A REVIEW OF LOW IMPACT DEVELOPMENT POLICIES: REMOVING INSTITUTIONAL BARRIERS TO ADOPTION

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EXECUTIVE SUMMARY

Managing stormwater runoff has historically presented technical challenges because of its diffuse and episodic nature, the range of pollutants requiring treatment, and the volume of runoff resulting from changes in land cover. Complicating the technical challenges is a regulatory environment that has been based on presumptive minimum treatment standards and has not effectively promoted innovative treatment approaches. Recent research and pilot applications have demonstrated efficient approaches to control and treat stormwater runoff and have removed many of the technical barriers. However, regulatory and institutional barriers still exist and can prevent application of effective control programs.

This analysis reviewed the State of California's primary mechanisms of regulating stormwater runoff and considered how low impact development (LID) approaches could be used for compliance purposes. A review of the country's more progressive regulatory approaches is also included to illustrate requirements or incentives for LID or other innovative treatment programs. California has already made steps toward a regulatory system that encourages better treatment performance and the application of LID; the State Water Resources Control Board's recent emphasis on limiting hydromodification impacts (changes in a site's runoff and transport characteristics) from development will create the framework for broader adoption of LID. In addition, the Porter-Cologne Act (commonly referred to as the California Water Code) allows the Water Boards broad discretion to implement innovative natural resource protection programs because it allows the regulation of any activity or factor that affects water quality and is not narrowly focused on end-of-pipe treatment.[1]

INTRODUCTION

When the Clean Water Act (CWA) was amended in 1987, a federal mandate to manage and control stormwater was established.[2] The past 20 years have witnessed significant shifts in the science and regulatory environment of municipal and post-construction runoff control. The recent movement to address stormwater on a watershed basis by limiting hydromodification and the volume of discharges is a departure from the convention of peak flow limitation and flood control. Advances in understanding the relationship between hydromodification and stream health and the science to preserve or restore water quality have greatly outpaced the changes in the regulatory environment and institutional structures that influence stormwater programs, neither of which having ever fully matured to achieve water quality or environmental goals.

With the technical approach coming into focus, the regulatory system needed to foster and propel these new strategies has not yet been developed. The intent of regulatory compliance is not necessarily meeting resource objectives. Regulations often set a minimum benchmark of environmental effort and often are not or cannot be designed to fully achieve water quality objectives. Maximum extent practicable or water quality standards along with other programs and efforts are used to augment regulations to achieve the full desired environmental outcome. Designing regulations and integrating them with other programs to achieve desired outcomes and benefits is critical to improving stormwater management.

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[1] California Water Code sections 13000, 13050(i), 13140, 13142, 13241.
[2] 40 CFR 122.26

Several states, including California, have begun to evaluate the regulatory changes that are required and the impacts that they will have on the success of their programs. This effort is one step in that process. This paper will focus on municipal and post-construction runoff and review the regulatory and institutional structure that influences stormwater control in California. It will also evaluate new programs and efforts aimed at improving stormwater management. Lastly it will evaluate policy and program options that could further advance the implementation of comprehensive water programs.

BACKGROUND

The diversity of climatic and geographic conditions within California has influenced the structure of the State's water agencies. The State Water Resources Control Board (SWRCB), created in 1967, has water allocation and water quality protection responsibilities. Nine Regional Water Quality Control Boards (RWQCBs), established along major watershed boundaries, have development and enforcement responsibilities of water quality objectives and implementation plans. The U.S. Environmental Protection Agency (EPA) has authorized the State to administer the National Pollutant Discharge Elimination System (NPDES) program, which uses statewide and regional programs to fulfill the mandated requirements. Municipal NPDES permits are issued by the Regional Boards.

The Porter-Cologne Water Quality Control Act, passed in 1969 and predating the CWA, is the main statute that governs water quality control in the state. Porter-Cologne subjects any activity or factor that affects water quality to regulation and covers point and non-point sources. By looking comprehensively at influences on water quality, not only are pollutant discharges subject to regulation, but also parameters such as flow or riparian or land use changes that can impose physical or temperature impacts.[3] Porter-Cologne applies to all waters of the state including wetlands and groundwater. It also establishes the tenant that waste discharges to state waters are a privilege and not a right.[4,5]

Through Porter-Cologne the SWRCB and RWQCBs are provided:[6]

1. Planning authority to designate beneficial uses of State waters, establish water quality objectives, and develop implementation programs to meet water quality objectives and designated uses.
2. Permitting authority.
3. Enforcement authority to ensure permit compliance.

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[3] J. M. Gerstein, et al., *State and Federal Approach to Control of Nonpoint Sources of Pollution*, University of California Cooperative Extension, August 2005.
[4] State Water Resources Control Board, *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program*, May 20, 2004.
[5] When the 1987 amendments to the CWA designated municipal stormwater runoff as a point source, regulation of stormwater came under the provisions of the National Pollutant Discharge Elimination System (NPDES) program. California, like other states, has a defined institutional and regulatory separation between municipal stormwater and other non-point sources that are influenced by Porter-Cologne.
[6] State Water Resources Control Board, *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program*, May 20, 2004.

With this authority, the SWRCB is responsible for setting statewide policy and regulations, in addition to developing statewide water quality control plans. Based on the SWRCB policies, the nine RWQCBs develop individual water quality control plans, referred to as Basin Plans. Once developed, the basin plans must be approved by the SWRCB, the Office of Chief Council, and the U.S. EPA.[7] The coordinated efforts between the State and Regional Boards constitute the primary mechanism through which the State addresses point and nonpoint source pollution and implements its control program. The SWRCB also has the authority to adopt statewide water quality control plans, like the California Ocean Plan, the Plan for California's Nonpoint Source Pollution Control Program, and the California Thermal Plan. The Ocean Plan contains a prohibition of any discharge of waste (e.g., stormwater) to waters designated as Areas of Special Biological Significance (ASBS).

In addition to the framework above, a number of other regulatory agents and programs (e.g., the California Water Boards and CWA 401 Certification, the California Coastal Commission and the Coastal Zone Act Reauthorization Amendments) also directly impact stormwater discharges in the state. Although not discussed in detail, the requirements of these programs work in concert with the stormwater program and can lead to more stringent pollutant discharge limitations in runoff.

NPDES Permits

Construction General Permit

The SWRCB last issued statewide general NPDES stormwater permits for designated construction activities in 1999 (SWRCB Order 99-08-DWQ). This permit contains minimum requirements to control post-construction runoff. Page 79 of SWRCB Order 99-08-DWQ states:

> *10. Post-Construction Storm Water Management*
>
> *The SWPPP shall include descriptions of the BMPs to reduce pollutants in storm water discharges after all construction phases have been completed at the site (Post-Construction BMPs). Post-Construction BMPs include the minimization of land disturbance, the minimization of impervious surfaces, treatment of storm water runoff using infiltration, detention/retention, biofilter BMPs, use of efficient irrigation systems, ensuring that interior drains are not connected to a storm sewer system, and appropriately designed and constructed energy dissipation devices. These must be consistent with all local post-construction storm water management requirements, policies, and guidelines. The discharger must consider site-specific and seasonal conditions when designing the control practices. Operation and maintenance of control practices after construction is completed shall be addressed, including short-and long-term funding sources and the responsible party.*

[7] State Water Resources Control Board, *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program*, May 20, 2004.

While this language describes LID techniques, there is no level of compliance specified. The standard for the Construction General Permit is Best Available Technology economically achievable/ Best Conventional pollutant control Technology (BAT/BCT).[8] However, since it is not easy to apply a technology standard to the practice of minimizing land disturbance, this permit language is difficult to enforce. Municipal permits have the standard of Maximum Extent Practicable (MEP) which lends itself more naturally to specifying and enforcing a level of compliance for low impact development.

In March 2007 the SWRCB released a preliminary draft NPDES stormwater permit for construction activities as part of the Reissuance process of SWRCB Order 99-08-DWQ. This preliminary draft permit contains much more specific requirements for post-construction stormwater runoff. If approved, the new permit would establish statewide post-construction runoff standards. This would significantly alter the existing framework that relies on the municipalities to address post-construction runoff and leaves the unincorporated areas of the State largely unaddressed. The draft permit requires mitigating hydromodification by maintaining pre-development hydrologic characteristics on a site.[9]

<u>Municipal Phase I Permits</u>

The Regional Boards are currently using their authority to issue municipal separate storm sewer system (MS4) permits to address post-construction runoff.[10] Each Regional Board issues individual MS4 NPDES stormwater permits to their qualifying or designated Phase I permittees. At a minimum these require the MS4 permittees to develop and implement plans such as Standard Urban Storm Water Mitigation Plans (SUSMPs) that address new development and redevelopment projects that disturb more than one acre.[11,12] For example, the SUSMPs in the Los Angeles Water Board jurisdiction establish which types of development will be required to implement stormwater controls and the control, pollutant removal, site design, and maintenance requirements. The Los Angeles County SUSMP stipulates the following runoff requirement:[13]

> *Post-development peak stormwater runoff discharge rates shall not exceed the estimated pre-development rate for developments where the increased peak stormwater discharge rate will result in increased potential for downstream erosion.*

This language, which is typical for many municipal stormwater permits in California and the country, establishes the regulated physical stormwater parameter as the *rate* of discharge. This definition is typically based on one or more single peak storm events rather than continual flow information from runoff events. The SUSMP regulatory construct is in line with the historical

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[8] State Water Resources Control Board, National Pollutant Discharge Elimination System General Permit for Storm Water Discharges Associated with Construction Activity, Water Quality Order 99-08-DWQ, p.1.

[9] State Water Resources Control Board, Draft National Pollutant Discharge Elimination General System General Permit Number CAR000002, Waste Discharge Requirements For Discharges Of Storm Water Runoff Associated With Construction Activity, March 2007.

[10] Personal communication, Eric Berntsen, State Water Resources Control Board, April 2007.

[11] Memo from the SWRCB Office of Chief Counsel on SWRCB Order WQ 2000-11: SUSMP, Craig M. Wilson, December 26, 2000.

[12] Los Angeles County Urban Runoff and Stormwater NPDES Permit, Standard Urban Stormwater Mitigation Plan, March 2000.

[13] Ibid.

thinking about stormwater impacts that postulated that the velocity of stormwater was the main factor impacting receiving stream quality and channel impacts. This primary requirement along with site design and treatment requirements form the range of requirements necessary to be satisfied for new development and redevelopment.

Municipal Phase II Permit

The SWRCB adopted a statewide General Phase II MS4 Permit in April, 2003 (SWRCB Order No. 2003-0005-DWQ). The permit contains similar post-construction language to Phase I permits.

The Central Coast Water Board requires municipalities, via the General Phase II MS4 Permit, to minimize negative impacts on aquatic ecosystems and degradation of water quality to the maximum extent practicable by incorporating LID methodology into new and redevelopment ordinances and design standards, unless permittees can demonstrate that conventional BMPs are equally effective, or that conventional BMPs would result in a substantial cost savings while still adequately protecting water quality and reducing discharge volume. In order to justify using conventional BMPs based on cost, permittees must show that the cost of low impact development would be prohibitive because the "cost would exceed any benefit to be derived." (State Water Resources Control Board Order No. WQ 2000-11). The Central Coast Water Board has determined that conventional site layouts, construction methods, and stormwater conveyance systems with "end-of-pipe" basins and treatment systems that do not address the changes in volume and rates of storm water runoff and urban pollutants (including thermal pollution) do not meet MEP standards.[14]

HYDROMODIFICATION

Changes in land cover are the cause of hydromodification: changes in a site's runoff and transport characteristics. Impervious surfaces, compacted soils, deforestation, and topographic modifications alter the distribution and flow of water across a site. Infiltration, interception, and evapotranspiration are diminished and a greater percentage of precipitation is converted to overland flow. These changes impact the water balance on site, less water infiltrates and is available for groundwater recharge or shallow subsurface flows that constitute the base flows of receiving streams. In addition, the increased volume of overland flow imparts physical impacts on receiving streams and transports pollutants that have collected on impervious surfaces.[15]

The effects of hydromodification can be demonstrated on a hydrograph, a representation of a site's stormwater discharge with respect to time. The hydrograph in Figure 1 shows development's impact on a site's runoff. Individual points on the curve represent the rate of stormwater discharge at a given time. The graph shows that development and corresponding changes in land cover result in greater discharge rates, greater volume, and a shorter time to reach the maximum discharge rate (referred to as time of concentration, T_c). In a natural or pre-

[14] Central Coast Water Board Low Impact Development web page, How LID is currently required: http://www.waterboards.ca.gov/centralcoast/stormwater/low%20impact%20devel/lid_index.htm (accessed November 2007).

[15] U.S. EPA, *Protecting Water Quality from Urban Runoff*, Nonpoint Source Control Branch, EPA-841-F-03-003, February 2003.

development condition the initial rainfall is absorbed by the soil and vegetation. Once these are saturated, or the initial losses are satisfied, runoff occurs. In the post-development condition there is generally a much shorter time before runoff begins because of connectivity of impervious and developed areas and the loss of vegetative cover.

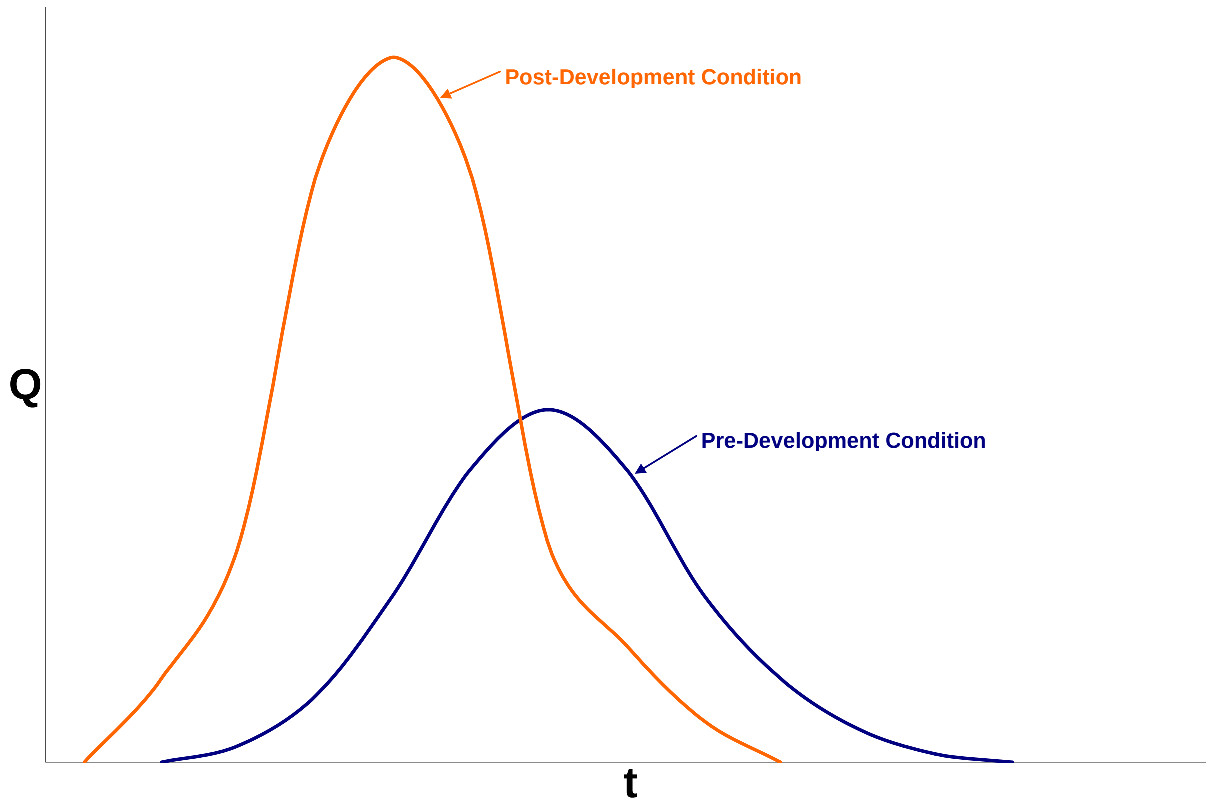

Figure 1. Hydrographs showing development's impact on runoff.
(Q = volumetric flow rate; t = time)

The area under the hydrographs represents the total volume of stormwater discharged. Along with the increased rate of discharge is an increased volume of discharge after development. The first analyses of these hydrograph impacts produced the consensus that the maximum rate of discharge was the critical parameter for protecting the integrity of receiving streams. The result of this concept was a regulatory structure, like those witnessed in many SUSMPs, that establishes requirements for the peak rate of discharge. Figure 2 shows how the post-development hydrograph responds to this type of regulatory structure.

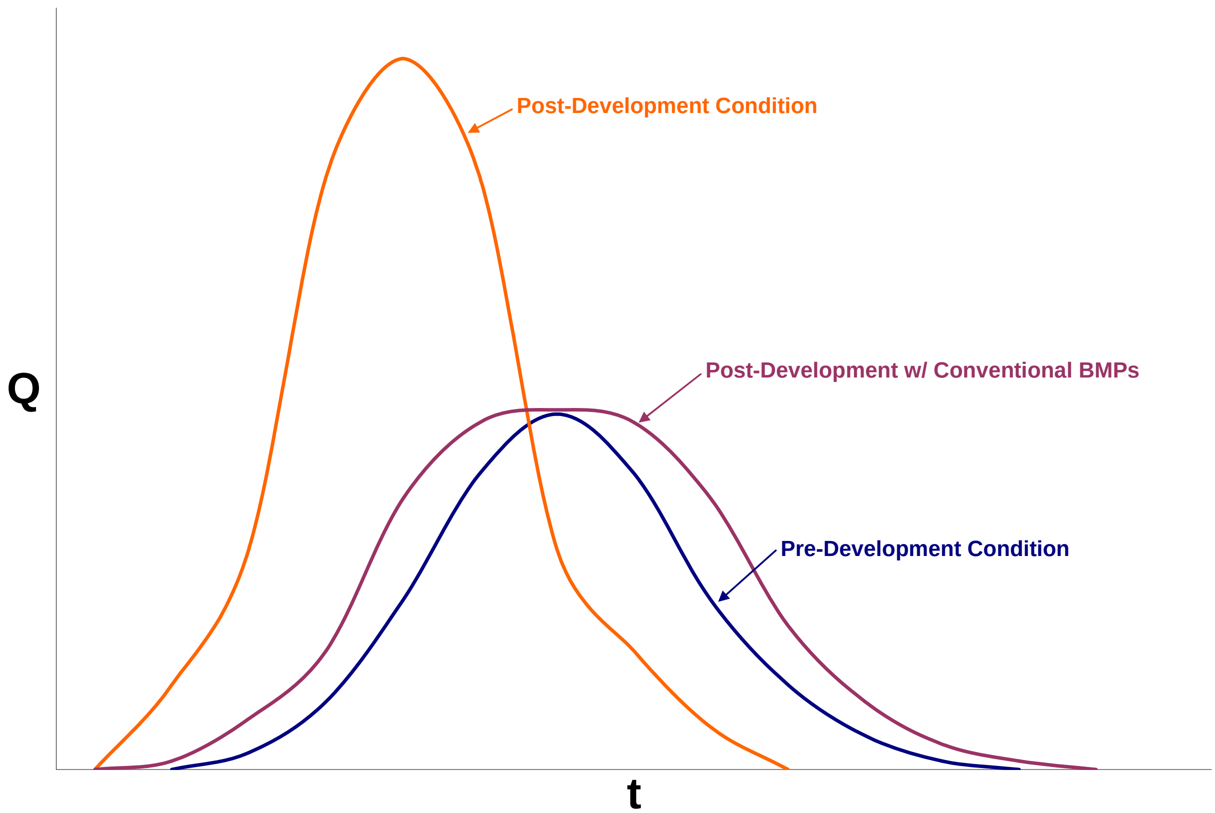

Figure 2. Post-development hydrograph response to conventional BMPs.
(Q = volumetric flow rate; t = time)

As Figure 2 illustrates, although the post-construction rate of stormwater discharge is equivalent to the pre-construction rate, it is sustained for a longer period of time and the total volume and energy of stormwater discharged, when compared to pre-development, is greater. This hydrograph response illustrates one reason why stormwater control efforts have been largely unsuccessful. Even when peak discharge rates are matched, the increased volume of stormwater delivers more energy and an increased amount of pollutants to the receiving stream when compared to pre-developed conditions. This result demonstrates the inefficiencies of the prevailing regulatory system and helps to predict that this type of framework will be unlikely to ultimately achieve water quality goals.

A regulatory system that attempts to address this deficiency and reduce the increase in the volume of stormwater discharge will propose a standard that stipulates that the rate of post-construction discharge will be equal not only to the pre-development peak rate, but also as every point-in-time along the hydrograph. This approach, a version of which is presented in the draft Construction stormwater NPDES permit, results in the hydrograph response represented in Figure 3.

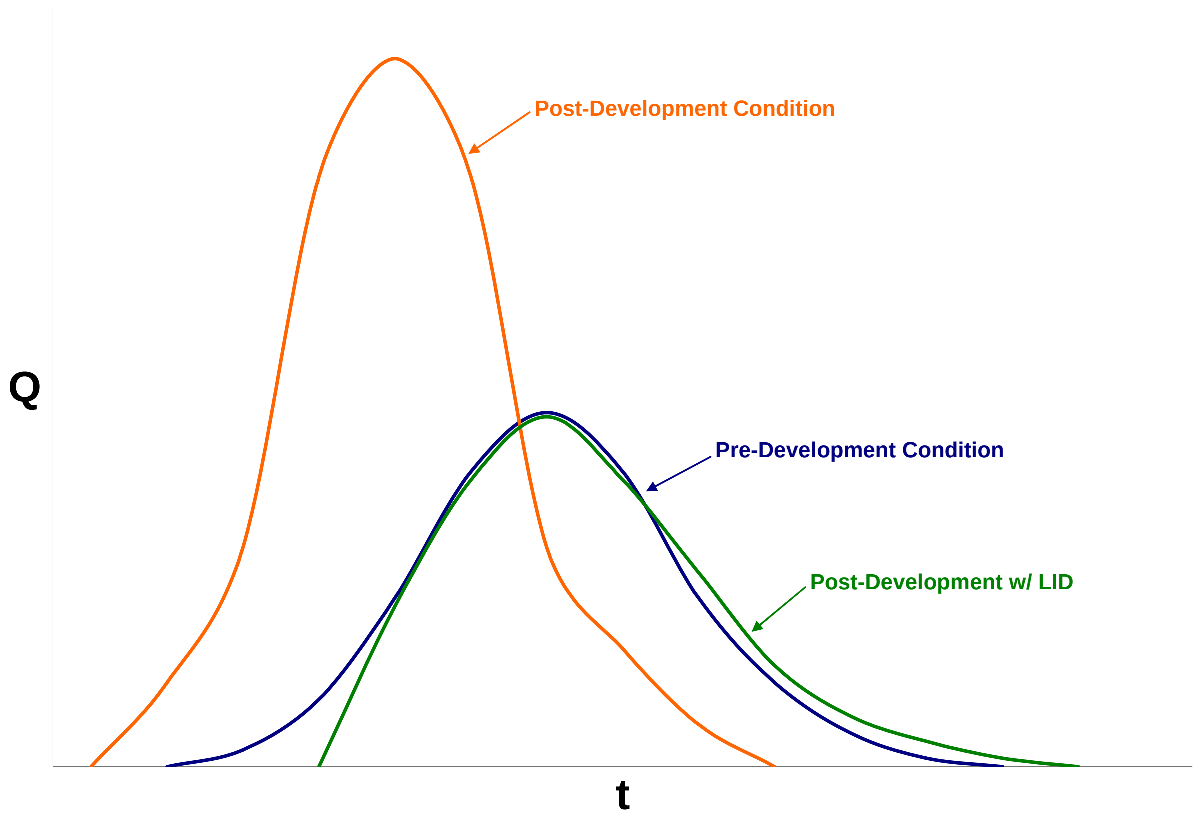

Figure 3. Post-development hydrograph response to LID controls.
(Q = volumetric flow rate; t = time)

Low Impact Development's Influence on Hydromodification

Traditionally, a wastewater collection and treatment system approach has been applied to stormwater management. End-of-pipe treatment and control technologies have been the predominate methods of stormwater control. However, this system of control essentially concedes the inevitability of hydromodification; that the only control options are those that deal with the consequences of development without addressing the root causes of the problem. To be fair, many stormwater management plans and manuals address site design, source control, and pollution prevention strategies. Mostly though, these are presented as "add-on" options that may be done above the standard end-of-pipe controls. The regulatory mandates still largely preserve the centralized collection and treatment system of control.

Over the past decade, LID has emerged as an alternative management approach. Rather than centralized, end-of-pipe controls, LID relies on an integrated system of decentralized, small-scale control measures. These measures range from site design practices to technology driven LID BMPs. The underlying principle of LID is that undeveloped land does not present a stormwater runoff or pollution problem. The evolved natural hydrology of any given site manages water in the most efficient manner. This most often translates to high rates of infiltration, vegetative interception, and evapotranspiration.

LID attempts to offset the inevitable consequences of development and changes in land cover by preserving or mimicking natural hydrology. It is a source control option that minimizes stormwater pollution by recognizing that the greatest efficiencies are gained by minimizing stormwater generation. This is a process that begins with functional conservation of watershed resources, reducing impacts of development, and then using innovative management practices to meet the stormwater objective; it is not the use of the management practices alone. Site preservation practices coupled with small-scale BMPs that rely on the environmental services of vegetation and soils or systems that mimic these services comprise the control approach of LID. These practices, taken in aggregate, limit the observed hydromodification on a developed site and present a more comprehensive and beneficial control approach.

Needing to be addressed, however, is the lag in broad LID implementation. Even though it has been demonstrated as an attractive strategy, its application is limited and has not yet been fully integrated. Several barriers have generally slowed and hampered greater LID adoption. Bureaucratic inertia involving the entrenchment of prevailing conventional practices, institutional structures, and regulatory shortfalls are the prime barriers preventing a broad shift in stormwater management philosophy. Of these, regulatory structure is the most critical barrier. If regulations are crafted appropriately and call for proper environmental performance, a significant catalyst for overcoming the other barriers will be created and facilitate further institutional changes.

To appropriately implement LID it is important to assess its role in water quality protection. LID is one part of a toolkit that can be used to better manage natural resources and limit the pollution delivered to waterways. It is not independent of watershed planning and to gain optimal benefits LID needs to be integrated with appropriate land use programs. LID by itself will not deliver the water quality outcomes desired; it does provide enhanced stormwater treatment and mitigate excess volume and flow rates. However, if not integrated in a comprehensive fashion, LID techniques can end up as a series of uncoordinated innovative BMPs that have limited water quality benefit.

The potential of LID is maximized when it is used in conjunction with other conservation and planning approaches. Programs like Smart Growth are the first step of the process. Before LID is used, decisions about where and how to develop within the watershed need to be evaluated to limit water quality impacts. Once these decisions are made, LID can then be used to mitigate the impacts of the development. Coordinating and integrating LID with Smart Growth and other innovative land use approaches will limit conversions in land cover, preserve natural watershed areas, and maximize the management of stormwater runoff. In urbanized areas, LID can be coordinated with green building and redevelopment efforts and it can be used to augment infrastructure projects by enhancing capacity. Retrofitting LID in urban locations provides opportunity to provide multiple environmental, social, and infrastructure benefits.

REGULATORY CLIMATE

Stormwater presents a significant challenge for establishing efficient and effective regulations. Its episodic and dynamic nature is the polar opposite of the largely predictable and constant nature of municipal and industrial wastewater discharges that have been such a large focus of the regulatory and permit efforts of the past decades. Incorporating stormwater into these programs has been an institutional and technological challenge.[16] The resulting approach to stormwater control has been an adoption and reliance on minimum control measures that are implemented to demonstrate compliance with stormwater management plans. Discharge flow limitations and water quality criteria are often required and influence the selection of control measures. Even with the best efforts of these programs, water quality and use designations of waters nationwide are still well short of their intended goals.

The prevailing problem is that the current construct of many stormwater regulations do not require the use of the best available technologies and do not address hydromodification. This regulatory shortfall has hampered innovative applications of new technologies and an institutional shift in the practice of stormwater management. In California and other locations around the country, innovative practices are being adopted with increasing frequency. In certain instances innovation and implementation are outpacing regulatory programs and driving the revision of regulations; in others, innovative regulations have been adopted to establish environmental performance criteria that provide a significant incentive to adopt new control strategies. In either case, the resulting regulatory and incentive structures are informative for new program development.

A critical differentiation in regulatory application exists and will be presented in the examples in the following section. Minimizing and mitigating hydromodification is a critical performance criterion for Greenfield development. Undisturbed, Greenfield sites still possess natural hydrologic characteristics and attributes that can be used to inform appropriate control and mitigation strategies. Development or redevelopment of previously developed urban areas will require surrogate performance criteria. The natural hydrology of these areas has largely been lost due to the impacts of decades or centuries of urbanization. Linking performance criteria to hydrology in these areas is not as practical as Greenfield sites, but other approaches are used to approximate the desired outcomes of limited runoff volumes and pollutant loads.

POLICIES AND PROGRAMS

The following examples demonstrate how various jurisdictions have crafted their regulations to mitigate hydromodification or an increase in the volume of stormwater discharge.

- ### 401 Certifications

  Section 401 of the CWA grants each state the right to ensure that the State's interests are protected concerning any federally permitted activity occurring in or adjacent to Waters of the State. In California, the Regional Water Quality Control Boards (Regional Boards) are the agency mandated to ensure protection of the State's waters. If a proposed project requires a U.S. Army Corps of Engineers CWA Section 404 permit, or involves dredge or fill activities that may result in a discharge to U.S. surface waters and/or "Waters of the State" the project proponent is required to obtain a Clean Water Act (CWA) Section 401 Water

[16] The NPDES program is not the only available avenue for regulating stormwater discharges. Other federal, state, and local water policies or programs offer significant opportunity for the development of comprehensive stormwater programs. In some cases, these provisions have influenced stormwater management, but municipal stormwater control is still largely driven by the NPDES program.

Quality Certification and/or Waste Discharge Requirements (Dredge/Fill Projects) from the Regional Board, verifying that the project activities will comply with state water quality standards.[17]

Section 401 gives the Regional Boards the authority to consider the impacts of the entire project and require mitigation for volume, velocity, and pollutant load of the discharge from new outfalls to surface waters. Some Regional Boards that have large areas not covered by Phase I or II Municipal permits, require low impact development and hydromodification mitigation consistent with municipal post-construction design standards.

- **404 Compliance**

Section 404 of the CWA regulates fill and disturbance of wetlands and waters of the United States. The US Corps of Engineers, Norfolk District, (which has permit review responsibilities) encourages 404 compliance with the use of LID principles. Projects applying for a permit are required to demonstrate that they have avoided and minimized impacts to jurisdictional areas to the maximum extent practicable. For unavoidable impacts, projects may be required to provide compensatory wetland mitigation. The Norfolk District office considers LID practices as partial mitigation, provided that there is no project-specific loss of wetland acreage.

This allowance is intended to minimize impacts that the Corps has witnessed to wetlands and streams that are associated with conventional stormwater management facilities. Therefore, the Corps allows consideration of LID BMPs (e.g., swales, bioretention facilities) as viable alternatives to in-channel or in-wetland stormwater basins. The initiative's goal is to reduce the number and size of conventional stormwater facilities impacting wetlands or waters of the U.S. In addition, the emphasis on LID design and BMPs is intended to ensure that the post-development and pre-development hydrographs are similar to reduce wetland impacts and maintain pre-development groundwater recharge.

- **Preliminary Draft California NPDES Construction General Permit for Stormwater Discharges**

The preliminary draft revised General Permit, released for comment in March 2007, included for the first time post-construction stormwater control performance standards.[18] Previously post-construction language was difficult to enforce as the standard of BAT/BCT was not easily applied to low impact development practices. If accepted, the draft permit will establish consistent state-wide post-construction standards that can be enhanced or augmented by the Regional Boards. The permit stipulates several performance standards for new development and redevelopment as identified below.

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[17] North Coast Water Board, 401 Certification web page: http://www.waterboards.ca.gov/northcoast/programs/wqwetcert.html, (accessed November 2007).
[18] State Water Resources Control Board, National Pollutant Discharge Elimination System (NPDES) General Permit for Storm Water Discharges - Associated Construction and Land Disturbance Activities, March 2, 2007.

1. *The discharger shall, through the use of non-structural and structural measures, ensure that the post-development runoff volume approximates the pre-project runoff volume for areas covered with impervious surfaces...*
2. *For projects whose disturbed project area exceeds two acres, the discharger shall preserve the post-construction drainage divides for all drainage areas serving a first order stream or larger and ensure that post-project time of concentration is equal or greater than pre-project time of concentration.*
3. *For projects whose disturbed project area exceeds 50 acres, the discharger shall preserve pre-construction drainage patterns by distributing their non-structural and structural controls within all drainage areas serving first order streams or larger and ensuring that post-project time of concentration is equal to or greater than pre-project time of concentration.*

The regulatory approach of the draft permit is one of volume and time of concentration control. Pre-development site hydrology must be evaluated and guides post-construction performance objectives. The pre-development water balance must be approximated so that there is no increase in the volume of runoff that leaves the site. In addition, while the regulation expressly permits the use of both non-structural and structural controls, it is likely that achieving the hydrologic objectives of the standard will require a significant reliance on LID techniques.

- **Santa Clara Valley Hydromodification Management Plan**

The RWQCB, San Francisco Bay Region, requires stormwater programs to develop and implement hydromodification management plans (HMPs). The Santa Clara Valley Urban Runoff Pollution Prevention Program was the first permit to include the new HMP requirements.[19] The Program's hydromodification control standard requires that those who discharge stormwater manage increases in peak runoff flow and increased runoff volume where the increased volume or flow can cause erosion or siltation problems. The implemented HMP limits post-construction runoff to pre-construction rates and/or durations.[20]

Performance criteria to demonstrate compliance with the hydromodification control standard are also presented in the permit. The first of which is that the project shall use stormwater controls to maintain pre-construction stream erosion potential.[21] The second requires that post-construction stormwater discharge rates and flow durations be equivalent to pre-construction values for flows from 10% of the 2-year peak flow up to the full 10-year peak flow.[22]

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[19] Santa Clara Valley Urban Runoff Pollution Prevention Program, Hydromodification Management Plan – Final Report, April 21, 2005.
[20] Ibid.
[21] Erosion potential is a measure of how a site's runoff hydraulically impacts a receiving stream. Greater volumes of stormwater released at greater rates and for longer durations impart greater physical impacts on receiving streams.
[22] Santa Clara Valley Urban Runoff Pollution Prevention Program, Hydromodification Management Plan – Final Report, April 21, 2005.

Santa Clara's HMP is an interesting case because the language differs greatly from conventional stormwater control regulations. By requiring quantification of the erosion potential of a site, the HMP directly addresses both the rate and volume of discharge. This requirement, coupled with flow duration criteria for small storms up to the 10-year storm, will require sites to maintain the pre-development hydrograph for a large percentage of storm events post construction.

This regulatory construct is efficient for several reasons. A great majority of stormwater regulations contain requirements for peak control only. As discussed in the background of this report, controlling only that single parameter is not sufficient to adequately protect receiving stream water quality because increased stormwater volumes and extended durations contribute larger mass loads of pollutants and impart greater physical impacts. By establishing discharge performance criteria for the volume, rate, and duration, these standards are more protective and demonstrate the full complement of factors that require control to limit the physical impacts of stormwater discharges.

Also important is the range of storms for which the duration of discharge must be controlled. Stormwater regulations routinely pick two design storms (often the two and 10 year events) for which peak flow rate requirements are established. The consequence of this is that no control is provided for the most frequently occurring small storms that are less than the two year event. Research shows that post-construction discharges from these small, frequent storms have much greater physical impacts than originally thought. Along this same line is the ability to effectively manage dry flows which can constitute a significant portion of runoff and pollutant transport in many areas of California. The duration control criterion recognizes the impacts of these small storms and established performance criteria designed to mitigate these effects.

- **San Diego County Phase I MS4 Permit**

In January 2007, the San Diego Regional Water Quality Control Board reissued the Phase I Municipal Stormwater Permit for San Diego County.[23] The permit has specific requirements for the implementation of low impact development BMPs and a Hydromodification Management Plan. Not only does the permit specify that LID is required to meet MEP for retail gas outlets and heavy industry meeting certain criteria, but also the permit requires all new and redevelopment projects to implement LID BMPs where feasible.

Priority Development Projects, a subset of development projects with a particular potential threat to water quality, as specified in the permit, are required to implement LID in the following ways:

[23] California Regional Water Quality Control Board, San Diego Region, Order No. R9-2007-0001, NPDES NO. CAS0108758, Water Discharge Requirements for Discharges of Urban Runoff from the Municipal Separate Storm Sewer Systems Draining the Watersheds of the County of San Diego, the Incorporated Cities of San Diego County, the San Diego Unified Port District, and the San Diego County Regional Airport Authority.

1. Draining a portion of the site's impervious areas into pervious areas prior to discharge to the MS4.[24]
2. Properly designing and constructing the pervious areas to effectively receive and infiltrate or treat runoff from impervious areas.
3. Constructing a portion of walkways, trails, overflow parking lots, alleys, or other low-traffic areas with permeable surfaces.

Another set of LID BMP requirements apply to Priority Development Projects where feasible:

1. Conserve natural areas, including existing trees, other vegetation, and soils.
2. Construct streets, sidewalks, or parking lot aisles to the minimum widths necessary, provided that public safety and a walkable environment for pedestrians are not compromised.
3. Minimize the impervious footprint of the project.
4. Minimize soil compaction.
5. Minimize disturbances to natural drainages (e.g., natural swales, topographic depressions).

Permittees are then given the responsibility of defining the applicability and feasibility of LID BMPs. They are required to establish minimum standards to maximize the use of LID practices and principles as a means of reducing stormwater runoff. This includes siting, design, and maintenance criteria for each LID BMP to ensure that they are constructed correctly and are effective at pollutant removal and/or runoff control. Additionally, prior to occupancy of a Priority Development Project, the LID BMPs must be inspected to verify compliance with specifications. Education concerning how to implement LID BMPs into the local regulatory programs and methods of minimizing impacts to receiving waters as a result of development is required for municipal personnel and development planning staff.

The permit's hydromodification requirements also apply to all Priority Development Projects. Each permittee must develop and apply criteria for priority projects so that runoff discharge rates, durations, and velocities are controlled to maintain or reduce downstream erosion conditions and protect stream habitat.

The Hydromodification Management Plan (HMP) must include:

1. A stability standard for channel segments which receive urban runoff discharges.
2. A range of runoff flows for which post-project runoff flow rates and durations shall not exceed pre-project runoff flow rates and durations.
3. Hydrologic control measures so that post-project runoff flow rates and durations do not exceed pre-project runoff flow rates and durations, and do not result in channel conditions which do not meet the channel standard.

[24] "Portion" corresponds with the total capacity of the project's pervious areas to infiltrate or treat runoff, taking into consideration the pervious areas' soil conditions, slope, and other pertinent factors.

4. Other performance criteria (numeric or otherwise) as necessary to prevent urban runoff from increasing erosion of channel beds and banks, silt pollutant generation, or other impacts to beneficial uses and stream habitat due to increased erosive force.
5. A review of pertinent literature.
6. A protocol to evaluate potential hydrograph change impacts to downstream watercourses.
7. A description of how the HMP requirements will be incorporated into the local approval processes.
8. The identified range of runoff flows to be controlled expressed in terms of peak flow rates of rainfall events.
9. Criteria for selection and design of management practices and measures to control flow rates and durations and address potential hydromodification impacts.
10. Technical information supporting standards and criteria proposed.
11. A description of inspections and maintenance to be conducted for management practices and measures to control flow rates and durations and address potential hydromodification impacts.
12. A description of pre- and post-project monitoring and other program evaluations to be conducted to assess the effectiveness of implementation of the HMP.
13. Mechanisms for addressing cumulative impacts within a watershed on channel morphology.
14. Information on evaluation of channel form and condition, including slope, discharge, vegetation, underlying geology.

Until the HMP is completed, the permit requires that interim criteria for projects disturbing 50 acres or more be established and implemented. The interim hydromodification criteria must contain a range of runoff flow rates for which Priority Development Project post-project runoff flow rates and durations shall not exceed pre-project runoff flow rates and durations.

While the San Diego Permit requirements have not been in effect long enough to draw conclusions about its implementation success, the concepts of:

- Including both LID and hydromodification requirements to address both on-site and receiving water concerns;
- Requiring the permittees to clearly define BMP feasibility in an effort to ensure maximum implementation;
- Including an education component for municipal staff to aid program implementation and consistency;
- Requiring inspection of management measures to ensure proper construction and long-term effectiveness; and
- Including interim requirements to implement until the more detailed plans have been approved.

The permit language and concepts are robust and specifically delineate LID and performance criteria requirements that are likely to lead to enhanced water quality protection and improvement.

- **Ventura County Draft Phase I MS4 Permit**

The August 2007 draft of the Ventura County Municipal Stormwater Permit also includes LID and hydromodification requirements.[25] The New Development and Redevelopment Criteria specify that all new and redevelopment shall integrate low impact development principles into project design. Permittees have 365 days to develop an LID technical guidance document for planners and developers that includes objectives and specifications for the integration of LID strategies, including:

1. Site assessment;
2. Site planning and layout;
3. Vegetative protection, re-vegetation, and maintenance;
4. Techniques to minimize land disturbance;
5. Techniques to implement LID measures at various scales;
6. Integrated water resources management practices;
7. LID design and flow modeling guidance;
8. Hydrologic analysis; and
9. LID credits.

In addition, the permit requires an LID training program for builders, design professionals, regulators, resource agencies, and stakeholders that addresses the integration of LID at various scales.

The permit's hydromodification control criteria require all new and redevelopment projects to implement control measures that prevent down stream erosion by maintaining the project's pre-development stormwater runoff flow rates and durations. The permit requires that the Erosion Potential (E_p) in streams be maintained at a value of 1, unless an alternative value is shown to be protective. The permit specifies a preference for LID strategies.

The Southern California Storm Water Monitoring Coalition is currently developing a regional methodology to eliminate adverse impacts from urbanization. The objectives for the Hydromodification Control Study (HCS) are:

1. Establishment of a stream classification for Southern California streams.
2. Development of a deterministic or predictive relationship between changes in watershed impervious cover and stream-bed/stream bank enlargement.
3. Development of a numeric model to predict stream bed/stream bank enlargement and evaluate the effectiveness of mitigation strategies.

Until the HCS is completed, permittees are required to implement the following interim hydromodification criteria:

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[25] California Regional Water Quality Control Board, Los Angeles Region, Waste Discharge Requirements for Storm Water (Wet Weather) and Non-Storm Water (Dry Weather) Discharges from the Municipal Separate Storm Sewer Systems within the Ventura County Watershed Protection District, County of Ventura and the Incorporated Cities therein, August 28, 2007.

1. Projects disturbing land area of less than fifty acres must implement hydromodification controls such that the 2-year 24-hour storm event post-development hydrograph peak flow and volume will match within one percent of the 2-year 24-hour storm event pre-development peak flow and volume hydrograph.
2. Projects disturbing land areas of fifty acres or greater shall develop and implement a Hydromodification Analysis Study that demonstrates that post-development conditions are not expected to alter the duration of sediment transporting flows in receiving waters. The HAS must demonstrate that the selected hydromodification control BMPs will maintain an E_p value of 1 unless an alternative value can be shown to be protective.

Once the HCS is completed, permittees must develop Hydromodification Control Plans (HCPs) that are watershed specific and identify:

1. Stream classifications;
2. Flow rate and duration control methods;
3. Sub-watershed mitigation strategies; and
4. Stream restoration measures which will maintain the stream and tributary E_p at 1 unless an alternative value can be shown to be protective.

In addition, the HCP must contain the following elements:

1. Hydromodification management standards;
2. Natural drainage areas and hydromodification management control areas;
3. New development and redevelopment projects subject to the HCP;
4. Description of authorized hydromodification management control BMPs;
5. Hydromodification management control BMP design criteria;
6. For flow duration control methods, the range of flows to control for, and goodness of fit criteria;
7. Allowable low critical flow, Q_c, which initiates sediment transport;
8. Description of the approved hydromodification model;
9. Any alternate hydromodification management model and design;
10. Stream restoration measures design criteria;
11. Monitoring and effectiveness assessment; and
12. Record keeping.

The permit requires that verification of maintenance provisions be provided for the hydromodification controls for all new and redevelopment projects and that LID and hydromodification measures be inspected to ensure proper installation prior to the issuance of occupancy certificates. The permit also specifies that the permittee implement a tracking system, and an inspection and enforcement program for new and redevelopment post-construction stormwater BMPs.

While this permit is still in draft form and has not yet been adopted, it has a broad scope of requirements. The permit requires:

- An LID Technical Guidance document;
- An LID training program;
- A Hydromodification Control Plan;
- Interim hydromodification criteria;
- Verification of maintenance provisions for hydromodification controls;
- A tracking, inspection, and enforcement program for post-construction stormwater BMPs; and
- Inspection of LID and hydromodification measures prior to the issuance of occupancy certificates.

This permit does not allow for a feasibility assessment for its LID requirements. It requires that all new and redevelopment projects integrate LID principles into project design and that the permittee develop a LID Technical Guidance document that includes the specifications for the integration of LID strategies.

- **New Jersey Stormwater Management Rules**

New Jersey's new stormwater requirements adopted in 2004 contain specific criteria for infiltration and the rate and volume of discharge.[26] The state establishes groundwater recharge requirements with the following performance standards.

1. *…that the site and its stormwater management measures maintain 100 percent of the average pre-construction groundwater recharge volume for the site; OR*
2. *…that the increase of stormwater runoff volume from pre-construction to post-construction for the two-year storm is infiltrated.*

The recharge provisions contain exemptions for the defined "urban redevelopment area," hot spots, and industrial stormwater exposed to source material.[27] These provisions are complemented by runoff quantity requirements.

1. *…that post-construction runoff hydrographs for the two, 10, and 100-year storm events do not exceed, at any point in time, the pre-construction runoff hydrographs for the same storm events; OR*
2. *…that there is no increase, as compared to the pre-construction condition, in the peak runoff rates of stormwater leaving the site for the two, 10, and 100-year storm events and that the increased volume or change in timing of stormwater runoff will not increase flood damage…; OR*
3. *…that the post-construction peak runoff rates for the two, 10, and 100-year storm events are 50, 75, and 80 percent, respectively, of the pre-construction peak runoff rates…*

In addition to the hydrologic performance standards, water quality standards requiring 80% total suspended solids (TSS) removal for the water quality design storm of 1.25 inches in two hours is also required. The New Jersey standards took important steps forward with their primary hydrologic requirements. Maintaining groundwater recharge rates or infiltrating the

[26] "Stormwater Management Rule," *New Jersey Register*, N.J.A.C., Vol. 7, No. 8 (February 2, 2004).
[27] Ibid.

post-construction volume increase for the two year storm addresses one of the significant impacts of development – lost infiltration and groundwater recharge. Establishing these requirements will help to maintain pre-development water balance on the site.

Most importantly the primary runoff volume language requiring the post-construction hydrograph to match the pre-development hydrograph at each and every point does not allow an increase in the volume of stormwater discharged. This is not only an environmentally protective standard, but it would necessarily encourage wide adoption of non-structural controls and LID.

- **Portland Stormwater Requirements**

Portland's stormwater requirements are a good example of urban standards. Hydrology is not as much of a driving factor with urbanized areas as natural hydrology has been greatly altered and is likely not replicable in many instances because of factors such as existing utilities, density, soil compaction, fill materials, and existing historical contamination. Portland also has a combined sewer system and has a great interest in reducing stormwater inflow into the system.

The city's code requires on-site stormwater management for new development and redevelopment, and encourages the use of green infrastructure techniques to meet this objective.[28] In addition, new city-owned buildings are required to have a green roof covering 70% of the roof area. As an incentive for other buildings, a zoning bonus that allows additional square footage is available for those that install a green roof. The city will also allow up to a 35% discount in the stormwater utility for properties with on-site stormwater management.[29] This provides an incentive for existing properties to retrofit with on-site controls.

These are some of the most progressive urban stormwater standards in the country. They establish defined performance criteria based upon retention of stormwater and are a departure from many urban models whose aim is to provide water quality treatment for the first-flush of stormwater. Existing urban areas are often confronted by infrastructure capacity and maintenance concerns in addition to water quality requirements. Limiting the volume of stormwater discharged is a critical factor in addressing these issues. By also encouraging the use of green infrastructure, Portland is adopting a policy that will yield multiple environmental benefits in additional to providing stormwater retention.

- **Seattle Green Factor**

Adopted in January 2007, the Green Factor is an alternative approach for urban stormwater control. The Green Factor is a landscaping requirement in neighborhood business districts that stipulates that 30% of a site must be vegetated. This system encourages multiple layers of visible plantings and plantings in the public rights-of-way adjacent to the properties. The

[28] Portland City Code Chapter 17.38, Policy Framework, Appeals, and Update Process.
[29] C. Kloss and C. Calarusse, *Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows*, Natural Resources Defense Council, June 2006.

system is flexible and weights different landscaping practices according to their effectiveness. The square footage of each practice is multiplied by its green factor and then aggregated with the score of each additional practice to satisfy the requirements. For example, asphalt and concrete have a green factor of 0, permeable pavements 0.6, and green roofs 0.7. Bonuses are also provided for utilizing rain water harvesting and low water-use plants.[30]

This regulatory construct is interesting because it is not stormwater specific, nor does it contain specific discharge performance requirements. However, because of the practices selected for green factors and the benefits gained by adding vegetation and other green infrastructure practices, this policy will beneficially impact the volume of stormwater runoff. It is similar to the Green Area Ratio program in Berlin, Germany that has been a catalyst for encouraging green roof installation and the preservation or creation of other green spaces. The downside to this approach is that stormwater benefit may not be as great as stormwater specific performance requirements because of the flexibility in selecting green options. However, this is a progressive, multi-benefit/multi-pollutant policy approach.

This approach also provides an opportunity to assess appropriate amounts of vegetative cover in urban areas and the benefits gained from a comprehensive greening program. Analysis of this program can determine the environmental benefits with respect to the urban aesthetics desired. In addition, this type of system lends itself to a trading scheme where vegetative cover percentages can be increased in one area to offset a lack elsewhere or to provide enhanced performance in a critical or sensitive area.

- **Washington D.C. Anacostia Redevelopment Standards**

The area along the Anacostia River in Washington, DC (hereafter, the District) is slated for major redevelopment in the coming years. The Anacostia is one of the most polluted rivers in the country with a significant amount of this pollution contributed by stormwater runoff and combined sewer overflows. The District realized that the redevelopment presented an opportunity to revitalize a historically neglected portion of the city and established social, economic, and environmental benchmarks for the development area.

A comprehensive set of environmental standards was developed that included provisions for: (1) integrated environmental design; (2) stormwater; (3) green building; and (4) site planning and preservation. Like Portland's standards, natural hydrology is not as much a consideration as stormwater volume retention to limit discharges from the MS4 system and combined sewer overflows. The stormwater standards adopted serve as another example of an innovative urban application.

The stormwater control requirements stipulate on-site retention of the first inch of rainfall for new development and redevelopment and water quality treatment for up to the two-year storm volume along with a stated preference for vegetated controls. Where it is not technically feasible for on-site retention of stormwater, an off-set provision allows developers to provide off-site mitigation for 1½ times the volume that could not be provided

[30] Seattle Municipal Code, SMC 23.47A, Council Bill Number: 115746, Ordinance Number: 122311.

for the developed area or to pay into a dedicated stormwater fund for twice the cost of an equivalent volume reduction.[31] The off-set provision was modeled after other environmental off-set provisions and intended to provide an incentive to maximize on-site treatment.

These standards are considered some of the most progressive in the country. The driving focus was to significantly decrease stormwater inflow into the collection system and provide enhanced water quality treatment for any discharge while also supporting a green building and sustainability focus within the city. The stormwater standards were used as a platform to provide not only advanced stormwater control, but also encourage the integration of green space throughout an urban redevelopment to gain the associated social, economic, and multi-media environmental benefits.

- **Maryland Stormwater Act of 2007**

The Maryland Stormwater Act was passed by the General Assembly in April 2007 and signed into law by the Governor. The new act stipulates that Environmental Site Design (ESD) using LID practices is the preferred stormwater control method in the State and must be utilized as the first control option for new development projects.[32] Only after the developer or designer can demonstrate that they have used ESD to the maximum extent practicable are they permitted to use conventional stormwater controls.

This is more of a command-and-control regulatory construct mandating the use of a particular stormwater control system. However, because of the expansive list of LID BMPs and techniques, there is a great deal of flexibility built into the regulation. It also provides alternative options when site constraints may limit ESD's ability to achieve the stormwater management requirements. A significant benefit of this new policy is the understood preference for a new stormwater control regime based on LID principles that signals a departure from the standard methods of stormwater control.

An additional benefit of the new legislation is that it moves the State program to a more performance based system of stormwater management. Moving away from minimum treatment standards for selecting end-of-pipe BMPs and towards a system of integrated site design principles begins to allow the regulatory system to address overall site performance and function.

[31] Anacostia Waterfront Corporation, *Final Environmental Standards,* June 1, 2007.
[32] *Maryland Stormwater Management Act of 2007,* Senate Bill 784 / House Bill 786, (available at http://mlis.state.md.us/2007RS/billfile/sb0784.htm).

Conclusions and Recommendations

The State of California has a well developed institutional framework that can aid the development of a comprehensive LID program. Many steps already taken by the State have established the necessary performance criteria needed for broader LID adoption. The draft general Construction permit establishes volume limitations for post-construction runoff rather than the traditional approach of limiting flow rate. Preserving pre-construction runoff volumes will require the use of site design approaches and LID that will limit stormwater generation and maximize natural hydrologic processes for treatment.

In addition, the San Francisco Region's requirement for hydromodification plans places the emphasis on in-stream impacts of stormwater runoff and the need to develop programs that effectively manage the increased volume and flow that contribute to these impacts. The critical link in both of these approaches is that they require stormwater volume to be limited. Establishing a performance criterion for volume will more than likely require LID or other similar approaches that limit the conversion of precipitation to runoff.

Importantly, the institutional structure within the State can function to efficiently promote the adoption of innovative control approaches. The coordinated efforts of the State Board establishing broad policy approaches and the Regional Boards setting additional requirements within their watersheds when needed allows for alternative and evolving regulatory approaches, as highlighted by the examples above. Critical to this is the authority granted by the Porter-Cologne Act to regulate any activity or factor that impacts water quality. This stipulation gives the State broad authority to assess the cause of stormwater runoff and pollution and develop strategies to mitigate the originating cause. This condition exceeds that of many states that are limited by choice or statute to manage stormwater as a waste product while giving limited attention to the upstream factors that affect runoff. The planning and permitting authority that exists in the State and Regional Boards allows for the development of comprehensive control requirements that maximize vegetation, natural systems, and LID.

Important to the successful application of LID, is evaluating how it will be used for new development and redevelopment or urban retrofit. The pre-draft of the Reissuance of the Statewide construction general permit and the hydromodification management plans apply to new development and redevelopment and assess pre-development hydrologic conditions. Matching pre-development hydrologic conditions is a fair method in Greenfield development and redevelopment situations where determinations of pre-development conditions can be made and will help to decrease the pollution impact of new development across the state.

However, existing development exerts a tremendous pollution impact largely due to the resulting, developed landscape and its associated runoff characteristics. Addressing it by matching pre-development hydrology may not always be possible because many urban areas lack land for stormwater control and natural hydrology has been altered so significantly. In these instances, the urban stormwater regulations in Portland and Washington, D.C. that require volume retention can serve as appropriate models. These regulations do not focus on the natural function of a site, but rather attempt to limit runoff as a means of pollution prevention and enhancing infrastructure capacity. The desired outcome is the same as the hydromodification approaches, but the assessment and control requirements are structured differently to account for urban conditions.

The important concept across all of these approaches is that the regulations established a performance requirement to limit the volume of stormwater discharges. The fact that volume is the critical regulatory requirement instead of maximum flow rate leads to greater adoption of LID and vegetated systems. The City of Salinas and the Central Coast Regional Water Quality Control Board found that ordinances that only encourage LID adoption had little voluntary implementation, but ordinances that require LID have resulted in more widespread implementation.[33]

Regulations can address new development or redevelopment but LID retrofits are also a critical need on existing development to mitigate existing stormwater pollution. Appropriately structured incentive programs can encourage LID adoption outside of a regulatory structure and reduce stormwater volume. Portland uses the potential for a discount from its stormwater utility fee to create an incentive for existing properties to retrofit to on-site stormwater controls. The recurring financial benefits that can be gained from a one-time capital investment and limited maintenance requirements can entice owners to adopt on-site practices that otherwise may not have.

Utility fees or other dedicated funding can serve multiple purposes. Portland's utility fee funds its program and provides an incentive for volume reductions. The off-set fee that is permissible in the Anacostia portion of Washington creates a revenue stream that the city can use for installations within right-of-ways or city owned property. To be effective for both purposes, a fee must be structured and valued to provide sufficient programmatic funding and allow for a fee discount sufficient to create an incentive. Washington's preference is for on-site controls, so the required off-set fee is based upon twice the cost to manage the volume of stormwater to encourage the maximization of on-site options.

LID is also a complement to other land use planning or environmental programs. The water quality benefits of Smart Growth programs can be enhanced by using LID. LID can also be used within the Leadership in Energy and Environmental Design (LEED®) system to gain points for environmentally sensitive design. Many LID practices provide benefits like energy conservation or other site design benefits in addition to stormwater control that can contribute to the overall LEED® rating of a project.

The State and Regional Boards have begun to implement policies that will encourage LID practices. These policies will likely lead to broader implementation of distributed, on-site stormwater techniques. Other policy options that have been adopted in other jurisdictions have the potential to augment California's existing efforts and develop a more robust regulatory system. The institutional framework within the State allows for regulatory innovation and should provide the necessary platform for a water resources program that fully incorporates LID.

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[33] Chris Conway, et al., *Technical Memorandum to the Central Coast Regional Water Quality Control Board and the City of Salinas – Model Low Impact Development (LID) Ordinance for Salinas and the Central Coast*, Kennedy/Jenks Consultants, January 22, 2007.