Box 2-6
Growth Management in the Pacific Northwest

In Oregon, the 1973 Legislative Assembly enacted the Oregon Land Use Act, which recognized that the uncoordinated use of lands threatens orderly development of the environment, the health, safety, order, convenience, prosperity and welfare of the people of Oregon. The state required all of Oregon's 214 cities and 36 counties to adopt comprehensive plans and land-use regulations. It specified planning concerns that had to be addressed, set statewide standards that local plans and ordinances had to meet, and established a review process to ensure that those standards were met. Aims of the program are to conserve farm land, forest land, coastal resources, and other important natural resources; encourage-efficient development; coordinate the planning activities of local governments and state and federal agencies; enhance the state's economy; and reduce the public costs that result from poorly planned development. Setting urban growth boundaries is a major mechanism for implementing the act.

The Washington State Legislature followed in 1990 with the Growth Management Act (GMA), adopted on grounds similar to Oregon's act. The GMA requires state and local governments to manage Washington's growth by identifying and protecting critical areas and natural resource lands, designating urban growth areas, preparing comprehensive plans, and implementing them through capital investments and development regulations. Similar again to Oregon, rather than centralize planning and decision-making at the state level, the GMA established state goals, set deadlines for compliance, offered direction on how to prepare local comprehensive plans and regulations, and set forth requirements for early and continuous public participation. Urban growth areas (UGAs) are those areas, designated by counties pursuant to the GMA, "within which urban growth shall be encouraged and outside of which growth can occur only if it is not urban in nature." Within these UGAs, growth is encouraged and supported with adequate facilities. Areas outside of the UGAs are reserved for primarily rural and resource uses. Urban growth areas are to be based on population forecasts made by counties, which are required to have a 20-year supply of land for future residential development inside the boundary—a time frame also pertaining in the Oregon system. In both states urban growth boundaries are reconsidered and sometimes adjusted to meet this criterion.

It is important to note that the growth management efforts in the two states have no direct relationship to stormwater management. Rather, the laws control development density, which has implications for how stormwater should be managed (see discussion in Chapter 5). The local jurisdictions in Washington have reacted in different ways to link growth management and stormwater management. For example, the King County, Washington, stormwater code requires drainage review to evaluate and deal with stormwater impacts for development that adds 2,000 square feet or more of impervious surface or clears more than 7,000 square feet. For rural residential lots outside the UGA, the impervious threshold is reduced to 500 square feet.

Sources:
http://bluebook.state.or.us/state/executive/Land_Conservation/land_conservation_history.htm
http://www.oregonmetro.gov/index.cfm/go/by.web/id=277
http://www.gmhb.wa.gov/gma/ and http://www.mrsc.org/Subjects/Planning/compfaqs.aspx

zoning categories, and can create needless impervious cover. Most local parking codes are overly generous and have few, if any, provisions to treat stormwater at the source (Wells, 1995). For example, in a co-housing project under construction in Fresno, California, current city codes require 27-foot-long parking spaces. The developer, in an effort to reduce construction costs, requested that the length of spaces be reduced to 24 feet. The city agreed to the smaller spaces if the developer would sign an indemnity clause guaranteeing that the local government would not be sued in case of an accident (Wenz, 2008).

Similarly, landscaping ordinances apply to certain commercial and institutional zoning categories and specify that a fixed percentage of site area be devoted to landscaping, screening, or similar setbacks. These codes may require as much as 5 to 10 percent of the site area to be landscaped, but seldom reference opportunities to capture and store runoff at the source, despite the fact that the area devoted to landscaping is often large enough to meet some or all of their stormwater treatment needs.

Zoning codes have evolved over the years as urban planning theory has changed, legal constraints have fluctuated, and political priorities have shifted. The various approaches to zoning can be divided into four broad categories: Euclidean, performance, planned unit development, and form-based.

Euclidean Zoning

Named for the type of zoning code adopted in the town of Euclid, Ohio, Euclidean zoning codes are by far the most prevalent in the United States, used extensively in small towns and large cities alike. Euclidean zoning is characterized by the segregation of land uses into specified geographic districts and dimensional standards stipulating limitations on the magnitude of development activity that is allowed to take place on lots within each type of district. Typical land-use districts in Euclidean zoning are residential (single- or multi-family), commercial, and industrial. Uses within each district are usually heavily prescribed to exclude other types of uses (for example, residential districts typically disallow commercial or industrial uses). Some "accessory" or "conditional" uses may be allowed in order to accommodate the needs of the primary uses. Dimensional standards apply to any structures built on lots within each zoning district and typically take the form of setbacks, height limits, minimum lot sizes, lot coverage limits, and other limitations on the building envelope.

Although traditional Euclidean zoning does not include any significant requirements for stormwater drainage, there is no reason that it could not. Modern Euclidean ordinances include a broad list of "development standards" that address topics like signage, lighting, steep slopes, and other topics, and that list could be expanded to included stormwater standards for private development.

Euclidean zoning is used almost universally across the country (with rare exceptions) because of its relative effectiveness, ease of implementation (one set of explicit, prescriptive rules), long-established legal precedent, and familiarity to planners and design professionals. However, Euclidean zoning has received heavy criticism for its unnecessary separation of land uses, its lack of flexibility, and its institutionalization of now-outdated planning theory. . In response, variances and other methods have been used to modify Euclidean zoning so that it is better adapted to localized conditions and existing patterns of development. The sections below briefly describe a range of innovations in local zoning regulations that have potential for incorporating stormwater controls into existing regulations.

Incentive Zoning. Incentive zoning systems are typically an add-on to Euclidean zoning systems. First implemented in Chicago and New York City in 1961, incentive zoning is intended to provide a reward-based system to encourage development that meets established urban development goals. Typically, a base level of prescriptive limitations on development will be established and an extensive list of incentive criteria with an associated reward scale will be established for developers to adopt at their discretion. Common examples include floor-arearatio bonuses for affordable housing provided on-site and height-limit bonuses for the inclusion of public amenities on-site.

With incentive zoning, developers are awarded additional development capacity in exchange for a public benefit, such as a provision for low- or moderate-income housing, or an amenity, such as additional open space. Incentive zoning is often used in more highly urbanized areas. Consideration for water quality treatment and innovative SCMs fits well within the incentive zoning model. For example, redevelopment sites in urbanized areas are often required to incorporate stormwater control measures into developments to minimize impacts on aging, undersized stormwater systems in that area, and to meet new water quality requirements. An incentive could be to allow greater building height, and therefore higher density, than under existing zoning, freeing up land area for SCMs that could also serve as a passive park area. Another example would be to allow a higher density on the site and to require not an on-site system but a cash payment to the governing entity to provide for consolidated stormwater management and treatment. Off-site consolidated systems, discussed more extensively in Chapter 5, may require creation of a localized maintenance district or an increase in stormwater maintenance fees to offset long-term maintenance costs.

Incentive zoning could be used to preserve natural areas or stream corridors as part of a watershed enhancement strategy. For example, transferrable development rights (TDR) could be used in the context of the urban or semi-urban interface with rural lands. Many of the formal TDR programs in Colorado (such as Fruita/Mesa County and Aspen/Pitkin) involve cities or counties seeking to preserve sensitive areas in the county, or outlying areas of the city, including the floodplain, in exchange for urban-level density on a more appropriate site (David D. Smith, Garfield & Hecht P.C., personal communication, 2008).

Incentive zoning allows for a high degree of flexibility, but it can be complex to administer. The more a proposed development takes advantage of incentive criteria, the more closely it has to be reviewed on a discretionary basis. The initial creation of the incentive structure can also be challenging and often requires extensive ongoing revision to maintain balance between incentive magnitude and value given to developers.

Performance Zoning

Performance zoning uses performance-based or goal-oriented criteria to establish review parameters for proposed development projects in any area of a municipality. At its heart, performance zoning deemphasizes the specific land uses, minimum setbacks, and maximum heights applicable to a development site and instead requires that the development meet certain performance standards (usually related to noise, glare, traffic generation, or visibility). Performance zoning sometimes utilizes a "points-based" system whereby a property developer can apply credits toward meeting established zoning goals through selecting from a menu of compliance options (some examples include mitigation of environmental impacts, providing public amenities, and building affordable housing units). Additional discretionary criteria may also be established as part of the review process.

The appeal of performance zoning lies in its high level of flexibility, rationality, transparency, and accountability. Because performance zoning is grounded in specific and in many cases quantifiable goals, it better accommodates market principles and private property rights with environmental protection. However, performance zoning can be extremely difficult to implement and can require a high level of discretionary activity on the part of the supervising authority. City staff must often be trained to use specialized equipment to measure the performance of the development, and sometimes those impacts cannot be measured until the building is completed and the activity operating, by which time it may be difficult and expensive to modify a building that turns out not to meet the required performance standards. Because stormwater performance is measurable (especially the amounts of water retained/detained and rates and amounts of water discharge), stormwater regulations could be integrated into a performance zoning system. As with other topics, however, it might be time-consuming or require special equipment to measure compliance (particularly before the building is built).

Planned Unit Development (Including Cluster Development and Conservation Design)

A planned unit development (PUD) is generally a large area of land under unified control that is planned and developed as a whole through a single development operation or series of development phases, in accord with a master plan. In California, these are known as Specific Plans. More specialized forms of PUDs include clustered subdivisions where density limitations apply to the development site as a whole but provide flexibility in the lot size, setback, and other standards that apply to individual house lots. These PUDs provide considerable flexibility in locating building sites and associated roads and utilities, allowing them to be concentrated in parts of the site, with the remaining land use for agriculture, recreation, preservation of sensitive areas, or other open-space purposes.

PUDs are typically, although not exclusively, found in new development areas and have significant open space and park areas that are often 25 percent or more of the total land area. This large amount of open space provides considerable opportunity for the use of consolidated, multifunctional stormwater controls.

Form-Based Zoning

Form-based zoning relies on rules applied to development sites according to both prescriptive and potentially discretionary criteria. These criteria are typically dependent on lot size, location, proximity, and other various site- and use-specific characteristics. Form-based codes offer considerably more flexibility in building uses than do Euclidean codes, but, as they are comparatively new, may be more challenging to create. When form-based codes do not contain appropriate illustrations and diagrams, they are criticized as being difficult to interpret.

One example of a recently adopted code with form-based features is the Land Development Code adopted by Louisville, Kentucky, in 2003. This zoning code creates "form districts" for Louisville Metro. Each form district intends to recognize that some areas of the city are more suburban in nature, while others are more urban. Building setbacks, heights, and design features vary according to the form district. As an example, in a "traditional neighborhood" form district, a maximum setback might be 15 feet from the property line, while in a suburban "neighborhood" there may be no maximum setback. Narrower setbacks allow increased density, requiring less land area for the same number of housing units and resulting in a smaller development footprint.

In rural and suburban areas, form-based codes can often reinforce the "open" character of development by preserving open site areas, which could be used for on-site stormwater management. In denser, urban areas, however, some form-based ordinances favor shorter, more pedestrian-scale buildings that cover more of the site than taller buildings of the same square footage, on the basis that keeping activity closer to the ground and enclosing street frontages results in a better pedestrian environment and urban form. One result of this preference is that there may be less of the site left potentially available for on-site stormwater detention or infiltration. Integrating stormwater management considerations into form-based codes may require a cash payment system where the developer contributes to financing of a district or regional stormwater treatment facility because on-site solutions are not available.

Building Codes

Building codes define minimum standards for the construction of virtually all types and scales of structures. With a few exceptions, building codes have limited direct impact on stormwater management. The main example is where structural and geotechnical design standards, which stem from the need to protect buildings and infrastructure from water damage, discourage or prohibit the potential infiltration of water adjacent to building foundations. Such standards can make it difficult to use landscape-based SCMs, such as porous pavement, bioinfiltration, and extended detention. There is a need to examine and redefine structural and geotechnical "standards of care" that ensure the structural integrity of buildings and other infrastructure like buried utilities, in order for landscaped areas adjacent to structures to be utilized more effectively for SCMs. For example, a developer building a mixed-use, medium-density infill development in Denver intended to incorporate innovative approaches to stormwater management by infiltrating stormwater in a number of areas around the site. The standard of care for the geotechnical design of building foundations typically requires that positive drainage be maintained a minimum of 5 feet from the building edge. The geotechnical engineer required, when informed that water might be infiltrated in the area of the building and without further study, that the minimum distance to an infiltration area must be at least to 20 feet from the building, greatly limiting the potential for using the building landscape areas as SCMs. The City of Los Angeles is in the process of updating its Building Code, but it is not clear if it will be sufficiently comprehensive to address the use of some LID practices, such as on-site infiltration. The 2002 Building Code now in effect is written to require the builder to convey water away from the building using concrete or some other "non-erosive device."

Engineering and Infrastructure Standards and Practices

Engineering standards and practices for public rights-of-way complement building and zoning codes which control development on private property. Engineering standards and practices typically describe requirements for public utilities such as stormwater and wastewater, roadways, and related basic services. For example, there are standards for parking and roadway design that typically describe the specific type of roadway and parking surfacing requirements. Regulations and standards often require minimum gradients for surface drainage, site grading, and drainage pipe size, all of which play an important role in how stormwater is transported. There are also often landscape planting requirements, including the requirement to mound landscape areas to screen cars, which can preclude the opportunity to incorporate SCMs into landscape areas.

Unless right-of-way improvements are constructed as part of the subdivision process by private developers, improvements in the right-of-way are typically provided for by city government and public agencies. Because engineering standards are often based on decades of refinement and have evolved regionally and nationally, they are difficult to change. For example, street widths are determined more by the ability to maneuver emergency equipment and to accommodate water and sewer easements than the need for adequate lane widths for vehicles. Street lane-width requirements might be as narrow as 11 feet for each travel lane, resulting in a street width of 22 to 24 feet. This could accommodate emergency vehicle access, which typically can require a minimum of 20 feet of unobstructed street. However, because most streets also include potable water distribution lines and easement requirements for the lines, which are a minimum of 30 feet in width, this results in a minimum roadway width of 30 feet.

Local drainage codes govern the disposal of stormwater and essentially dictate the nature and capacity of the stormwater infrastructure from the roof to the floodplain. Like many codes, they were developed over time to address problems such as basement flooding, nuisance drainage problems, maintenance of floodplain boundaries, and protection of infrastructure such as bridges and sewers from storm damage. Local drainage codes, many of which predate the EPA's stormwater program, often involve peak discharge control requirements for a series of design storm events ranging from the 2-year storm up to the 100-year event. Traditional drainage codes can often conflict with effective approaches to reducing runoff volume or removing pollutants from stormwater. Examples of such codes include requirements for positive drainage, directly connected roof leaders, curbs and gutters, lined channels, storm-drain inlets, and large-diameter storm-drain pipes discharging to a downstream detention or flood control basins.

Often, standards have been tested through legal precedent, and case law has developed around certain standards of care, which can further deter innovation. Changes in design standards could result in unknown legal exposure and liability. Specific types of equipment, maintenance protocols and procedures, and extensive training further discourage changes in established standards and procedures.

Innovations in Codes and Regulations to Promote Better Stormwater Management

A number of innovations have been developed in the previously described zoning, building codes, and infrastructure and engineering standards that make them more amenable to stormwater management. These are described in detail below.

Separate Ordinances for New and Infill Development

Redevelopment of existing urban areas is almost universally more difficult and expensive than Greenfield development because of the deconstruction costs of the former, higher costs of designing around existing infrastructure, upgrading existing infrastructure, and higher costs and risks associated with assuming liability of pre-existing problems (contamination, etc). Redevelopment often occurs in areas of medium to high levels of impervious surface (e.g., downtown areas). Such severely space-limited areas with high land costs drive up stormwater management costs. Consequently, holding developers of such areas to the same stormwater standard as for Greenfield developments creates a financial disincentive for redevelopment. Without careful application, stormwater requirements may discourage needed redevelopment in existing urban areas. This would be unfortunate because redevelopment can take pressure off of the development of lands at the urban fringe, it can accommodate growth without introducing new impervious surfaces, and it can bring improvements in stormwater management to areas that had previously had none.

Stormwater planning can include the development of separate ordinances for infill and new developments. Wisconsin has administrative rules that establish specific requirements for stormwater management based on whether the site is new development, redevelopment, or infill. Requirements for new development include reducing total suspended solids (TSS) by 80 percent, maintaining the pre-development peak discharge for the 2-year, 24-hour storm, infiltrating 90 percent of the pre-development infiltration volume for residential areas, and infiltrating 60 percent of the pre-development infiltration volume for non-residential areas. Redevelopment varies from new development only in that the TSS requirement is less at 40 percent reduction. Requirements for existing developed areas in incorporated cities, villages, and towns do not include peak flow reduction or infiltration performance standards, but the municipalities must achieve a 40 percent reduction in their TSS load by 2013. Other requirements unique to developed areas include public education activities, proper application of nutrients on municipality property, and elimination of illicit discharges (www.dnr.state.wi.us/org/water/wm/nps/stormwater/post-constr/). Chapter 5 makes recommendations for the specific types of SCMs that should be used for new, low-density residential development as opposed to redevelopment of existing urban and industrial areas.

Integrated Stormwater Management and Growth Policies

In the city of San Jose, California, an approach was taken to link water quality and development policies that emphasized higher density in-fill development and performance-based approaches to achieving water quality goals. The city's approach encourages stormwater practices such as minimizing impervious surface and incorporating swales as the preferred means of conveyance and treatment. In urbanized areas, the policy then goes on to define criteria to determine the practicability of meeting numeric sizing requirements for stormwater control measures, and identifies Equivalent Alternative Compliance Measures for cases where on-site controls are impractical. Equivalent Measures can include regional stormwater treatment and other specific projects that "count" as SCMs, including certain affordable and senior housing projects, significant redevelopment within the urban core, and Brownfield projects. This is similar to in lieu fee programs that are sometimes implemented by municipalities to provide additional regulated parties with compliance options (see discussion in Chapter 6).

This approach is a breakthrough in terms of measuring environmental performance, which is now focused only on what happens within the boundaries of a site for a project. This myopic view tends to allow many environmentally unfriendly projects that encourage sprawl and expand the city's boundaries to qualify as "low impact," while more intense projects on a small footprint appear to have a much higher impact because they cover so much of the site. San Jose brought several other layers of review, including location in the watershed (close to other uses or not) as a means of estimating performance. A PowerPoint presentation describing their approach in greater detail is linked here (http://www.cmcgc.com/media/handouts/260126/THR-PDF/040-Ketchum.PDF, Lisa Nisenson, Nisenson Consulting, LLC, personal communication, May 8, 2007).

Unified Development Codes

A unified development code (UDC) consolidates development-related regulations into a single code that represents a more consistent, logical, integrated, and efficient means of controlling development. UDCs integrate zoning and subdivision regulations, simplifying development controls that are often conflicting, confusing, and that require multiple layers of review and administration. UDC development standards may include circulation standards that address how vehicles and pedestrians move, including provision for adequate emergency access. Utility standards are described for water distribution and sewage collection, and necessary utility easements are prescribed. Because of the integrated nature of the code, efficiencies in requirements for right-of-way can reduce street widths or the reduction in setbacks, for example, resulting in more compact development.

Design Review Incentives to Speed Permitting

A number of incentives have been put in place to promote innovative stormwater control measures in cities such as Portland and Chicago, where environmental concerns have been identified as a key goal for development and redevelopment. Practices such as the waiver or reduction of development fees, preferential treatment and review and approval of innovative plans, reduction in stormwater fees, and related incentives encourage the use of innovative stormwater practices. In Chicago, the Green Permit Program initiated in April 2005 has proven attractive to many developers as it speeds up the permitting process. Under the Green Permit Program, a green building adviser reviews design plans under an aggressive schedule long before a permit application is submitted. There is one point of contact with intimate knowledge about the project to help speed up the permit process. Projects going through the Green Permit Program receive benefits based on their "level of green." Tier I commercial projects are designed to be Leadership in Energy and Environmental Design (LEED) certified (see Box 2-7). Tier II projects must obtain LEED silver rating. At this level, outside consultant review fees, which range from $5,000 to $50,000, are waived. Tier III projects must earn LEED gold. The goal for a Tier III project is to issue a permit in three weeks for a small project such as a 12-unit condo building. Thus, there is both time and money saved. Private developers are interested in the time savings because they can pay less interest on their construction loans by completing the building faster. By the end of 2005, 19 green permits were issued. The program's director estimated that about 50 would be issued in 2006, which exceeds the city's goal of 40.

In Portland, Oregon, the city's Green Building Program is considering instituting a new High-Performance Green Building Policy. Along with goals for reducing global warming pollution, it proposes (1) waiving development fees if goals are exceeded by specified percentages and (2) eligibility for cash rewards and qualification for state and federal financial incentives and tax credits if even higher goals are achieved. Developers can earn credits by

Box 2-7
Innovative Building Codes

An increased interest in energy conservation and more environmentally friendly building practices in general has led to various methods by which buildings can be evaluated for environmentally friendly construction, in addition to conventional code compliance. The most popular system in the United States is the Leadership in Energy and Environmental Design (LEED) system developed in 2000.

The LEED Green Building Rating System is a voluntary, consensus-based national rating system for developing high-performance, sustainable buildings. LEED addresses all building types and emphasizes state-of-the-art strategies in five areas: sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality. The U.S. Green Building Council is a 501(c)(3) nonprofit organization that certifies sustainable businesses, homes, hospitals, schools, and neighborhoods.

The LEED system encourages progressive stormwater management practices as part of its rating system. The LEED system has identified specific criteria, with points assigned to each of the criteria, to assess the success of stormwater strategies. Generally, the criteria are based on LID principles and practices and relate directly to the *Better Site Design Handbook* of the Center for Watershed Protection (CWP, 1998). The system identifies eight categories by which building sites and site-planning practices are evaluated. Of the 69 points possible to achieve the highest LEED rating, 16 points are directly related to innovative site design and stormwater management practices. Six of the eight criteria describing sound site-planning practices relate directly to good stormwater practices, including the following:

Erosion and sediment control;
Site selection to protect farmland, wetlands, and watercourses;
Site design to encourage denser infill development to protect Greenfield sites;
Limitations on site disturbance;
Specific requirements for the management of stormwater rate and quantity; and
Specific requirements for the treatment of stormwater for TSS and phosphorous removal.

The LEED rating system has been criticized because it focuses on individual buildings in building sites. A new category, LEED neighborhood development, was developed in response to consider the interrelationship of buildings and building sites and connections to existing urban infrastructure. The category is currently in pilot testing. Evaluation criteria related directly to stormwater include

All requirements of the original site design criteria,
A reduced requirement for parking based on access to transit and reduced auto use, and
Site planning that emphasizes compact development.

incorporating enhanced stormwater management and water conservation features into their projects, including the use of green roofs (Wenz, 2008).

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There are parallel challenges in the realm of community development and city building that tend to discourage innovative stormwater management policies and practices. Building codes and zoning have evolved to reflect the complex relationship of legal, political, and social processes and frequently do not promote or allow the most innovative stormwater management. Engineering standards and practices that guide the development of roads and utilities present equal and possibly greater challenges, in that legal and technical precedents and large investments in public equipment and infrastructure present even more intractable reasons to resist change.

The difficulty of implementing stormwater control measures cannot be attributed to an individual code, standard, or regulation. It is important to unravel the complexities of codes, regulations, ordinances, and standards and practices that discourage innovative stormwater management and target the particular element (or multiple elements) that is a barrier to innovation. Elements that are barriers might not have been considered previously. For example, roadway design is controlled more by access for emergency equipment and utilities rights-of-way than by the need for wide travel lanes; it is the fire marshal and the water department that should be the focus of attention, rather than the transportation engineer.

LIMITATIONS OF THE FEDERAL STORMWATER PROGRAM

The regulation of stormwater discharges seems an inevitable next step to the CWA's objective of "restoring the nation's waters," and EPA's stormwater program is still evolving. Yet, in its current configuration EPA's approach seems inadequate to overcome the unique challenges of stormwater and therefore runs the risk of only being partly effective in meeting its goals. A number of regulatory, institutional, and societal obstacles continue to hamper stormwater management in the United States, as described below.

The Poor Fit Between the Clean Water Act's Regulatory Approach and the Realities of Stormwater Management

Controlling stormwater discharges with the CWA introduces a number of obstacles to effective stormwater regulation. Unlike traditional industrial effluent, stormwater introduces not only contaminants but also surges in volume that degrade receiving waterbodies; yet the statute appears focused primarily on the "discharge" of "pollutants." Moreover, unlike traditional effluent streams from manufacturing processes, the pollutant loadings in stormwater vary substantially over time, making effluent monitoring and the development of enforceable control requirements considerably more challenging. Traditional use of end-of-pipe control technologies and automated effluent monitors used for industrial effluent do not work for the episodic and variable loading of pollutants in stormwater unless they account for these eccentricities by adjustments such as flow-weighted measurements. Finally, at the root of the stormwater problem is increasingly intensive land use. Yet the CWA contains little authority for regulators to directly limit land development, even though the discharges that result from these developments increase stormwater loading at a predictably rapid pace. The CWA thus expects regulators to reduce stormwater loadings, but gives them incomplete tools for effectuating this goal.

A more straightforward way to regulate stormwater contributions to waterbody impairment would be to use flow or a surrogate, like impervious cover, as a measure of stormwater loading (such as in the Barberry Creek TMDL [Maine DEP, 2003, pp. 16–20] or the Eagle Brook TMDL [Connecticut DEP, 2007, pp. 8–10]). Flow from individual stormwater sources is easier to monitor, model, and even approximate as compared to calculating the loadings of individual contaminants in stormwater effluent. Efforts to reduce stormwater flow will automatically achieve reductions in pollutant loading. Moreover, flow is itself responsible for additional erosion and sedimentation that adversely impacts surface water quality. Flow provides an inexpensive, convenient, and realistic means of tracking stormwater contributions to surface waters. Congress itself recently underscored the usefulness of flow as a measure for aquatic impairments by requiring that all future developments involving a federal facility with a footprint larger than 5,000 square feet ensure that the development achieves predevelopment hydrology to the maximum extent technically feasible "with regard to the temperature, rate, volume, and duration of flow" (Energy Independence and Security Act of 2007, § 438). Several EPA regions have also used flow in modeling stormwater inputs for TMDL purposes (EPA, 2007a, Potash Brook TMDL, pp. 12–13).

Permitting and Enforcement

For industrial wastewater discharged directly from industrial operations (rather than indirectly through stormwater), the CWA requirements are relatively straightforward. In these traditional cases, EPA essentially identifies an average manufacturer within a category of industry, like iron and steel manufacturers engaged in coke-making, and then quantifies the pollutant concentrations that would result in the effluent if the industry installed the best available pollution control technology. EPA promulgates these effluent standards as national, mandatory limits (e.g., see Table 2-7).

TABLE 2-7 Effluent Limits for Best Available Technology Requirements for By-product Coke-making in Iron and Steel Manufacture.

SUBPART A—EFFLUENT LIMITATIONS (BAT)

Regulated parameter	Maximum daily [1]	Maximum monthly avg. [1]
Ammonia-N	0.00293	0.00202
Benzo(a)pyrene	0.0000110	0.00000612
Cyanide	0.00297	0.00208
Naphthalene	0.0000111	0.00000616
Phenols (4AAP)	0.0000381	0.0000238

[1] Pounds per thousand lb of product.

SOURCE: 40 C.F.R. § 420.13(a).

By contrast, the uncertainties and variability surrounding both the nature of the stormwater discharges and the capabilities of various pollution controls for any given industrial site, construction site, or municipal storm sewer make it much more difficult to set precise numeric limits in advance for stormwater sources. The quantity and quality of stormwater are quite variable over time and vary substantially from one property to another. Natural causes of variation in the pollutant loads in stormwater runoff include the topography of a site, the soil conditions, and of course, the nature of storm flows in intensity, frequency, and volume. In addition, the manner in which the facility stores and uses materials, the amount of impervious cover, and sometimes even what materials the facility uses can vary and affect pollutant loads in runoff from one site to another. Together, these sources of variability, particularly the natural features, make it much more difficult to identify or predict a meaningful "average" pollutant load of stormwater runoff from a facility. As a result, EPA generally leaves it to the regulated facilities, with limited oversight from regulators, to identify the appropriate SCMs for a site. Unfortunately, this deferential approach makes the permit requirements vulnerable to significant ambiguities and difficult to enforce, as discussed below for each permit type.

Municipal Stormwater Permits. MS4 permits are difficult to enforce because the permit requirements have not yet been translated into standardized procedures to establish end-of-pipe numerical effluent limits for MS4 stormwater discharges. CWA Section 402(p) requires that pollutants in stormwater discharges from the MS4 be reduced to the maximum extent practicable and comply with water quality standards (when so required by the permitting authority). However, neither EPA nor NPDES-delegated states have yet expressed these criteria for compliance in numerical form.

The EPA has not yet defined MEP in an objective manner that could lead to convergence of MS4 programs to reduce stormwater pollution. Thus, at present MS4 permittees have no more guidance on the level of effort expected other than what is stated in the CWA:

> [S]hall require controls to reduce the discharge of pollutants to the maximum extent practicable, including management practice, 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. [CWA Section 402(p)(3)(B)(iii)]

A legal opinion issued by the California Water Board's Office of Chief Counsel in 1993 stated that MEP would be met if MS4 permittees implemented technically feasible SCMs, considering costs, public acceptance, effectiveness, and regulatory compliance (Memorandum from Elizabeth Miller Jennings, Office of Chief Counsel, to Archie Matthews, Division of Water Quality, California Water Board, February 11, 1993). In its promulgation of the Phase II Rule in 1999, the EPA described MEP as a flexible site-specific standard, stating that:

> The pollutant reductions that represent MEP may be different for each [MS4 Permittee] given the unique local hydrological and geological concerns that may exist and the differing possible pollutant control strategies. (64 Fed. Reg. 68722, 68754)

As matters stand today, MS4 programs are free to choose from the EPA's menu of SCMs, with MEP being left to the discretionary judgment of the implementing municipality. Similarly, there are no clear criteria to be met for industrial facilities that discharge to MS4s in order for the MS4s to comply with MEP. The lack of federal guidance for MS4s is understandable. A stormwater expert panel convened by the California EPA State Water Board in 2006 (CA SWB, 2006) concluded that it was not yet feasible to establish strictly enforceable end-of-pipe numeric effluent limits for MS4 discharges. The principal reasons cited were (1) the lack of a design storm (because in any year there are few storms sufficiently large in volume and/or intensity to exceed the design volume capacity or flow rates of most treatment SCMs) and (2) the high variability of stormwater quality influenced by factors such as antecedent dry periods, extent of connected impervious area, geographic location, and land use.

Industrial and Construction Stormwater Permits. The industrial and construction stormwater programs suffer from the same kind of deficiencies as the municipal stormwater program. These stormwater discharges are not bound by the MEP criterion, but they are required to comply with either technology-based or, less often, water quality-based effluent limitations. In selecting SCMs to comply with these limitations, the industrial discharger or construction operator similarly selects from a menu of options devised by the EPA or, in some cases, the states or localities for their particular facility (EPA, 2006a, p. 15). For example, the regulated party will generally identify structural SCMs, such as fences and impoundments that minimize runoff, and describe how they will be installed. The SWPPP must also include nonstructural SCMs, like good housekeeping practices, that require the discharger to minimize the opportunity for pollutants to be exposed to stormwater. The SWPPP and the accompanying SCMs constitute the compliance requirements for the stormwater discharger and are essentially analogous to the numeric effluent limits listed for industrial effluents in the Code of Federal Regulations.

This set of requirements leaves considerable discretion to regulated parties in several important ways. First, the regulations require the discharger to evaluate the site for problematic pollutants; but where the regulated party does not have specific knowledge or data, they need only offer "estimates" and "predictions" of the types of pollutants that might be present at the site (EPA, 1996a, pp. IV-3, V-3). With the exception of visible features, the deferential site investigation requirements allow regulated parties to describe site conditions in ways that may effectively escape accountability unless there is a vigorous regulatory presence.

Second, dischargers enjoy considerable discretion in drafting the SWPPP (EPA, 1996a, p. IV-3). Despite EPA's instructions to consider a laundry list of considerations that will help the facility settle on the most effective plan (EPA, 2006a, p. 20), rational operators may take advantage of the wiggle room and develop ambiguous requirements that leave them with considerable discretion in determining whether they are in compliance (EPA, 2006a, pp. 15, 20, 132). Indeed, the federal regulations do little to prevent regulated parties from devising requirements that maximize their discretion. Instead, EPA describes many of the permit requirements in general terms. For example, in its industrial stormwater permit program the EPA commands the regulated party to "implement any additional SCMs that are economically reasonable and appropriate in light of current industry practice, and are necessary to eliminate or reduce pollutants in . . . stormwater discharges" (EPA, 2006a, p. 23).

EPA's program provides few rewards or incentives for dischargers to go beyond the federal minimum and embrace rigorous or innovative SCMs. In fact, if the regulated party invests resources to measure pollutant loads on their property, they are creating a paper trail that puts them at risk of greater regulation. Under the EPA's regulations, a regulated party "must provide a summary of existing stormwater discharge sampling data previously taken at [its] facility," but if there are no data or sampling efforts, then the facility is off the hook (EPA, 2006a, p. 20). Quantitative measures can thus be incriminating, particularly in a regulatory setting where the regulator is willing to settle for estimates.

Dilemma of Self-Monitoring

Unlike the wastewater program where there are relatively rigid self-monitoring requirements for the end-of-pipe effluent, self-monitoring is much more difficult to prescribe for stormwater discharges, which are variable over time and space. [For example, *compare* 33 U.S.C. § 1342(a)(2)-(b)(2) (2000) (outlining requirements for compliance under NPDES) *with* EPA, 2006a, p. 26 (outlining requirements for self-compliance under EPA regulations.)] EPA's

Chapter 3
Hydrologic, Geomorphic, and Biological Effects of Urbanization on Watersheds

A watershed is defined as the contributing drainage area connected to an outlet or waterbody of interest, for example a stream or river reach, lake, reservoir, or estuary. Watershed structure and composition include both naturally formed and constructed drainage networks, and both undisturbed areas and human dominated landscape elements. Therefore, the watershed is a natural geographic unit to address the cumulative impacts of urban stormwater. Urbanization has affected change to natural systems that tends to occur in the following sequence. First, land use and land cover are altered as vegetation and topsoil are removed to make way for agriculture or subsequently buildings, roads, and other urban infrastructure. These changes, and the introduction of a built drainage network, alter the hydrology of the local area, such that receiving waters in the affected watershed can experience radically different flow regimes than they did prior to urbanization. This altered hydrology, when combined with the introduction of pollutant sources that accompany urbanization (such as people, domesticated animals, industries, etc.), has led to water quality degradation of many urban streams.

This chapter first discusses the typical land-use and land-cover composition of urbanized watersheds. This is followed by a description of changes to the hydrologic and geomorphic framework of the watershed that result from urbanization, including altered runoff, streamflow mass transport, and stream-channel stability. The chapter then discusses the characteristics of stormwater runoff, including its quantity and quality from different land covers, as well as the characteristics of dry weather runoff. Finally, the effects of urbanization on aquatic ecosystems and human health are explored.

LAND-USE CHANGES

Land use has been described as the human modification of the natural environment into the built environment, such as fields, pastures, and settlements. Important characteristics of different land uses are the modified surface characteristics of the land and the activities that take place within that land use. From a stormwater viewpoint, land uses are usually differentiated by building density and comprised of residential, commercial, industrial, institutional, recreational, and open-space land uses, among others. Each of these land uses usually has distinct activities taking place within it that affect runoff quality. In addition, each land use is comprised of various amounts of surface land cover, such as roofs, roads, parking areas, and landscaped areas. The amount and type of each cover also affect the quality and quantity of runoff from urban areas. Changes in land use and in the land covers within the land uses associated with development and redevelopment are therefore important considerations when studying local receiving water problems, the sources of these problems within the watershed, and the stormwater control opportunities.

Land-Use Definitions

Although there can be many classifications of residential land use, a crude and common categorization is to differentiate by density. High-density residential land use refers to urban single-family housing at a density of greater than 6 units per acre, including the house, driveway, yards, sidewalks, and streets. Medium density is between 2 and 6 units per acre, while low density refers to areas where the density is 0.7 to 2 units per acre. Another significant residential land use is multiple-family housing for three or more families and from one to three stories in height. These units may be adjoined up-and-down, side-by-side, or front-and-rear.

There are a variety of commercial land uses common in the United States. The strip commercial area includes those buildings for which the primary function is the sale of goods or services. This category includes some institutional lands found in commercial strips, such as post offices, court houses, and fire and police stations. This category does not include warehouses or buildings used for the manufacture of goods. Shopping centers are another common commercial area and have the unique distinction that the related parking lot that surrounds the buildings is at least 2.5 times the area of the building roof area. Office parks are a land use on which non-retail business takes place. The buildings are usually multi-storied and surrounded by larger areas of lawn and other landscaping. Finally, downtown central business districts are highly impervious areas of commercial and institutional land use.

Industrial areas can be differentiated by the intensity of the industry. For example, "manufacturing industrial" is a land use that encompasses those buildings and premises that are devoted to the manufacture of products, with many of the operations conducted outside, such as power plants, steel mills, and cement plants. Institutional areas include a variety of buildings, for example schools, churches, and hospitals and other medical facilities that provide patient overnight care.

Roads constitute a very important land use in terms of pollutant contributions. The "freeway" land use includes limited-access highways and the interchange areas, including any vegetated rights-of-ways. Finally, there are a variety of open-space categories, such as cemeteries, parks, and undeveloped land. Parks include outdoor recreational areas such as municipal playgrounds, botanical gardens, arboretums, golf courses, and natural areas. Undeveloped lands are private or publicly owned with no structures and have a complete vegetative cover. This includes vacant lots, transformer stations, radio and TV transmission areas, water towers, and railroad rights-of-way.

The preceding land-use descriptions are the traditional categories that make up the vast majority of the land in U.S. cities. However, there are emerging categories of land use, such as those espoused under the term New Urbanism, which combine several area types (such as commercial and high-density residential areas). Although land use can be broadly and generally categorized, local variations can be extremely important such that locally available land-use data and definitions should always be used. For example, local planning agencies typically do not separate the medium-density residential areas into subcategories. However, this may be necessary to represent different development trends that have occurred with time, and to represent newly emerging types of land uses for an area. Box 3-1 discusses the subtle influence that tree canopy could have on the residential land-use classification.

BOX 3-1
The Role of Tree Cover in Residential Land Use

Figure 3-1 shows two medium-density residential neighborhoods, one older and one newer. Tree canopy is obviously different in each case, and it may have an effect on seasonal organic debris in an area and possibly on nutrient loads (although nutrient discharges appear to be more related to homeowner fertilizer applications). Increased tree canopy cover also has a theoretical benefit in reducing runoff quantities due to increased interception losses. In both cases, however, monitoring data to quantify these benefits are sparse. Xiao (1998) examined the effect urban tree cover had on the rainfall volume striking the ground in Sacramento, California. The results indicated that the type of tree or type of canopy cover affected the amount of rainfall reduction measured during a rain event, such that large broad-leafed evergreens and conifers reduced the rainfall that reached the ground by 36 percent, while medium-sized conifers and deciduous trees reduced the rainfall by 18 percent. Cochran (2008) compared the volume and intensity of rain that reached the ground in an open area (no canopy cover) versus two areas with intact canopy covers in Shelby County, Alabama, over a year. The sites were sufficiently close to each other to assume that the rainfall characteristics were the same in terms of the intensity and the variation of intensity and volume during the storm. Rainfall "throughfall" was reduced by about 13.5 percent during the spring and summer months when heavily wooded cover existed. The rainfall characteristics at the leafless tree sites (winter deciduous trees) were not significantly different from the parking lot control sites. In many locations around the county, very high winds are associated with severe storms, significantly decreasing the interception losses. Of course, mature trees are known to provide other benefits in urban areas, including shading to counteract stormwater temperature increases and massive root systems that help restore beneficial soil structure conditions. Additional research is needed to quantify the benefits of urban trees through a comprehensive monitoring program.

FIGURE 3-1 Two medium-density residential areas (no alleys); the area on the right is older.

Trends in Urbanization

Researchers at Columbia University (de Sherbinin, 2002) state that 83 percent of the Earth's land surface has been affected by human settlements and activities, with the urbanized areas comprising about 4 percent of the total land use of the world. Urban areas are expanding world-wide, especially in developing countries. The United Nations Population Division estimates suggest that the world's population will become mostly urbanized by 2010, whereas only 37 percent of the world's population was urbanized in 1970. De Sherbinin (2002) concludes that although the extent of urban areas is not large when compared with other land uses (such as agriculture or forestry) their environmental impact is significant. Population densities in the cities are large, and their political, cultural, and economic influence is great. Most industrial activity is also located near cities. The influence of urban areas extends beyond their boundaries due to the need for large amounts of land for food and energy production, to generate raw materials for industry, for building water supplies, for obtaining other resources such as construction materials, and for recreational areas. One study estimated that the cities of Baltic Europe require from 500 to more than 1,000 times the urbanized land area (in the form of forests, agricultural, marine, and wetland areas) to supply their resources and to provide for waste disposal (de Sherbinin, 2002).

Currently, considerable effort is being spent investigating land-use changes world-wide and in the United States in support of global climate change research. The U.S. Geological Survey (USGS, 1999) has prepared many research reports describing these changes; Figure 3-2 shows the results for one study in the Chicago and Milwaukee areas, and Figure 3-3 shows the results for a study in the Chesapeake Bay area. These maps graphically show the dramatic rate of change in land use in these areas. The very large growth in urban areas during the 20 years between 1975 and 1995 is especially astonishing. By 1995, Milwaukee and Chicago's urbanized areas more than doubled in size from prior years. Even more rapid growth has occurred in the Washington, D.C.–Baltimore area.

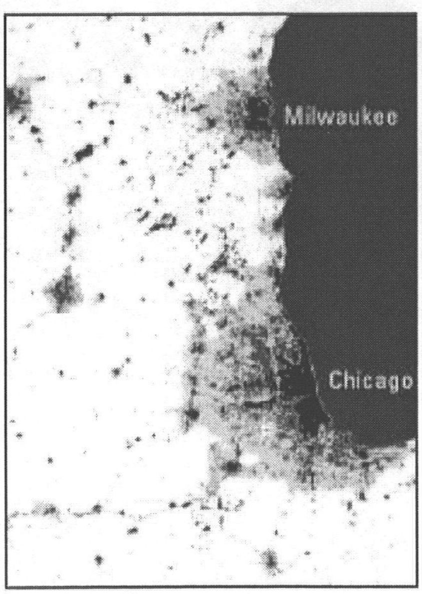

FIGURE 3-2 The extent of urban land in Chicago and Milwaukee in 1955 (black), 1975 (red), and 1995 (yellow). SOURCE: USGS (1999).

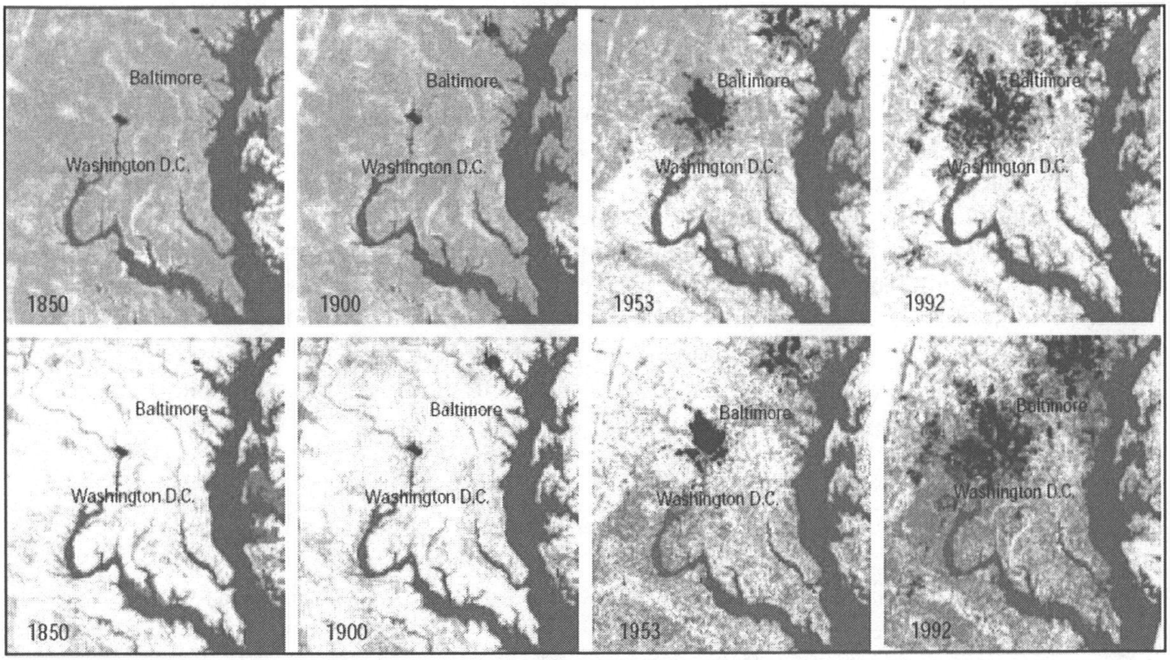

FIGURE 3-3 This series of maps compares changes in urban, agricultural, and forested lands in the Patuxent River watershed over the past 140 years. The top series shows the extent of urban areas (red) along with agriculture (gold), which was at its peak in the mid- to late 1800s. Since 1900, the amount of agricultural land has declined as urban and forested land (green) has increased. SOURCE: USGS (1999).

Many different metrics can be used to measure the rate of urbanization in the United States, including the number of housing starts and permits and the level of new U.S. development. The latter is tracked by the U.S. Department of Agriculture's (USDA) National Resources Inventory (USDA, 2000). The inventory, conducted every five years, covers all non-federal lands in the United States, which is 75 percent of the U.S. total land area. The inventory uses land-use information from about 800,000 statistically selected locations. From 1992 to 1997, about 2.2 million acres per year were converted from non-developed to developed status. According to the USDA (2000), the per capita developed land use (acres per person, a classical measure of urban sprawl) has increased in the United States between the years of 1982 and 1997 from about 0.43 to about 0.49 acres per person. The smallest amount of developed land used per person was for New York and Hawaii (0.15 acres), while the largest land consumption rate was for North Dakota, at about 10 times greater. Surprisingly, Los Angeles is the densest urban area in the country at 0.11 acres per person. The amount of urban sprawl is also directly proportionate to the population growth. According to Beck et al. (2003):

> In the 16 cities that grew in population by 10 percent or less between 1970 and 1990 (but whose population did not decline), developed area expanded 38 percent—more than in cities that declined in population but considerably less than in the cities where population increased more dramatically. Cities that grew in population by between 10 and 30 percent sprawled 54 percent on average. Cities that grew

between 31 and 50 percent sprawled 72 percent on average. Cities that grew in population by more than 50 percent sprawled on average 112 percent. These findings confirm the common sense, but often unacknowledged proposition, that there is a strong positive relationship between sprawl and population growth.

In most areas, the per capita use of developed land has increased, along with the population growth. However, even some cities that had no population growth or had negative growth, such as Detroit, still had large amounts of sprawl (increased amounts of developed land used per person), but usually much less than cities that had large population growth. Los Angeles actually had an 8 percent decreased rate of land consumption per resident during this period, but the city still experienced tremendous growth in land area due to its very large population growth. The additional 3.1 million residents in the Los Angeles area during this time resulted in the development of almost an additional 400 square miles.

Land-Cover Characteristics in Urban Areas

As an area urbanizes, the land cover changes from pre-existing rural surfaces, such as agricultural fields or forests, to a combination of different surface types. In municipal areas, land cover can be separated into various common categories—pictured and described in Box 3-2—that include roofs, roads, parking areas, storage areas, other paved areas, and landscaped or undeveloped areas.

Most attention is given to impervious cover, which can be easily quantified for different types of land development. Given the many types of land cover described in Box 3-2, impervious cover is composed of two principal components: building rooftops and the transportation system (roads, driveways, and parking lots). Compacted soils and unpaved parking areas and driveways also have "impervious" characteristics in that they severely hinder the infiltration of water, although they are not composed of pavement or roofing material. In terms of total impervious area, the transportation component often exceeds the rooftop component (Schueler, 1994). For example, in Olympia, Washington, where 11 residential multifamily and commercial areas were analyzed in detail, the areas associated with transportation-related uses comprised 63 to 70 percent of the total impervious cover (Wells, 1995). A significant portion of these impervious areas—mainly parking lots, driveways, and road shoulders—experience only minimal traffic activity. Most retail parking lots are sized to accommodate peak parking usage, which occurs only occasionally during the peak holiday shopping season, leaving most of the area unused for a majority of the time. On the other hand, many business and school parking areas are used to their full capacity nearly every work day and during the school year. Other differences at parking areas relate to the turnover of parking during the day. Parked vehicles in business and school lots are mostly stationary throughout the work and school hours. The lighter traffic in these areas results in less vehicle-associated pollutant deposition and less surface wear in comparison to the greater parking turnover and larger traffic volumes in retail areas (Brattebo and Booth, 2003).