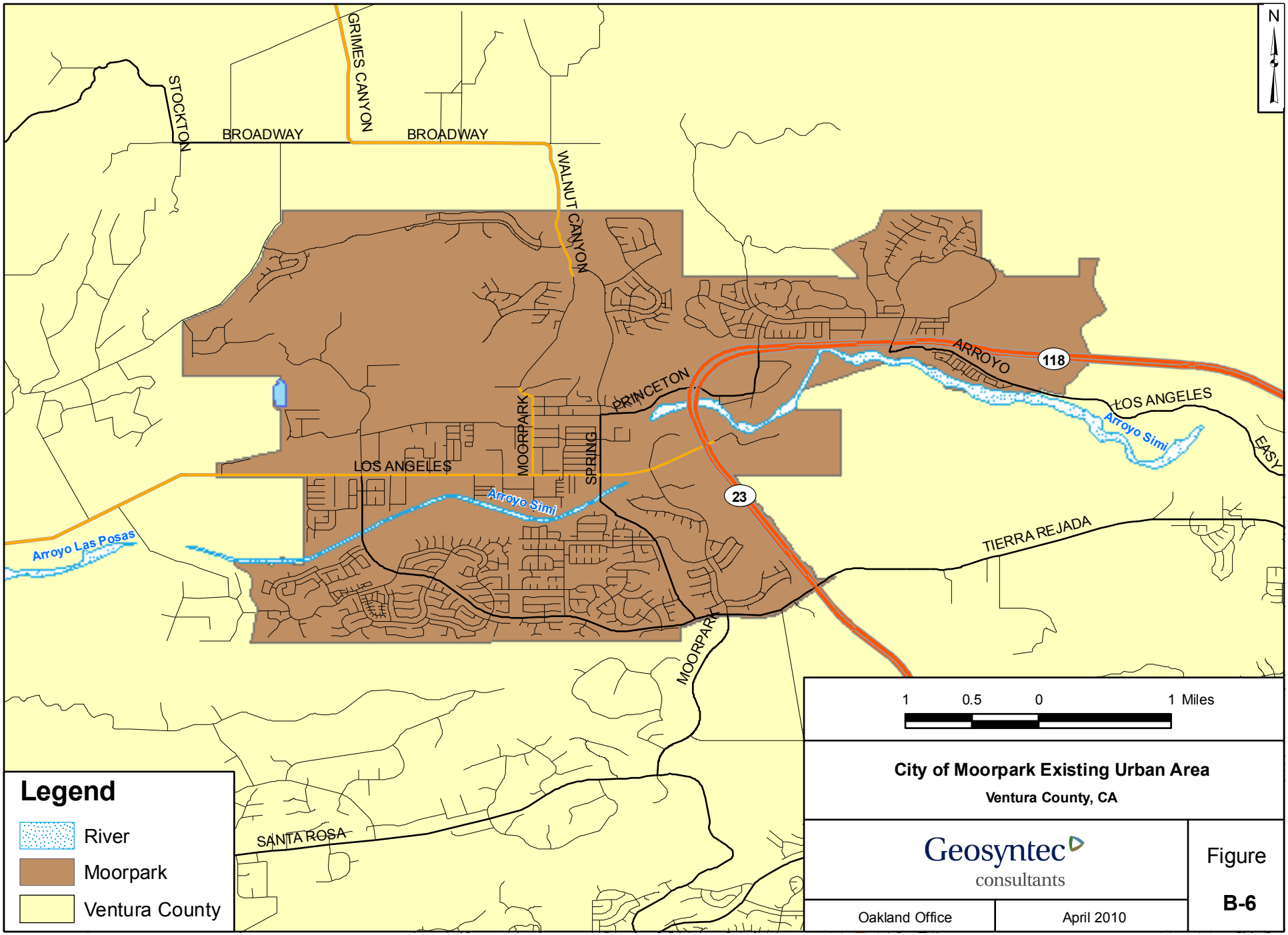
April 2010

Figure

B-5

P:\GIS\Ventura_County_Manual\Projects\B-5Fillmore_MS4_Pop_Areas_092310.mxd, WHL, September 24, 2010



City of Moorpark Existing Urban Area

Ventura County, CA

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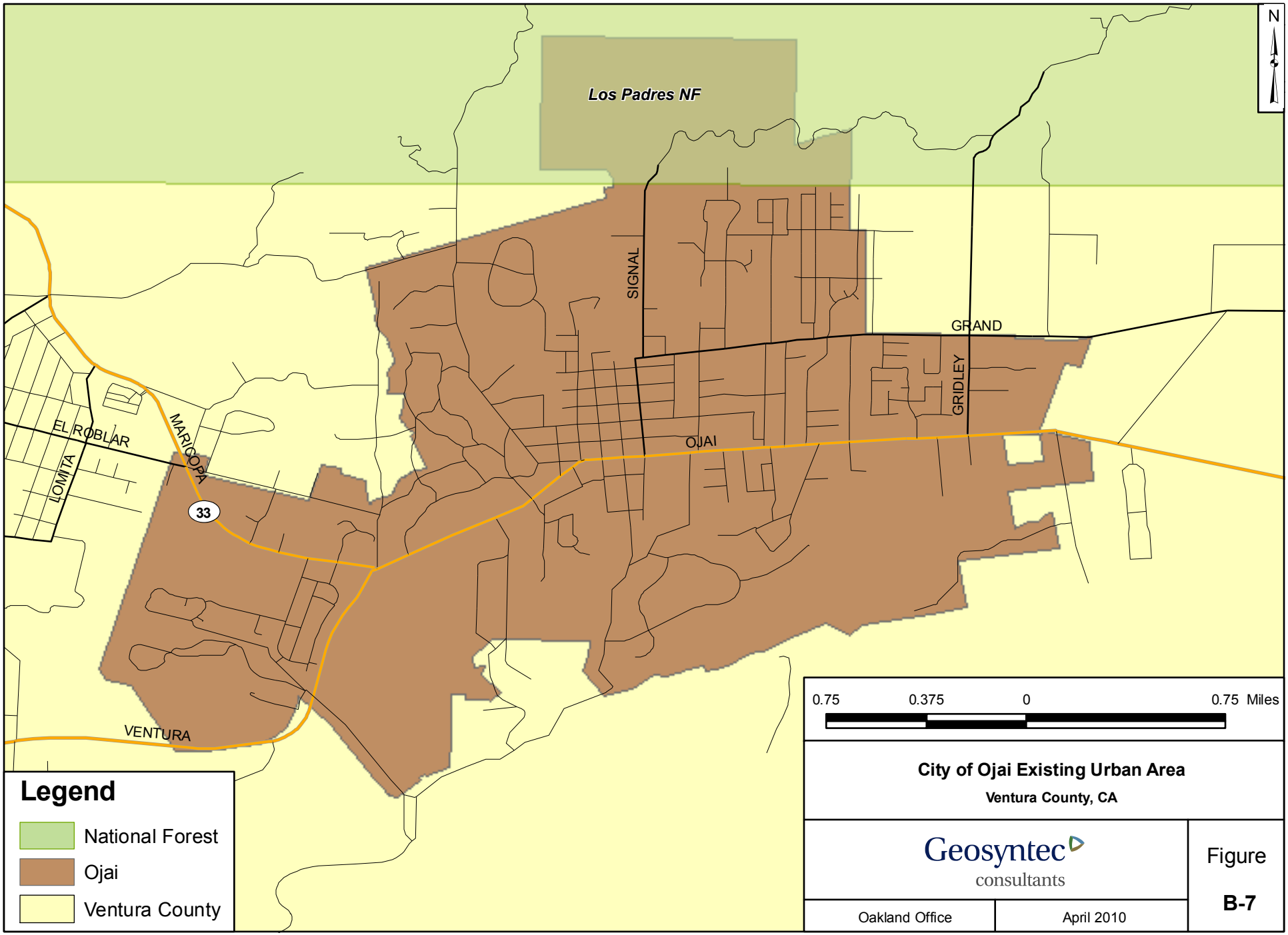
Figure **B-6**

P:\GIS\Ventura_County_Manual\Projects\B-6_Moorpark_MS4_Pop_Areas_092310.mxd, WHL, September 23, 2010



City of Ojai Existing Urban Area

Ventura County, CA

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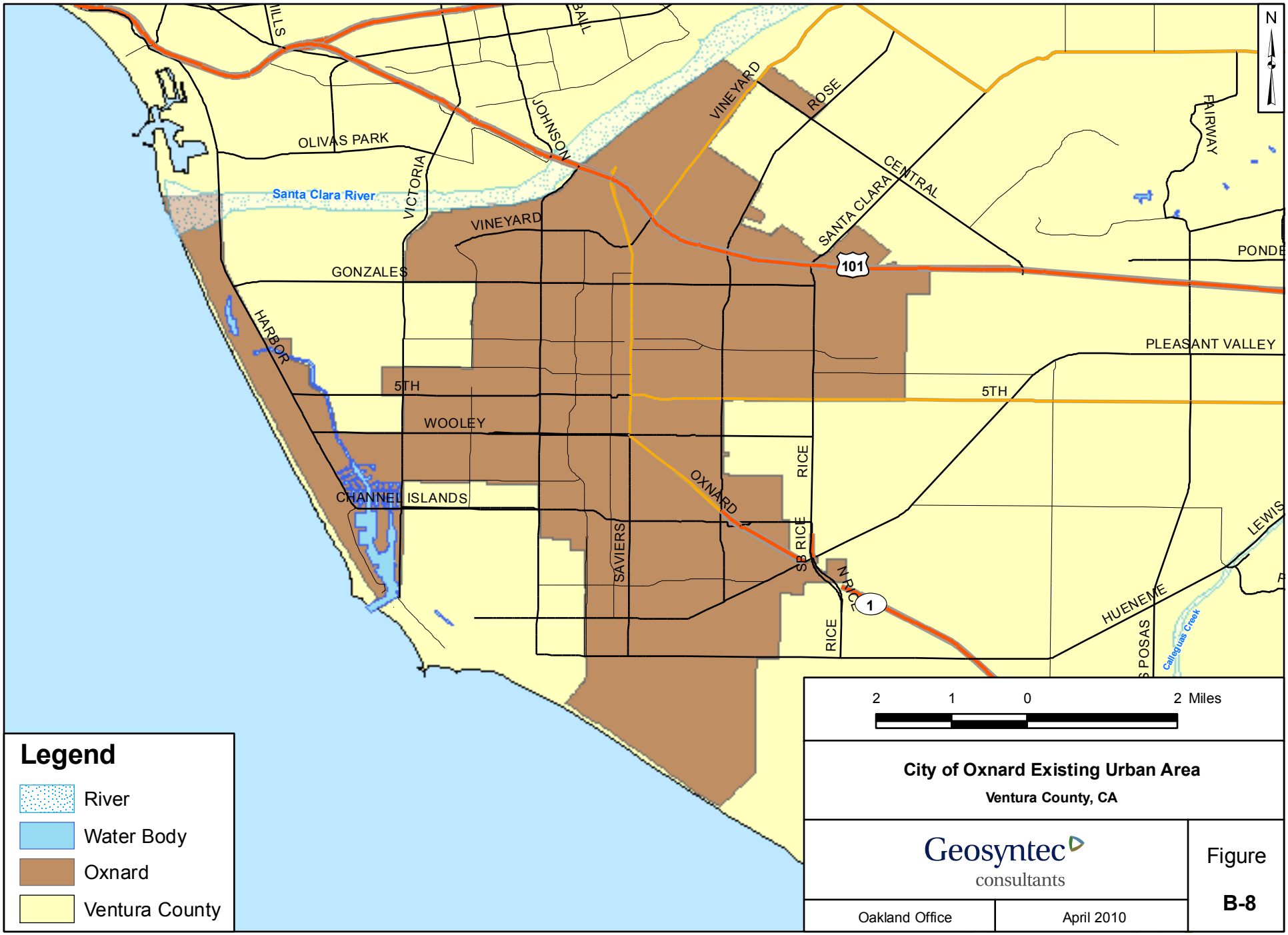
Figure **B-7**

P:\GIS\Ventura_County_Manual\Projects\B-7_Ojai_MS4_Pop_Areas_092310.mxd, WHL, September 23, 2010



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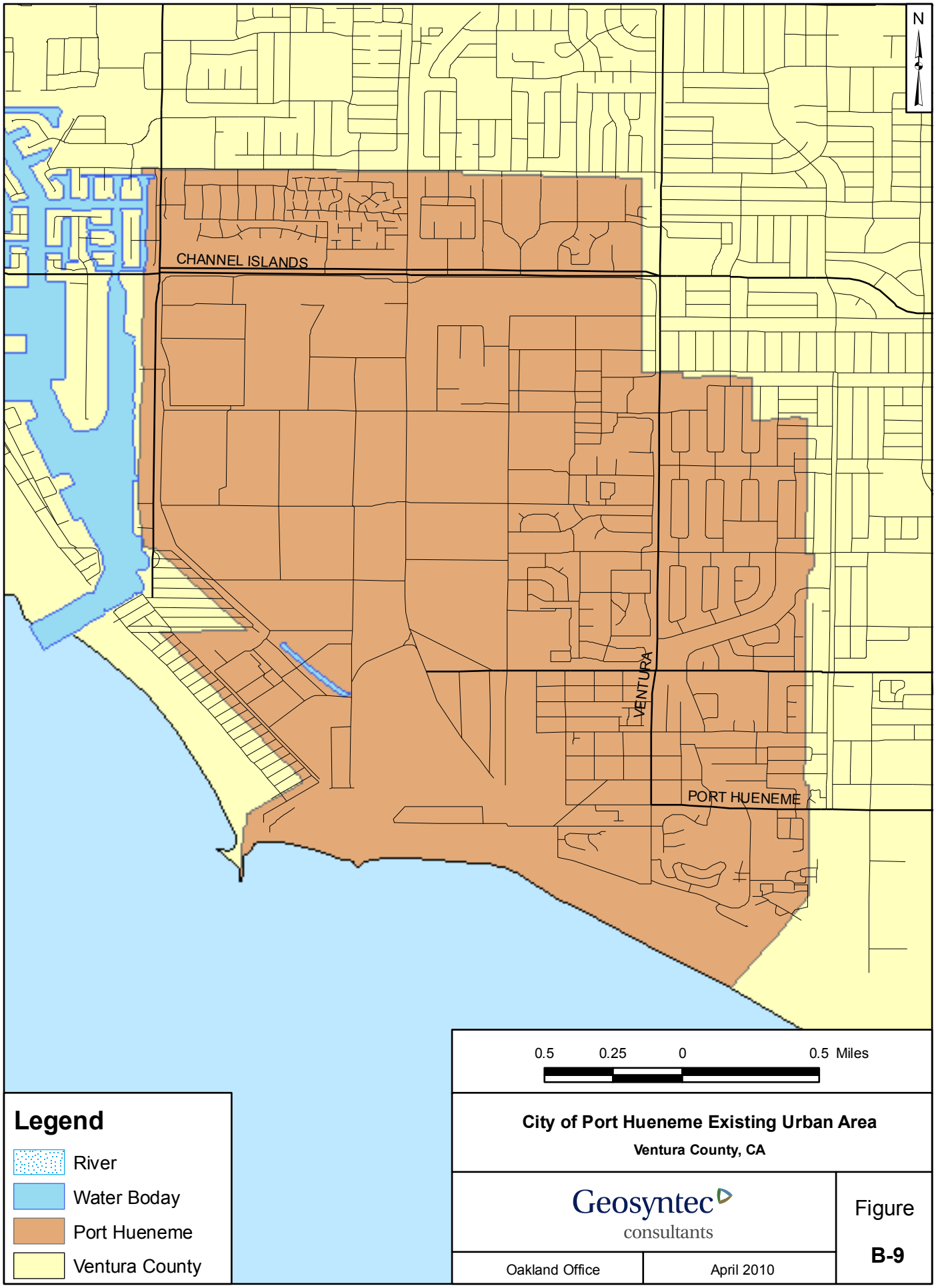

City of Port Hueneme Existing Urban Area

Ventura County, CA

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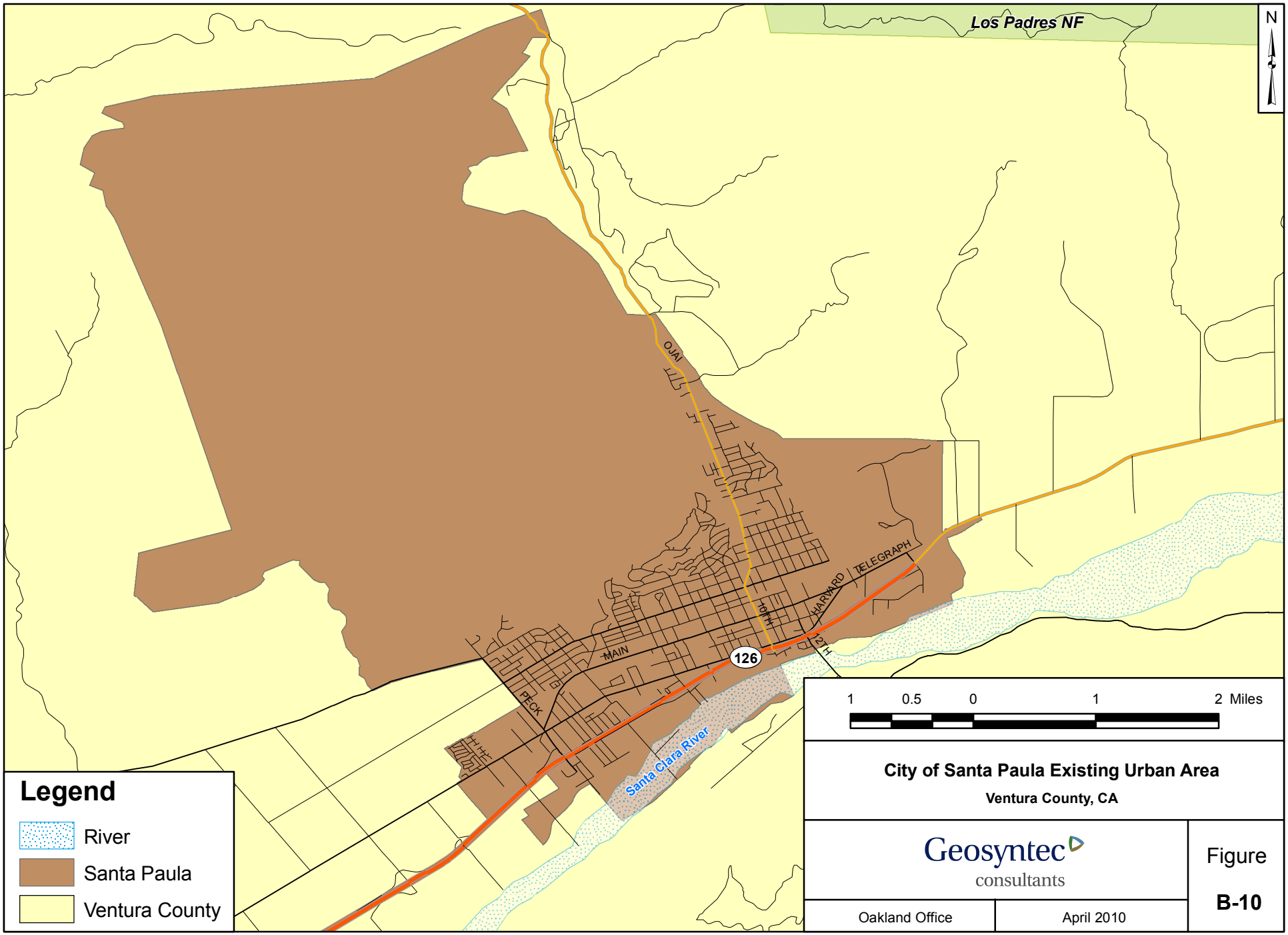
Figure **B-9**

P:\GIS\Ventura_County_Manual\Projects\B-9_Port_Hueneme_MS4_Urban_Areas_092310.mxd, WHL, September 23, 2010



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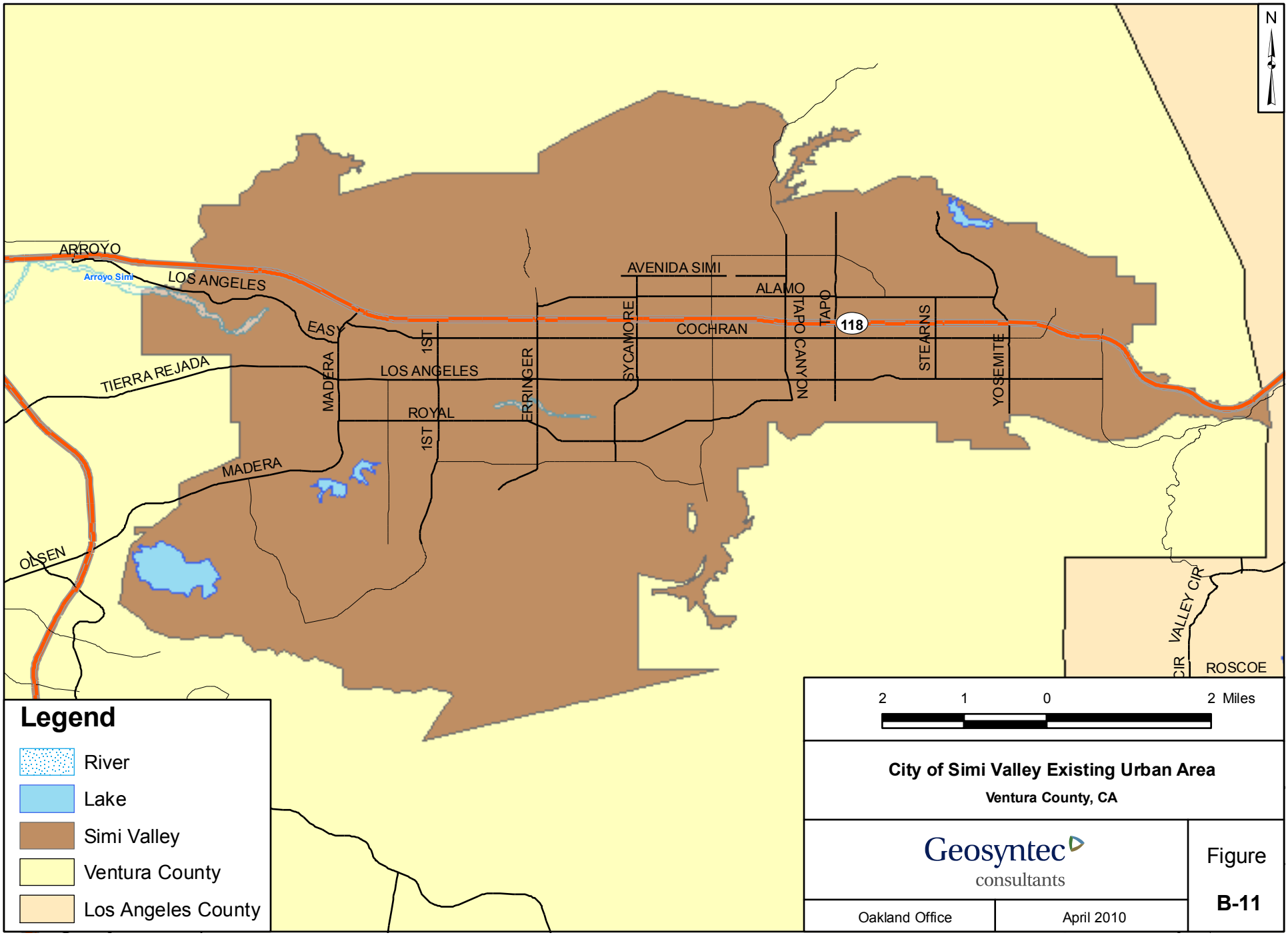

City of Simi Valley Existing Urban Area

Ventura County, CA

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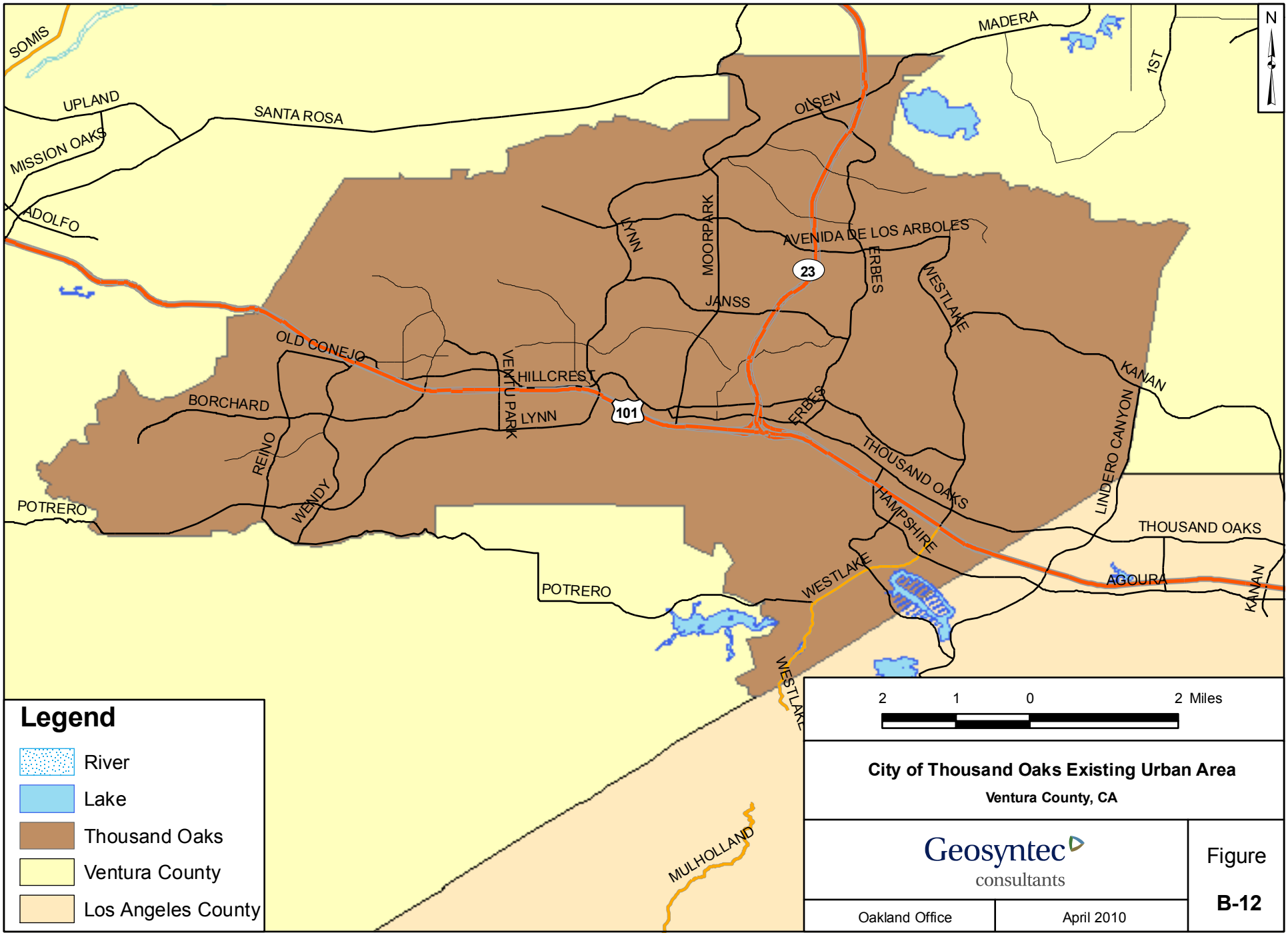
Figure **B-11**

P:\GIS\Ventura_County_Manual\Projects\Simi_Valley_MS4_Pop_Areas_092310.mxd, WHL, September 23, 2010



City of Thousand Oaks Existing Urban Area

Ventura County, CA

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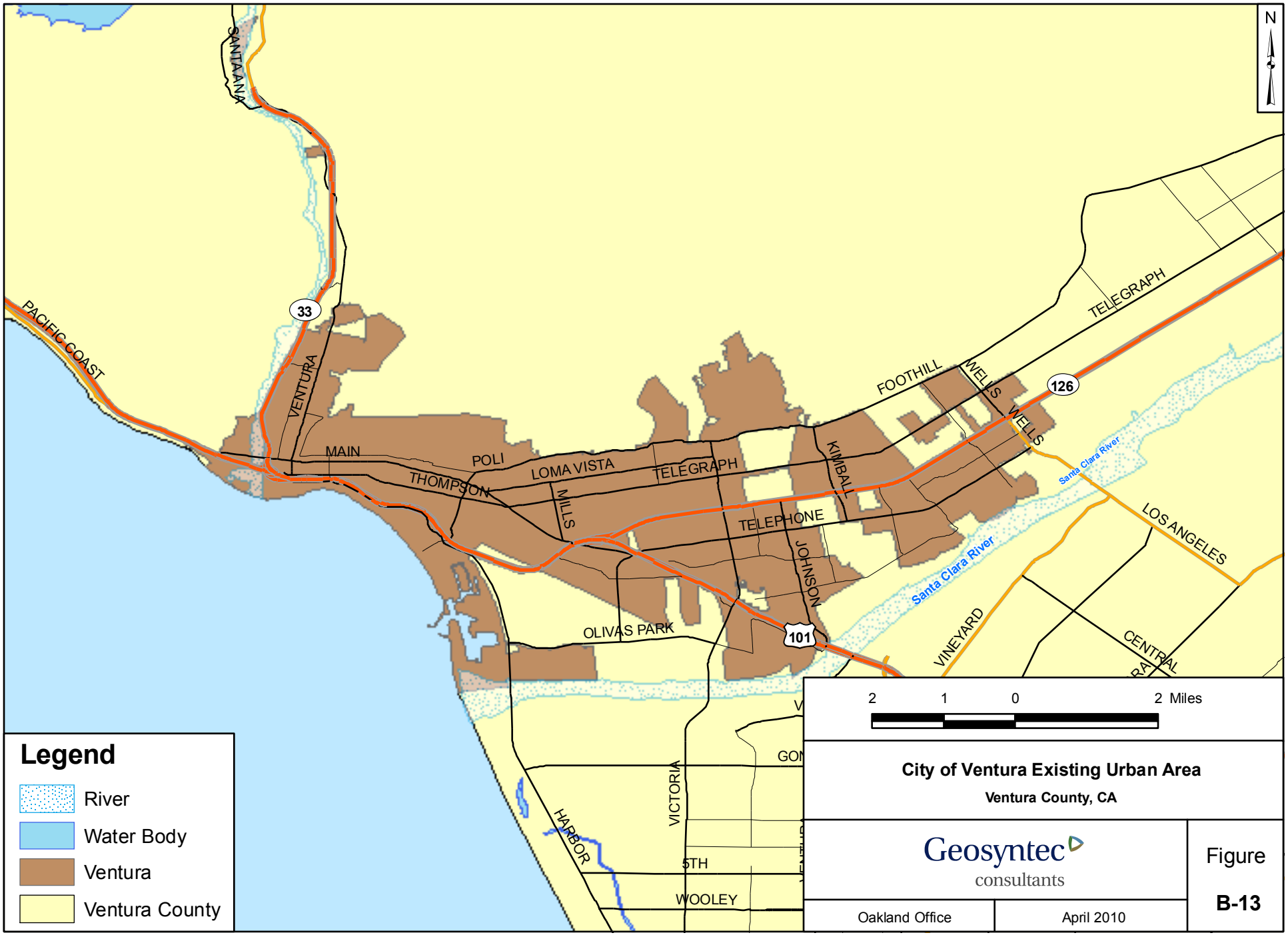
Figure **B-12**

P:\GIS\Ventura_County_Manual\Projects\B-12_Thousand_Oaks_MS4_Pop_Areas_092310.mxd, WHL, September 23, 2010



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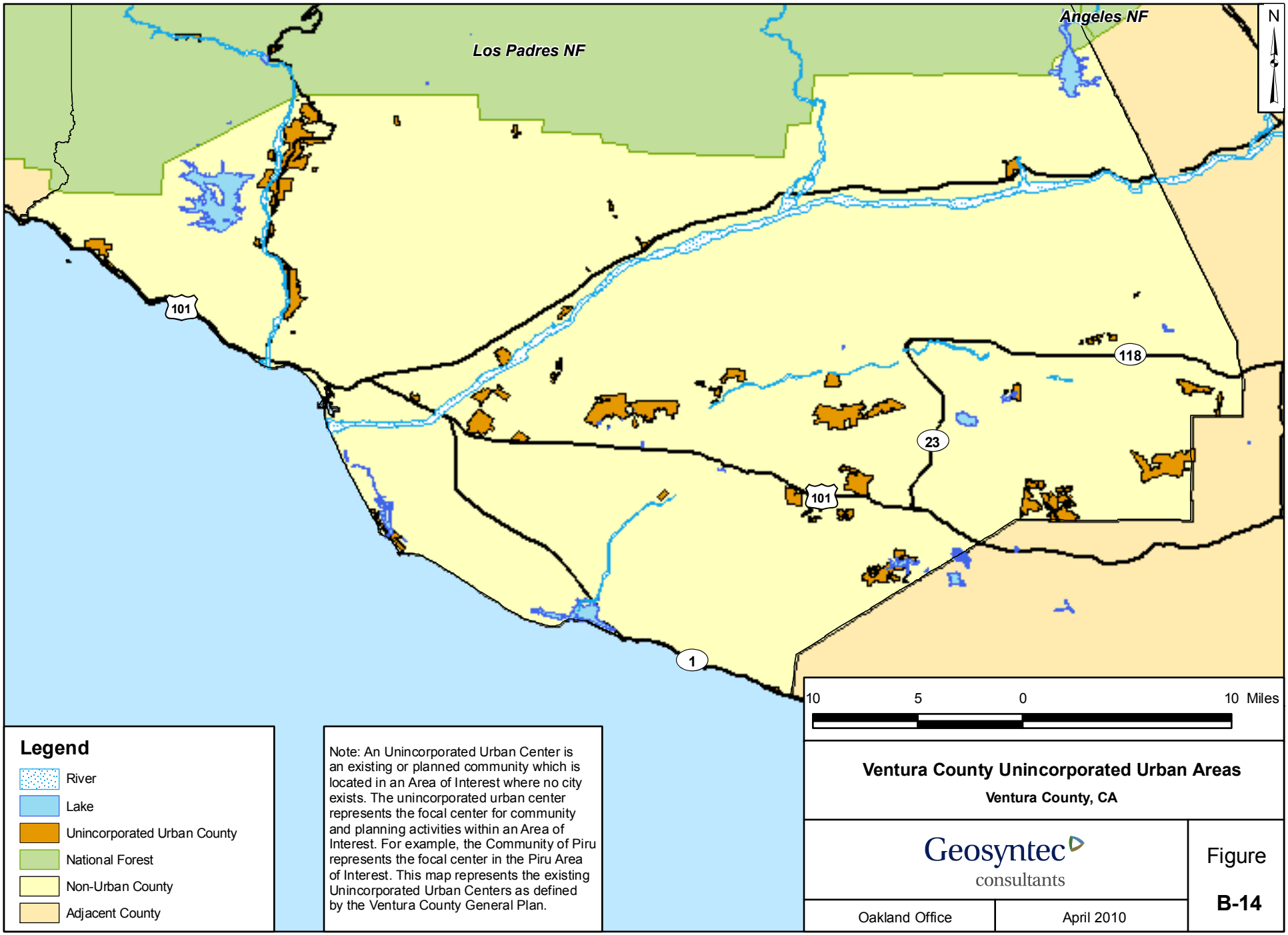

Ventura County Unincorporated Urban Areas

Ventura County, CA

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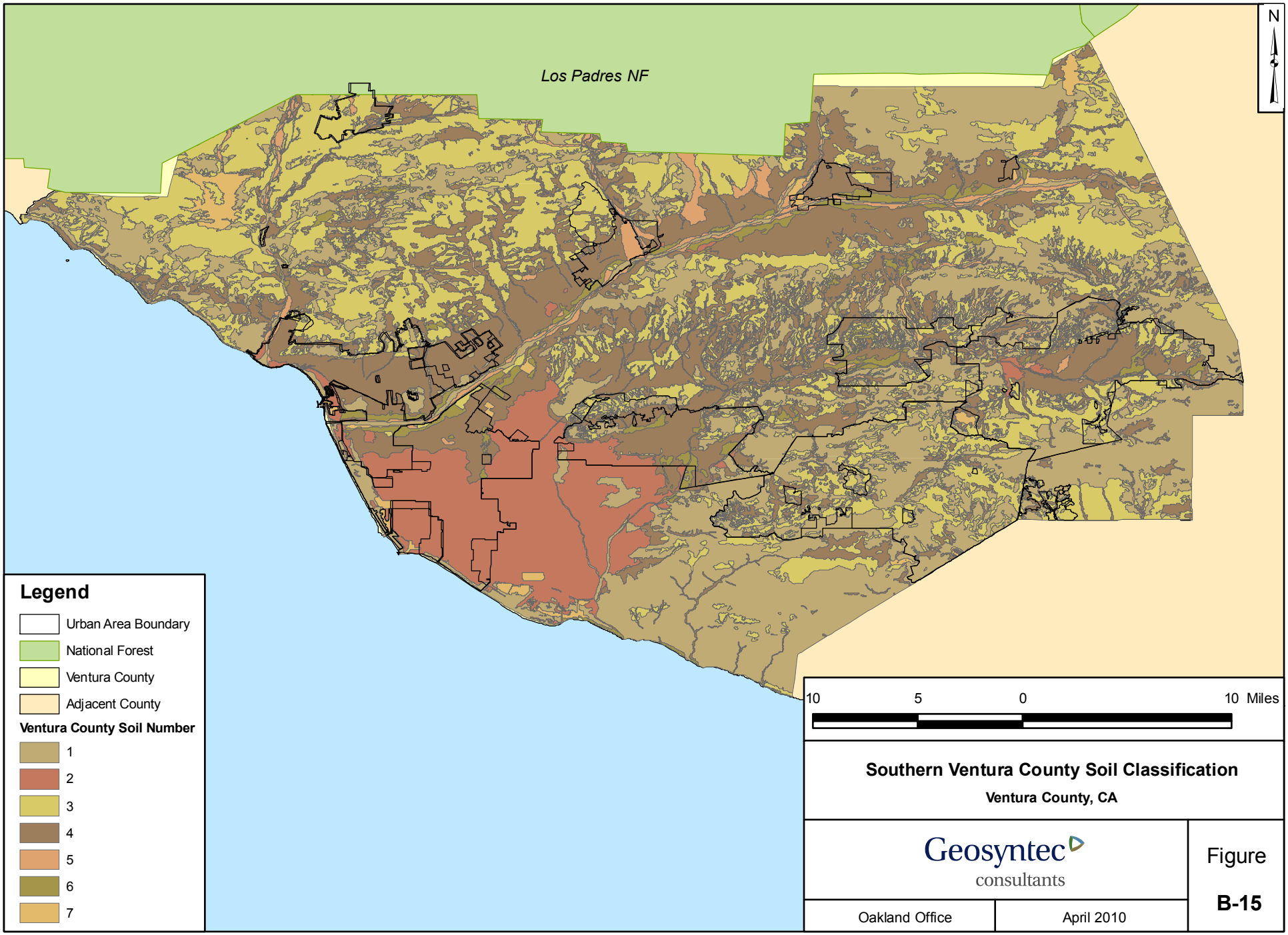
Figure **B-14**

P:\GIS\Ventura_County_Manual\Projects\B-14_Ventura_County_Urban_092310.mxd, WHL, September 23, 2010



Southern Ventura County Soil Classification

Ventura County, CA

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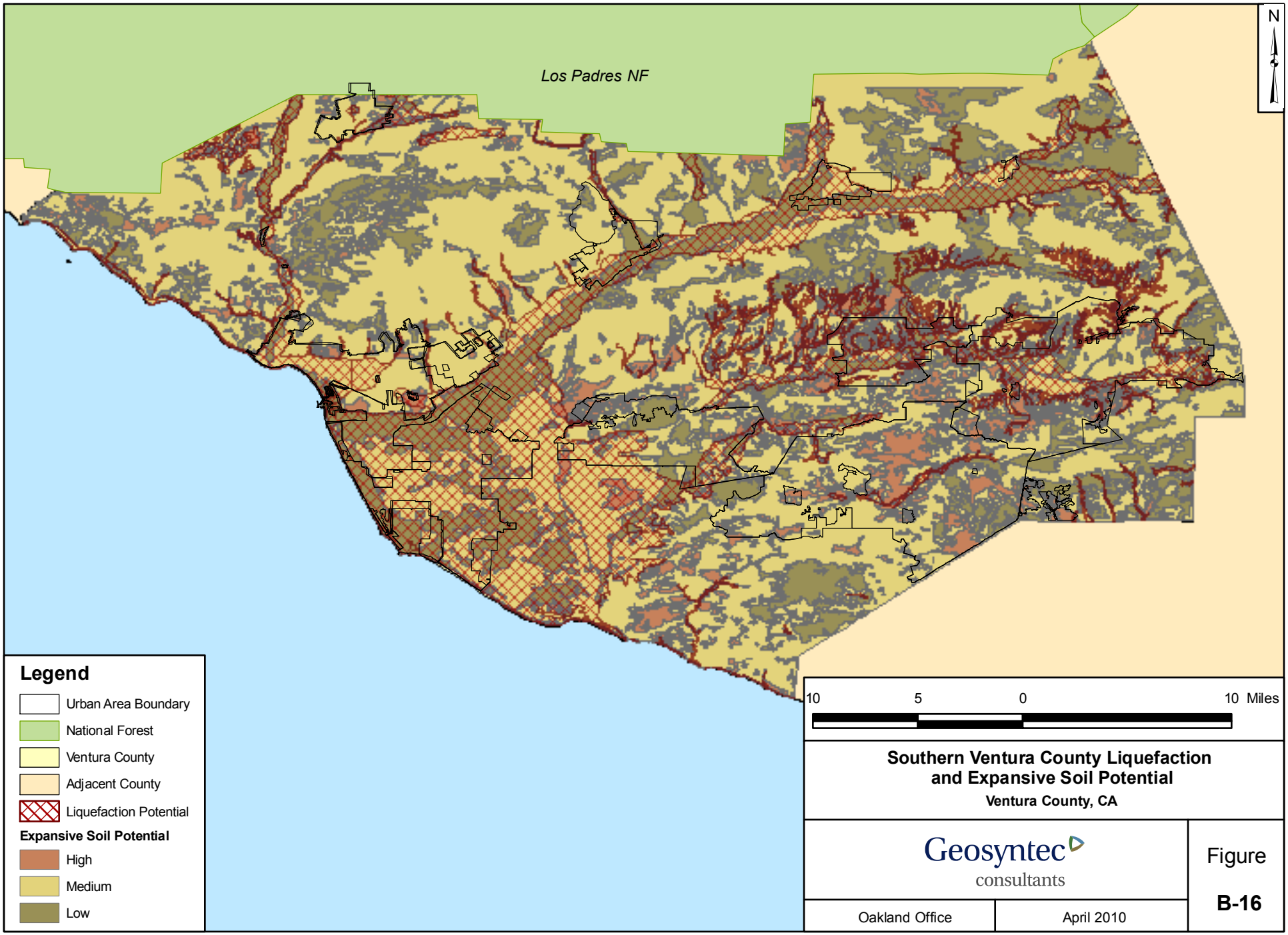
Figure **B-15**

P:\GIS\Ventura_County_Manual\Projects\B-15_Ventura_Soils_092310.mxd, WHL, September 23, 2010



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APPENDIX C: SITE SOIL TYPE AND INFILTRATION TESTING

C.1 Introduction

The purpose of site soil and infiltration testing is to more accurately determine where LID and structural treatment BMPs should be located and if infiltration is feasible on the site. The preliminary site assessment, discussed in Section 3, will likely reduce the number of test pit investigations needed by identifying candidate test sites that are most amenable to infiltration. This section summarizes the methods for conducting (1) soil test pit investigations and (2) infiltration testing at key locations identified in the preliminary site assessment that require further investigation.

A qualified soil scientist or geotechnical professional should conduct the test pit investigation and infiltration tests. The professional should be experienced with the testing procedures as well as the hydraulic functioning of the potential BMPs to ensure that additional information regarding BMP siting is acquired during the test pit investigation and infiltration tests.

This appendix is not intended to be applied as a protocol for conducting soil and infiltration testing. Instead, this section is provided to assist in specifying and standardizing soil and infiltration testing techniques across sites within Ventura County where development is occurring.

C.2 Test Pit Investigations

A test pit investigation is an integral part of assessing site soil conditions. Soil maps and hydrologic soil groups are based on regional data and provide only a general understanding of what to expect; however, there are undoubtedly unknowns that will be discovered during these initial field observations. A test pit investigation involves digging or excavating a test pit (deep hole). By excavating a test pit, overall soil conditions (both vertically and horizontally) can be observed in addition to the soil horizons. To maximize the knowledge gained during the test pit investigation, many tests and observations should be conducted during this process.

Test pits should be excavated to a depth at least three feet deeper than the proposed bottom of non-infiltration BMPs and at least eleven feet deeper than the proposed bottom of infiltration BMPs. A project that imports fill must characterize the proposed soil profile at the specified depths. For example, if the proposed depth of fill is 5 feet below grade and an infiltration BMP is to be used in the location of the fill, both the fill and the native subsoil require soil characterization. Figure C-1 illustrates the proposed soil profile that would result with 3 feet of fill. Since the test pit must be excavated to a depth that is 11 feet deeper than the bottom of the proposed infiltration BMP, a test pit investigation of the top 8 feet of native subsoil is required, in addition to the laboratory sample of the fill material. Characterization of the fill material should be conducted in a laboratory. It is recommended that soil compaction is limited in the location of a proposed infiltration BMP.

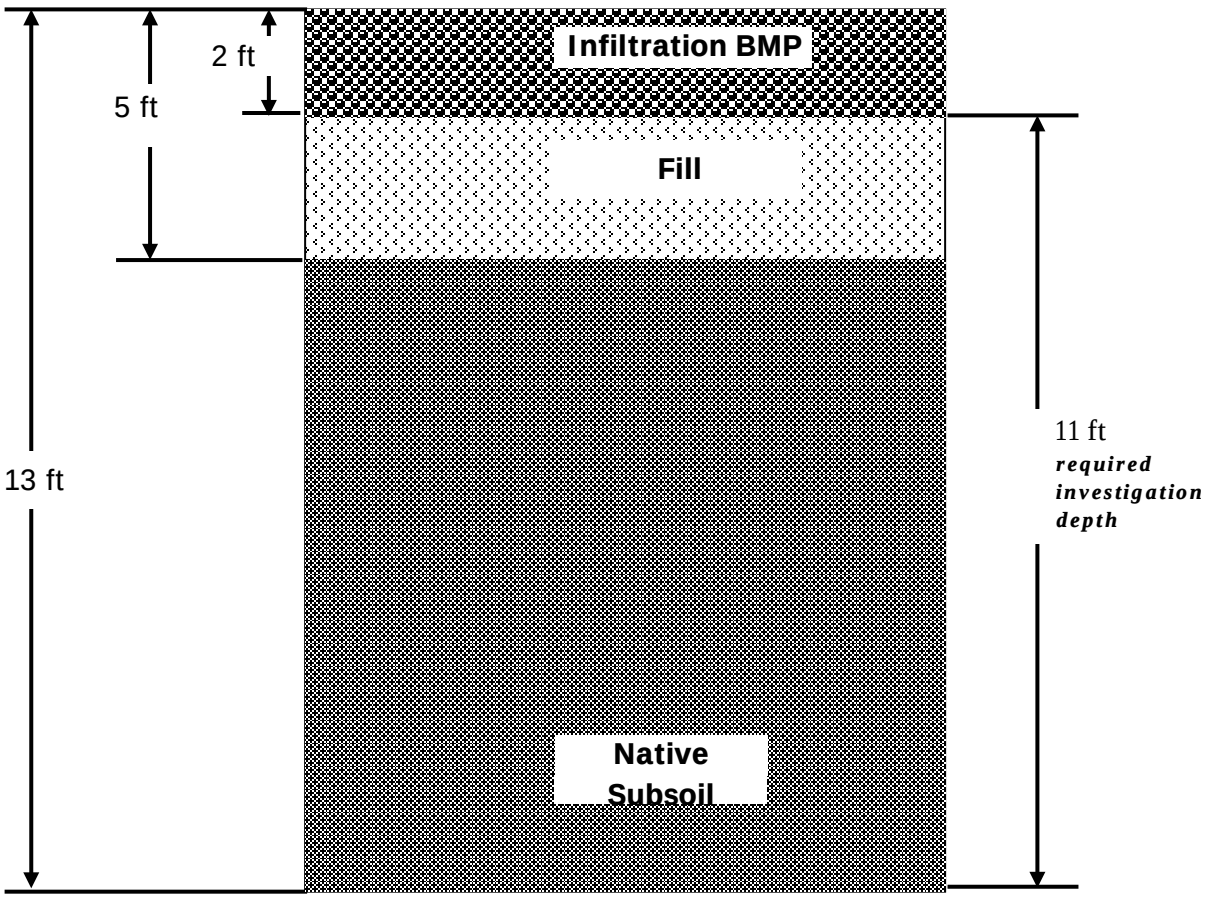

Figure C-1: Post-fill Soil Profile

As the test pit is excavated, the following measurements should be made:

Standard penetration testing to determined the relative density as it changes with depth (minimum intervals of 2 - 3 feet), and

Infiltration testing with at least one test occurring at the proposed bottom of the BMP and one test occurring of the bottom of the test pit (11 feet below the bottom of the infiltration BMP).

In addition, many observations should be made during and after the excavation of the soil pit, including:

- Elevation of groundwater table or indications of seasonally high groundwater table should be noted using the NRCS hydric soil field indicators guide (NRCS, 2003).
- Soil horizon observations, including: depths indicating upper and lower boundaries of the soil horizons, depths to limiting layers (i.e., bedrock and clay), soil textures, colors and their patterns, and estimates of the type and percent of coarse fragments.

- Locations and descriptions of macropores (i.e., pores and roots).
- Other pertinent information/observations.

The number of test pits required depends largely on the specific site and the proposed development plan. Additional tests should be conducted if local conditions indicate significant variability in soil types, geology, water table elevations, bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are required. Excessive testing and disturbance of the soil prior to construction is not recommended. When test pit investigations are complete, including infiltration testing, the pits should be refilled with the original soil and the surface replaced with the original topsoil.

C.3 Infiltration Testing

There are a variety of infiltration field test methodologies available to determine the infiltration rate of a soil. Infiltration tests should be conducted in the field in order to ensure that the measurements are representative of actual site conditions (including inherent heterogeneity). As mentioned above, usually infiltration rates should be determined at a minimum of two locations in each test pit and one must be conducted at the proposed bottom depth of the BMP. The actual number of infiltration tests required depends on the soil conditions; if the soils are highly variable, more tests may be required. To ensure groundwater is protected and that the infiltration BMP is not rendered ineffective by overload, it is important to periodically verify infiltration rates of the constructed BMP(s).

For BMPs that infiltrate water through the surface soil layer (e.g., bioretention areas, permeable pavement), choosing a method that measures infiltration in surface soils is important. For infiltration trenches and drywells, infiltration will occur at a greater depth in the soil matrix; therefore, borehole methods may be more appropriate.

Depending on the type of infiltration BMP and depth at which the infiltration test should be conducted, there are several types of infiltration tests that can be used including: disc permeameters, single and double ring infiltrometers, and borehole permeameters. Disc permeameters are typically used to provide estimates of soil near saturation but can prove to be difficult due to measures of three dimensional flow. This device is also commonly used for assessing infiltration rates of already constructed permeable pavements and is generally not used for assessing infiltration rates prior to site disturbance; therefore, the disc permeameter method will not be discussed further in this Appendix. Single and double ring infiltrometers directly measure vertical flow into the surface of the soil. Double ring infiltrometers account for lateral flow boundary affects with the addition of an outer water reservoir and are generally the preferred method for surface infiltration. Borehole permeameters are best suited to collect infiltration measurements below the soil surface. Two subsurface infiltration methods are discussed below including the Guelph and falling-head permeameters.

C.4 Double Ring Infiltrometer

The double ring infiltrometer method consists of driving two cylinders, one inside the other, into the ground and partially filling them with water and maintaining the liquid at a constant level (ASTM D3385-94). The volume of water added to the inner ring from a separate water reservoir, to maintain the constant head level is comparable to the volume of water infiltrating into the soil. The volume of water added to the inner ring divided by the time period for which the water was added is equal to the infiltration rate. A photograph of a common double ring infiltrometer is provided in Figure C-2.

Figure C-2: Double Ring Infiltrometer

Photo Credit: Geosyntec Consultants (Braga and Fitsik, 2008)

C.5 Borehole Guelph Infiltration Test

For shallow boreholes, the Guelph Permeameter has been developed as a field portable kit. This permeameter consists of a tube that is placed in a hand-drilled shallow borehole and water is provided to the tube through a separate reservoir. Water loss in the reservoir is used to estimate the hydraulic conductivity of the soil, which may be used to calculate infiltration based on various standard models (Soil Moisture Equipment, 2005). A photograph of a Guelph Permeameter is provided in Figure C-3. It is important to remember that this method will include vertical and lateral water flow from the borehole.

Figure C-3: Guelph Permeameter for Shallow Borehole Permeability

Photo Credit: USDA, 2005

C.6 Falling-Head Borehole Infiltration Test

The falling-head borehole infiltration test is commonly applied to assess infiltration at greater depths (e.g. 5 - 25 ft). The method is generally performed according to United States Bureau of Reclamation procedure 7300-89 (USBR, 1990). Caltrans has used the method to site stormwater infiltration structures (Caltrans, 2003). Essentially the method consists of boreholes, installing well casing with slots cut to release water at the target depths, backfilling the borehole, adding pre-soak water, and then filling again with water and recording the stage loss. An example diagram is shown in Figure C-4.

The testing procedures are summarized as follows:

1) Remove any smeared soil surfaces to provide a natural soil interface for testing the percolation of water. Remove all loose material. The U.S. EPA recommends scratching the sides with a sharp pointed instrument. (Note: upon tester's discretion, a 2-inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment.) Fill casing with clean water and allow to pre-soak for 24 hours or until the water has completely infiltrated.

2) Refill casing and monitor water level (distance from top of casing to top of water) for 1 hour. Repeat this procedure a total of four times. (Note: upon tester's discretion, the final field rate may either be the average of the four observations

or the value of the last observation. The final rate shall be reported in inches per hour.)

3) Testing may be done through a boring or open excavation.

4) The location of the test must be near the proposed facility.

5) Upon completion of the testing, the casings shall be immediately pulled and the test pit shall be back-filled.

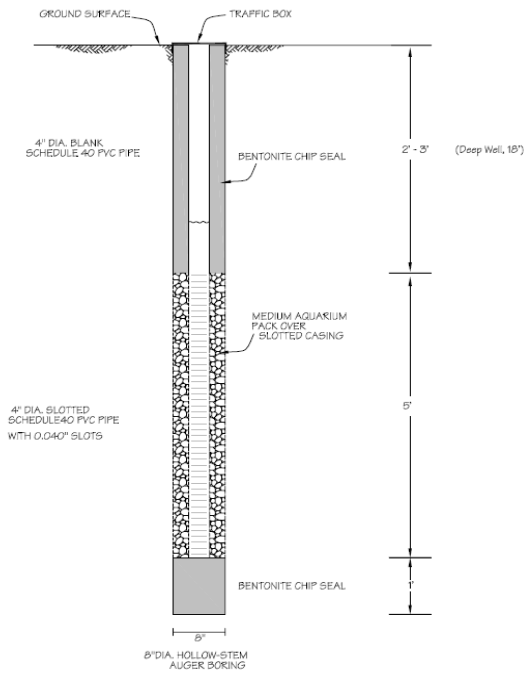

Figure C-4: Falling-Head Permeameter for Deep Borehole Permeability

Diagram Credit: Group Delta Consultants, 2008

C.7 Laboratory Soil Tests

If fill materials imported from off-site are part of an infiltration BMP design, a laboratory test is required to determine the infiltration rate of the fill soil. A sample of the fill soil from each area where a BMP will be located must be tested. The soil sample must be compacted to the same degree that will be present after final grading. Once prepared, the sample should be sent to a specialty laboratory to conduct a test of the infiltration rate. These results may then be used to assess the applicability of a specific BMP.

C.8 Assessment of Test Results

The results from field infiltration methods should be examined to consider data variability and sample distribution to determine if there has been adequate sampling. If the spatial variability (heterogeneity) is large, then additional field measurements may be necessary. The infiltration results should be compared to the information gathered on site soils and geology to see if they are consistent. The results of the site soils and infiltration testing may then be used in the siting, selection, sizing, and design of LID site design techniques and structural treatment BMPs.

C.9 References

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APPENDIX D : BMP PERFORMANCE GUIDANCE

D.1 Permit Requirement

Part 3, Section A.3 of Order R4-2010-0108 states the following:

3. *Each Permittee shall require that treatment control BMPs being implemented under the provisions of this Order shall be designed, at a minimum, to achieve the BMP performance criteria for storm water pollutants likely to be discharged as identified in Attachment "C", for an 85th percentile 24-hour runoff event determined as the maximized capture storm water volume for the area using a 48 to 72-hour draw down time, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998). Expected BMP pollutant removal performance for effluent quality was developed from the WERF-ASCE/ U.S. EPA International BMP Database. Permittees shall select Treatment BMPs based on the primary class of pollutants likely to be discharged from the site/facility (e.g. metals from an auto repair shop). Permittees may develop guidance for appropriate Treatment BMPs for project type based on Attachment "C". For the treatment of pollutants causing impairments within the drainage of the impaired waterbody, permittees shall select BMPs from the top three performing BMP categories or alternative BMPs that are designed to meet or exceed the performance of the highest performing BMP for the pollutant causing impairment.*

Attachment C contains the following table:

Effluent Concentrations as Median Values

BMP Category	Total Suspended Solids (mg/L)	Total Nitrate-Nitrogen (mg/L)	Total Copper (µg/L)	Total Lead (µg/L)	Total Zinc (µg/L)
Detention Pond	27	0.48	15.9	14.6	58.7
Wet Pond	10	0.2	5.8	3.4	21.6
Wetland Basin	13	0.13	3.3	2.5	29.2
Biofilter	18	0.36	9.6	5.4	27.9
Media Filter	11	0.66	7.6	2.6	32.2
Hydrodynamic Device	23	0.29	11.8	5	75.1

Expected BMP pollutant performance for effluent quality was developed from the WERF-ASCE/U.S. EPA International BMP Database, 2007

D.2 Using Performance Statistics for BMP Selection

The observed performance of stormwater BMPs provides valuable quantitative information that can be used to infer the potential water quality benefits of stormwater BMP implementation. However, water quality data sets and the statistical methods used to summarize them inherently contain a high level of uncertainty. Consideration of this uncertainty is fundamental to the proper and responsible use of statistics. Some of the key issues that should be considered when

drawing conclusions from data contained in the ASCE International BMP Database for the purposes of developing BMP selection guidance are discussed below.

Number of Representative BMPs

Some BMP types are not well represented in the ASCE International BMP Database due to small data sets. For example, the "Wetland Basin" category only included nine studies nationwide as compared to over 50 for biofilters at the time the data analysis was conducted for the MS4 permit (2007). For some pollutants, such as total copper, data are only available for four Wetland Basin studies. While the BMP Database continues to grow, there are currently less than 300 BMP studies included, with only approximately 50 in California. The size of the data set provides an indicator of the reliability of that data in representing the "typical" effluent concentration for that BMP type.

BMP Categorization

The BMP studies within the BMP database represent a wide spectrum of BMP types with a variety of designs and sizing criteria. While some guidance is provided on how to categorize BMPs, data providers are responsible for categorizing their own BMPs. Some of these BMPs could be poorly categorized due to a variety of reasons, such as differences in terminology, missing or inadequately sized treatment components (e.g., forebays, vegetation, or permanent pools) or variable treatment function (e.g., a seasonal wet pond). Ideally, the BMPs should be grouped according to common design components and/or sizing criteria, but there currently aren't enough data with design information to support such analyses. However, the BMP Database is currently undergoing a restructuring that is redefining or sub-categorizing the current BMP categories within the database.

Statistical Significant Difference between BMP Influent/Effluent

Some of the median effluent values reported in the BMP Database are not statistically different than the median influent values (i.e., no concentration reductions on average). No significant difference may indicate either low influent concentrations or poor performing BMPs for that pollutant. In either case, the effluent value alone would not be a reliable indicator of BMP performance. For example, as summarized in Geosyntec and Wright Water (2008), the data for Wetland Basins, a "top performing" BMP according to Attachment C of the MS4 permit, did not conclusively show statistically significant removals of TSS, nitrate-nitrogen, or total lead. Data for hydrodynamic separators and media filters indicate they are also ineffective at reducing nitrate-nitrogen concentrations.

Statistical Significant Differences in Effluent between BMP Types

The median effluent concentrations of the various BMP types are not necessarily statistically significantly different from each other. Statistical significance can be determined by analyzing whether the 95th percent confidence intervals overlap. The

number of data points and the variability of those data points determine the confidence interval of each median value. If the effluent medians are not statistically significantly different from each other, it may not be possible to determine the "top three" performing BMPs as specified in the MS4 Permit. Confidence intervals about the median effluent concentrations for each BMP type are provided in Geosyntec and Wright Water (2008) (see attached).

D.3 Comparison of the Performance of Biofiltration BMPs and Retention BMPs

Background

Projects that demonstrate technical infeasibility for reducing EIA to ≤5% using Retention BMPs are eligible to use Biofiltration BMPs to achieve the EIA performance standard. Section 4.E.III.1.(b) of Order R4-2010-0108 states:

> *If on-site retention is determined to be technically infeasible pursuant to 4.E.III.2(b), an on-site biofiltration system that achieves equivalent stormwater volume and pollutant load reduction as would have been achieved by on-site retention shall satisfy the EIA limitation.*

Volume-based biofiltration BMPs shall be sized to treat 1.5 times the volume not retained using Retention BMPs. The remaining EIA requirement may also be satisfied with flow-based Biofiltration BMPs. Flow-based Biofiltration BMPs shall be sized for the remaining drainage area from which runoff must be retained (A_{Retain}) with a rainfall intensity that varies with time of concentration for the catchment tributary to the flow-based Biofiltration BMP, according to the following. Using this flow-based sizing method will achieve or exceed capture and treatment of 80% of the average annual runoff volume.

Time of Concentration, minutes	Design Intensity for 150% Sizing, in/hr
30	0.24
20	0.25
15	0.28
10	0.31
5	0.35

Methodology

A planning-level analysis was conducted to assess whether the range of Biofiltration BMPs included in the 2010 TGM, sized per these volume- or flow-based sizing criteria, would achieve equivalent pollutant load reduction to Retention BMPs. The following describes the step-wise method taken for the analysis.

Step 1: Estimate the Catchment Annual Load

Assumptions:

- Average Annual Rainfall- 14.5 inches (Oxnard Gauge) (precipitation, P)
- One acre Catchment (area, A)

Calculations:

1) Determine developed runoff coefficients for single-family, multi-family, commercial, and industrial land use types

    - Use average imperviousness values from Ventura Hydrology Manual (Exhibit 14B)
    - Assume soil group 2/3 (Group C soils) for pervious runoff coefficient (Cp, conservative value = 0.1)
    - Use developed runoff coefficient (C_d) equation from hydrology manual:

$$C_d = 0.95*(\text{imperviousness}) + (Cp)*(1\text{-imperviousness})$$

2) Calculate Average Annual Runoff Volume (cu-ft) using:

$$V_{avg\ annual} = C_d*(P/12)*A*43560$$

3) Multiply average annual runoff volume by respective event mean concentrations (EMCs) for pollutants of concern to get average annual loads.

    - Look at "EMC Arithmetic Means" to see EMCs by land use type.
    - EMCs calculated based on LA County Land Use specific data (LACDPW, 2000). Descriptive statistics estimated using the parametric bootstrap method suggested by Singh, Singh, and Engelhardt (1997).
    - Pollutants of concern: Total Suspended Solids (TSS), Total Copper, Total Zinc, and Total Nitrogen. TSS is representative of the sediment pollutant class as well as pollutants that are associated with particulates (e.g., total phosphorous, some metals, pesticides, some organics). Copper and zinc represent metals – lead has been removed from the environment using True Source Control (removal of lead from gasoline) and thus is not an important POC for Biofiltration BMP selection and design. Total nitrogen is representative in that it includes all of the species of nitrogen (organic nitrogen, ammonia, nitrate, and nitrite) and instead of focusing on one species (nitrate).

Step 2: Estimate Retention BMP Load Reduction

1) Determine Retention BMP Design volume:

- Design storm = 0.75”
- Use land use-based coefficients
- $V_{design} = C_d*(0.75/12)*A*43560$

2) Determine Retention BMP capture volume using CASQA 48-hour Drawdown Figure for Oxnard Gauge (CASQA, 2003)
   - Calculate Unit Basin Storage Volume using:
     - Unit Basin Storage Vol = V_{design} / A
   - Using developed runoff coefficients, interpolate between runoff coefficient lines to determine the percentage of total runoff captured by Retention BMP.
3) Determine Annual Load Reduction
   - The percentage of the annual load that is reduced is the same as the percentage of runoff captured by the Retention BMP, assuming that all captured runoff is retained. The percent capture calculated in (2) can be multiplied by the catchment annual pollutant load to obtain the load reduction.

Step 3: Estimate Biofiltration BMP Load Reduction

1) Determine BMP Design volume as described in 2.a above, except:
   - Design storm = 1.5*0.75 = 1.125 inches
2) Determine BMP capture volume using CASQA 24-hour Drawdown Figure for Oxnard Gauge (CASQA, 2003) as described in 2.b. above
3) Determine annual load reduction. Load reduction in Biofiltration BMPs can occur via two pathways: incidental infiltration and treatment.
   - Incidental infiltration in Biofiltration BMPs was discussed in a publication by Strecker, Quigley, Urbonas, and Jones (Strecker et al, 2004). That study observed as much as 40% volume reduction through incidental infiltration. A recent summary of the studies in the ASCE BMP Database found the following average volume reductions: filter strips, 38%; vegetated swales, 48%; and bioretention with underdrain, 61% (Geosyntec, 2011; attached to this appendix).
   - Pollutant Load reduction via incidental infiltration can be calculated as follows (20% is the percent of the captured volume assumed to be reduced via incidental infiltration for this discussion):

Load reduced = Average annual Load * Percent Runoff Captured by BMP * 20%

- Load reduction through treatment calculated based on published literature on pollutant removals from biofiltration facilities.

- Load reduction through treatment is calculated as follows:

Load reduced = Average annual Load * Percent Runoff Captured by BMP *80% * Assumed Average Percent Removal

Note: 80% = 100%-20%, i.e. the captured runoff that was not infiltrated via incidental infiltration

Constituent	Range of Reported Removal Efficiencies from Literature[1]	Selected Removal Efficiency for Effectiveness Evaluation[2]	Selected Removal Efficiency for Enhanced Nitrogen Removal[3]
TSS	54-89	79	79
Total Zinc	48-96	77	77
Total Copper	33-92	72	72
Total Nitrogen	21-54	25	50

[1] Range of values from literature cited below:

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6. Geosyntec Consultants and Wright Water Engineers, Inc., 2008. Overview of Performance by BMP Category and Common Pollutant Type, International Stormwater BMP Database Update. June 2008
7. Geosyntec Consultants and Wright Water Engineers, Inc., 2010. Categorical Summary of BMP Performance for Nutrient Concentration Data Contained in the International Stormwater BMP Database. December, 2010

[2] Removal efficiency for TSS, Total Zinc, and Total Copper represent average of values from literature. Removal efficiency for TN is that expected from a 'standard biofilter', that is, one not designed for enhanced nitrogen removal

[3] Removal efficiency for TN represented as average value of removals from bioretention systems with an anaerobic zone for enhanced removal of nitrogen

- The total load reduction is calculated as the sum of the reductions from these two pathways. The percent load reduction is calculated by dividing the total load reduction by the annual pollutant load from the catchment

Step 4: Comparison of Annual Load Reductions

1) Load reductions are compared by subtracting the load reduction calculated for Biofiltration BMPs from the load reduction calculated for Retention BMPs to determine the 'deficit' load reduction.

Results

Step 1: Estimate the Catchment Annual Load

1) Determine developed runoff coefficients for single-family, multi-family, commercial, and industrial land use types

Land Use	Imperviousness	Runoff Coefficient (C)
Single Family Residential	0.3	0.36
Multi Family Residential	0.69	0.69
Commercial	0.85	0.82
Industrial	0.93	0.89

2) Calculate Average Annual Runoff Volume (cu-ft), and

3) Multiply average annual runoff volume by respective event mean concentrations (EMCs) for pollutants of concern to get average annual loads.

Land Use	Arithmetic Means from Lognormal EMC Statistics			
	TSS (mg/L)	Total Zinc (mg/L)	Total Copper (mg/L)	Total Nitrogen (mg/L as N)
Single Family Residential	124.2	71.9	18.7	3.74
Multi Family Residential	39.9	125.1	12.1	3.31
Commercial	67	237.1	31.4	3.99
Industrial	219.2	537.4	34.5	3.74

Land Use	Average Annual Runoff Volume (cu-ft)	Catchment Pollutant Loads (kg/yr)			
		TSS	Total Zinc	Total Copper	Total Nitrogen
Single Family Residential	18,685	65,716	38	10	1,979
Multi Family Residential	36,134	40,826	128	12	3,387
Commercial	43,292	82,135	291	38	4,891
Industrial	46,871	290,933	713	46	4,964

Step 2: Estimate Retention BMP Load Reduction

1) Determine Retention BMP Design volume

Land Use	Design Volume (cu-ft)
Single Family Residential	967
Multi Family Residential	1869
Commercial	2239
Industrial	2424

2) Determine Retention BMP capture volume using CASQA 48-hour Drawdown Figure for Oxnard Gauge (CASQA, 2003)

Land Use	Design Volume (cu-ft)	Unit Basin Storage Volume (inches)	Approx % Capture
Single Family Residential	966	0.27	60.0%
Multi Family Residential	1,869	0.51	62.5%
Commercial	2,239	0.62	62.5%
Industrial	2,424	0.67	60.0%

3) Determine Annual Load Reduction

	Average Annual Pollutant Load Reduction (kg/yr) = Influent * Approx % Cap			
Land Use	TSS	Total Zinc	Total Copper	Total Nitrogen
Single Family Residential	39,429	23	5.9	1,187
Multi Family Residential	25,516	80	7.7	2,117
Commercial	51,335	182	24.1	3,057
Industrial	174,560	428	27.5	2,978

	Percent of Total Annual Loads			
Land Use	TSS	Total Zinc	Total Copper	Total Nitrogen
Single Family Residential	60.0%	60.0%	60.0%	60.0%
Multi Family Residential	62.5%	62.5%	62.5%	62.5%
Commercial	62.5%	62.5%	62.5%	62.5%
Industrial	60.0%	60.0%	60.0%	60.0%

Step 3: Estimate Biofiltration BMP Load Reduction

1) Determine Biofiltration BMP Design volume

Land Use	Design Volume (cu-ft)
Single Family Residential	1,450
Multi Family Residential	2,803
Commercial	3,359
Industrial	3,637

2) Determine BMP capture volume using CASQA 24-hour Drawdown Figure for Oxnard Gauge (CASQA, 2003)

Land Use	Design Volume (cu-ft)	Unit Basin Storage Volume (inches)	Approx % Capture
Single Family Residential	1,450	0.40	87.50%
Multi Family Residential	2,803	0.77	87.50%
Commercial	3,359	0.93	90.00%
Industrial	3,637	1.00	87.50%

3) Determine annual load reduction. Load reduction in Biofiltration BMPs can occur via two pathways: incidental infiltration and treatment.

Incidental Infiltration Scenario #1: 20% Volume Reduction

Land Use	Pollutant Load Reduction from 20% Incidental Infiltration (kg/yr)			
	TSS	Total Zinc	Total Copper	Total Nitrogen
Single Family Residential	11,500	7	2	346
Multi Family Residential	7,144	22	2	593
Commercial	14,784	52	7	880
Industrial	50,913	125	8	869

Land Use	Pollutant Load Reduction from Standard Treatment (kg/yr)				Enhanced Nitrogen Load Reduction (kg/yr)[1]
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	36,341	21	5	346	693
Multi Family Residential	22,577	69	6	593	1,185
Commercial	46,719	161	20	880	1,761
Industrial	160,886	384	23	869	1,737

[1] Anticipated removal if an anaerobic zone is provided for Enhanced Nitrogen removal.

Land Use	Total Pollutant Load Reduction from Standard Treatment + Incidental Infiltration (20%) (kg/yr)				Enhanced Nitrogen Load Reduction + Incidental Infiltration (20%) (kg/yr)
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	47,841	27	6.7	693	1,039
Multi Family Residential	29,721	91	8.4	1,185	1,778
Commercial	61,503	213	26.8	1,761	2,641
Industrial	211,799	509	31.0	1,737	2,606

Land Use	Percent of Total Annual Loads from Standard Treatment + Incidental Infiltration (20%)				Enhanced Nitrogen % Load Reduction + Incidental Infiltration (20%)
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	72.8%	71.4%	67.7%	35.0%	52.5%
Multi Family Residential	72.8%	71.4%	67.7%	35.0%	52.5%
Commercial	74.9%	73.4%	69.6%	36.0%	54.0%
Industrial	72.8%	71.4%	67.7%	35.0%	52.5%

Step 4: Comparison of Annual Load Reductions

Load reductions are compared by subtracting the load reduction calculated for Biofiltration BMPs from the load reduction calculated for Retention BMPs to determine the 'deficit' load reduction.

Land Use	Biofiltration Pollutant Load Reduction Deficit - Standard Treatment + Incidental Infiltration (20%) (kg/yr)				Enhanced Nitrogen + Incidental Infiltration (20%) Pollutant Load Reduction Deficit (kg/yr)
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	-8,412	-4	-0.8	495	148
Multi Family Residential	-4,205	-11	-0.6	931	339
Commercial	-10,168	-32	-2.7	1,296	416
Industrial	-37,239	-81	-3.5	1,241	372

Note: a negative deficit means Biofiltration has a higher pollutant load reduction than Retention.

Land Use	Biofiltration Pollutant Load Reduction Deficit - Standard Treatment + Incidental Infiltration (20%) (%)				Enhanced Nitrogen + Incidental Infiltration (20%) Pollutant Load Reduction Deficit (%)
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	-12.8%	-11.4%	-7.7%	25.0%	7.5%
Multi Family Residential	-10.3%	-8.9%	-5.2%	27.5%	10.0%
Commercial	-12.4%	-10.9%	-7.1%	26.5%	8.5%
Industrial	-12.8%	-11.4%	-7.7%	25.0%	7.5%

Conclusion: Biofiltration BMPs sized for 1.5 times the SQDV, with an average incidental infiltration of 20% of the average annual runoff volume, which is a conservative estimate of incidental infiltration for all types of Biofiltration Treatment Measures, provide equivalent pollutant load reduction to Retention BMPs for TSS and metals.

Incidental Infiltration Scenario #2: 40% Volume Reduction

Land Use	Pollutant Load Reduction from 40% Incidental Infiltration (kg/yr)			
	TSS	Total Zinc	Total Copper	Total Nitrogen
Single Family Residential	23,000	13	3	693
Multi Family Residential	14,289	45	4	1,185
Commercial	29,569	105	14	1,761
Industrial	101,827	250	16	1,737

Land Use	Pollutant Load Reduction from Standard Treatment (kg/yr)				Enhanced Nitrogen Load Reduction (kg/yr)[1]
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	27,256	15	3.7	260	519
Multi Family Residential	16,932	52	4.7	445	889
Commercial	35,039	121	14.9	660	1,321
Industrial	120,665	288	17.2	652	1,303

[1] Anticipated removal if an anaerobic zone is provided for Enhanced Nitrogen removal.

Land Use	Total Pollutant Load Reduction from Standard Treatment + Incidental Infiltration (40%) (kg/yr)				Enhanced Nitrogen Load Reduction + Incidental Infiltration (40%) (kg/yr)
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	50,256	29	7.2	952	1,212
Multi Family Residential	31,221	97	9.0	1,630	2,074
Commercial	64,608	225	28.8	2,421	3,082
Industrial	222,491	538	33.3	2,389	3,040

Land Use	Percent of Total Annual Loads from Standard Treatment + Incidental Infiltration (40%)				Enhanced Nitrogen % Load Reduction + Incidental Infiltration (40%)
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	76.5%	75.4%	72.6%	48.1%	61.3%
Multi Family Residential	76.5%	75.4%	72.6%	48.1%	61.3%
Commercial	78.7%	77.6%	74.7%	49.5%	63.0%
Industrial	76.5%	75.4%	72.6%	48.1%	61.3%

Step 4: Comparison of Annual Load Reductions

Load reductions are compared by subtracting the load reduction calculated for Biofiltration BMPs from the load reduction calculated for Retention BMPs to determine the 'deficit' load reduction.

	Biofiltration Pollutant Load Reduction Deficit - Standard Treatment + Incidental Infiltration (40%) (kg/yr)				Enhanced Nitrogen + Incidental Infiltration (40%) Pollutant Load Reduction Deficit (kg/yr)
Land Use	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	-10,827	-6	-1.2	235	-25
Multi Family Residential	-5,705	-17	-1.3	487	42
Commercial	-13,273	-44	-4.7	636	-24
Industrial	-47,931	-110	-5.8	589	-62

Note: a negative deficit means Biofiltration has a higher pollutant load reduction than Retention.

	Biofiltration Pollutant Load Reduction Deficit - Standard Treatment + Incidental Infiltration (40%) (%)				Enhanced Nitrogen + Incidental Infiltration (40%) Pollutant Load Reduction Deficit (%)
Land Use	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	-16.5%	-15.4%	-12.6%	11.9%	-1.3%
Multi Family Residential	-14.0%	-12.9%	-10.1%	14.4%	1.2%
Commercial	-16.2%	-15.1%	-12.2%	13.0%	-0.5%
Industrial	-16.5%	-15.4%	-12.6%	11.9%	-1.3%

Conclusion: Biofiltration BMPs sized for 1.5 times the SQDV, with an average incidental infiltration of 40% of the average annual runoff volume, which is representative of vegetated swales and filter strips, provide equivalent pollutant load reduction to Retention BMPs for all of the pollutants of concern.

Incidental Infiltration Scenario #3: 60% Volume Reduction

Land Use	Pollutant Load Reduction from 60% Incidental Infiltration (kg/yr)			
	TSS	Total Zinc	Total Copper	Total Nitrogen
Single Family Residential	34,501	20	5	1,039
Multi Family Residential	21,433	67	6	1,778
Commercial	44,353	157	21	2,641
Industrial	152,740	374	24	2,606

Land Use	Pollutant Load Reduction from Standard Treatment (kg/yr)				Enhanced Nitrogen Load Reduction (kg/yr)[1]
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	18,170	10	2	173	346
Multi Family Residential	11,288	34	3	296	593
Commercial	23,359	81	10	440	880
Industrial	80,443	192	11	434	869

[1] Anticipated removal if an anaerobic zone is provided for Enhanced Nitrogen removal.

Land Use	Total Pollutant Load Reduction from Standard Treatment + Incidental Infiltration (60%) (kg/yr)				Enhanced Nitrogen Load Reduction + Incidental Infiltration (60%) (kg/yr)
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	52,671	30	7.7	1,212	1,385
Multi Family Residential	32,722	102	9.6	2,074	2,371
Commercial	67,712	238	30.7	3,082	3,522
Industrial	233,183	567	35.5	3,040	3,475

Land Use	Percent of Total Annual Loads from Standard Treatment + Incidental Infiltration (60%)				Enhanced Nitrogen % Load Reduction + Incidental Infiltration (60%)
	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	80.2%	79.5%	77.6%	61.3%	70.0%
Multi Family Residential	80.2%	79.5%	77.6%	61.3%	70.0%
Commercial	82.4%	81.7%	79.8%	63.0%	72.0%
Industrial	80.2%	79.5%	77.6%	61.3%	70.0%

Step 4: Comparison of Annual Load Reductions

Load reductions are compared by subtracting the load reduction calculated for Biofiltration BMPs from the load reduction calculated for Retention BMPs to determine the 'deficit' load reduction.

	Biofiltration Pollutant Load Reduction Deficit - Standard Treatment + Incidental Infiltration (60%) (kg/yr)				Enhanced Nitrogen + Incidental Infiltration (60%) Pollutant Load Reduction Deficit (kg/yr)
Land Use	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	-13,242	-7	-1.7	-25	-198
Multi Family Residential	-7,206	-22	-1.9	42	-254
Commercial	-16,378	-56	-6.7	-24	-465
Industrial	-58,623	-139	-8.1	-62	-496

Note: a negative deficit means Biofiltration has a higher pollutant load reduction than Retention.

	Biofiltration Pollutant Load Reduction Deficit - Standard Treatment + Incidental Infiltration (60%) (%)				Enhanced Nitrogen + Incidental Infiltration (60%) Pollutant Load Reduction Deficit (%)
Land Use	TSS	Total Zinc	Total Copper	Total Nitrogen	Total Nitrogen
Single Family Residential	-20.2%	-19.5%	-17.6%	-1.3%	-10.0%
Multi Family Residential	-17.7%	-17.0%	-15.1%	1.2%	-7.5%
Commercial	-19.9%	-19.2%	-17.3%	-0.5%	-9.5%
Industrial	-20.2%	-19.5%	-17.6%	-1.3%	-10.0%

Conclusion: Biofiltration BMPs sized for 1.5 times the SQDV, with an average incidental infiltration of 60% of the average annual runoff volume, which is representative of bioretention with an underdrain, is equivalent to or exceeds the pollutant load reduction of Retention BMPs for all of the pollutants of concern.

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APPENDIX E : BMP SIZING WORKSHEETS

E.1 Structural Treatment BMP Sizing Criteria

The BMP sizing criteria for determining the design volume or design flow for a proposed BMP are discussed in this appendix. These criteria must be used for all stormwater BMPs installed in new and re-development projects in Ventura County. This section outlines the rainfall analyses, Ventura County MS4 Permit sizing criteria, and recommended sizing methods for both volumetric and flow-based analysis.

Sizing Criteria

The type of rainfall analysis required depends on whether the BMP is a volume-based or flow-based BMP. This distinction between volume-based and flow-based controls is not always clear, especially in a sequence of BMPs or a treatment train. The following are general guidelines for each type of control.

- Volume-based BMPs are designed to treat a volume of runoff, which is detained for a certain period of time to allow for the settling of solids and associated pollutants. Volume-based BMPs included in this manual are bioretention, planter boxes, infiltration systems, and retention/detention BMPs.

- Flow-based BMPs treat water on a continuous flow basis. Flow-based BMPs included in this manual are vegetated swales, filter strips, filtration systems, and hydrodynamic devices.

The four volume-based and three flow-based BMP sizing criteria included in the Ventura County MS4 Permit (Order No. 09-0057) are included below.

The water quality design volume for volume-based BMPs must be determined using one of the following options:

1) The 85th percentile 24-hour runoff event determined as the maximized capture stormwater volume for the area using a 48 to 72-hour draw down time, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998); or

2) The volume of annual runoff based on unit basin storage water quality volume to achieve 80 percent or more volume treatment; or

3) The volume of runoff produced from a 0.75 inch storm event; or

4) 80 percent of the average runoff volume using an appropriate public domain continuous flow model [such as Storm Water Management Model (SWMM) or Hydrologic Engineering Center – Hydrologic Simulation Program – Fortran (HEC-HSPF)], using the local rainfall record and relevant BMP sizing and design data.

Flow-based BMPs must be designed to capture and treat the water quality design flow rate generated from one of the following criterion:

1) The flow of runoff produced from a rain event equal to at least 0.2 inches per hour intensity; or

2) The flow of runoff produced from a rain event equal to at least 2 times the 85th percentile hourly rainfall intensity as determined from local rainfall records; or

3) Eight percent of the 50-year storm design flow rate as determined from the method provided below.

These sizing methods are explained below.

Methods for Determining the Water Quality Design Volume

Method 1: Urban Runoff Quality Management (URQM) Approach

The volume-based BMP sizing methodology described in Urban Runoff Quality Management (WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998), pages 175-178) estimates the "maximized stormwater quality capture volume." The URQM approach is based on the translation of rainfall to runoff using two regression equations. The first regression equation, which relates rainfall to runoff, was developed using two years of data from more than 60 urban watersheds nationwide. The second regression equation relates mean annual runoff-producing rainfall depths to the "Maximized Water Quality Capture Volume" which corresponds to the "knee of the cumulative probability curve". This second regression was based on analysis of long-term rainfall data from seven rain gages representing climatic zones across the country. The Maximized Water Quality Capture Volume corresponds to approximately the 85th percentile runoff event, and ranges from 82 to 88%.

The two regression equations that form the URQM approach are as follows:

$$C = 0.858imp^3 - 0.78imp^2 + 0.774imp + 0.04 \qquad \text{(Equation E-1)}$$

$$P_o = (a \cdot C) \cdot P_6 \qquad \text{(Equation E-2)}$$

Where:

C	=	watershed runoff coefficient (unitless)
imp	=	watershed impervious ratio which is equal to the percent total imperviousness divided by 100 (ranges from 0 to 1)
P_o	=	maximized detention storage volume based on the volume capture ratio as its basis (watershed inches)

a	=	regression constant from least-squares analysis (unit less), a=1.582 and a=1.963 for 24 and 48 hour draw down, respectively
P_6	=	mean storm precipitation volume (watershed inches)

P_6 can be determined by two ways: Figure 5.3 in Urban Runoff Quality Management, or by performing analysis on local historical rainfall data. To determine the mean precipitation, EPA's Synoptic Rainfall Analysis Program – SYNOP – can be applied (see *Other Rainfall Analysis Methods* below).

The runoff coefficient equation in the URQM approach (Method 1) is not appropriate for the California BMP Handbook approach (Method 2), as Equation E-4 was developed in conjunction with the regression constants used in Method 1.

Method 2: Treatment of 80% or more of the Total Volume

Most water quality facilities are designed to treat only a portion of the runoff from a given site, as it is not economically feasible to capture 100% of the runoff. The percent of runoff treated by a basin is referred to as the "percent capture". There are a number of methods which allow calculation of the percent capture, including the California Stormwater Quality Association (CASQA) method (recommended by the 2002 Ventura County Manual), and using the EPA Stormwater Management Model (SWMM).

CASQA Method

The California Stormwater Quality Association (CASQA) BMP Handbook method estimates the basin volume to achieve various levels of volume capture (e.g., 80% for this sizing criterion). In the CASQA BMP Handbook New Development and Redevelopment (2003), a proprietary version of the Storage, Treatment, Overflow, Runoff Model (STORM) is used as the basis for the volume-based BMP sizing criteria. The model results are presented as the relationship between "unit basin storage volume" and "% volume capture" of the BMP", varying with drawdown time and runoff coefficient. Knowing the drawdown time, the runoff coefficient, and the desired percent capture will yield the "unit basin storage volume". The "unit basin storage volume" can then be used to size the BMP using the following equation (note that "unit basin storage volume" is given in inches, so units will have to be adjusted accordingly):

$$\text{BMP Volume} = \text{Unit Basin Storage Volume} \times \text{Tributary Area} \qquad \text{(Equation E-3)}$$

Results for several rain gauges are presented in Appendix D of the CASQA BMP Handbook New Development and Redevelopment (CASQA, 2003). Results are provided for a range of runoff coefficients and for 24 hour and 48 hour drawn down times. In order to use the curves provided in Appendix D, it is necessary to know the

runoff coefficient for the area tributary to the BMP, the drawn down time (a.k.a. drain time) of the facility, and the percent capture goal (e.g., 80%).

Drawdown time is the time required to drain a facility that has reached its design capacity; usually expressed in hours. Drain time is important as it is a surrogate for residence time, which affects the particle settling in the basin. Estimates for design drain time vary, and ideally would be determined based on site-specific information on the size, shape, and density or settling velocity of suspended particulates in the runoff. Because this information is generally not available for a specific site, estimates of appropriate ranges for settling time have generally relied on settling column test information reported in the literature.

An important source of drain time information is settling column tests conducted by Grizzard et. al. (1986) as part of the Nationwide Urban Runoff Program (NURP). Grizzard found that settling times of 48 hours resulted in removals of 80% to 90% of total suspended solids (TSS). Rapid initial removal was also observed in stormwater samples with medium (100 to 215 mg/L) and high (721 mg/L) initial TSS concentrations. For example, at settling times of 24 hours, the 80% to 90% removals were already achieved in samples with medium and high initial TSS, whereas only 50% to 60% removal was achieved in those with low initial TSS.

Given the data provided above, a drain time of 36 to 48 hours is recommended for sizing volume-based BMPs. This is also consistent with the recommendation of vector control agencies that structures be designed to drain in less than 72 hours to minimize mosquito breeding.

The rain gauge that is recommended for use for the area permitted by the Ventura county MS4 Permit (Order No. 09-0057) is the Oxnard Equipment Yard Gauge (168), which has a 40 year rainfall record. The graph included in the CASQA handbook can be seen in Figure E-1 below.

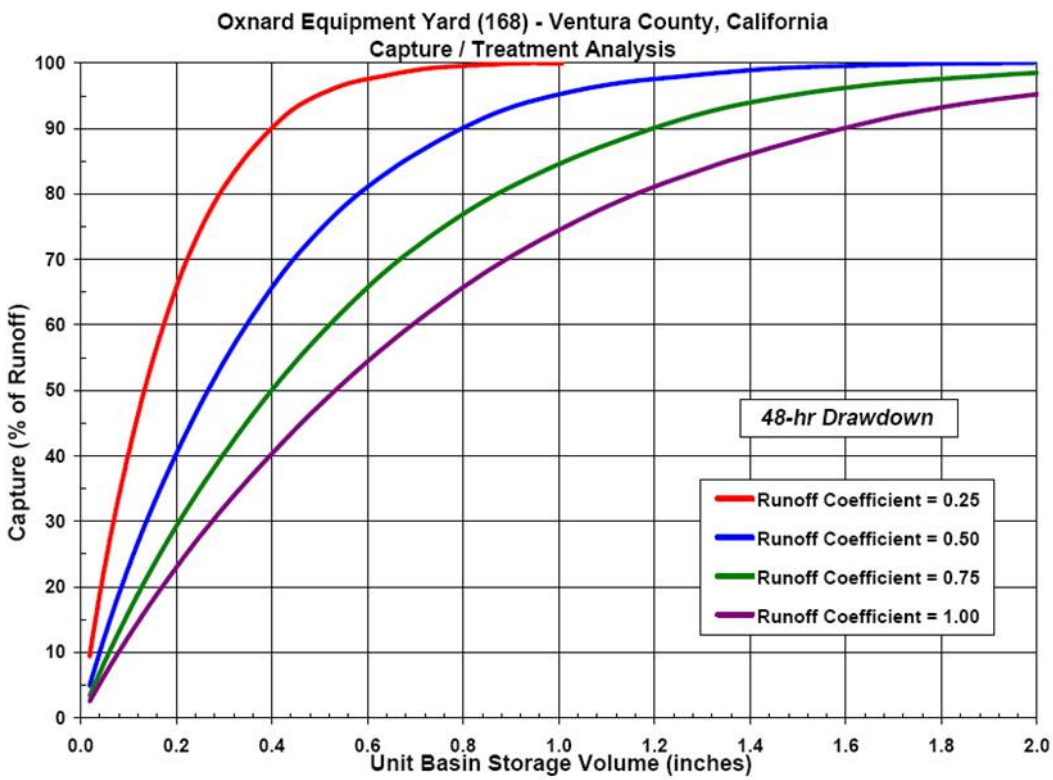


Figure E-1: CASQA 48-hour Drawdown Figure for Oxnard Gauge

This method has been modified for Ventura County. To use this method, follow the calculation procedure below. This refers to Figure E-3.

Ventura County Calculation Procedure

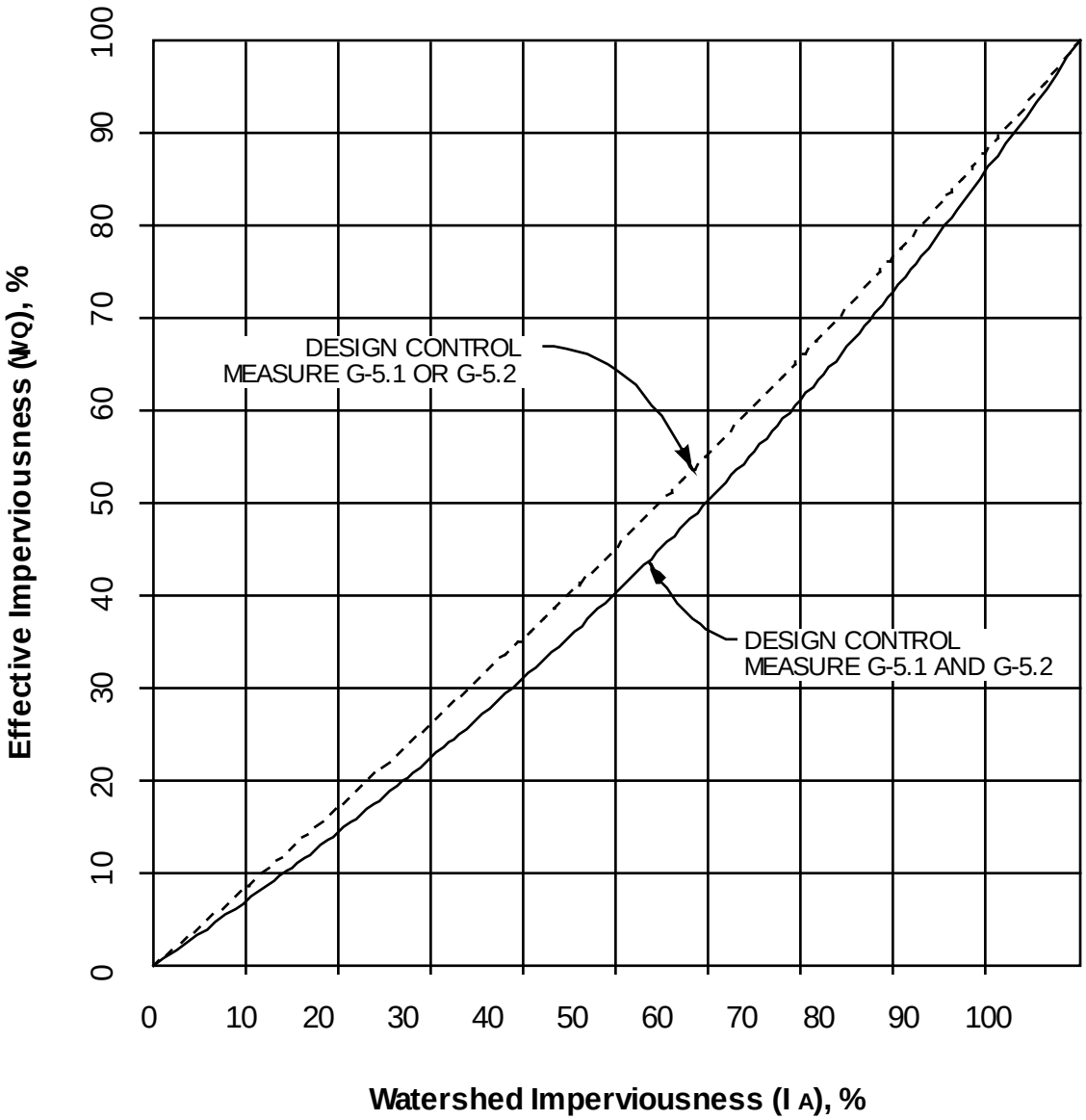
1) Review the area draining to the proposed treatment control measure. Determine the effective imperviousness (I_{WQ}) of the drainage area.

2) Estimate the total imperviousness (impervious percentage) of the site by the determining the weighted average of individual areas of like imperviousness.

3) Enter Figure E-2 along the horizontal axis with the value of total imperviousness calculated in Step 1. Move vertically up Figure E-2 until the appropriate curve (G-5.1 (filter strip) or G-5.2 (vegetated swale) employed individually or G-5.1 and G-5.2 employed together) is intercepted. Move horizontally across Figure E-2 until the vertical axis is intercepted. Read the Effective Imperviousness value along the vertical axis.

4) Note that if G-5.1 and/or G-5.2 are implemented on only a portion of the site, the site may be divided and effective imperviousness determined for the portion of the site for which site design controls have been implemented. The resulting effective imperviousness may be combined with total imperviousness of the

remainder of the site to determine a weighted average total imperviousness for the entire site.



G-5.1: TURF BUFFER
G-5.2: GRASS-LINED CHANNEL

ADAPTED FROM URBAN STORM DRAIN CRITERIA MANUAL VOL. 3 - BEST MANAGEMENT PRACTICES, URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, 11/99

Figure E-2: Effective Imperviousness based on Watershed Imperviousness

5) Figure E-3 provides a direct reading of Unit Basin Storage Volumes required for 80% annual capture of runoff for values of "I_{WQ}" determined in Step 1. Enter the horizontal axis of Figure E-3 with the "I_{WQ}" value from Step 1. Move vertically up

Figure E-3 until the appropriate drawdown period line is intercepted. (The design drawdown period specified in the respective Fact Sheet for the proposed treatment control measure.) Move horizontally across Figure E-3 from this point until the vertical axis is intercepted. Read the Unit Basin Storage Volume along the vertical axis.

6) Figure E-3 is based on Precipitation Gage 168, Oxnard Airport. This gage has a data record of approximately 40 years of hourly readings and is maintained by Ventura County Flood Control District. Figure E-3 is for use only in the permit area specified in Regional Board Order No. 00-108, NPDES Permit No. CAS004002.

7) The SQDV for the proposed treatment control measure is then calculated by multiplying the Unit Basin Storage Volume by the contributing drainage area. Due to the mixed units that result (e.g., acre-inches, acre-feet) it is recommended that the resulting volume be converted to cubic feet for use during design.

Example Stormwater Quality Design Volume Calculation

1) Determine the drainage area contributing to control measure, A_t. Example: 10 acres.

2) Determine the area of impervious surfaces in the drainage area, A_i. Example: 6.4 acres.

3) Calculate the percentage of impervious, $I_A = (A_i / A_t)*100$

   Example:

   Percent Imperviousness = $(A_i / A_t)*100$ = (6.4 acres/10 acres)*100 = 64%

4) Determine Effective Imperviousness using Figure 3-4.

   I_{WQ} = 60%

5) Determine design drawdown period for proposed control measure.

6) Determine the Unit Basin Storage Volume for 80% Annual Capture, V_u using Figure E-3.

   For $I_{WQ}/100$ = 0.60 and drawdown = 40 hrs, V_u = 0.64 in.

7) Calculate the volume of the basin, V_b, where

$$V_b = V_u * A_t. \qquad \text{(Equation E-4)}$$

Where

V_b = Volume of basin

V_u = Unit basin storage volume

A_t = Total tributary area

8) V_b = (0.64 in)(10 ac)(ft/12 in(43,560 ft^2 / ac) = 23,232 ft^3.

9) Solution: Size the proposed control measure for 23,232 ft^3 and 40-hour drawdown.

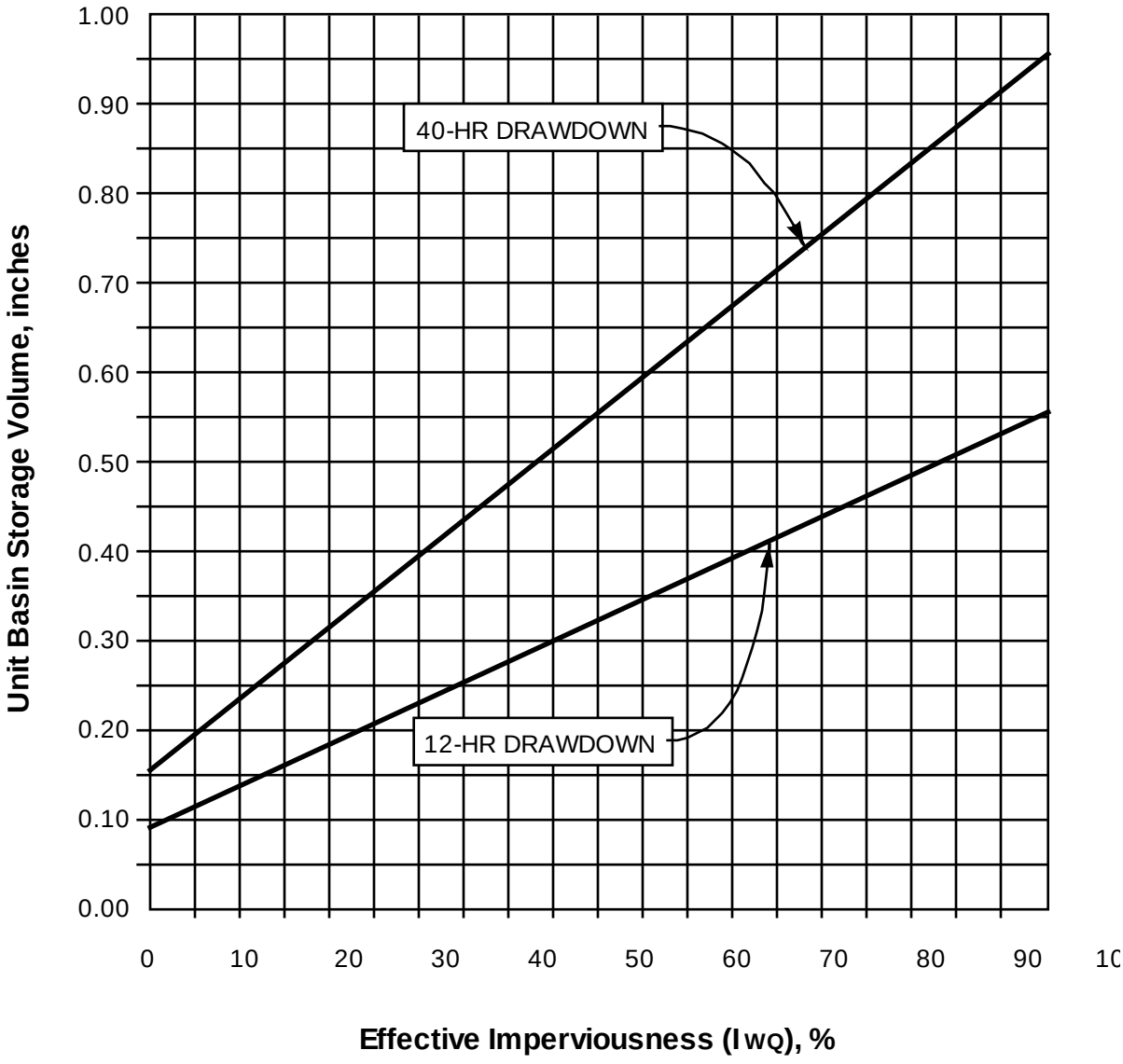


Figure E-3: Unit Basin Storage Volume for Design Volume Method 2

Method 3: 0.75 Inch Design Storm Approach

Equation E-8 can be used to determine the water quality design volume for Method 3.

Calculation Procedure

1) Determine the area from which runoff must be retained on-site (A_{retain}) using the method below:

   The allowable EIA for a project site can be calculated as follows:

   $EIA_{allowable} = (A_{project})*(\%_{allowable})$ (Equation E-5)

Where:

$EIA_{allowable}$	=	the maximum impervious area from which runoff can be treated and discharged off-site [and not retained on-site] (acres).
$A_{project}$	=	the total project area (acres). "Total project area" for new development and redevelopment projects is defined as the disturbed, developed, and undisturbed portions within the project's property (or properties) boundary, at the project scale submitted for first approval.
$\%_{allowable}$	=	ranges from 5 percent to 30 percent, based on a project specific assessment of technical feasibility for retaining runoff and whether the project is located in an existing urban area.

The drainage area from which Project generated runoff must be retained on-site is the total impervious area minus the $EIA_{allowable}$, which can be calculated as follows:

$A_{retain} = TIA - EIA_{allowable} = (P*A_{project}) - EIA_{allowable}$ (Equation E-6)

Where:

A_{retain}	=	the drainage area from which runoff must be retained (acres)
TIA	=	total impervious area (acres)
$EIA_{allowable}$	=	the maximum impervious area from which runoff can be treated and discharged off-site [and not retained on-site] (acres).
P	=	imperviousness of project area (%)/100
$A_{project}$	=	the total project area (acres)

Calculation Procedure

1) Determine the area from which runoff must be retained on-site (A_{retain}) using method above.

2) Determine the runoff coefficient per the following method:

$$C = 0.95*imp + C_p (1-imp) \quad \text{(Equation E-7)}$$

Where:

C	=	runoff coefficient
imp	=	impervious fraction of watershed
C_p	=	pervious runoff coefficient, determined using table below

Table E-1: Pervious Runoff Coefficient Based on Ventura Soil Type

Ventura Soil Type (Soil Number)	Cp value
1	0.15
2	0.10
3	0.10
4	0.05
5	0.05
6	0
7	0

3) The volume can be calculated using equation E-8 below:

$$SQDV = C*(0.75/12)*A_{retain} \quad \text{(Equation E-8)}$$

Where:

SQDV	=	the water quality design volume (acre-feet)
C_{imp}	=	runoff coefficient, calculated by equation (4) above
0.75	=	the design rainfall depth (in) [based on sizing method (c)]
A_{retain}	=	the drainage area from which runoff must be retained (acres)

Method 4: 80 percent of the average runoff volume using an appropriate public domain continuous flow model

Models that can be used for this calculation include the Storm Water Management Model (SWMM) or Hydrologic Engineering Center – Hydrologic Simulation Program – Fortran (HEC-HSPF)], using the local rainfall record and relevant BMP sizing and design data.

Sizing Method 4 allows for alternative sizing methods to be used as long as the selected method produces a water quality design volume based on historical rainfall records that achieves 80% capture of the average runoff volume. While sizing Methods 2 and 3 are appropriate for low lying areas within Ventura County, continuous simulation (using historical rainfall record) is well suited to sizing BMPs in locations with higher average rainfall. This method is the recommended sizing method for Ventura County, using appropriate local data inputs. For BMP locations at higher elevations, with larger rainfall, Method 1 is also better suited to sizing volume-based BMPs using rainfall representative of the site where the BMP will be located.

Continuous runoff modeling takes a long, uninterrupted record of observed rainfall data and transforms it into a record of runoff data. This is done by use of a set of mathematical algorithms that represent the rainfall-runoff processes. EPA's Stormwater Management Model (U.S. EPA, 2000) (SWMM) is one type of continuous runoff model. The runoff module of SWMM subdivides each drainage area into two inclined planes, one for impervious areas and one for pervious areas. Manning's equation is applied to estimate runoff taking into account rainfall intensity, initial losses, evapotranspiration, and infiltration (for pervious areas). The width and length of each plane is selected based on the drainage area configuration and existing and proposed drainage features. Hourly rainfall data is the primary model input for generating runoff volumes and rates. Additional input data are required to characterize imperviousness, soils, topography, and losses associated with evapotranspiration, infiltration, and initial losses.

Sizing BMPs using this type of alternative should only be conducted by qualified personnel with a thorough understanding of the simulated hydrologic processes and operation of the selected hydrology model.

Methods for Determining the Water Quality Design Flow

Each of the flow-based sizing alternatives is described in detail below.

Method 1: Runoff Produced by 0.2 Inches per Hour Rainfall Intensity

The rainfall analysis for flow-based controls focuses on estimating the design rainfall intensity, which is then converted to a design flow rate using the rational method shown in Equation E-9.

$$SQDF = CiA \qquad \text{(Equation E-9)}$$

Where:

SQDF	=	design flow rate (cfs)
C	=	runoff coefficient, calculated with the Ventura County Hydrology Manual method (see Equation E-5) (unitless)
i	=	rainfall intensity (in/hr) (0.2 in/hr)
A	=	watershed area (acres)

Note that 1 acre-in/hr = 1.0083 cfs; this conversion factor can be used with Equation D-9, but is not necessary as the uncertainty for the other parameters is generally well above 0.8%.

Method 2: Runoff Produced by Twice the 85th Percentile Rainfall Intensity

This method is analogous to the rational method used in Method 1, except that twice the historical 85th percentile rainfall intensity for the site location is used for the design rainfall intensity. This method is expected to result in a higher design rainfall intensity and design flow rate compared to Method 1 for most of the rain gages in the District.

Method 3: Runoff Produced by eight percent of the 50-year storm design flow rate

The Stormwater Quality Design Flow (SQDF) is defined to be equal to 8 percent of the peak rate of runoff flow from the 50-year storm as determined using the procedures set forth in the *Hydrology Manual*.

Calculation Procedure

1) The Stormwater Quality Design Flow (SQDF) in Ventura County is defined as SQDF

2) Calculate the peak rate of flow from the 50-year storm ($Q_{P,\ 50\ yr.}$) using the procedures set forth in the *Hydrology Manual* or as directed by the local agency Drainage Master Plan.

3) Convert $Q_{P,\ 50yr}$ (Step 2) to $Q_{P,\ SQDF}$ (Step 1).

$$Q_{P,\ SQDF} = 0.1 \times Q_{P,\ 50yr} \qquad \text{(Equation E-10)}$$

Example Stormwater Quality Design Flow Calculation

The steps below illustrate calculation of SQDF:

1) Calculate the peak rate of flow from a 50-year storm.

$Q_{p,\ 50\ yr.}$ = 10 cfs from the *Ventura County Hydrology Manual*

4) Convert $Q_{p,50\ yr}$ (Step 2) to $Q_{p,\ SQDF}$ (Step 1)

SQDF = 0.8 x 10 cfs (Equation E-11)

SQDF = 0.8 cfs

Rainfall Analysis Methods

The rainfall analysis methods listed below have the benefits of including the most recent rainfall data. Additionally, if the site is not close to an isohyet map rainfall gauge, these methods may be more accurate due to the variability of rainfall due to changing microclimates caused by elevation and distance from the ocean.

A resource available for obtaining rainfall data in Ventura County is the data collected and compiled by the National Climatic Data Center (NCDC).

There are many NCDC stations within Ventura County that collect or have collected hourly precipitation data. Some of these stations are no longer in operation and others may not have a sufficiently long period of record over which precipitation data has been collected to be of use for properly sizing treatment BMPs. NCDC data may be obtained online at the NCDC website http://www.ncdc.noaa.gov/oa/ncdc.html.

Rainfall Analysis Using EPA'S SYNOP Program

US EPA's Synoptic Rainfall Data Analysis Program (SYNOP) aggregates hourly rainfall data into individual storm events and computes event descriptive statistics. The SYNOP program calculates the duration, volume, and intensity for individual storms as well as average annual statistics. Recurrence interval and probability results are also available as output options. The SYNOP program allows the user to screen out storms that are not expected to result in runoff (see step 2 below).

The SYNOP rainfall analysis is conducted to output event-specific data in addition to average annual statistics. The individual storm event data can be ranked to give the 85th percentile storm or averaged to give the mean storm size.

Steps for conducting SYNOP rainfall analysis are as follows:

1) Obtain the hourly rainfall data for the gage of interest from the NCDC or other agency.

2) Run SYNOP for the available rain gage data. Model input parameters include the inter-event time and a minimum storm event size. The inter-event time specifies the minimum duration in which precipitation does not occur, used to define separate storm events, while the minimum storm event is the depth of precipitation generated by a storm below which runoff generally does not occur. Typically, an inter-event time of 6 hours (USEPA, 1989), and a minimum storm

event size of 0.10 inches are used (i.e., storms of 0.10 inches or less are not considered to produce runoff typically). Model results include event-specific and annual statistics during the period of record analyzed.

3) Rank and average the SYNOP storm event output.

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E.2 INF-1 Infiltration Basin/ INF-2 Infiltration Trench/ INF-4 Drywell

This worksheet can be used for sizing INF-1 Infiltration Basins, INF-2 Infiltration Trenches, or INF-4 drywells. An infiltration basin is an earthen basin constructed into naturally pervious soils which retains the SQDV and allows the retained runoff to percolate into the underlying native soils over a specified period of time. Infiltration trenches are long, narrow, gravel-filled trenches, often vegetated, that infiltrate stormwater runoff from small drainage areas. Drywells are similar to infiltration trenches, but the geometry and materials are slightly different. A dry well may be either a small excavated pit filled with aggregate or a prefabricated storage chamber or pipe segment, with the depth of the drywell greater than the width.

Sizing Methodology

Infiltration facilities can be sized using one of two methods: a simple sizing method or a routing modeling method. With either method the SQDV volume must be completely infiltrated within 12 to 72 hours (see Appendix E, Section E.1 for a discussion on drawdown time and BMP performance). The simple sizing procedures provided below can be used for either infiltration basins, infiltration trenches (see INF-2: Infiltration Trench) or drywells (INF-4: Drywell). For the routing modeling method, refer to VEG-8 Sand Filters.

Step 1: Calculate the design volume

Infiltration facilities shall be sized to capture and infiltrate the SQDV volume (see Section 2 and Appendix E) with a 12 - 72 hour drawdown time (see Appendix E, Section E.1).

Step 2: Determine the Design Percolation Rate

The percolation rate will decline between maintenance cycles as particulates accumulate in the infiltrative layer and the surface becomes occluded. Additionally, monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For infiltration trenches, the design percolation rate discussed here is the percolation rate of the underlying soils, which will ultimately drive infiltration through the trench, and not the percolation rate of the filter media bed (refer to the "Geometry and Sizing" section of INF-2 for the recommended composition of the filter media bed for infiltration trenches). See INF-1: Infiltration Basin for guidance in developing design percolation rate correction factors.

Step 3: Calculate Surface Area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus (for infiltration trenches/ drywells with aggregate)

the void spaces within the filter media based on the computed porosity of the media (normally about 32%).

1) Determine the maximum depth of runoff that can be infiltrated within the required drain time as follows:

$$d_{\max} = \frac{P_{design}}{12} t$$ (Equation E-12)

Where:

d_{max} = the maximum depth of water that can be infiltrated within the required drain time (ft)

P_{design} = design percolation rate of underlying soils (in/hr)

t = required drain time (hrs)

2) Choose the ponding depth (d_p) and/or trench depth (d_t) such that:

$$d_{\max} \geq d_p$$ For Infiltration Basins (Equation E-13)

$$d_{\max} \geq n_t d_t + d_p$$ For Infiltration Trenches or aggregate-filled Drywells (Equation E-14)

Where:

d_{max} = the maximum depth of water that can be infiltrated within the required drain time (ft)

d_p = ponding depth (ft)

n_t = trench/drywell fill aggregate porosity (unitless)

d_t = depth of trench/drywell filter media (ft)

3) Calculate infiltrating surface area (filter bottom area) required:

$$A = \frac{SQDV}{((TP_{design}/12) + d_p)}$$ For Infiltration Basins (Equation E-15)

$$A = \frac{SQDV}{((TP_{design}/12) + n_t d_t + d_p)}$$ For Infiltration Trenches or aggregate-filled Drywells (Equation E-16)

Where:

$SQDV$ = stormwater quality design volume (ft^3)

n_t	=	trench fill aggregate porosity (unitless)
P_{design}	=	design percolation rate (in/hr)
d_p	=	ponding depth (ft)
d_t	=	depth of trench filter media (ft)
T	=	fill time (time to fill to max ponding depth with water) (hrs) [use 2 hours for most designs]

Step 4: Size the forebay (applies to infiltration basins and trenches)

Infiltration facilities require pre-treatment to reduce sediment load into the basin. If a separate pre-treatment unit is not used, a forebay should be constructed for the facility. If a forebay is used, all inlets must enter the sediment forebay. The sediment forebay must be sized to 25% of the basin volume. The forebay must have interior slopes no steeper than 4:1.

1) Calculate the volume of the sediment forebay:

$$V_{forebay} = 0.25 \times SQDV \qquad \text{(Equation E-17)}$$

Where:

$V_{forebay}$	=	Volume of sediment forebay
SQDV	=	Stormwater Quality Design Volume of Infiltration Basin

2) Select the depth of forebay, $d_{forebay}$. This is recommended to be...

3) Determine bottom surface area of forebay:

$$A_{forebay} = \frac{V_{forebay}}{d_{forebay}} \qquad \text{(Equation E-18)}$$

Where:

$A_{forebay}$	=	Bottom surface area of forebay
$V_{forebay}$	=	Volume of forebay
$d_{forebay}$	=	Depth of forebay

4) Size forebay outlet pipe. Pipe must 8 inches in diameter, minimum, and must be sized such that the forebay drains completely within 10 minutes.

Step 5: Provide conveyance capacity for filter clogging

The infiltration facility should be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged. Spillway and overflow

structures should be designed in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.

Sizing Worksheet

Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ = acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (%) (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ = %
1-3. Determine the maximum allowable effective impervious area (acres), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$= acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA= acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} = acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =
1-9. Enter design rainfall depth of the storm (in), P_i	P_i = in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560\times C*P*A_{retain}$	SQDV= ft^3
Step 2: Determine the design percolation rate	
2-1. Enter measured soil percolation rate (in/hr, 0.5 in/hr min.), $P_{measured}$	$P_{measured}$ = in/hr
2-2. Determine percolation rate correction factor, S_A based on suitability assessment (see Section 6 INF-1)	S_A =

2-3. Determine percolation rate correction factor, S_B based on design (see Section 6 INF-1)	S_b =
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} = in/hr
Step 3: Calculate the surface area	
3-1. Enter required drain time(hours,72 hrs max.), t	t = hrs
3-2. Calculate max. depth of runoff that can be infiltrated within the t (ft), $d_{max} = P_{design}\ t/12$	d_{max} = ft
3-3. For basins, select ponding depth (ft), d_p, such that $d_p \leq d_{max}$	d_p = ft
3-4. For trenches, enter trench fill aggregate porosity, n_t	n_t =
3-5. For trenches, enter depth of trench fill (ft), d_t	d_t = ft
3-5. For trenches, select ponding depth d_p such that $d_p \leq d_{max} - n_t d_t$	d_p= ft
3-6. Enter the time to fill infiltration basin or trench with water (Use 2 hours for most designs), T	T = hrs
3-7. Calculate infiltrating surface area for infiltration basin (ft²): $A_b = SQDV/(T\ P_{design}\ /12+d_p)$ OR Calculate infiltrating surface area for infiltration trenches or aggregate- filled drywells (ft²): $A_t = SQDV/(T\ P_{design}\ /12+n_t d_t+dp)$	A_b = ft² A_t = ft²
Step 4: Size the forebay (infiltration basins or trenches)	
If a separate pre-treatment unit is designed for the infiltration facility, skip to Step 5. If not, continue through 4-1 through 4-4.	

4-1. Calculate the volume of the forebay (ft^3), $V_{forebay}$=0.25*SQDV	$V_{forebay}$= ft^3
4-2. Determine forebay depth (ft), $d_{forebay}$	$d_{forebay}$= ft
4-3. Calculate forebay bottom surface area (ft^2), $A_{forebay}=V_{forebay}/d_{forebay}$	$A_{forebay}$= ft^2
4-4. Provide outlet pipe such that the forebay drains to the infiltration facility within 10 minutes.	
Step 5: Provide conveyance capacity for filter clogging	
5-1.The infiltration facility should be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged. Design emergency overflow in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.	

Design Example

Step 1: Determine water quality design volume

For this design example, a 10-acre residential development with a 60% total impervious area is considered to drain to an infiltration basin. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter Project area (acres), $A_{project}$	A =	10	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (%) (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	5	
1-3. Determine the maximum allowable effective impervious area (acres), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	0.5	acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=	0.6	
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA=	6	acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	5.5	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-9. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560\times C*P*A_{retain}$	SQDV =	8,500	ft^3

Step 2: Calculate Design Infiltration Rate

Infiltration facilities require a minimum soil infiltration rate of 0.5 in/hr. If the rate exceeds 2.4 in/hr as in this example, then the runoff should be fully treated in an upstream BMP prior to infiltration to protect the groundwater quality.

Step 2: Determine the design percolation rate	
2-1. Enter measured soil percolation rate (0.5 in/hr min.), $P_{measured}$	$P_{measured}$ = 4.0 in/hr
2-2. Determine percolation rate correction factor, S_A, based on suitability assessment (see Section 6 INF-1)	S_A = 3
2-3. Determine percolation rate correction factor, S_B, based on design (see Section 6 INF-1)	S_b = 3
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S = 9
2-5. Calculate the design percolation rate, $P_{design} = P_{measured}/S$	P_{design} = 0.44 in/hr

Step 3: Determine Facility Size

The size of the infiltrating surface is determined by assuming the SQDV will fill the available ponding depth (plus the void spaces of the computed porosity (usually about 32%) of the gravel in the trench).

Step 3: Calculate the surface area	
3-1. Enter drawdown time (72 hrs max.), t_d	t = 72 hrs
3-2. Calculate max. depth of runoff that can be infiltrated within the t, $d_{max} = P_{design}\ t/12$	d_{max}= 2.4 ft
3-3. Enter trench fill aggregate porosity, n_t	n_t= 0.32
3-4. Enter depth of trench fill, d_t	d_t = 4 ft
3-5. Select trench ponding depth d_p such that $d_p \leq d_{max} - n_t d_t$	d_p= 1.1 ft
3-6. Enter the time to fill infiltration basin or trench with water (Use 2 hours for most designs), T	T = 2 hrs

3-7. Calculate infiltrating surface area for infiltration basin: $A_b = SQDV/(T\ P_{design}\ /12+d_p)$	A_b = 7,250 ft^2

Step 4: Size the Forebay

A sediment forebay will be provided for this example as there is no separate pre-treatment unit provided.

Step 4: Size the forebay	
4-1. Calculate the volume of the forebay, $V_{forebay}$=0.25*SQDV	$V_{forebay}$= 2,100 ft^3
4-2. Determine forebay depth, $d_{forebay}$	$d_{forebay}$= 3 ft
4-3. Calculate forebay bottom surface area, $A_{forebay}=V_{forebay}/d_{forebay}$	$A_{forebay}$= 700 ft^2
4-4. Provide outlet pipe such that the forebay drains to the infiltration facility within 10 minutes.	

Step 5: Provide Conveyance Capacity for Flows Higher than Qwq

The infiltration facility should be placed off-line, but an emergency overflow for flows greater than the peak design storm must still be provided in the event the filter becomes clogged. Design emergency overflow in accordance with applicable standards of the Ventura County Flood Control District or local jurisdiction.

E.3 INF-3 Bioretention

Sizing Methodology

Bioretention areas can be sized using one of two methods: a simple sizing method or a routing method. The simple sizing procedure is summarized below. Continuous simulation modeling, routing spreadsheets, and/or other forms of routing modeling that incorporate rainfall-runoff relationships and infiltrative (flow) capacities of bioretention may be used to size facilities. Alternative sizing methodologies should be prepared with good engineering practices. For the routing modeling method, refer to the Sand Filter design guidance (FILT-1). A bioretention sizing worksheet and example are provided in this appendix. Planter boxes are sized the same as bioretention areas with underdrains using parameters appropriate for planter boxes.

With either method, the runoff entering the facility must completely drain the ponding area within 48 hours, and runoff must be completely infiltrated within 96 hours. Bioretention is to be sized, with or without underdrains, such that the SQDV will fill the available ponding depth, the void spaces in the planting soil, and the optional gravel layer below the media.

Step 1: Determine the stormwater quality design volume (SQDV)

Bioretention areas should be sized to capture and treat the water quality design volume (see Section E.1).

Step 2: Determine the Design Percolation Rate

The percolation rate will decline between maintenance cycles as particulates accumulate in the infiltrative layer and the surface becomes occluded. Additionally, monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For infiltrating bioretention facilities, the design percolation rate discussed here is the percolation rate of the underlying soils, which will drive infiltration through the facility. See INF-3: Bioretention for guidance in developing design percolation rate correction factors.

Step 3: Calculate the bioretention surface area

1) Determine the maximum depth of surface ponding that can be infiltrated within the required surface drain time:

$$d_{\max} = \frac{P_{design} \times t_{ponding}}{12 \frac{in}{ft}}$$

Where:

$t_{ponding}$	=	required drain time of surface ponding (48 hrs)
P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)
d_{max}	=	the maximum depth of surface ponding water that can be infiltrated within the required drain time (ft)

2) Choose surface ponding depth (dp) such that:

$$d_p \leq d_{\max} \qquad \text{(Equation E-19)}$$

Where:

d_p	=	selected surface ponding depth (ft)
d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)

3) Choose thickness(es) of amended media and aggregate layer(s) and calculate total effective storage depth of the bioretention area as follows:

$$d_{effective} \leq d_p + n^*_{media} l_{media} + n_{gravel} l_{gravel} \qquad \text{(Equation E-20)}$$

Where:

$d_{effective}$	=	total equivalent depth of water stored in bioretention area (ft)
d_p	=	surface ponding depth (ft)
n^*_{media}	=	available porosity of amended soil media (ft/ft), approximately 0.25 ft/ft accounting for antecedent moisture conditions
l_{media}	=	thickness of amended soil media layer (ft)
n_{gravel}	=	porosity of optional gravel layer (ft/ft), approximately 0.30 ft/ft
l_{gravel}	=	thickness of optional gravel layer (ft)

4) Check that entire effective depth (surface plus subsurface storage) infiltrates in no greater than 96 hours as follows:

$$t_{total} = \frac{d_{effective}}{P_{design}} \times 12 \frac{in}{ft} \leq 96\ hr \qquad \text{(Equation E-21)}$$

Where:

$d_{effective}$ = total equivalent depth of water stored in bioretention area (ft)

P_{design} = design percolation rate of underlying soils (in/hr) (see Step 2, above)

If t_{total} > 96 hrs, then reduce surface ponding depth and/or amended media thickness and/or gravel thickness and return to Step [A].

If $t_{total} \leq$ 96 hrs, then proceed to Step [E].

5) Calculate required infiltrating surface area (filter bottom area):

$$A_{req} = \frac{SQDV}{d_{effective}} \qquad \text{(Equation E-22)}$$

Where:

$SQDV$ = stormwater quality design volume (ft3)

Step 4: Calculate the bioretention total footprint

Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is measured at the as the filter bottom area (toe of side slopes).

Sizing Worksheet

Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ = acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (%) (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ = %
1-3. Determine the maximum allowable effective impervious area (acres), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$= acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA= acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} = acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =
1-9. Enter design rainfall depth of the storm (in), P_i	P_i = in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560\times C*P*A_{retain}$	SQDV= ft^3

Step 2: Determine the design percolation rate	
2-1. Enter measured soil percolation rate (in/hr) (0.5 in/hr minimum), $P_{measured}$	$P_{measured}$ = in/hr
2-2. Determine percolation rate correction factor, S_A based on suitability assessment (see Section 6 INF-3)	S_A =

2-3. Determine percolation rate correction factor, S_B based on design (see Section 6 INF-3)	S_B =
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} = in/hr
Step 3: Calculate Bioretention Infiltrating surface area	
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV = ft^3
3-2. Enter design percolation rate (in/hr), P_{design}	P_{design} = in/hr
3.3 Enter the required drain time (48 hours), $t_{ponding}$	$t_{ponding}$ = hours
3-3. Calculate the maximum depth of surface ponding that can be infiltrated within the required drain time (ft): $d_{max} = (P_{design} \times t_{ponding})/12$	d_{max} = ft
3-4. Select surface ponding depth (ft), d_p, such that $d_p \leq d_{max}$	d_p = ft
3-5. Select thickness of amended media (ft,2 feet minimum, 3 preferred), l_{media}	l_{media} = ft
3-6. Enter porosity of amended media (roughly 25% or 0.25 ft/ft), n_{media}	n_{media}= ft/ft
3-7. Select thickness of optional gravel layer (ft), l_{gravel}	l_{gravel} = ft
3-8. Enter porosity of gravel (roughly 30% or 0.3 ft/ft), n_{gravel}	n_{gravel}= ft/ft
3-9. Calculate the total effective storage depth of bioretention facility (ft): $d_{effective} \leq (d_p + n_{media}l_{media} + n_{gravel}l_{gravel})$	$d_{effective}$= ft

3-10. Check that the entire effective depth infiltrates in required drainage time, 96 hours: $t_{total} = (d_{effective}/P_{design}) \times 12$ If t_{total} > 96 hours, reduce surface ponding depth and/or amended media thickness and/or gravel thickness and return to 3-4. If $t_{total} \leq$ 96 hours, proceed to 3-11.	t_{total} = hours
3-11. Calculate the required infiltrating surface area (ft^2): $A_{req} = SQDV/d_{effective}$	A_{req} = ft^2
Step 4: Calculate Bioretention Area Total Footprint	
4-1. Calculate total footprint required by including a buffer for side slopes and freeboard (ft^2) [A_{req} is measured at the as the filter bottom area (toe of side slopes)], A_{tot}	A_{tot} = ft^2

Design Example

Bioretention areas have several components that allow the pretreatment, spreading, filtration, collection and discharge of the incoming flows.

Step 1: Determine water quality design volume

For this design example, a 10-acre site with soil type 4 and 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ =	10	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (%) (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	5	
1-3. Determine the maximum allowable effective impervious area (acres), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	0.5	acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=	0.6	
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA=	6	acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	5.5	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-9. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560\times C*P*A_{retain}$	SQDV=	8,500	ft^3

Step 2: Determine the design percolation rate

For this design example, a native soil percolation rate of 1.5 in/hr is assumed.

Step 2: Determine the design percolation rate	
2-1. Enter measured soil percolation rate (in/hr, 0.5 in/hr minimum), $P_{measured}$	$P_{measured}$ = 4.0 in/hr
2-2. Determine percolation rate correction factor, S_A, based on suitability assessment (see Section 6 INF-1)	S_A = 3
2-3. Determine percolation rate correction factor, S_B, based on design (see Section 6 INF-1)	S_b = 3
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S = 9
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} = 0.44 in/hr

Step 3: Determine bioretention/ planter box area footprint

A bioretention area is designed with two components: (1) temporary storage reservoir to store runoff, and (2) a plant mix filter bed (planting soil mixed with sand content = 70%) through which the stored runoff must percolate to obtain treatment.

Step 3: Calculate bioretention/planter box surface area	
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV = 8,500 ft^3
3-2. Enter design percolation rate (in/hr), P_{design}	P_{design} = 0.375 in/hr
3.3 Enter the required drain time (48 hours), $t_{ponding}$	$t_{ponding}$ = 48 hours
3-3. Calculate the maximum depth of surface ponding (ft) that can be infiltrated within the required drain time (48 hours): $d_{max} = (P_{design} \times t_{ponding})/12$	d_{max} = 1.5 ft
3-4. Select surface ponding depth d_p such that $d_p \leq d_{max}$	d_p = 1.5 ft
3-5. Select thickness of amended media (2 feet minimum, 3 preferred), l_{media}	l_{media} = 3 ft

Step 3: Calculate bioretention/planter box surface area	
3-6. Enter porosity of amended media (roughly 25% or 0.25 ft/ft), n_{media}	n_{media}= 0.25 ft/ft
3-7. Select thickness of optional gravel layer (ft), l_{gravel}	l_{gravel} = 1 ft
3-8. Enter porosity of gravel (roughly 30% or 0.3 ft/ft), n_{gravel}	n_{gravel}= 0.3 ft/ft
3-9. Calculate the total effective storage depth of bioretention facility (ft): $d_{effective} \leq (d_p + n_{media} l_{media} + n_{gravel} l_{gravel})$	$d_{effective}$= 2.6 ft
3-10. Check that the entire effective depth infiltrates in required drainage time, 96 hours: $t_{total} = (d_{effective}/P_{design}) \times 12$ If t_{total} > 96 hours, reduce surface ponding depth and/or amended media thickness and/or gravel thickness and return to 3-4. If $t_{total} \leq$ 96 hours, proceed to 3-11.	t_{total} = 82 hours
3-11. Calculate the required infiltrating surface area (ft²), $A_{req} = SQDV/d_{effective}$	A_{req} = 3,300 ft²

Step 4: Calculate Bioretention Area Total Footprint

For this design example, a natural-shaped bioretention area is assumed, with 3:1 side slopes. To calculate the total footprint, the side slopes would be added to the design geometry.

E.4 INF-5 Permeable Pavement

Sizing Methodology

Permeable pavement (including the base layers) shall be designed to drain in less than 72 hours. The basis for this is that soils must be allowed to dry out periodically in order to restore hydraulic capacity; this is essential in order to receive flows from subsequent storms, maintain infiltration rates, maintain adequate sub soil oxygen levels for healthy soil biota, and to provide proper soil conditions for biodegradation and retention of pollutants.

Permeable pavement must be built and designed by a licensed civil engineer in accordance with Ventura County roadway and pavement specifications.

Step 1: Calculate the design volume

Permeable pavement shall be sized to capture and treat the stormwater quality design volume, SQDV (see Section 2 and Appendix E).

Step 2: Determine the Design Percolation Rate

The percolation rate will decline between maintenance cycles as particulates accumulate in the infiltrative layer and the surface becomes occluded. Additionally, monitoring of actual facility performance has shown that the full-scale infiltration rate is far lower than the rate measured by small-scale testing. It is important that adequate conservatism is incorporated in the selection of design percolation rates. For infiltrating bioretention facilities, the design percolation rate discussed here is the percolation rate of the underlying soils, which will drive infiltration through the facility. See INF-5: Permeable Pavement for guidance in developing design percolation rate correction factors.

Step 3: Determine gravel drainage layer depth

Permeable pavement (including the base layers) shall be designed to drain in less than 72 hours. The basis for this is that soils must be allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate sub soil oxygen levels for healthy soil biota, and to provide proper soil conditions for biodegradation and retention of pollutants.

1) Calculate the maximum depth of runoff, d_{max}, that can be infiltrated within the drawdown time:

$$d_{\max} = \frac{P_{design} \bullet t}{12} \qquad \text{(Equation E-23)}$$

Where:

d_{max}	=	maximum depth that can be infiltrated (ft)
P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)
t	=	drawdown time (72 hrs maximum) (hr)

1) Select the gravel drainage layer depth, *l*, such that:

$$d_{\max} \geq n \times l \qquad \text{(Equation E-24)}$$

Where:

d_{max}	=	maximum depth that can be infiltrated (ft) (see 1) above)
n	=	gravel drainage layer porosity(unitless) (generally about 32% or 0.32 for gravel)
l	=	gravel drainage layer depth (ft)

Step 4: Determine infiltrating surface area

1) Calculate infiltrating surface area for permeable pavement, A:

$$A = \frac{SQDV}{\frac{TP_{design}}{12} + nl} \qquad \text{(Equation E-25)}$$

Where:

P_{design}	=	design percolation rate of underlying soils (in/hr) (see Step 2, above)
n	=	gravel drainage layer porosity(unitless)[about 32% or 0.32 for gravel]
l	=	depth of gravel drainage layer (ft)
T	=	time to fill the gravel drainage layer with water (use 2 hours for most designs) (hr)

Step 5: Provide conveyance capacity for clogging

The permeable pavement must have an emergency overflow for storm events greater than the design and in the event the permeable pavement becomes clogged. See INF-5 Permeable Pavement for overflow details.

Sizing Worksheet

Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ = acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (%) (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ %
1-3. Determine the maximum allowable effective impervious area (acres), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$= acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA= acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} = acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =
1-9. Enter design rainfall depth of the storm (in), P_i	P_i = in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560\times C*P*A_{retain}$	SQDV= ft^3
Step 2: Determine the design percolation rate	
2-1. Enter measured soil percolation rate (0.5 in/hr minimum), $P_{measured}$	$P_{measured}$ = in/hr
2-2. Determine percolation rate correction factor, S_A based on suitability assessment (see Section 6 INF-5)	S_A =

Step 2: Determine the design percolation rate	
2-3. Determine percolation rate correction factor, S_B based on design (see Section 6 INF-5)	S_B =
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S =
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} = in/hr
Step 3: Determine the Gravel Drainage Layer Depth	
3-1. Enter drawdown time (hours, 72 hrs max.), t	t = hours
3-2. Calculate max. depth of runoff (ft) that can be infiltrated within the t, $d_{max}=P_{design}t/12$	d_{max} = ft
3-3. Enter the gravel drainage layer porosity, n (typically 32% or 0.32 for gravel)	n =
3-4. Select the gravel drainage layer depth (ft) such that $d_{max} \geq n \times l$	l = ft
Step 4: Determine infiltrating surface area	
4-1. Enter gravel drainage layer porosity, n	n =
4-2. Enter depth of gravel drainage layer (ft), l	l = ft
4-3. Enter the time to fill the gravel drainage layer with water (Use 2 hours for most designs), T	T = hrs
4-4. Calculate infiltrating surface area (ft^3): $A=SQDV/((TP_{design}/12)+nl)$	A = ft^2
Step 5: Provide conveyance capacity for clogging	
5-1. The permeable pavement must have an emergency overflow for storm events greater than the design and in the event the permeable pavement becomes clogged.	

Design Example

Step 1: Determine Water Quality Design Volume

For this design example, a 10-acre residential development with a 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine Water Quality Design Volume			
1-1. Enter Project area (acres), $A_{project}$	A =	10	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (%) (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowableble}$ =	5	
1-3. Determine the maximum allowable effective impervious area (acres), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	0.5	acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=	0.6	
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA=	6	acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	5.5	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-9. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560\times C*P*A_{retain}$	SQDV =	8,500	ft^3

Step 2: Calculate Design Percolation Rate

Permeable pavement with no underdrain requires a minimum soil infiltration rate of 0.5 in/hr. For this design example, a native soil percolation rate of 1.5 in/hr is assumed.

Step 2: Determine the design percolation rate	
2-1. Enter measured soil percolation rate (0.5 in/hr min.), $P_{measured}$	$P_{measured}$ = 4.0 in/hr
2-2. Determine percolation rate correction factor, S_A, based on suitability assessment (see Section 6 INF-1)	S_A = 3
2-3. Determine percolation rate correction factor, S_B, based on design (see Section 6 INF-1)	S_b = 3
2-4. Calculate combined safety factor, $S = S_A \times S_b$	S = 9
2-5. Calculate the design percolation rate (in/hr), $P_{design} = P_{measured}/S$	P_{design} = 0.44 in/hr

Step 3: Determine maximum depth that can be infiltrated

Based on the design infiltration rate and the max drawdown, determine the maximum depth that can be infiltrated within the time constraints.

Step 3: Determine maximum depth that can be infiltrated	
3-1. Enter drawdown time (72 hrs max.), t	t = 72 hrs
3-2. Calculate max. depth of runoff (ft) that can be infiltrated within the t, $d_{max}=P_{design}t/12$	d_{max} = 2.6 ft
3-3. Enter the gravel drainage layer porosity, n (typically 32% or 0.32 for gravel)	n = 0.32
3-4. Select the gravel drainage layer depth (ft) such that $d_{max} \geq n \times l$	l = 8 ft

Step 4: Determine the infiltrating surface area (pavement area)

Using the depth calculated in Step 3, the required infiltrating surface area of the pavement can be calculated.

Step 4: Determine the infiltrating surface area			
4-1. Enter gravel drainage layer porosity, *n*	n =	0.32	
4-2. Enter depth of gravel drainage layer (ft), *l*	l =	8	ft
4-3. Enter the time to fill the gravel drainage layer with water (Use 2 hours for most designs), *T*	T =	2	hrs
4-4. Calculate infiltrating surface area (ft^3): $A=SQDV/(TP_{design}/12)+n*l))$	A =	1,630	ft^2

Step 5: Provide conveyance capacity for clogging

The permeable pavement must have an emergency overflow for storm events greater than the design and in the event the permeable pavement becomes clogged.

E.5 VEG-1 Bioretention/VEG-2 Planter Box

Sizing Methodology

Bioretention areas can be sized using one of two methods: a simple sizing method or a routing method. The simple sizing procedure is summarized below. Continuous simulation modeling, routing spreadsheets, and/or other forms of routing modeling that incorporate rainfall-runoff relationships and infiltrative (flow) capacities of bioretention may be used to size facilities. Alternative sizing methodologies should be prepared with good engineering practices. For the routing modeling method, refer to the Sand Filter design guidance (FILT-1). A bioretention sizing worksheet and example are provided in this appendix. Planter boxes are sized the same as bioretention areas with underdrains using parameters appropriate for planter boxes.

With either method, the runoff entering the facility must completely drain the ponding area within 48 hours, and runoff must be completely infiltrated within 96 hours. Bioretention is to be sized, with or without underdrains, such that the SQDV will fill the available ponding depth, the void spaces in the planting soil, and the optional aggregate layer.

Step 1: Determine the stormwater quality design volume (SQDV)

Bioretention areas should be sized to capture and treat the water quality design volume (see Section E.1).

Step 2: Determine the Design Percolation Rate

Sizing is based on the design saturated hydraulic conductivity (K_{sat}) of the amended soil layer. A target K_{sat} of 5 inches per hour is recommended for newly installed non-proprietary amended soil media. The media K_{sat} will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the amended soil layer. A factor of safety of 2.0 should be applied such that the resulting recommended design percolation rate is 2.5 inches per hour. This value should be used for sizing unless sufficient rationale is provided to justify a higher design percolation rate.

Step 3: Calculate the bioretention or planter box surface area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus the void spaces in the media, based on the computed porosity of the filter media and optional aggregate layer.

1) Select a surface ponding depth (d_p) that satisfies geometric criteria and congruent with the constraints of the site. Selecting a deeper ponding depth (18 inches maximum) generally yields a smaller footprint, however requires greater consideration for public safety and energy dissipation.

2) Compute time for selected ponding depth to filter through media:

$$t_{ponding} = \frac{d_p}{K_{design}} 12 \frac{in}{ft} \leq 48 \text{ hours} \qquad \text{(Equation E-26)}$$

Where:

$t_{ponding}$	=	required drain time of surface ponding (48 hrs)
d_p	=	selected surface ponding water depth (ft)
K_{design}	=	design saturated hydraulic conductivity (in/hr) (see Step 2, above)

If $t_{ponding}$ exceeds 48 hours, return to (1) and reduce surface ponding or increase media K_{design}. Otherwise, proceed to next step.

Note: In nearly all cases, $t_{ponding}$ will not approach 48 hours unless a low Kdesign is specified.

3) Compute depth of water that may be considered to be filtered during the design storm event as follows:

$$d_{filtered} = Minimum\left[\frac{K_{design} \times T_{routing}}{12 \, in/ft}, \frac{d_p}{2}\right] \qquad \text{(Equation E-27),}$$

Where:

$d_{filtered}$	=	depth of water that may be considered to be filtered during the design storm event (ft) for routing calculations; this value should not exceed half of the surface ponding depth (d_p)
K_{design}	=	design saturated hydraulic conductivity (in/hr) (see Step 2, above)
$T_{routing}$	=	storm duration that may be assumed for routing calculations; this should be assumed to be **3 hours** unless rationale for an alternative assumption is provided
d_p	=	selected surface ponding water depth (ft)

4) Calculate required infiltrating surface area (filter bottom area):

$$A_{req} = \frac{SQDV}{d_p + d_{filtered}} \qquad \text{(Equation E-28)}$$

Where:

A_{req}	=	required area at bottom of filter area (ft^2); does not account for side slopes and freeboard
$SQDV$	=	stormwater quality design volume (ft^3)
d_p	=	selected surface ponding water depth (ft)
$d_{filtered}$	=	depth of water that can be considered to be filtered during the design storm event (ft) for routing calculations (See previous step)

Step 4: Calculate the bioretention total footprint

Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is measured at the filter bottom area (toe of side slopes).

Step 5: Calculate underdrain system capacity

Underdrains are required for planter boxes and bioretention with underdrains. For guidance on sizing, refer to step 5 of the worksheet below. Alternatively, the Ventura County Hydrology Manual can be used for pipe sizing guidance.

Sizing Worksheet

Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ = acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ %
1-3. Determine the maximum allowed effective impervious area (ac), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$= acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA= acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} = acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =
1-9. Enter design rainfall depth of the storm (in), P_i	P_i = in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560 \bullet C*P*A_{retain}$	SQDV= ft^3

Step 2: Determine the design percolation rate	
2-1. Enter the design saturated hydraulic conductivity of the amended filter media (2.5 in/hr recommended rate), K_{design}	K_{design} = in/hr

Step 3: Calculate Bioretention/Planter Box surface area	
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV = ft^3
3-2. Enter design saturated hydraulic conductivity (in/hr), K_{design}	K_{design} = in/hr
3-3. Enter ponding depth (max 1.5 ft for Bioretention, 1 ft for Planter Box) above area, d_p	d_p = ft
3-4. Calculate the drawdown time for the ponded water to filter through media (hours), $t_{ponding} = (d_p/K_{design}) \times 12$	$t_{ponding}$= hrs
3-5. Enter the storm duration for routing calculations (use 3 hours unless there is rationale for an alternative), $T_{routing}$	$T_{routing}$ = hrs
3-6. Calculate depth of water (ft) filtered by using the following two equations: $d_{filtered,1} = (K_{design} \times T_{routing})/12$ $d_{filteret,2} = d_p /2$	$d_{filtered,1}$ = ft $d_{filtered,2}$ = ft
3.7 Enter the resultant depth (ft) (the lesser of the two calculated above), $d_{filtered}$	$d_{filtered}$ = ft
3-8. Calculate the infiltrating surface area as follows (ft^2): $A_{req} = SQDV/(d_p + d_{filtered})$	A_{req} = ft^2
Step 4: Calculate Bioretention Area Total Footprint	
4-1. Calculate total footprint required by including a buffer for side slopes and freeboard (ft^2) [A_{req} is measured at the as the filter bottom area (toe of side slopes)], A_{tot}	A_{tot} = ft^2
Step 5: Calculate Underdrain System Capacity	
To calculate the underdrain system capacity, continue through steps 5-1 to 5-7.	

Step 5: Calculate Underdrain System Capacity	
5-1. Calculated filtered flow rate to be conveyed by the longitudinal drain pipe, $Q_f = K_{design} A_{req}/43{,}200$	Q_f = cfs
5-2. Enter minimum slope for energy gradient, S_e	S_e =
5-3. Enter Hazen-Williams coefficient for plastic, C_{HW}	C_{HW} =
5-4. Enter pipe diameter (min 6 inches), D	D = in
5-5. Calculate pipe hydraulic radius (ft), $R_h = D/48$	R_h = ft
5-6. Calculate velocity at the outlet of the pipe (ft/s), $V_p = 1.318 C_{HW} R_h^{0.63} S_e^{0.54}$	V_p = ft/s
5-7. Calculate pipe capacity (cfs), $Q_{cap} = 0.25\pi(D/12)^2 V_p$	Q_{cap} = cfs

Design Example

Bioretention areas have several components that allow the pretreatment, spreading, filtration, collection and discharge of the incoming flows.

Step 1: Determine water quality design volume

For this design example, a 10-acre residential development with a 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine Water Quality Design Volume			
1-1. Enter drainage area, A	A =	10	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowableble}$ =	5	
1-3. Determine the maximum allowed effective impervious area, $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	0.5	acres
1-4. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-5. Determine the Project Total Impervious area, $TIA=A_{project}*Imp$	TIA=	6	acres
1-6. Determine the total area from which runoff must be retained, $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	5.5	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-9. Enter design rainfall depth of the storm, P_i (in)	P_i =	0.75	in
1-10. Calculate rainfall depth, $P = P_i/12$	P =	0.06	ft
1-11. Calculate water quality design volume, $SQDV = 43560 \bullet P*A_{retain}*C$	SQDV =	8,500	ft^3

Step 2: Determine the design percolation rate

For this design example, the recommended amended filter hydraulic conductivity is used, 2.5 in/hr.

Step 2: Determine the design percolation rate	
2-1. Enter the design saturated hydraulic conductivity of the amended filter media (2.5 in/hr recommended rate), K_{design}	K_{design} = 2.5 in/hr

Step 3: Determine bioretention/ planter box area footprint

A bioretention area is designed with two components: (1) temporary storage reservoir to store runoff, and (2) a plant mix filter bed (planting soil mixed with sand content = 70%) through which the stored runoff must percolate to obtain treatment.

Step 3: Calculate Bioretention/Planter Box surface area	
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV = 8,500 ac-ft
3-2. Enter design saturated hydraulic conductivity (in/hr), K_{design}	K_{design} = 2.5 in/hr
3-3. Enter ponding depth (max 1.5 ft for Bioretention, 1 ft for Planter Box) above area, d_p	d_p = 1.5 ft
3-4. Calculate the drawdown time for the ponded water to filter through media (hours), $t_{ponding} = (d_p/K_{design}) \times 12$	$t_{ponding}$= 7.2 hrs
3-5. Enter the storm duration for routing calculations (use 3 hours unless there is rationale for an alternative), $T_{routing}$	$T_{routing}$ = 3 hrs
3-6. Calculate depth of water (ft) filtered by using the minimum of the following two equations: $d_{filtered,1} = (K_{design} \times T_{routing})/12$ $d_{filteret,2} = d_p /2$	$d_{filtered,1}$ = 0.63 ft $d_{filtered,2}$ = 0.75 ft
3.7 Enter the resultant depth (the minimum of the two calculated above), $d_{filtered}$	$d_{filtered}$ = 0.63 ft
3-8. Calculate the infiltrating surface area as follows (ft^2): $A_{req} = SQDV/(d_p + d_{filtered})$	A_{req} = 4,000 ft^2

Step 4: Calculate Bioretention Area Total Footprint

For this design example, a natural-shaped bioretention area is assumed, with 3:1 side slopes. To calculate the total footprint, the side slopes would be added to the design geometry.

Step 5: Calculate filter longitudinal underdrain collection pipe

All underdrain pipes must be 6 inches or greater in diameter to facilitate cleaning.

Step 5: Calculate underdrain system (required for planter box)			
To calculate the underdrain system capacity, continue through steps 5-1 to 5-7. If you don't need to calculate the underdrain capacity, skip this step.			
5-1. Calculated filtered flow rate to be conveyed by the longitudinal drain pipe (cfs), $Q_f = K_{design} A_{req}/43{,}200$	Q_f =	0.085	cfs
5-2. Enter minimum slope for energy gradient, S_e	S_e =	0.005	
5-3. Enter Hazen-Williams coefficient for plastic, C_{HW}	C_{HW} =	140	
5-4. Enter pipe diameter (min 6 in), D	D =	6	in
5-5. Calculate pipe hydraulic radius (ft), $R_h = D/48$	R_h =	0.13	ft
5-6. Calculate velocity at the outlet of the pipe (ft/s), $V_p = 1.318 C_{HW} R_h^{0.63} S_e^{0.54}$	V_p =	2.9	ft/s
5-7. Calculate pipe capacity (cfs), $Q_{cap} = 0.25\pi(D/12)^2 V_p$	Q_{cap} =	0.57	cfs

E.6 VEG-3 Vegetated Swale

Sizing Methodology

The flow capacity of a vegetated swale is a function of the longitudinal slope (parallel to flow), the resistance to flow (i.e. Manning's roughness), and the cross sectional area. The cross section is normally approximately trapezoidal and the area is a function of the bottom width and side slopes. The flow capacity of vegetated swales should be such that the design water quality flow rate will not exceed a flow depth of 2/3 the height of the vegetation within the swale or 4 inches at the water quality design flow rate. Once design criteria have been selected, the resulting flow depth for the design water quality design flow rate is checked. If the depth restriction is exceeded, swale parameters (e.g. longitudinal slope, width) are adjusted to reduce the flow depth.

Procedures for sizing vegetated swales are summarized below. A vegetated swale sizing worksheet and example are also provided.

Step 1: Select design flows

The swale sizing is based on the stormwater quality design flow SQDF (see Section E.1).

Step 2: Calculate swale bottom width

The swale bottom width is calculated based on Manning's equation for open-channel flow. This equation can be used to calculate discharges as follows:

$$Q = \frac{1.49 A R^{0.67} S^{0.5}}{n}$$

(Equation E-29)

Where:

Q	=	flow rate (cfs)
n	=	Manning's roughness coefficient (unitless)
A	=	cross-sectional area of flow (ft^2)
R	=	hydraulic radius (ft) = area divided by wetted perimeter
S	=	longitudinal slope (ft/ft)

For shallow flow depths in swales, channel side slopes are ignored in the calculation of bottom width. Use the following equation (a simplified form of Manning's formula) to estimate the swale bottom width:

$$b = \frac{SQDF * n_{wq}}{1.49 y^{0.67} s^{0.5}} \qquad \text{(Equation E-30)}$$

Where:

b	=	bottom width of swale (ft)
$SQDF$	=	stormwater quality design flow (cfs)
n_{wq}	=	Manning's roughness coefficient for shallow flow conditions = 0.2 (unitless)
y	=	design flow depth (ft)
s	=	longitudinal slope (along direction of flow) (ft/ft)

Proceed to Step 3 if the bottom width is calculated to be between 2 and 10 feet. A minimum 2-foot bottom width is required. Therefore, if the calculated bottom width is less than 2 feet, increase the width to 2 feet and recalculate the design flow depth y using the Equation 4-13, where Q_{wq}, n_{wq}, and s are the same values as used above, but b = 2 feet.

The maximum allowable bottom width is 10 feet; therefore if the calculated bottom width exceeds 10 feet, then one of the following steps is necessary to reduce the design bottom width:

1) Increase the longitudinal slope (s) to a maximum of 6 feet in 100 feet (0.06 feet per foot).

2) Increase the design flow depth (y) to a maximum of 4 inches.

3) Place a divider lengthwise along the swale bottom (Figure 3-1) at least three-quarters of the swale length (beginning at the inlet), without compromising the design flow depth and swale lateral slope requirements. Swale width can be increased to an absolute maximum of 16 feet if a divider is provided.

Step 3: Determine design flow velocity

To calculate the design flow velocity through the swale, use the flow continuity equation:

$$V_{wq} = SQDF / A_{wq} \qquad \text{(Equation E-31)}$$

Where:

V_{wq}	=	design flow velocity (fps)
$SQDF$	=	stormwater quality design flow (cfs)

A_{wq} = $by + Zy^2$ = cross-sectional area (ft²) of flow at design depth, where Z = side slope length per unit height (e.g., Z = 3 if side slopes are 3H:1V)

If the design flow velocity exceeds 1 foot per second, go back to Step 2 and modify one or more of the design parameters (longitudinal slope, bottom width, or flow depth) to reduce the design flow velocity to 1 foot per second or less. If the design flow velocity is calculated to be less than 1 foot per second, proceed to Step 4. *Note: It is desirable to have the design velocity as low as possible, both to improve treatment effectiveness and to reduce swale length requirements.*

Step 4: Calculate swale length

Use the following equation to determine the necessary swale length to achieve a hydraulic residence time of at least 7 minutes:

$$L = 60 t_{hr} V_{wq} \qquad \text{(Equation E-32)}$$

Where:

L = minimum allowable swale length (ft)

t_{hr} = hydraulic residence time (min)

V_{wq} = design flow velocity (fps)

The minimum swale length is 100 feet; therefore, if the swale length is calculated to be less than 100 feet, increase the length to a minimum of 100 feet, leaving the bottom width unchanged. If a larger swale can be fitted on the site, consider using a greater length to increase the hydraulic residence time and improve the swale's pollutant removal capability. If the calculated length is too long for the site, or if it would cause layout problems, such as encroachment into shaded areas, proceed to Step 5 to further modify the layout. If the swale length can be accommodated on the site (meandering may help), proceed to Step 6.

Step 5: Adjust swale layout to fit on site

If the swale length calculated in Step 4 is too long for the site, the length can be reduced (to a minimum of 100 feet) by increasing the bottom width up to a maximum of 16 feet, as long as the 10 minute retention time is retained. However, the length cannot be increased in order to reduce the bottom width because Manning's depth-velocity-flow rate relationships would not be preserved. If the bottom width is increased to greater than 10 feet, a low flow dividing berm is needed to split the swale cross section in half to prevent channelization.

Length can be adjusted by calculating the top area of the swale and providing an equivalent top area with the adjusted dimensions.

1) Calculate the swale treatment top area based on the swale length calculated in Step 4:

$$A_{top} = (b_i + b_{slope})L_i \qquad \text{(Equation E-33)}$$

Where:

A_{top} = top area (ft^2) at the design treatment depth

b_i = bottom width (ft) calculated in Step 2

b_{slope} = the additional top width (ft) above the side slope for the design water depth (for 3:1 side slopes and a 4-inch water depth, b_{slope} = 2 feet)

L_i = initial length (ft) calculated in Step 4

2) Use the swale top area and a reduced swale length L_f to increase the bottom width, using the following equation:

$$L_f = A_{top}/(b_f + b_{slope}) \qquad \text{(Equation E-34)}$$

Where:

L_f = reduced swale length (ft)

b_f = increased bottom width (ft).

3) Recalculate V_{wq} according to Step 3 using the revised cross-sectional area A_{wq} based on the increased bottom width b_f. Revise the design as necessary if the design flow velocity exceeds 1 foot per second.

4) Recalculate to assure that the 10 minute retention time is retained.

Step 6: Provide conveyance capacity for flows higher than SQDF

Vegetated swales may be designed as flow-through channels that convey flows higher than the water quality design flow rate, or they may be designed to incorporate a high-flow bypass upstream of the swale inlet. A high-flow bypass usually results in a smaller swale size. If a high-flow bypass is provided, this step is not needed. If no high-flow bypass is provided, proceed with the procedure below. Flow splitter structure design is described in Appendix G.

1) Check the swale size to determine whether the swale can convey the flood control design storm peak flows (Refer to the Ventura County Hydrology Manual, 2006).

2) The peak flow velocity of the flood control design storm (e.g., flood control design storm – see Ventura County Hydrology Manual, 2006)) must be less than 3.0 feet per second. If this velocity exceeds 3.0 feet per second, return to Step 2 and

increase the bottom width or flatten the longitudinal slope as necessary to reduce the flood control design storm peak flow velocity to 3.0 feet per second or less. If the longitudinal slope is flattened, the swale bottom width must be recalculated (Step 2) and must meet all design criteria.

Sizing Worksheet

Step 1: Determine water quality design flow		
1-1. Enter Project area (acres), $A_{project}$	A_{design} =	acres
1-2. Enter impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp =	
1-3. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	
1-5. Enter design rainfall intensity (in/hr), *i*	i =	in/hr
1-6. Calculate water quality design flow (cfs), *SQDF= CiA*	SQDF =	cfs
Step 2: Calculate swale bottom width		
2-1. Enter water quality design flow (cfs), *SQDF*	SQDF =	cfs
2-2. Enter Manning's roughness coefficient for shallow flow conditions, $n_{wq} = 0.2$	n_{wq} =	
2-3. Calculate design flow depth (ft), *y*	y =	ft
2-4. Enter longitudinal slope (ft/ft) (along direction of flow), *s*	s =	ft/ft
2-5. Calculate bottom width of swale (ft), $b = (SQDF*n_{wq})/(1.49y^{0.67}s^{0.5})$	b =	ft
2-6. If *b* is between 2 and 10 feet, go to Step 3		
2-7. If b is less than 2 ft, assume b = 2 ft and recalculate flow depth, $y = ((SQDF*n_{wq})/(2.98\ s^{0.5}))^{1.49}$	y =	ft

2-8. If b is greater than 10 ft, one of the following design adjustments must be made (recalculate variables as necessary): • Increase the longitudinal slope to a maximum of 0.06 ft/ft. • Increase the design flow depth to a maximum of 4 in (0.33 ft). • Place a divider lengthwise along the swale bottom (Figure 3-1) at least three-quarters of the swale length (beginning at the inlet). Swale width can be increased to an absolute maximum of 16 feet if a divider is provided.	
Step 3: Determine design flow velocity	
3-1. Enter side slope length per unit height (H:V) (e.g. 3 if side slopes are 3H :1V), *Z*	Z =
3-2. Enter bottom width of swale (ft), *b*	b = ft
3-3. Enter design flow depth (ft), *y*	y = ft
3-4. Calculate the cross-sectional area of flow at design depth (ft^2), $A_{wq} = by + Zy^2$	A_{wq} = ft^2
3-5. Calculate design flow velocity (ft/s), $V_{wq} = SQDF/ A_{wq}$	V_{wq} = ft/s
3-6. If the design flow velocity exceeds 1 ft/s, go back to Step 2 and change one or more of the design parameters to reduce the design flow velocity. If design flow velocity is less than 1 ft/s, proceed to Step 4.	
Step 4: Calculate swale length	
4-1. Enter hydraulic residence time (minutes, minimum 7 min), t_{hr}	t_{hr} = min
4-2. Calculate swale length (ft), $L = 60 t_{hr} V_{wq}$	L = ft

Step 4: Calculate swale length	
4-3. If L is too long for the site, proceed to Step 5 to adjust the swale layout If L is greater than 100 ft and will fit within the constraints of the site, skip to Step 6 If L is less than 100 ft, increase the length to a minimum of 100 ft, leaving the bottom width unchanged, and skip to Step 6	
Step 5: Adjust swale layout to fit within site constraints	
5-1. Enter the bottom width calculated in Step 2 (ft), $b_i = b$	b_i = ft
5-2. Enter design flow depth (ft), y	y= ft
5-3. Enter the swale side slope ratio (H:V), Z	Z = ft:ft
5-4. Enter the additional top width above the side slope for the design water depth (ft), $b_{slope} = 2Zy$	b_{slope} = ft
5-5. Enter the initial length calculated in Step 4 (ft), $Li = L$	L_i = ft
5-6. Calculate the top area at the design treatment depth (ft²), $A_{top} = (b_i + b_{slope}) \times L_i$	A_{top} = ft²
5-7. Choose a reduced swale length based on site constraints (ft), L_f	L_f = ft
5-8. Calculate the increased bottom width (ft), $b_f = (A_{top}/L_f) - b_{slope}$	b_f = ft
5-9. Recalculate the cross-sectional area of flow at design depth (ft2), $A_{wq,f} = b_f y + Zy^2$	$A_{wq,f}$ = ft²
5-10. Recalculate design flow velocity (ft/s), $V_{wq} = SQDF / A_{wq}$ Revise design as necessary if design flow velocity exceeds 1 ft/s.	V_{wq} = ft/s

5-11. Recalculate the hydraulic residence time (min), $t_{hr} = L_f/(60V_{wq})$ Ensure that t_{hr} is greater or equal to 10 minutes.	t_{hr} = min
5-12. When V_{wq} and t_{hr} are recalculated to meet requirements, proceed to Step 6.	
Step 6: Provide conveyance capacity for flows higher than SQDF (if swale is on-line)	
6-1. If the swale already includes a high-flow bypass to convey flows higher than the water quality design flow rate, skip this step and verify that all parameters meet design requirements to complete sizing	
6-2. If swale does not include a high-flow bypass, determine that the swale can convey flood control design storm peak flows. Calculate the capital peak flow velocity per Ventura County requirements (ft/s), V_p	V_p = ft/s
6-3. If V_p > 3.0 feet per second, return to Step 2 and increase the bottom width or flatten the longitudinal slope as necessary to reduce the flood control design storm peak flow velocity to 3.0 feet per second or less. If the longitudinal slope is flattened, the swale bottom width must be recalculated (Step 2) and must meet all design criteria.	

Design Example

Step 1: Determine water quality design Flow

For this design example, a 10-acre site with Type 4 soil and 60% total imperviousness is considered. Flow-based sizing Method 1 is assumed. Therefore, the design intensity is 0.2 in/hr.

Step 1: Determine water quality design flow			
1-1. Enter Project area (acres), $A_{project}$	A =	10	acres
1-2. Enter impervious fraction, Imp (e.g. 60% = 0.60)	Imp =	0.60	
1-3. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1\text{-}imp)$	C =	0.59	
1-5. Enter design rainfall intensity (in/hr), i	i =	0.2	in/hr
1-6. Calculate water quality design flow (cfs), $SQDF = CiA$	$SQDF$=	1.18	cfs

Step 2: Calculate Swale Bottom Width

The swale bottom width is calculated based on Manning's equation. The grass height in the swale will be maintained at 6-inches. The design flow depth is assumed to be 2/3 of the grass height, or 4 inches (0.33 ft). The default Manning's roughness coefficient is assumed appropriate for expected vegetation density and design depth. The slope was assumed to be 0.04.

Step 2: Calculate swale bottom width			
2-1. Enter water quality design flow (cfs), $SQDF$	SQDF =	1.18	cfs
2-2. Enter Manning's roughness coefficient for shallow flow conditions, n_{wq} = 0.2	n_{wq} =	0.2	
2-3. Calculate design flow depth (ft), y	y =	0.33	ft
2-4. Enter longitudinal slope (along direction of flow) (ft/ft), s	s =	0.04	ft/ft
2-5. Calculate bottom width of swale (ft),	b =	5.0	ft

Step 2: Calculate swale bottom width	
$b = Q_{wq}n_{wq} / 1.49y^{0.67}s^{0.5}$	
2-6. If *b* is between 2 and 10 feet, go to Step 3	
2-7. If *b* is less than 2 ft, assume *b* = 2 ft and recalculate flow depth, $y = (Q_{wq}n_{wq} / 2.98s^{0.5})^{1.49}$	Not applicable
2-8. If *b* is greater than 10 ft, one of the following design adjustments must be made (and recalculate as necessary): Increase the longitudinal slope to a maximum of 0.06 ft/ft. Increase the design flow depth to a maximum of 4 in (0.33 ft). Place a divider lengthwise along the swale bottom (Figure 3-1) at least three-quarters of the swale length (beginning at the inlet). Swale width can be increased to an absolute maximum of 16 feet if a divider is provided.	Not applicable

Step 3: Determine Design Flow Velocity

For this design example, it is assumed the side slopes will be designed as 3H: 1V, so Z = 3.

Step 3: Determine design flow velocity	
3-1. Enter side slope length per unit height (H:V) (e.g. 3 if side slopes are 3H :1V), *Z*	Z = 3
3-2. Enter bottom width of swale (ft), *b*	b = 5.0 ft
3-3. Enter design flow depth (ft), *y*	y = 0.33 ft
3-4. Calculate the cross-sectional area of flow at design depth (ft²), $A_{wq} = by + Zy^2$	A_{wq} = 2.0 ft²
3-5. Calculate design flow velocity (ft/s), $V_{wq} = SQDF / A_{wq}$	V_{wq} = 0.59 ft/s
3-6. If the design flow exceeds 1 ft/s, go back to Step 2 and change one or more of the design parameters to reduce the design flow velocity. If design flow velocity is less than 1 ft/s, proceed to Step 4.	

Step 4: Calculate Swale Length

Using the design flow velocity and a minimum residence time of 7 minutes, the length of the swale is calculated as follows. The swale length must be a minimum of 100 ft.

Step 4: Calculate swale length	
4-1. Enter hydraulic residence time (min 7 min), t_{hr} (min)	t_{hr} = 10 min
4-2. Calculate swale length, $L = 60 t_{hr} V_{wq}$	L = 354 ft
4-3. If L is too long for the site, proceed to Step 5 to adjust the swale layout If L is greater than 100 ft and will fit within the constraints of the site, skip to Step 6 If L is less than 100 ft, increase the length to a minimum of 100 ft, leaving the bottom width unchanged, and skip to Step 6	Not Applicable

Site constraints only allow a swale length of 300 feet. Therefore proceed to Step 5 to adjust the swale length.

Step 5: Adjust Swale Layout to Fit Within Site Constraints

To adjust swale length to 300 feet, the bottom width needs to be increased (up to a maximum of 16 ft if a divider is provided).

Step 5: Adjust swale layout to fit within site constraints	
5-1. Enter the bottom width calculated in Step 2 (ft), $b_i = b$	b_i = 5.0 ft
5-2. Enter design flow depth (ft), y	y= 0.33 ft
5-3. Enter the swale side slope ratio (H:V), Z	Z = 3 ft:ft
5-4. Enter the additional top width above the side slope for the design water depth (ft), $b_{slope} = 2Zy$	b_{slope} = 2 ft
5-5. Enter the initial length calculated in Step 4 (ft), $Li = L$	L_i = 354 ft
5-6. Calculate the top area at the design treatment depth (ft^2), $A_{top} = (b_i + b_{slope}) \times L_i$	A_{top} = 2,480 ft^2

5-7. Choose a reduced swale length based on site constraints (ft), L_f	L_f = 300 ft
5-8. Calculate the increased bottom width (ft), $b_f = (A_{top}/L_f) - b_{slope}$	b_f = 6.3 ft
5-9. Recalculate the cross-sectional area of flow at design depth (ft2), $A_{wq,f} = b_f y + Zy^2$	$A_{wq,f}$ = 2.4 ft^2
5-10. Recalculate design flow velocity (ft/s), $V_{wq} = SQDF/ A_{wq}$ Revise design as necessary if design flow velocity exceeds 1 ft/s.	V_{wq} = 0.49 ft/s
5-11. Recalculate the hydraulic residence time (min), $t_{hr} = L_f/(60V_{wq})$ Ensure that t_{hr} is greater or equal to 10 minutes.	t_{hr} = 10.2 min
5-12. When V_{wq} and t_{hr} are recalculated to meet requirements, proceed to Step 6.	

Since the new length and width yields V_{wq} and t_{hr} which meet requirements, continue to Step 6.

Step 6: Provide Conveyance Capacity for Flows Higher than SQDF

The swale will be offline such that all flows greater than SQDF will be bypassed.

E.7 VEG-4 Filter Strip

Sizing Methodology

The flow capacity of a vegetated filter strips (filter strips) is a function of the longitudinal slope (parallel to flow), the resistance to flow (e.g., Manning's roughness), and the width and length of the filter strip. The slope shall be small enough to ensure that the depth of water will not exceed 1 inch over the filter strip. Similarly, the flow velocity shall be less than 1 ft/sec. Procedures for sizing filter strips are summarized below. A filter strip sizing example is also provided.

Step 1: Calculate the design flow rate

The design flow is calculated based on the stormwater quality design flow rate, SQDF, as described in Section E.1.

Step 2: Calculate the minimum width

Determine the minimum width (i.e. perpendicular to flow) allowable for the filter strip and design for that width or larger.

$$W_{min} = (SQDF) / (q_{a,min}) \qquad \text{(Equation E-35)}$$

Where

W_{min}	=	minimum width of filter strip
$SQDF$	=	stormwater quality design flow (cfs)
$q_{a,min}$	=	minimum linear unit application rate, 0.005 cfs/ft

Step 3: Calculate the design flow depth

The design flow depth (d_f) is calculated based on the width and the slope (parallel to the flow path) using a modified Manning's equation as follows:

$$d_f = 12 * [SQDF * n_{wq} / 1.49 W_{trib} s^{0.5}]^{0.6} \qquad \text{(Equation E-36)}$$

Where:

d_f	=	design flow depth (inches)
$SQDF$	=	stormwater quality design flow (cfs)
W_{trib}	=	width (perpendicular to flow = width of impervious surface contributing area (ft))
s	=	slope (ft/ft) of strip parallel to flow, average over the whole width

n_{wq} = Manning's roughness coefficient (0.25-0.30)

If d_f is greater than 1 inch (0.083 ft), then a shallower slope is required, or a filter strip cannot be used.

Step 4: Calculate the design velocity

The design flow velocity is based on the design flow, design flow depth, and width of the strip:

$$V_{wq} = SQDF / (d_f \, W_{trib}) \qquad \text{(Equation E-37)}$$

Where:

$d_{f,ft}$ = design flow depth (ft) (d_f/12)

$SQDF$ = stormwater quality design flow (cfs)

W_{trib} = width (perpendicular to flow = width of impervious surface contributing area (ft))

Step 5: Calculate the desired length of the filter strip

Determine the required length (L) to achieve a desired minimum residence time of 7 minutes using:

$$L = 60 t_{hr} V_{wq} \qquad \text{(Equation E-38)}$$

Where:

L = minimum allowable strip length (ft)

t_{hr} = hydraulic residence time (s)

V_{wq} = design flow velocity (fps)

Sizing Worksheet

Step 1: Calculate the design flow		
1-1. Enter Project area (acres), $A_{project}$	A_{design} =	acres
1-2. Enter impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp =	
1-3. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1\text{-}imp)$	C =	
1-5. Enter design rainfall intensity (in/hr), *i*	i =	in/hr
1-6. Calculate water quality design flow (cfs), *SQDF= CiA*	SQDF =	cfs
Step 2: Calculate the minimum width		
2-1. Enter the stormwater quality design flow (cfs), *SQDF*	SQDF =	cfs
2-2. Enter the minimum linear unit application rate (0.005 cfs/ft), $q_{a,min}$	$q_{a,min}$=	cfs/ft
2-3. Calculate the minimum width of filter strip (ft), W_{min}	W_{min}=	ft
Step 3: Calculate the design flow depth		
3-1. Enter filter strip longitudinal slope, *s* (ft/ft)	*s* =	ft/ft
3-2. Enter Manning roughness coefficient (0.25-0.30), n_{wq}	n_{wq} =	
3-3. Enter width of impervious surface contributing area (perpendicular to flow), *W* (ft)	W =	ft

Step 3: Calculate the design flow depth	
3-4. Calculate average depth of water using Manning equation (inches), $d_f = 12 * [SQDF * n_{wq} / 1.49 W_{trib} s^{0.5}]^{0.6}$	d_f = inches
3-5. If d_f > 1" (0.083 ft), go back step 3-1 and decrease the slope	
3-6. If the slope cannot be changed due to construction constraints, go to step 3-3 and increase the width perpendicular to flow.	
Step 4: Calculate the design velocity	
4-1. Enter depth of water (ft), $d_{f,ft} = d_f / 12$	d_f = ft
4-2. Enter width of strip (ft), W	W = ft
4-3. Calculate design flow velocity (ft/s), $V_{wq} = SQDF / (d_{f,ft} W)$	V_{wq}= ft/s
4-4. If the V_{wq} >1 ft/s, go back to step 3-1 and decrease the slope.	
Step 5: Calculate the length of the filter strip	
5-1. Enter desired residence time (minimum 7 minutes), t	t = min
5-2. Enter design flow velocity (ft/s), V_{wq}	V_{wq}= ft/s
5-3. Calculate length of the filter strip (ft), $L = 60 t V_{wq}$	L = ft
5-4. If L < 4 ft, go to step 3-1 and increase the slope	

Design Example

Step 1: Determine water quality design Flow

For this design example, a 10-acre site with Type 4 soil and 60% total imperviousness is considered. Flow-based sizing Method 1 is used, as described in Section E.1.

Step 1: Calculate the design flow			
1-1. Enter Project area (acres), $A_{project}$	A_{design} =	10	acres
1-2. Enter impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp =	0.60	
1-3. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-4. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1\text{-}imp)$	C =	0.59	
1-5. Enter design rainfall intensity (in/hr), *i*	i =	0.2	in/hr
1-6. Calculate water quality design flow (cfs), *SQDF= CiA*	SQDF =	1.18	cfs

Step 2: Calculate the minimum width of filter strip

Determine the minimum width (i.e. perpendicular to flow) allowable for the filter strip and design for that width or larger.

Step 2: Calculate the minimum width			
2-1. Enter the stormwater quality design flow (cfs), *SQDF*	SQDF =	1.18	cfs
2-2. Enter the minimum linear unit application rate (0.005 cfs/ft), $q_{a,min}$	$q_{a,min}$=	0.005	cfs/ft
2-3. Calculate the minimum width of filter strip (ft), $W_{min}=SQDF/q_{a,min}$	W_{min}=	240	ft

Step 3: Calculate the Design Flow Depth

A slope of 3% was assumed for the filter strip (2-4% recommended). The design water depth should not exceed 1 inch. For this design example a manning's coefficient of 0.27 was used.

Step 3: Calculate the design flow depth	
3-1. Enter filter strip longitudinal slope, *s* (ft/ft)	s = 0.03 ft/ft
3-2. Enter Manning roughness coefficient (0.25-0.30), n_{wq}	n_{wq} = 0.27
3-3. Enter width of strip (=impervious surface contributing area perpendicular to flow), at least W_{min} (ft), *W*	W = 240 ft
3-4. Calculate average depth of water using Manning equation (inches), $d_f = 12 * [SQDF * n_{wq} / 1.49 W s^{0.5}]^{0.6}$	d_f = 0.51 in
3-5. If d_f > 1" (0.083 ft), go back step 3-1 and decrease the slope	
3-6. If the slope cannot be changed due to construction constraints, go to step 3-3 and increase the width perpendicular to flow.	

Step 4: Calculate the Design Velocity

The designed flow velocity should not exceed 1 foot/second across the filter strip.

Step 4: Calculate the design velocity	
4-1. Enter depth of water (ft), $d_{f,ft} = d_f / 12$	d_f = 0.043 ft
4-2. Enter width of strip (ft), *W*	W= 240 ft
4-3. Calculate design flow velocity (ft/s), $V_{wq} = SQDF / (d_{f,ft} W)$	V_{wq} = 0.11 ft/s
4-4. If the V_{wq} >1 ft/s, go back to step 3-1 and decrease the slope.	

Step 5: Calculate the Length of the Filter Strip

The filter strip should be at least 4 feet long (in the direction of flow) and accommodate a minimum residence time of 7 minutes to provide adequate water quality treatment.

Step 5: Calculate the length of the filter strip	
5-1. Enter desired residence time (minimum 10 minutes), t	t = 10 min
5-2. Enter design flow velocity (ft/s), V_{wq}	V_{wq}= 0.11 ft/s
5-3. Calculate length of the filter strip (ft), $L = 60tV_{wq}$	L = 66 ft
5-4. If L < 4 ft, go to step 3-1 and increase the slope	

E.8 TCM-1 Dry Extended Detention Basin

Sizing Methodology

Dry extended detention (ED) basins are basins designed such that the stormwater quality design volume, SQDV, is detained for 36 to 48 hours. This allows sediment particles and associated pollutants to settle and be removed from stormwater. Procedures for sizing extended detention basins are summarized below. A sizing example is also provided.

Step 1: Calculate the design volume

Dry extended detention facilities shall be sized to capture and treat the water quality design volume (see Section E.1).

Step 2: Calculate the volume of the active basin

The total basin volume shall be increased an additional 20% of the stormwater quality design volume to account for sediment accumulation, at a minimum. If the basin is designed only for water quality treatment then the basin volume would be 120% of the stormwater quality design volume, SQDV. Freeboard is in additional to the total basin volume. Calculate the volume of the active basin, V_a:

$$V_a = 1.20*SQDV \qquad \text{(Equation E-39)}$$

Step 3: Determine detention basin location and preliminary geometry based on site constraints

Based on site constraints, determine the basin geometry and the storage available by developing an elevation-storage relationship for the basin. The cross-sectional geometry across the width of the basin shall be approximately trapezoidal with a maximum side slope of 4:1 (H:V) on interior slopes and 3:1 (H:V) on exterior slopes unless specifically permitted by Ventura County (see Side Slopes below). Shallower side slopes are necessary if the basin is designed to have recreational uses during dry weather conditions.

1) Calculate the width of the basin footprint, W_{tot}, as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}} \qquad \text{(Equation E-40)}$$

Where:

A_{tot} = total surface area of the basin footprint (ft^2)

L_{tot} = total length of the basin footprint (ft)

2) Calculate the length of the active volume surface area including the internal berm but excluding the freeboard, $L_{av\text{-}tot}$:

$$L_{av-tot} = L_{tot} - 2Zd_{fb} \qquad \text{(Equation E-41)}$$

Where:

Z = interior side slope as length per unit height

d_{fb} = freeboard depth

3) Calculate the width of the active volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot}$:

$$W_{av-tot} = W_{tot} - 2Zd_{fb} \qquad \text{(Equation E-42)}$$

4) Calculate the total active volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot}$:

$$A_{av-tot} = L_{av-tot} \times W_{av-tot} \qquad \text{(Equation E-43)}$$

5) Calculate the area of the berm, A_{berm}:

$$A_{berm} = W_{berm} \times L_{berm} \qquad \text{(Equation E-44)}$$

Where:

W_{berm} = width of the internal berm

L_{berm} = length of the internal berm

6) Calculate the surface area excluding the internal berm and freeboard, A_{av}:

$$A_{av} = A_{av=tot} - A_{berm} \qquad \text{(Equation E-45)}$$

Step 4: Determine Dimensions of Forebay

5-15% of the basin active volume, V_a, is required to be within the active volume of the forebay.

1) Calculate the active volume of forebay, V_1:

$$V_1 = \frac{V_a \times \%V_1}{100} \qquad \text{(Equation E-46)}$$

Where:

$\%V_1$ = percent of V_a in forebay (%)

V_a = active volume (ft^3)

2) Calculate the surface area for the active volume of forebay, A_1:

$$A_1 = \frac{V_1}{d_1} \qquad \text{(Equation E-47)}$$

Where:

d_1 = average depth for the active volume of forebay (ft)

3) Calculate the length of forebay, L_1:

$$L_1 = \frac{A_1}{W_1} \qquad \text{(Equation E-48)}$$

Where:

W_1 = width of forebay (ft)

Step 5: Determine Dimensions of Cell 2

Cell 2 will consist of the remainder of the basin's active volume.

1) Calculate the active volume of Cell 2, V_2:

$$V_2 = V_a - V_1 \qquad \text{(Equation E-49)}$$

Where:

V_a = total basin active volume (ft^3)

V_1 = volume of forebay (ft^3)

2) Calculate the surface area, A_2, for the active volume of Cell 2:

$$A_2 = A_{av} - A_1 \qquad \text{(Equation E-50)}$$

Where:

A_{av} = basin surface area excluding berm and freeboard (ft^2)

A_1 = surface area of forebay (ft^2)

3) Calculate the average depth, d_2, for the active volume of Cell 2:

$$d_2 = \frac{V_2}{A_2} \qquad \text{(Equation E-51)}$$

4) Calculate the length of Cell 2, L_2:

$$L_2 = \frac{A_2}{W_2} \qquad \text{(Equation E-52)}$$

Where:

W_2 = width of Cell 2 (ft)

5) Verify that the length-to-width ratio of Cell 2 at half of d_2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the basin should be chosen. Calculate the length-to width, LW_{mid2}, ratio of Cell 2 at half of d_2 follows:

$$LW_{mid2} = \frac{L_{mid2}}{W_{mid2}} \qquad \text{(Equation E-53)}$$

Where:

$W_{mid2} = W_2 - Zd_2$ and (Equation E-54)

$L_{mid2} = L_2 - Zd_2$ (Equation E-55)

W_{mid2} = width of Cell 2 at half of d_2 (ft)

L_{mid2} = length of Cell 2 at half of d_2 (ft)

Z = interior side slope as length per unit height (H:V)

Step 6: Ensure Design Requirements and Site Constraints are achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or alternative treatment BMP.

Step 7: Size Outlet Structure

The total drawdown time for the basin should be 36-48 hours. The outlet structure shall be designed to release the bottom 50% of the detention volume (half-full to empty) over 24-32 hours, and the top half (full to half-full) in 12-16 hours. A primary overflow should be sized to pass the peak flow rate from the developed capital design storm. See Section 6 for outlet structure sizing methodologies.

Step 8: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass

the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Sizing Worksheet

Step 1: Determine water quality design volume		
1-1. Enter Project area (acres), $A_{project}$	A =	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	%
1-3. Determine the maximum allowed effective impervious area (ac), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=	
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA=	acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	
1-9. Enter design rainfall depth of the storm (in), P_i	P_i =	in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P =	ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560 \bullet C*P*A_{retain}$	SQDV =	ft^3
Step 2: Calculate the volume of the active basin		
2-1. Calculate basin active volume (includes water quality design volume + sediment storage volume) (ft^3), $V_a = 1.20 \times SQDV$	V_a =	ft^3

Step 3: Determine Detention Basin Location and Preliminary Geometry Based on Site Constraints	
3-1. Based on site constraints, determine the basin geometry and the storage available by developing an elevation-storage relationship for the basin. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2.	
3-2. Enter the total surface area of the basin footprint based on site constraints (ft^2), A_{tot}	A_{tot} = ft^2
3-3. Enter the length of the basin footprint based on site constraints (ft), L_{tot}	L_{tot} = ft
3-4. Calculate the width of the basin footprint (L:W = 1.5:1 min) (ft), $W_{tot} = A_{tot} / L_{tot}$	W_{tot} = ft
3-5. Enter interior side slope as length per unit height (H:V, min = 3), Z	Z =
3-6. Enter desired freeboard depth (ft), d_{fb} (min: 2 ft on-line; 1 ft offline)	d_{fb} = ft
3-7. Calculate the length of the active volume surface area including the internal berm but excluding freeboard, $L_{av\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{av\text{-}tot}$ = ft
3-8. Calculate the width of the active volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{av\text{-}tot}$ = ft
3-9. Calculate the total active volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot} = L_{av\text{-}tot} \times W_{av\text{-}tot}$	$A_{av\text{-}tot}$ = ft^2
3-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} = ft
3-11. Enter the length of the internal berm (ft), $L_{berm} = W_{av\text{-}tot}$	L_{berm} = ft
3-12. Calculate the area of the berm (ft^2), $A_{berm} = W_{berm} \times L_{berm}$	A_{berm} = ft^2
3-13. Calculate the surface area excluding the internal berm and freeboard (ft^2), $A_{av} = A_{av\text{-}tot} - A_{berm}$	A_{av} = ft^2

Step 4: Determine Dimensions of forebay	
4-1. Enter the percent of V_a in forebay (5-15% required), $\%V_1$	$\%V_1$ = %
4-2. Calculate the active volume of forebay, $V_1 = (V_a \bullet \%V_1)/100$	V_1 = ft^3
4-3. Enter a desired average depth for the active volume of forebay, d_1	d_1 = ft
4-4. Calculate the surface area for the active volume of forebay, $A_1 = V_1 / d_1$	A_1 = ft^2
4-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 = ft
4-6. Calculate the length of forebay (<u>Note:</u> inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 = ft
Step 5: Determine Dimensions of Cell 2	
5-1. Calculate the active volume of Cell 2, $V_2 = V_a - V_1$	V_2 = ft^3
5-2. Calculate the surface area of the active volume of Cell 2, $A_2 = A_{av} - A_1$	A_2 = ft^2
5-3. Calculate the average depth for the active volume of Cell 2, $d_2 = V_2 / A_2$	d_2 = ft
5-4. Enter the width of Cell 2, $W_2 = W_1 = W_{av\text{-}tot} = L_{berm}$	W_2 = ft
5-5. Calculate the length of Cell 2, $L_2 = A_2 / W_2$	L_2 = ft
5-6. Calculate the width of Cell 2 at half of d_2, $W_{mid2} = W_2 - Zd_2$	W_{mid2} = ft
5-7. Calculate the length of Cell 2 at half of d_2, $L_{mid2} = L_2 - Zd_2$	L_{mid2} = ft

5-8. Verify that the length-to-width ratio of Cell 2 at half of d_2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the basin should be chosen, $LW_{mid2} = L_{mid2} / W_{mid2}$	LW_{mid2} =
Step 6: Ensure Design Requirements and Site Constraints are Achieved	
6-1. Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or alternative treatment BMP.	
Step 7: Size Outlet Structure	
7-1. The total drawdown time for the basin should be 36-48 hours. The outlet structure shall be designed to release the bottom 50% of the detention volume (half-full to empty) over 24-32 hours, and the top half (full to half-full) in 12-16 hours. A primary overflow should be sized to pass the peak flow rate from the developed capital design storm. See Section 6 for outlet structure sizing methodologies.	
Step 8: Determine Emergency Spillway Requirements	
8-1. For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.	

Design Example

Step 1: Determine water quality design volume

For this design example, a 10-acre residential development with a 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter Project area (acres), $A_{project}$	A =	10	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	5	
1-3. Determine the maximum allowed effective impervious area (ac), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	0.5	acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=	0.6	
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA=	6	acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	5.5	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-9. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560 \bullet C*P*A_{retain}$	SQDV =	8,500	ft^3

Step 2: Calculate Volume of the Active Basin and the Forebay Basin

Step 2: Calculate the design volume of the active basin	
2-1. Calculate basin active design volume (includes water quality design volume + sediment storage volume), $V_a = 1.20*SQDV$	V_a = 10,000 ft^3

Step 3: Determine Detention Basin Location and Preliminary Geometry Based on Site Constraints

The detention basin in this example has an internal berm separating the forebay (Cell 1) and the main basin (Cell 2). The internal berm elevation is 2 ft below the elevation of the SUSMP volume within the entire basin. The berm length is equal to the width of the basin when filled to the active design volume.

Step 3: Determine Detention Basin Location and Preliminary Geometry Based on Site Constraints	
3-1. Based on site constraints, determine the basin geometry and the storage available by developing an elevation-storage relationship for the basin. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2.	
3-2. Enter the total surface area of the basin footprint based on site constraints, A_{tot}	A_{tot} = 8,000 ft^2
3-3. Enter the length of the basin footprint based on site constraints, L_{tot} (L:W = 1.5:1 min)	L_{tot} = 200 ft
3-4. Calculate the width of the basin footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} = 40 ft
3-5. Enter interior side slope as length per unit height (min = 3), Z	Z = 3
3-6. Enter desired freeboard depth, d_{fb} (min: 2 ft on-line; 1 ft offline)	d_{fb} = 2 ft
3-7. Calculate the length of the active volume surface area including the internal berm but excluding freeboard, $L_{av\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{av\text{-}tot}$ = 188 ft

Step 3: Determine Detention Basin Location and Preliminary Geometry Based on Site Constraints	
3-8. Calculate the width of the active volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{av\text{-}tot}$ = 28 ft
3-9. Calculate the total active volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot} = L_{av\text{-}tot} \bullet W_{av\text{-}tot}$	$A_{av\text{-}tot}$ = 5,300 ft^2
3-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} = 6 ft
3-11. Enter the length of the internal berm, $L_{berm} = W_{av\text{-}tot}$	L_{berm} = 28 ft
3-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} = 170 ft^2
3-13. Calculate the surface area excluding the internal berm and freeboard, $A_{av} = A_{av\text{-}tot} - A_{berm}$	A_{av} = 5,130 ft^2

Step 4: Calculate Dimensions of Cell 1

Calculate the dimensions of the forebay (Cell 1) based on the active design volume for Cell 1 (25% of V_a) and a desired average depth, d_1. The width of the forebay, W_1, is equivalent to the length of the berm, L_{berm}, and the width of Cell 2, W_2.

Step 4: Determine Dimensions of forebay	
4-1. Enter the percent of V_a in forebay (5-15% required), $\%V_1$	$\%V_1$ = 25 %
4-2. Calculate the active volume of forebay (including sediment storage), $V_1 = (V_a \bullet \%V_1)/100$	V_1 = 2,500 ft^3
4-3. Enter a desired average depth for the active volume of forebay, d_1	d_1 = 5 ft
4-4. Calculate the surface area for the active volume of forebay, $A_1 = V_1 / d_1$	A_1 = 500 ft^2

4-5. Enter the width of forebay, $W_1 = W_{wq\text{-}tot} = L_{berm}$	W_1 = 28 ft
4-6. Calculate the length of forebay (Note: inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 = 18 ft

Step 5: Calculate the Dimensions of Cell 2

Calculate the dimensions of the main basin (Cell 2) based on the active design volume for Cell 2 and a desired average depth, d_2. A calculation of the length, L_{mid2}, and width, W_{mid2}, at half basin depth, d_2, is conducted in order to verify that the length-to-width ratio at half d_2 is greater than 1.5:1.

Step 5: Calculate the dimensions of Cell 2	
5-1. Calculate the active volume of Cell 2, $V_2 = V_a - V_1$	V_2 = 7,500 ft^3
5-2. Calculate the surface area of the active volume of Cell 2, $A_2 = A_{av} - A_1$	A_2 = 4,630 ft^2
5-3. Calculate the average depth of the active volume of Cell 2, $d_2 = V_2 / A_2$	d_2 = 1.6 ft
5-4. Enter the width of Cell 2, $W_2 = W_1 = W_{av\text{-}tot} = L_{berm}$	W_2 = 28 ft
5-5. Calculate the length of Cell 2, $L_2 = A_2 / W_2$	L_2 = 166 ft
5-6. Calculate the width of Cell 2 at half of d_2, $W_{mid2} = W_2 - Zd_2$	W_{mid2} = 23 ft
5-7. Calculate the length of Cell 2 at half of d_2, $L_{mid2} = L_2 - Zd_2$	L_{mid2} = 161 ft
5-8. Verify that the length-to-width ratio of Cell 2 at half of d_2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the basin should be chosen, $LW_{mid2} = L_{mid2} / W_{mid2}$	LW_{mid2} = 7

Step 6: Ensure Design Requirements and Site Constraints are Achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or an alternative treatment BMP.

Step 7: Size Outlet Structure

The total drawdown time for the basin should be 36-48 hours. The outlet structure shall be designed to release the bottom 50% of the detention volume (half-full to empty) over 24-32 hours, and the top half (full to half-full) in 12-16 hours. A primary overflow should be sized to pass the peak flow rate from the developed capital design storm. See Section 6 for outlet structure sizing methodologies.

Step 8: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

E.9 TCM-2 Wet Detention Basin

Sizing Methodology

Wet Detention basins may be designed with or without extended detention above the permanent pool. The extended detention portion of the wet detention basin above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see VEG-5: Dry Extended Detention Basin). If there is no extended detention provided, wet detention basins shall be sized to provide a minimum wet pool volume equal to the stormwater quality design volume plus an additional 5% for sediment accumulation. If extended detention is provided above the permanent pool, the sizing is dependent of the functionality of the basin; the basin may function as water quality treatment only or water quality plus peak flow attenuation.

If and the basin is designed for water quality treatment only, then the permanent pool volume shall be a minimum of 10 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) shall make up the remaining 90 percent. If extended detention is provided above the permanent pool and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume shall be equal to the water quality treatment volume, and the surcharge volume shall be sized to attenuate peak flows in order to meet the peak runoff discharge requirements. The extended detention portion of the wet detention basin above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see VEG-5: Dry Extended Detention Basin).

Step 1: Calculate the design volume

Wet detention basins shall be sized with a permanent pool volume equal to the SQDV volume (see Section 2 and Appendix E).

Step 2: Determine the active design volume for the wet detention basin without extended detention

The active volume of the wet detention basin, V_a, shall be equal to the SQFV plus an additional 5% for sediment accumulation.

$$V_a = 1.05 \times SQDV \qquad \text{(Equation E-56)}$$

Step 3: Determine pond location and preliminary geometry based on site constraints

Based on site constraints, determine the pond geometry and the storage available by developing an elevation-storage relationship for the pond. Note that a more natural geometry may be used and is in many cases recommended; the preliminary basin geometry calculations should be used for sizing purposes only.

1) Calculate the width of the pond footprint, W_{tot}, as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}}$$ (Equation E-57)

Where:

A_{tot} = total surface area of the pond footprint (ft^2)

L_{tot} = total length of the pond footprint (ft)

7) Calculate the length of the active volume surface area including the internal berm but excluding the freeboard, $L_{av\text{-}tot}$:

$$L_{av-tot} = L_{tot} - 2Zd_{fb}$$ (Equation E-58)

Where:

Z = interior side slope as length per unit height

d_{fb} = freeboard depth

8) Calculate the width of the active volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot}$:

$$W_{av-tot} = W_{tot} - 2Zd_{fb}$$ (Equation E-59)

9) Calculate the total active volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot}$:

$$A_{av-tot} = L_{av-tot} \times W_{av-tot}$$ (Equation E-60)

10) Calculate the area of the berm, A_{berm}:

$$A_{berm} = W_{berm} \times L_{berm}$$ (Equation E-61)

Where:

W_{berm} = width of the internal berm

L_{berm} = length of the internal berm

11) Calculate the active volume surface area excluding the internal berm and freeboard, A_{wq}:

$$A_{wq} = A_{wq=tot} - A_{berm}$$ (Equation E-62)

Step 4: Determine Dimensions of Forebay

The wet detention basin shall be divided into two cells separated by a berm or baffle. The forebay shall contain between 5 and 10 percent of the total volume. The berm or

baffle volume shall not count as part of the total volume. Calculate the active volume of forebay, V_1:

$$V_1 = \frac{V_a \times \%V_1}{100} \qquad \text{(Equation E-63)}$$

Where:

$\%V_1$ = percent of SQDV in forebay (%)

1) Calculate the surface area for the active volume of forebay, A_1:

$$A_1 = \frac{V_1}{d_1} \qquad \text{(Equation E-64)}$$

Where:

d_1 = average depth fo rhte active volume of forebay (ft)

2) Calculate the length of forebay, L_1. Note, inlet and outlet should be configured to maximize the residence time.

$$L_1 = \frac{A_1}{W_1} \qquad \text{(Equation E-65)}$$

Where:

W_1 = width of forebay (ft), $W_1 = W_{av\text{-}tot} = L_{berm}$

Step 5: Determine Dimensions of Cell 2

Cell 2 will consist of the remainder of the basin's active volume.

3) Calculate the active volume of Cell 2, V_2:

$$V_2 = V_a - V_1 \qquad \text{(Equation E-66)}$$

4) The minimum wetpool surface area includes 0.3 acres of wetpool per acre-foot of permanent wetpool volume. Calculate A_{min2}:

$$A_{min2} = (V_2 \times 0.3 \frac{acres}{acre-feet}) \qquad \text{(Equation E-67)}$$

5) Calculate the actual wetpool surface area, A_2:

$$A_2 = A_{av} - A_1 \qquad \text{(Equation E-68)}$$

Verify that A_2 is greater than A_{min2}. If A_2 is less than A_{min2}, then modify input parameters to increase A_2 until it is greater than A_{min2}. If site constraints limit this criterion, then another site for the pond should be chosen.

6) Calculate the top length of Cell 2, L_2:

$$L_2 = \frac{A_2}{W_2} \qquad \text{(Equation E-69)}$$

Where:

W_2 = width of Cell 2 (ft), $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$

7) Verify that the length-to-width ratio of Cell 2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen.

$$LW_2 = \frac{L_2}{W_2} \qquad \text{(Equation E-70)}$$

8) Calculate the emergent vegetation surface area, A_{ev}:

$$A_{ev} = \frac{A_2 \bullet \%A_{ev}}{100} \qquad \text{(Equation E-71)}$$

Where:

$\%A_{ev}$ = percent of surface area that will be planted with emergent vegetation

9) Calculate the volume of the emergent vegetation shallow zone (1.5 – 3 ft), V_{ev}:

$$V_{ev} = A_{ev} \bullet d_{ev} \qquad \text{(Equation E-72)}$$

Where:

d_{ev} = average depth of the emergent vegetation shallow zone (1.5 – 3 ft)

10) Calculate the length of the emergent vegetation shallow zone, L_{ev}:

$$L_{ev} = \frac{A_{ev}}{W_{ev}} \qquad \text{(Equation E-73)}$$

Where:

W_{ev} = width of the emergent vegetation shallow zone (ft), $W_{ev} = W_2$

11) Calculate the volume of the deep zone, V_{deep}:

$$V_{deep} = V_2 - V_{ev} \qquad \text{(Equation E-74)}$$

12) Calculate the surface area of the deep (>3 ft) zone, A_{deep}:

$$A_{deep} = A_2 - A_{ev} \quad \text{(Equation E-75)}$$

13) Calculate the average depth of the deep zone (4-8 ft), d_{deep}:

$$d_{deep} = \frac{V_{deep}}{A_{deep}} \quad \text{(Equation E-76)}$$

14) Calculate length of the deep zone, L_{deep}:

$$L_{deep} = \frac{A_{deep}}{W_{deep}} \quad \text{(Equation E-77)}$$

Where:

W_{deep} = width of the deep zone (ft), $W_{deep} = W_2$

Step 6: Ensure design requirements and site constraints are achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location for the BMP.

Step 7: Size Outlet Structure

For extended detention wet detention basin, outlet structures shall be designed to provide 12 to 48 hour emptying time for the water quality volume above the permanent pool.

The basin outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

Step 8: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the water quality design storm. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Sizing Worksheet

Step 1: Determine water quality design volume		
1-1. Enter drainage area, A	A =	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	%
1-3. Determine the maximum allowed effective impervious area, $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	acres
1-4. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	
1-5. Determine the Project Total Impervious area, $TIA=A_{project}*Imp$	TIA=	acres
1-6. Determine the total area from which runoff must be retained, $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	
1-9. Enter design rainfall depth of the storm, P_i (in)	P_i =	in
1-10. Calculate rainfall depth, $P = P_i/12$	P =	ft
1-11. Calculate water quality design volume, $SQDV = 43560 \bullet P*A_{retain}*C$	SQDV =	ft^3
Step 2: Determine active design volume for the wet pond without extended detention		
2-1. Calculate the active design volume (without extended detention), $V_a = 1.05*SQDV$	V_a =	ft^3

Step 3: Determine Pond Location and Preliminary Geometry Based on Site Constraints	
3-1. Based on site constraints, determine the pond geometry and the storage available by developing an elevation-storage relationship for the pond. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2.	
3-2. Enter the total surface area of the pond footprint based on site constraints, A_{tot}	A_{tot} = ft^2
3-3. Enter the length of the pond footprint based on site constraints, L_{tot}	L_{tot} = ft
3-4. Calculate the width of the pond footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} = ft
3-5. Enter interior side slope as length per unit height (min = 3), Z	Z =
3-6. Enter desired freeboard depth, d_{fb} (1 ft min)	d_{fb} = ft
3-7. Calculate the length of the water quality volume surface area including the internal berm but excluding freeboard, $L_{av\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{av\text{-}tot}$ = ft
3-8. Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{av\text{-}tot}$ = ft
3-9. Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot} = L_{av\text{-}tot} \bullet W_{av\text{-}tot}$	$A_{av\text{-}tot}$ = ft^2
3-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} = ft
3-11. Enter the length of the internal berm, $L_{berm} = W_{av\text{-}tot}$	L_{berm} = ft
3-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} = ft^2

3-13. Calculate the water quality volume surface area excluding the internal berm and freeboard, $A_{av} = A_{av\text{-}tot} - A_{berm}$	A_{av} = ft^2
Step 4: Determine Dimensions of forebay	
4-1. Enter the percent of V_a in forebay (5-10% required), $\%V_1$	$\%V_1$ = %
4-2. Calculate the active volume of forebay (includes sediment storage volume), $V_1 = (V_a \bullet \%V_1) /100$	V_1 = ft^3
4-3. Enter desired average depth of forebay (5-9 ft including sediment storage of 1 ft), d_1	d_1 = ft
4-4. Calculate the surface area for the active volume of forebay, $A_1 = V_1 / d_1$	A_1 = ft^2
4-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 = ft
4-6. Calculate the length of forebay (<u>Note:</u> inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 = ft
Step 5: Determine Dimensions of Cell 2	
5-1. Calculate the active volume of Cell 2, $V_2 = V_a - V_1$	V_2 = ft^3
5-2. Determine minimum wetpool surface area, $A_{min2} = V_2 \bullet 0.3$	A_{min2} = ft^2
5-3. Determine actual wetpool surface area, $A_2 = A_{av} - A_1$	A_2 = ft^2
5-4. • If A_2 is greater than A_{min2} then move on to step 5-5. • If A_2 is less than A_{min2}, then modify input parameters to increase A_2 until it is greater than A_{min2}. If site constraints limit this criterion, then another site for the pond should be chosen.	
5-5. Enter width of Cell 2, $W_2 = W_1 = W_{av\text{-}tot} = L_{berm}$	W_2 = ft

5-6. Calculate top length of Cell 2, $L_2 = A_2 / W_2$	L_2 = ft
5-7. Verify that the length-to-width ratio of Cell 2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen, $LW_2 = L_2 / W_2$	LW_2 =
5-8. Enter percent of surface area that will be planted with emergent vegetation (25-75%), $\%A_{ev}$	$\%A_{ev}$ = %
5-9. Calculate emergent vegetation surface area, $A_{ev} = (A_2 \bullet \%A_{ev})/100$	A_{ev} = ft^2
5-10. Enter average depth of emergent vegetation shallow zone (1.5 – 3 ft), d_{ev}	d_{ev} = ft
5-11. Calculate volume of emergent vegetation shallow zone (1.5 – 3 ft), $V_{ev} = A_{ev} \bullet d_{ev}$	V_{ev} = ft^3
5-12. Enter width of emergent vegetation shallow zone, $W_{ev} = W_2$	W_{ev}= ft
5-13. Calculate length of emergent vegetation shallow zone, $L_{ev} = A_{ev} / W_{ev}$	L_{ev} = ft
5-14. Calculate volume of deep zone, $V_{deep} = V_2 - V_{ev}$	V_{deep} = ft^3
5-15. Calculate surface area of deep (>3 ft) zone, $A_{deep} = A_2 - A_{ev}$	A_{deep} = ft^2
5-16. Calculate average depth of deep zone (4 - 8 ft), $d_{deep} = V_{deep} / A_{deep}$	d_{deep} = ft
5-17. Enter width of deep zone, $W_{deep} = W_2$	W_{deep} = ft
5-18. Calculate length of deep zone, $L_{deep} = A_{deep} / W_{deeo}$	L_{deep} = ft

Step 6: Ensure Design Requirements and Site Constraints are Achieved
6-1. Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location for the BMP.
Step 7: Size Outlet Structure
7-1. The basin outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.
Step 8: Determine Emergency Spillway Requirements
8-1. For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the water quality design storm. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Design Example

Wet detention basin siting requires the following considerations prior to construction: (1) availability of base flow – wet detention basins require a regular source of water if water level is to be maintained, (2) surface space availability – large footprint area is required, and (3) compatibility with flood control – basins must not interfere with flood control functions of existing conveyance and detention structures.

The wet detention basin in this example does not have extended detention. An internal berm separates the forebay (Cell 1) and the main basin (Cell 2). The berm is at the elevation of the active volume design surface which is also the permanent wetpool elevation.

Step 1: Determine Water Quality Design Volume

For this design example, a 20-acre residential development with a 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter drainage area, A	A =	20	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	5	
1-3. Determine the maximum allowed effective impervious area, $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	1.0	acres
1-4. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	0.6	
1-5. Determine the Project Total Impervious area, $TIA=A_{project}*Imp$	TIA=	12	acres
1-6. Determine the total area from which runoff must be retained, $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	11	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-9. Enter design rainfall depth of the storm, P_i (in)	P_i =	0.75	in
1-10. Calculate rainfall depth, $P = P_i/12$	P =	0.06	ft

1-11. Calculate water quality design volume, $SQDV = 43560 \bullet P * A_{retain} * C$	SQDV = 17,000 ft^3

Step 2: Determine Active Design Volume for a Wet Detention Basin without Extended Detention

If there is no extended detention provided, wet detention basins shall be sized to provide a minimum wet pool volume equal to the water quality design volume plus an additional 5% for sediment accumulation.

Step 2: Determine Active Design Volume for a Wet Detention Basin without Extended Detention	
2-1. Calculate the active design volume (without extended detention), $V_a = 1.05 * SQDV$	V_a = 17,800 ft^3

Step 3: Determine Pond Location and Preliminary Geometry Based on Site Constraints

A total footprint area and total length available for the basin is provided. This step calculates the total active volume surface area which is equivalent to the permanent wetpool surface area. This step also calculates the dimensions of the internal berm.

Step 3: Determine Pond Location and Preliminary Geometry Based on Site Constraints	
3-1. Based on site constraints, determine the pond geometry and the storage available by developing an elevation-storage relationship for the pond. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2.	
3-2. Enter the total surface area of the pond footprint based on site constraints, A_{tot}	A_{tot} = 7,500 ft^2
3-3. Enter the length of the pond footprint based on site constraints, L_{tot}	L_{tot} = 150 ft
3-4. Calculate the width of the pond footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} = 50 ft
3-5. Enter interior side slope as length per unit height (min = 3), Z	Z = 3

Step 3: Determine Pond Location and Preliminary Geometry Based on Site Constraints			
3-6. Enter desired freeboard depth, d_{fb} (1 ft min)	d_{fb} =	2	ft
3-7. Calculate the length of the water quality volume surface area including the internal berm but excluding freeboard, $L_{av\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{av\text{-}tot}$ =	138	ft
3-8. Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{av\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{av\text{-}tot}$ =	38	ft
3-9. Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{av\text{-}tot} = L_{av\text{-}tot} \bullet W_{av\text{-}tot}$	$A_{av\text{-}tot}$ =	4,940	ft^2
3-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} =	6	ft
3-11. Enter the length of the internal berm, $L_{berm} = W_{av\text{-}tot}$	L_{berm} =	38	ft
3-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} =	230	ft^2
3-13. Calculate the water quality volume surface area excluding the internal berm and freeboard, $A_{av} = A_{av\text{-}tot} - A_{berm}$	A_{av} =	4,710	ft^2

Step 4: Determine Dimensions of forebay

It should be assumed that the forebay should be 5-10% of the total active design volume, V_a.

Step 4: Determine Dimensions of Cell 1			
4-1. Enter the percent of V_a in forebay (5-10% required), $\%V_1$	$\%V_1$ =	20	%
4-2. Calculate the active volume of forebay (includes sediment storage volume), $V_1 = (V_a \bullet \%V_1) / 100$	V_1 =	3,560	ft^3
4-3. Enter desired average depth of forebay (5-9 ft including sediment storage of 1 ft), d_1	d_1 =	8	ft

4-4. Calculate the surface area for the active volume of forebay, $A_1 = V_1 / d_1$	A_1 =	440	ft^2
4-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 =	38	ft
4-6. Calculate the length of forebay (Note: inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 =	12	ft

Step 5: Determine Dimensions of Cell 2

Verify that the surface area and length-to-width ratio of Cell 2 meet the design criteria. Calculate volumes, depths and surface areas for the emergent vegetation shallow zone and the deep zone.

Step 5: Determine Dimensions of Cell 2			
5-1. Calculate the active volume of Cell 2, $V_2 = V_a - V_1$	V_2 =	14,200	ft^3
5-2. Determine minimum wetpool surface area, $A_{min2} = V_2 \bullet 0.3$	A_{min2} =	4,270	ft^2
5-3. Determine actual wetpool surface area, $A_2 = A_{av} – A_1$	A_2 =	4,270	ft^2
5-4. If A_2 is greater than A_{min2} then move on to step 5-5. If A_2 is less than A_{min2}, then modify input parameters to increase A_2 until it is greater than A_{min2}. If site constraints limit this criterion, then another site for the pond should be chosen.			
5-5. Enter width of Cell 2, $W_2 = W_1 = W_{av\text{-}tot} = L_{berm}$	W_2 =	38	ft
5-6. Calculate top length of Cell 2, $L_2 = A_2 / W_2$	L_2 =	110	ft
5-7. Verify that the length-to-width ratio of Cell 2 is at least 1.5:1 with ≥ 2:1 preferred. If the length-to-width ratio is less than 1.5:1, modify input parameters until a ratio of at least 1.5:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen, $LW_2 = L_2 / W_2$	LW_2 =	2.9	
5-8. Enter percent of surface area that will be planted with emergent vegetation (25-75%), $\%A_{ev}$	$\%A_{ev}$ =	25	%

Step 5: Determine Dimensions of Cell 2	
5-9. Calculate emergent vegetation surface area, $A_{ev} = (A_2 \bullet \%A_{ev})/100$	A_{ev} = 1,070 ft^2
5-10. Enter average depth of emergent vegetation shallow zone (1.5 – 3 ft), d_{ev}	d_{ev} = 2 ft
5-11. Calculate volume of emergent vegetation shallow zone (1.5 – 3 ft), $V_{ev} = A_{ev} \bullet d_{ev}$	V_{ev} = 2,130 ft^3
5-12. Enter width of emergent vegetation shallow zone, $W_{ev} = W_2$	W_{ev}= 38 ft
5-13. Calculate length of emergent vegetation shallow zone, $L_{ev} = A_{ev} / W_{ev}$	L_{ev} = 56 ft
5-14. Calculate volume of deep zone, $V_{deep} = V_2 - V_{ev}$	V_{deep} = 13,100 ft^3
5-15. Calculate surface area of deep (>3 ft) zone, $A_{deep} = A_2 - A_{ev}$	A_{deep} = 3,200 ft^2
5-16. Calculate average depth of deep zone (4 - 8 ft), $d_{deep} = V_{deep} / A_{deep}$	d_{deep} = 4.1 ft
5-17. Enter width of deep zone, $W_{deep} = W_2$	W_{deep} = 28 ft
5-18. Calculate length of deep zone, $L_{deep} = A_{deep} / W_{deeo}$	L_{deep} = 114 ft

Step 6: Ensure Design Requirements and Site Conditions are Achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location for the BMP.

Step 7: Size Outlet Structure

The basin outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

Step 8: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm to prevent overtopping of

the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the water quality design storm. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

E.10 TCM-3 Constructed Wetland

Sizing Methodology

In most cases, the constructed treatment wetland permanent pool shall be sized to be greater than or equal to the stormwater quality design volume. If extended detention is provided above the permanent pool and the wetland is designed for water quality treatment only, then the permanent pool volume shall be a minimum of 80 percent of the stormwater quality design volume and the surcharge volume (above the permanent pool) shall make up the remaining 20 percent and provide at least 12 hours of detention. If extended detention is provided and the basin is designed for water quality treatment and peak flow attenuation, then the permanent pool volume shall be equal to the water quality treatment volume and the surcharge volume shall be sized to attenuate peak flows to meet the peak runoff discharge requirements. The extended detention portion of the wetland above the permanent pool, if provided, functions like a dry extended detention (ED) basin (see VEG-5: Dry Extended Detention Basin).

Step 1: Calculate the design volume

Constructed wetlands shall be sized to be greater than or equal to the SQDV volume (see Section 2 and Appendix E).

Step 2: Determine the Wetland Location, Wetland Type and Preliminary Geometry Based on Site Constraints

Based on site constraints, determine the wetland geometry and the storage available by developing an elevation-storage relationship for the wetland. The equations provided below assume a trapezoidal geometry for cell 1 (Forebay) and cell 2, and assumes that the wetland does not have extended detention.

1) Calculate the width of the wetland footprint, W_{tot}, as follows:

$$W_{tot} = \frac{A_{tot}}{L_{tot}} \qquad \text{(Equation E-78)}$$

Where:

A_{tot} = total surface area of the wetland footprint (ft^2)

L_{tot} = total length of the wetland footprint (ft)

12) Calculate the length of the water quality volume surface area including the internal berm but excluding the freeboard, $L_{wq\text{-}tot}$:

$$L_{wq-tot} = L_{tot} - 2Zd_{fb} \qquad \text{(Equation E-79)}$$

Where:

Z = interior side slope as length per unit height

d_{fb} = freeboard depth

13) Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{wq\text{-}tot}$:

$$W_{wq-tot} = W_{tot} - 2Zd_{fb} \quad \text{(Equation E-80)}$$

14) Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{wq\text{-}tot}$:

$$A_{wq-tot} = L_{wq-tot} \times W_{wq-tot} \quad \text{(Equation E-81)}$$

15) Calculate the area of the berm, A_{berm}:

$$A_{berm} = W_{berm} \times L_{berm} \quad \text{(Equation E-82)}$$

Where:

W_{berm} = width of the internal berm

L_{berm} = length of the internal berm

16) Calculate the water quality surface area excluding the internal berm and freeboard, A_{wq}:

$$A_{wq} = A_{wq=tot} - A_{berm} \quad \text{(Equation E-83)}$$

Step 3: Determine Dimensions of Forebay

30-50% of the SQDV is required to be within the active volume of forebay.

1) Calculate the active volume of forebay, V_1:

$$V_1 = \frac{SQDV \times \%V_1}{100} \quad \text{(Equation E-84)}$$

Where:

$\%V_1$ = percent of SQDV in forebay (%)

2) Calculate the surface area for the active volume of forebay, A_1:

$$A_1 = \frac{V_1}{d_1} \quad \text{(Equation E-85)}$$

Where:

d_1 = average depth fo rhte active volume of forebay (2 -4 ft) (ft)

3) Calculate the length of forebay, L_1. Note, inlet and outlet should be configured to maximize the residence time.

$$L_1 = \frac{A_1}{W_1} \qquad \text{(Equation E-86)}$$

Where:

W_1 = width of forebay (ft), $W_1 = W_{av\text{-}tot} = L_{berm}$

Step 4: Determine Dimensions of Cell 2

Cell 2 will consist of the remainder of the basin's active volume.

1) Calculate the active volume of Cell 2, V_2:

$$V_2 = SQDV - V_1 \qquad \text{(Equation E-87)}$$

2) Calculate the surface area of Cell 2, A_2:

$$A_2 = A_{wq} - A_1 \qquad \text{(Equation E-88)}$$

3) Calculate the top length of Cell 2, L_2:

$$L_2 = \frac{A_2}{W_2} \qquad \text{(Equation E-89)}$$

Where:

W_2 = width of Cell 2 (ft), $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$

4) Verify that the length-to-width ratio of Cell 2, LW_2, is at least 3:1 with ≥ 4:1 preferred. If the length-to-width ratio is less than 3:1, modify input parameters until a ratio of at least 3:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen.

$$LW_2 = \frac{L_2}{W_2} \qquad \text{(Equation E-90)}$$

5) Calculate the very shallow zone surface area, A_{vs}:

$$A_{vs} = \frac{A_2 \bullet \%A_{vs}}{100} \qquad \text{(Equation E-91)}$$

Where:

$\%A_{vs}$ = percent of surface area of very shallow zone

6) Calculate the volume of the shallow zone, V_{vs}:

$$V_{vs} = A_{vs} \bullet d_{vs}$$ (Equation E-92)

Where:

d_{vs} = average depth of the very shallow zone (0.1 – 1 ft)

7) Calculate the length of the very shallow zone, L_{vs}:

$$L_{vs} = \frac{A_{vs}}{W_{vs}}$$ (Equation E-93)

Where:

W_{vs} = width of the very shallow zone (ft), $W_{vs} = W_2$

8) Calculate the surface area of the shallow zone, A_s:

$$A_s = \frac{A_2 \bullet \%A_s}{100}$$ (Equation E-94)

Where:

$\%A_s$ = percent of surface area of shallow zone

9) Calculate the volume of the shallow zone, V_s:

$$V_s = A_s \bullet d_s$$ (Equation E-95)

Where:

d_s = average depth of shallow zone (1 - 3 ft)

10) Calculate length of the shallow zone, L_s:

$$L_s = \frac{A_s}{W_s}$$ (Equation E-96)

Where:

W_s = width of the shallow zone (ft), $W_s = W_2$

11) Calculate the surface area of the deep zone, A_{deep}:

$$A_{deep} = A_2 - A_{vs} - A_s$$ (Equation E-97)

12) Calculate the volume of the deep zone, V_{deep}:

$$V_{deep} = V_2 - V_{vs} - V_s$$ (Equation E-98)

13) Calculate the average depth of the deep zone (3-5 ft), d_{deep}:

$$d_{deep} = \frac{V_{deep}}{A_{deep}} \qquad \text{(Equation E-99)}$$

14) Calculate length of the deep zone, L_{deep}:

$$L_{deep} = \frac{A_{deep}}{W_{deep}} \qquad \text{(Equation E-100)}$$

Where:

W_{deep} = width of the deep zone (ft), $W_{deep} = W_2$

Step 5: Ensure design requirements and site constraints are achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the basin is inadequate to meet the design requirements, choose a new location or alternative treatment BMP.

Step 6: Size Outlet Structure

For wetlands with detention, the outlet structures shall be designed to provide 12 hours emptying time for the water quality volume or the required detention necessary for achieving the peak runoff discharge requirements if the extended detention is designed for flow attenuation.

The wetland outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for on-line basins or flows greater than the peak runoff discharge rate for the 100-year, 24-hr design storm for on-line basins.

Step 7: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point. For sites where the emergency spillway discharges to a steep slope, an emergency overflow riser, in addition to the spillway should be provided.

Sizing Worksheet

Step 1: Determine water quality design volume		
1-1. Enter drainage area, A	A =	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	%
1-3. Determine the maximum allowed effective impervious area, $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	acres
1-4. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	
1-5. Determine the Project Total Impervious area, $TIA=A_{project}*Imp$	TIA=	acres
1-6. Determine the total area from which runoff must be retained, $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	
1-9. Enter design rainfall depth of the storm, P_i (in)	P_i =	in
1-10. Calculate rainfall depth, $P = P_i/12$	P =	ft
1-11. Calculate water quality design volume, $SQDV = 43560 \bullet P*A_{retain}*C$	SQDV =	ft^3
Step 2: Determine Wetland Location, Wetland Type and Preliminary Geometry Based on Site Constraints		
2-1. Based on site constraints, determine the wetland geometry and the storage available by developing an elevation-storage relationship for the wetland. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2. The wetland does not have extended detention.		

2-2. Enter the total surface area of the wetland footprint based on site constraints, A_{tot}	A_{tot} = ft^2
2-3. Enter the length of the wetland footprint based on site constraints, L_{tot}	L_{tot} = ft
2-4. Calculate the width of the wetland footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} = ft
2-5. Enter interior side slope as length per unit height (min = 3), Z	Z =
2-6. Enter desired freeboard depth, d_{fb}	d_{fb} = ft
2-7. Calculate the length of the water quality volume surface area including the internal berm but excluding freeboard, $L_{wq\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{wq\text{-}tot}$ = ft
2-8. Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{wq\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{wq\text{-}tot}$ = ft
2-9. Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{wq\text{-}tot} = L_{wq\text{-}tot} \bullet W_{wq\text{-}tot}$	$A_{wq\text{-}tot}$ = ft^2
2-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} = ft
2-11. Enter the length of the internal berm, $L_{berm} = W_{wq\text{-}tot}$	L_{berm} = ft
2-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} = ft^2
2-13. Calculate the water quality volume surface area excluding the internal berm and freeboard, $A_{wq} = A_{wq\text{-}tot} - A_{berm}$	A_{wq} = ft^2
Step 3: Determine Dimensions of forebay	
3-1. Enter the percent of SQDV in forebay (30-50% required), $\%V_1$	$\%V_1$ = %
3-2. Calculate the active volume of forebay (includes water quality volume + sediment storage volume),	V_1 = ft^3

V_1 = (SQDV • %V_1) /100	
3-3. Enter desired average depth of forebay1 (2-4 ft including sediment storage of 1 ft), d_1	d_1 = ft
3-4. Calculate the surface area for the water quality volume of forebay, $A_1 = V_1 / d_1$	A_1 = ft^2
3-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 = ft
3-6. Calculate the length of forebay (<u>Note:</u> inlet and outlet should be configured to maximize the residence time), $L_1 = A_1$ / W1	L_1 = ft
Step 4: Determine Dimensions of Cell 2	
4-1. Calculate the active volume of Cell 2, V_2 = SQDV - V_1	V_2 = ft^3
4-2. Calculate surface area of Cell 2, $A_2 = A_{wq} - A_1$	A_2 = ft^2
4-3. Enter width of Cell 2, $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$	W_2 = ft
4-4. Calculate top length of Cell 2, $L_2 = A_2 / W_2$	L_2 = ft
4-5. Verify that the length-to-width ratio of Cell 2 is at least 3:1 with ≥ 4:1 preferred. If the length-to-width ratio is less than 3:1, modify input parameters until a ratio of at least 3:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen, $LW_2 = L_2 / W_2$	LW_2 =
4-6. Enter percent of surface area of very shallow zone, $\%A_{vs}$	$\%A_{vs}$ = %
4-7. Calculate very shallow zone surface area, A_{vs} = (A_2 • $\%A_{vs}$)/100	A_{vs} = ft^2
4-8. Enter average depth of very shallow zone (0.1 - 1 ft), d_{vs}	d_{vs} = ft
4-9. Calculate volume of very shallow zone, $V_{vs} = A_{vs}$ • d_{vs}	V_{vs} = ft^3
4-10. Enter width of very shallow zone, $W_{vs} = W_2$	W_{vs} = ft

4-11. Calculate length of very shallow zone, $L_{vs} = A_{vs} / W_{vs}$	L_{vs} = ft
4-12. Enter percent of surface area of shallow zone, $\%A_s$	$\%A_s$ = %
4-13. Calculate surface area of shallow zone, $A_s = (A_2 \bullet \%A_s)/100$	A_s = ft^2
4-14. Enter average depth of shallow zone (1 - 3 ft), d_s	d_s = ft
4-15. Calculate volume of shallow zone, $V_s = A_s \bullet d_s$	V_s = ft^3
4-16. Enter width of shallow zone, $W_s = W_2$	W_s = ft
4-17. Calculate length of shallow zone, $L_s = A_s / W_s$	L_s = ft
4-18. Calculate surface area of deep zone, $A_{deep} = A_2 - A_{vs} - A_s$	A_{deep} = ft^2
4-19. Calculate volume of deep zone, $V_{deep} = V_2 - V_{vs} - V_s$	V_{deep} = ft^3
4-20. Calculate average depth of deep zone (3 - 5 ft), $d_{deep} = V_{deep} / A_{deep}$	d_{deep} = ft
4-21. Enter width of deep zone, $W_{deep} = W_2$	W_{deep} = ft
4-22. Calculate length of deep zone, $L_{deep} = A_{deep} / W_{deeo}$	L_{deep} = ft
Step 5: Ensure Design Requirements and Site Constraints are Achieved	
5-1. Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the wetland is inadequate to meet the design requirements, choose a new location for the wetland or select an alternative treatment BMP.	

Step 6: Size Outlet Structure
6-1. The wetland outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flow from the capital storm for on-line basins.
Step 7: Determine Emergency Spillway Requirements
7-1. For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point.

Design Example

Wetland siting requires the following considerations prior to construction: (1) availability of base flow – stormwater wetlands require a regular source of water to support wetland biota, (2) slope stability – stormwater wetlands are not permitted near steep slope hazard areas, (3) surface space availability – large footprint area is required, and (4) compatibility with flood control – basins must not interfere with flood control functions of existing conveyance and detention structures.

The wetland in this example does not have extended detention. An internal berm separates the forebay (Cell 1) and the main basin (Cell 2). The berm is at the elevation of the active volume (SQDV plus sediment storage volume) design surface which is also the permanent wetpool elevation.

Step 1: Determine Water Quality Design Volume

For this design example, a 20-acre residential development with a 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter drainage area, A	A =	20	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	5	
1-3. Determine the maximum allowed effective impervious area, $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	1.0	acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=	0.6	
1-5. Determine the Project Total Impervious area, $TIA=A_{project}*Imp$	TIA=	12	acres
1-6. Determine the total area from which runoff must be retained, $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	11	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-9. Enter design rainfall depth of the storm, P_i (in)	P_i =	0.75	in

1-10. Calculate rainfall depth, $P = P_i/12$	P = 0.06 ft
1-11. Calculate water quality design volume, $SQDV = 43560 \cdot P * A_{retain} * C$	SQDV = 17,000 ft^3

Step 2: Determine Pond Location and Preliminary Geometry Based on Site Constraints

A total footprint area and total length available for the wetland is provided. This step calculates the total active volume surface area which is equivalent to the permanent wetpool surface area. This step also calculates the dimensions of the internal berm.

Step 2: Determine Wetland Location, Wetland Type and Preliminary Geometry Based on Site Constraints	
2-1. Based on site constraints, determine the wetland geometry and the storage available by developing an elevation-storage relationship for the wetland. For this simple example, assume a trapezoidal geometry for cell 1 (forebay) and cell 2. The wetland does not have extended detention.	
2-2. Enter the total surface area of the wetland footprint based on site constraints, A_{tot}	A_{tot} = 7,500 ft^2
2-3. Enter the length of the wetland footprint based on site constraints, L_{tot}	L_{tot} = 200 ft
2-4. Calculate the width of the wetland footprint, $W_{tot} = A_{tot} / L_{tot}$	W_{tot} = 38 ft
2-5. Enter interior side slope as length per unit height (min = 3), Z	Z = 3
2-6. Enter desired freeboard depth, d_{fb}	d_{fb} = 2 ft
2-7. Calculate the length of the water quality volume surface area including the internal berm but excluding freeboard, $L_{wq\text{-}tot} = L_{tot} - 2Zd_{fb}$	$L_{wq\text{-}tot}$ = 188 ft
2-8. Calculate the width of the water quality volume surface area including the internal berm but excluding freeboard, $W_{wq\text{-}tot} = W_{tot} - 2Zd_{fb}$	$W_{wq\text{-}tot}$ = 26 ft

Step 2: Determine Wetland Location, Wetland Type and Preliminary Geometry Based on Site Constraints			
2-9. Calculate the total water quality volume surface area including the internal berm and excluding freeboard, $A_{wq\text{-}tot} = L_{wq\text{-}tot} \bullet W_{wq\text{-}tot}$	$A_{wq\text{-}tot}$ =	4,900	ft^2
2-10. Enter the width of the internal berm (6 ft min), W_{berm}	W_{berm} =	6	ft
2-11. Enter the length of the internal berm, $L_{berm} = W_{wq\text{-}tot}$	L_{berm} =	26	ft
2-12. Calculate the area of the berm, $A_{berm} = W_{berm} \bullet L_{berm}$	A_{berm} =	160	ft^2
2-13. Calculate the active volume surface area excluding the internal berm and freeboard, $A_{wq} = A_{wq\text{-}tot} - A_{berm}$	A_{wq} =	4,740	ft^2

Step 3: Determine Dimensions of Forebay

It should be assumed that the forebay should be 30-50% of the SQDV.

Step 3: Determine Dimensions of forebay			
3-1. Enter the percent of SQDV in forebay (30-50% required), $\%V_1$	$\%V_1$ =	30	%
3-2. Calculate the active volume of forebay (including sediment storage), V_1 = (SQDV • $\%V_1$)/100	V_1 =	5,100	ft^3
3-3. Enter desired average depth of forebay (2-4 ft including sediment storage of 1 ft), d_1	d_1 =	4	ft
3-4. Calculate the surface area for the water quality volume of forebay, $A_1 = V_1 / d_1$	A_1 =	1,275	ft^2
3-5. Enter the width of forebay, $W_1 = W_{av\text{-}tot} = L_{berm}$	W_1 =	38	ft
3-6. Calculate the length of forebay (<u>Note:</u> inlet and outlet should be configured to maximize the residence time), $L_1 = A_1 / W1$	L_1 =	34	ft

Step 4: Determine Dimensions of Cell 2

Verify that the surface area and length-to-width ratio of Cell 2 meet the design criteria. Calculate volumes, depths and surface areas for the very shallow, shallow and deep zones.

Step 4: Determine Dimensions of Cell 2			
4-1. Calculate the active volume of Cell 2, V_2 = SQDV - V_1	V_2 =	11,900	ft^3
4-2. Calculate surface area of Cell 2, $A_2 = A_{wq} - A_1$	A_2 =	3,460	ft^2
4-3. Enter width of Cell 2, $W_2 = W_1 = W_{wq\text{-}tot} = L_{berm}$	W_2 =	26	ft
4-4. Calculate top length of Cell 2, $L_2 = A_2 / W_2$	L_2 =	130	ft
4-5. Verify that the length-to-width ratio of Cell 2 is at least 3:1 with ≥ 4:1 preferred. If the length-to-width ratio is less than 3:1, modify input parameters until a ratio of at least 3:1 is achieved. If the input parameters cannot be modified as a result of site constraints, another site for the pond should be chosen, $LW_2 = L_2 / W_2$	LW_2 =	5	
4-6. Enter percent of surface area of very shallow zone, $\%A_{vs}$	$\%A_{vs}$ =	15	ft^2
4-7. Calculate very shallow zone surface area, $A_{vs} = (A_2 \bullet \%A_{vs})/100$	A_{vs} =	520	ft^2
4-8. Enter average depth of very shallow zone (0.1 - 1 ft), d_{vs}	d_{vs} =	1	ft
4-9. Calculate volume of very shallow zone, $V_{vs} = A_{vs} \bullet d_{vs}$	V_{vs} =	520	ft^3
4-10. Enter width of very shallow zone, $W_{vs} = W_2$	W_{vs} =	26	ft
4-11. Calculate length of very shallow zone, $L_{vs} = A_{vs} / W_{vs}$	L_{vs} =	20	ft
4-12. Enter percent of surface area of shallow zone, $\%A_s$	$\%A_s$ =	55	
4-13. Calculate surface area of shallow zone, $A_s = (A_2 \bullet \%A_s)/100$	A_s =	1,900	ft^2
4-14. Enter average depth of shallow zone (1 - 3 ft), d_s	d_s =	3	ft
4-15. Calculate volume of shallow zone, $V_s = A_s \bullet d_s$	V_s =	5,700	ft^3
4-16. Enter width of shallow zone, $W_s = W_2$	W_s =	26	ft
4-17. Calculate length of shallow zone, $L_s = A_s / W_s$	L_s =	220	ft

Step 4: Determine Dimensions of Cell 2			
4-18. Calculate surface area of deep zone, $A_{deep} = A_2 - A_{vs} - A_s$	A_{deep} =	1,040	ft^2
4-19. Calculate volume of deep zone, $V_{deep} = V_2 - V_{vs} - V_s$	V_{deep} =	5,680	ft^3
4-20. Calculate average depth of deep zone (3 - 5 ft), $d_{deep} = V_{deep} / A_{deep}$	d_{deep} =	5	ft
4-21. Enter width of deep zone, $W_{deep} = W_2$	W_{deep} =	26	ft
4-22. Calculate length of deep zone, $L_{deep} = A_{deep} / W_{deeo}$	L_{deep} =	40	ft

Step 5: Ensure Design Requirements and Site Conditions are Achieved

Check design requirements and site constraints. Modify design geometry until requirements are met. If the chosen site for the wetland is inadequate to meet the design requirements, choose a new location for the wetland or select an alternative treatment BMP.

Step 6: Size Outlet Structure

6-1. The wetland outlet pipe shall be sized, at a minimum, to pass flows greater than the stormwater quality design peak flow for off-line basins or flow from the capital storm for on-line basins.

Step 7: Determine Emergency Spillway Requirements

For online basins, an emergency overflow spillway should be sized to pass flows greater than the design peak runoff discharge rate for the 100-yr, 24-hr storm in order to prevent overtopping of the walls or berms in the event that a blockage of the riser occurs. For offline basins, an emergency spillway or riser should be sized to pass the 100-yr, 24-hr post-development peak storm water runoff discharge rate directly to the downstream conveyance system or another acceptable discharge point.

E.11 TCM-4 Sand Filters

Sizing Methodology

A sand filter is designed with two parts: (1) a temporary storage reservoir to store runoff, and (2) a sand filter bed through which the stored runoff must percolate. Usually the storage reservoir is simply placed directly above the filter, and the floor of the reservoir pond is the top of the sand bed. For this case, the storage volume also determines the hydraulic head over the filter surface, which increases the rate of flow through the sand.

Two methods are available for sizing sand filters: a simple method and a routing modeling method. The simple method uses standard values to define filter hydraulic characteristics for determining the sand surface area. This method is useful for planning purposes, for a first approximation to begin iterations in the detailed method, or when use of the detailed computer model is not desired or not available. The simple method very often results in a larger filter than the routing method.

Background

Sand filter design is based on Darcy's law:

$$Q = KiA \qquad \text{(Equation E-101)}$$

Where:

Q	=	water quality design flow (cfs)
K	=	hydraulic conductivity (fps)
A	=	surface area perpendicular to the direction of flow (ft^2)
i	=	hydraulic gradient (ft/ft) for a constant head and constant media depth, computed as follows:

$$i = \frac{h + l}{l} \qquad \text{(Equation E-102)}$$

Where:

h	=	average depth of water above the filter (ft), defined for this design as $d/2$
d	=	maximum storage depth above the filter (ft)
l	=	thickness of sand media (ft)

Darcy's law underlies both the simple and the routing methods of design. The filtration rate V, or more correctly, $1/V$, is the direct input in the sand filter design. The relationship between the filtration rate V and hydraulic conductivity K is revealed by equating Darcy's law and the equation of continuity, $Q = VA$. Specifically:

$$Q = KiA \quad \text{and} \quad Q = VA$$

So, $$VA = KiA$$

Or: $$V = Ki \qquad \text{(Equation E-103)}$$

Where,

V = filtration rate (ft/s)

Note that $V \neq K$. That is, the filtration rate is not the same as the hydraulic conductivity, but they do have the same units (distance per time). K can be equated to V by dividing V by the hydraulic gradient i, which is defined above.

The hydraulic conductivity K does not change with head nor is it dependent on the thickness of the media, only on the characteristics of the media and the fluid. A design hydraulic conductivity of 1 inch per hour (2 feet per day) used in this simple sizing method is based on bench-scale tests of conditioned rather than clean sand (KCSWDM, 2005) and represents the average sand bed condition as silt is captured and held in the sand bed.

Unlike the hydraulic conductivity, the filtration rate V changes with head and media thickness, although the media thickness is constant in the sand filter design.

Simple Sizing Method

The simple sizing method does not route flows through the filter. It determines the size of the filter based on the simple assumption that inflow is immediately discharged through the filter as if there were no storage volume. An adjustment factor (0.7) is applied to compensate for the greater filter size resulting from this method. Even with the adjustment factor, the simple method generally produces a larger filter size than the routing method.

Step 1: Determine the water quality design volume

Sand filters should be sized to capture and treat the stormwater quality design volume (see Section E.1).

Step 2: Determine maximum storage depth of water

Determine the maximum water storage depth (d) above the sand filter. This depth is defined as the depth at which water begins to overflow the reservoir pond, and it

depends on the site topography and hydraulic constraints. The depth is chosen by the designer, but shall be 6 feet or less.

Step 3: Calculate the sand filter area

Determine the sand filter area using the following equation:

$$A_{sf} = \frac{V_{wq} RL}{Kt(h+L)} \qquad \text{(Equation E-104)}$$

Where,

A_{sf}	=	surface area of the sand filter bed (ft^2)
V_{wq}	=	water quality design volume (ft^3)
R	=	routing adjustment factor (use R = 0.7)
L	=	sand bed depth (ft)
K	=	design hydraulic conductivity (use 2 ft/day)
t	=	drawdown time (use 1 day)
h	=	average depth of water above the filter (ft), (use $d/2$ with d from Step 1)

Routing Method

A continuous runoff model, such as US EPA's Storm Water Management Model (SWMM) Model, can be used to optimally size a sand filter. A continuous simulation model consists of three components: a representative long term period of rainfall data (≈ 20 years or greater) as the primary model input; a model component representing the tributary area to the sand filter that takes into account the amount of impervious area, soil types of the pervious area, vegetation, evapotranspiration, etc.; and a component that simulates the sand filter. Using this method, the filter should be sized to capture and treat the WQ design volume from the post-development tributary area.

The continuous simulation model routes predicted tributary runoff to the sand filter, where treatment is simulated as a function of the infiltrative (flow) capacity of the sand filter and the available storage volume above the sand filter. In a continuous runoff model such as SWMM, the physical parameters of the sand filter are represented with stage-storage-discharge relationships. Due to the computational power of ordinary desktop computers, long-term continuous simulations generally take only minutes to run. This allows the modeler to run several simulations for a range of sand filter sizes, varying either the surface area of the filter (and resulting flow capacity) or the storage capacity above the sand filter, or both. Sufficient

continuous model simulations should be completed so that results encompass the WQ design volume capture goal.

Model results should be plotted for both varying storage depths above the filter and for varying filter surface area (and resulting flow capacity) while keeping all other parameters constant. The resulting relationship of percent capture as a function of sand filter flow and storage capacity can be used to optimally size a sand filter based on site conditions and restraints.

In addition to continuous simulation modeling, routing spreadsheets and/or other forms of routing modeling that incorporate rainfall-runoff relationships and infiltrative (flow) capacities of sand filters may be used to size facilities. Alternative sizing methodologies should be prepared with good engineering practices.

Sizing Worksheet

Step 1: Determine water quality design volume		
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ =	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	%
1-3. Determine the maximum allowed effective impervious area (ac), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	acres
1-4. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=	
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA=	acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	
1-9. Enter design rainfall depth of the storm (in), P_i	P_i =	in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P =	ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560 \bullet C*P*A_{retain}$	SQDV=	ac-ft
Step 2: Determine maximum storage depth of water		
2-1. Determine the maximum storage depth (max 6 ft) of water above the sand filter, *d* (ft)	*d* =	ft

Step 3: Calculate sand filter area	
3-1. Enter water quality design volume, *SQDV*	SQDV = ft^3
3-2. Enter routing adjustment factor (use R =0.7), R	R =
3-3. Enter thickness of sand filter (min. 2 ft, 3 ft preferred), L	L = ft
3-4. Enter design hydraulic conductivity of media (use 2 ft/day), K_{des}	K = ft/day
3-5. Enter drawdown time, t	t = day
3-6. Calculate average depth of water above the filter, $h = d/2$	h = ft
3-7. Calculate sand filter area, $A_{sf} = (SQDV*RL)/(Kt\ (h+L))$	A_{sf} = ft^2
Step 4: Determine filter dimensions	
4-1. Sand filter area, A_{sf}	A_{sf} = ft^2
4-2. Enter geometric configuration, LR:W ratio (2:1 or greater), L_R	L_R =
4-3. Select the width of the sand filter, W	W = ft
4-4. Calculate the length of the sand filter, $L=WL_R$	L = ft
4-5. Calculate rate of filtration, $r_{wq} = K_i$; where $i = \frac{h+l}{l}$	r_{wq} = ft/d
Step 5: Calculate filter longitudinal underdrain collection pipe	
5-1. Calculated filtered flow rate, $Q_f = r_{wq}A_{sf}/86400$	Q_f = cfs
5-2. Enter minimum slope for energy gradient, S_e	S_e =

5-3. Enter Hazen-Williams coefficient for plastic, *C*	C =	
5-4. Enter pipe diameter (6" min.), *D*	D =	in
5-5. Calculate pipe hydraulic radius, $R_h = D/48$	R_h =	ft
5-6. Calculate velocity at the outlet of the pipe, $V_p = 1.318CR_h0.63S_e0.54$	V_p =	ft/s
5-7. Calculate pipe capacity, $Q_{cap} = 0.25\pi(D/12)^2V_p$	Q_{cap} =	cfs
Step 7: Provide conveyance capacity for filter clogging		
7-1. The sand filters should be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged.		

Design Example

Step 1: Determine water quality design volume

For this design example, a 10-acre site with soil type 4 and 60% total impervious area is considered. The 85th percentile storm event for the project location is 0.75 inches.

Step 1: Determine water quality design volume			
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ =	10	acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ =	5	
1-3. Determine the maximum allowed effective impervious area (ac), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$=	0.5	acres
1-4. Enter Project impervious fraction, Imp (e.g. 60% = 0.60)	Imp=	0.6	
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA=	6	acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} =	5.5	acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =	0.05	
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =	0.59	
1-9. Enter design rainfall depth of the storm (in), P_i	P_i =	0.75	in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P =	0.06	ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560 \bullet C*P*A_{retain}$	SQDV=	0.20	ac-ft

Step 1a: Determine maximum storage depth of water

Determine the maximum storage depth of water above the sand filter.

Step 1a: Determine maximum storage depth of water	
1a-1. Determine the maximum storage depth (max 6 ft) of water above the sand filter, *d* (ft)	*d* = 6 ft

Step 2: Calculate Sand Filter Area

A sand filter is designed with two components: (1) temporary storage reservoir to store runoff, and (2) a sand filter bed through which the stored runoff must percolate getting treatment.

The simple sizing method does not rout flows through the filter. The size of the filter is determined based on the simple assumption that inflow is immediately discharged through the filter. The adjustment factor, R, is applied to compensate for the greater filter size resulting from this method.

Step 2: Calculate sand filter area	
2-1. Enter water quality design volume, *SQDV*	SQDV = o.20 ac-ft
2-2. Enter routing adjustment factor (use R =0.7), *R*	*R* = 0.7
2-3. Enter thickness of sand filter (min. 2 ft, 3 ft preferred), *L*	*L* = 2 ft
2-4. Enter design hydraulic conductivity (use 2 ft/day), *K*	*K* = 2 ft/day
2-5. Enter drawdown time (use 1 day), *t*	*t* = 2 day
2-6. Calculate average depth of water above the filter, $h = d/2$	h = 3 ft
2-7. Calculate sand filter area, $A_{sf} = (SQDV*RL)/(Kt\ (h+L))$	A_{sf} = 0.014 acre

Step 3: Determine Filter Dimensions

Step 3: Determine filter dimensions	
3-1. Sand filter area in ft², $A_{sf(feet)}=A_{sf(acre)}*43{,}560$	A_{sf} = 610 ft²
3-2. Enter geometric configuration, LR:W ratio (2:1 min.), L_R	L_R = 2
3-3. Calculate the width of the sand filter, *W*	W = 18 ft

Step 3: Determine filter dimensions			
3-4. Calculate the length of the sand filter, L	L =	36	ft
3-5. Calculate rate of filtration, $r_{wq} = Ki$, where $i = \frac{h+l}{l}$	r_{wq} =	2.3	ft/d

Step 4: Calculate Filter Longitudinal Underdrain Collection Pipe

All underdrain pipes must be 6 inches or greater to facilitate cleaning.

Step 5: Calculate filter longitudinal underdrain collection pipe			
5-1. Calculated filtered flow rate, $Q_f = r_{wq}A_{sf}/86400$	Q_f =	0.01	cfs
5-2. Enter minimum slope for energy gradient, Se	S_e =	0.005	
5-3. Enter Hazen-Williams coefficient for plastic, C	C =	140	
5-4. Enter pipe diameter (6” min), D	D =	6	in
5-5. Calculate pipe hydraulic radius, $R_h = D/48$	R_h =	0.13	
5-6. Calculate velocity at the outlet of the pipe, $V_p = 1.318CR_h^{0.63}S_e^{0.54}$	V_p =	2.9	ft/s
5-7. Calculate pipe capacity, $Q_{cap} = 0.25\pi(D/12)^2V_p$	Q_{cap} =	0.57	cfs

Step 5: Provide Conveyance Capacity for Filter Clogging

The sand filters should be placed off-line, but an emergency overflow must still be provided in the event the filter becomes clogged.

APPENDIX F : FLOW SPLITTER DESIGN SPECIFICATIONS

F.1 Flow Splitter Introduction

Flow splitters must be provided for off-line facilities to divert the water quality design flow to the BMP and bypass higher flows. In most cases, it is a designer's choice whether storm water treatment BMPs described in this manual are designed as on-line or off-line; exceptions are vegetated strip filters, permeable pavement, and building BMPs which are designed on-line.

A crucial factor in designing flow splitters is to ensure that low flows are delivered to the treatment facility up to the water quality design flow rate. Above this rate, additional flows remain in the storm drain or are diverted to a bypass drain with minimal increase in head at the flow splitter structure to avoid surcharging the water quality facility under high flow conditions.

Flow splitters are typically manholes or vaults with baffles. In place of baffles, the splitter mechanism may be a half tee section with a solid top and an orifice in the bottom of the tee section. A full tee option may also be used (see "Design Criteria" below). Two possible design options for flow splitters are shown in the figures in this Appendix. Other equivalent designs that achieve the result of splitting low flows, up to the WQ design flow, into the WQ treatment facility and divert higher flows around the facility are also acceptable.

Flow splitters may be modeled using standard level pool routing techniques, as described in the Handbook of Applied Hydrology (Ven te Chow; 1964) and elsewhere. The stage/discharge relationship of the outflow pipes shall be determined using backwater analysis techniques. Weirs shall be analyzed as sharp-crested weirs.

Design Criteria

1) A flow splitter shall be designed to deliver the required water quality design flow rate to the storm water treatment facility.

17) The top of the weir shall be located at the water surface for the design flow. Remaining flows enter the bypass line.

18) The maximum head shall be minimized for flow in excess of the water quality design flow. Specifically, flow to the treatment facility at the flood control design storm water surface shall not increase the design water quality design flow by more than 10%.

19) Example designs are shown in the figures in this Appendix. Equivalent designs are also acceptable.

20) Special applications, such as roads, may require the use of a modified flow splitter. The baffle wall may be fitted with a notch and adjustable weir plate to proportion runoff volumes other than high flows.

21) For ponding facilities, backwater effects must be included in designing the height of the standpipe in the manhole.

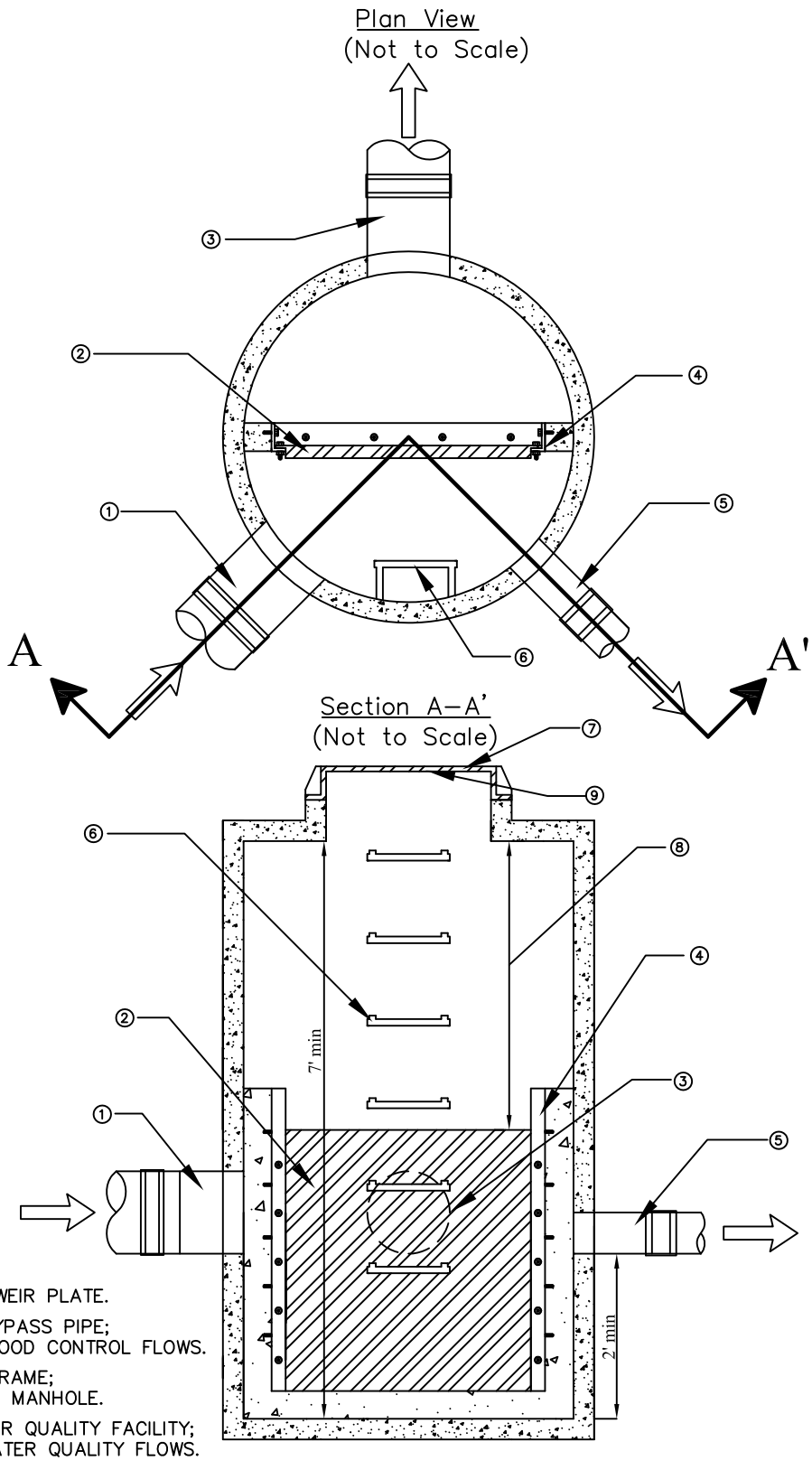
22) Ladder or step and handhold access shall be provided. If the weir wall is higher than 36 inches, two ladders, on the either side of the wall, are required.

F.2 Material Requirements

1) The splitter baffle shall be installed in a standard manhole or vault. The baffle wall shall be made of material resistant to corrosion (minimum 4-inch thick reinforced concrete, Type 302 or Type 316 stainless steel plate, or equivalent).

23) The minimum clearance between the top of the baffle wall and the bottom of the manhole or vault cover shall be 4 feet; otherwise, dual access points shall be provided.

24) All metal parts shall be corrosion resistant. Examples of preferred materials include aluminum, stainless steel, and plastic. Zinc and galvanized materials are not permitted because of aquatic toxicity. Painting metal parts shall not be allowed because of poor longevity.



NOTES:

① INLET PIPE.

② ADJUSTABLE WEIR PLATE.

③ HIGH FLOW BYPASS PIPE; SIZED FOR FLOOD CONTROL FLOWS.

④ WEIR PLATE FRAME; ANCHORED TO MANHOLE.

⑤ PIPE TO WATER QUALITY FACILITY; SIZED FOR WATER QUALITY FLOWS.

⑥ ACCESS STEPS.

⑦ 24" ROUND FRAME AND SOLID LID.

⑧ 4' MIN DISTANCE OR PROVIDE SEPARATE ACCESS ON BOTH SIDES OF WEIR.

⑨ AFFIX PERMANENT IDENTIFICATION TAG.

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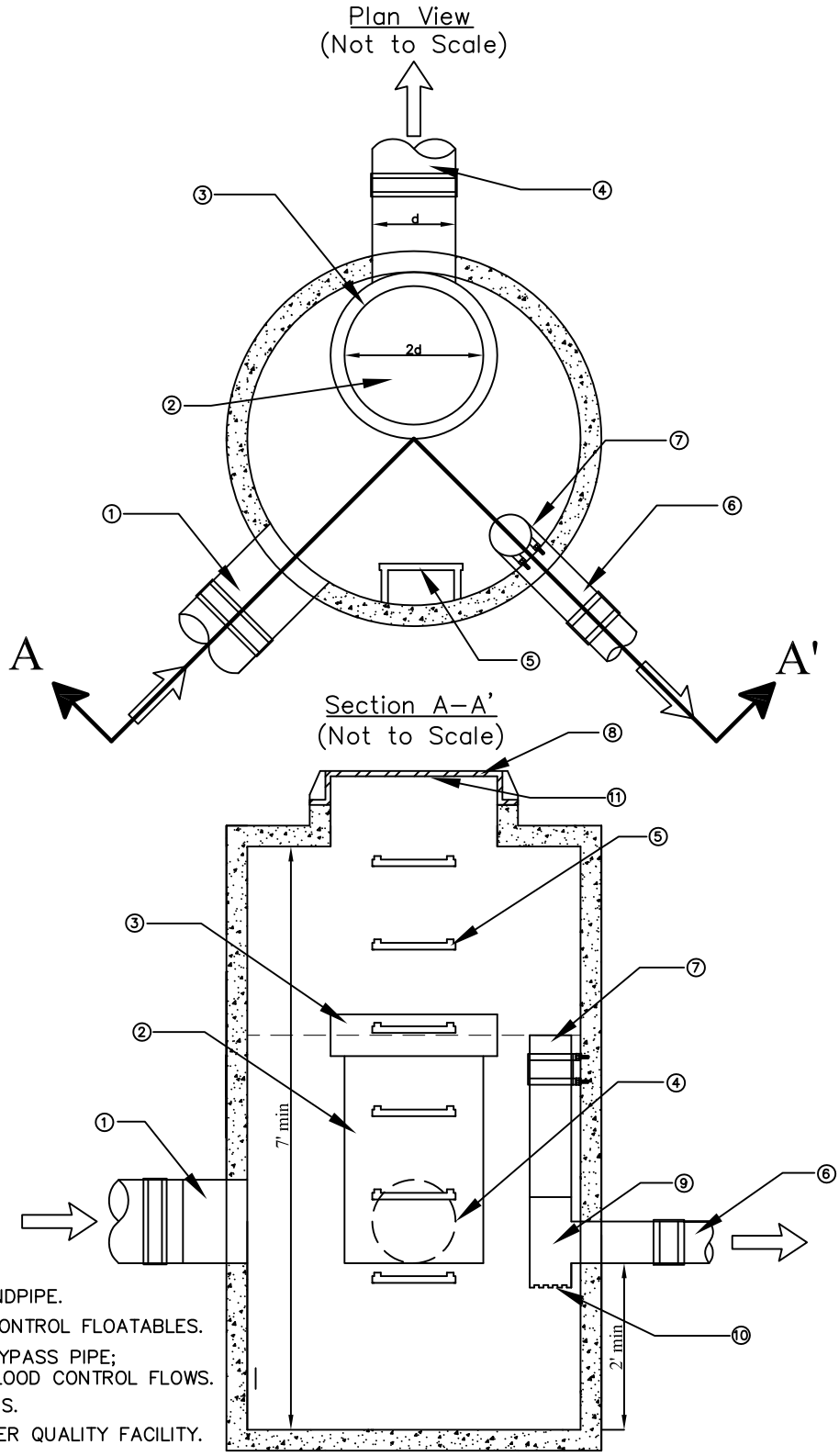
Figure F-1: Flow Splitter Option A



NOTES:

① INLET PIPE.
② BYPASS STANDPIPE.
③ BAFFLE TO CONTROL FLOATABLES.
④ HIGH FLOW BYPASS PIPE; SIZED FOR FLOOD CONTROL FLOWS.
⑤ ACCESS STEPS.
⑥ PIPE TO WATER QUALITY FACILITY.
⑦ RISER PIPE; TOP OF PIPE AT DESIGN ELEVATION FOR WATER QUALITY FLOWS.
⑧ 24" ROUND FRAME AND SOLID LID.
⑨ REMOVABLE "TEE" SECTION FOR CLEANOUT.
⑩ RISER PIPE ORIFICE SIZED FOR WATER QUALITY FLOWS.
⑪ AFFIX PERMANENT IDENTIFICATION TAG.

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Figure F-2: Flow Splitter Option B

APPENDIX G: DESIGN CRITERIA CHECKLISTS FOR STORMWATER RUNOFF BMPS

BIO-1 Bioretention Checklist

- ☐ Has the bioretention facility been sized to treat the water quality design volume, SQDV (see worksheet)?
- ☐ Does the bioretention have a maximum ponding depth of 18 in.?
- ☐ Is the planting soil depth at least 2 feet?
- ☐ Has an underdrain been provided if native soil permeability is less than 0.5 in/hr and infiltration is not possible/allowed?
- ☐ Has a gravel drainage layer been provided if native soil permeability is greater than 0.5 in/hr and infiltration is possible/allowed?
- ☐ Does the bioretention ponding depth drain below the planting soil in less than 48 hours?
- ☐ Is the gravel drainage layer sized to adequately meet the maximum drawdown time of 96 hours?
- ☐ Has the bioretention facility been properly sized as recommended in the manual?
- ☐ Does the flow entrance meet specifications (dispersed, low velocity flow; dispersed flow across pavement; flow spreading trench; cuts or wheel slots for parking lots)?
- ☐ Does the pipe flow entrance include erosion protection material to dissipate flow energy?
- ☐ Is the flow path unblocked by trees and shrubs?
- ☐ Is the underdrain at least 6 inches in diameter?
- ☐ Is the underdrain pipe made of accepted material (slotted PVC pipe conforming to ASTM C 3034 or equivalent HDPE pipe conforming to AASHTO 252M)?
- ☐ Does the slotted pipe have correct sizing and spacing of slots?
- ☐ Is the underdrain sloped at 0.5% or more?
- ☐ Are rigid observation pipes connected to underdrain every 250 to 300 feet of installed pipe?
- ☐ Do the observation pipe wells/clean outs extend 6 inches above top elevation of bioretention facility mulch and are they capped as required?

- ☐ Does the gravel underdrain bedding consist of the correct aggregate?
- ☐ If geotextile fabric is placed between the planting media and gravel layer, does it meet the specifications outlined in the manual?
- ☐ Does the gravel underdrain bedding extend at least 6 inches below the underdrain pipe (if needed) and does it provide 1 foot depth around top and sides of pipe?
- ☐ Does the underdrain drain freely to the accepted discharge point?
- ☐ Is an overflow device consisting of vertical PVC pipe included in design?
- ☐ Has the overflow device been installed at the 18-inch ponding depth?
- ☐ Is the overflow riser at least 6 inches in diameter?
- ☐ Has the inlet to the riser been positioned at least 6 inches above the planting media and capped with a spider cap?
- ☐ If bioretention is close to roads or infrastructure, have infiltration pathways been restricted with geomembrane (at least 30 mm) or clay liners?
- ☐ Is planting soil composed of correct aggregate (60-70% sand; 30-40% compost) and free of stones, stumps and roots?
- ☐ Does compost have acceptable characteristics?
- ☐ Is constructed bioretention facility covered with well-aged mulch, free of seeds, weeds, soil and roots, and at least 2-3 inches thick?
- ☐ Is all bioretention vegetation tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 72 hours?
- ☐ Have an adequate number of different plant species been incorporated into the bioretention (It is recommended that 3 tree, 3 shrub, and 3 herbaceous groundcover species be included)?
- ☐ Have native plants been used to the maximum extent practicable?

BIO- 2 Planter Box Checklist

- ☐ Is the planter box tributary area less than 15,000 ft2?
- ☐ Is the groundwater level at least 2 feet below the bottom of the planter box?
- ☐ Is there adequate relief between land surface and stormwater conveyance system to permit vertical percolation?
- ☐ Is the planter box located in an area with adequate sunlight to support selected vegetation?
- ☐ Is the planter box sized to treat the water quality design volume, Vwq (see worksheet)?
- ☐ Does the planter box have a maximum ponding depth of 12 inches?
- ☐ Is the planting soil depth at least 2 feet (3 feet preferred)?
- ☐ Does the ponded water drain below the planting soil in less than 48 hours?
- ☐ Has the distance between the downspouts and the overflow outlet been maximized?
- ☐ Has the planter box been sized the same as a Bioretention facility with planter box parameters?
- ☐ Has the planter box been constructed with an appropriate non-leaching permanent material?
- ☐ Has the planter box structure been adequately sealed to ensure that water exits only via the underdrain?
- ☐ Has an underdrain been provided?
- ☐ If the entrance to the planter box is piped, has erosion protection been included in the design (erosion protection includes rock, splash blocks, etc.)?
- ☐ Is the entrance flow path unimpeded by woody plants (trees, shrubs)?
- ☐ Is the underdrain at least 6 inches in diameter?
- ☐ Is the underdrain pipe made of accepted material (slotted PVC pipe conforming to ASTM C 3034 or equivalent HDPE pipe conforming to AASHTO 252M)?
- ☐ Does the slotted pipe have correct sizing and spacing of slots?
- ☐ Is the underdrain sloped at 0.5% or more?

- ☐ Are rigid observation pipes connected to underdrain every 250 to 300 feet of installed pipe?
- ☐ Do the observation pipe wells/clean outs extend 6 inches above top elevation of the planter box mulch and are they capped as required?
- ☐ Does the gravel underdrain bedding consist of the correct aggregate?
- ☐ Does the gravel underdrain bedding extend at least 6 inches below the underdrain and does it provide 1 foot depth around top and sides of pipe?
- ☐ If geotextile fabric is used in the underdrain design, does it meet minimum materials requirements?
- ☐ Is the underdrain elevated from the bottom of the planter box by 6 inches?
- ☐ Does the underdrain drain freely to the intended discharge point?
- ☐ Is an overflow device consisting of vertical PVC pipe included in design?
- ☐ Is the overflow riser at least 6 inches in diameter?
- ☐ Is the inlet to the riser 6 inches above planting soil and capped with a spider cap?
- ☐ Has a waterproof barrier consisting of a 30 mil geomembrane or equivalent been provided to protect foundations from moisture?
- ☐ Is planting soil composed of correct aggregate (60-70% sand; 30-40% compost) and gradation, and free of stones, stumps and roots?
- ☐ Does compost have acceptable characteristics (see planting/storage media)?
- ☐ Is planter box covered with well-aged mulch, free of seeds, weeds, grass clippings, bark, soil and roots, and at least 2-3 inches thick?
- ☐ Do all soil minerals meet requirements?
- ☐ Is all planter box vegetation tolerant of summer drought, ponding fluctuations, and saturated soil conditions for 48 to 72 hours?
- ☐ Have an adequate number of different plant species been incorporated into the planter box design (It is recommended that 3 tree, 3 shrub, and 3 herbaceous groundcover species be included)?
- ☐ Have native plants been used to the maximum extent practicable?
- ☐ Have only slow-release fertilizers been included in the design?
- ☐ Have arrangements been made to replace planter box mulch layer annually?

- ☐ Have low-maintenance plants been selected for design?
- ☐ Has an effort been made to ensure that no treated wood or galvanized metal is used anywhere within the planter box design?

BIO-3 Proprietary Biotreatment Device Checklist

- ☐ Has the proprietary biotreatment device been selected from the list provided in the manual of from another Ventura County- approved list?
- ☐ Has the vendor been contacted for the latest design guidance on cartridge selection?
- ☐ Has the proprietary biotreatment device been installed as directed by the vendor?
- ☐ Have appropriate maintenance and operation arrangements been made to ensure upkeep of the device?
- ☐ Has the biotreatment device been sized to capture and treat the water quality design flow?

BIO-4 Vegetated Swale Checklist

- ☐ Does the climate provide adequate conditions for maintaining a vegetative cover? Has adequate vegetation been chosen given the climate?
- ☐ Is the grade in the area shallow so as to not allow ponding?
- ☐ Is the swale compatible with existing flood control functions?
- ☐ Has the swale been designed with a depth of one foot or less?
- ☐ Is the overall depth from the top of the side walls to the bottom of the swale at least 12 inches?
- ☐ Is the swale bottom width at least 2 feet?
- ☐ Is the swale bottom width no greater than 10 feet, or 16 feet with a dividing berm?
- ☐ If the swale is required to convey flood flows in addition to the water quality design flow, has the swale been designed for the flood control design storm and does it include 2 feet of freeboard?
- ☐ Have gradual meandering bends been incorporated into the design?
- ☐ Is the longitudinal slope (in direction of flow) between 1% and 6%?
- ☐ Has an underdrain been provided if soils are poorly drained and longitudinal slope is less than 1.5%? Has a soils report been provided if this is the case?
- ☐ If the longitudinal slope is greater than 6%, have appropriate check dams with vertical drops of 12 inches or less been provided in the design to reduce the slope?
- ☐ Is the horizontal slope at the bottom of the swale flat to discourage channeling?
- ☐ Has the swale been designed so that the water depth does not exceed 4 inches or 2/3 the height of vegetation (2 inches in frequently mowed turf swales?
- ☐ Does the swale length provide a minimum hydraulic residence time of 7 minutes?
- ☐ If soil and slope conditions require it, has an acceptable low flow drain been installed?
- ☐ Has the swale been designed to convey the SQDF?

- ☐ Has the swale been sized as recommended in Chapter 6 (also see worksheet, Appendix E)?
- ☐ Has the swale been designed as a flow-through channel or has a high-flow bypass been incorporated into the design for flows higher than the water quality design flow?
- ☐ Has inflow been directed towards the upstream end of the swale or, at a minimum, evenly over the length of the swale?
- ☐ If the swale is online, has it been designed to convey flows up to the post-development 100 year 24 hour storm, with freeboard, and velocities below 3 ft/s?
- ☐ If the swale is off-line, has it been designed to convey the water quality design flow rate using a flow splitter with velocities below 1 ft/s?
- ☐ If check dams are incorporated in the design, have flow spreaders been added at the toe of each vertical drop?
- ☐ If curb cuts are used, has pavement been placed 1 – 2 inches above the elevation of the vegetated area?
- ☐ Is the swale inflow designed to function long term with minimal maintenance?
- ☐ Has flow spreading at the inlet of the swale been achieved by a leveled anchored flow spreader or similar method?
- ☐ Does the flow spreader project a minimum of 2 inches above the ground surface with appropriately spaced notches and extend horizontally beyond facility to prevent erosion
- ☐ If an underdrain is required, does it meet appropriate criteria (PVC or equivalent, correct slot spacing and sizing, 6 inches minimum in diameter, sloped at 0.5%)?
- ☐ Is there gravel bedding at least 6 inches below and 1 foot to the top and sides of the underdrain?
- ☐ If a geotextile is included in the design, does it meet requirements?
- ☐ Does gravel drainage layer meet recommended criteria?
- ☐ Does swale divider, if included, meet criteria (minimum height of 1 inch above flow, slopes no steeper than 2H:1V, stable foundation)?

- ☐ Has swale soil been amended with compost if organic content is less than 10%?
- ☐ Have appropriate, hardy and native plants been used to the maximum extent practical?
- ☐ Is vegetative cover at least 4 inches in height (ideally 6 inches)?
- ☐ Has the swale been located away from trees that may drop leaves or provide insufficient sunlight?

BIO-5 Vegetated Filter Strip Checklist

- ☐ Is the slope of the filter strip designed to avoid both erosive flows and ponding?
- ☐ Has the strip been designed to evenly distribute flow across width and promote sheet flow?
- ☐ Does the width of the filter strip extend across the full width of the tributary area?
- ☐ Is the upstream boundary of the filter located contiguous to developed area?
- ☐ If filter strip is used for water quality purposes, is the length between 15 and 150 feet (25 feet preferred)? If the strip is used for pretreatment, is it at least 4 feet in length?
- ☐ Is the slope of the strip parallel to the direction of flow between 2% and 6%?
- ☐ Is the lateral slope (perpendicular to flow) of the strip 4% or less?
- ☐ Is grading across strip even?
- ☐ Has the top of the strip been installed 2 to 5 inches below any adjacent pavement (a beveled transition is also acceptable)?
- ☐ Are the top and toe of the slope as flat as possible (graded flat for engineered filter strips) to encourage sheet flow and prevent erosion?
- ☐ Has the design flow been calculated using the SQDF (see worksheet)?
- ☐ Has the design flow depth been calculated using a modified Manning's equation (see worksheet)?
- ☐ Have the design velocity and length been calculated using the design flow and design flow depth as recommended (see worksheet)?
- ☐ Has a flow spreader been implemented to uniformly distribute contributing flow along width of filter strip?
- ☐ If a gravel flow spreader is used, is it at least 6 inches deep, 12 inches wide and a minimum or 1 inch below the paved surface?
- ☐ Has the gravel flow spreader been leveled even where ground is not level?
- ☐ If the gravel flow spreader is placed along a roadway, have LA county design specifications been consulted and implemented?

- ☐ If a notched curb spreader and through-curb spreader are used, have they been used in conjunction with a gravel spreader?
- ☐ Have curb port/interrupted curb openings been spaced at intervals of at least every 6 feet?
- ☐ Do the curb port/interrupted curb openings have a width of at least 11 inches?
- ☐ Does 15% or more of the curb length consist of open ports and does each port discharge no more than 10% of the flow?
- ☐ Have energy dissipaters (such as a riprap pad) been used if a sudden slope drop occurs?
- ☐ Has access been provided at the upper edge of filter strip for mowing equipment and to enable maintenance of spreader?
- ☐ Is the design water depth 1 inch or less?
- ☐ Does the design velocity not exceed 1 foot per second?
- ☐ If the organic content of the filter strip soil does not exceed 10%, has the soil been amended with at least 2 inches of well-rotted acceptable compost at a depth of 6 inches?
- ☐ Is filter strip uniformly graded and densely vegetated with erosion-resistant grasses (preferably native or adapted species)?
- ☐ Has irrigation been provided to establish grasses?
- ☐ Have maintenance arrangements been made to maintain grass at a height of 2 to 4 inches?
- ☐ Have trees and shrubs been limited along the filter strip?
- ☐ Has an effort been made to ensure that no treated wood or galvanized metal is used anywhere within the design?

BIO-6 Green Roof Checklist

- ☐ Is the roof shallow enough to support a green roof (<25% slope)?
- ☐ Are the roof supports sufficient to support additional weight of soil, water, vegetation, and a drainage layer (if needed) [a licensed structural engineer should be consulted]?
- ☐ Has an appropriate waterproof membrane been placed below the green roof?
- ☐ Has an appropriate drainage layer been incorporated in the design (if required)?
- ☐ Has an appropriate soil mix been used in the design to allow for drainage, support vegetative growth, and that is not excessively heavy when wet?
- ☐ Has vegetation been carefully selected to improve aesthetics, resist erosion, withstand extreme environments, and tolerate drought without the need for fertilizers and pesticides and without a lot of maintenance requirements (see Appendix H for a recommended plant list)?
- ☐ Have native plants been chosen to the maximum extent practical?
- ☐ If trees or shrubs are incorporated, has an adequate soil depth been provided and is the additional soil depth supported by the roof structure?
- ☐ Has irrigation been provided to establish vegetation?
- ☐ Does vegetation cover 90% of the total area?
- ☐ Is the green roof located in an area without excessive shade to avoid poor vegetative growth?
- ☐ Is there an appropriate drain pipe or gutter to convey any runoff from roof to a stormwater BMP or stormwater conveyance system?

FILT-1 Sand Filter Checklist

- ☐ Has sand filter been located away from trees and areas that could contribute eroded sediment?
- ☐ If there is a chance for sediment to be present in flow to be treated, has pretreatment been provided?
- ☐ Does site have adequate relief to permit vertical percolation through sand filter and into conveyance system?
- ☐ Has pretreatment (vegetated swale or filter strip, hydrodynamic separator) been adequately provided to reduce the sediment load entering the filter?
- ☐ Has the sand filter been sized to capture the SQDV?
- ☐ Has the sand filter been designed with a 1.5:1 length to width ratio or greater?
- ☐ Is the filter bed depth at least 2 feet (3 feet preferred)?
- ☐ Is the depth of water storage over the filter bed 6 feet or less?
- ☐ Is the overflow structure designed to pass the water quality design storm?
- ☐ Has the sizing of the filter been determined using the adapted Darcy's Law equation recommended in the sizing methodology section in Chapter 6 (also see worksheet, Appendix E)?
- ☐ Does the sand meet the recommended specifications (0.2-0.35 mm diameter, Cu < 3, ASTM C 33 size gradation, etc.)?
- ☐ Has an underdrain been employed in the design? [Examples: central underdrain w/lateral pipes, longitudinal pipes, single pipe for small filters]
- ☐ Is the underdrain placed in an 8 inch minimum gravel backfill or drain rock bed?
- ☐ Are all underdrain pipes and connectors 6 inches or greater with clean-out risers of equal diameter?
- ☐ Have clean-out risers been placed at the terminal ends of all pipes and extend to the surface of the filter?
- ☐ Has a valve box been provided for access to the clean-outs and is it water tight?
- ☐ Are underdrain pipes laid with perforations downward, and are perforations at least ½ inch in diameter?

- ☐ Are all lateral collection pipes within 9 feet or less of each other (perpendicular distance)?
- ☐ Have all pipes been placed with a minimum slope of 0.5%?
- ☐ Is the invert of the underdrain outlet above the seasonal high groundwater level?
- ☐ Is gravel backfill present around the underdrain pipe at least 6 inches below and to the sides of the pipe and 8 inches above the pipe?
- ☐ Does the bottom gravel have a diameter of at least 2 times the size of the perforated openings to the drainage system and meet other specifications (specific gravity of 2.5 or more, rounded, free of debris)?
- ☐ Has an appropriate geotextile layer (see underdrain section) or 2-inch transition layer been placed between the sand layer and the drain rock/ gravel backfill layer?
- ☐ Has a flow spreader been installed at the inlet along one side of the filter (long side of the filter if L: W is 2:1 or greater; 20% of perimeter for curved or irregular shape)?
- ☐ Has erosion protection been provided along the first foot of the sand bed adjacent to the flow spreader (i.e. geotextile weighted with sand bags; quarry spalls)?
- ☐ Has no topsoil, clay, or sod (except sod grown in sand) has been added to the sand filter bed?
- ☐ Has vegetation been selected properly (i.e. must withstand drought, heavy saturation, etc.)?
- ☐ Are no permanent structures built on top of the sand filter bed?
- ☐ No large shrubs or trees should be planted in sand filter bed or within 15 feet of inlet or outlet pipes
- ☐ Have native plants been used to the maximum extent practicable?
- ☐ Has an emergency overflow structure been provided?
- ☐ Are interior side slopes above water quality design depth no steeper than 3:1 H:V?
- ☐ Are exterior side slopes no steeper than 2:1 H:V?
- ☐ If pond walls are vertical retaining walls, do they meet recommended specifications (see side slopes section)?

- ☐ Do embankments meet appropriate criteria [top width or 20 feet, constructed on native consolidated soil, in accordance with standard specifications, proper excavation, constructed of appropriate compacted soil]?
- ☐ Are maintenance access roads/ramps to filter provided?
- ☐ Have trees and shrubs been planted further than 10 feet away from inlet and outlet pipes (50 feet for 'water-seeking' plants such as willows and poplars)?
- ☐ Have prohibited non-native plants been removed from the site?
- ☐ Has an effort been made to ensure that no treated wood or galvanized metal is used anywhere within the planter box design?

FILT-2 Cartridge Media Filter

- ☐ Has the vendor been contacted for the latest design guidance on cartridge selection?
- ☐ Has the cartridge media filter been provided with a system to completely drain the system and prevent vector annoyances?
- ☐ Has the cartridge media filter been sized to capture and treat the SQDF?
- ☐ Have site considerations been taken into account when sizing the cartridge media filter and selecting features (often vendor websites offer assistance with this)?

INF-1 Infiltration Trench Checklist

- ☐ Has the infiltration trench been located away from steep slopes (>25%)?
- ☐ Is the infiltration trench set back from structures and leach fields?
- ☐ Is there at least 10 feet or vertical separation between the bottom of the infiltration trench and the shallow groundwater table?
- ☐ Is the depth to bedrock adequate to provide proper infiltration?
- ☐ Has the site been checked to ensure that no preexisting contamination is present?
- ☐ Does the site have low sediment loading rates to prevent infiltration trench clogging?
- ☐ Has a soil assessment report been completed, which determines the suitability of the site for an infiltration trench, recommends a design infiltration rate, identifies the high depth to groundwater table surface elevation, and examines how the stormwater runoff will move in the soil?
- ☐ Has a geotechnical investigation and report been provided if needed?
- ☐ Has the infiltration trench been located at a site that does not receive run off from sites that store or use chemicals or hazardous waste outside?
- ☐ Has the infiltration trench been set back from existing septic system drain fields and drinking water wells?
- ☐ Has pretreatment been provided with a vegetated swale, filter strip, sand filter or proprietary device?
- ☐ Is the trench at least 2 feet wide and 3 to 5 feet deep?
- ☐ Is the longitudinal slope of the trench 3% or less?
- ☐ Is the top layer of the media filter gravel/choking stone/geotextile fabric if flow is sheet flow and 12 inches of surface soil if flow enters through an underground pipe?
- ☐ Is middle layer of media filter 3-5 feet of washed 1.5 to 3 in. gravel with void space of 30 to 40%?
- ☐ Is bottom layer of media filter 6” of clean, washed sand?
- ☐ Have one or more observation wells been installed?

- ☐ Do observation wells consist of recommended slotted 4-6 inch diameter PVC well screen capped with lockable, above-ground lid?
- ☐ Has the infiltration trench been sized to capture and infiltrate the SUSMP defined water quality design volume?
- ☐ Has the infiltration trench been designed to infiltrate all runoff within 72 hours?
- ☐ Has the maximum depth of runoff, ponding depth/trench depth and infiltrating surface area been calculated using recommended design equations (see sizing methodology section/worksheet)?
- ☐ Is the bottom of the infiltration bed native soil, over-excavated to at least one foot in depth and replaced uniformly (with 2-4 inches of coarse sand amendments) without compaction?
- ☐ Has all vertical piping been classified correctly (see drainage section in manual)?
- ☐ Has an observation well been incorporated into the design to ensure that the 72 hour maximum drawdown time is met?
- ☐ Has an overflow route been provided to safely convey flows that overtop the facility or in the case that the facility becomes clogged?
- ☐ Has the overflow channel been designed to safely convey flows from peak design storm to a downstream conveyance system or acceptable discharge point?
- ☐ Has the infiltration trench been kept free of vegetation, and is all existing vegetation surrounding the trench been planted away from trench to avoid drip lines overhanging the facility?
- ☐ Is there safe maintenance access provided to the site for both wet and dry conditions?
- ☐ Has an access road along the length of the trench been provided if there is no existing road or parking lot that can be used for maintenance access?
- ☐ Has access to “operate a backhoe at ‘arms length’” been provided?
- ☐ Was the entire area draining to the facility stabilized before construction began?
- ☐ Have you ensured that the infiltration trench is not hydraulically connected to the storm water conveyance system?

- ☐ If heavy construction material was used to compact subgrade (not recommended), has the infiltrative capacity of the soil been restored via tilling or aerating prior to placing the infiltration bed?
- ☐ Were the exposed subgrade soils inspected by a civil engineer prior to construction to confirm suitable soil conditions for the infiltration facility?

INF-2 Drywell Checklist

- ☐ Has the drywell been located away from steep slopes (>25%)?
- ☐ Is the drywell set back from structures and leach fields?
- ☐ Is there at least 10 feet or vertical separation between the bottom of the drywell and the shallow groundwater table?
- ☐ Is the depth to bedrock adequate to provide proper infiltration?
- ☐ Has the site been checked to ensure that no preexisting contamination is present?
- ☐ Does the site have low sediment loading rates to prevent drywell from clogging?
- ☐ Has pretreatment been provided for all non-rooftop runoff flowing to the drywell?
- ☐ Has a geotechnical investigation and report been provided to ensure site meets specifications for an infiltration facility (including soil infiltration rate, groundwater separation, and no steep slopes)?
- ☐ Has a soil assessment report been completed, which determines the suitability of the site for an drywell, recommends a design infiltration rate, identifies the high depth to groundwater table surface elevation, and examines how the stormwater runoff will move in the soil?
- ☐ Has the drywell been located at a site that does not receive run off from sites that store or use chemicals or hazardous waste outside?
- ☐ Has the drywell been set back from existing septic system drain fields and drinking water wells?
- ☐ Has pretreatment been provided to prevent sediment and other large particulates?
- ☐ Is the surface area of the drywell large enough to infiltrate the storage volume in 72 hours based on maximum allowable depth?
- ☐ Is the top layer of the media filter gravel/choking stone/geotextile fabric if flow is sheet flow and 12 inches of surface soil if flow enters through an underground pipe (pipe should be fitted with a screen)?
- ☐ Is middle layer of media filter 3-5 feet of washed 1.5 to 3 in. gravel with void space of 30 to 40%?
- ☐ Is bottom layer of media filter 6” of clean, washed sand?

- ☐ Have one or more observation wells been installed?
- ☐ Do observation wells consist of recommended slotted 4-6 inch diameter PVC well screen capped with lockable, above-ground lid?
- ☐ Has the drywell been sized to capture and infiltrate the SUSMP defined water quality design volume?
- ☐ Has the drywell been designed to infiltrate all runoff within 72 hours?
- ☐ Has a long term percolation rate of 10% of the measured percolation rate been used in design (due to occlusion and particulate accumulation)?
- ☐ Has the maximum depth of runoff, ponding depth/trench depth and infiltrating surface area been calculated using recommended design equations (see sizing methodology section/worksheet)?
- ☐ Is the bottom of the infiltration bed native soil, over-excavated to at least one foot in depth and replaced uniformly (with 2-4 inches of coarse sand amendments) without compaction?
- ☐ Has all vertical piping been classified correctly (see drainage section in manual)?
- ☐ Has an observation well been incorporated to ensure that the 72 hour maximum drawdown time is met?
- ☐ Has an overflow route been provided to safely convey flows that overtop the facility or in the case that the facility becomes clogged?
- ☐ Has the overflow channel been designed to safely convey flows from peak design storm to a downstream conveyance system or acceptable discharge point?
- ☐ Has the drywell been kept free of vegetation, and is all existing vegetation surrounding the trench been planted away from trench to avoid drip lines overhanging the facility?
- ☐ Is there safe maintenance access provided to the site for both wet and dry conditions?
- ☐ Has maintenance access been provided?
- ☐ Was the entire area draining to the facility stabilized before construction began?
- ☐ Have you ensured that the infiltration trench is not hydraulically connected to the storm water system?

- ☐ If heavy construction material was used to compact subgrade (not recommended), has the infiltrative capacity of the soil been restored via tilling or aerating prior to placing the infiltration bed?
- ☐ Were the exposed subgrade soils inspected by a civil engineer prior to construction to confirm suitable soil conditions for the infiltration facility?

INF-3 Proprietary Infiltration BMPs Checklist

- ☐ Has the infiltration facility been located away from steep slopes (>25%)?
- ☐ Is the infiltration facility set back from structures and leach fields?
- ☐ Is there at least 10 feet or vertical separation between the bottom of the infiltration facility and the shallow groundwater table?
- ☐ Is the depth to bedrock adequate to provide proper infiltration?
- ☐ Has the site been checked to ensure that no preexisting contamination is present?
- ☐ Does the site have low sediment loading rates to prevent infiltration facility clogging?
- ☐ Has pretreatment been provided to prevent premature failure (If infiltration facility fails, complete construction is required)?
- ☐ Has infiltration facility been designed to receive runoff only from sections of the site that have been stabilized?
- ☐ If infiltration facility fails, complete construction is required
- ☐ Has a geotechnical investigation and report been provided to ensure site meets specifications for an infiltration facility (including soil infiltration rate, groundwater separation, and no steep slopes)?
- ☐ Has a soil assessment report been completed, which determines the suitability of the site for an infiltration trench, recommends a design infiltration rate, identifies the high depth to groundwater table surface elevation, and examines how the stormwater runoff will move in the soil?
- ☐ Has the infiltration trench been located at a site that does not receive run off from sites that store or use chemicals or hazardous waste outside?
- ☐ Has the infiltration BMP been sized to capture and treat the water quality design volume?
- ☐ Has a long term percolation rate of 10% of the measured percolation rate been used in design (due to occlusion and particulate accumulation)?
- ☐ Have the recommended sizing guidelines set by the vendor been referenced and used for selection and use of infiltration facility?

INF-4 Permeable Pavement Checklist

- ☐ Has the permeable pavement been located away from steep slopes (>25%)?
- ☐ Is the permeable pavement set back from structures and leach fields?
- ☐ Is there at least 10 feet or vertical separation between the bottom of the permeable pavement and the shallow groundwater table?
- ☐ Is the depth to bedrock adequate to provide proper infiltration?
- ☐ Has the site been checked to ensure that no preexisting contamination is present?
- ☐ Does the site have low sediment loading rates to prevent infiltration trench clogging?
- ☐ Has the permeable pavement been designed to receive runoff only from sections of the site that have been stabilized?
- ☐ Has a geotechnical investigation and report been provided to ensure site meets specifications for an infiltration facility (including soil infiltration rate, groundwater separation, and no steep slopes)?
- ☐ Has a soil assessment report been completed, which determines the suitability of the site for an infiltration trench, recommends a design infiltration rate, identifies the high depth to groundwater table surface elevation, and examines how the stormwater runoff will move in the soil?
- ☐ Has the permeable pavement been located at a site that does not receive run off from sites that store or use chemicals or hazardous waste outside?
- ☐ Has the run off been assessed for necessity of pretreatment?
- ☐ If pretreatment is required, has it been provided to treat run on before it reaches permeable pavement?
- ☐ Has the infiltration BMP been sized to capture and treat the water quality design volume?
- ☐ Have the infiltration capabilities of the site been assessed (i.e. full, partial, or no infiltration allowed)?
- ☐ If no infiltration is allowed, has an underdrain been prohibited?

- ☐ If permeable pavement is located on a site with a slope greater than 2%, has the area been terraced to prevent lateral flow through subsurface?
- ☐ Has the permeable pavement been designed to infiltrate flows through four different layers (incl. top wearing layer, stone reservoir, and transition layers) of material (or through a similar system)?
- ☐ Has the depth of each layer (and void space), along with the hydrology, hydraulics, and structural requirements of the site been determined and approved by a licensed civil engineer?
- ☐ If proprietary permeable pavement is used (i.e. concrete or other pavers), have the design requirements and installation steps been obtained from the vendor and referenced in the selection and construction of the permeable pavement?
- ☐ Has the permeable pavement been designed to drain in less than 72 hours and allowed to dry out periodically?
- ☐ Has a long term percolation rate of 10% of the measured percolation rate been used in design (due to occlusion and particulate accumulation)?
- ☐ Has an overflow mechanism been included in the pavement design?
- ☐ If the overflow mechanism employed is perimeter control, have controls such as a perimeter vegetated swale, perimeter Bioretention, storm drain inlets, or other acceptable control been implemented?
- ☐ If the overflow mechanism employed are overflow pipes, have the pipes been connected to the underdrain, are they located away from vehicular traffic, and is the top of the pipe fitted with a screen?
- ☐ Has the pavement been laid close to level with bottom of base layers level to ensure uniform infiltration?
- ☐ Are site materials stored away from permeable pavement?
- ☐ Has landscaping and stabilization of adjacent areas been completed before installation of pavement?

GS-1 Hydrodynamic Separation Device Checklist

- ☐ Has the vendor been contacted for the latest model and design guidance prior to selection of device?
- ☐ Has the device been sized to capture and treat the water quality design flow rate?
- ☐ Has the vendor been contacted for sizing and installation guidance?
- ☐ Has periodic maintenance been scheduled and budgeted for?

GS-2 Catch Basin Insert Checklist

- ☐ Has the vendor been contacted for the latest model and design guidance prior to selection of device?
- ☐ Has the insert been sized to capture and treat the water quality design flow rate?
- ☐ Has the vendor been contacted for sizing and installation guidance?
- ☐ Has periodic maintenance been scheduled and budgeted for?

APPENDIX H: STORMWATER CONTROL MEASURE ACCESS AND MAINTENANCE AGREEMENTS

(Long Form)

Recorded at the request of:

City of _____

After recording, return to:

City of _____

City Clerk

Stormwater Treatment Device Access and Maintenance Agreement

OWNER:

PROPERTY ADDRESS:_____

APN:

THIS AGREEMENT is made and entered into in_____, California, this___day of_____, by and between_____ _____, hereinafter referred to as "Owner" and the CITY OF____ _____, a municipal corporation, located in the County of Ventura, State of California hereinafter referred to as "CITY";

WHEREAS, the Owner owns real property ("Property") in the City of _____, County of Ventura, State of California, more specifically described in Exhibit "A" and depicted in Exhibit "B", each of which exhibits is attached hereto and incorporated herein by this reference;

WHEREAS, at the time of initial approval of development project known as____ _____within the Property described herein, the City required the project to employ on-site control measures to minimize pollutants in urban runoff;

WHEREAS, the Owner has chosen to install a _____ _____, hereinafter referred to as "Device", as the on-site control measure to minimize pollutants in urban runoff;

WHEREAS, said Device has been installed in accordance with plans and specifications accepted by the City;

WHEREAS, said Device, with installation on private property and draining only private property, is a private facility with all maintenance or replacement, therefore, the sole responsibility of the Owner in accordance with the terms of this Agreement;

WHEREAS, the Owner is aware that periodic and continuous maintenance, including, but not necessarily limited to, filter material replacement and sediment removal, is required to assure peak performance of Device and that, furthermore, such maintenance activity will require compliance with all Local, State, or Federal laws and regulations, including those pertaining to confined space and waste disposal methods, in effect at the time such maintenance occurs;

NOW THEREFORE, it is mutually stipulated and agreed as follows:

1) Owner hereby provides the City of City's designee complete access, of any duration, to the Device and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by City's Director of Public Works no advance notice, for the purpose of inspection, sampling, testing of the Device, and in case of emergency, to undertake all necessary repairs or other preventative measures at owner's expense as provided in paragraph 3 below. City shall make every effort at all times to minimize or avoid interference with Owner's use of the Property.

2) Owner shall use its best efforts diligently to maintain the Device in a manner assuring peak performance at all times. All reasonable precautions shall be exercised by Owner and Owner's representative or contractor in the removal and extraction of material(s) from the Device and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. As may be requested from time to time by the City, the Owner shall provide the City with documentation identifying the material(s) removed, the quantity, and disposal destination.

3) In the event Owner, or its successors or assigns, fails to accomplish the necessary maintenance contemplated by this Agreement, within five (5) days of being given written notice by the City, the City is hereby authorized to cause any maintenance necessary to be done and charge the entire cost and expense to the Owner or Owner's successors or assigns, including administrative costs, attorneys fees and interest thereon at the maximum rate authorized by the Civil Code from the date of the notice of expense until paid in full.

4) The City may require the owner to post security in form and for a time period satisfactory to the city of guarantee of the performance of the obligations stated herein. Should the Owner fail to perform the obligations under the Agreement, the City may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, require the sureties to perform the obligations of the Agreement. As an additional remedy, the Director may withdraw any previous stormwater related approval with respect to the

property on which a Device has been installed until such time as Owner repays to City it's reasonable costs incurred in accordance with paragraph 3 above.

5) This agreement shall be recorded in the Office of the Recorder of Ventura County, California, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, and also a lien in such amount as will fully reimburse the City, including interest as herein above set forth, subject to foreclosure in event of default in payment.

6) In event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner and its successors or assigns agree(s) to pay all costs incurred by the City in enforcing the terms of this Agreement, including reasonable attorney's fees and costs, and that the same shall become a part of the lien against said Property.

7) It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with said Property and constitute a lien there against.

8) The obligations herein undertaken shall be binding upon the heirs, successors, executors, administrators and assigns of the parties hereto. The term "Owner" shall include not only the present Owner, but also its heirs, successors, executors, administrators, and assigns. Owner shall notify any successor to title of all or part of the Property about the existence of this Agreement. Owner shall provide such notice prior to such successor obtaining an interest in all or part of the Property. Owner shall provide a copy of such notice to the City at the same time such notice is provided to the successor.

9) Time is of the essence in the performance of this Agreement.

10) Any notice to a party required or called for in this Agreement shall be served in person, or by deposit in the U.S. Mail, first class postage prepaid, to the address set forth below. Notice(s) shall be deemed effective upon receipt, or seventy-two (72) hours after deposit in the U.S. Mail, whichever is earlier. A party may change a notice address only by providing written notice thereof to the other party.

IF TO CITY:	IF TO OWNER:
_____	_____
_____	_____
_____	_____

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

APPROVED AS TO FORM:

_____

City Attorney

OWNER:

_____

Owner

Name: _____

Title: _____

CITY OF_____:

_____

Name:_____

Title:_____

OWNER:

_____

Name:_____

Title:_____

ATTEST:

_____

City Clerk Date

Notaries on Following Page

EXHIBIT A

(Legal Description)

EXHIBIT B

(Map/illustration)

(Short Form)

Recorded at the request of and mail to:

_____

_____

_____

Covenant and Agreement Regarding

Stormwater Treatment Device Maintenance

The undersigned hereby certify that we are the owners of hereinafter legally described real property located in the City of _____, County of Ventura, State of California.

Legal Description: _____

_____

as recorded in Book _____, Page_____,Records of Ventura County,

which property is located and known as **(Address):** _____

_____.

And in consideration of the City of _____ allowing_____

_____

on said property, we do hereby covenant and agree to and with said City to maintain according to the Maintenance Plan (Attachment 1), all structural stormwater treatment devices including the following:

_____

_____.

This Covenant and Agreement shall run all of the above described land and shall be binding upon ourselves, and future owners, encumbrances, their successors, heirs, or assignees and shall continue in effect until released by the authority of the City upon submittal of request, applicable fees, and evidence that this Covenant and Agreement is no longer required by law.

NOTARIES ON FOLLOWING PAGE

APPENDIX I : STORMWATER CONTROL MEASURE MAINTENANCE PLAN GUIDELINES AND CHECKLISTS

Included in this appendix are a series of checklists that can be used by both inspectors and maintenance personnel to ensure that observed deficiencies in BMPs are maintained appropriately. The BMP Inspection/Maintenance Checklists are presented in the following order:

1) Bioretention/Planter Box

25) Vegetated Swale Filter

26) Vegetated Filter Strip

27) Sand Filter

28) Infiltration BMPs

29) Permeable Pavement

30) Constructed Treatment Wetland

31) Wet Retention Basin

32) Dry Extended Detention Basin

33) Proprietary Devices

I.1 Bioretention/Planter Box Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1, or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Appearance	Untidy			
Trash and Debris Accumulation	Trash, plant litter and dead leaves accumulated on surface.			
Vegetation	Unhealthy plants and appearance.			
Irrigation	Functioning incorrectly (if applicable).			
Inlet	Inlet pipe blocked or impeded.			
Splash Blocks	Blocks or pads correctly positioned to prevent erosion.			
Overflow	Overflow pipe blocked or broken.			
Filter media	Infiltration design rate is met (e.g., drains 36-48 hours after moderate - large storm event).			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

I.2 Vegetated Swale Filter Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1, or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Appearance	Untidy			
Trash and Debris Accumulation	Trash and debris accumulated in the swale.			
Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation start to take over.			
Excessive Shading	Vegetation growth is poor because sunlight does not reach swale. Evaluate vegetation suitability.			
Poor Vegetation Coverage	When vegetation is sparse or bare or eroded patches occur in more than 10% of the swale bottom. Evaluate vegetation suitability.			
Sediment Accumulation	Sediment depth exceeds 2 inches or covers more than 10% of design area.			
Standing Water	When water stands in the swale between storms and does not drain freely.			
Flow spreader or Check Dams	Flow spreader or check dams uneven or clogged so that flows are not uniformly distributed through entire swale width.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1, or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Constant Baseflow	When small quantities of water continually flow through the swale, even when it has been dry for weeks and an eroded, muddy channel has formed in the swale bottom.			
Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.			
Erosion/ Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows. Eroded or rilled side slopes.			
	Eroded or undercut inlet/outlet structures			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

I.3 Vegetated Filter Strip Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1 or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Appearance	Untidy			
Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.			
Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.			
Excessive Shading	Grass growth is poor because sunlight does not reach swale. Evaluate grass species suitability.			
Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom. Evaluate grass species suitability.			
Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.			
Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.			
Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

I.4 Sand Filter Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 square feet of filter bed area (one standard garbage can). In general, there shall be no visual evidence of dumping. If less than threshold all trash and debris will be removed as part of next scheduled maintenance.			
Inlet erosion	Visible evident of erosion occurring near flow spreader outlets.			
Slow drain time	Standing water long after storm has passed (after 24 to 48 hours) and/or flow through the overflow pipes occurs frequently.			
Concentrated Flow	Flow spreader uneven or clogged so that flows are not uniformly distributed across the sand filter.			
Appearance of poisonous, noxious or nuisance vegetation	Excessive grass and weed growth. Noxious weeds, woody vegetation establishing, Turf growing over rock filter			
Standing Water	Standing water long after storm has passed (after 24 to 48 hours), and/or flow through the overflow pipes occurs frequently.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Tear in Filter Fabric	When there is a visible tear or rip in the filter fabric allowing water to bypass the fabric.			
Pipe Settlement	If piping has visibly settled more than 1 inch.			
Filter Media	Drawdown of water through the media takes longer than 1 hour and/or overflow occurs frequently.			
Short Circuiting	Flows do not properly enter filter cartridges.			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

I.5 Infiltration BMP Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Appearance, vegetative health	Mowing and trimming vegetation is needed to prevent establishment of woody vegetation, and for aesthetic and vector reasons.			
Vegetation	Poisonous or nuisance vegetation or noxious weeds.			
	Excessive loss of turf or ground cover (if applicable).			
Trash & Debris	Trash and debris > 5 cf/1,000 sf (one standard size garbage can).			
Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants.			
Erosion	Undercut or eroded areas at inlet or outlet structures.			
Sediment and Debris	Accumulation of sediment, debris, and oil/grease on surface, inflow, outlet or overflow structures.			
Sediment and Debris	Accumulation of sediment and debris, in sediment forebay and pretreatment devices.			
Water drainage rate	Standing water, or by visual inspection of wells (if available), indicates design drain times are not being achieved (i.e., within 72 hours).			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Media clogging surface layer	Lift surface layer (and filter fabric if installed) and check for media clogging with sediment (function may be able to be restored by replacing surface aggregate/filter cloth).			
Media clogging	Lift surface layer (and filter fabric if installed) and check for media clogging with sediment (partial or complete clogging which may require full replacement).			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

I.6 Permeable Pavement Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Sediment Accumulation	Sediment is visible			
Missing gravel/sand fill	There are noticeable gaps in between pavers			
Weeds/mosses filling voids	Vegetation is growing in/on permeable pavement			
Trash and Debris Accumulation	Trash and debris accumulated on the permeable pavement.			
Dead or dying vegetation in adjacent landscaping	Vegetation is dead or dying leaving bare soil prone to erosion			
Surface clog	Clogging is evidenced by ponding on the surface			
Overflow clog	Excessive build up of water accompanied by observation of low flow in observation well (connected to underdrain system) If a surface overflow system is used, observation of an obvious clog			
Visual contaminants and pollution	Any visual evidence of oil, gasoline, contaminants or other pollutants.			
Erosion	Tributary area Exhibits signs of erosion Noticeably not completely stabilized			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Deterioration/ Roughening	Integrity of pavement is compromised (i.e., cracks, depressions, crumbling, etc.)			
Subsurface Clog	Clogging is evidenced by ponding on the surface and is not remedied by addressing surface clogging.			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

I.7 Constructed Treatment Wetland Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 sf of basin area (one standard garbage can). In general, there shall be no visual evidence of dumping. If less than threshold all trash and debris will be removed as part of next scheduled maintenance. If trash and debris is observed blocking or partially blocking an outlet structure or inhibiting flows between cells, it shall be removed quickly			
Sediment Accumulation	Sediment accumulation in basin bottom that exceeds the depth of sediment zone plus 6 inches in the sediment forebay. If sediment is blocking an inlet or outlet, it shall be removed.			
Erosion	Erosion of basin's side slopes and/or scouring of basin bottom.			
Oil Sheen on Water	Prevalent and visible oil sheen.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Noxious Pests	Visual observations or receipt of complaints of numbers of pests that would not be naturally occurring and could pose a threat to human or aquatic health.			
Water Level	First cell empty, doesn't hold water.			
Aesthetics	Minor vegetation removal and thinning. Mowing berms and surroundings			
Noxious Weeds	Any evidence of noxious weeds.			
Tree Growth	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering, do not remove. Dead, diseased, or dying trees shall be removed.			
Settling of Berm	If settlement is apparent. Settling can be an indication of more severe problems with the berm or outlet works. A geotechnical engineer shall be consulted to determine the source of the settlement if the dike/berm is serving as a dam.			
Piping through Berm	Discernable water flow through basin berm. Ongoing erosion with potential for erosion to continue. A licensed geotechnical engineer shall be called in to inspect and evaluate condition and recommend repair of condition.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Tree and Large Shrub Growth on Downstream Slope of Embankments	Tree and large shrub growth on downstream slopes of embankments may prevent inspection and provide habitat for burrowing rodents.			
Erosion on Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.			
Gate/Fence Damage	Damage to gate/fence, including missing locks and hinges			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

I.8 Wet Retention Basin Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 sf of basin area (one standard garbage can) or if trash and debris is excessively clogging the outlet structure. If less than threshold all trash and debris will be removed as part of next scheduled maintenance.			
Sediment Accumulation	Sediment accumulation in basin bottom that exceeds the depth of the design sediment zone plus 6 inches, usually in the first cell.			
Erosion	Erosion of basin's side slopes and/or scouring of basin bottom.			
Oil Sheen on Water	Prevalent and visible oil sheen.			
Noxious Pests	Visual observations or receipt of complaints of numbers of pests that would not be naturally occurring and could pose a threat to human or aquatic health.			
Water Level	First cell empty, doesn't hold water.			
Algae Mats	Algae mats over more than 20% of the water surface.			
Aesthetics	Minor vegetation removal and thinning. Mowing berms and surroundings			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Noxious Weeds	Any evidence of noxious weeds.			
Tree Growth	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering, do not remove. Dead, diseased, or dying trees shall be removed.			
Settling of Berm	If settlement is apparent. Settling can be an indication of more severe problems with the berm or outlet works. A geotechnical engineer shall be consulted to determine the source of the settlement if the dike/berm is serving as a dam.			
Piping through Berm	Discernable water flow through basin berm. Ongoing erosion with potential for erosion to continue. A licensed geotechnical engineer shall be called in to inspect and evaluate condition and recommend repair of condition.			
Tree and Large Shrub Growth on Downstream Slope of Embankments	Tree and large shrub growth on downstream slopes of embankments may prevent inspection and provide habitat for burrowing rodents.			
Erosion on Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.			
Gate/Fence Damage	Damage to gate/fence, including missing locks and hinges			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

I.9 Dry Extended Detention Basin Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1 or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
General				
Appearance	Untidy, un-mown (if applicable)			
Vegetation	Access problems or hazards; dead or dying trees			
	Poisonous or nuisance vegetation or noxious weeds			
Insects	Insects such as wasps and hornets interfere with maintenance activities.			
Rodent Holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes			
Trash and Debris	Trash and debris > 5 cf/1,000 sf (one standard size garbage can).			
Pollutants	Any evidence of oil, gasoline, contaminants or other pollutants			
Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris. Basin not draining.			
Erosion	Erosion of the basin's side slopes and/or scouring of the basin bottom that exceeds 2-inches, or where continued erosion is prevalent.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1 or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Piping	Evidence of or visible water flow through basin berm.			
Settlement of Basin Dike/Berm	Any part of these components that has settled 4-inches or lower than the design elevation, or inspector determines dike/berm is unsound.			
Overflow Spillway	Rock is missing and/or soil is exposed at top of spillway or outside slope.			
Sediment Accumulation in Basin Bottom	Sediment accumulations in basin bottom that exceeds the depth of sediment zone plus 6-inches.			
Tree or shrub growth	Trees > 4 ft in height with potential blockage of inlet, outlet or spillway; or potential future bank stability problems			
Debris Barriers (e.g., Trash Racks)				
Trash and Debris	Trash or debris that is plugging more than 20% of the openings in the barrier.			
Damaged/ Missing Bars	Bars are bent out of shape more than 3 inches.			
	Bars are missing or entire barrier missing.			
	Bars are loose and rust is causing 50% deterioration to any part of barrier.			
Inlet/Outlet Pipe	Debris barrier missing or not attached to pipe.			
Fencing				
Missing or broken parts	Any defect in the fence that permits easy entry to a facility.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0, 1 or 2)†	Date Maintenance Performed	Comments or Action(s) Taken to Resolve Issue
Erosion	Erosion more than 4 inches high and 12-18 inches wide, creating an opening under the fence.			
Damaged Parts	Damage to gate/fence, posts out of plumb, or rails bent more than 6 inches.			
Deteriorating Paint or Protective Coating	Part or parts that have a rusting or scaling condition that has affected structural adequacy.			
Gates				
Damaged or missing member	Missing gate or locking devices, broken or missing hinges, out of plum more than 6 inches and more than 1 foot out of design alignment, or missing stretcher bar, stretcher bands, and ties.			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

I.10 Proprietary Device Inspection and Maintenance Checklist

Date: _____ Work Order # _____

Type of Inspection: □ post-storm □ annual □ routine □ post-wet season □ pre-wet season

Facility: _____ Inspector(s): _____

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Refer to the manufacturer's instructions for maintenance/inspection requirements, below are generic guidelines to supplement manufacturer's recommendations.				
Underground Vault				
Sediment Accumulation on Media	Sediment depth exceeds 0.25-inches.			
Sediment Accumulation in Vault	Sediment depth exceeds 6-inches in first chamber.			
Trash/Debris Accumulation	Trash and debris accumulated on compost filter bed.			
Sediment in Drain Pipes or Cleanouts	When drain pipes, clean-outs, become full with sediment and/or debris.			
Damaged Pipes	Any part of the pipes that are crushed or damaged due to corrosion and/or settlement.			
Access Cover Damaged/Not Working	Cover cannot be opened; one person cannot open the cover using normal lifting pressure, corrosion/deformation of cover.			
Vault Structure Includes Cracks in Wall, Bottom, Damage to	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.			

Defect	Conditions When Maintenance Is Needed	Inspection Result (0,1, or 2) †	Date Maintenance Performed	Comments or Action(s) taken to resolve issue
Frame and/or Top Slab	Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.			
Baffles	Baffles corroding, cracking warping, and/or showing signs of failure as determined by maintenance/inspection person.			
Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, or misaligned.			
Below Ground Cartridge Type				
Filter Media	Drawdown of water through the media takes longer than 1 hour and/or overflow occurs frequently.			
Short Circuiting	Flows do not properly enter filter cartridges.			

†Maintenance: Enter 0 if satisfactory, 1 if maintenance is needed and include WO#. Enter 2 if maintenance was performed same day.

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June 20, 2014

Via email: santaana@waterboards.ca.gov

Regional Water Quality Control Board – Santa Ana Region
Attn: Adam Fischer
3737 Main Street, Suite 500
Riverside, CA 92501

RE: Comments on Draft Orange County Municipal Separate Storm Sewer System ("MS4") Permit, NDPES Permit No. CAS61080

Dear Mr. Fischer,

Orange County Coastkeeper ("Coastkeeper") respectfully submits the following comments on the draft Orange County Municipal Separate Storm Sewer System ("MS4") permit, Tentative Order No. R8-2014-0002 ("Draft Permit"). We appreciate the opportunity to submit these comments to the Regional Water Quality Control Board ("Regional Board") on the Draft Permit.

BACKGROUND

Urban runoff is the leading source of estuarine pollution in coastal communities and Orange County's most urgent pollution problem.[1] Arguably, it is the most difficult to solve. Each storm event causes storm water contaminated with bacteria, metals, and other pollutants through Orange County's streams, creeks, rivers and beaches in harmful amounts. Polluted urban runoff results in elevated bacteria levels and increased illness among swimmers and surfers, and the association between heavy precipitation (leading to increased runoff) and waterborne disease outbreaks is well documented.[2] Human contact with waters contaminated with storm water runoff can lead to chills, fever, ear infections and discharge, coughing and respiratory ailments, vomiting, diarrhea and other gastrointestinal illness, and skin rashes.[3]

Controlling storm water pollution originating from Orange County's MS4 system will result in statewide economic and social benefits. Orange County is one of the principal tourism destinations in the nation's largest ocean economy. According to the California Resources Agency, the state ranks "number one

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[1] Santa Ana Regional Water Quality Control Board, Orange County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R8-2002-0010, Fact Sheet, II; NPDES Permit No. CAS618030, January 18, 2002; *see also* US Environmental Protection Agency, 1999, 40 CFR Parts 9, 122, 123, 124, National Pollution Discharge Elimination System – Regulations for Revision of the Water Pollution Control Program Addressing Storm Water Discharges; Final Rule, 64 FR 68727.

[2] Curriero et al., (August 2001) *The Association Between Extreme Precipitation and Waterborne Disease Outbreaks in the United States*, 1949-1994, American Journal of Public Health, 91:8 1194-1199.

[3] See, e.g., Haile, et al. (1999) *The Health Effects of Swimming in Ocean Water Contaminated by Storm Drain Runoff*, Epidemiology 10(4):355-63, at 356-57; Haile, R. W. et al (1996) *An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay*, Santa Monica Bay Restoration Project, 70 pp, at 3.

overall for both employment and gross state products…."[4] One study, which reviewed data originating from Orange County, estimated that local beachgoers in California spend as much as $9.5 billion annually and the non-market value associated with beach-going in Southern California alone may be as high as $2 billion annually."[5]

In a region renowned for its beaches and strong tourism economy, polluted runoff keeps people out of the water and off Orange County beaches for at least 72 hours after a rain event greater than 0.2 inches. As a result, storm water runoff in Orange County's coastal waters causes or contributes to an enormous number of beach closures and advisories each year.[6] The health impacts and corresponding economic cost to the region caused by high bacteria levels is significant. One study demonstrated that swimming at polluted beaches in Los Angeles and Orange Counties caused between 627,800 and 1,479,200 excess cases of gastroenteritis per year, resulting in annual health costs of between $21 and $51 million, or $176 and $414 million per year (depending on whether only market costs or both market and non-market costs, such as willingness-to-pay not to get sick, were considered).[7]

Orange County's copermittees cannot solve this problem in isolation. It will take municipalities partnering with businesses, environmental groups, planning groups, fishing clubs, and even the local PTA for us to tackle these pollution issues and restore our waters to a healthy state where they support all designated beneficial uses. Because we can only solve our urban runoff problem with help and buy-in from municipalities, businesses and residents working together, the Draft Permit must foster a watershed-based planning process that involves the whole community in achieving a healthier watershed.

Coastkeeper believes the Draft Permit successfully improves upon the existing permit in numerous way, including mere readability. However, we are concerned that in other aspects, the Draft Permit fails to meet the requirements of the federal Clean Water Act and California's Porter Cologne Act, and is otherwise inconsistent with both state and federal law. We strongly encourage the Regional Board to revise the Draft Permit in accordance to the recommendations detailed below. Working with the Regional Board, Coastkeeper hopes a modified Draft Permit can be adopted sometime during fall 2014 and work can begin on the consolidated Inland Empire MS4 permit later this year.

COMMENTS

I. Section IV.A of the Draft Permit Creates an Illegal Safe Harbor that Violates Federal Anti-Backsliding Requirements.

8.1

Co-permittees have requested, and the Regional Board has included, a "safe harbor" provision to the existing MS4 permit's Receiving Water Limitation ("RWL") section. Since 2002, Orange County's MS4 permits have included language to "ensure that discharges from MS4 systems do not cause or contribute

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[4] Kildow, J. and Colgan, C.S. (2005) National Ocean Economics Program, California's Ocean Economy: A Report to the Resources Agency, State of California, at 1.
[5] Pendleton, L. (July 2004) *Harvesting Ocean Observing Technologies to Improve Beach Management: Estimating the Regional Economic Benefits of Improvements in the California Coastal Ocean Observing System*, Arlington, VA: Ocean. Unnumbered Report. July; see also, Chapman, D. and Hanemann, M. (2001) *Environmental Damages in Court: the American Trader Case*, in The Law and Economics of the Environment (Hayes, edit.), pp. 319-367 (estimating a "consumer surplus" of $8.16 to $60.79 per visit for each beachgoer).
[6] NRDC (2012) Testing the Waters: A Guide to Water Quality at Vacation Beaches, at California Chapter Summary. Orange County reported 761 total closing or advisory days in 2011 from all sources. This number does not include days of county-wide rain advisory events. Reported closing or advisory days are for events lasting six consecutive weeks or less. Available at http://www.nrdc.org/water/oceans/ttw/ttw2012.pdf
[7] Given, S., et al. (2006) *Regional Public Health Cost Estimates of Contaminated Coastal Waters: A Case Study of Gastroenteritis at Southern California Beaches*, Environmental Science & Technology 40(16): 4851-4858, at 4856.

to violations of applicable water quality standards in receiving waters."[8] Rather than maintaining the existing MS4 permit's clear prohibition against discharges that cause or contribute to an exceedance of water quality standards, the Draft Permit exempts compliance with RWL for Co-permittees that prepare and submit a draft plan. These safe harbors violate multiple provisions of the Clean Water Act and other state and federal regulations, rendering the Draft Permit unlawful.

The Draft Permit creates a "safe harbor" by deeming a permittee to be in compliance with the Draft Permit's RWLs (which the 2002 and 2009 MS4 permit required compliance with), when a draft plan has been submitted or, if final, is being implemented. The Ninth Circuit defined a "safe harbor" as "the proposition that compliance with certain provisions shall forgive non-compliance with the discharge prohibitions." (Natural Resources Defense Council, Inc., v. County of Los Angeles, 673 F.3d at 897 (rev'd and remanded on other grounds).) Regional Board staff proposes such a "safe harbor" when proposing permittees to prepare and submit draft plans whose goal is to ensure storm water discharges do not cause or contribute to exceedances of RWLs, and that TMDL WLAs are achieved. If a Permittee meets the program requirements for the plan, it is deemed to *legally* comply with the Draft Permit's RWLs, regardless of whether the RWLs are *actually* achieved. To adopt such language, the Regional Board would necessarily take the position that the Draft Permit excuses exceedances of water quality standards. The result of these draft plans is to render RWLs as inoperative.

8.1

The Clean Water Act prohibits renewal permits, like the Draft Permit, from containing weaker standards than those contained in previous permits, unless certain circumstances apply. (See, 33 U.S.C. § 1342(o)(1); 40 C.F.R. § 122.44(l)(1).) The "safe harbors" included in the Draft Permit render RWLs less stringent than the previous permit and do not quality as exceptions to the federal Clean Water Act anti-backsliding rule. The Draft Permit must require compliance with water quality standards, without a "safe harbor" provision. The State Water Resources Control Board issued a precedential order implementing U.S. EPA's requirement that permit language contain no such provision.[9] The 2002 and 2009 Orange County MS4 permits did not include a safe harbor provision, and the Regional Board is precluded from including such a provision here.

Claims by permittees that recent decisions originating from the Ninth Circuit imperil municipalities by exposing permittees to liability for MS4 permit violations if their discharges cause or contribute to an exceedance of water quality standards are false. The prohibition against discharges that cause or contribute to exceedances of water quality standards have been in Orange County's MS4 permits since 2002. Recent decisions have not created municipal liability, the liability has existed for well over a decade. Throughout this period, the interpretation of RWLs has remained constant and permittees have not been subject to Regional Board or third party enforcement as a result of the existing RWL language. For these reasons, the Regional Board must remove the "safe harbors" in the Draft Permit.

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[8]Santa Ana Regional Water Quality Control Board, Orange County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R8-2002-0010, Sec. IX.2.; NPDES Permit No. CAS618030, January 18, 2002.

[9] State Water Resources Control Board, Order No. WQ 99-05, June 17, 1999 (revising receiving water limitations language).

II. The Inclusion of Numeric Action Levels Will Lead to Improved Triggers for Implementation of the Iterative Process

The Draft Permit's Technical Report details widespread chronic deficiencies in co-permittee triggers to initiate the iterative process.[10] Nonexistent or poorly defined performance metrics frustrate program effectiveness assessments and delay improvements in water quality. The Regional Water Quality Control Board – San Diego Region's ("San Diego Regional Board") recently adopted MS4 Permit included numeric action levels to foster a more robust iterative process.[11] Adopting the same, or similar, process through the Draft Permit could foster a more robust countywide iterative process.

8.2

As the Draft Permit's Technical Report describes, the iterative process detailed in WQ 99-05 has "never been initiated before in the Santa Ana Region in spite of the Co-permittee's collection of substantial water quality data."[12] The failure of the iterative process to be formally initiated in the manner designed in WQ 99-05, and embraced in prior MS4 permits by the Regional Board, indicates the need for objective standards. The San Diego Regional Board established storm water and non-stormwater numeric action levels to be incorporated into the Water Quality Improvement Plans for south Orange County.[13] Numeric action levels exist for non-stormwater discharges from MS4s to: ocean surf zones; harbors, bays, lagoons, and estuaries; and inland surface waters.[14] Storm water discharges from MS4s to receiving waters exist as well.[15] The inclusion of objective standards, such as numeric action levels, by the Regional Board would be consistent with permit requirements currently placed on Orange County by the San Diego Regional Board and would assist Co-permittee's in initiating the iterative process.

III. Areas of Draft Permit Improvement Based on a Review of the San Diego Regional Board's MS4 Permits

As a county divided between two Regional Boards, Orange County is subject to more than one MS4 permit. Consequently, the differences between the two permits should be considered upon permit renewal to analyze whether those differences should be harmonized. Coastkeeper makes the recommendations below based on our review of the successful portions of the San Diego Regional Board's MS4 permits that have been absent from permits adopted by this Regional Board.

8.3

Section X of the Draft Permit requires Co-permittees to maintain an inventory of commercial sites within their jurisdiction who are engaged in commercial activities. Section X.2 describes the information necessary to be included in the inventory. Section X.3 lists the types of activities that a site would automatically qualify for listing in the inventory. The San Diego Regional Board adopted MS4 permit requirements requiring additional detail in the inventory that provides staff and the public with valuable

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[10] Santa Ana Regional Water Quality Control Board, Orange County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R8-2014-0002, Draft Technical Report, Sec. VIII.A.; NPDES Permit No. CAS618030.

[11] *See* San Diego Regional Water Quality Control Board, Orange County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R9-2013-0001, Sec. II.C.; NPDES Permit No. CAS0109266, May 8, 2013.

[12] Santa Ana Regional Water Quality Control Board, Orange County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R8-2014-0002, Draft Technical Report, Sec. VIII.A; NPDES Permit No. CAS618030.

[13] San Diego Regional Water Quality Control Board, Orange County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R9-2013-0001, Sec. II.C.; NPDES Permit No. CAS0109266, May 8, 2013.

[14] *Id.*

[15] *Id.*

8.3 information on facilities that could contribute significant pollutant loads to the MS4 system. In response, the Regional Board should modify Section X.2 of the Draft Permit to add: "pollutants potentially generated by the site/source"; "whether the site is tributary to 303(d) water body segment and whether the facility generates pollutants for which the water body segment is impaired"; and a "narrative description including SIC codes which best reflects the principal products or services provided by each facility."[16]

8.4 Section X.3 of the Draft Permit should be modified to include: "automobile (or other vehicle) parking lots and storage facilities; cement mixing or cutting; equipment repair, maintenance, fueling or cleaning; mobile auto or other vehicle washing; mobile drape, carpet or furniture cleaning; power washing services; and retail or wholesale fueling". [17] Requiring more complete information to the Co-permittees will allow for a more efficient municipal inspection program of commercial sites and promote a more tailored response to water quality impairments in the event specific commercial sites can be more easily isolated for further inspections.

8.5 Section XIV.A.1 of the Draft Permit lists the facilities that must be included in the inventory of municipal facilities/activities that have the potential to discharge pollutants in urban runoff. Recent San Diego Regional Board MS4 permits have included, and Coastkeeper believes the Draft Permit should include, public golf courses, public swimming pools, special event venues, and landscape maintenance on municipal property.

8.6 Section XIV.D.2 of the Draft Permit lists sites owned or controlled by Co-permittees which must be categorized as "high priority" fixed facility sites. Co-permittee's must inspect "high priority" sites at least annually.[18] Coastkeeper strongly encourages the Regional Board to modify Section XIV.D.2 of the Draft Permit to include fuel storage areas, and other facilities at which chemicals or materials have a high potential to be discharged as storm water.

8.7 Section XIV.F of the Draft Permit seeks to control and reduce the use of unwarranted or excessive application of fertilizer and pesticides at facilities owned or controlled by Co-permittees. To achieve this goal, the Regional Board relies heavily on integrated pest management to control chemical and fertilizer storm water loading. In addition to the use of integrated pest management, U.S. EPA guidance references non-chemical solutions, including the selection of native vegetation that is "naturally adapted to local conditions and therefore requires fewer chemical and water inputs, reducing exposure of the chemicals to water by scheduling application according to weather forecasts and plant needs."[19] U.S. EPA derived this guidance after it reviewed the prior San Diego Regional Board's MS4 permit for San Diego County as a model for Pesticide, Herbicide, and Fertilizer Application and Management practices. [20] Based on U.S. EPA guidance, the Regional Board should first modify Section XIV.F of the Draft Permit to specifically include herbicide.

8.8 Second, the Regional Board should stress non-chemical integrated pest management solutions, such as the use of native plants, reducing grass mowing to allow for greater pollutant removal, and limiting the areas of fertilizer application near storm drains. In addition to contributing to a more

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[16] San Diego Regional Water Quality Control Board, Orange County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R9-2009-0002, Sec. F.3.b(1)(a); NPDES Permit No. CAS0108740, December 16, 2009.

[17] *Id.* at Sec. F.3.b(1)(a)(i)

[18] See Santa Ana Regional Water Quality Control Board, Orange County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R8-2014-0002, Sec. XIV.D.1.a; NPDES Permit No. CAS618030.

[19] U.S. Environmental Protection Agency. 2010. MS4 Permit Improvement Guide. EPA 833-R-10-001, Washington, DC: Office of Wastewater Management, 82-3

[20] Id., *see also* San Diego Regional Water Quality Control Board, Orange County Municipal Separate Stormwater National Pollutant Discharge Elimination System (NPDES) Permit; Order No. R9-2009-0002, Sec. F.3(a)(3); NPDES Permit No. CAS0108740, December 16, 2009.

8.8 effective program to control landscape related pollutants, these modifications will reduce water demand and encourage the use of drought tolerant or native landscapes at municipal facilities.

In conclusion, Coastkeeper appreciates this opportunity to comment on the Draft Permit. Please feel free to contact me directly at 714-850-1965 ext. 307 or at colin@coastkeeper.org with any questions of concerns you may have.

Sincerely,

Colin Kelly
Staff Attorney
Orange County Coastkeeper

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SINCE 1933

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June 20, 2014

Michelle Beckwith
Santa Ana Regional Water Quality Control Board
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Subject: ***Comments on Renewal of Waste Discharge Requirements, Orange County Flood Control District, County of Orange and Incorporated Cities of Orange County, Areawide Urban Storm Water Runoff Management Program (NPDES Permit No. CAS 618030) Order No. R8-2014-0002***

Dear Ms. Beckwith,

The Orange County Water District (OCWD, the District) is a special district formed in 1933 to manage the Orange County Groundwater Basin (Basin). The Basin currently provides approximately two-thirds of the water supply for 2.4 million residents of north and central Orange County within the District's boundary.

In 1936, OCWD began actively recharging the Basin with water from the Santa Ana River. Currently, OCWD operates 30 recharge facilities in and around the Cities of Anaheim and Orange in which it recharges Santa Ana River base flow, recycled water, imported water, and storm water. An average of 50,000 acre-feet per year of storm water, or enough water for 100,000 families, is recharged by OCWD each year. Given water supply realities in southern California, storm water is a critical source of local water supply in Orange County.

OCWD covers must but not all of the urbanized areas within the permit area. One of OCWD's primary objectives in managing the Basin is protecting groundwater quality. As part of this effort, OCWD regularly monitors the quality of all recharge sources, including storm flow.

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As manager of the Orange County Groundwater Basin, please accept the following comments on the draft Orange County MS4 Permit. The first section of this letter contains our general comments, followed by specific comments and suggested modifications to the language of the permit.

GENERAL COMMENTS

Protection of Groundwater Quality

OCWD recognizes the environmental benefits of utilizing the principles of low-impact development and reducing pollution caused by urban runoff. The District's primary concern, as the 5th term MS4 permit is adopted for the County of Orange, is managing infiltration in a manner that protects groundwater from degradation and contamination. Such protection is best accomplished through careful siting and management of infiltration facilities utilizing knowledge of water quality generated by various land uses within Orange County, site-specific land uses, depths to groundwater, and underlying groundwater quality, among other factors. Specific comments listed below are intended to strengthen provisions for protecting groundwater quality when infiltration BMPs are utilized for managing stormwater on-site.

Definition of Receiving Waters

12.1

The definition of "receiving waters" should be clarified in the permit. Section IV.A states,

> "Discharges from Co-permittees' MS4s must not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface or ground waters..."

Please make clear whether the provisions of Section IV, Receiving Water Limitations, apply to both surface water and groundwater. The Monitoring and Reporting Program contains extensive requirements for surface water monitoring, however, these do not appear to apply to groundwater.

The permit needs to contain provisions that are protective of both surface water and groundwater quality. To this end, continuing to collect data on the performance of infiltration BMPs in protecting groundwater quality is critical, as explained in the comment below.

Need for Studies of Performance of Infiltration BMPs Related to Groundwater Quality Protection

Section XII.B.5.g of the 4th term Orange County permit (R8-2009-0030) required the principal permittee to "develop a pilot program to monitor the impact of groundwater infiltration systems on the quality of groundwater."

12.2

To date, we are only aware of one study in Orange County, being conducted by the City of Anaheim, where data are being collected to evaluate the impacts of on-site LID groundwater infiltration systems on the quality of groundwater. One study alone cannot come close to characterizing the impact of on-site LID style groundwater infiltration systems within an area as large and diverse as Orange County.

It is critical that site-specific data within Orange County continue to be collected. Studies conducted by the Los Angeles and San Gabriel Watershed Council that suggest that infiltration LID BMPs do not result in degradation of groundwater quality may be valid for these areas but are not substitutes for collecting Orange County specific data. To this end, we recommend that the requirement for pilot studies be continued in the 5th term permit to ensure that on-site LID infiltration practices within Orange County are protective of groundwater quality.

Consultation with Groundwater Management Agencies

12.3

The 4th term permit provided for consultation with groundwater management agencies, such as OCWD, when infiltration BMPs are proposed for new developments and significant re-developments (XII.C.4). Some co-permittees have incorporated this consultation as part of the process of reviewing and approving Preliminary/Conceptual and Final WQMPs. This allowed OCWD to review the plans and suggest changes to provide greater protection of groundwater quality, if needed. It appears that this consultation process is not included in the new draft permit.

OCWD recommends that the 5th term permit continue this consultation process and strengthen it to make it mandatory that co-permittees consult with the appropriate groundwater management agencies for all WQMPs that incorporate the use of infiltration BMPs. Recommended language to Section XII.I. can be found below.

Regional and Sub-Regional Infiltration Facilities

The Orange County stormwater program must include the development of regional and sub-regional facilities as alternatives to on-site LID BMPs. OCWD believes that it will be more effective to manage and monitor infiltration systems that are grouped or clustered on a regional basis, compared to having individual systems at a larger number of locations. In addition, regional facilities have a greater potential to contribute to replenish groundwater supplies.

12.4 In order for infiltration to provide a water supply benefit, infiltration needs to occur in areas where it replenishes the aquifers that are used for water supply. There are areas of the groundwater basin where infiltration would recharge the shallow aquifer system which is not widely used for water supply. In such areas, it would be more effective, from a water supply perspective, to relocate on-site infiltration to a regional or sub-regional facility located in an area where infiltration replenishes aquifers more heavily utilized for water supply. This is an alternative compliance approach that should be allowed as long as it provides equivalent water quality benefits as on-site LID BMPs.

We urge the Regional Board to continue to encourage development of regional/sub-regional facilities, striking a balance between requiring on-site LID controls and utilizing alternative compliance approaches that (1) improve surface water quality, (2) maximize beneficial use of stormwater for water supply, and (3) protect groundwater quality.

Maintenance of Infiltration Facilities

12.5 We continue to be concerned that individual, small-scale infiltration facilities will not be maintained properly over the long term and their performance will suffer, negating both LID principles and reducing groundwater recharge. OCWD's experience through more than seventy years of operating groundwater recharge facilities is that all infiltration facilities clog and thus require regular maintenance to sustain their recharge performance.

Vertical Separation between BMPs and Groundwater

12.6 Both the 4th term permit and the draft 5th term permit require a vertical separation from the bottom of an infiltration facility to the seasonal high groundwater of 10 feet or more. There is an exception from this 10-foot separation for cases where groundwater does not support or have the potential to support beneficial uses. Please note that the entire Orange County Groundwater Basin supports or has the potential to support beneficial uses, therefore, this exception language is unnecessary.

SPECIFIC COMMENTS
(Note: Underlined sections are suggested additions, cross-outs are suggested deletions)

IX.B.2: An industrial site must be prioritized as high priority if the site meets any of the following criteria: … e. Infiltration LID BMPs have been installed on-site.

IX.B.3: These factors include, but are not limited to: … b. the potential for pollutants to be mobilized by stormwater into surface waters or groundwater.

IV.A.: Discharges from the Co-permittees' MS4s must not cause or contribute to exceedances of receiving water quality standards (designated beneficial uses and water quality objectives) for surface water or cause or contribute to degradation or contamination of groundwater or …"

XII.A.1.c: Minimize the quantity of urban runoff draining directly to impermeable surfaces and MS4s; maximize the use of permeable surfaces to percolate storm water into the ground consistent with protection of groundwater quality.

12.7 XII.A.1.e: Encourage the use of infiltration, rainwater harvest and use, green or brown roofs, and other low-impact development methods where those methods are protective of groundwater quality and are likely to be effective…

XII.A (add new subsection 8): The co-permittees, in consultation with the appropriate groundwater management agency, shall continue to develop pilot projects to monitor the impact of groundwater infiltration systems on the quality of groundwater. This monitoring program should be implemented by identifying two or more new pilot project locations. The studies would involve at each location: (1) analyzing the quality of the runoff prior to infiltration; (2) monitoring the quality of the infiltrate through the vadose zone; and (3) monitoring groundwater quality upgradient and downgradient of the infiltrations system(s).

XII C.12.a.viii: depth and screened interval for any infiltration system.

XII.D.12. Structural treatment control BMPs must not cause or contribute to an exceedance of groundwater quality objectives, Maximum Contaminant Levels (MCLs), or otherwise contribute to the degradation of groundwater quality.

XII.D (add new subsection 15): Infiltration systems must not be used for areas of industrial or light industrial activity; areas subject to high vehicular traffic (25,000 or more daily traffic); auto repair shops; car washes; fleet storage areas; nurseries or any other high threat to water quality land uses or activities. [Note: This language is taken from in R8-2009-0003 Section XII.B.5.f.]

XII.F.2: The Co-permittees must require retention LID BMPs for the design capture volume, or the maximum portion thereof, wherever, based on Substantial Evidence, such controls are… and d. where impacts to groundwater quality will not cause an exceedance of water quality objectives or MCLs or otherwise contribute to degradation of groundwater quality.

XII.G.3: When retention LID BMPs are demonstrated to be infeasible according to Section XII.G.1. above, the Co-permittees must require biotreatment control BMPs whenever these are… and d. where impacts to groundwater quality will not cause an exceedance of water quality objectives or MCLs or otherwise contribute to degradation of groundwater quality.

12.7

XII.I.2: This section requires a vertical separation from the bottom of an infiltration facility to the seasonal high groundwater of 10 feet or more ~~except for cases where groundwater does not support or have the potential to support beneficial uses.~~

XII.I: Add to the end of the section a new subsection 9: Where a grading plan or similar specific plan of development proposes to infiltrate the entire design capture volume or a portion thereof (infiltration LID BMPs), the co-permittee shall consult with the appropriate agency managing the affected or potentially affected groundwater basin at an early stage of the process of reviewing the project WQMP and prior to the approval of the final WQMP. The co-permittee shall provide adequate information to allow said agency to review the potential effects of the BMP.

Thank you for the opportunity to submit these comments.

Sincerely,

Michael R. Markus, P.E., D.WRE, BCEE, F.ASCE
General Manager

ORANGE COUNTY BUSINESS COUNCIL
2 Park Plaza, Suit 100 | Irvine, CA 92614| P 949.476.2242 | F 949.476.0043 | www.ocbc.org

June 19, 2014

Kurt Berchtold, Executive Officer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, California 92501

Re: North Orange County MS4 Permit

Dear Mr. Berchtold:

The Orange County Business Council (OCBC) represents nearly 300 of Southern California's largest businesses that employ over 250,000 men and women in our region and more than two million employees globally. OCBC's mission is to enhance the region's economic prosperity while maintaining a high quality of life. OCBC focuses on four initiatives: improving infrastructure, enhancing workforce development, increasing the supply of workforce housing and maintaining a robust economic climate.

We are aware it is currently the comment period for the North Orange County MS4 Permit (Permit). As such, we have the following questions for the benefit of those who are trying to understand the Permit.

6.1 **A. GENERAL PLAN MANDATES TO CITIES.** Section XII.A of the Permit requires the cities to create and report on specific "measurable and verifiable" items in their General and Specific Plans including specific treatment controls and design features. As you know, the General Plan is an expression of the community's development goals and objectives in a broad context. It seems highly irregular, and inappropriate, to require precise regulatory requirements in the General Plan which applies to all actions a City may take. Has staff reviewed the likely impacts this would cause to cities from a legal and planning perspective? Given the level of specificity required in all other municipal activities, including the approval of Water Quality Management Plans, the General and Specific Plan requirements seem unnecessary.

6.2 **B. URBAN RUNOFF FUNDS AND CREDITS.** Section XII.E.2 and XII.E.4 of the 2009 MS4 Permit (Order R8-2009-0030) provides allowances for Permittees to create urban runoff funds and water quality credit systems to increase the feasibility of regional treatment programs without detracting from the region's overall runoff water

ORANGE COUNTY BUSINESS COUNCIL
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6.2 quality. Is there a specific reason why the Board eliminated this provision in the draft Permit? In 2011, OCBC wrote to the Board supporting the creation a comprehensive Model Water Quality Management Plan and Technical Guidance Document. This program, now in effect, cost our taxpayers millions of dollars. We are concerned that many of the proposed changes to the Permit impede the progress the cities and County are achieving under the existing program, and that they may decrease, not increase, the effective deployment of financial resources away from achieving water quality results.

6.3 **C. ECONOMIC ANALYSIS.** The Permit's Draft Technical Report notes that while economic considerations were taken into account when authoring the Permit, that it is "not necessary for the Regional Board to perform a Cost-Benefit analysis or other formal economic analyses." We feel the cost of Permit implementation closely informs the feasibility of the Permit requirements and would be interested in further information as to why the Regional Board feels a more detailed economic analysis is not necessary.

OCBC remains committed to investing in water quality as a top priority in the County of Orange and we urge you and the Board to ***be focused on ensuring the use of public resources effectively achieves our shared goal of improving water quality***. Thank you for your willingness to address our questions.

Sincerely,

Bryan Starr
Senior Vice President Government Affairs

CC: ADAM.FISCHER@WATERBOARDS.CA.GOV

From:	Dean Kirk
To:	Fischer, Adam@Waterboards
Cc:	"Boon, Richard"; Sat Tamaribuchi (sat.tamaribuchi@gmail.com); "Eric Strecker"; "Aaron Poresky"
Subject:	FW: Suggested Changes
Date:	Tuesday, May 27, 2014 11:44:51 AM
Attachments:	image002.png DRAFT HCOCs Redline NOC MS4- 5-20-2014.docx

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Adam,

Please find attached our suggested changes to Section XII of the draft MS-4 permit that we would like to discuss with you today at our 130 pm conference call. Talk to you soon. Dean

Dean S. Kirk
Vice President
Environmental Affairs
Irvine Company

550 Newport Center Dr. | Newport Beach, California | 92660-7011
Phone 949.720.2878 | Fax 949.720.2448
dkirk@irvinecompany.com

From: Eric Strecker [mailto:Estrecker@Geosyntec.com]
Sent: Tuesday, May 27, 2014 11:05 AM
To: Dean Kirk; Sat Tamaribuchi
Subject: Suggested Changes

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Eric Strecker, P.E., BCEE
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XII.N. Hydrologic Conditions of Concern (Pg. 52)

1. Co-permittees must address the changes in a priority project site's hydrology in the project WQMP according to the requirements of this Section except under any of the following conditions:

    a. The runoff volume and time of concentration for the two-year frequency, 24-hour storm event are not significantly affected by the project. A significant effect must be deemed to occur only where:

        i. The calculated runoff volume from the site increases by 5% or more over the pre-project condition, and/or

        ii. The calculated time of concentration for runoff from the site decreases by 5% or more over the pre-project condition.

    b. All downstream conveyance channels that will receive runoff from the project are engineered~~, hardened,~~[1] and regularly maintained to accommodate the necessary design flow capacity as dictated by the latest version of the County Hydrology Manual, and no sensitive stream habitat areas have the potential to be adversely affected by discrete or cumulative changes in hydrology.

    c. The project has the demonstrated capacity to infiltrate, harvest and use, evaporate, or evapotranspirate the volume of runoff produced by a two-year storm event within a 48-hour period.

11.1

    d. The Executive Officer grants an individual or general variance in writing to the Permittee(s).

        i. The granting of such variances must be supported by objective and relevant studies.

        ii. The Co-permittees must comply with any conditions placed on the issuance of the variance by the Executive Officer.

        iii. The Executive Officer and the requesting Co-permittee(s) must provide the public an opportunity to comment on the proposed variance for a period of not less than 30-days prior to its issuance.

2. For those priority projects that do not meet the conditions in Subsection XII.N.1. above, the Co-permittees must apply the following conditions:

    a. The project WQMP must include a hydrology study that quantifies the pre- and post-project runoff volumes, peak flow rates, and times of concentration for a 2-year storm event.

    b. ~~The~~ Except as provided in section XII.N.2.c, the project WQMP must provide BMPs that modify runoff ~~flow rates,~~ volumes and times of concentration~~ to pre-~~ from the project ~~conditions~~site for ~~a~~the 2-year, 24-hour storm such that:

[1] Engineered channels may include hardened channels and/or channels with engineered grade control structures or similar features designed to provide the necessary flow capacity and to be geomorphically stable under discrete and expected cumulative changes in hydrology.

i. Post-project runoff volumes for the 2-year, 24-hour storm event ~~or to within~~do not increase by more than 10% ~~thereof~~compared to the pre-project runoff volumes for the 2-year, 24-hour storm event, and

ii. Post project times of concentration for the 2-year, 24-hour storm event do not decrease by more than 10% compared to the pre-project times of concentration for the 2-year, 24-hour storm event.

c. The provisions of section XII.N.2.b shall apply unless any of the following ~~has~~have occurred:

i. A Clean Water Act Section 401 Water Quality Standards Certification has been issued authorizing discharges of fill associated with channel modifications that would accommodate the project's changes in hydrology while protecting beneficial uses.

ii. Site design and/or structural treatment control BMPs proposed for the site to reduce pollutants in urban runoff already effectively modify runoff volumes and times of concentration such that they satisfy Provision XII.N.2.b~~.~~, above.

11.1

iii. The Project WQMP has demonstrated that it is infeasible to satisfy the criteria of XII.N.2.b, above, through the use of infiltration and/or harvest and use, and the project has provided site design, structural treatment control, and/or flow control BMPs such that the post-project peak runoff flow rates for the 2-year, 24-hour storm event are not increased by more 10% compared to the pre-project peak flow rates for the 2-year, 24-hour storm event.

Comment [ES1]: We could offer up some reduction beyond 10% or the option to do a hydromod plan.

3. Co-permittees must prepare a set of watershed maps that identify management areas tributary to drainages that have not been engineered~~, hardened,~~ and regularly maintained to accommodate the design flow capacity, as dictated by the latest version of the Orange County Hydrology Manual, and where sensitive stream habitat areas have the potential to be adversely affected by discrete or cumulative changes in hydrology (see Provision XII.N.1.b. above).

a. The Co-permittees must submit the watershed maps in draft form to the Executive Officer for approval no later than 6 months following the adoption of this Order.

b. The Co-permittees must make changes requested by the Executive Officer within 30-days of receipt of the request. The Executive Officer is authorized to approve the watershed maps conditioned upon completion of the changes.

c. Upon approval by the Executive Officer, the Co-permittees must consistently use the applicable maps to identify projects that will be subject to the limitations on changes in runoff volumes ~~and~~, times of concentration~~-~~, and peak flow rates provided in this Section (Section XII.N).

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

JUN 20 2014

Adam Fischer
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501.

Re: Draft MS4 Permit for Orange County (Permit No. CAS618030)

Dear Mr. Fischer:

The following are EPA Region 9's comments on the draft NPDES permit (permit No. CAS618030) for discharges from the municipal separate storm sewer system (MS4) serving the portion of Orange County under the jurisdiction of the Santa Ana Regional Water Quality Control Board (Regional Board), which the Regional Board released for public comment on May 2, 2014. In an email dated January 31, 2014, we provided comments on an earlier "administrative draft" of this permit. We appreciate the opportunity to provide early input during the permit development process. However, we are disappointed that the May 2, 2014 draft permit contains problematic new provisions allowing for compliance with water-quality provisions based on Permittee submittal of draft plans (or providing a notice of intent to submit a plan) to the Executive Officer. Following below are our comments on the latest draft permit.

A. Total Maximum Daily Load (TMDL) Requirements

We have concerns with the draft permit's new options for complying with permit requirements associated with approved TMDLs upon the Permittees' written notification to the Executive Officer of their intent to develop a plan to comply with applicable wasteload allocations (WLAs). Each of the TMDLs listed in Appendices B through H of the draft permit was incorporated into the Santa Ana Regional Board's 2009 Orange County MS4 Permit (R8-2009-0030), so implementation of these TMDLs should be ongoing. We'd prefer that the draft permit be revised to retain the same approach for compliance with WLAs as the 2009 permit, and as is incorporated into the San Diego Regional Board's 2013 Regional MS4 permit (NPDES Permit No.CAS0109266). It's our conclusion that basing TMDL compliance on plans limits enforceability and makes it difficult to confirm that the TMDL water quality targets are being attained. If a plan-based compliance approach is to be included, it's important for the draft permit to be revised to include a more rigorous analysis including how specifically identified BMPs will directly result in achievement of WLAs, and the expectations that interim milestones be provided to track progress towards achieving WLAs. Also, contrary to the draft permit, this option for compliance should only be available upon approval of the plan (following opportunity for public comment) by the Executive Officer.

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13.4

13.5 Per Clean Water Act and federal regulations at 40 CFR 122.44 regarding TMDLs, permit language must be modified in several places to accurately describe that Permittee's discharges must comply with water quality-based effluent limits (WQBELs), not the TMDL WLAs. Specifically, we recommend/request these language changes be made within permit section XVIII – TMDL Implementation and in each of the TMDL Appendices B-H. For example, the responsible Permittees must comply with WQBELs established in this permit; those WQBELs are consistent with WLAs within approved TMDLs.

13.6 In our emailed comments of January 31, 2014, we expressed concern that compliance with WLAs (established as WQBELs in the permit as noted above) would be determined in accordance with a schedule (yet-to-be determined) where such determinations could be as infrequent as once every five years. We had recommended WLA compliance determinations at least once/year; we noted this would consistent with the implementation language in at least one TMDL adopted by the Regional Board (organochlorine compounds TMDL). The monitoring requirements of the latest draft permit (Attachment A) have been revised to require monitoring consistent with TMDL assessment periods, but do not specify in detail the monitoring frequency that would be necessary for consistency. To clarify the requirements and to avoid any misunderstandings of the TMDL requirements, we recommend that the permit either include the monitoring frequency that would be required for consistency with each TMDL, or direct the Permittee to a specific document where it could be found.

13.7 Furthermore, the permit should be revised to include action levels as part of the permits monitoring and reporting program and, if appropriate, the Permittees' water quality improvement plans. The goal of including both non-stormwater and stormwater action levels is to guide implementation efforts and measure progress towards the protection of water quality and designed beneficial uses of the state from adverse impacts caused or contributed to by MS4 discharges. Notably, action levels were included in the Riverside County MS4 permit (2010, Santa Ana Regional Board) and the San Diego Regional permit (2013).

13.8 Section XVIII.B.4 of the draft permit would allow exceedances of a WLA at a frequency that is less than or equal to a site-specific exceedance frequency found in the State's policy guide for developing the CWA section 303(d) list. If retained, this provision should be further discussed and supported in the fact sheet. Our understanding is that the exceedance frequency in the section 303(d) listing guide does not affect the applicability of approved WLAs, and would not justify the proposed exceedances that would be allowed under the permit. Absent adequate justification for section XVIII.B.4, we recommend it be removed from the permit.

13.9 The draft permit does not currently include any requirements related to TMDLs that may be approved during the term of the permit. To expedite implementation of additional controls that may be necessary for compliance with such TMDLs, we recommend the permit include a provision similar to section O of the 2012 MS4 permit

for the City of Salinas (permit No. CA0049981) issued by the Central Coast Regional Board. The Salinas permit requires development and submittal within one year of final TMDL approval of a plan for complying with newly approved TMDLs. This is preferable to waiting for the next permit renewal to incorporate newly approved TMDLs. We understand that the Santa Ana Regional Board is currently developing a TMDL for selenium for the Newport Bay Watershed; our recommended provision would expedite compliance with the selenium TMDL and any others that may be approved during the term of the permit.

13.9

In Appendix G, we recommend that the second paragraph be modified to clarify that the metals and selenium TMDLs were only promulgated by EPA, and were not developed nor adopted by the Santa Ana Regional Board. We recommend the following edits to the paragraph:

> "The WLAs in this Appendix are based on the Toxic Pollutants (Metals and Se) TMDLs. ~~The Toxic Pollutants TMDL has been approved by Santa Ana Regional Water Quality Control Board, the State Water Resources Control Board, the Office of Administrative Law ("OAL") and USEPA. The Toxic Pollutants TMDL was adopted by the Santa Ana Regional Water Quality Control Board in Resolution No. R8-2003-0039.~~ The metals and Se TMDLs were promulgated by USEPA on June 17, 2002."

13.10

B. New Development (Including Significant Redevelopment)

Section XII.A.7 requires the Principal Permittee to submit retrofit studies. While this is a step in the right direction, it falls far short of the retrofit provisions included in the San Diego Regional Board's Regional MS4 permit (CAS019266). We recommend incorporation of the San Diego permit's section II.E.5.(e)(1) "Retrofitting and Rehabilitating Areas of Existing Development." The San Diego permit requires each Co-permittee to identify areas of existing development as candidates for retrofitting, focusing on areas where retrofitting will address pollutants and/or stressors that contribute to the highest priority water quality conditions. This more comprehensive approach will better identify areas within the built environment where retrofits would result in water quality improvements. The San Diego permit also requires a strategy to facilitate implementation of projects identified as potential candidates for retrofits, which is lacking in the draft Orange County permit. Moreover, many of the potential retrofit BMPs (such as bioretention) would provide additional benefits such as groundwater recharge which would help alleviate current and future drought conditions; this factor increases the importance of an effective retrofit program.

13.11

Section XII.K discusses off-site treatment controls. We recognize that in some cases off-site projects can effectively address the post-construction control requirements for new development and significant redevelopment projects. This is particularly the case where off-site controls are located to optimize infiltration to replenish groundwater

13.12

supplies. However, it is necessary that water quality protections are in place at the site of the triggering development/redevelopment project, and the draft permit should be revised to make this explicitly clear. We recommend the Los Angeles County MS4 permit (CAS004001), which effectively addresses this issue in section VI.D.7.c.iii(7) by specifying Water Quality Mitigation Criteria that must be met for New and Redevelopment Projects that have been approved for offsite projects.

13.12

It is not clear whether regional or sub-regional biotreatment facilities would be required to treat 1½ times the capture volume required for retention facilities, as would be the case when on-site biotreatment replaces on-site retention. This requirement should be included in the permit. We further recommend that in situations where there may be a choice in using off-site retention or off-site biotreatment that the permit include a preference for retention (similar to the preference for retention over biotreatmemt for on-site controls).

13.13

The draft permit appears to lack any requirements for off-site mitigation when on-site LID is determined to be infeasible and regional or sub-regional facilities are not being used. We recommend that mitigation using off-site LID be required for any portion of the design capture volume for which retention or biotreatment is determined to be infeasible onsite. Such a requirement would be consistent with the 2012 Los Angeles County permit.

13.14

Finally, section XII.L of the draft permit provides for a waiver of structural controls under certain circumstances. For example, a waiver could be available if the costs are shown to disproportionately outweigh the benefits. The waiver provisions are not explained in the fact sheet and further explanation and justification should be included. Given the experience throughout California implementing LID controls pursuant to MS4 permits, which has shown the widespread feasibility of implementing LID measures in connection with new development and redevelopment projects, we're very skeptical that this waiver provision is necessary.

13.14.1

C. Receiving Water Limitations

In our emailed comments of January 31, 2014, we expressed support for the receiving water limitations (RWLs) language that had been included in the administrative draft. At the time, this language closely tracked State Water Board WQ Order 99-05 and the Regional Board's 2009 MS4 permit for Orange County. Unfortunately, the May 2, 2014 draft permit (section IV) includes a new provision under which a Permittee would be deemed in compliance with RWLs upon submittal of a draft plan for compliance to the Executive Officer. As an alternative to this new draft permit language, it's our preference that the permit retain the same RWLs language contained in your 2009 Orange County MS4 permit. As you are no doubt aware, at a November 2012 workshop, the State Water Board indicated it may consider revising WQ Order 99-05. The State Board has recommended that MS4 permits include a permit reopener to address potential revisions

13.15

13.15 to WQ Order 99-05. We suggest incorporation of such a reopener in the Orange County permit; section II.H.4.a of the San Diego permit provides appropriate language.

We are aware that while the State Board considers revisions to WQ Order 99-05, some stakeholders have been urging Regional Boards to develop new approaches for determining how RWLs compliance is determined. While our strong preference is to stick with the approach used in your 2009 permit, we have reviewed one alternative that we could support. During the development of the San Diego Regional Board's Regional MS4 permit, RB9 staff developed an option (referred to as Option 2) that would have made use of detailed Water Quality Improvement Plans to demonstrate measurable progress to achieve RWLs (included in the RB9 staff's Revised Tentative Order posted March 27, 2013). Under Option 2, after Water Quality Improvement Plan approval, its implementation would be the vehicle for achievement of RWLs. Ultimately at its May, 2013 hearing, the San Diego Regional Board chose not to adopt Option 2, and instead, with EPA's full support, adopted its Regional MS4 permit with RWLs language consistent with WQ Order 99-05. The Los Angeles MS4 permit also lays out a thorough, rigorous planning process for determining compliance with RWLs. However, we have gone on record as opposing this approach used by the Los Angeles Regional Board, given that the alternative compliance approach is available before the Plans are approved.

Unlike the San Diego Regional Board's staff proposal (Option 2) or the Los Angeles County MS4 permit, the draft Orange County permit does not provide necessary details on Permittee programs to demonstrate rigorous efforts to achieve RWLs. The deficiencies in the draft permit include the absence of measurable interim milestones and modeling efforts supporting assurances that BMPs will achieve RWLs. Again, our
3.16 preference is to retain the RWLs language of the 2009 permit, but if a plan-based compliance approach is being seriously considered it should use the methodology developed by the San Diego and Los Angeles Regional Board staff, and should be available for compliance purposes only after plan approval.

D. Other Comments

1. Whole Effluent Toxicity (WET) Requirements

In our emailed comments of January 31, 2014, we had recommended that the Orange County MS4 permit include WET requirements (using EPA's Test for Significant Toxicity (TST) procedure) modeled after those in the 2012 Los Angeles County MS4 permit. The Los Angeles County permit requires tests using 100% effluent and 100%
13.17 receiving water. However, the Orange County permit requires tests on a series of dilutions (section F.3 of Attachment A), and the selection of these dilutions should be explained in the fact sheet. We note the dilution series in the draft permit was commonly used in the WET data analysis methods used prior to the TST and may have been inadvertently carried over from previous permits.

2. Monitoring Program

13.18 The list of parameters in the monitoring program for pesticides appears incomplete (Table 4 of Attachment A), in that only a limited number of organophosphate pesticides would be sampled. We recommend the list be broadened to include a wider variety of pesticide compounds in current use, such as pyrethroids (e.g., bifenthrin, cypermithrin, esfenvalerate, gamma cyhalothrin, permithrin, etc.) and neonicotinoides (e.g., clothianidin, imidocloprid, thiamethoxam).

13.19 Section II.D of Attachment A requires monitoring at representative "MS4 outfalls" but does not provide any guidance concerning the required number of locations to be sampled, or the specific locations themselves. We recommend the permit at least clarify that representative sampling locations must be selected that would allow a compliance determination with each applicable WLA. The fact sheet also notes that the intent of the permit is largely to continue the existing monitoring program, and it appears the Regional Board has generally been satisfied with the program in previous years. Nevertheless, we recommend the fact sheet further describe the program (e.g., number and location of sampling sites, frequency of sampling) to provide the public with a better sense of the scope of the program.

13.20 Based on information contained in Orange County's 2011-2012 Unified Annual Report, the County did not adequately compare dry weather receiving water composite sample results against the California Toxics Rule (CTR), specifically the chronic criteria, as required by section III.1(a) of the monitoring and reporting program requirements of the 2009 permit. Sampling results reported by Orange County were compared to the CTR acute toxicity criteria only. The lack of adequate sampling and/or analysis of dry weather composite samples against the chronic CTR criteria limits the County's ability to identify trends, potential sources, and appropriate responses to exceedances of applicable water quality standards. For the new permit, the Regional Board should ensure that the County clearly understands it responsibilities on this matter.

13.21 Finally, we note that bacteria sampling (section II.I.1.c of Attachment A) is not allowed on days when rain has occurred. The basis for this condition should be explained in the fact sheet.

3. Public Review of Updated Monitoring Program

13.22 Section II.B.6 of Attachment A provides that the Executive Officer wlll provide the opportunity for public comment on changes to the initial monitoring program which is submitted, but this opportunity seems missing for the initial submittal itself. We recommend the Executive Officer ensure such an opportunity for the initial submittal as well since it will likely be of greater interest than any changes in subsequent years.

We appreciate the opportunity to provide our views on the draft permit. If you have any questions regarding this matter, please contact Eugene Bromley of the NPDES Permits Office at (415) 972-3510.

Sincerely,

Eugene Bromley

for David Smith, Manager
NPDES Permits Office (WTR-5)

CITY OF ORANGE

CITY MANAGER PHONE: (714) 744-2222 • FAX (714) 744-5147

June 20, 2014

Mr. Kurt Berchtold
Executive Officer
California Regional Water Quality Control Board
Santa Ana Region
3737 Main Street, Suite 500
Riverside, CA 92501-3348

Subject: Draft MS4 NPDES Permit Order No. R8-2014-0002

Dear Mr. Berchtold:

The City of Orange appreciates the opportunity to comment on the proposed MS4 Permit for Orange County Draft Order No. R8-2014-0002. As a co-permittee under the Draft Order, the City will be heavily impacted by the Order's proposed requirements and would like to take the opportunity to comment on a few issues of concern. The County of Orange has provided an in depth analysis and proposed recommendations for the Draft Order and the City supports those comments by reference. A short summary of issues of concern is provided in the following paragraphs and a complete write-up is provided in the attachment to this letter.

In the Draft Order, the model programs in the Drainage Area Management Plan (DAMP), Local Implementation Plan (LIP), Model WQMP, Technical Guidance Document and other documents developed and adopted by the co-permittees in previous years are not referenced and instead individual requirements are listed for each storm water program element. The Technical Report states that those documents have been decoupled from the Draft Order to provide greater flexibility to the co-permittees and their programs.

While decoupling existing program documents from the Draft Order might provide some flexibility, it is nearly impossible to condense those documents into a new Order. This is particularly problematic in Section XII of the New Development /Significant Redevelopment program where documents covering over 400 pages are distilled down to 19 pages. In the course of distilling those documents, certain information is bound to be missed, which is the concern.

The co-permittee approved documents cover much more information than what is contained in the Draft Order and provide guidance to assist in evaluating projects and complying with the existing Order. Given that this program is also

fairly new, consideration should be given to allowing more time to assess how the New Development program is working under the existing Order before new requirements are imposed.

In other sections the Draft Order becomes too prescriptive where instead of identifying the desired goals or results, the manner of compliance is prescribed (what needs to be included in enforcement programs, how to discipline employees who violate standard operating procedures, where training records need to be kept, and many more) contrary to Section 13360 of Porter-Cologne.

In the New Development/Significant Redevelopment section certain provisions interfere with City land development application processes. Provision XII.A.6 requires cities to not accept applications as complete until a report of waste discharge has been filed with the Regional Board when there is a discharge of dredge or fill material to waters of the U.S.

The discharge of dredge or fill material to waters of the U.S. is not a permit that is issued by cities but by the US Army Corp of Engineers under a 404 permit and the companion 401 water quality certification is issued by regional boards. To require cities to not accept land planning applications as complete until a report of waste discharge is submitted to the Regional Board could potentially delay project review and action by cities for an indefinite time period because the timing and submittal of the discharge permit applications to federal and state agencies could be months or years.

Another issue of significant importance is the requirement to designate all projects exposed to storm water (XII.M.1), where co-permittees have approval authority, as Priority or Nonpriority projects (XII.B.2). This provision has the potential to bring issuance of over the counter building permits to a virtual halt and significantly increase the cost of projects previously deemed inconsequential to the storm water program. Projects such as roof repair, patio covers, solar panels, block walls, small residential additions and others would now be required to have Nonpriority WQMPs prepared by licensed professionals (XII.M.5).

These and other issues are discussed in the attachment. Questions regarding these comments may be directed to Gene Estrada at 714-744-5547.

Sincerely,

John W. Sibley
City Manager

cc: Joe DeFrancesco, Public Works Director
Frank Sun, Deputy Director/City Engineer
Chris Crompton, Manager, Public Works Environmental Resources
Adam Fischer, Santa Ana Region Water Quality Control Board

Comments Draft Order No. R8-2014- 0002

XII. NEW DEVELOPMENT (INCLUDING SIGNIFICANT REDEVELOPMENT)

7.1 **Comment 1:** This section specifies the requirements for new development and significant redevelopment that co-permittees are intended to comply with and has purposely ignored the reference to existing co-permittee technical documents such as Model WQMP and Technical Guidance Documents. Those documents consisting of over 400 pages were prepared and approved by the regional board executive officer over the course of two years and define the existing new development/significant redevelopment program. To distill the documents down to 19 pages will almost certainly result in omission of program elements that are currently used by co-permittees to review and approve projects. Among these omissions is to not fully recognize how hydrological conditions of concern may be complied with by reducing peak design flow rates to existing flow rates. Another example is not recognizing that meeting the 80% treatment performance can be achieved by infiltrating in shorter or longer periods than the 48 hours specified in the order based on soil infiltration rates and corresponding BMP sizes. And there are many other examples too long to list.

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7.4 While it cannot be expected that the order cover the contents of the co-permittee approved documents, it does point out the deficiency with not referencing existing documents.

Recommendation: Refer back to approved co-permittee documents such as the Model WQMP and Technical Guidance Document for implementation of new development/significant redevelopment program. Where changes are proposed explicit reasons should be provided for the reasoning.

Comment 2: This section of the draft order does not recognize alternative compliance programs such as water quality credits and in lieu fee programs that were previously allowed in Order R8-2009-0030 and existing co-permittee documents when the available suite of BMPs cannot be used onsite or through a regional BMP.

7.5 Water quality credits can be beneficial by encouraging development of sites that might otherwise be unattractive for development such as brown fields, high density development and other uses specified in the previous permit. These credits should also be made available directly to the project by allowing a reduction in the treatment capacity required due to the credits applicable to the project instead of allowing a reduction in treatment only if onsite BMPs cannot treat the required design volumes or discharges, which effectively the credits useless.

Recommendation: Include language to allow alternative compliance programs such as water quality credits and other in lieu programs as previously allowed by Order R8-2009-0030 with water quality credits allowed to be taken directly from the required treatment requirements.

Order Specific Comments

A.6 This paragraph requires co-permittees to not accept applications as complete until a report of waste discharge has been filed with the Regional Board when there is a discharge of dredge or fill material to waters of the U.S.

It is not clear why this requirement is being imposed on the co-permittees. Co-permittees are involved in accepting and processing applications for land development. Co-permittees can also impose conditions or restrictions on projects to meet local regulations. The discharge of dredge or fill material to waters of the U.S. requires submittal of applications to federal and state agencies (404 permit and 401certification) where co-permittees do not have any jurisdiction. The timing of these applications is also very different from the submittal of an initial land development application (months or years) and this requirement would greatly interfere and delay a co-permittees right to accept land development applications. Co-permittees could impose project conditions requiring other permits to be obtained prior to the issuance of city land development permits but the order should not interfere with a co-permittee's land application process.

7.6

Recommendation: Delete requirement to not accept applications as complete until a report of waste discharge has been filed with the Regional Board when there is a discharge of dredge or fill material to waters of the U.S. Alternatively, reword provision to require a project condition to obtain a permit from the Regional Board.

B.2 The paragraph requires co-permittees to classify all projects over which they have approval authority as Priority or Nonpriority.

The provision in this paragraph along with the definition provided in paragraph M.1 for Nonpriority projects that include projects exposed to storm water or are sources of urban runoff is broad and will result in co-permittee expenditure of resources and costs that are unnecessary. An unambiguous reading of these provisions would require projects such as reroofs, patio covers, solar panel roof installations, block walls, swimming pools and spas and other projects typically issued by building departments over the counter to prepare WQMPs. This will not only cause project delays but will also prove costly adding potentially thousands of dollars to projects because applicants must now hire a licensed professional (civil engineer, landscape architect, provision M.5) to prepare the WQMP. This requirement is clearly impracticable and unreasonable.

7.7

For illustrative purposes, Orange conducted a review of the number of building permits issued between July 1, 2013 and April 30, 2014. In those ten months 1927 permits were issued. Of those permits, 579 permits (200 reroof, 250 solar panel installations, 40 patio covers, 89 other (residential additions, block walls, etc.) about 30%, could be subject to WQMPs as Nonpriority projects since they would be exposed to storm water. As a basis for comparison, the City has reported the approval of 23 Nonpriority projects during the last 4 years in its

annual NPDES reports. That is an average of 6 Nonpriority projects approved per year compared to almost 700 that might require WQMPs annually.

7.7 Clearly, this is not a reasonable requirement nor does it make sense. Implementation of these provisions will bring issuance of over the counter permits to a halt and have significant economic consequences for each project and would require cities to add a significant number of personnel to review and process the project WQMPs.

Recommendation: delete this requirement or revise to be consistent with the Model WQMP, which clearly defines Nonpriority projects as those projects requiring discretionary co-permittee approval that cannot be classified as Priority WQMPs.

L.1.d The paragraph requires the Executive Officer to approve waivers for projects that cannot employ any structural treatment controls BMPs.

The current permit only requires the Executive Officer to be notified 30 days prior to the issuance of a waiver by the co-permittees along with justification. Final approval of the waiver is left to the co-permittees unless the Executive Officer rejects the waiver within the 30 days.

7.8

Revising the language to require the Executive Officer to approve the waiver may result in project approval delays if the EO fails to act within 30 days. The current language in the existing Order was approved after lengthy discussions during Regional Board hearings of the last permit. Unless, there is substantial evidence that waivers are being issued indiscriminately by co-permittees, the existing language in the existing permit should remain or require action within 30 days.

Recommendation: Delete this provision or require E.O approval in 30 days.

M. 5 The paragraph requires a registered engineer or licensed landscape architect to prepare and sign a Nonpriority plans.

This requirement may make sense where structural BMPs implemented require technical knowledge possessed by design professionals. It does not make sense in Nonpriority plans that do not require this technical knowledge and will add thousands of dollars to a project's costs that are unnecessary. For example, hiring a licensed professional for a simple Nonpriority plan that must be approved by a city such as a small restaurant outdoor patio dining expansion where only a canopy may be used makes no sense where someone other than a licensed professional can prepare a simple plan.

7.9

Recommendation: Revise language to require a licensed professional to prepare a Nonpriority plan only where structural BMPs are implemented.

XIV. MUNICIPAL FACILITIES/ACTIVITIES

7.10

C. The paragraph requires 80% annual inspection of flood management and storm water conveyance systems.

7.10

As written, this provision requires annual inspection of 80% of its storm water conveyance facilities, which include storm drains. Adding storm drains to the annual inspection requirement would be a huge drain on co-permittee resources and added costs that are unnecessary. Storm drains were required to be inspected during the first term permit in 1990 primarily for the identification of illicit connections. This requirement was removed during the second term permit when it was found that illicit connections were not a problem countywide. Subsequent permits required inspection of storm drains on an as needed basis based on local knowledge. The previous MS4 permit, Order No. R8-2009-0030 Section XIV.11, required cleaning and maintenance of 80% of drainage facilities (catch basins, storm drain inlets and open channels) on an annual basis. These drainage facilities are easily visible from the surface and do not require confined space permits or video equipment. To require inspection of storm drains is problematic and expensive without evidence that storm drains are creating a problem.

Recommendation: Revise "storm water conveyance" to "drainage facilities" and define as catch basins, storm drain inlets and open channels.

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June 20, 2014

VIA EMAIL (santaana@waterboards.ca.gov)

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C/O Adam Fischer
Environmental Scientist
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Re: Comments on Draft Orange County MS4 Permit, Tentative Order No. R8-2014-0002

Dear Mr. Fischer:

15.1 Best Best & Krieger represents City of Santa Ana ("City") in matters involving water quality. The City submits the following comments on the Draft Orange County Municipal Separate Storm Sewer System ("MS4") Permit, Order No. R8-2014-0002 ("Draft Permit"). The City is committed to improving and sustaining water quality in the Santa Ana and San Diego Creek Watersheds and has undertaken extensive efforts to further these goals. The City is aware that the County of Orange has prepared and submitted comments on the Draft Permit. The City would like to express its support for the County's comment letter and to join with the County in the submission of those comments. The comments in this letter supplement the County's letter and are intended to allow the City and other Co-permittees to continue working toward the common goal of improving water quality in the region.

1. THE DRAFT PERMIT NEEDS TO GIVE THE CITY FLEXIBILITY TO UNDERTAKE ACTIVITIES CURRENTLY REQUIRED OF THE PRINCIPLE PERMITTEE

15.2 The City requests that the Draft Permit be revised to include language clarifying that a Co-permittee may elect to undertake activities directly affecting the Co-permittee, which the County, as Principal Permittee, is currently required to undertake. For example, the Draft Permit requires the County to write a training curriculum on the City's enforcement tools (Draft Permit,

§ XVI.B), to establish thresholds for what constitutes "unusually large quantities of pollutants" (Draft Permit, § XIV.C.4)[1], and to conduct certain monitoring activities on behalf of the City (Draft Permit, MRP). The Co-permittees, rather than the County, may be better situated to undertake these or similar activities currently assigned to the County. The City therefore requests that the Draft Permit be revised to allow the City to undertake such activities either in conjunction with the County or on its own.

15.2

2. THE CITY REQUESTS THAT THE DRAFT PERMIT BE REVISED TO REMOVE REQUIREMENTS THAT FORCE THE CITY TO ADDRESS ISSUES THAT ARE OUTSIDE OF ITS PHYSICAL AND LEGAL JURISDICTION.

A. A Co-permittee cannot be liable or responsible for permit conditions for which it is not the operator

The City objects to the Draft Permit to the extent it creates or impliedly relies on a system of joint and several liability that contradicts the Clean Water Act and Porter-Cologne. Both the Clean Water Act and Porter-Cologne hold dischargers responsible only for those pollutants that discharge from their point sources. (33 U.S.C. §§ 1311, 1319, 1342, subd. (p)(3)(B) and 1362, subd. (12); Water Code §§ 13350, subd. (a), 13263, subd. (f) and 13376.)[2] The Clean Water Act's definition of "Co-permittee" is a permittee who "is only responsible for permit conditions relating to the discharge for which it is operator." (40 C.F.R. § 122.26, subd. (b)(1).) Although storm water permits may be issued on a system – or jurisdiction – wide basis, a Co-permittee need only comply with permit conditions relating to discharges from the MS4 which it is operating. (33 U.S.C. § 1342(p)(3)(B)(i); 40 C.F.R. § 122.26(a)(3)(vi); *So. Fla. Water Mgmt. Dist. v. Miccosukee Tribe of Indians* (2004) 541. U.S. 95, 105; *Jones v. E.R. Shell Contractor, Inc.* (N.D. Ga. 2004) 333 F.Supp.2d 1344; *In re City of Irving, Texas, Mun. Separate Storm Sewer Sys.* (EPA July 16, 2001) 10 E.A.D. 11; 40 C.F.R. §§ 122.26, subd. (a)(3)(vi).)

15.3

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[1] The City does not waive the objection to the inclusion of this term as set forth in the County's comment letter. The City submits these comments in the event this term is included in the final permit contrary to the County's comments.

[2] The City acknowledges that EPA and others believe that the watershed approach would result in better water quality results. (*See, e.g.,* EPA's Watershed-Based NPDES Permitting Policy Statement dated January 7, 2003 and the conclusions of the National Research Council's 2009 Report on Urban Stormwater Management in the United States [concluding that the "course of action most likely to check and reverse degradation of the nation's aquatic resources would be to base all stormwater and other wastewater discharge permits on watershed boundaries instead of political boundaries."].) However, structural changes in the Clean Water Act and the laws of authorized states are required to implement such a watershed permitting approach. (*See, e.g.,* National Research Council Report, p 524 [noting that the "national watershed-based approach to stormwater is likely to require legislative amendments . . . ."].) In the absence of such structural changes, the Clean Water Act must be applied as currently written, and as currently written, its focus is on jurisdictional boundaries.

15.3

Porter-Cologne has a similar focus on individual discharges. (Water Code, § 13260.) For example, Porter-Cologne makes watershed planning an option that Co-permittees may pursue, not a mandatory requirement with which Co-permittees must comply. (Water Code, §§ 16101, subd. (a), 13263, 13350, subd. (a).) The purpose of such voluntary watershed planning is to allow permittees to implement existing and future water quality requirements and regulations on a watershed rather than a jurisdictional level. (*Id.*) If the Regional Board incorporates watershed planning into the waste discharge requirements issued to a permittee, the implementation of the plan by the permittee may represent compliance with waste discharge requirements. (Water Code, § 16102 subd. (d) and (c).) Thus, the voluntary watershed approach of Water Code section 16100 *et seq.* allows permittees to *elect* the pursue a watershed approach and *offers* the permittee a compliance option as an incentive to move from a jurisdictional approach to a watershed approach. Porter-Cologne does not <u>require</u> a Co-permittee to expend resources to address discharges beyond its jurisdiction. (40 C.F.R. § 122.26, subd. (b)(1).)

B. State and Federal Law do not permit the Draft Permit's creation of joint and several liability

15.4

Mandatory watershed requirements which are not linked directly to pollutants discharged to or from a Co-permittee's MS4 are contrary to the plain meaning of the Clean Water Act. Such requirements are also beyond the responsibility of that Co-permittee and should be removed from the Draft Permit. The Draft Permit's Receiving Waters Limitations, Total Maximum Daily Load ("TMDL") Implementation requirements, and Monitoring and Reporting Program ("MRP") include multiple requirements for joint efforts by the City, without regard to the City's jurisdictional boundaries. (Draft Permit, § IV, XIII, MRP.) For example, the Draft Permit creates a system of joint and several liability by requiring "Co-permittees [to] implement BMPs to achieve the Waste Load Allocations ("WLAs") specified in Appendices B through H of this Order."[3] (Draft Permit, § XVIII.A.) Under this provision, the City would be unable to establish compliance with its WLAs unless it is complying with its own WLAs and it can show that all other dischargers are also in full compliance with their WLAs. If only one Co-permittee fails to implement BMPs to achieve WLAs, all Co-permittees may be held liable for a resulting water quality exceedance contrary to the Clean Water Act and Porter-Cologne.

Co-permittees may develop and implement a plan to comply with WLAs and where an execcedance is measured, revise the TMDL WLA compliance plan. (Draft Permit, § XVIII.C.5.) Under this draft requirement, any time an exceedance is measured in a receiving water, the Co-permittees must participate in revising the compliance plan, even if all Co-permittees have complied with their WLAs and with the approved TMDL WLA compliance plan. (Draft Permit, § XVIII.C.5.) If a Co-permittee other than the City violates the TMDL WLA compliance plan

[3] Other Permit sections impose joint liability, including: MRP sections II.A.2; II.B.3; II.C.1.a; II.C.5; II.D.1; II.H; II.I; II.J.

and causes an exceedance, and that Co-permittee refuses to act, the City would not be able to comply with the Draft Permit's TMDL requirements. In that instance, the City could be held liable for failure to amend, revise, or comply with a TMDL WLA compliance plan, as required in the Draft Permit, even though the City fully complied with requirements applicable to the City. Such a result is unjust and contrary to the Clean Water Act and Porter-Cologne.

15.4

The Regional Board has no authority to impose such liability on the City. (40 C.F.R. § 122.26, subd. (b)(1); *City of Modesto Redevelopment Agency v. Superior Court* (2004) 119 Cal.App.4th 28; *In re Alvin Bacharach and Barbara Borsuk* (Order No. WQ 91-07, SWRCB 1991.) Any permit conditions that impose responsibility or liability for discharges or other Draft Permit violations that are not caused by the Co-permittee being held responsible or liable exceed the Regional Board's authority and must be removed from the permit. The City also seeks clarification incorporated into the Draft Permit that the Draft Permit does not intend to hold the City liable or responsible for permit conditions which do not relate to a discharge for which it is operator.

15.5

3. THE CITY REQUESTS THAT DRAFT PERMIT SECTION XII'S NEW DEVELOPMENT AND REDEVELOPMENT REQUIREMENTS BE REVISED TO INCORPORATE THE CITY'S EXISTING PROGRAM

A. Co-permittees' existing new and redevelopment program adequately regulates pollutants in storm water and the Draft Permit should not require any changes to the program.

The City and the other Co-permittees have expended great resources to develop a program for implementing new and redevelopment standards consistent with the current MS4 Permit. There is no reason that this program should be changed. The Draft Permit and its Technical Report do not include any evidence demonstrating that a change to the existing program is necessary or better for the environment. For this reason, the City requests that the Permit be revised to allow the existing program to continue.

15.6

Additionally, the City objects to the New Development and Redevelopment regulations in the Draft Permit on the grounds that they improperly regulate the discharge of storm water as a surrogate for the regulation of pollutants. (Draft Permit, § XII.) For this reason, the new development and redevelopment standards should be removed from the Draft Permit or be modified to incorporate the City's existing requirements.

15.7

B. The Draft Permit regulates storm water as a surrogate for pollutants

While stating that Co-permittees "must require priority projects to use source control, site design, and structural treatment control BMPs to remove pollutants in urban runoff[,]" the Draft Permit actually regulates storm water flows rather than pollutants. Draft Permit sections XII.A.1.c and XII.D mandate the methods by which Co-Permittees must minimize the quantity of "urban runoff" draining directly to impermeable surfaces and MS4s by establishing, in part, BMP requirements for all priority projects as defined in the Draft Permit. Priority projects include areas of new development and redevelopment. (Draft Permit, § XII.B.5.) The primary methods for attaining these goals is through the use of infiltration, evaporation, evapotranspiration, rainwater harvesting and use, green or brown roofs, and other low impact development ("LID") methods. (Draft Permit, §§ XII.A.1.c, e.) Urban runoff is defined as:

15.8

> [A]ll flows in a storm water conveyance system from urban areas which include residential, commercial, industrial, and construction areas. Urban runoff consists of the following components: (1) storm water runoff and (2) authorized non-storm water discharges (See Section III of this Order). Urban runoff does not include runoff from undeveloped open space, feedlots, dairies, farms, and agricultural fields. (Draft Permit, Glossary.)

Storm water on a priority project site does not qualify as "urban runoff" because it has not entered a storm water conveyance system. Further, storm water on a priority project site is not a "pollutant" under the Clean Water Act or a "Waste" under Porter-Cologne. The intent of section XII's New Development requirements appears to be the regulation of storm water runoff from priority project sites and authorized non-storm water discharges from priority project sites as a surrogate for the regulation of pollutants.

C. Regulation of storm water as a surrogate for pollutants is contrary to the Clean Water Act and Porter-Cologne

Contrary to the requirements of the Clean Water Act and Porter-Cologne, the Draft Permit regulates the discharge of storm water as a pollutant, rather than the pollutants in the storm water. (*Virginia Department of Transportation v. EPA* (E.D. Va., Jan. 3, 2013) 2013 U.S. Dist. Lexis 981, 43 ELR. 20002 ("*VDOT*").)

15.9

Regulation of storm water alone rather than pollutants or waste in storm water exceeds the Regional Board's authority under both the Clean Water Act and Porter-Cologne. (*Ibid.*) In *VDOT*, the US EPA had established a TMDL for Accotink Creek to limit the flow of storm water into the creek. The purpose of the TMDL was to regulate the amount of sediment into Accotink,

based on EPA's belief that the sediment was the primary cause of its impairment. The parties to the case and the court agreed that sediment is a "pollutant" under the Clean Water Act, and that storm water is not a pollutant. In an attempt to justify the storm water flow TMDL, the EPA claimed that the storm water flow rate was a "surrogate" for sediment. The Court, however, held that EPA had no authority under the CWA to regulate the flow of storm water into the creek, stating:

> The language of § 1313(d)(1)(C) is clear. EPA is authorized to set TMDLs to regulate pollutants, and pollutants are carefully defined. Stormwater runoff is not a pollutant, so EPA is not authorized to regulate it via TMDL. Claiming that the stormwater maximum load is a surrogate for sediment, which is a pollutant and therefore regulatable, does not bring stormwater within the ambit of EPA's TMDL authority. Whatever reason EPA has for thinking that a stormwater flow rate TMDL is a better way of limiting sediment load than a sediment load TMDL, EPA cannot be allowed to exceed its limited statutory authority. (*Id.* at pp. 14-15.)

15.9

By mandating the elimination of pollutants through the control of storm water and authorized non-storm water, the Draft Permit treats storm water as a surrogate for all, unspecified pollutants in the same way that the EPA treated storm water as a surrogate for sediment. Accordingly, the Regional Board in this case has no authority under the Clean Water Act to regulate discharges from completed project sites without specifically identifying a particular pollutant of concern.

Similar restrictions exist in State law. Porter-Cologne prohibits the discharge of "Waste" without a permit. (Water Code, §§ 13260; 12363; 13264.) Waste is defined as:

> sewage and any and all other waste substances, liquid, solid, gaseous, or radioactive, associated with human habitation, or of human or animal origin, or from any producing, manufacturing, or processing operation, including waste placed within containers of whatever nature prior to, and for purposes of, disposal. (Water Code, § 13050, subd. (d).)

Storm water itself is not Waste, though it may contain Waste. The Clean Water Act only authorizes the regulation of pollutants. Porter-Cologne only authorizes the regulation of Waste. Draft Permit terms, such as section XII's New Development regulations, which seek to regulate storm water flows without identifying specific pollutants in such flows are beyond the authority of the Regional Board and must be removed from the Draft Permit. In the event such

15.10

15.10 requirements are modified to regulate only pollutants and Waste, the Draft Permit should also be revised to permit Co-permittees' current program to satisfy the section XII's revised requirements.

4. THE CITY REQUESTS THAT DRAFT PERMIT SECTION XII BE REVISED TO REMOVE REQUIREMENTS THAT THE CITY IMPOSE MITIGATION ON PROJECTS IN EXCESS OF THE PROJECT'S IMPACTS.

15.11 The City objects to the Draft Permit's LID provisions to the extent they require mitigation of pollutants in storm water which are not caused by a project. (Draft Permit, §§ XII.D, E, G, H, K [requiring treatment of runoff from tributary areas], B.5.iv ["numeric sizing requirements must be applied to runoff from the entire development"].) The City requests these changes to the Draft Permit to provide clarity that the intent of section XII is to control pollutants directly caused by a project. Forcing the City to require mitigation in excess of a project's impacts exposes the City to potential liability for takings claims.

A. The Draft Permit requires exactions on projects which exceed a project's scope.

15.12 As applied to redevelopment priority projects and nonpriority projects, the Draft Permit's hydromodification and LID requirements exceed the scope of both the City's and the Regional Board's authority regarding exactions under State and Federal law. For example, in areas where redevelopment results in the addition or replacement of more than 50% of the impervious surfaces of an existing developed site, compliance with Section XII will generally require a redevelopment project proponent to retain all storm water runoff on site or mitigate off-site, even where the runoff is not caused or increased by the redevelopment project. (Draft Permit, § B.5.a.iv.) In this way, the Draft Permit requires the City to impose mitigation and/or exactions for impacts that are not a result of the redevelopment project itself.

15.13 Similarly, the Draft Permit requires a Non-Priority Project Plan, source control and site design BMPs for all non-priority projects that modify, improve or affect areas exposed to storm water. (Draft Permit, § XII.M.) This requirement would apply to projects that do not create any additional run-off or change the type of pollutants in existing run-off, such as roof-top solar panel installations and patio covers. By requiring a Non-Priority Project Plan, source control and site design BMPs to address run-off that is not changed, caused, or affected by a project, the Draft Permit requires the City to impose mitigation and/or exactions for impacts that are not a result of the non-priority project itself.

B. California law prohibits exactions on a project in excess of a project's impact.

When imposing a condition on a development permit, a local government is required under the federal and state constitutions to impose only those conditions bearing a reasonable relationship to the impacts of the project. (*Building Indus. Assn v. City of Patterson* (2009) 171 Cal. App. 4th 886, 898.) This rule applies to legislatively enacted requirements and impact fees or exactions. (*Ibid.*) Fees imposed on a discretionary ad hoc basis are subject to heightened scrutiny under a two-part test. (*Nollan v. California Coastal Comm'n.* (1987) 483 U.S. 825, 837 ("*Nollan*").) First, local governments must show that there is a substantial relationship between the burden created by the impact of development and any fee or exaction. (*Ibid.*) Second, a project's impacts must bear a "rough proportionality" to any development fee or exaction. (*Dolan v. City of Tigard* (1994) 512 U.S. 374, 391 ("*Dolan*").)

15.12 Under California law, the *Nollan/Dolan* heightened scrutiny test also applies to in-lieu fees. (*Ehrlich v. City of Culver City* (1996) 12 Cal.4th 854, 876.) The Legislature has memorialized these requirements in the Mitigation Fee Act which establishes procedures that local governments must follow to impose impact fees. (Gov. Code, §§ 66000-66025.) By requiring certain redevelopment priority projects to retain all storm water on-site, the City would be requiring a project developer to make changes to the project site that are not related to the project's impacts. Imposing such requirements would exceed the City's (and the State's) authority under *Nollan, supra,* 483 U.S. at p. 837 and *Dolan, supra,* 512 U.S. at p. 391.

Draft Permit conditions requiring mitigation of pollutants in storm water which are not caused by a project violate the *Nollan/Dolan* limitations. For this reason, Draft Permit section XII must be revised to reflect the limitations of the City's and State's authority. Without requesting the inclusion of new and redevelopment standards or waiving the objections set forth herein, if the new and redevelopment standards are modified in such a way as to require exactions commensurate with a project's scope, the City and Co-permittees' existing program should be recognized as satisfying all such Draft Permit requirements.

5. SECTION XII'S LID REQUIREMENTS ARE NOT SUPPORTED BY EVIDENCE AND NEED TO BE REMOVED.

15.14 The City objects to the Draft Permit's new LID requirements on the grounds that there is no evidence in the record demonstrating that a universal requirement to implement LID requirements in every development and redevelopment priority and non-priority project improves water quality. (Draft Permit, § XII.) As described above, the City and other Co-permittees have expended great resources to develop a program for implementing LID requirement consistent with the current MS4 Permit. There is no evidence in the record

demonstrating that a change to the existing program is necessary or would benefit the environment.

The Regional Board admits that the LID requirements are based on "a *presumption* that carrying out the actions prescribed in the permit . . . will improve water quality." (Draft Permit, Technical Report, at p. 18 [emphasis added].) Instead of relying on substantial evidence, the Regional Board appears to base all New and Significant Redevelopment Draft Permit requirements on the findings of Appendix D, to the Ventura County Technical Guidance Manual for Storm Water Quality Control Measures (Manual Update 2011). This document itself contains no evidence that LID requirements and their resulting reduction in flows of storm water to receiving waters results in water quality benefits. (*Ibid.*)

15.14

For these reasons, the hydromodification and LID requirements lack substantial evidence and are arbitrary and capricious under the California Administrative Procedure Act and violate the Clean Water Act in that the requirements do not, on their face, demonstrate water quality benefits. These requirements should be removed from the Draft Permit or modified to the extent that substantial evidence demonstrates: (1) the LID requirements control pollutants rather than storm water; and (2) an improvement to receiving water quality from reduced storm water flows.

6. THE PERMIT'S RECEIVING WATERS LIMITATIONS DISCHARGE PROHIBITIONS EXCEED THE REQUIREMENTS OF FEDERAL LAW

The City greatly appreciates the Regional Board's efforts to find a middle ground by incorporating an iterative compliance path for the Draft Permit's RWL requirements. However, because the Clean Water Act does not require receiving waters limitations to be incorporated into the Draft Permit, the City requests that the receiving waters limitations requirements in the Draft Permit simply be removed.

15.15

The City would like to highlight the fact that it views the current RWL requirements in the Draft Permit as a preferred alternative to the approaches taken by the San Diego and Los Angeles Regional Water Quality Control Boards. Nonetheless, the proposed requirements will impose a substantial burden on the City. If the Regional Board is going to look to other approaches on this issue, the City requests that the Regional Board adopt the approach taken by the Colorado Basin Regional Water Quality Control Board which provides a BMP-based, iterative compliance path. In all cases, it is the City's preference that the Regional Board simply remove the RWL prohibitions from the Draft Permit, as they are not required by Federal law.

A. *Federal Law does not require receiving waters limitations to be incorporated into the Draft Permit.*

The Clean Water Act does not require direct incorporation of water quality standards into municipal storm water permits. (*Defenders of Wildlife v. Browner* (9th Cir. 1999) 191 F.3d 1159 ("*Defenders of Wildlife*").) When adopting Section 402, Congress chose "not to include a similar provision [i.e., strict compliance with state water quality standards] for municipal storm-sewer discharges." (*Id.* at p. 1165.) Although the Clean Water Act does not require incorporation of receiving waters limitations into the permit, the Draft Permit requires compliance with water quality standards until a draft plan for compliance is submitted to the Regional Board.

Under Provision IV.D, a draft plan must be submitted *after* a determination has been made "that a discharge is causing or contributing to the exceedance of an applicable water quality standard." (Draft Permit, § IV.D.) Thus, compliance with water quality standards is mandatory, and only *after* non-compliance may a Co-permittee develop and submit a compliance plan. In this manner, the Draft Permit exceeds federal law by directly incorporating water quality standards and prevents compliance with receiving waters limitations through the iterative process until after an exceedance is demonstrated. Inclusion of the receiving waters limitations provision exceeds the Clean Water Act without the inclusion of an immediate compliance option
15.15 and may function to impair water quality by: (1) preventing the development of a compliance plan until after an exceedance is detected, and (2) disregarding compliance plans developed in a manner other than the manner provided in Draft Permit Provision IV.D, such as TMDL compliance plans.

The Draft Permit should be revised to remove the mandatory receiving waters limitations language, or alternatively and in accordance with Comment 5B, below, to allow Co-permittees to comply with Provision IV by implementing plans developed in a manner other than the manner provided in Draft Permit Provisions IV.D, such as TMDL compliance plans.

B. *Inclusion of the receiving waters limitations provisions under Porter-Cologne is inconsistent with precedential state Board Orders*

Inclusion of the Receiving Waters Limitations requirements in the Draft Permit pursuant to Porter-Cologne must comply with precedential Water Resources Control Board ("State Board") orders. (Gov. Code, § 11425.60; State Board Order WQ 2001-15; State Board Order WR 96-1, footnote 11 ["the [State Board] designates all decisions or orders adopted by the [State Board] at a public meeting to be precedent decisions"].) State Board Order WQ 2001-15 states that compliance with water quality standards is to be achieved over time, through an iterative approach requiring improved BMPs. Compliance with precedential State Board orders is

mandatory. (See *California Assn of Sanitation Agencies v. State Water Resources Control Board* (2012) 208 Cal.App.4th 1438, 1461, fn. 20.)

15.15 By mandating immediate compliance with the Draft Permit's Receiving Waters Limitations requirements, the Draft Permit violates the State Board's precedential order. As demonstrated in State Board Order WQ 2001-15, compliance with receiving waters limitations must be achieved through the iterative process. The Draft Permit should recognize plans already developed for the purpose of attaining reductions in pollutant loads as satisfying the compliance plan provision under Draft Permit section IV.A. The Draft Permit cannot prevent compliance through the iterative process until after an exceedance occurs. Draft Permit Provision IV needs to be revised to align the language with the State Board's precedential orders.

7. THE CITY REQUESTS THAT THE DRAFT PERMIT'S TMDL REQUIREMENTS BE REVISED TO CLARIFY THAT COMPLIANCE IS TO BE ATTAINED THROUGH THE IMPLEMENTATION OF BMPS.

The Clean Water Act does not require TMDLs to be incorporated into the Draft Permit. (Draft Permit, § XVIII.) The City seeks clarification on the following points: (1) that the Permit does not require immediate compliance with all WLAs; (2) that the WLAs do not constitute numeric effluent limitations; and (3) that implementation of BMPs on an iterative basis constitutes compliance with the Permit.

A. *Federal Law does not require TMDLs to be incorporated into the Draft Permit.*

15.16 The Clean Water Act does not require a TMDL to be incorporated into the Draft Permit. (*Defenders of Wildlife, supra,* 191 F.3d 1159.) Unlike industrial dischargers, who must comply strictly with state water quality standards, municipal storm sewer discharges are not required to comply strictly with water quality standards. (*Id.* at p. 1165.)

Because any inclusion of TMDLs in the Draft Permit is not required under the Clean Water Act, any such inclusion in the Draft Permit is a function of State law at the discretion of the Regional Board. As explained more fully below, the manner in which the Regional Board included the nutrient, fecal coliform, organochlorine compounds, diazinon, chlorpyrifos, toxics, and sediment TMDLs for San Diego Creek and Newport Bay Watershed, and the Coyote Creek Metals TMDL for the San Gabriel River into the Draft Permit represents an abuse of discretion, and the Draft Permit must be revised.

B. *To the extent that any TMDL is incorporated as an effluent limit, the Regional Board is required to follow Federal Regulations.*

The City requests that the Regional Board clarify that the Draft Permit's TMDL requirements are not effluent limits.

Federal law does not require the inclusion of TMDLs in municipal storm water permits, when issuing NPDES permits, the Regional Board is required to follow federal regulations regarding such inclusion. (See 40 C.F.R. § 122.44, subd. (d); 23 Cal. Code Regs., § 2235.2 ["Waste discharge requirements for discharge from point sources to navigable waters shall be issued and administered in accordance with the currently applicable federal regulations for the National Pollutant Discharge Elimination System (NPDES) program"].) Before it can incorporate any TMDL Waste Load Allocations ("WLAs") into the Draft Permit as effluent limits, the Regional Board must first find that there is a "reasonable potential" that the discharge of the pollutant to be regulated "has the reasonable potential to cause, or contributes to an in-stream excursion above a narrative or numeric criteria within a State water quality standard." (40 C.F.R. § 122.44, subd. (d)(1)(iii).)[4]

15.16

To determine whether a permitted discharge "causes, has the reasonable potential to cause, or contributes to an in-stream excursion above the allowable ambient concentration of a State numeric criteria within a State water quality standard[,]" the Regional Board must:

> use procedures which account for existing controls on point and nonpoint sources of pollution, the variability of the pollutant or pollutant parameter in the effluent, the sensitivity of the species to toxicity testing (when evaluating whole effluent toxicity), and where appropriate, the dilution of the effluent in the receiving water. (40 C.F.R. § 122.44, subd. (d)(1)(ii).)

There are two generally accepted approaches to conducting reasonable potential analysis: "A permit writer can conduct a reasonable potential analysis using effluent and receiving water data and modeling techniques, or using a non-quantitative approach." (NPDES Permit Writers' Manual, September 2010, pages 6-23.)

The first approach requires end of pipe monitoring data to be evaluated against in-stream generated ambient (dry weather) data. There is no evidence in the Draft Permit or the Draft Technical Report that the Regional Board based the Draft Permit's requirements on any such

[4] Pursuant to the *Defenders of Wildlife* decision, 40 C.F.R. § 122.44(d) does not require incorporation of TMDLs or WQBELs into municipal storm water permits. When incorporated, however, Section 122.44(d) requires implementation of WQBELs to attain water quality standards.

data. (Draft Technical Report, pages 63-67.) Nor is there any information regarding the performance of the second approach, a non-quantitative analysis based on recommended criteria described in the EPA guidance. Neither the Draft Permit nor the Draft Technical Report contain any evidence that a reasonable potential analysis has been performed in accordance with 40 C.F.R. section 122.44(d).

15.16

If the TMDL requirements are being imposed as effluent limits, the Regional Board must comply with requirements for developing those limits instead of passing those on to the Co-permittees.

C. *The Draft Permit's TMDL requirements need to be consistent with applicable implementation plans developed for each TMDL.*

Consistent with TMDL requirements, Co-permittees have developed and implemented or are in the process of developing and implementing compliance plans for several TMDLs in the Newport Bay watershed. The Executive Officer has reviewed and approved some of these plans, and the Co-permittees are implementing the plans. Where a TMDL provides for the development and implementation of a compliance plan, the Draft Permit should reflect such a provision. Implementation of BMPs and other requirements consistent with these plans should be sufficient for permit compliance.

15.17

8. SECTION XII.B.1 SHOULD BE REVISED TO EXEMPT CO-PERMITTEE PROJECTS FROM COMPLYING WITH NEW REQUIREMENTS ONCE A PROJECT IS FUNDED

Section XII.B.1 of the Draft Permit requires Co-permittee-initiated "projects for which funding is approved on the date of the adoption of this Order" to comply with the new and redevelopment standards set out in the Draft Permit. The intent of this provision appears to be to exempt projects for which funding is approved on the date of the adoption of the Draft Permit from complying with the standards. The language, however, accomplishes the opposite and requires such projects to comply with the Permit requirements. If the Draft Permit's intent is the require such compliance, all projects which have been approved, funded, or are partially constructed on the date of the Draft Permit's adoption must cease all construction activity, be redesigned, deconstructed, and reconstructed to comply with the new requirements. Such interference with City projects may result in an unconstitutional impairment of contracts in violation of the contract clauses of the United States and California Constitutions. (U.S. Const. art. I, § 10; Cal. Const. art. I, § 9.)

15.18

The City offers the following revised language:

> The requirements of Section XII.B., and subsequent sub-sections of Section XII., apply to initial project applications received by the Co-Permittees 12 months after adoption of this Order. For projects initiated by the Co-permittees, the requirements of Section XII. do not apply to projects that have been approved within 12 months after the date of the adoption of this Order. In the interim, the relevant requirements of Order No. R8-2009-0030 shall apply.

15.18

9. THE REGIONAL BOARD HAS FAILED TO COMPLY WITH WATER CODE SECTIONS 13000, 13263, AND 13241

Under the California Supreme Court's holding in *Burbank v. State Board* (2005) 35 Cal.4th 613 ("*Burbank*"), a regional board must consider the factors set forth in sections 13263, 13241 and 13000 when adopting an NPDES Permit, unless consideration of those factors "would justify including restrictions that do not comply with federal law." (*Id.* at 627.) Section 13263 directs regional boards, when issuing waste discharge requirements, to take into account various factors including those set forth in Section 13241." (*Id.* at 625, emphasis added.) Specifically, the Court held that to the extent NPDES Permit requirements are not compelled by federal law, the regional boards are required to consider, among other factors, the "economic" impacts of such requirements on the dischargers themselves; such a requirement means that the boards must analyze the "discharger's cost of compliance." (*Id.* at 618.)

15.19

A. Finding 31 and Technical Report section X do not adequately consider economic impacts of complying with the state mandated requirements.

To the extent the Draft Permit provisions are not compelled by federal law, a regional board must consider the factors set forth in sections 13263, 13241 and 13000 when adopting an NPDES Permit, unless consideration of those factors "would justify including restrictions that do not comply with federal law." (*Burbank*, *supra*, 35 Cal.4th 6 at p. 627.) Specifically, regional boards are required to consider the "economic" impacts of Draft Permit requirements on Co-permittees, with the Court finding that such a requirement means that the boards must analyze the "discharger's cost of compliance." (*Id.* at 618.)

The Draft Permit does not undertake a complete analysis of the Co-permittees' costs of complying with the Draft Permit's requirements which exceed the federal minimum. According to the Draft Permit, a lack of comprehensive or reliable economic data on the costs and benefits makes performing a formal economic analysis impractical at this time. (Draft Permit, Draft

Technical Report, at p. 31.) After asserting that such an analysis is impractical and not required, the Draft Permit then considers economic factors. (*Id.* at pp. 30-31.) The Draft Permit relies on the partial, outdated and irrelevant data provided by the US EPA, State Water Resources Control Board and regional boards, as well as a Willingness to Pay and Travel Cost Analysis to conclude that the "benefits of protecting beneficial uses . . . considerably exceed the annual per-household costs of the MS4 programs summarized in [the studies]." (*Id.* at p. 33.) Despite concluding that the benefits exceed the costs, the economic considerations set out in the Draft Permit expressly excludes "a Cost-Benefit analysis or other formal economic analyses." (*Id.* at p. 31.)

15.19

Section 13241 is not satisfied by relying on partial and unreliable data or its irrelevant "per household" consideration of an informal cost-benefit analysis. As a result, the Draft Permit's economic consideration is arbitrary and capricious and must be reconsidered to include data relevant to the Co-permittees and to the Draft Permit's specific requirements. Nothing in the Draft Technical Report links the permits studied by the US EPA and the state and regional boards generally with any of the specific requirements of the Draft Permit. Therefore, the studies tell the public nothing about the costs to implement the Draft Permit.

15.20

The data included in the Technical Report are outdated, ranging from 9 to 17 years old. The costs and benefits are also calculated on a meaningless basis in terms of a Co-permittee's funding of the Draft Permit's costs: a per household basis. Co-permittees do not incur costs or collect revenues to implement Draft Permit requirements on a per household basis. Indeed, Co-permittees cannot collect revenues on such a basis unless the public approves such a method in an election. (Cal. Const. arts. XIIIC, XIIID.) Since 1995, only 67% of such water-specific storm water measures have been approved by voters. (Public Policy Institute of California, Paying For Water in California, Technical Appendix E (Mar. 2014), p. 11 ("PPIC Report").) Not only are the data in the PPIC Report nearly a decade more recent than the data in the Draft Permit, the PPIC Report considered Draft Permit requirements which did not exist when the studies cited in the Draft Permit were conducted. The PPIC Report concludes that, even using state wide household cost estimates, "the total annual costs of meeting urban storm water permit requirements are currently in the range of $1 billion to $1.5 billion, with costs likely to continue to rise as new permit requirements come due." (*Ibid.*) Public agencies, such as the City, "are likely to have stable funding for no more than half that amount, leaving a gap of $500 million to $800 million per year, or $40 to $65 per household." (*Ibid.*) Not only is the annual funding gap identified by the most recent data twice as much as the Draft Permit estimates as the total per-household cost to comply with the Draft Permit, the City currently has no authority to address the funding gap on a per-household basis. (Cal. Const. arts. XIIIC, XIIID.)

15.21

In addition to relying on outdated and inapplicable data, the Regional Board's cost analysis is fundamentally flawed because it tells the public nothing at all about the relationship between the cost of any particular BMP and the pollution control benefits to be achieved by

implementing that BMP. Under this "generalized" approach, extremely costly requirements that bear little or even no relationship (or even a negative relationship) to the pollution control benefits to be achieved could be "justified" as long as the "overall" program costs are within what the Regional Board deems to be an acceptable range.

15.21 A generalized approach to economic considerations is not a proper way to assess the cost of complying with the Draft Permit's particular requirements. A more individualized assessment of cost is required. Otherwise, dischargers may be required to implement very costly controls that have no relationship to pollution control benefits, a result inconsistent with MEP. This analytical flaw in the Technical Report is compounded by the approach taken to assess the benefits of the Draft Permit. The Draft Permit relies on the Willingness to Pay and Travel Cost Analysis to calculate the benefit of the Draft Permit requirements at $180 per household (2005 dollars). (Draft Permit, Technical Report, at p. 33.) Here again, the assessment approach misses the mark because it tells the public nothing about the pollution control benefits to be achieved by implementation of the controls in the Draft Permit and ignores the Co-permittees' inability to collect such funds on a per-household basis without an affirmative vote of such households. All the Technical Report indicates, in essence, is that people like clean water and, in theory, may be willing to pay for it. The PPIC Report demonstrates that, for as much as people like clean water, only 67% of the time are they willing to actually pay for it. (2014 PPIC Report, Appendix E, at
15.22 p. 11.) The Draft Permit's analysis sheds no light on the relationship between the actual cost of complying with the Draft Permit and the pollution control benefits to be achieved by implementing the Draft Permit's requirements and must be reconsidered using current and relevant data.

B. Section XVIII does not adequately consider economic or non-economic factors required by Water Code sections 13000, 13263, and 13241.

As described above, Federal Law does not require TMDLs to be included in municipal storm water permits. (*Defenders of Wildlife*, *supra*, 191 F.3d at p. 1165; 40 C.F.R. § 122.44, subd. (d).) Consequently, the Regional Board is required to consider the factors listed in Water Code sections 13000, 13263 and 13241 before including the TMDL in the Draft Permit.
15.23 (*Burbank, supra,* 35 Cal.4th 613.)

Water Code sections 13000, 13263, and 13241 require much more than an economic analysis. They require an analysis, in part, of the following elements:

(a) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto;

(b) Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area;

(c) The need for developing housing within the region;

(d) The need to develop and use recycled water;

(e) An analysis of whether the proposed Permit terms are "reasonable, considering all demands being made and to be made on [receiving] waters[;]" and

15.23

(f) whether specific Permit requirements are necessary, given "the beneficial uses to be protected, the water quality objectives reasonably required for that purpose, other waste discharges." (Water Code, §§ 13000, 13241, subds. (b)-(f), 13263, subd. (a).)

The Draft Permit ignores the environmental characteristics of the watershed. (Water Code, § 13241, subd. (b).) Co-permittees have undertaken extensive programs to improve water quality and have prepared a thorough report on the quality of waters in the watershed. The Draft Permit disregards these efforts and the present state of the waters and increases Co-permittees obligations under the Draft Permit without any reference to the water quality conditions that could reasonably be achieved through the Draft Permit's additional requirements. The Draft Permit should be based on the state of the environment and only impose requirements on Co-permittees designed to address specific environmental problems.

The Draft Permit likewise ignores the present state of the law and the scheme of joint and several liability established by the Draft Permit in facilitating coordination among Co-permittees. (Water Code, § 13241, subd. (c).) The practical effect of the Draft Permit's scheme and the Ninth Circuit's decision in *Natural Resources Defense Council v. County of Los Angeles* (9th Cir. 2013) 725 F.3d 1194 will be to reduce coordination among Co-permittees. Where the City may be liable for another Co-permittee's failure to implement TMDL requirements, for example, the City is unlikely to participate with other Co-permittees in developing or implementing a TMDL compliance plan. (See Draft Permit, § XVIII.C.) A scheme of joint and several liability that discourages coordination is also unnecessary to protect beneficial uses and attain water quality objectives. (Water Code, § 13263, subd. (a).) Because the Draft Permit does not identify how a scheme of joint and several liability promotes coordination and is necessary to protect beneficial uses, such a scheme should be removed or explicitly denounced in the Draft Permit.

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15.23

Finally, the Draft Permit does not address how its requirements affect the need for developing housing within the region (Water Code, § 13241, subd. (e)); the need to develop and

use recycled water (Water Code, § 13241, subd. (f)); or whether the proposed Draft Permit terms are "reasonable, considering all demands being made and to be made on [receiving] waters" (Water Code, § 13000).

15.23 The inclusion of the TMDL in the Draft Permit violates sections 13263, 13241 and 13000, as well as the California Supreme Court's decision in *Topanga Association for a Scenic Community v. County of Los Angeles* (1974) 11 Cal.3d 506. For these reasons, the TMDL requirements should be removed from the Draft Permit or modified to address the concerns raised in this letter.

10. THE STATE MANDATES ANALYSIS IN FINDING 32 AND TECHNICAL REPORT SECTION VI.E CONSIDER IMPROPER FACTORS AND IS NOT SUPPORTED BY THE EVIDENCE.

The only agency charged with determining whether a mandate is imposed by the state is the Commission on State Mandates ("Commission"). (Gov. Code, § 17552.) The Draft Permit, however, concludes that the Draft Permit's requirements are federal mandates. (Draft Permit, Finding 32; Draft Permit, Technical Report, VI.E.) This conclusion is based on improper 15.25 factors, such as a comparison of the Co-permittee's obligations with the obligations imposed on non-governmental and new dischargers. (Draft Permit, Finding 32.b.) The proper analysis for determining whether a requirement is a state mandate is to compare the express requirements of federal law with the requirements of the state action. (See *San Diego Unified School District v. Commission on State Mandates* (23004) 33 Cal.4th 859, 868.) Because the Commission has authority to determine whether the Draft Permit's requirements are State mandates and because the analysis set forth in the Draft Permit does not apply a proper state mandates analysis, the Draft Permit should be revised to remove all state mandates analyses.

11. FINDINGS 10, 31, TECHNICAL REPORT SECTION V, AND THE GLOSSARY IMPROPERLY CLASSIFY NATURAL WATERS AS PART OF THE MS4.

Natural waters cannot be both receiving waters and part of the MS4. (40 C.F.R. § 122.26, subd. (b)(8); (*Los Angeles County v. NRDC* (2013) 133 S.Ct. 710.) The Draft Permit 15.26 states that development often makes use of natural drainage patterns and features as conveyances for runoff. (Draft Permit, Finding 13.) Finding 13 goes on to state that rivers, streams and creeks in developed areas used in this manner and under the ownership and control of the Co-permittees are part of an MS4, whether the river, stream or creek is natural, anthropogenic or partially modified. It further states that these natural water bodies are both an MS4 and a receiving water.

Finding 13 is expressly contradicted by the Federal Regulation defining an MS4 and by recent United States Supreme Court case law. Federal Regulations define a municipal separate storm sewer system as:

> a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains):
>
> i. Owned or operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) ... including special districts under state law such as a sewer district sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act that discharges into waters of the United States;
>
> ii. Designed or used for collecting or conveying stormwater;
>
> iii. Which is not a combined sewer; and
>
> iv. Which is not part of a publicly owned treatment works (POTW) as defined at 40 C.F.R. 122.2. (40 C.F.R. § 122.26, subd. (b)(8).)

15.26

The definition of a municipal separate storm sewer system is specifically limited to *man-made* channels and systems and does not encompass natural water bodies. Discharging to a natural water body does not transform a natural water body into an MS4. A discharge makes a natural water body a "receiving water." Similarly, improving natural rivers, streams and creeks does not make them MS4s, or part of an MS4. They simply become improved waters of the United States. The US Supreme Court recently confirmed this conclusion when it determined that the flow of water from an improved portion of a navigable flood control channel into an unimproved portion of the same waterway is not a "discharge of a pollutant" under the Clean Water Act. (*Los Angeles County v. NRDC* (2013) 133 S.Ct. 710.)

Lastly, municipalities do not generally own, control or operate natural rivers, streams and creeks. Such water bodies are often administrated by the State of California in the public trust for

the right of the people to use such waters for certain purposes or are privately owned. The Legislature, acting within the confines of the common law public trust doctrine, is the ultimate administrator of the trust and may often be the final arbiter of permissible uses of trust lands. Such waters are not therefore, part of the City's MS4. For these reasons, Finding 13 and Technical Report section V, and reference to "natural drainage features or channels" and "modified natural channels" in the Glossary's definition of Municipal Separate Storm Sewer System should be deleted. 15.26

CONCLUSION

The City appreciates this opportunity to comment on the Draft Permit. The City believes that the Regional Board has a genuine interest in working with all interested parties to develop a permit that protects the waters in the Santa Ana and Newport Bay/San Diego Creek Watersheds while at the same time giving dischargers such as the City the ability to comply with the permit's requirements.

Thank you for considering the City's comments and feel free to contact me if you have any questions.

Sincerely,

J. G. Andre Monette
for BEST BEST & KRIEGER LLP