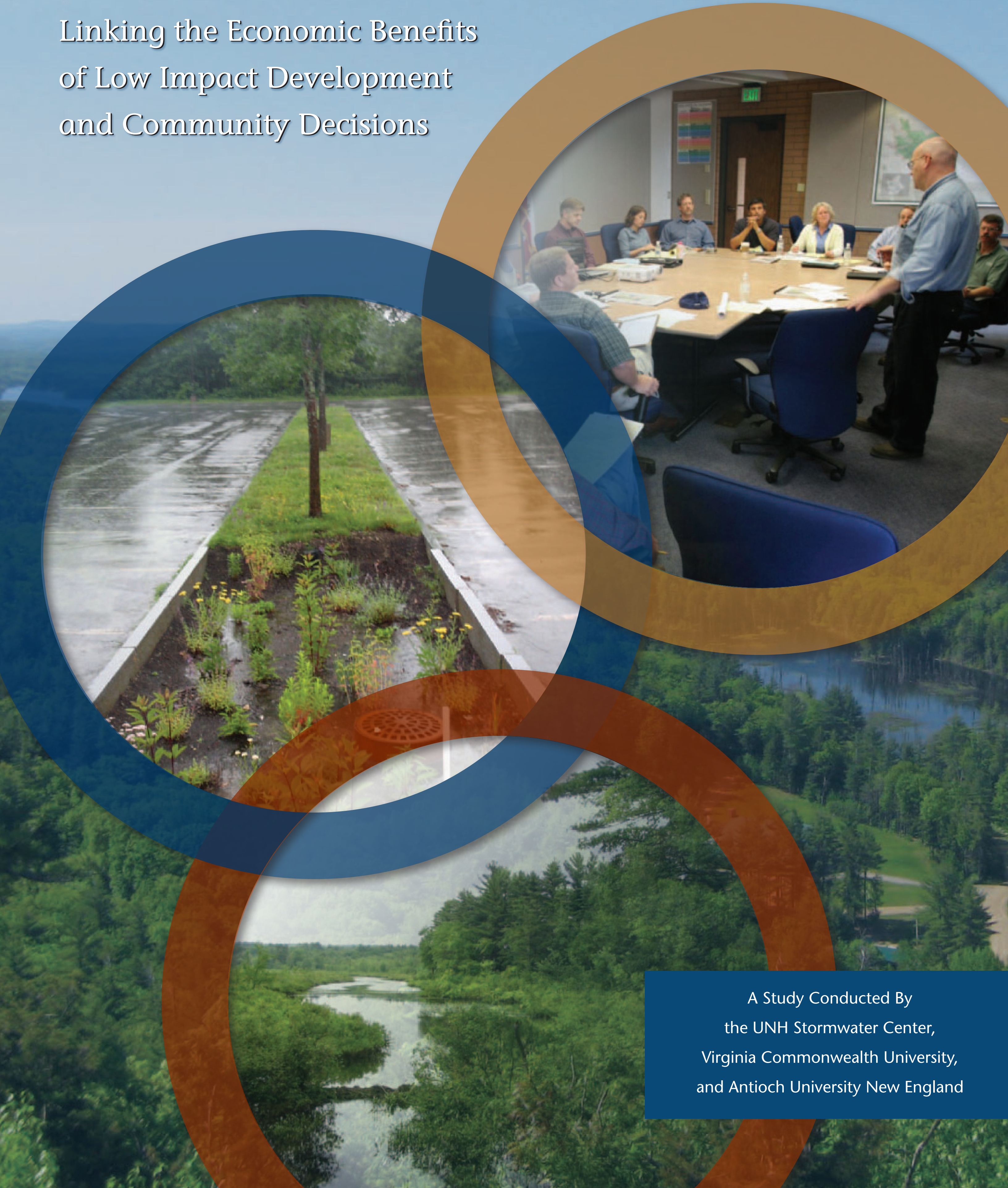
FORGING THE LINK

Linking the Economic Benefits of Low Impact Development and Community Decisions



A Study Conducted By
the UNH Stormwater Center,
Virginia Commonwealth University,
and Antioch University New England

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Linking the Economic Benefits of Low Impact Development and Community Decisions

This study was conducted by the University of New Hampshire Stormwater Center, the Virginia Commonwealth University, and Antioch University New England.

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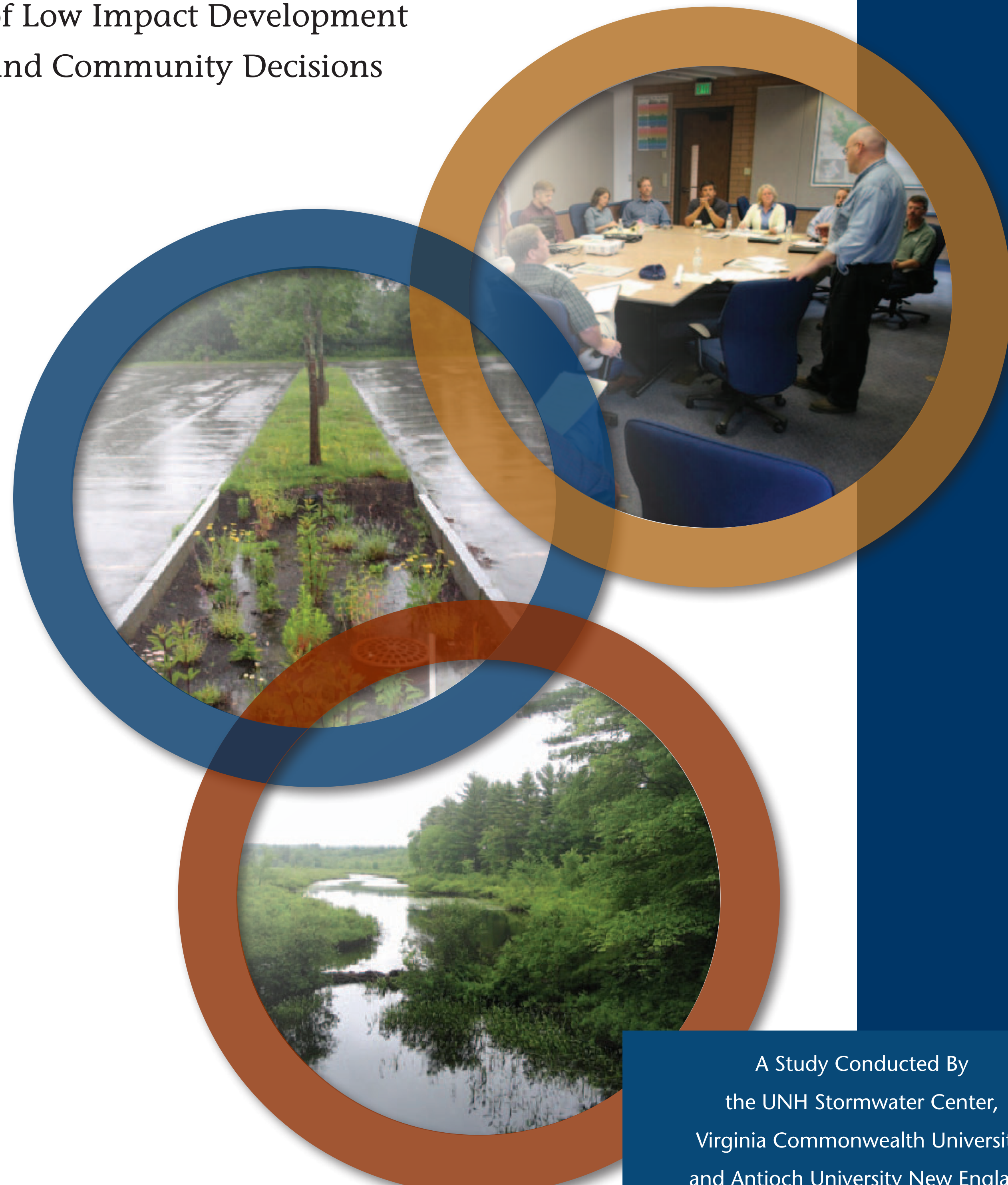

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FORGING THE LINK

Linking the Economic Benefits of Low Impact Development and Community Decisions

The guiding principle of this project is to illustrate the advantages of Low Impact Development (LID) in the economic terms of how municipal land use decisions are commonly made.

In addition to the environmental and water quality benefits for which Low Impact Development (LID) is so commonly known, considerable economic, infrastructure, and adaptation planning benefits are also being realized through the incorporation of LID-based strategies.

Forging the Link demonstrates the substantive economic benefits—for both construction budgets and project life-cycle costs—that are increasingly being observed by municipalities, commercial developers, and others when using Green Infrastructure for stormwater management.

In addition, the FTL curriculum demonstrates the use of LID as a means for building community resiliency to changing climates in a water resources management context.

THE FTL CURRICULUM DEMONSTRATES:

1. The ecological benefits of LID with respect to protection of water quality, aquatic habitat and watershed health
2. The economic benefits of using both traditional and innovative infrastructure to manage stormwater
3. The capability of LID to be used as a climate change adaptation planning tool to minimize the stress to urban stormwater infrastructure.

The FTL curriculum was developed in partnership with the Nonpoint Education for Municipal Officials (NEMO), Coastal Training Programs (CTP), Sea Grant Coastal Community Development Specialists, Cooperative Extension Agents, National Estuary Program (NEP) Staffs, and numerous volunteer municipal decision makers.

BENEFITS OF LOW IMPACT DEVELOPMENT

Low Impact Development (LID) is an innovative approach to stormwater management that is based upon the principle of managing rainfall at the source. The goal of LID is to mimic the predevelopment hydrology of a site using a combination of site planning and structural design strategies to control runoff rate and volumes. LID can be applied to new development, urban retrofitting, and redevelopment, and helps communities achieve a balance between public safety, economic development and ecological protection.

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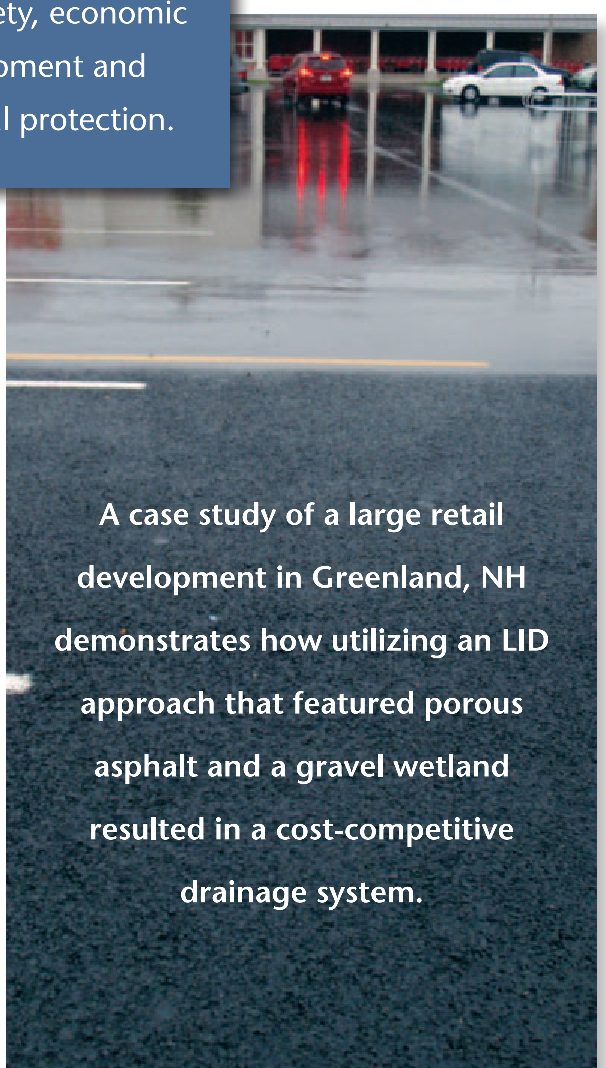


A case study of a large retail development in Greenland, NH demonstrates how utilizing an LID approach that featured porous asphalt and a gravel wetland resulted in a cost-competitive drainage system.

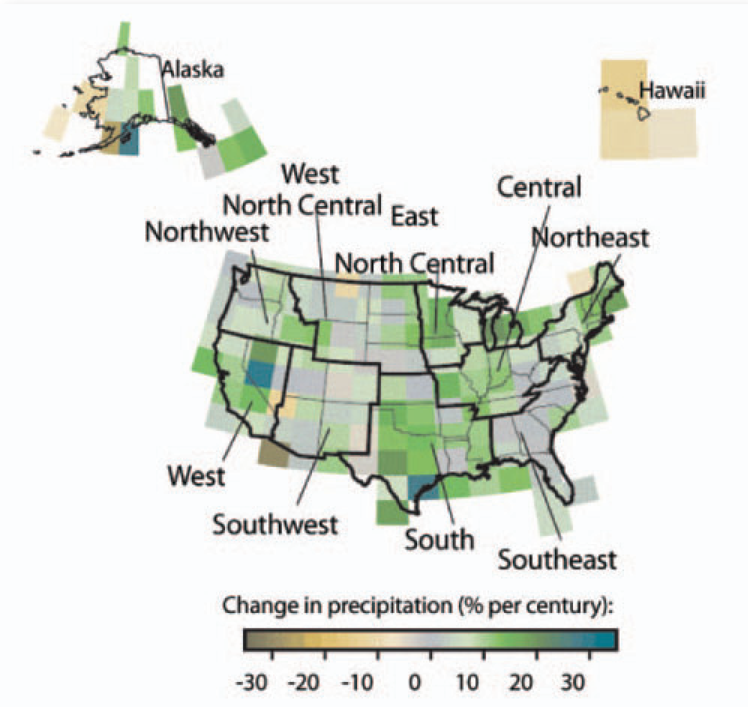
ECONOMICS AND LID

While better known for its capacity to reduce pollution and manage stormwater more sustainably, LID designs are also economically beneficial and more cost-effective as compared to conventional stormwater controls. LID is commonly misperceived as only adding expense to a project; however, this perspective fails to acknowledge the broader benefits that can be observed in terms of whole project costs for new construction, and in some instances, increased life-cycle benefits as well. By combining both gray (traditional) and a green (LID) approaches, the added expense of LID are offset by the reductions in other traditional practices such as curb and gutter or detention ponds.

HISTORIC AND PROJECTED CLIMATE CHANGE

The state of the earth's climate has been a topic of extreme debate. However, there is near consensus that climate change is expected to continue through the 21st century, and that for many regions of North America, projections are for an increase in the depth, frequency and duration of precipitation events. Concurrently, there are projections indicating sea level rise. Historically, many communities have made anecdotal observations regarding the timing of spring thaw or first frost and recent data has confirmed those observations to be accurate.

> Scientists from around the globe have recorded changes in the hydrologic cycle, a decline in glaciers and polar ice, and shifts in precipitation intensity and trends.



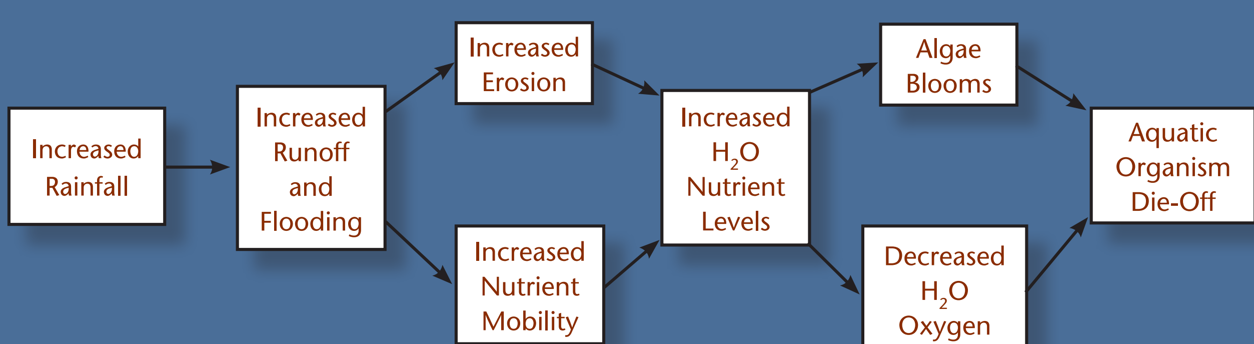
Average Precipitation Changes for the US (NOAA Climatic Data Center)

LID AS A CLIMATE CHANGE ADAPTATION TOOL

Low Impact Development planning and structural controls have the ability to manage increased stormwater flows from a changing climate. The same strategies that are applied to managing increased runoff volume from impervious surfaces can be used to manage increased storm size from climate change. The use of Green Infrastructure for adding distributed storage and infiltration throughout a project can also have a cumulative positive effect in a watershed and be used as a climate change adaptation tool for building resiliency to extreme precipitation events.

IMPACTS DUE TO CLIMATE CHANGE EFFECTS ON RAINFALL AND RUNOFF

PRIMARY IMPACTS SECONDARY IMPACTS TERTIARY IMPACTS



OVERCOMING THE BARRIERS TO THE IMPLEMENTATION OF LID

During the 2000 census, many coastal communities experienced as much as 25 percent population growth and are expected to increase by another 5 percent by 2015. This tremendous growth pressure is forcing municipalities and other watershed stakeholders to develop strategies for managing growth while maintaining watershed health. In addition shrinking local budgets, due to challenging economic climates, reduces the ability of many municipalities to respond to their local demands. Overcoming these challenges require significant effort in outreach, communication and resource development.

IDENTIFIED BARRIERS

- Cost
- Education and Training
- Language
- Political WIll
- Lack of Capacity to Build Social Capital
- Credibility
- Maintenance and Operations Plans

FORGING THE LINK

is a science-based curriculum targeting the primary barrier to implementation of LID, identified as cost, as the core of the project.

THE FTL CURRICULUM CONTAINS:

- Scripted PowerPoint Presentation (modifiable by the end user)
- PowerPoint Presentation Delivery Guide
- Post Presentation Facilitated Discussion Process
- Resource Manual
- Executive Summaries of each chapter
- Web-Based Materials: www.unh.edu/unhsc/forgingthelink

Presentations may be delivered by staff of the UNHSC, upon request.

FORGING THE LINK: Linking the Economic Benefits of Low Impact Development and Community Decisions • www.unh.edu/unhsc/forgingthelink

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CHAPTER 1

Guiding Principles

The guiding principle of the Forging the Link project is to illustrate the advantages of Low Impact Development (LID) in the economic terms of how municipal land use decisions are commonly made. In addition to the environmental and water quality benefits for which LID is so commonly known, considerable economic, infrastructure, and adaptation planning benefits are also being realized through the incorporation of LID-based strategies.

The project was grounded with direct interviews and market surveys with municipal decision makers from the regions of the Western and Eastern Great Lakes and New England. These participants provided valuable insight in the identification of the barriers many have faced in making informed decisions. Those participants confirmed that municipal decision making is faced with the stark economic reality of shrinking budgets coupled with increasing financial demands. The financial demands are driven by the need for permits (TMDLs, MS4 GPs, etc). Regulatory demands are increasing at the same time municipal budget are decreasing.

> Considerable economic, infrastructure, and adaptation planning benefits are being realized through the incorporation of LID-based strategies.

Forging the Link aims to demonstrate the substantive economic benefits—for both construction budgets and project life-cycle costs—that are increasingly being observed by municipalities, commercial developers, and others when using Green Infrastructure for stormwater management. This manual presents background and case studies for commercial development and municipal infrastructure projects. It also includes information on the use of Low Impact Development as an adaptation planning tool, and, in particular, as a means for building community resiliency in managing water resources.

The value of LID within the context of Forging the Link has three parts:

1. LID protects water quality, aquatic habitat and watershed health.
2. LID has demonstrated cost savings for developers and municipalities.
3. LID helps protect communities from threats of increased flooding through increased resiliency.

LOW IMPACT DEVELOPMENT BENEFITS FOR THE PROTECTION OF WATER QUALITY AND WATERSHED HEALTH

LID is widely recognized as a highly effective strategy for the protection of water quality and watershed health. The 2007 EPA Green Infrastructure Statement of Intent indicates a programmatic commitment to implementing Green Infrastructure as a means for protecting drinking water supplies, public health and reducing stormwater pollution. Also, the National Research Council (NRC) report entitled Urban Stormwater Management in the United States (2008) details the failings of the current standard of practice for both stormwater management and regulatory permitting. In particular, the NRC report identifies widespread urbanization, increases in impervious surface, nonpoint source derived pollution, and increased runoff volumes as the primary issues that need to be addressed. Remedies include the use of a combination of innovative stormwater management practices that are targeted at both pollutant and runoff volume reduction and through protection of buffers and undisturbed natural resources and public education.

FIGURE 1-1
An example of an effective Green Infrastructure element, Portland, Oregon

THE ECONOMIC BENEFITS OF GRAY AND GREEN INFRASTRUCTURE FOR STORMWATER MANAGEMENT

Less widely known are the potential economic benefits of using a combination of Green Infrastructure (or LID) and Gray Infrastructure (conventional) for stormwater management. LID is commonly misperceived as only adding expense to a project; however, this perspective fails to acknowledge the broader benefits that can be observed in terms of whole project costs for new construction, and in some instances, increased life-cycle benefits as well.

The misperception generally focuses on budget line item increases, such as the added expense associated with incorporating bioretention instead of standard landscaping, or the additional costs of utilizing porous pavements over traditional pavement.

While individually, Green Infrastructure elements will add expense to a project, at the same time, costs savings are often realized on an overall project basis as the need for conventional stormwater infrastructure such as curbing, catch-basins, piping, ponds, and other hydraulic controls are reduced.

Of course, cost savings are not observed when compared with a complete lack of stormwater management, but rather for projects consistent with new state and federal permitting requirements addressing volume and pollutant reduction. Basic stormwater management strategies such as ponds and swales are generally cheaper to design and install, but may not meet regulatory guidelines with respect to water quality treatment (Ballestero, 2006, NURP, 1999).

This project focuses on project costs that are typically the basis for most municipal budgeting decisions. LID structural controls will rarely be less expensive than minimal stormwater management and cost benefits may not be possible for retrofitting of existing stormwater man agement facilities. The greatest potential economic benefit exists for management of combined sewer overflow, which is often the single greatest municipal expense for communities that are required to separate stormwater and wastewater sewers. However, there are ecological services and benefits that provide cost savings by protecting adjacent and downstream abutters from property loss by storing and treating the water before it leaves the site.

LID is commonly misperceived as only adding expense to a project. This perspective fails to acknowledge the broader benefits that can be observed in terms of whole project costs for new construction, and in some instances, increased life-cycle benefits as well.

LID AS A CLIMATE CHANGE ADAPTATION PLANNING TOOL

> Communities that actively engage in hazard and resiliency planning are less prone to disaster, recover faster from disasters which do occur, and endure less economic hardship than those communities that do not.

Another under-realized benefit to LID planning and LID structural controls is the ability to manage increased stormwater flows from a changing climate. The same strategies that are applied to managing increased runoff volume from impervious surfaces can be used to manage increased storm size from climate change. The use of Green Infrastructure for adding distributed storage and infiltration throughout a project can also have a cumulative positive effect in a watershed and be used as a climate change adaptation tool for building resiliency to extreme precipitation events. A 2010 report from the National Oceanic and Atmospheric Administration entitled Hazard and Resiliency Planning: Perceived Benefits and Barriers Among Land Use Planners identifies "communities that actively engage in hazard and resiliency planning are less prone to disaster, recover faster from disasters which do occur, and endure less economic hardship than those communities that do not." Preparedness includes an emphasis on non-structural controls such as land use planning and buffer protection, as well as structural controls like LID. Additionally, there is the potential for LID implementation to yield economic benefits by reducing the maintenance burden on existing municipal infrastructure and preventing the need for costly repairs and replacement while building community resilience to impacts from land use changes and climate change.

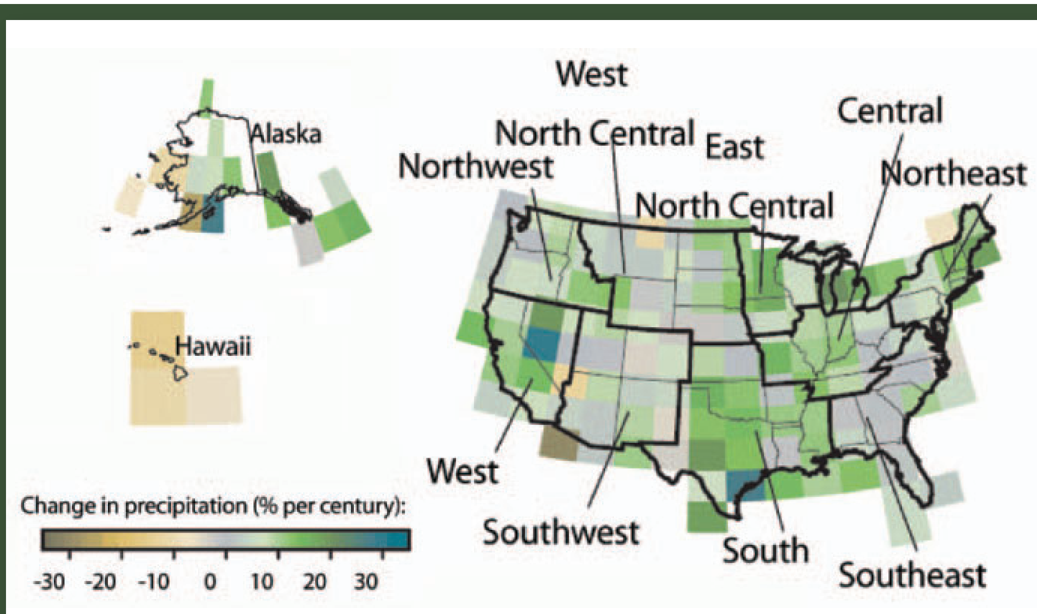


FIGURE 1-2
Climatic records for the US collected from 48 states since the early 20th century indicating increases in average precipitation (NOAA Climatic Data Center)

FACT SHEET

The Benefits of Low Impact Development

Low Impact Development (LID) is an innovative approach to stormwater management that is based on the principle of managing runoff at the source.

The goal of LID is to mimic the predevelopment hydrology of a site using a combination of site planning and structural design strategies to control runoff rate and volumes.

LID approaches can be used in any type of development scenario:

- new development,
- redevelopment, or
- existing condition retrofitting.

LID IS:

- A balanced watershed approach to managing altered hydrology
- A science-based solution to mitigating the impacts of smart development
- A way to decentralize and integrate stormwater best management

LID IS NOT:

- A silver bullet
- A substitute for proper planning
- A way to permit unfavorable development
- A single best management practice

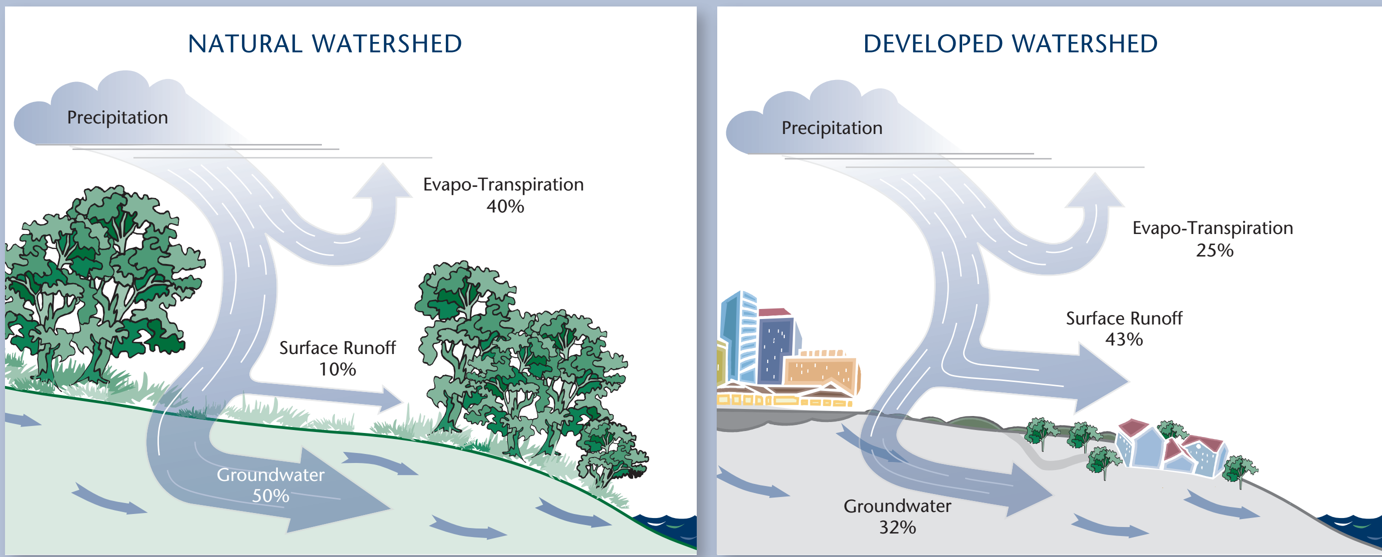
WHY LID, WHY NOW?

Historically, wetlands, rivers, lakes, and estuaries provided the work of cleaning and protecting water resources.

Intense development can significantly impair water quality and change how surface and groundwater interact.

Increases in impervious surfaces result in increased runoff, making it harder and harder to protect receiving waters.

FORGING THE LINK



TYPICAL PRE- AND POST-DEVELOPMENT HYDROLOGY PATTERNS

OLD DESIGN APPROACHES

Detention basins do an effective job of addressing flood protection requirements by detaining larger volumes of runoff from high levels of impervious surfaces. However, research has shown that sole reliance upon basins to manage stormwater has proven to be ineffective in protecting water resources.

TOWARD A BETTER APPROACH

The work of community board members and municipal decision makers in towns and cities throughout the country is critically important for shaping community character and protecting local natural, cultural and economic resources. This can be done by requiring effective LID designs that:

- attempt to decentralize drainage infrastructure,
- maximize onsite storage filtration and infiltration
- make use of natural landscape features to best manage runoff
- reduce the need for large detention structures

FORGING THE LINK: Linking the Economic Benefits of Low Impact Development and Community Decisions • www.unh.edu/unhsc/forgingthelink
Chapter 2: The Benefits of Low Impact Practices

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CHAPTER 2

The Benefits of Low Impact Development

Low Impact Development (LID) is an innovative approach to stormwater management that is based upon the principle of managing rainfall at the source. The goal of LID is to mimic the predevelopment hydrology of a site using a combination of site planning and structural design strategies to control runoff rate and volumes. LID can be applied to new development, urban retrofitting, and redevelopment, and helps communities achieve a balance between public safety, economic development and ecological protection.

Traditionally, stormwater has been managed using drainage networks to efficiently move rainwater away from residential areas for the purpose of protecting the public from the effects of flooding. Stormwater has been managed as a nuisance and threat to growing communities. The first modern approach to managing stormwater appeared in the 1970s where the primary objectives of management were to reduce the effects of downstream flooding by slowing the peak discharge rates (Debo, T.N., Reese, A.J., 2002). In developing urban areas, the addition of new roads, buildings, and parking lots increases the percentage of impervious cover and decreases the landscape's ability to absorb rainwater. The streams that receive runoff from these newly developed areas respond through increases in channel width and depth in order to compensate for the increases in impervious areas, causing erosion and property loss. This is because more water is carried directly to the streams as less water is absorbed into the ground from the impervious surface increase. A stream channel will naturally adjust to the volume, intensity and duration of water it receives.

LID can be applied to new development, urban retrofitting, and redevelopment, and helps communities achieve a balance between public safety, economic development and ecological protection.

Historically, stormwater swales and basins are the most common approach used for managing peak runoff rates from developed areas. Swales simply convey stormwater runoff to offsite locations and are only adequate for small drainage areas. Detention basins do an effective job of addressing flood protection requirements by detaining larger volumes of runoff from high levels of impervious surfaces. Unfortunately, sole reliance upon basins to manage stormwater has proven to be ineffective to protect water resources.

Effective LID designs attempt to decentralize drainage infrastructure, maximize onsite storage and infiltration, and make use of natural landscape features to best manage runoff.

Reliance on stormwater basins and swales to manage runoff problems has led to water quality and altered urban hydrology. Common stormwater basin designs were typically targeted for a single large storm such as a 10- 25- 50- or 100-yr event. The majority of smaller, more frequent storm events aren't handled as effectively because they were not considered as part of the flood control design and are typically passed through the treatment structure. These more frequent and smaller storms have tremendous stream channel forming capacities and the ability to alter channel dimensions and also affect the availability and condition of aquatic habitat. The focus on runoff rate control rather than volume based hydrology results in increases in the width and depth of stream channels, and ultimately changes and decreases biological habitat indices dramatically. The focus on runoff rate control rather than volume-based hydrology results in increases in the width and depth of stream channels, and ultimately changes and decreases in biological habitat indices, bank erosion, property loss, and damage to infrastructure.

Conventional stormwater basins often fail to protect water resources because of poor design, inadequate construction and installation, or a lack of maintenance. Outlet structures can be under- or oversized resulting in minimal treatment for the majority of flows or increased incidences of high flow by-pass. Many conventional stormwater treatment systems fail at least two-thirds of the time for some water quality constituents (Ballestero et al 2006). Failure can be simply defined as runoff leaving the stormwater system that is dirtier than when it entered. The use of stormwater basins to manage runoff rates has resulted in longer durations and higher frequencies of channel forming flows leading to heavy erosion and deterioration of receiving streams.

LID uses predevelopment hydrology measures of runoff rate and volume as the hydrologic management goals for a development project. The same targets are useful whether considering a new developed site or a redevelopment project. In theory, the water that leaves a project site should match the same rate, quality and quantities that existed in a predevelopment condition. Effective LID designs attempt to make use of natural landscape features to best manage runoff and maximize onsite storage and infiltration. LID incorporates soil filtration/infiltration, biological uptake of water and nutrients, and cultivation of useful microbe populations in natural soils to transform many of the complex contaminants that can be found in stormwater. The use of LID strategies reduces the need for downstream structural practices that concentrate stormwater flows and contaminants into large basins at the end of a pipe.

The combination of Gray Infrastructure (typical pipe and drainage) with Green LID Infrastructure can effectively manage both extreme storm events and provide treatment and usage of the smaller more frequent storm events. Research has shown that conventional stormwater management approaches limit groundwater recharge; can degrade receiving water quality; increase runoff volumes, peak discharges, and flow velocities; and can lead to municipal infrastructure vulnerability. As research, technology, and information transfer have improved, alternative approaches are being sought by the public and regulators to reduce the adverse environmental and economic impacts from development. Integrating LID management strategies has emerged as an effective way to address these issues through better site planning and design processes and the incorporation of multiple stormwater management strategies early on in the planning process to provide runoff reduction, water quality treatment, and flood control.

NATURAL RESOURCE-BASED PLANNING CONCEPTS

LID strategies do not replace comprehensive resource based land planning. LID management strategies such as environmental site design, porous pavement, and filtration/infiltration practices provide important hydrologic benefits but do not replace the ecological value of greenspace. Clean water supplies are essential to life, yet many factors threaten water resources. In particular, increases in impervious surfaces and reduction of natural lands disrupt the connection between surface and groundwater and impair overall water quality. As seen in

A BRIEF WORD ABOUT WATER QUANTITY, FLOOD CONTROL, AND WATER QUALITY

The recent shift of focus toward water quality management does not lessen the importance of flood control. For the last 40 years the primary purpose of stormwater management programs was to avoid flooding while providing quick and efficient drainage for all storms except the largest most infrequent events. Today's drainage designs still require water quantity control to address flooding concerns. Matching modeled pre and post development peak flow rates has been the most common management measure to date.

Water quality management represents a broadening of the overall objectives of drainage design and is in line with the objectives of the very first Clean Water Act in 1972. Treating for water quality is most effective when starting at the source of the stormwater and implementing techniques that promote intercepting, infiltrating, filtering and evaporating to the maximum extent practicable. Employing an integrated treatment mechanism that addresses stormwater quality will reduce the end-of-pipe treatments necessary, thus resulting in smaller and cleaner volumes of rainfall runoff.

Figure 2-1, there is a direct correlation between increasing impervious surfaces and water quality impairment.

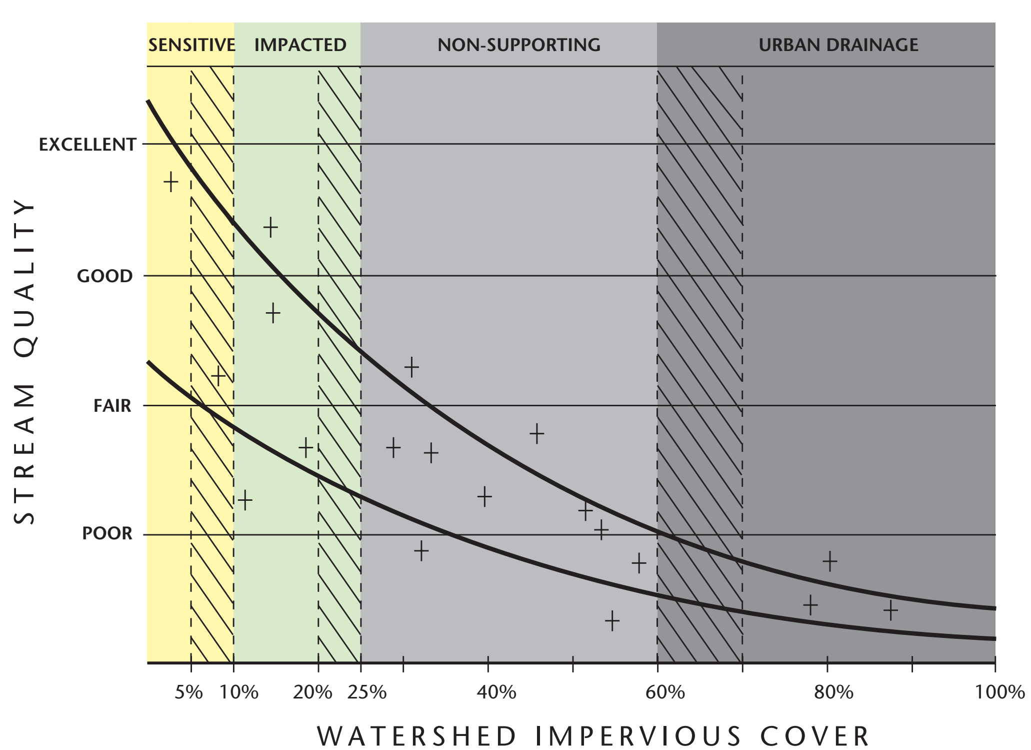
Effective water resource management requires local governments, businesses, community organizations, and residents to not only work together, but also adopt integrated approaches to stormwater impacts. Stormwater management is just one of a range of strategies at their disposal. Foremost are policies, programs, and regulations designed to protect watershed function, manage developed areas, and to protect natural resources.

Balancing Development

Historically, our wetlands, rivers, lakes, and estuaries have provided the work of cleaning and protecting our water resources, referred to as ecosystem services. Intense development can significantly impair water quality and change how surface and groundwater interact. With increases in impervious surfaces, the landscape's ability to absorb rainwater runoff decreases thus reducing the amount of groundwater recharge. A variety of strategies exist for protecting water resources including non-structural approaches such as buffer conservation and stormwater ordinance adoption; decentralized structural controls such as rain gardens and porous pavements; and centralized strategies like subsurface infiltration chambers. Figure 2-2 represents the relative complexity and costs involved when trying to balance the negative impacts of land development with water quality. Table 2-1 further illustrates important components of balancing development.

FIGURE 2-1
Relationship between Impervious Cover and Stream Quality

(adapted from Schueler, et al., 2009)



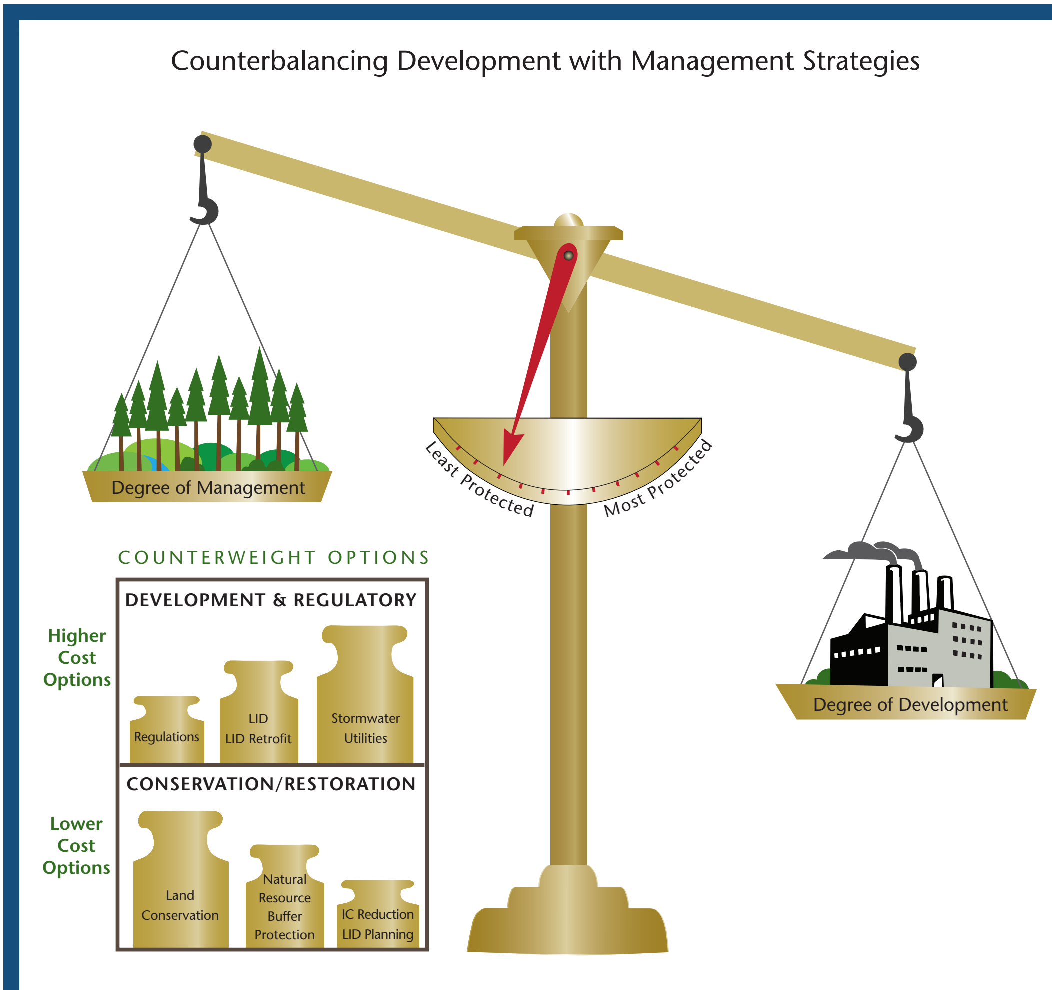


FIGURE 2-2
Counterbalance of development with management strategies. The weights represent management strategies that will compensate or counterbalance the degree of development. The shelves represent a tiered approach with respect to both cost and complexity.

LOW IMPACT DEVELOPMENT GOALS

The primary goal of LID is to mimic predevelopment hydrology of a given development site. This is achieved by maximizing site design techniques that intercept, evaporate, filter, store, and infiltrate runoff. Ultimately LID is a development strategy that preserves as much of nature's original development plan as possible. Where human impacts are necessary, LID can restore, to a degree, nature's approach to stormwater runoff management by dealing with rainfall as close to the source as possible using decentralized controls. A site's predevelopment hydrology is preserved by using design techniques based on the premise that water is a resource that should be preserved and maintained on site as much as possible. Instead of centralizing runoff from impervious surfaces into traditional pipe and pond management controls located at the bottom of drainage areas, LID addresses stormwater through smaller, cost-effective landscape features distributed throughout a development landscape.

> LID does not replace the need for proper planning and zoning.

SITE DESIGN

> Preservation of hydrologic soils best suited for infiltration practices will help reduce runoff volumes, preserving the quality of adjacent waterbodies, minimizing erosion, and recharging groundwater resources.

LID design principles have many names including environmental site design, conservation design, and sustainable site design. Regardless of name, the principles are relatively simple and are part of a low impact approach. Any design should begin with identifying and trying to conserve sensitive resource areas such as wetlands, springs or seeps; forest and riparian buffers; significant stands of trees or valuable upland wildlife habitat; aquifers and source waters. Soils should be assessed beyond the SCS/NRCS or county conservation district soil survey maps and every effort should be made to preserve soils suitable for infiltration in order to protect groundwater recharge and allow for stormwater practices that infiltrate. During the planning stages, road locations should be made to avoid crossing streams or wetlands and to keep away from steep slopes or floodplain wetlands. During construction, cut and fill should be minimized and grading should mimic natural land contours to the maximum extent practicable.

In the land planning and design stage, efforts should be made to minimize impervious surfaces by shortening driveways, placing homes closer to roadways, minimizing street widths, reducing the amount of parking in retail locations, as well as shrinking residential lot sizes in order to lower the amount of roadway needed. When considering stormwater management, the designs should evaluate the predevelopment condition. Where impervious surface cannot be minimized through land planning approaches and where drainage infrastructure is necessary, LID strategies should be implemented to decentralize infrastructure by disconnecting flow paths. Decentralizing infrastructure, disconnecting flow paths, will help retain a runoff rate similar to the predevelopment hydrology. Delaying the rate by which stormwater leaves a development site will maximize the water quality treatment. LID principles include:

- Resource conservation (watershed and site)
- Minimize cut and fill and reduce effective impervious cover (site level)
- Strategic timing and decentralization of runoff (watershed and site level)
- Integrated management practices (site level)
- Pollution prevention

Resource Conservation and Minimizing Cut and Fill

Local ordinances and regulations can require conservation of sensitive resources such as buffers, shoreland, wetlands and aquifers. There are many other resources to consider when planning for growth. Preservation of buffers and forested areas helps delay, treat and infiltrate runoff as well as provide habitat for wildlife. Preservation of hydrologic soils best suited for infiltration practices will help reduce runoff volumes, preserving the quality of adjacent waterbodies, minimizing erosion, and recharging groundwater resources. Soils classified as hydrologic soil groups A and B are considered well drained and are typically sand or silty loamy soils that easily infiltrate water.

Site development considerations should involve evaluation of the topography of the site to integrate a phased grading plan that retains the natural characteristics of the landscape, where possible. Use of existing site topography for location of structures can aid in the control of runoff by preserving the natural landscape's ability to retain stormwater and release it slowly into the environment. Minimizing cut and fill operations and preserving these natural drainage patterns can translate into construction cost savings and lead to a more sustainable development.

Reduce Effective Impervious Cover (EIC)

Impervious land cover or impervious surface refers to areas that do not allow water to infiltrate into the soil. The greater the amounts of impervious cover within a watershed, the greater the potential for degraded waters. Impervious cover accelerates the accumulation, flow and contamination of water over the landscape, and is increasingly causing pollutant loading overall. However, not all impervious cover is created equal. An important distinction should be made between Impervious Cover (IC) and Effective Impervious Cover (EIC). IC is the total land area that is covered with impervious materials, while EIC is that portion of the total amount of impervious cover on a building site that drains directly to the storm drain system. EIC includes street surfaces, paved driveways connected to the street, parking lots, rooftops, and heavily compacted soils that drain into local stormwater treatment systems. Impervious cover that drains to vegetated areas where stormwater can be infiltrated, filtered, and stored is not considered part of the EIC. Some methods used for disconnecting impervious cover from the storm drain network include redirecting downspouts away from paved surfaces and onto vegetated zones, and installing rain gardens or bioretention cells between paved surfaces and storm systems. Another mechanism for reducing EIC is the use of porous pavements that provide a hard surface but allow stormwater to infiltrate into the soil, thereby disconnecting it from the drainage system. An additional benefit of porous pavements is that they typically require much less road salt for de-icing in northern winter climates as compared to conventional pavements. This is a considerable benefit for water quality in cold climate regions, where chloride levels in many surface waters are rising, and to municipal and commercial managers seeking to reduce property maintenance costs (UNHSC 2010).

DEFINITION

Impervious Cover
Effective Impervious Cover

Impervious Cover (IC) is the total land area that is covered with impervious materials.

Effective Impervious Cover (EIC) is that portion of the total amount of impervious cover on a building site that drains directly to the storm drain system.

Strategic Timing and Decentralized Runoff Flow

Over the past 50 years, conventional stormwater drainage design preferred using curbs, catch basins and pipes to efficiently convey stormwater offsite. As urban and suburban density increases, "offsite" can represent an adjacent property, or an already overburdened municipal storm drainage network. Today, much more emphasis is being placed on managing stormwater onsite, before it enters the receiving waters.

> Instead of concentrating runoff into a single location or treatment, LID strategically integrates stormwater controls throughout the urban landscape.

Collecting and concentrating flow from a development site into a centralized treatment system, such as a stormwater pond or basin, does not necessarily yield the water quality treatment required by federal regulations. Removing curb structures and allowing water to flow to treatment and infiltration areas can mimic the natural flow patterns that predated the development. The use of decentralized infiltration areas, both structural (i.e. raingardens, infiltration trenches, porous pavements) and non-structural (buffers and high infiltration capacity soils) will reduce runoff volumes and slow runoff rates. Small-scale, distributed approaches may provide better treatment and be able to approximate predevelopment timing and flow patterns. This approach uses natural site storage and can yield a more protective and sustainable approach to managing runoff. A decentralized approach can also often have lower capital costs.

Integrated Management Practices

LID offers an innovative approach to urban stormwater management that is very different than conventional pipe and pond strategies. Instead of concentrating runoff into a single location or treatment, LID strategically integrates stormwater controls throughout the urban landscape. As there are no 100 percent effective strategies when it comes to stormwater management, an integrated approach incorporates multiple treatments that work cooperatively to address contaminants of concern. As Figure 2-3 illustrates, this integrated approach involves the use of site design and structural controls to manage runoff. There will be water quality and water quantity treatment objectives for any site, however, each of the integrated approaches – whether it is environmental site design or a structural Best Management Practice – will treat and reduce a certain amount of the overall runoff volume to be managed. For instance, although water quality management usually involves treatment of a smaller volume of water, that volume of runoff that is detained and infiltrated can reduce the overall volume that remains to be treated. Thus, with sufficient infiltration and runoff reduction, an integrated approach may not require large detention systems to treat larger storm events. If detention is still required, the structure will be far smaller and less costly than a conventional strategy would require.

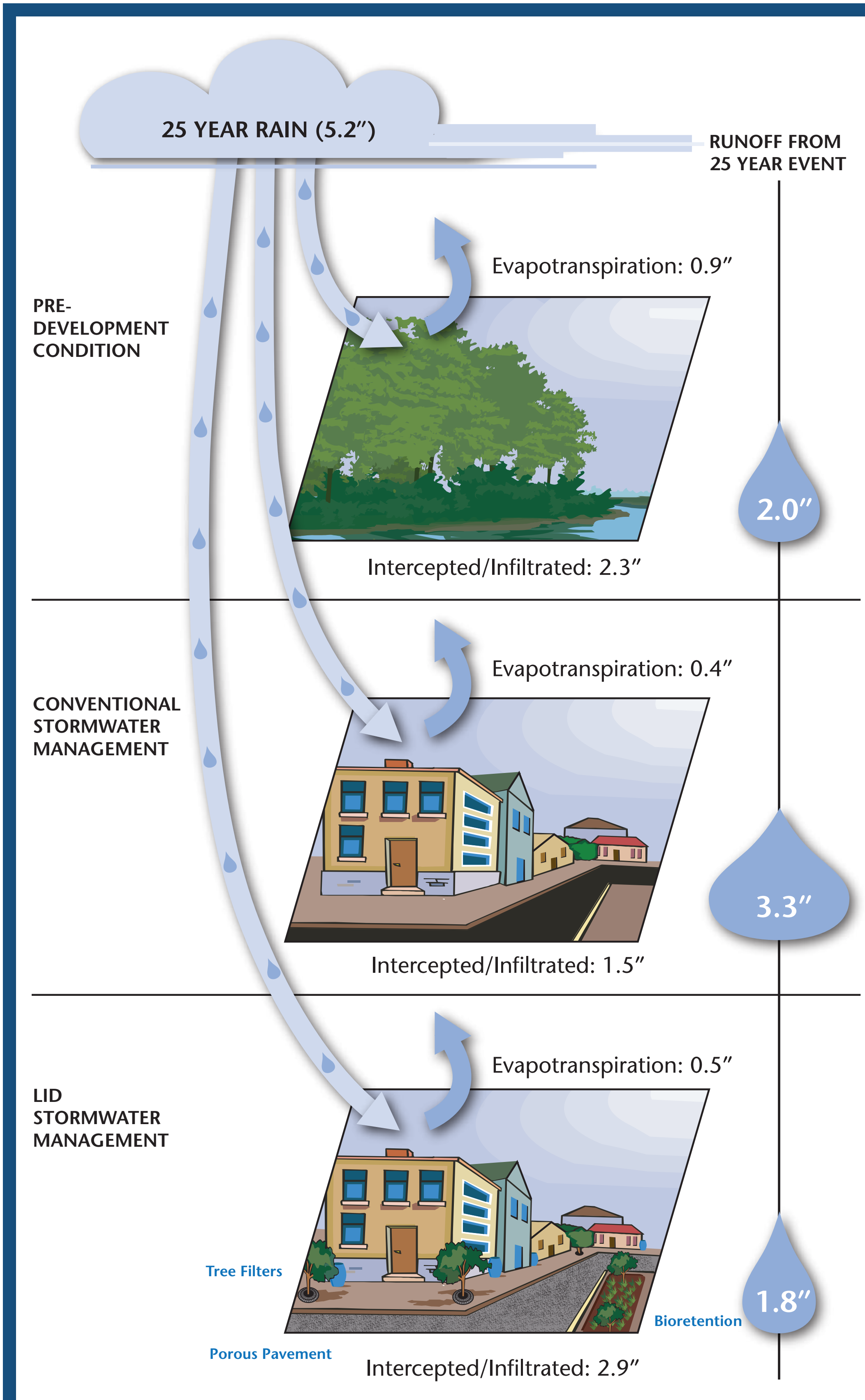


FIGURE 2-3
An integrated approach to stormwater management considers non-structural site design and structural controls to manage and reduce runoff. Through these measures the volume and rate of runoff treated at the end of the pipe can be reduced.

BEST MANAGEMENT PRACTICE NOMENCLATURE

Municipal decision makers must try to make the most informed decisions with the best available information. Often, confusing names and nomenclature associated with the variety of BMPs imply a process or performance expectation that does not exist. To add to the confusion, criteria for pollutant or effluent treatment is often changing. The functional treatment mechanism for each stormwater treatment practice that removes a certain type and level of pollutants from the runoff is referred to as the unit operations and processes (UOPs). Pollutant removal capacities of BMPs follow the same principles of physics, biology and chemistry that are used to design municipal water treatment facilities. Consideration of the UOP presents a classification of stormwater treatment technologies which communicate the system's treatment capacity.

> The functional treatment mechanism for each stormwater treatment practice that removes a certain type and level of pollutants from the runoff is referred to as the unit operations and processes (UOPs).

Introduction to Treatment Process

Table 2-1 illustrates the major categories of treatment practices that most stormwater management systems utilize to treat runoff (NCHRP 2006).

Hydrologic Operations

Hydrologic operations are defined as methods of treatment involving alterations in the movement and distribution of water. Most every stormwater management system utilizes these mechanisms to some extent. Longer retention of stormwater volumes enhances the function of the practice as it allows more time for other removal mechanisms to act on pollutants. The primary hydrologic operations employed by stormwater BMPs are flow diversion, retention, and infiltration. Flow diversion

TABLE 2-1
The major categories of unit operations and processes (UOPs) of stormwater management systems.

CATEGORY	UOP	TARGET	BMP TYPES
HYDROLOGIC	Flow alteration	Divert flow	All BMPs
	Volume reduction	Infiltration	Filtration/Infiltration BMPs, Most LID systems
PHYSICAL	Sedimentation	Sediment	Retention/Detention Systems and Filtration/Infiltration Systems with sufficient volume
	Enhanced sedimentation	Sediment	Hydrodynamic Devices
	Filtration	Sediment	Filtration/Infiltration BMPs, Most LID systems
BIOLOGICAL	Microbial	Nitrogen	Many LID systems that have sufficient organic materials and microbes.
	Vegetative	Nitrogen/ Phosphorus	Most LID Systems, systems with vegetation
CHEMICAL	Sorption	Phosphorus	Some Media Filters with sufficient amount of organics

FIGURE 2-4
Wastewater Treatment Plant

and retention is usually accomplished by placing hydraulic control structures to slow runoff velocities and delay peak flows. Infiltration operations involve the use of storage in combination with native soils capable of recharging runoff into the ground, thus reducing the overall volume of runoff.

Physical Operations

Physical operations are defined as methods of treatment in which the removal of contaminants is brought about by physical means. The two major physical operations employed by stormwater BMPs are sedimentation and filtration. Sedimentation is an operation by which particles fall out of suspension and to the bottom of a water column due to a difference in density between water and solids. Many BMPs use sedimentation as a fundamental treatment mechanism.

Filtration is an operation dictated by the physical straining of particles through a porous media. Treatment effectiveness is largely determined by the void space of the filter media; hence the logic that fine sand provides better filtration than coarse sand, and coarse sand is more efficient at removal of particulates than coarse gravel. Unlike settling operations, the amount of time stormwater is stored in a device (often referred to as residence time) generally does not dictate removal efficiencies for pollutants such as sediments, hydrocarbons and metals. Residence time has a positive impact on the removal of nutrients that are generally treated by other functional characteristics. Residence time can also have a major impact on other UOPs such as biological processes where the longer the residence time, the more opportunity plants and microorganisms have to process nutrients in the runoff.

FIGURE 2-5
Top: Biological Processing;
Bottom: Chemical Processing

Biological Processes

Biological processes are defined as methods of treatment in which the removal of contaminants is brought about by biological reactions. The two major biological processes employed by stormwater BMPs are vegetative uptake and microbially-mediated transformations. Vegetative uptake refers to the removal of pollutants by plants through bioaccumulation. Through bioaccumulation, substances are incorporated into the living tissue of the plant and become part of the overall biomass of the vegetation. It is important to note that vegetative uptake is a temporary storage mechanism. Plants undergo a period of aging, vegetative loss and decomposition of a portion of their biomass. This can be clearly seen in cold climates where above ground biomass dies off and decomposes every winter. Through decomposition, the constituents retained in the vegetative matter can make their way back into the environment, unless the vegetation is routinely removed from the system.

Microbially-mediated transformations involve the respiration process of microorganisms. These processes include degradation of organic pollutants as well as the oxidation or reduction of inorganic materials such as nitrate, iron, manganese, and sulfate. This process occurs in wetlands where the nitrate reduction produces nitrogen gas. The use of anaerobic denitrification is very important for the removal of nitrogen from stormwater.

Chemical Processes

Chemical processes are defined as methods of treatment in which the removal of contaminants is brought about by chemical reactions. The major chemical process employed by stormwater BMPs is sorption, coagulation/flocculation and disinfection. Sorption can be both a physical and a chemical process and encompasses the processes of absorption and adsorption simultaneously, where the materials to be removed adhere to the surface of a specific molecule. The reverse process is desorption. Both sorption and desorption are highly affected by chemical characteristics such as pH and the ionic strength of the runoff. Generally, absorption refers to the uptake or removal of constituents without altering the chemical nature of the absorbing substance. The best example would be a sponge absorbing water, where the water is retained or absorbed by the sponge without chemically altering the makeup of the sponge. Adsorption refers to the chemical binding of a dissolved constituent to the surface of a solid. The binding to the surface is usually weak and reversible and is best illustrated by the types of removals seen in charcoal based home water filters.

COMPARING PERFORMANCE OF TREATMENT PROCESSES

Over the past decade much has been learned regarding the water quality treatment capacity of structural stormwater management systems. Systems can be designed to treat for peak flow, volume reduction, and water quality control. Though each system design can be unique, pollutant removal capabilities are highly correlated to the unit operations and treatment processes the systems incorporate. Rigorous scientific research, evaluating the range of stormwater management treatment strategies, has produced an overwhelming amount of evidence that pipe and pond stormwater treatment strategies do not meet general water quality objectives. Research clearly indicates that structures designed without explicit consideration for stormwater quality improvements are generally ineffective. This research also indicates that many water quality issues are regional, highly complex, and require studied approaches and case by case solutions.

The majority of stormwater management systems control sediment to some degree. That said, LID devices (indicated in green in Figure 2-6) are much more effective at controlling sediments and

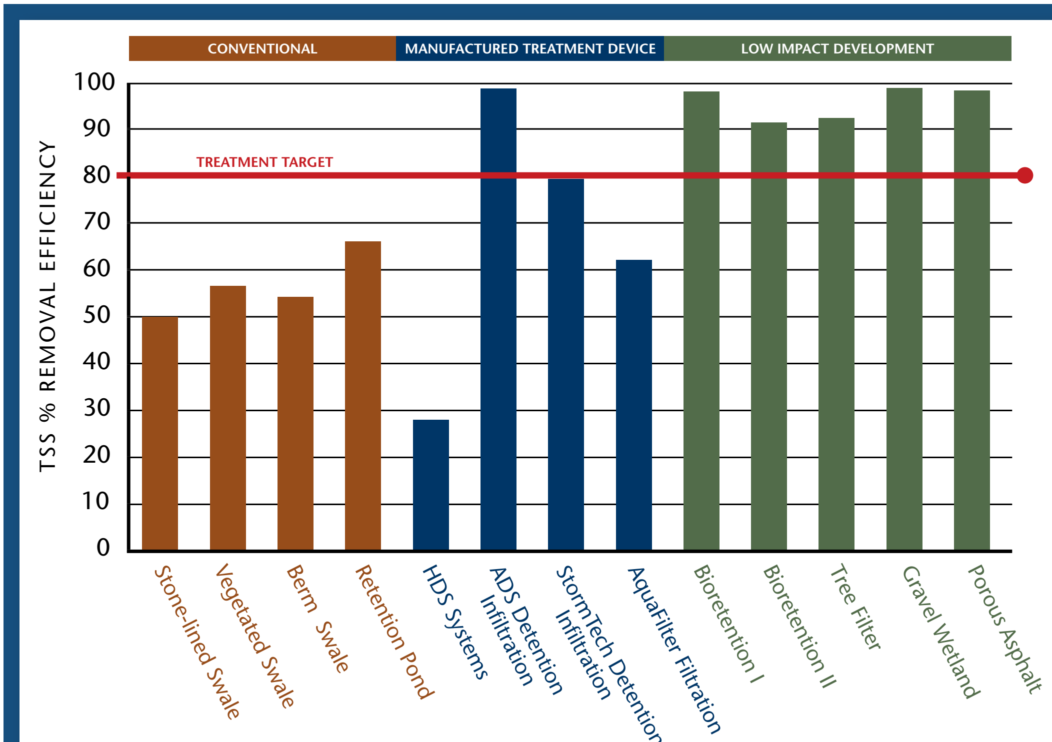


FIGURE 2-6 Total Suspended Solids (TSS) removal efficiencies for a range of stormwater BMPs; red line indicates commonly required performance treatment

(Adapted from UNHSC 2010).

the range of other associated contaminants from non-point source pollution. LID strategies should be required to the maximum extent reasonable.

Nitrogen removal is very complex. Fundamentally, there are two primary mechanisms for nitrogen removal or sequestration. One mechanism includes vegetative uptake which temporarily stores nitrogen within the biomass of the vegetation. The other treatment mechanism involves permanent transformation through microbially-mediated processes into nitrogen gas. As Figure 2-7 indicates, nitrogen removal does not occur with great frequency in most studied systems, and should be directly designed for where treatment is applicable.

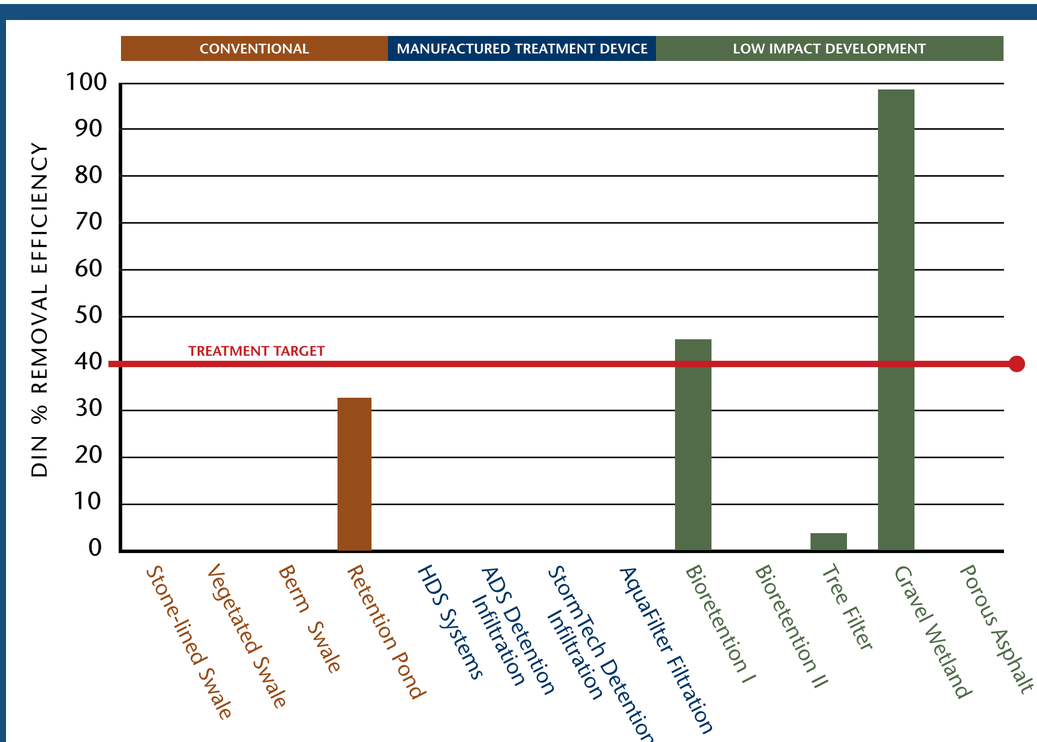
Total phosphorus removal is associated with organic content in a filtration media. In many cases, since up to 75 percent of the TP is sediment-associated, one should expect that any system that adequately removes TSS should also have a correspondingly adequate TP removal. It seems evident that TP removal is primarily a chemical sorption phenomenon that relies upon appropriate soil chemistry, cation exchange capacity (CEC), and seasonal variations such as dissolved oxygen levels.

MAINTENANCE

Historically, the responsibility for maintenance of stormwater infrastructure has fallen on the owner of the system or the discharge pipe. This is in contrast to maintenance for other water resource management systems, namely drinking water supply systems and wastewater treatment systems, where consumers are charged per unit

FIGURE 2-7
Nitrogen removal efficiencies for a range of stormwater BMPs; red line indicates commonly required performance treatment

(Adapted from UNHSC 2010)



supplied or treated, which includes necessary maintenance and operations costs. While assigning maintenance responsibility to stormwater treatment systems is different than water supply or sewer systems, there are many physical and operational similarities. The advancement of federal, state and local regulations is bringing these similarities to the forefront for water resource managers to consider.

The approaches to maintenance of stormwater management systems are diverse and range from proactive to reactive maintenance, to no maintenance at all. Historically, many stormwater management systems may have required maintenance plans that rarely were followed. This trend, while inexpensive, poses a significant threat to water quality, community resilience, and public safety.

Local governments should consider it a priority to develop and pass maintenance requirements to help ensure the long term operation and performance of permitted stormwater management Best Management Practices (BMPs). Any new regulation should include the following maintenance-specific components:

The approaches to maintenance of stormwater management systems are diverse and range from proactive to reactive maintenance, to no maintenance at all.

1. Inspection Frequency

All stormwater management systems require maintenance to perform properly. Most systems should be inspected annually at the very least. For most cases this maintenance is unenforced and little information exists with respect to post construction BMP operation

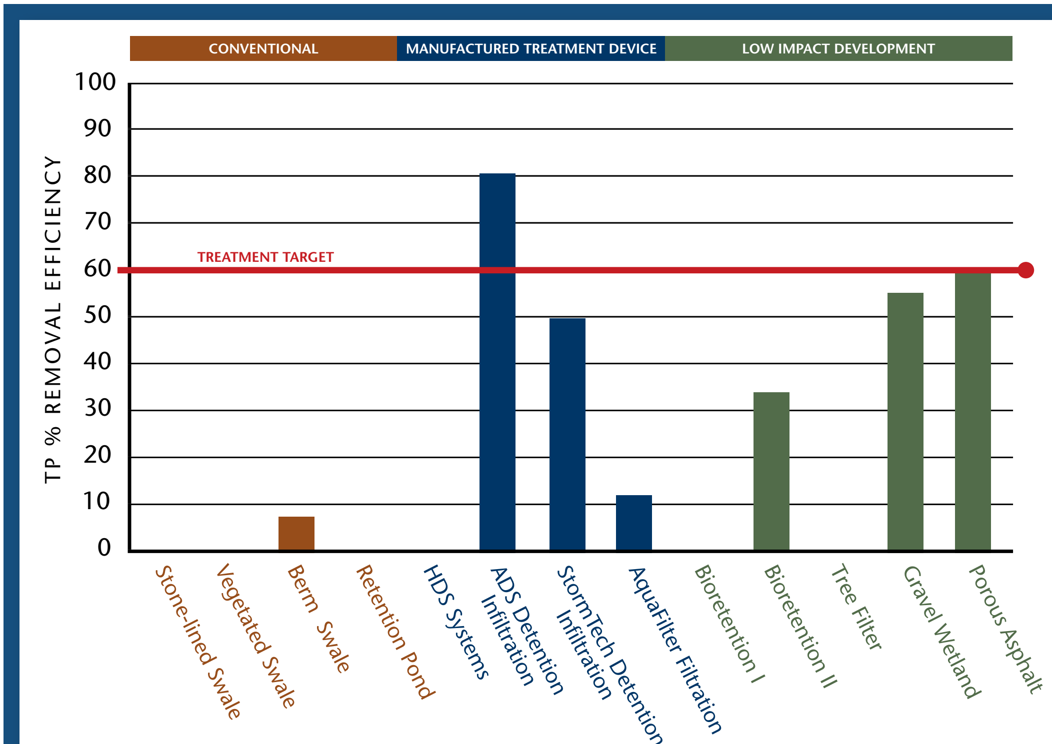


FIGURE 2-8
Phosphorus removal efficiencies for a range of stormwater BMPs; red line indicates commonly required performance treatment

(Adapted from UNHSC 2010).

and maintenance. Maintenance and inspection frequency would typically vary across similar watershed conditions largely depending on size, relative system effectiveness, accessibility and maintenance plan objectives (reactive vs. proactive approaches). Some generalities include: surface systems are easier to inspect than subsurface systems; larger systems with higher storage capacities require less frequent inspection than smaller systems with lower capacities; and more effective systems require more frequent inspections than lower efficiency or less effective systems.

The conventional wisdom that an ounce of prevention is worth a pound of cure applies directly to the selection and long-term maintenance of stormwater management BMPs.

2. Maintenance Complexity

Maintenance complexity is a combination of a municipality's familiarity with certain maintenance procedures and the availability of updated tools and equipment to ensure performance. For many, the maintenance procedures for stormwater BMPs are an evolving process. There has often been minimal guidance provided to ensure performance; however, over time new guidelines have been developed and may continue to do so as new information is collected. Maintenance guidelines for porous pavement systems or gravel wetlands are currently under development and recommendations may call for specialty equipment such as vacuum sweepers. Maintenance complexity also involves the specific type of maintenance activity that may be obscured by historical standards of practice. For instance, most vegetated-media filtration systems require maintenance activities more in line with routine landscaping approaches. These may be less familiar to many Department of Public Works (DPW) personnel but may be affordably subcontracted. Other maintenance practices such as catch basin cleaning or pond dredging

FIGURE 2-9
Example of a vegetated media system requiring specialized maintenance

PRACTICE	USEPA (1999)	WEISS et al. (2005)
Sand Filters	11% – 13%	0.9% – 9.5%
Infiltration Trenches	5% – 20%	5.1% – 126%
Infiltration Basins	1% – 10%	2.8% – 4.9%
Wet Ponds	Not reported	1.9% – 10.2%
Dry Ponds	<1%	1.8% – 2.7%
Rain Gardens	5% – 7%	0.7% – 10.9%
Constructed Wetlands	2%	4% – 14.2%
Swales	5% – 7%	4% – 178%
Filter Strips	$320/acre (maintained)	—

TABLE 2-2
Expected and reported annual maintenance cost as a percentage of total BMP construction cost.

Disparity in costs are due to a lack of available data.

(Adapted from Erikson, et al. 2009)

may be readily achievable but use of such systems has proven less efficient at achieving permit and water quality requirements.

3. Maintenance Cost

Cost estimates of annual maintenance activities vary. Published literature exists for dry ponds, wet ponds, constructed wetlands, rain gardens and vegetated swales as a percentage of total system construction cost (Erickson, et al., 2009). What is not evaluated is the cost of compliance with current stormwater regulations, environmental services (related to pollutant removal and watershed health) and total system lifecycle costs. The conventional wisdom that an ounce of prevention is worth a pound of cure applies directly to the selection and long-term maintenance of stormwater management BMPs. This becomes increasingly apparent as municipalities continue to wrestle with complex regulations over impaired receiving waters. It is much more efficient to keep our watersheds clean than restoring them after they cease to meet designated uses.

LAND USE REGULATIONS AND ORDINANCES

Planning for better stormwater management is challenging because water resources are not confined to municipal boundaries and watershed plans are not always integrated into master plans. In addition, the visions supported by master plans are not always implemented through regulations or zoning. Sound planning should help communities (and their neighbors within the watershed) set the groundwork for sound policies and ultimately better stormwater management. While most communities have a master plan or comprehensive plans outlining a vision for the community, many land use decisions are made on a parcel-by-parcel basis. These parcel-by-parcel decisions can have cumulative impacts on water resources, stormwater infrastructure, and municipal budgets.

A growing trend is emerging where municipalities are updating local regulations and developing guidelines to reflect the higher treatment standards of today. This is being accomplished

TABLE 2-3 Water resource management strategies in a developing landscape. Adapted from UNHSC (2007).

VOLUNTARY STRATEGIES → REGULATORY STRATEGIES

LAND CONSERVATION	BUFFERS	LOW IMPACT DEVELOPMENT	STORMWATER UTILITIES	LAND USE REGULATIONS
Many communities are using voluntary land conservation strategies, such as easements, to permanently protect parcels of natural land. However, since it is highly unlikely that most communities can secure sufficient funding to acquire conservation easements or ownership for all lands identified as critical for protection, it's safe to assume that the remaining unprotected areas will face development pressure in the near future. As a result, it's important for communities to also adopt land use regulations that provide guidance and tools to limit the impacts of development that does occur.	A buffer is a naturally vegetated area along a shoreline, wetland, or stream where development is restricted or prohibited. Its primary function is to physically protect the water body from future disturbance or encroachment. Benefits of buffers are plentiful and include protection of municipal infrastructure and private property from floods and erosion; recharge of aquifers and groundwater resources; prevention of erosion; and water quality protection for surface waters including takes, streams, and wetlands.	Low impact development (LID) is an innovative approach that uses natural, or predevelopment hydrology, as a guide for design. In the area of stormwater management, LID uses a combination of processes – infiltration, filtration, and detention/storage – to manage rainfall at the source (ideally) and to mimic predevelopment hydrology. LID stormwater strategies are applicable in nearly all locations. However, infiltration into groundwater is only appropriate in certain situations. LID is most effective when used in conjunction with land conservation efforts	Stormwater utilities are a way for communities to collect user fees to fund a range of stormwater management activities such as catchbasin cleaning, street sweeping, and stormwater infrastructure upgrades required by the Clean Water Act. User fees are generally proportional to the amount of runoff generated by a parcel. There are many different types of stormwater utilities, ranging from taxes to user fees. A common stormwater utility strategy used in the Northeast incorporates a dedicated enterprise fund, similar to those used to manage water and sewer utilities. An enterprise fund is based on a flat fee per unit of impervious area.	Land use regulations are the second essential component in a two-pronged approach to protecting water resources in a developing landscape. When paired with land conservation practices, the regulation of the location, density, and design of development can help reduce the negative impacts on water resources. For example, land use ordinances may include environmental characteristics zoning, cluster/ conservation development, and performance standards.

through the following processes (in descending order of effectiveness):

1. Protection of Critical Resource Areas

The most permanent and assured protection of sensitive resource areas is achieved through the use of conservation easements and conservation land acquisitions. Sensitive areas can also be effectively protected or buffered from development impacts by establishing overlay districts that prohibit or restrict development in drinking water or wellhead source areas, wetlands, shoreland buffers, wildlife corridors, cold water streams, and other critical natural resource areas.

2. Advanced Stormwater Management

Updated stormwater ordinances typically reflect a BMP toolbox which now includes many systems capable of advanced stormwater management. These systems typically incorporate some form of filtration and/or infiltration. Unfortunately, many toolboxes include ineffective practices as part of the accepted list. Rather, the trend is to add BMPs and leave the selection to the designer. Cost is a primary reason simple conventional practices are still widely used despite the availability of more effective practices. Until these ineffective practices are removed from consideration, their widespread usage will remain.

3. Stormwater Utilities

When reviewing development proposals, long-term and cumulative costs for municipal stormwater infrastructure should be considered. Communities pay for maintaining, replacing, and upgrading aging infrastructure. Many municipalities, while already burdened with aging and inadequate infrastructure, are facing new federal requirements for managing stormwater to higher levels and are unsure as to how to finance these necessary upgrades. Some communities are addressing costs by implementing stormwater utility fees. The stormwater utility fee is similar to those paid for electricity or drinking water that is based on usage and supports stormwater infrastructure and management. The funds are dedicated exclusively to stormwater needs. Fees are typically based on lot characteristics such as impervious area, and reductions in the fee are often offered for practices that reduce discharges and treat for water quality. These fee reductions can serve as an incentive to encourage more innovative and effective stormwater management practices. Stormwater utility fees are commonly based on an equivalent residential unit (ERU) that represents the average impervious area of a single family lot, usually several thousand square feet. Land uses with higher impervious areas, such as commercial developments, would pay an ERU multiple as higher levels of impervious area require more maintenance and management. In areas of the US, fees in the range of $2-$6 per ERU per month have been documented for residential properties and range from $25-$75 per month per acre of impervious area for commercial properties. Stormwater utilities are an essential element to successful municipal compliance with federal stormwater regulations.

4. Adoption of Innovative Land Use Ordinances

Land use ordinances can be used to help protect water resources by incorporating environmental characteristics in zoning, or requirements, or by providing incentives for conservation developments, as well as establishing environmental protection performance standards that development proposals must meet.

Watershed-based zoning is a land use management technique that identifies specific permitted uses within a defined watershed boundary as opposed to political boundaries. Typically, watershed-based zoning is conducted as part of a larger land use or watershed planning effort that protects specific resources by setting limits on the level of impervious surfaces and density within a zone. To achieve the success of watershed-based zoning necessary to reach water quality protection, land planning zoning standards are often required. Successful watershed-based zoning may typically require an initial assessment of existing conditions, that may include a natural resources inventory; an analysis of existing impervious surfaces and future conditions/ build out; and the development of Master Plan language consistent with the zone recommendations, with specific prescriptive actions to mitigate the impacts of land use changes in the zone and long term monitoring (CWP, 2008).

Overlay zones, such as the County of York, VA Overlay District (Appendix C) are a zoning district that is placed on top of the base zoning district to impose additional restrictions beyond the underlying zoning standards. In an LID context, the goal is to protect natural resources while retaining the underlying zone. The result is a cumulative effect of zoning standards due to the layering of requirements which may include impervious surface limits, density limits, or additional stormwater management requirements. Overlay zones may include: resource conservation districts, aquifer protection districts, watershed protection districts, shoreland or riparian protection areas, agricultural districts, and historic resources districts.

An Urban Growth Boundary, such as the City of Portland, Oregon Urban Boundary (Appendix D) is a locally adopted, mapped line that separates an urban development area from its adjacent greenspace. The urban growth boundary is intended to direct growth to population service centers while retaining rural character and agrarian-based industry. Typically, urban growth boundaries have a defined life span with specific language identifying their duration of use. This tool is often used to encourage a more compact development pattern in order to achieve a reduction in infrastructure, roadways, and unnecessary additional service areas. The adjacent greenspace areas may include forest protection boundaries, agricultural or natural areas and is intended to maintain the diversity of uses and habitat within an urban area. In an LID context, the concept of directing growth to areas already growing provides for concentrated impervious areas and a reduction in infrastructure needs while maintaining a reduced impervious cover in other areas of a watershed.

Open Space Development, such as the examples shown in Figure 2-10, also called clustered development or conservation subdivision design, is an alternative site planning technique that concentrates dwelling units in a compact area to reserve undeveloped space elsewhere on the site while still allowing the maximum number of lots for the zone. In this technique, lot sizes, setbacks, and frontage distances are reduced in order to minimize the impervious surfaces on the individual lot and meet some Smart Growth design goals by making communities that are more connected. Typical open space development creates less impervious cover and reduces the need to clear and grade sites. Open space areas are often used for neighborhood recreation, stormwater management facilities, or conservation purposes. Open space, preserved in a natural condition, needs

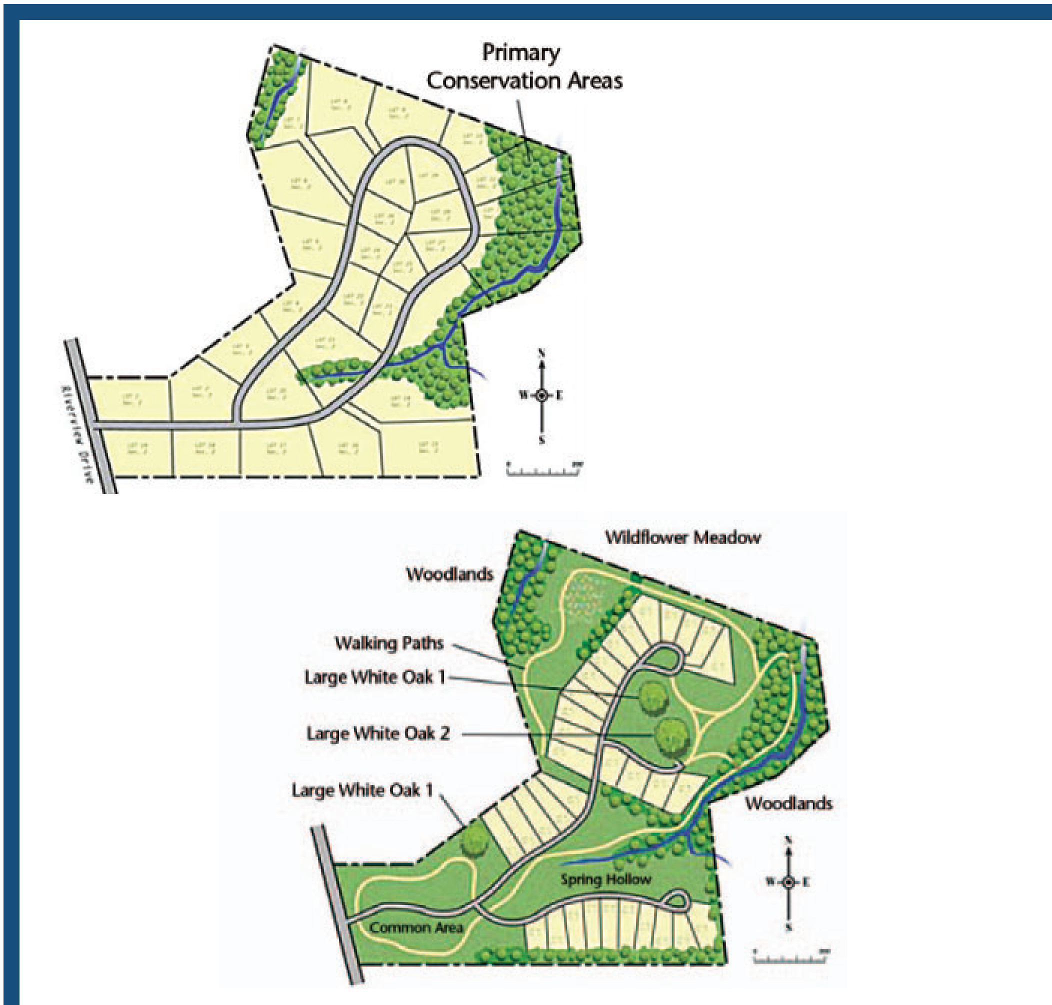


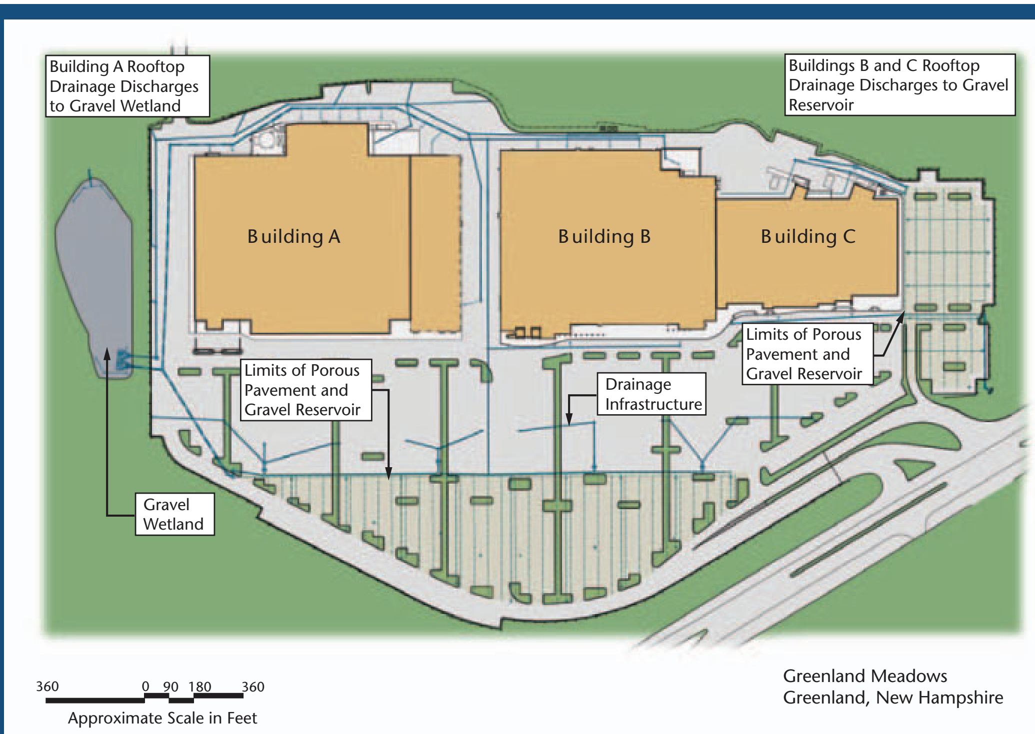
FIGURE 2-10 Examples of Conservation Subdivision Designs

little maintenance and helps to reduce and sometimes to treat stormwater runoff from development while providing urban wildlife habitat.

Another landuse approach to lowering the amount of stormwater runoff is to reduce the amount of impervious surface associated with roadways and parking lots. One of the keys to successfully minimizing these impervious surfaces is finding a compromise between fire and rescue needs, parking limits, appropriate vehicle volume, as well as access. Often, residential roadway widths are established from outdated local codes based upon higher than necessary volume criteria, overestimates of on-street parking demands, and extra width to ensure fire and rescue vehicle needs. Evaluating actual needs and projected uses for the roadway can significantly reduce the width for some smaller neighborhoods. For most low traffic roads, widths less than 24 feet may be sufficient to accommodate two-way traffic (Table 2-4). To further reduce roadway width and impervious surfaces, queuing streets or placing parking on only one side or the road may be utilized. This configuration has one lane of travel and two lanes for either parking or queuing. Cul-de-sacs

FIGURE 2-11
Example of a commercial development designed to reduce amount of impervious surface: Greenland Meadows

(UNHSC)



are common in newer subdivisions and are often sources of excessive impervious surfaces. Cul-de-sacs may often be designed up to 80 feet in diameter and can generate large amounts of runoff. A simple approach to reducing the impervious cover is to install a landscaped island in the middle of the circle while still accommodating turning space for large vehicles. These islands may be further designed as bioretention areas to treat runoff from the adjacent properties and roadway. Additional alternatives include reducing the radii of the cul-de-sac or creating a loop road in place of a circle.

Many communities build overly large parking areas to accommodate requirements for seasonal use. These large impervious surfaces are significant contributors to stormwater runoff. Minimizing the effects of parking areas can be accomplished through a few strategies that include providing for the actual need of parking based upon local or regional studies, or by providing for compact car spaces. Parking requirements may be reduced based upon access to mass transit relative to the project site, or through the integration of transit stops. Additional installation of bioretention areas, porous pavement, vegetated swales, or other LID approaches can treat stormwater on site and minimize the need for large catch basins or costly underground pipe storage.

There are many tools for understanding how local policies, codes and ordinances may encourage additional impervious surfaces and/or discourage the use of LID. Two complimentary tools are the Center for Watershed Protection's Code and Ordinance Worksheet and Better Site Design Guidebook and the USEPA Water Quality Scorecard. These tools provide an easy scoring system for understanding

WIDTH (FEET)	SOURCE
20	National Fire Protection Administration
18 (minimum)	Massachusetts State Fire Marshall
22	American Association of State Highway and Transportation Officials
24 (on-street parking) 16 (no on-street parking)	Baltimore County, Maryland
20	Prince George's County, Maryland
18 (one lane of parking) 26 (parking both sides)	Portland, Oregon

TABLE 2-4
Recommended Minimum Street Widths

(CWP, 1998)

policy actions that the communities may need to improve to better implement innovative practices in the development process. These tools compare the community's standards, ordinances, and codes to a set of model standards that encourage innovative approaches. The Code and Ordinance Worksheet can be found in Appendix A. The tool outlines twelve areas that will be evaluated through the Code and Ordinance Worksheet process, as identified below:

1. Zoning Ordinances
2. Subdivision Ordinances
3. Street Standards or Road Design Manual
4. Parking Requirements
5. Building and Fire Regulations/ Standards
6. Stormwater Management or Drainage Criteria
7. Buffer or Floodplain Regulations
8. Environmental Regulations
9. Tree Protection or Landscaping Ordinances
10. Erosion and Sediment Control Ordinances
11. Public Fire Defense Master Plans
12. Grading Ordinances

The USEPA Water Quality Scorecard has two main goals: to help communities protect water quality by identifying ways to reduce the amount of stormwater flows in a community. and educate stakeholders on the wide range of polices and regulations that have water quality implications. A sample of the Scorecard can be found in Appendix B and the entire document can be found at: http://www.epa.gov/smartgrowth/water_scorecard.htm.

UPDATING SITE PLAN AND SUBDIVISION REVIEW REGULATIONS

More effective stormwater management strategies and performance requirements need to be outlined in town regulations and considered by developers and municipal staff early in the development planning process. Promoting the latest state and federal standards such as water quality treatment and infiltration is the best way to prevent problems before they happen. If not already detailed in a land use ordinance, these regulations should specify the standards developers need to meet. Developers should submit designs that meet performance standards, have requirements for inspections, and incorporate financial sureties that stormwater, erosion, and sediment control measures will be built and maintained as proposed.

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FACT SHEET

Economics and LID Practices

The economic advantages of Low Impact Development are often not well understood and are deserving of close attention to inform municipal land use decisions.

Economic benefits are being realized through the incorporation of LID-based strategies by municipalities, commercial developers, and others. There are increasing numbers of case studies that demonstrate the substantive economic benefits for commercial development and municipal infrastructure projects—for both construction budgets and project life-cycle costs. These economic benefits are increasingly being observed when using a combination of Gray and Green Infrastructure for stormwater management.

WISE LAND-USE PLANNING DECISIONS

have the potential to ease some of the financial demands driven by regulatory compliance. While individually, green infrastructure elements may add expense to a project, costs savings are often realized on an overall project basis as the need for conventional stormwater infrastructure—such as curbing, catch-basins, piping, ponds, and other controls—is reduced.

ECONOMIC BENEFITS ASSOCIATED WITH THE USE OF LID:

- Whole project cost savings for new development by reduction of drainage infrastructure
- Land development savings from a reduced amount of disturbance
- Higher property values of 12 to 16 percent
- Reduction in home cooling by 33 to 50 percent from the use of natural vegetation and reduced pavement area.

Utilizing an LID approach that featured porous asphalt and a gravel wetland, a cost-competitive drainage system was designed for a large retail development in Greenland, NH.

Three LID Case Studies that identify the scales at which there are clear economic incentives:

RESIDENTIAL SITE: Boulder Hills

This LID condominium community features a porous asphalt road and incorporated porous pavements and rooftop infiltration systems. The benefits included: improved local permitting, positive exposure for the developers, an 11 percent reduction in the amount of disturbed land and a stormwater management cost savings of 6 percent compared to a conventional design. Although porous asphalt was more costly, cost savings are realized through the reduction in drainage piping, erosion control measures, catch basins, and the elimination of curbing, outlet control structures, and stormwater detention ponds.

COMMERCIAL SITE: Greenland Meadows

This retail shopping center features the largest porous asphalt installation in the Northeast. The 56-acre development includes porous asphalt, landscaping areas, a large gravel wetland and other advanced stormwater management. Costly conventional strategies were avoided, and there was a cost savings of 26 percent for stormwater management.

COMBINED SEWER OVERFLOW

On a larger scale, communities are faced with the challenges of managing their combined sewer overflows to reduce the discharge of untreated sewage into waterways. These large often outdated systems carry price tags in the billions of dollars to store, separate and treat. By combining a gray and green approach the costs and volumes of stormwater are significantly reduced. For example, the city of Portland, Oregon was able to save an estimated $63M as compared to an estimated $144M, by considering a green approach, and the city of Chicago, Illinois, was able to divert over 70M gallons of stormwater from their CSO, in one year.

FORGING THE LINK: Linking the Economic Benefits of Low Impact Development and Community Decisions • www.unh.edu/unhsc/forgingthelink
Chapter 3: Economics and LID Practices

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CHAPTER 3

Economics and LID Practices

Low Impact Development (LID) represents one of the most progressive trends in the area of stormwater management and water quality. This approach involves utilizing strategies to control precipitation as close to its source as possible in order to reduce runoff volumes, promote infiltration, and protect water quality. While better known for its capacity to reduce pollution and manage stormwater more sustainably, LID designs are also economically beneficial and more cost-effective as compared to conventional stormwater controls.

In the vast majority of cases, the U.S. Environmental Protection Agency (EPA) has found that implementing well-chosen LID practices saves money for developers, property owners, and communities while also protecting and restoring water quality (USEPA, 2007). Specifically, utilizing LID designs can result in project cost savings by decreasing the amount of expensive below ground drainage infrastructure required, as well as reducing or eliminating the need for other stormwater management-related facilities including curbs, erosion control measures, catch basins, and outlet control structures.

> In the vast majority of cases, the EPA has found that implementing well-chosen LID practices saves money for developers, property owners, and communities while also protecting and restoring water quality.

LID designs also have space-saving advantages and can reduce the amount of land disturbance required during construction, saving money on site preparation expenses. In northern Frederick County, Maryland, a number of cost saving benefits were realized by redesigning a conventional subdivision with LID designs. This included eliminating two stormwater ponds representing a reduction in infrastructure costs of roughly $200,000; increasing the number of buildable lots from 68 to 70, which added roughly $90,000 in value; and allowing the site design to preserve approximately 50 percent of the site in undisturbed wooded condition, which reduced clearing and grubbing costs by $160,000 (Clar, 2003). Also, an infill site in northern Virginia was able to save over 50 percent in cost for infrastructure by minimizing impervious surfaces, protecting sensitive areas, reducing setback requirements, and treating stormwater at the source (CWP et al., 2001).

Lots in the conservation subdivisions cost an average of $7,000 less to produce, resulted in a 50 percent decrease in selling time, and had a value of 12 to 16 percent more as compared to lots in conventional subdivisions.

Additional economic benefits of LID include reduced flooding costs as well as lower home cooling expenses. For example, natural vegetation and reduced pavement area in the Village Homes LID development in Davis, CA helped lower home energy bills by 33 to 50 percent as compared to surrounding neighborhoods (MacMullan, 2007). Further economic incentives to developers for LID inclusion include the potential for higher property values as well as a reduction in permitting fees; in Dane County, WI, permit fees for development are calculated based on the amount of impervious area in a site, providing an incentive for developers to use LID. In another example, an analysis of 184 lots in one community found that conservation subdivisions were more profitable than conventional subdivisions. Lots in the conservation subdivisions cost an average of $7,000 less to produce, resulted in a 50 percent decrease in selling time, and had a value of 12 to 16 percent more as compared to lots in conventional subdivisions (Mohamed, 2006).

Additionally, incentives encouraging the implementation of LID may include the means to support new construction. This may include a range of incentives such as an increase in floor to area ratio (FAR), rebates, and tax credits. The City of Portland, OR has a Green Roof bonus that provides an additional three square feet of floor area for every one square foot of green roof, provided the roof is covered by at least 60 percent. Some cities offer builders a cost-share and/or rebates when they install green infrastructure such as in the case of King County, WA that pays 50 percent of the costs, up to $20,000. Similarly Austin, Chicago and Santa Monica provide discounts for homes that employ LID. Reducing taxes is another strategy employed to encourage implementation. In New York City a project can earn a one year tax credit up to $100,000 for inclusion of a green roof on 50 percent of the structure, and in Maryland green building credits are being used to offset property taxes and can be carried forward for ten years (MacMullan, 2010).

Traditionally, land planning and development projects are often based upon on fundamental economic decisions: costs versus benefits. The costs are the real and documented costs of mobilizing, constructing, landscaping, compliance, and marketing. The benefits are the real project income. However, there are other costs that exist and these burdens are either born by the landowner, known as lost opportunity costs or the public as natural and social capital. Lost opportunity costs are associated with other options for the land rather than what was built. For example, a land development project may have generated benefits greater than economic costs, whereas alternative options might have generated more net benefits. Since opportunity costs are primarily borne by the landowner, it is certainly within the landowner's right to develop the parcel to their desire, as long as it complies with State and local codes and regulations. However, the expenditure of natural and social capital is usually borne by the public: in essence the land developer passes off costs to the public. Natural capital represents the ecological value of the goods and services provided by the environment. In the case of stormwater, if streams are degraded because of poor stormwater management, that is an expenditure of natural capital. If the degraded stream is in need of restoration, often this is done by the expenditure of public funds. Just as water quality and water quantity affect the health of an ecosystem, the built environment affects and reflects the community. Healthy environments, foster stronger community connections: whether through community groups, recreational activities, or social gatherings. Societies that have demonstrated stronger community connections (social capital) reduce community costs, such as crime, emergency response, transportation, etc (Knack and Keefer, 1997). Better stormwater management at the site level ultimately minimizes the expenditures of natural and social capital which translates to less long term adverse impacts to community budgets.

While these additional benefits are recognized, the focus of this section is to clearly articulate, through case studies and detailed examples, the hard cost benefits of implementing LID.

CASE STUDIES

ECONOMIC BENEFITS OF LID PRACTICES

The following case studies show how utilizing an LID approach to site drainage engineering, specifically with porous asphalt installation, led to more cost-effective site and stormwater management designs.

BOULDER HILLS

In addition to more effective stormwater management, an economic benefit was gained by utilizing an LID approach that featured porous asphalt for a residential development.

FIGURE 3-1
Boulder Hills

Boulder Hills is a 24-unit active adult condominium community in Pelham, New Hampshire that features the state's first porous asphalt road. The development was built by Stickville LLC on 14 acres of previously undeveloped land and includes a total of 5 buildings, a community well, and a private septic system. In addition to the roadway, all driveways and sidewalks in the development are also composed of porous asphalt. Located along the sides and

FIGURE 3-2
Comparison of Two Designs, LID Design (top) and Conventional (bottom) for Boulder Hills, Pelham, NH

(SFC, 2009)

the backs of the buildings are fire lanes consisting of crushed stone that also serve as infiltration systems for rooftop runoff.

SFC Engineering Partnership Inc. designed the project site and development plan including all drainage. The University of New Hampshire (UNH) Stormwater Center advised the project team and worked with Pelham town officials, providing guidance and oversight with the installation and the monitoring of the porous asphalt placements.

Prior to development, the project site was an undeveloped woodland area sitting atop a large sand deposit. Soils on the parcel were characterized with a moderate infiltration rate and consisted of deep, moderately well to well drained soils. Wetland areas were located in the south and east sections of the parcel, with a portion of the site existing in a 100-year flood zone.

The benefits of implementing an LID design as compared to a conventional development and stormwater management plan included cost savings and positive exposure for the developers, improved water quality and runoff volume reduction, as well as less overall site disturbance and the ability to stay out of wetland and flood zone areas. Over time, the porous asphalt placements are also anticipated to require less salt application for winter de-icing, resulting in additional economic and environmental benefits. By the end of the first winter 2009-2010, the project owners reported using substantially less salt for winter ice management.

The benefits of implementing an LID design as compared to a conventional development and stormwater management plan included cost savings and positive exposure for the developers, improved water quality and runoff volume reduction, as well as less overall site disturbance and the ability to stay out of wetland and flood zone areas.

DESIGN PROCESS

Initially, SFC Engineering Partnership began designing a conventional development and stormwater management plan for the project. However, according to David Jordan, P.E., L.L.S., manager of SFC's Civil Engineering Department, difficulty was encountered because of the site's layout and existing conditions. "The parcel was burdened by lowland areas while the upland areas were fragmented and limited," Jordan said. "Given these conditions, it was challenging to make a conventional drainage design work that would meet town regulations. We found ourselves squeezing stormwater mitigation measures into the site design in order to meet criteria. The parcel also did not have a large enough area that could serve as the site's single collection and treatment basin. Instead, we were forced to design two separate stormwater detention basins, which was more expensive. This approach was also cost prohibitive because of the necessity of installing lengthy underground drainage lines."

When LID and specifically, porous asphalt, emerged as a possible stormwater management option for the site, the developer, Stickville LLC, was receptive.

Stickville was aware of the advantages of LID and porous pavement and was interested in utilizing these measures as a possible marketing tool which could help differentiate them as green-oriented developers. SFC advised Stickville LLC to pursue this option. Jordan had attended a seminar on porous pavement presented by The UNH Stormwater Center which covered the multiple benefits of utilizing this material, including its effectiveness for being able to meet stormwater quantity and quality requirements.

"Per regulations, the amount of stormwater runoff from the site after development could not be any greater than what it was as an undeveloped parcel," Jordan said. "In addition to controlling runoff, stormwater mitigation measures also had to be adequate in terms of treatment. Porous pavement allows us to do both. For a difficult site such as Boulder Hills, that represents a huge advantage."

According to Jordan, the Town of Pelham responded very favorably to the idea of incorporating LID with the project. "The planning board was on board from the very beginning," he said. "They were very supportive of utilizing porous asphalt and recognized the many benefits of this option."

ECONOMIC COMPARISONS

SFC Engineering Partnership designed two development options for the project. One option was a conventional development and drainage plan that included the construction of a traditional asphalt roadway and driveways. The other option, an LID approach, involved replacing the traditional asphalt in the roadway and driveways with porous asphalt and using subsurface infiltration for rooftop runoff, essentially eliminating a traditional pipe and pond approach.

Although porous asphalt was more costly as compared to traditional asphalt, the engineers found that by utilizing this material, cost savings in other areas could be realized. For one, installing porous asphalt significantly lowered the amount of drainage piping and infrastructure required. Using porous asphalt also reduced the quantity of temporary and permanent erosion control measures needed while cutting in half the amount of rip-rap, and lowering the number of catch basins from 11 to 3. Additionally, the LID option completely eliminated the need to install curbing, outlet control structures, as well as two large stormwater detention ponds. Another benefit was a 1.3 acre reduction in the amount of land that would need to be disturbed, resulting in less site preparation costs.

> Although porous asphalt was more costly as compared to traditional asphalt, the engineers found that by utilizing this material, cost savings in other areas could be realized.

Table 3-1 shows the construction estimate cost comparisons between the conventional and the low impact development options. As shown, the LID option resulted in higher costs for roadway and driveway construction. However, considerable savings were realized for site preparation, temporary and permanent erosion control, curbing, and most

TABLE 3-1
Comparison of Unit Costs for Materials for Boulder Hills LID Subdivision

(SFC, 2009)

ITEM	CONVENTIONAL	LID	DIFFERENCE
Site Preparation	$23,200.00	$18,000.00	–$5,200.00
Temp. Erosion Control	$5,800.00	$3,800.00	–$2,000.00
Drainage	$92,400.00	$20,100.00	–$72,300.00
Roadway	$82,000.00	$128,000.00	$46,000.00
Driveways	$19,700.00	$30,100.00	$10,400.00
Curbing	$6,500.00	$0.00	–$6,500.00
Perm. Erosion Control	$70,000.00	$50,600.00	–$19,400.00
Additional Items	$489,700.00	$489,700.00	$0.00
Buildings	$3,600,000.00	$3,600,000.00	$0.00
PROJECT TOTAL	$4,389,300.00	$4,340,300.00	–$49,000.00

noticeably, drainage. Overall, the LID option was calculated to save the developers $49,128 ($789,500 vs. LID cost of $740,300) or nearly 6 percent of the stormwater management costs as compared to the conventional option.

Overall, the LID option was calculated to save the developers $49,128 or nearly 6 percent of the stormwater management costs as compared to the conventional option.

CONCLUSIONS

Beyond its effectiveness at reducing stormwater runoff, facilitating more groundwater infiltration, and promoting water quality benefits, porous asphalt was shown in this case study to be capable of bringing positive economic results. Primarily, cost savings were achieved in the Boulder Hills site development design through a significant reduction in the amount of drainage infrastructure and catch basins required, in addition to completely eliminating the need for curbing and stormwater detention ponds. Moreover, with considerably less site clearing needed, more economic and environmental benefits were realized. Compared to a conventional development plan, an option utilizing LID featuring porous asphalt was shown in this example to be more economically feasible.

GREENLAND MEADOWS

Utilizing an LID approach which featured porous asphalt, a cost-competitive drainage system was designed for a large retail development.

FIGURE 3-3
Greenland Meadows

OVERVIEW

Greenland Meadows is a retail shopping center built in 2008 by Newton, Mass.-based Packard Development in Greenland, New Hampshire that features the largest porous asphalt installation in the Northeast. The development is located on a 55.95-acre parcel and includes three, one-story retail buildings (Lowe's Home Improvement, Target, and a future supermarket), paved parking areas consisting of porous asphalt and non-porous pavements, landscaping areas, a large gravel wetland, as well as advanced stormwater management facilities. The total impervious area of the development – mainly from rooftops and non-porous parking areas – is approximately 25.6 acres, considerably more as compared to pre-development conditions. Prior to development, the project site contained an abandoned light bulb factory with a majority of the property vegetated with grass and trees.

Framingham, Mass.-based Tetra Tech Rizzo provided all site engineering services and design work for the stormwater management system, which included two porous asphalt installations covering a total of 4.5 acres along with catch basins, sub-surface crushed stone reservoir, sand filter, and underground piping and catch basins. Dr. Roseen of the UNH Stormwater Center provided guidance and oversight with the porous asphalt installations and supporting designs.

This case study will show how a combination porous asphalt and standard pavement design with a sub-surface gravel reservoir management system was more economically feasible as compared to a standard pavement design with a conventional subsurface stormwater management detention system. Additionally, this analysis will cover some of the site-specific challenges, as well as the environmental issues with this development that mandated the installation of an advanced LID-based stormwater management design.

> "Since there was interest in this project from many environmental groups, especially CLF, permitting the project proved to be very challenging. We were held to very high standards in terms of stormwater quality because Pickering Brook and the Great Bay are such valuable natural resources."

ENVIRONMENTAL CONCERNS

During the initial planning stage, concerns arose about potential adverse water quality impacts from the project. The development would increase the amount of impervious surface on the site resulting in a higher amount of stormwater runoff as compared to existing conditions. These concerns were especially heightened given the fact that the development is located immediately adjacent to Pickering Brook, an EPA-listed impaired waterway that connects the Great Bog to the Great Bay. One group that was particularly interested in the project's approach to managing stormwater was the Conservation Law Foundation (CLF), an environmental advocacy organization.

According to Austin Turner, a senior project civil engineer with Tetra Tech Rizzo, CLF feared that a conventional stormwater treatment system would not be sufficient for protecting water quality. "Since there was interest in this project from many environmental groups, especially CLF, permitting the project proved to be very challenging," Turner said. "We were held to very high standards in terms of stormwater quality because Pickering Brook and the Great Bay are such valuable natural resources. The CLF wanted this project to have the gold standard in terms of discharge."

In order to ensure a high level of stormwater treatment as well as gain project approval, Tetra Tech Rizzo worked closely with Packard Development, the UNH Stormwater Center, the New Hampshire Department of Environmental Services, and CLF on the design of an innovative stormwater management system with LID designs.

HYDROLOGIC CONSTRAINTS

Brian Potvin, P.E., director of land development with Tetra Tech Rizzo, said one of the main challenges in designing a stormwater management plan for the site was the very limited permeability of the soils. "The natural underlying soils are mainly clay in composition, which is very prohibitive towards infiltration," Potvin said. "Water did not infiltrate well during site testing and the soils were determined to not be adequate for receiving runoff." As such, Tetra Tech Rizzo focused on a stormwater management design that revolved around stormwater quantity attenuation, storage, conveyance, and treatment.

ECONOMIC COMPARISONS

Tetra Tech Rizzo prepared two site work and stormwater management design options for the Greenland Meadows development:

1. Conventional

This option included standard asphalt and concrete pavement along with a traditional sub-surface stormwater detention system consisting of a gravel sub-base and stone backfill, stormwater wetland, and supporting infrastructure.

2. LID

This option included the use of porous asphalt and standard paving in addition to a sub-surface crushed stone reservoir, sand filter beneath the porous asphalt, a subsurface gravel wetland, and supporting infrastructure.

The western portion of the property would receive a majority of the site's stormwater prior to discharge into Pickering Brook. Table 3-2 compares the total construction cost estimates for the conventional and the LID option.

As shown, paving costs were estimated to be considerably more expensive (by $884,000) for the LID option because of the inclusion of the porous asphalt, sand filter, and porous asphalt crushed stone reservoir layer. However, the LID option was also estimated to save $71,000 in earthwork costs as well as $1,743,000 in total stormwater management costs, primarily due to piping for storage. Overall, comparing the total site work and stormwater management cost estimates for each option, the LID alternative was estimated to save the developers a total of $930,000 compared to a conventional design, or about 26 percent of the overall total cost for stormwater management.

Overall, comparing the total site work and stormwater management cost estimates for each option, the LID alternative was estimated to save the developers a total of $930,000 compared to a conventional design, or about 26 percent of the overall total cost for stormwater management.

TABLE 3-2 Comparison of Unit Costs for Materials for Greenland Meadows Commercial Development

Item	Conventional Option	LID Option	Cost Difference
Mobilization / Demolition	$555,500	$555,500	$0
Site Preparation	$167,000	$167,000	$0
Sediment / Erosion Control	$378,000	$378,000	$0
Earthwork	$2,174,500	$2,103,500	–$71,000
Paving	$1,843,500	$2,727,500	$884,000
Stormwater Management	$2,751,800	$1,008,800	–$1,743,000
Addtl Work-Related Activity (Utilities, Lighting, Water & Sanitary Sewer Service, Fencing, Landscaping, Etc.)	$2,720,000	$2,720,000	$0
Project Total	$10,590,300	$9,660,300	–$930,000

* Costs are engineering estimates and do not represent actual contractor bids.

Tables 3-3 and 3-4 further break down the differences in stormwater management costs between the conventional and LID designs by comparing the total amount of piping required under each option.

Although distribution costs for the LID option were higher by $159,440, the LID option also completely removed the need to use large diameter piping for subsurface stormwater detention. The elimination of this piping amounted to a savings of $1,356,800. "The piping was replaced by the subsurface gravel reservoir beneath the porous asphalt in the LID alternative," Potvin said. "Utilizing void spaces in the porous asphalt sub-surface crushed stone reservoir to detain stormwater allowed us to design a system using significantly less large diameter pipe. This represented the most significant area of savings between each option."

The LID option completely removed the need to use large diameter piping for subsurface stormwater detention, which amounted to a savings of $1,356,800. "The piping was replaced by the subsurface gravel reservoir beneath the porous asphalt in the LID alternative," Potvin said.

CONSERVATIVE LID DESIGN

Although the developers were familiar with the benefits of porous asphalt, Potvin said they were still concerned about the possibility of the systems clogging or failing. "The developers didn't have similar projects they could reference," he said. "For this reason, they were tentative on relying on porous asphalt alone."

In order to resolve this uncertainty, the Tetra Tech Rizzo team equipped the porous pavement systems with relief valve designs: additional stormwater infrastructure including leaching catch basins. "This was a conservative 'belt and suspenders' approach to the porous asphalt design," Potvin said. "Although the porous pavement system is not anticipated to fail, this design and strategy provided the developers with a safety factor and insurance in the event of limited surface infiltration."

To further alleviate concerns, a combination paving approach was utilized. Porous asphalt was limited to passenger vehicle areas and installed at the far end of the front main parking area as well as in the side parking area, while standard pavement was

TABLE 3-3
Conventional Option Piping

	TYPE	QUANTITY	COST
Distribution	6 to 30-inch piping	9,680 linear feet	$298,340
Detention	36 and 48-inch piping	20,800 linear feet	$1,356,800

TABLE 3-4
LID Option Piping

	TYPE	QUANTITY	COST
Distribution	4 to 36-inch piping	19,970 linear feet	$457,780
Detention*	—	0	$0

*Costs associated with detention in the LID option were accounted for under "earthwork" in Table 3-2.

put in near the front and more visible sections of the retail center and for the loop roads, delivery areas expected to receive truck traffic. "This way, in case there was clogging or a failure, it would be away from the front entrances and would not impair access or traffic into the stores," Potvin said.

LID SYSTEM FUNCTIONALITY

The two porous asphalt drainage systems – one in the main parking lot and one in the side parking area – serve to attenuate peak flows, while the aggregate reservoirs, installed directly below the two porous asphalt placements, serve as storage. The aggregate reservoirs are underlain by sand filters which provide an additional means of stormwater treatment. Runoff from the sand filters flows through perforated underdrain pipes that converge to a large header pipe. Peak flow attenuation is attained by controlling the rate at which runoff exits the header pipe with an outlet control structure.

After being collected in catch basins, a majority of the stormwater runoff from rooftops and nonporous pavement areas flow to particle separator units, which treat stormwater prior to discharging into the crushed stone reservoir layers below the porous asphalt.

Outlet from the smaller aggregate reservoir, located underneath the side parking area, flows to an existing wetland on the east side of the site, while outlet from the larger aggregate reservoir flows to the gravel wetland on the west side of the site. The gravel wetland is designed as a series of flow-through treatment cells providing an anaerobic system of crushed stone with wetland soils and plants. This innovative LID design works to remove pollutants as well as mitigate the thermal impacts of stormwater.

CONCLUSIONS

Although the use of porous asphalt in large-scale commercial and residential development is still a relatively new application, this case study showed how porous asphalt systems, if designed correctly and despite significant site constraints, can bring significant water quality and economic benefits. With Greenland Meadows, an advanced LID-based stormwater design was implemented given the proximity of the development to the impaired Pickering Brook waterway. But in addition to helping alleviate water quality concerns, the LID option featuring porous asphalt systems eliminated the need to install large diameter drainage infrastructure. This was estimated to result in significant cost savings in the site and stormwater management design.

Although the use of porous asphalt in large-scale commercial and residential development is still a relatively new application, this case study showed how porous asphalt systems, if designed correctly and despite significant site constraints, can bring significant water quality and economic benefits.

LID RETROFIT: UNH PARKING LOT BIORETENTION

A bioretention retrofit was performed at the University of New Hampshire (UNH) for a site consisting of a landscaped area with existing stormwater infrastructure. Existing infrastructure consisted of curbing, catch-basins, and a drainage network that directed stormwater runoff offsite. The system was designed by UNH Stormwater Center in conjunction with the Maine Department of Environmental Protection (MEDEP). The system is a conversion of an existing landscape island into a bioretention and used as a source control measure to manage water quantity and improve water quality for parking lot run-off.

FIGURE 3-4
Bioretention retrofit installation at the University of New Hampshire, 2008

(UNHSC, 2008)

OVERVIEW

Retrofitting of stormwater infrastructure is commonly considered to be very costly compared to new construction. However, in certain instances using existing resources, simple retrofits can be performed at minimal expense. Typically Gray Infrastructure represents the largest expense for construction of stormwater controls, and in combination with labor and equipment, may represent the bulk of project costs. Institutions such as municipalities that have a Public Works can provide both labor and equipment for retrofitting existing infrastructure. In these instances retrofit expenses are limited to design and materials costs only, while installation expenses for labor, equipment, and some infrastructure can be avoided provided the labor is idle and/or municipal operations are already engaged in infrastructure updates or replacements. Public Works Department personnel training for construction of many LID structural controls such as bioretention can be simple. Training often consists of simply having qualified installation oversight to instruct and train personnel at system construction. The following example details the process and expenses associated with the installation of a bioretention system for an existing parking area on the University of New Hampshire campus.

PROJECT LOCATION

The bioretention system is installed in an existing commuter parking lot located on-campus in Durham, New Hampshire with routine commuter and bus traffic. The parking lot is a standard design consisting of parking stalls and landscaped islands that are raised, curbed, and vegetated. These islands are approximately 500 feet long, 9 feet wide, and are designed to shed rainwater onto the adjacent impervious surface while the curbing directs run-off to storm drains. Existing stormwater management consists of a conventional catch basin and pipe network draining to a swale. Two catch basins are located near the center of the island, one on each side, draining approximately one acre each with a 12 inch concrete pipe running under the island.

PROJECT DESCRIPTION

The bioretention was designed to treat runoff from a one-inch rainfall on 0.8 acres of pavement over a 24 hour period, and includes a filter area that is 30 feet long and 9 feet wide. The cross-sectional layout of the system from the bottom up consists of native soil; 10 inches of crushed stone; three inches of ¾-inch pea gravel; 24 inches of an engineered bioretention soil mix (BSM); and a 2-inch layer of hardwood mulch. The top layer was planted with several varieties of native perennial wild flowers. The BSM mix was based upon a design develop to meet the State of Maine regulatory requirements for bioretention areas. The system was underdrained and includes an infiltration reservoir, and high-flow bypass. All drainage was connected to the existing drainage infrastructure by coring into the adjacent catchbasin underneath the retrofit. The sides of the system were fitted with an impermeable liner to prevent runoff from migrating under the existing pavement as well as to prevent migration of adjacent soils into the system. Bioretention construction took three working days and included a construction team consisting of two skilled contractors in addition to an engineering staff which provided oversight.

> Institutions such as municipalities that have a Public Works can provide both labor and equipment for retrofitting existing infrastructure. In these instances retrofit expenses are limited to design and materials costs only.

PROJECT COST

Total project cost per acre was $14,000. With labor and install provided, costs are limited to materials and plantings at $5,500 (see Table 3-5). Costs could be further reduced with onsite preparation of the BSM saving additional materials and trucking expenses.

In addition to this example, numerous municipal projects have been implemented utilizing bioretention, dry well, tree filter, and porous pavement retrofit installations. In these instances

TABLE 3-5
Project Cost per Acre

ITEM	COST PER ACRE
Labor and Installation	$8,500
Materials	$4,675
Plantings	$825
Total	$14,000

minimal expenses were incurred by the municipal partner beyond contribution of labor and equipment. Expenses were typically limited to materials, design, and installation oversight (which doubled as training of municipal personnel and is not expected to be a recurring expense for future installs). In all instances, community partners (such as university cooperative extensions and watershed groups) contributed both expertise in plant selection and installation, and often donated materials as well.

FIGURE 3-5
Completed Bioretention Retrofit Installation 2008

(UNHSC, 2008)

CASE STUDIES

LID PRACTICES FOR CSO MANAGEMENT

Combined sewer overflows (CSOs) represent major water quality threats to hundreds of cities and communities in the U.S. that are served by a combined sewer system (CSS). CSO events cause the release of untreated stormwater and wastewater into receiving rivers, lakes, and estuaries, causing a host of environmental and economic-related problems. Costs associated with CSO management are expensive. The U.S. Environmental Protection Agency (EPA) estimates the costs of controlling CSOs throughout the U.S. are approximately $56 billion (MacMullan, 2007).

The traditional approach to CSO management involves the development of a separate drainage system to convey stormwater flows or the use of gray infrastructure and conventional stormwater controls for enhancing the storage and conveyance capacity of combined systems. These approaches can include the construction of large underground storage tunnels that store sewage overflows during rain events for later treatment, as well as necessary improvements and upgrades to municipal treatment facilities in order to handle increasing volumes. Both approaches, while effective for CSO controls, are very expensive.

Integrating Green Infrastructure strategies and LID designs into a CSO mitigation plan can help communities achieve CSO management requirements at lower costs. In addition to many benefits including groundwater recharge, water quality improvements, and reduced treatment costs, the use of LID can help minimize the number of CSO events and the volume of contaminated flows by managing more stormwater on site and keeping volumes of runoff out of combined sewers (MacMullan, 2007).

Integrating Green Infrastructure strategies and LID designs into a CSO mitigation plan can help communities achieve CSO management requirements at lower costs.

Utilizing a combination approach of gray and Green Infrastructure strategies can be a considerably more cost-effective method for CSO management as compared to a traditional gray infrastructure approach alone. Indeed, LID methods can cost less to install, can have lower operations and maintenance (O&M) costs, and can provide more cost-effective stormwater management and water quality services than conventional stormwater controls (MacMullan, 2007). Some LID alternatives are also being initiated by the private sector. While municipalities may provide oversight and consultation, as is the case with the City of Portland, OR, these projects are not controlled by municipalities in regards to implementation, operation, and maintenance. The purpose of this study is to show the cost-benefits of integrating Green Infrastructure strategies with traditional gray infrastructure.

Although communities rarely attempt to quantify and monetize the avoided treatment costs from the use of LID designs, the benefits of these practices for decreasing the need for CSO storage and conveyance systems should be factored into any economic analyses (EPA, 2007).

The following case studies are presented to develop an economic context for the use of Green Infrastructure and LID designs as a strategy for CSO compliance. The case studies will also identify and contrast historical gray infrastructure approaches to CSO management using store, pump, and treat with approaches using Green Infrastructure/LID designs that focus on reduced stormwater runoff volumes.

NARRAGANSETT BAY COMMISSION

A Baseline Gray Infrastructure Approach to CSO Management

FIGURE 3-6
Narragansett Bay

The Narragansett Bay Commission (NBC) in Providence, Rhode Island, oversees the operation and maintenance of approximately 89 miles of combined sewer interceptors, including two wastewater treatment facilities. These systems serve a total of 10 different communities, including 360,000 residents, 8,000 businesses, and 160 major industrial users. According to the NBC, approximately 66 CSO events occur each year in the NBC service area, accounting for an estimated 2.2 billion gallons of untreated combined sewage released into Narragansett Bay and its tributaries.

In order to mitigate these CSOs and protect the Narragansett Bay and the region's urban rivers from sewage overflows, the NBC initiated a three-phase CSO Abatement Plan. Phase I of the project, which began in 2001, was completed and went on-line in November 2008. The chief component of Phase I includes a three-mile long, 30-foot

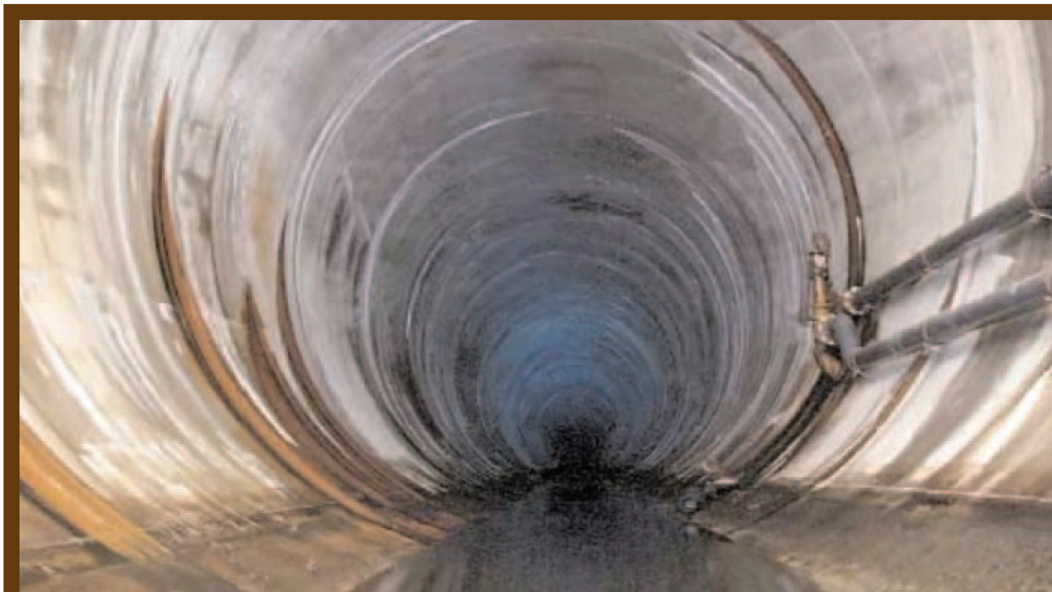


FIGURE 3-7
Phase I
Tunnel System

diameter deep rock tunnel 250 feet below the surface. The Phase I tunnel system has a 62 million gallon capacity and is anticipated to effectively reduce overflow volumes by approximately 40 percent.

ECONOMIC CONTEXT

The total capital costs for Phase I of the NBC's CSO Abatement plan were $365 million. The associated operational and maintenance costs of Phase I, the bulk of which are attributed to electrical costs for pumping, are $1 million per every one billion gallons of stormwater and sewage flow, or $1 for every 1000 gallons (Brueckner, 2009). Phase II of the CSO abatement plan, which will begin in 2011, includes two near-surface interceptors that will convey additional flow to the Phase I tunnel. The estimated capital costs for the Phase II project are $250 million.

The NBC's regulations regarding stormwater management require developers to execute stormwater mitigation plans if required by the NBC. These plans encourage the use of LID strategies, BMPs, and other methods to eliminate or reduce storm flows. Between 2003 and 2008, a total of 67 stormwater mitigation plans were approved and implemented which accounted for 8.9 million gallons of stormwater diverted from the combined system (Zuba, 2009). Calculating in 2009 dollars, the 67 LID projects can save approximately $9,000/yr in operating costs for CSO abatement. Over time, as electricity costs increase, the avoided cost of the 67 projects also increases. With increased implementation of LID projects, we can expect those cost savings to be realized in the same manner.

> Between 2003 and 2008, a total of 67 stormwater mitigation plans were approved and implemented which accounted for 8.9 million gallons of stormwater diverted from the combined system. Calculating in 2009 dollars, the 67 LID projects can save approximately $9,000/year in operating costs for CSO abatement.

PORTLAND, OREGON

Economic Benefits of Utilizing Green Infrastructure Programs for CSO Management

FIGURE 3-8
Portland, Oregon street scene; inset: CSO Tunnel system

BACKGROUND

The City of Portland, Oregon is considered a national leader in the implementation of innovative stormwater management strategies and designs. Included among the city's Sustainable Stormwater Management Programs is the Innovative Wet Weather Program, the Green Street Program, the Portland Eco-Roof Program, and individual case studies and projects that include commercial and multifamily stormwater retrofits and porous pavement placements.

With Portland receiving an average of 37 inches of precipitation annually, creating roughly 10 billion gallons of stormwater runoff per year, these programs are very important for helping reduce flooding and erosion as well as minimizing CSO events.

Innovative Wet Weather Program

This city-wide program encourages the implementation of stormwater projects that improve water quality and watershed health, reduce CSO events and stormwater pollution, and control stormwater runoff peaks and volumes. The program goals include:

- Capturing and detaining stormwater runoff as close to the source as possible;
- Reducing the volume of stormwater entering the combined sewer system;
- Filtering stormwater to remove pollutants before the runoff enters groundwater, streams, or wetlands;
- Using and promoting methods that provide multiple environmental benefits; and
- Using techniques that are less costly than traditional piped solutions.

Green Streets Program

Portland's Green Street Program promotes the use of natural above-ground and vegetated stormwater controls in public and private development in order to reduce the amount of untreated stormwater entering Portland's rivers, streams, and sewers. The program is geared towards diverting stormwater from the city's overworked combined system and decreasing the amount of impervious surface so that stormwater can infiltrate and recharge groundwater systems.

The program takes a sustainable and blended approach to finding the most optimal solution for storm and sanitary sewer management. This includes overlaying and integrating green and sustainable stormwater strategies with traditional gray infrastructure to maintain or improve the city's sewer capacity (Dobson, 2008).

Green streets have been demonstrated to be effective tools for inflow control of stormwater to Portland's CSO system. Two such green street designs, the Glencoe Rain Garden and the Siskiyou Curb Extension facilities, were shown to reduce peak flows that cause basement sewer backups and aid compliance with CSO regulations by reducing runoff volumes sent to the CSO Tunnel system (Portland, 2007).The City of Portland also conducted simulated storm event modeling for basement sewer back-ups and determined that two green street project designs would reduce peak flows from their drainage areas to the combined sewer by at least 80 to 85 percent. The City of Portland also ran a simulation of a CSO design storm and found that the same two green street project designs retained at least 60 percent of the storm volume, which is believed to be a conservative estimate.

ECONOMIC BENEFIT

The following sections of this case study communicate the economic context for both the application of LID strategies in Portland, as well as the city's programs that promote the use of Green Infrastructure designs for stormwater management.

Green Streets Program

For the City of Portland, utilizing green streets is the preferred strategy for helping relieve sewer overflow conditions because it is the most cost-effective and eliminates the need for expensive below-ground repairs, which often involve replacing infrastructure (Dobson, 2008). As an example, a basement flooding relief project that was under design was projected to cost 60 percent less than what would have been the cost of a traditional pipe upsize and replacement project. This is because the solution, a mix of green streets and private system disconnects, intercepts and infiltrates the water before it enters the public storm system thereby reducing the need to dig up and upsize the existing piped infrastructure (Portland, 2007).

For the City of Portland, utilizing green streets is the preferred strategy for helping relieve sewer overflow conditions because it is the most cost-effective and eliminates the need for expensive below-ground repairs.

COST COMPARISONS BETWEEN GRAY AND GREEN INFRASTRUCTURE STRATEGIES

Tabor to the River: The Brooklyn Creek Basin Program

In June of 2000, prior to implementation of the Green Street Program, the City of Portland was faced with the need to upgrade an undersized sewer pipe system in the Brooklyn Creek Basin, which extends from the Willamette River to Mt. Tabor between SE Hawthorne and SE Powell boulevards, and covers approximately 2.3 square miles. Upgrades were needed in order to improve the sewer system reliability, contain street flooding, stop sewer backups from occurring in basements, and help control CSOs to the Willamette River.

At that time, the city considered constructing a new separated stormwater collection system to support the existing undersize pipes in this basin. The original cost estimate for constructing this new system using traditional gray infrastructure was $144 million (2009 dollars). However, following this proposal, a second plan was developed that included a basin redesign using a combined gray and Green Infrastructure approach. Including a total of $11 million allocated for green solutions, the cost estimate for this integrated approach was $81 million, a savings of $63 million for the city (Portland, 2009).

The combined gray and green approach was chosen as the 2006 Recommended Plan for the Brooklyn Creek Basin, and includes project objectives of reducing CSO events, improving surface and groundwater hydrology, protecting and improving sewer infrastructure, optimizing cost-effectiveness, boosting water quality, and enhancing community livability.

The approved basin improvement plan consists of 35 public and private sector projects over the next 10-20

FIGURE 3-9
Tabor raingarden planting

TABLE 3-6
CSO Infrastructure Costs for City of Portland, Oregon

PROJECT	TOTAL CAPITAL COSTS	ANNUAL O&M COSTS
East Side CSO Tunnel	$624,892,000	$22,700
Swan Island CSO Pump Station – Phase 2	$7,500,000	$3,100,000
Portsmouth Force Main	$55,306,000	$12,000
Balch Consolidated Conduit	$22,052,000	$3,900

years. Gray infrastructure upgrades include repairing or replacing 81,000 feet of combined sewer pipes, while the Green Infrastructure strategies include building green roofs, retrofitting parking lots with sustainable stormwater controls, planting nearly 4,000 street trees, and adding more than 500 green streets with vegetated curb extensions and stormwater planters.

GREEN INFRASTRUCTURE FOR CSO COMPLIANCE: COST COMPARISONS

Portland's combined sewer system covers 26,000 acres and contains 4,548,000 linear feet (861 miles) of gravity drained, combined sewer pipe. The city's combined system also includes 42 separate basins connected via three major interceptor systems and served by three major pump stations.

The City of Portland, under federal and state requirements as well as stipulations from the Clean Water Act to comply with regulations regarding CSO management, initiated the construction of a new pump station and two CSO tunnels (West Side and East Side CSO Tunnels) which would serve as the primary means to protect the city's receiving waters from future CSO events. However, in addition to these initiatives, more projects and programs were needed for providing additional CSO mitigation.

In December of 2005, the City of Portland's Bureau of Environmental Services prepared a report (Portland, 2005) charged with sizing of the East Side CSO Tunnel and providing recommendations for long-term operations and flow management of the Willamette CSO system. The city's final recommendations included the following for the Willamette CSO tunnels and supporting infrastructure:

East Side CSO Tunnel This storage facility will be constructed with a 22-foot diameter and will have a capacity of 83 MG. Total length is 29,145 linear feet; annual O&M costs are $0.78 per linear foot. Design life is 50 years.

Swan Island CSO Pump Station This facility pumps approximately 500 MG per year with an annual O&M cost of $0.0002 per gallon for pump station operations and $0.006 per gallon for Columbia Boulevard Wastewater Treatment Plant treatment. Design life is 50 years.

Portsmouth Force Main This infrastructure is 66 inches in diameter and 15,000 feet in length. Annual O&M costs are $0.80 per linear foot. Design life is 50 years.

Balch Consolidated Conduit This infrastructure is 84 inches in diameter and 4,900 linear feet. Annual O&M costs are $0.80 per linear foot. Design life is 50 years.

Along with determining the final recommendations for the East Side CSO Tunnel and supporting infrastructure, the city considered a range of possible alternatives for additional CSO mitigation. This included 12 different stormwater separation projects as well as a number of watershed health initiatives, some of which involved Green Infrastructure strategies including:

Eastside Curb Extensions
Involved the use of vegetated swales at a cost of $50,000 per acre and O&M costs of $2,000/year/acre.

Eastside Roof & Parking Inflow Control
Parking retrofits use vegetated infiltration basins at a cost of $90,000 per acre and O&M costs of $1,100/year/acre. Rooftop stormwater controls use either stormwater planters ($40,000 per acre; O&M costs of $600/year/acre), or vegetated infiltration basins.

Green Roof Legacy Project
Retrofit 20 acres of rooftop in an industrial district with eco-roofs. Project costs include $285,000/acre/year for design/construction and $935/acre/year for O&M activities.

Extended Downspout Disconnection Program (DDP)
Continues the city's successful existing DDP at the cost of $22,300 per acre and O&M costs of $7/year/downspout. Depending on site conditions, this can include the use of LID strategies including rain gardens and soakage trenches built by private citizens with City of Portland consultation.

The City's goal was to determine which project/program alternatives would be the most cost-effective for long-term CSO management. The basic metric common to the projects identified for CSO control was the amount of stormwater volume that could be removed from the CSO tunnel system. The city's final evaluation was based on the relationship between project capital costs and stormwater volume that could be removed from the system. This analysis took into account cumulative capital costs, marginal costs for gallons removed, and cumulative volume removed from the system.

Table 3-6 shows all stormwater separation and watershed health projects/programs considered by the City of Portland. The projects/programs are sorted by dollars per gallons of stormwater that can be removed (marginal cost). Project staff agreed that cost-effectiveness was determined by an inflection point, or knee-of-the-curve point, on a graph that compared costs to stormwater volume that could be diverted from the CSO system. This inflection point was determined to be approximately $4 per gallon removed the system.

Projects/programs costing at or below $4 per gallon were the ones recommended for further design and eventual implementation for long-term CSO control. These projects/programs are the first seven listed in Table 3-7.

The projects/programs chosen on the basis of cost-effectiveness included the Eastside curb extension projects (vegetated swales), the Eastside roof and

TABLE 3-7 CSO Control Alternatives Costing for Portland, Oregon.

Project/Program	Effective Imp. Acres Controlled	Est. 3-year Volume Removed (MG)	Capital Cost	Marginal Cost ($/ Gallon)	Cumulative Volume Removed (MG)	Cumulative Capital Cost
Extended Downspout Disconnection Program (can include LID)	284	7.45	$6,633,000	$0.89	7.45	$6,633,000
School Disconnection*	68	1.77	$1,954,000	$1.10	9.22	$8,587,000
Church Disconnection*	32	0.96	$2,031,000	$2.12	10.18	$10,618,000
Beech-Essex Sewer Separation	37	1.40	$3,889,000	$2.78	11.58	$14,507,000
ES Curb Extensions (LID)	349	4.29	$12,323,000	$2.87	15.87	$26,830,000
Tanner Phase 3 Sewer Separation	85	3.10	$10,767,616	$3.47	18.97	$37,598,000
ES Roof & Parking IC (LID)	475	17.64	$72,047,000	$4.08	36.61	$109,645,000
NWN Pre-design – Tanner North Sewer Separation	14	0.22	$1,127,000	$5.12	36.83	$110,772,000
Carolina Stream & Storm Separation	93	1.02	$5,319,000	$5.21	37.85	$116,091,000
NWN Pre-design – Tanner South Sewer Separation	13	0.26	$1,602,000	$6.16	38.11	$117,693,000
NWN Pre-design – Tanner Central Sewer Separation	2	0.04	$269,000	$7.60	38.14	$117,962,000
NWN Pre-design – Nicolai/ Outfall Sewer Separation	34	0.54	$6,321,000	$11.76	38.68	$124,283,000
NWN Pre-design – Nicolai/ Outfall 13 Sewer Separation	52	0.68	$8,217,000	$12.04	39.36	$132,500,000
Green Roof Legacy Project (LID)	20	1.04	$14,179,000	$13.65	40.40	$146,679,000
NWN Pre-design – Nicolai/ Outfall 15 Sewer Separation	24	0.36	$6,546,000	$17.98	40.77	$153,225,000
Holladay Sewer Separation	125	0.69	$14,360,000	$20.94	41.45	$167,585,000
NWN Pre-design – Balch Neighborhood Sewer Separation	8	0.14	$7,664,000	$55.06	41.59	$175,249,000
NWN Pre-design – Balch/ Forest Park Storm Separation	5	0.13	$12,026,000	$93.82	41.72	$187,275,000

* Church and School Disconnection programs assumed downspout disconnection and drywells would remove this stormwater volume. The former is an LID method.

parking inflow control projects (vegetated infiltration basins & stormwater planters), three disconnection programs (which can include LID strategies) and two stormwater separation projects.

LID AVOIDANCE COSTS

The City of Portland recognizes two avoidance costs for incorporating LID strategies with combined sewer systems.

One of these avoidance costs is annual O&M costs to pump and convey stormwater through the existing combined sewer system. The city measures this by applying a rate of $0.0001 per gallon treated and $0.0001 per gallon pumped. This equates to an annual O&M avoidance cost of $0.0002 per gallon.

Secondly, the City of Portland recognizes an avoidance cost that benefits the CSO system. This is based on the relationship between project capital costs and stormwater volume removed from the CSO system, which was described above. The cost-effectiveness point for projects/programs that remove stormwater volume from the CSO system ($4 per gallon) is also considered as the avoidance cost of constructing a larger CSO tunnel. In life-cycle cost analyses, this "savings" can reduce the capital costs of other LID facilities that the city builds for objectives other than CSO control (e.g. water quality improvements, basement flooding relief), but still removes stormwater from entering the CSO tunnels (Owen, 2009).

KANSAS CITY, MISSOURI

ECONOMIC BENEFITS OF INTEGRATING GREEN SOLUTIONS WITH GRAY INFRASTRUCTURE FOR CSO COMPLIANCE

FIGURE 3-10 Raingarden, Kansas City, Missouri

BACKGROUND

The City of Kansas City, Missouri has committed to implementing a green design initiative that will be considered a community amenity and will work to reduce the amount of water entering the city's combined system.

Under a USEPA mandate, the City of Kansas City, Missouri is required to update its network of aging sewer infrastructure in order to address overflows from its combined and separate sewer systems. Kansas City's 318-square mile sewer system includes 58 square miles of a combined system and 260 miles of a separated system. The overall system serves 668,000 people and includes 7 wastewater treatment plants with a total capacity of 153 million gallons per day (MGD).

Overflows in the combined system amount to 6.4 billion gallons in a typical year, and on average, 12 rain events per year are responsible for 67 percent of this total overflow. This contributes to the poor water quality of Kansas City's streams, urban lakes and rivers.

The original planned improvements associated with upgrading the city's combined system include 310 MGD of additional treatment capacity, 25 million gallons (MG) of in-line storage, 10 separation areas, neighborhood sewer rehabilitations, as well as pump station and treatment plant modifications. Three storage tunnels from 16 to 26 feet in diameter are also proposed which would run between 1.4 and 3.4 miles in length and would be capable of storing 78 MG of overflow. The goals of the improvements in the combined sewer system are to capture 88 percent of flows, reduce the frequency of overflow events by 65 percent, and lower the 6.4 billion gallons of overflow per year down to 1.4 billion gallons (KCWSD(a), 2009).

The original estimated capital costs associated with overhauling Kansas City's total sewer system is $2.4 billion dollars, of which $1.4 billion would go towards the combined system. The yearly operations and maintenance costs (O&M) of this total upgrade are estimated at $33 million per year.

> Under a USEPA mandate, the City of Kansas City, Missouri is required to update its network of aging sewer infrastructure in order to address overflows from its combined and separate sewer systems.

GREEN SOLUTIONS

In developing a plan for the combined sewer system upgrade, Kansas City began exploring the possibility of incorporating Green Infrastructure strategies in combination with gray infrastructure improvements. The city formed a green solutions subcommittee and later developed a green solutions position paper, which eventually resulted in a city council resolution directing city staff to develop a plan to implement Green Infrastructure strategies.

GREEN OVERFLOW CONTROL PLAN

In May of 2008 the Kansas City Water Services Department proposed $30 million in green solutions during the first five years of the proposed $1.4 billion overflow control plan. This plan included language to allow green solutions to replace gray infrastructure. Upon review, however, the city council determined that additional Green Infrastructure strategies were needed in the overflow control plan and directed the water services department to request a 6-month extension for submittal of the plan. The extension was granted by the Missouri Department of Natural Resources and EPA Region 7.

The city estimated that it should be possible to completely replace two CSO storage tanks with distributed green solutions without increasing costs or reducing CSO control performance.

The city moved ahead in developing a more green-orientated overflow control plan and conducted reviews of basins located within the combined system in order to identify areas where green solutions could replace gray infrastructure in whole or in-part. High altitude desktop analyses were performed in order to assess the potential for shifting from gray storage to green solutions for storage in three major basins. The types of green solutions considered included catch basin retrofits, curb extension swales, pervious pavement, street trees, green roofs and stormwater planters.

Two principal assumptions were included with these considerations. Firstly, storage volume in green solutions would replace an equal volume in conventional storage facilities; and secondly, each 1-MG of green storage would result in 0.5 MGD reduction in capacity of downstream pumping stations and treatment facilities due to infiltration and evaporation (KCWSD, 2009). Following revisions, the city's submitted a new plan that proposed a total of $80 million in green solutions programs.

ECONOMIC BENEFIT

Based on city analyses, it was determined that replacing gray infrastructure with green solutions would be cost-effective in portions of the Middle Blue River Basin (MBRB), a 744-acre region with 34 percent impervious surface. Based on calculations, the city estimated that it should be possible to completely replace two CSO storage tanks with distributed green solutions without increasing costs or reducing CSO control performance (Leeds, 2009).

The original MBRB Plan was based on a traditional gray infrastructure design with controls capable of proving 3 MG of storage. The capital costs associated with these upgrades were estimated at $54 million, an average of $18 per gallon, and would be capable of reducing overflows in the MBRB to less than 6 per year, on average.

The revised MBRB Plan is a non-traditional design that includes gray infrastructure projects as well as Green Infrastructure strategies and will provide distributed storage of at least 3.5 MG. The revised plan would also eliminate the need for storage tanks while still achieving the goal of reducing the amount of overflows to less than 6 per year. The projected costs associated with this revised plan are $35 million, potentially $19 million less than the original gray infrastructure plan. However, because of uncertainties, the green solutions project budget has been set at $46 million. Note: Construction uncertainties are a routine consideration in the planning of any construction budget. The uncertainties will be reduced overtime as developers, contractors, and practitioners become more familiar with these practices.

MIDDLE BLUE RIVER BASIN GREEN SOLUTIONS PILOT PROJECT

A large-scale study was needed to test the city's key assumptions regarding the performance of green solutions. As such, the city initiated a pilot project within a 100-acre area of the MBRB. The MBRB Green Solutions Pilot Project will help determine the effects of widespread implementation of distributed storage utilizing green solutions, infiltration, and inflow rehabilitation on combined sewer overflows and is potentially the largest green solutions-based CSO control project in the nation (KCWSD(b) 2009).

Green-based strategies in the pilot area will be installed on both residential and commercial areas and will need to provide at least 0.5 MG of distributed storage, replacing an equal amount of stormwater stored in conventional concrete tanks. Following implementation, post-construction monitoring will be conducted to determine functionality and performance.

GREEN SOLUTIONS UNIT COSTS

In developing unit costs for green solutions, the city used a number of assumptions including:

- Green roofs have incremental costs above normal roof replacements with 3 to 4 inches of growth media providing 1 inch of storage. Incremental capital costs associated with green roofs are $14 per square foot.
- Deciduous street trees have interception storage of 0.032 inches, 20-foot crown radius, with 25 gallons per tree.
- Porous pavements would provide effective storage for an area approximately 3 times its surface area.

Table 3-8 presents unit costs, in dollars per gallon, used by the city for each type of green solution.

The results of the pilot project will be used to guide work in the remaining 644 acres as well as other future green solutions projects.

TABLE 3-8
Unit Costs for Green Solutions

GREEN SOLUTION	UNIT COST ($/GAL)
Catch Basin Retrofits in Road and Street ROW	$2.28-$7.13 (avg $5.00)
Porous Pavement	$4.62
Street Trees (Residential)	$10.80
Street Trees (Commercial)	$23.36
Curb Extension Swales	$10.86
Replacement of Sidewalks in ROW with porous pavement	$11.62
Conversion of Roof Areas to Green Roofs	$22.68
Stormwater Planters	$26.83

Presentation at the Midwest AWMA Annual Technical Conference (January 2009) by Terry Leeds, Overflow Control Program Manager, Kansas City Water Services Department.

CHICAGO, ILLINOIS

UTILIZING GREEN INFRASTRUCTURE FOR REDUCING CSS VOLUMES

Figure 3-11
City Hall,
Chicago, Illinois

BACKGROUND

The City of Chicago has implemented a number of innovative plans geared towards building community resiliency toward climate change, while promoting sustainability and conservation and is recognized as a worldwide leader in terms of its environmental initiatives. In addition to green building and energy efficiency, Chicago has implemented advanced city-wide programs that address water quality, water efficiency, and stormwater management.

As part of the Chicago Water Agenda, the city is committed to managing stormwater more sustainably and encourages the use of BMPs that include a range of Green Infrastructure designs such as green roofs, permeable paving, filter strips, rain gardens, drainage swales, naturalized detention basins, as well as the use of rain barrels and natural landscaping. These measures are important strategies for facilitating infiltration, improving water quality and minimizing the potential for basement flooding. BMP strategies which divert water away from the combined sewer system also reduce the energy demands associated with pumping and treating the combined sewage.

Chicago's gravity based combined collection system includes 4,400 miles of sewer main lines that flow to interceptor sewers that are owned and operated by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC). The interceptor sewers are a pumped system which conveys dry weather flow to the MWRDGC's treatment plants. During storm events, excess flows are diverted to the MWRDGC's Tunnel and

Reservoir Plan system for storage, which is intended to prevent combined sewer overflows to the city's waterways. This tunnel reservoir system is the largest in the world and includes 109 miles of 30-foot diameter pipes that is generally located 200 feet below the Chicago River system.

CSO events occur with regular frequency each year, causing untreated wastewater and stormwater to be released into the city's river systems as well as Lake Michigan. Green Infrastructure controls and other BMP measures are needed in order to limit inflow stormwater volumes to the system, thus reducing the frequency and intensity of CSO events.

Chicago Green Alley Program

One of the city's more progressive Green Infrastructure initiatives is the Chicago Green Alley Program, which has been developed to alleviate flooding in the city's extensive alley network, which consists of approximately 1,900 miles of public alleys and roughly 3,500 acres of impervious surface. The program encourages the use of porous pavements in order to reduce the city's quantity of impervious surface, as well as filter runoff, and recharge groundwater.

In addition to facilitating infiltration and diverting stormwater from Chicago's combined system, the Green Alley Program brings environmental benefits such as heat reduction, material recycling, energy conservation, and glare reduction.

ECONOMIC BENEFIT

The City of Chicago actively records the ongoing number or coverage area of various green BMP designs that are added within city limits. This includes the year-to-date number of rain gardens and rain barrels added / downspouts disconnected, as well as the effective square footage of green roofs, green paving, turf to native grass, and Stormwater Management Ordinance (SMO) permits. Each of these BMP designs has been assigned an equivalence factor by the City of Chicago, which, when multiplied by the actual number or amount of square footage of each BMP, will calculate a more accurate shed of capture for each representative design.

Table 3-9 presents data that shows estimated year-to-date numbers or

TABLE 3-9
City of Chicago Volume Reductions and Square Footage for CSO Controls

City of Chicago draft Stormwater Carbon Calculator

BMP	Actual SF or number	Annual volume (gals) diverted from combined system
Green Paving (SF)	182,000	4,832,000
Green Roofs (SF)	100,000	1,907,000
Rain Gardens (#)	5	53,000
Rain Barrels/Downspout Disconnections (#)	2,220	8,281,000
Turf to Native Grass (SF)	1,701,000	23,426,000
SMO Permits (SF) 1	1,869,000	31,684,000

* SMO permits can include any number of BMP designs. SMO permit data does not overlap with data from individual BMPs.

square footage totals (as of November, 2009) for each type of BMP measure that has been implemented.

In order to calculate the volume of stormwater that is diverted from the combined system, the City of Chicago uses a conversion factor of 21.19 that is multiplied by the SF equivalence of each corresponding BMP design. Based on the above BMPs, equivalent factors, and calculations, a total of 70,182,236 gallons of stormwater is estimated to have been diverted from Chicago's combined system in 2009 through November, 2009.

NEW YORK CITY, NEW YORK

IMPLEMENTING A GREEN INFRASTRUCTURE PLAN FOR CSO REDUCTION

FIGURE 3-12
The Brookly Bridge spanning the East River.

BACKGROUND

The City of New York, facing the need to improve the water quality of New York City's waterways and coastal waters, has developed a multi-tiered, long-term plan that will draw upon green infrastructure strategies towards managing stormwater more sustainably. The NYC Green Infrastructure Plan, an extension of the City's *Sustainable Stormwater Management Plan* and Mayor Bloomberg's PlaNYC initiative towards a cleaner, greener city, will employ a hybrid approach towards controlling Combined Sewer Overflows (CSO) and improving water quality. The NYC Green Infrastructure Plan will employ such practices as porous pavements, green streets, green and blue roofs, swales, rain gardens, street trees, constructed wetlands, and other strategies. The City of New York has already built or planned to build over $2.9B in grey infrastructure specifically to reduce CSO volumes. In the NYC Green

Infrastructure Plan, these are referred to as the Cost-Effective Grey Infrastructure Investments and are the most cost beneficial practices to achieve their goal. In addition, the City will also implement measures to optimize the performance of the existing system reduce CSO events and reduce stormwater runoff volumes.

According to analyses by the New York City Department of Environmental Protection (DEP), which examined areas of the New York Harbor where water quality standards have not been met, the biggest remaining challenge is to further reduce CSOs. Since 2005, the City has spent over $1.5 billion towards CSO reduction including infrastructure improvements and CSO storage facility upgrades. A conventional approach for CSO reduction would include the construction of large piping networks to store or separate stormwater and wastewater. However, according to the September 2010 NYC Green Infrastructure Plan report, these types of CSO reduction projects are very expensive and do not provide the sustainability benefits that New Yorkers have come to expect from multi-billion dollar public fund investments. Furthermore, officials feel that while meeting water quality goals is the primary consideration for future DEP investments, the long-range alternatives it considers should also be consistent with the City's sustainability goals. CSO reduction strategies, according to the report, would be more valuable if they incorporated a sustainable approach, managing stormwater at its source through the creation of vegetated filtration (i.e. rain gardens, street trees, constructed wetlands) and green infrastructure.

Conclusions formulated in the City's *Sustainable Stormwater Management Plan* found that green infrastructure could be more cost-effective than certain large infrastructure projects such as CSO storage tunnels. DEP modeling efforts demonstrated that the use of green infrastructure in combination with other strategies would be more effective at controlling CSOs as compared to grey strategies alone, but would also provide the additional benefits of cooling the city, reducing energy costs, and increasing property values. Moreover, green-based strategies would provide further economic benefits in terms of lower operations and maintenance (O&M) costs, a greater distribution of O&M costs towards jobs potentially resulting in job creation, improved air quality, and reducing CO_2 emissions.

PERFORMANCE COMPARISONS BETWEEN GREEN AND GREY STRATEGIES

DEP evaluated and compared two different infrastructure investment plans for long-term CSO management and reduction. These two plans included a Green Strategy and a Grey Strategy. The main components of each respective strategy include:

Green Strategy

- Green Infrastructure
- Cost-Effective Grey Infrastructure Investments
- System Optimization and Reduced Flow

Grey Strategy

- Cost-Effective Grey Infrastructure Investments
- Potential Tanks, Tunnels, and Expansions

Utilizing an InfoWorks computer model to estimate future City CSO flows, DEP modeled CSO volume projections under both strategies in order to access and compare future CSO control performances for each alternative.

One of the assumptions made by DEP in reference to modeling of Green Infrastructure – which would be implemented as a combination of infiltration and detention technologies – included the capture and infiltration of the first inch of rainfall on 10 percent of existing impervious surfaces in each combined sewer watershed in the city.

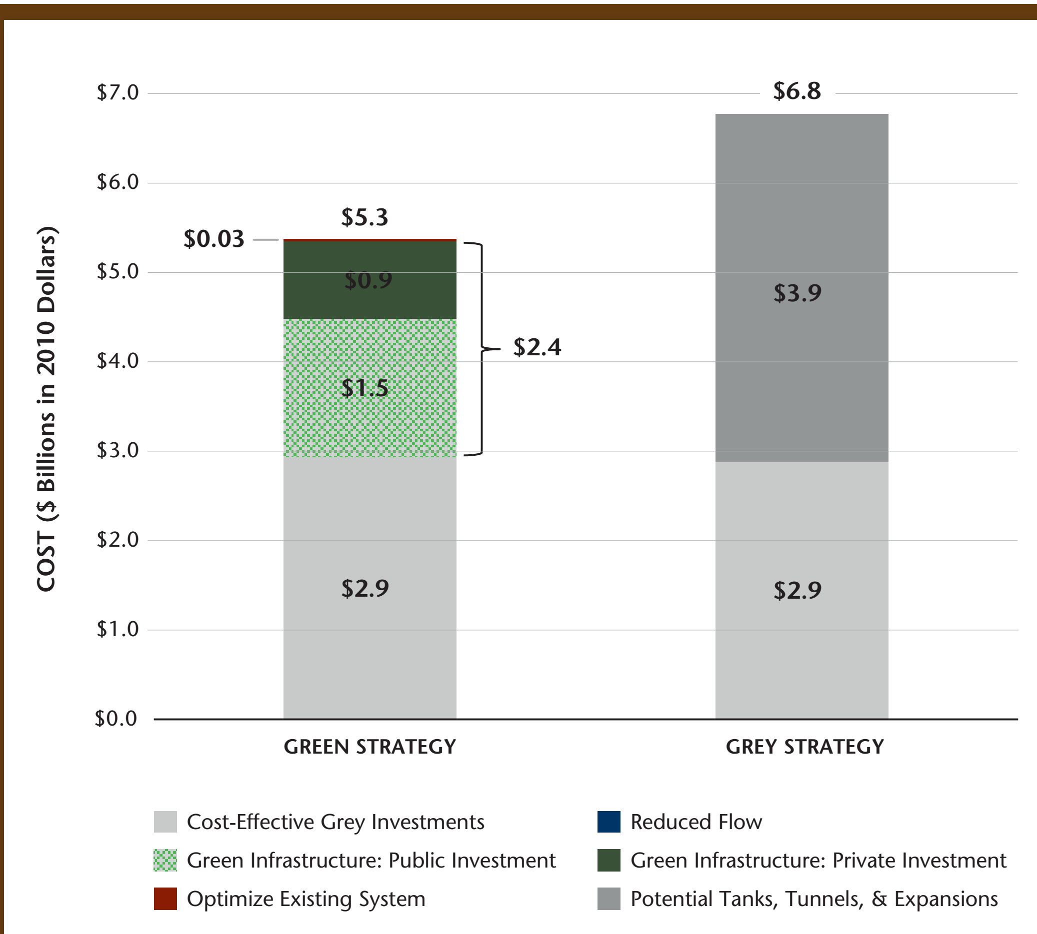
According to predictions by DEP, implementation of the Green Strategy over a 20-year time frame will reduce CSO volumes from approximately 30 billion gallons per year (bgy) to approximately 17.9 bgy. This is nearly 2 bgy more of CSO reduction as compared to the Grey Strategy, which was estimated to reduce CSO volumes down to 19.8 bgy.

ECONOMIC BENEFIT

In addition to significant citywide CSO reductions every year, DEP also predicted considerable economic

FIGURE 3-13
Citywide Costs of CSO Control Scenarios (after 20 years)

(NYC Green Infrastructure Plan, 2010)



benefits in several areas that would result from implementation of a Green Strategy as compared to a Grey Strategy.

Total Citywide Costs

According to DEP estimates compiled in the Green Infrastructure report, costs associated with full implementation of the Green Strategy are anticipated to be considerably less as compared to costs for the Grey Strategy. Figure 3-13, taken directly from the Green Infrastructure Plan report, depicts the estimated total citywide costs after 20 years under both the Green and Grey Strategy scenarios.

As shown, the total cost of the Grey Strategy is approximately $6.8 billion (2010 dollars), which includes $3.9 billion for the potential tanks, tunnels, and expansions component of the plan. The cost for the city-wide Green Strategy, however, is estimated at approximately $5.3 billion, of which $2.4 billion would be allocated towards green infrastructure programs for capturing 10 percent of the combined sewer watersheds' impervious areas. In total, the Green Strategy is forecasted by DEP to save the City $1.5 billion over the next 20 years.

The costs for each strategy were also broken down for comparison on a unit cost basis. This is shown in Figure 3-14, borrowed from the Green Infrastructure Plan. Examining the cost per gallon of CSO reduction for each

FIGURE 3-14
Estimated Citywide Costs per Gallon of CSO Reduced

(NYC Green Infrastructure Plan, 2010)

respective alternative, the Grey Strategy is estimated to be the more expensive option (**$0.62** per gallon for Grey Strategy vs. **$0.45** per gallon for Green Strategy).

Figure 3-14 also further breaks down the cost per gallon of CSO reduction for each component of both strategies. These unit costs include:

Green Strategy ($0.45)

- Cost-Effective Grey Investments
- Reduced Flow
- Green Infrastructure
- Optimize Existing System

Grey Strategy ($0.62)

- Cost-Effective Grey Investments
- Potential Tanks, Tunnels and Expansions

As displayed, the cost per gallon of CSO reduced for the Green Infrastructure component is estimated to be considerably less than the cost per gallon of CSO reduced for the potential tanks, tunnels, and expansions of the Grey Strategy. Also, as discussed in the report, the overall Green Strategy is more of an affordable alternative as compared to the Grey Strategy in part because optimizing the existing system – a part of the Green Strategy – is the most cost-effective component-strategy.

Operations and Maintenance Cost Estimates

DEP also estimated and compared long-term operations and maintenance (O&M) costs to the City under both Green and Grey Strategy scenarios. O&M expenses evaluated included salaries, electricity and natural gas, contracts, supplies and equipment, as well as fringe costs. As shown in Figure 3-15, borrowed from the Green Infrastructure report, O&M costs for the Green Strategy would be higher in the initial years as green infrastructure controls are implemented relatively quickly. However, according to the estimates, O&M costs for the Grey Strategy would eventually outrun those of the Green Strategy as tanks, tunnels and expansions are completed and come online. Another factor contributing to this cost difference is energy costs, including electricity and natural gas expenses, which are not needed for green infrastructure but would weigh in much heavier under a Grey Strategy scenario.

Economic Sustainability Benefits

Further value-added advantages predicted by DEP as a result of implementation of the Green Infrastructure Plan include benefits related to a reduced urban heat island effect, greater recreational opportunities, energy savings, improved air quality, and higher property values. In addition, the Green Infrastructure Plan shows a greater distribution of funds to support maintenance-related activities in the form of salaries and benefits. For every year scenario, there is a greater distribution of monies to support jobs rather than to pay for utilities (electric and gas). This is an important finding as job creation is one element of sustainability that is often overlooked.

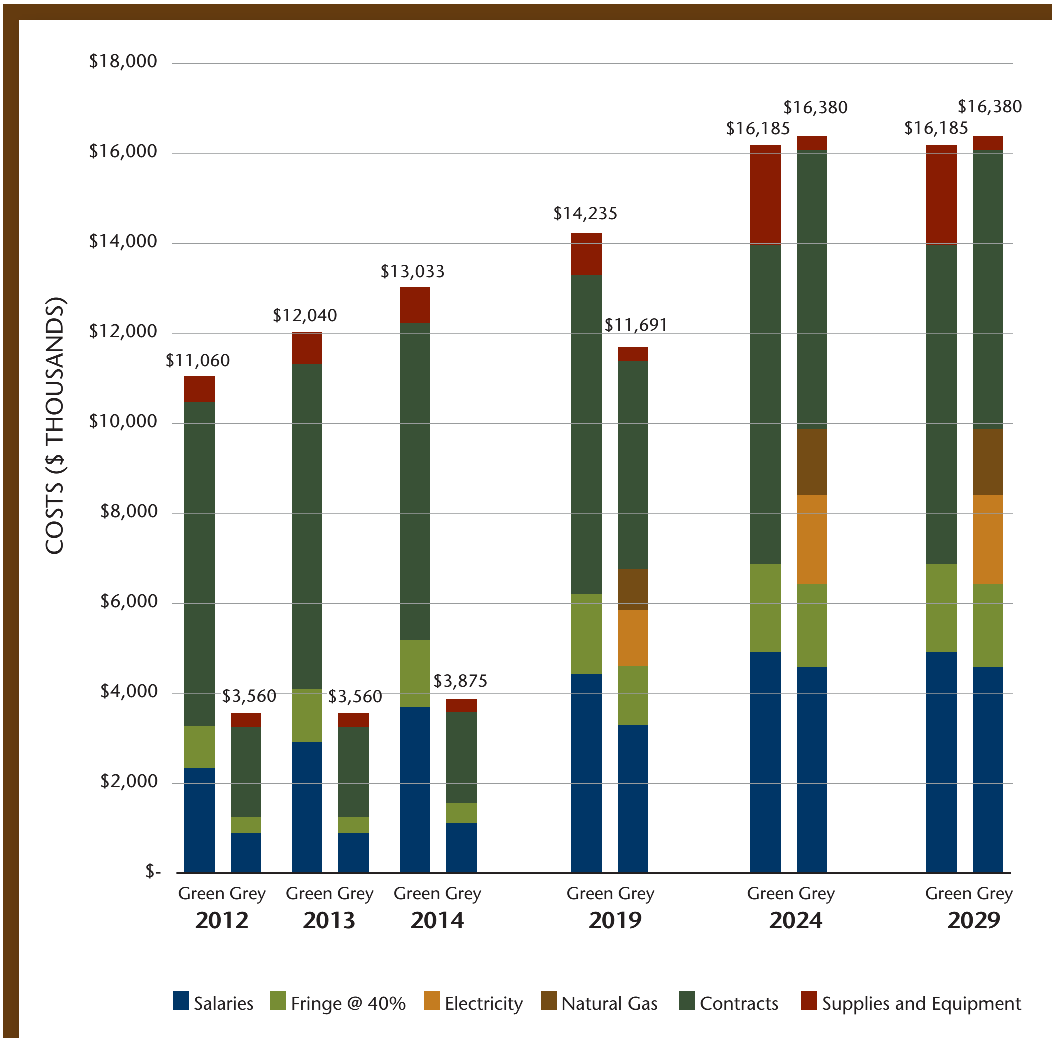


FIGURE 3-15
O&M Costs to the City of CSO Control Scenarios

(NYC Green Infrastructure Plan, 2010)

In order to estimate these dollar-based benefits, DEP first generated a working model to anticipate the amount of land that would be converted from impervious surfaces to planted areas. DEP's modeling efforts forecasted that the amount of total city-wide vegetated surface area by 2030 would range from 1,085 acres up to 3,255 acres. Of this range, DEP assumed that half of all planted green infrastructure would be fully vegetated (such as green roofs), with the other half partially vegetated (to account for a lower ratio of surface area in order to drain impervious surfaces in the right-of-way).

Next, DEP estimated a dollar per acre benefit for both fully and partially vegetated infrastructure controls. For this process, DEP used the economic values for street trees located in the *New York Municipal Forest Resource Analysis* (MFRA) as well as the energy benefit assumptions for green roofs in *Green Roofs in the New York Metropolitan Region,* as cited in the Green Infrastructure Plan. Utilizing these data, DEP estimated the annual economic benefits resulting from fully and partially

TABLE 3-10 New York City Annual Benefits of Vegetated Source Controls in 2030 ($/acre)

	Fully Vegetated	Partially Vegetated
Energy	8,522	2,504
CO_2	166	68
Air Quality	1,044	474
Property Value	4,725	4,725
Total	14,457	7,771

vegetated infrastructure controls on a dollar per acre basis in the year 2030.

The results of DEP's analysis are displayed in Table 3-10, which is taken directly from the Green Infrastructure Plan report. As displayed in the table, DEP estimates that in the year 2030, every fully vegetated acre will result in a total annual benefit of $14,457, with partially-vegetated acres $7,771 per year. This includes annual economic benefits from reduced energy demand, reduced CO_2 emissions, improved air quality, and increased property values.

Utilizing a combination of grey and green infrastructure strategies for CSO management can be considerably more economically viable than using grey infrastructure alone.

DEP also estimated a range of accumulated economic benefits from new green infrastructure controls over a 20-year implementation time frame. According to DEP's modeling efforts, the total accumulated sustainability benefits (through lower energy costs, reduced CO_2, better air quality and increased property values) will range from $139 to $418 million, depending on the amount of vegetation used in the source controls.

CONCLUSIONS

The previous examples show how incorporating a green infrastructure strategy with LID can help cities and municipalities reduce stormwater runoff volumes entering combined systems, lowering treatment costs. Also, as shown, utilizing a combination of grey and green infrastructure strategies for CSO management can be considerably more economically viable than using grey infrastructure alone.

This was clearly demonstrated in the City of Portland's Tabor to the River plan, which showed a cost benefit of $63 million to the city by the inclusion of green strategies in combination with a grey infrastructure approach for upgrading an undersized sewer pipe system in order to help control CSOs and improve sewer system reliability. An economic benefit potentially as much as $19 million was also estimated by the City of Kansas City for incorporating green infrastructure strategies along with a traditional grey infrastructure approach for the Middle Blue River Basin Plan, a part of Kansas City's city-wide Overflow Control Program.

An economic context for the use of LID was also established for the

City of Portland's overall approach for CSO management. The City of Portland determined that watershed health initiatives, which included LID and green infrastructure strategies, were cost-effective project alternatives for the city to implement as part of its approach for long-term CSO management.

Chicago's initiatives demonstrate the city's commitment to using green infrastructure for the purpose of CSO control. Although economically-based information depicting the future cost of construction for CSO separation was not available, the City of Chicago has shown a major reduction of stormwater volume to its combined system as a result of LID.

Additionally, New York City forecasted long-term performance and economic benefits by incorporating a CSO reduction plan that includes green infrastructure in combination with cost-effective grey infrastructure investments. New York City's estimates also included future economic sustainability benefits in the form of lower energy costs, reduced emissions, improved air quality, increased property values, as well as a greater distribution of operations and maintenance costs leading to the potential for more employment opportunities.

The projects and plans presented in this article establish an economical and performance-based benefit for LID and green infrastructure. Shown in the context of actual project designs, incorporating these strategies alongside grey infrastructure improvements can result in significant cost savings for cities pursuing and implementing CSO management. This article demonstrates the beneficial economic context for the implementation of green infrastructure and LID design for future CSO compliance projects.

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FACT SHEET

Historic and Projected Climate Change

Scientists from around the globe and across the US have recorded changes in the hydrologic cycle, a decline in glaciers and polar ice, and shifts in precipitation intensity and trends.

This evidence strongly indicates that the earth's climate is changing (Bates et al., 2008, Clark et al., 2009, and Lawler et al., 2009).

A widespread consensus of research amongst the world's scientists indicates that:

- Human activities are changing the composition of the Earth's atmosphere. Since pre-industrial times, increasing atmospheric levels of GHGs (greenhouse gasses) like carbon dioxide (CO_2) are well-documented.
- The atmospheric buildup of CO_2 and other GHGs is largely the result of human activities such as the burning of fossil fuels.
- A warming trend of about 1.0 to 1.7°F occurred from 1906-2005. Warming occurred in both the Northern and Southern Hemispheres.
- Major GHGs emitted by human activities remain in the atmosphere from decades to centuries leading to a high degree of certainty that concentrations will continue to rise over the next few decades.
- Increasing GHG concentrations tend to warm the planet.

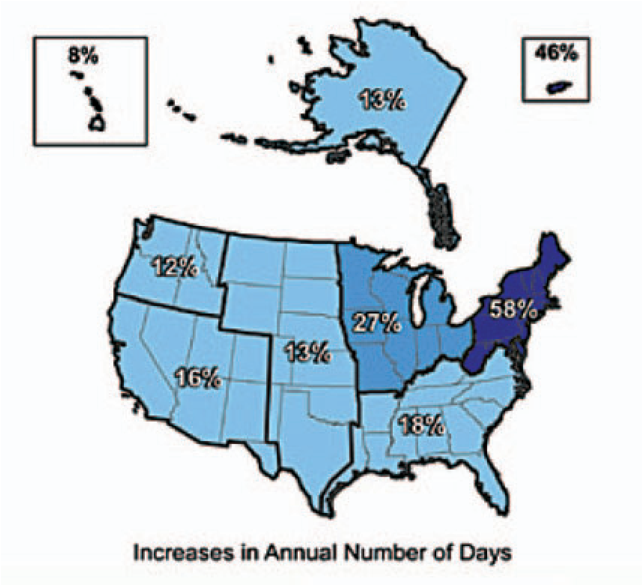
LONG-TERM CLIMATE RECORDS

Since last mid-century, CO_2 concentrations have increased dramatically. In the 1990s, global CO_2 emissions increased 1.3 percent per year, but since 2000, this rate has jumped to 3.3 percent per year. Data from the Mauna Loa Observatory, located on the island of Hawaii, indicates that current atmospheric CO_2 levels have risen approximately 138 percent above those of the pre-industrial period (Tans, 2010).

NATURAL AND HUMAN INFLUENCES

The long record of climate evidence found in ice cores, tree rings, and other natural records show that earth's climate patterns have undergone rapid shifts from one stable state to another within as short of a period as a decade. Paralleling the rise in global and regional temperatures are increases in the associated average precipitation and number of extreme storm events across the U.S.'s northern latitudes. Since the early 20th century, average precipitation has increased 6.1 percent. In New England from 1979 to 2000, there was a 20 to 28 percent increase in the average amount of rain that fell in a twenty-four hour period (Stack et al., 2005; Simpson et al., 2008).

INCREASE IN HEAVY RAINFALL EVENTS 1958-2007 (KARL 2009)



The northern states have shown trends over the last few decades that are associated with global temperature and precipitation change, including:

- Increase in frequency of intense storms
- Warmer winters
- Decreased snowfall
- Fewer days with snow on the ground
- Earlier spring runoff and later date of first frost
- Lake ice-out 9-16 days earlier
- Shifts in U.S. Department of Agriculture plant Hardiness Zones and earlier spring flower bloom dates
- More frequent summer drought periods

PROJECTED CHANGES IN CLIMATE (PRECIPITATION AND INTENSITY)

Based on building evidence from around the world, the United Nations created the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC released its Fourth Assessment Report (2007) assessing current climatic changes and projecting future climatic changes. This IPCC report is a culmination of decades of research and contributions from more than 1,200 authors and 2,500 scientific expert reviewers from over 130 countries.

According to multiple research efforts and studies, by mid-century across the northern tier of the U.S., the following can be expected:

- Temperatures will rise, with winters warming the fastest.
- The number of summer days exceeding 90°F will increase.
- Winter precipitation will increase with more precipitation falling in the form of rain as compared to snow.
- Summer precipitation will remain relatively the same.
- Snow-pack will not last as long and will melt earlier in the spring.
- The frequency of intense storms and storms with greater amounts of precipitation will increase.
- Rising temperatures will cause evaporation rates to increase, reducing soil moisture.
- The frequency of short-term summer droughts will increase.

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CHAPTER 4

Historic and Projected Climate Change

Since 1990 scientists have clearly demonstrated the increasing evidence of climatic impacts from increasing heat trapping greenhouse gases (GHG). Scientists from the U.S. and around the globe have registered "abrupt and rapid" changes that are occurring over decades including sustained modifications in the hydrologic cycle, rapid decline of glaciers and ice fields, shifts in major ocean currents, as well as significant increases in the rate of release of GHG and methane that had been trapped in the permafrost of the northern latitudes. This evidence strongly indicates that the earth's climate is changing (Bates et al. 2008, Clark et al. 2009, and Lawler et al. 2009).

The United Nations created the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC recently released its Fourth Assessment Report (2007) assessing current climatic changes and projecting future climatic changes. This IPCC report is a culmination of decades of research and contributions from more than 1,200 authors and 2,500 scientific expert reviewers from over 130 countries.

Recent research by Bates et al., Clark et al., and Lawler et al. (2008, 2009, 2009, respectively) indicates widespread consensus amongst the world's scientists that there is a virtual certainty that:

- Human activities are changing the composition of Earth's atmosphere. Since pre-industrial times, increasing atmospheric levels of heat trapping gasses like carbon dioxide (CO_2) are well-documented and understood.
- The atmospheric buildup of CO_2 and other heat trapping gasses is largely the result of human activities such as the burning of fossil fuels.
- An "unequivocal" warming trend of about 1.0 to 1.7°F occurred from 1906-2005. Warming occurred in both the Northern and Southern Hemispheres, and over the oceans.

> Scientists attribute observed global and regional temperature rises to the increase of greenhouse gas concentrations in the atmosphere, including CO_2. A warming atmosphere allows it to hold greater amounts of water vapor, which in turn influences both the increase in average precipitation as well as the associated increase in the frequency of large pre-cipitation events.

- Major GHGs emitted by human activities remain in the atmosphere for time periods ranging from decades to centuries. It is therefore virtually certain that atmospheric concentrations of GHGs will continue to rise over the next few decades.
- Increasing GHG concentrations tend to warm the planet.

LONG-TERM CLIMATE RECORDS

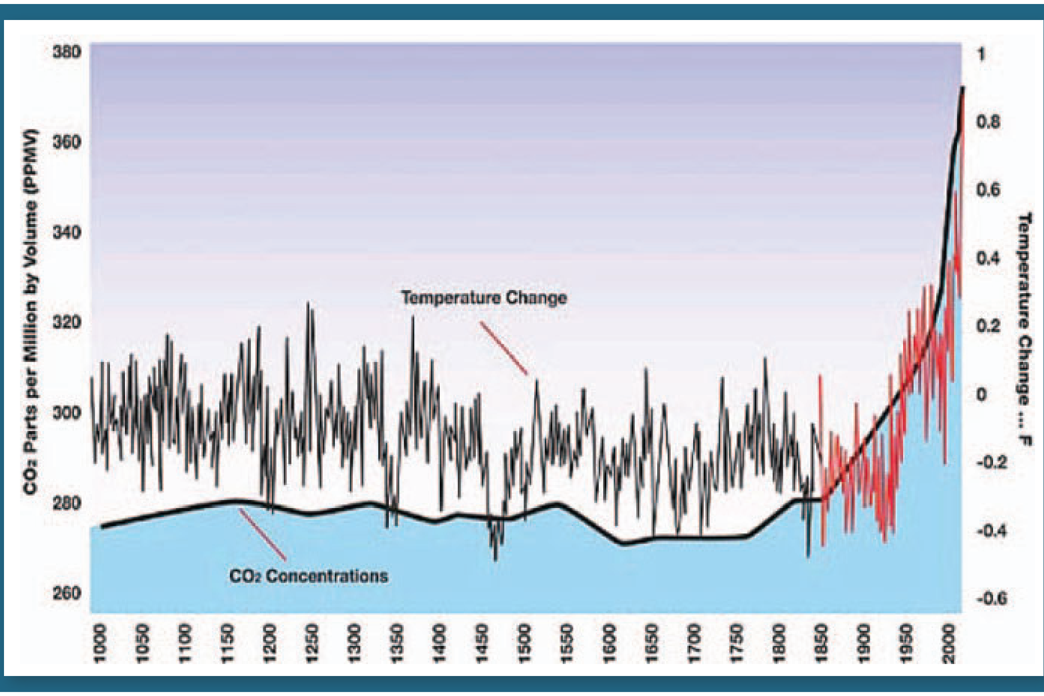
The Pew Center on Global Climate Change defines "greenhouse effect" as the insulating effect of atmospheric greenhouse gases that maintains the Earth's temperature. This effect is not only related to the concentration of CO_2 in the atmosphere, but also gases such as nitrous oxide, ozone, methane and even water vapor. These gases, in addition to others, have the capability of trapping heat within the atmosphere.

CO_2 concentrations as far back as 400,000 years can be explained by looking at historical concentrations of CO_2 gas trapped in Greenland and Antarctic ice. While historically, CO_2 levels very seldom exceeded a concentration of 280 parts per million (ppm), since last mid-century, a dramatic increase has occurred. A similar trend has been recorded for other gases as well, including methane (CH4) and nitrous oxide (N20) (Petit et al., 1999).

Once in the atmosphere, carbon derived gases can persist for only a few days or weeks, while others can remain a long time, continuing their influence on global warming. As an example, methane can last for decades, while CO_2 can persist for thousands of years (Archer, 2005). In the 1990s, global CO_2 emissions increased 1.3 percent per year, but since 2000 this rate has jumped to 3.3 percent per year. The latest data from the Mauna Loa observatory, located on the big

FIGURE 4-1
Concentrations of CO_2

(IPCC, 2007)



island of Hawaii, indicates that current CO_2 atmospheric levels have risen to a yearly average of 385 ppm, an increase of approximately 138 percent above the long-term, pre-industrial high of 80 ppm (Tans, 2010) (see Figure 4-1).

Over the last 1000 years, there has been a paralleling of global temperature fluctuations in concert with changes in CO_2. Examining oxygen isotopes and GHGs found trapped in ice cores of the Vostok Ice Sheet in the Antarctic, the relationship between global temperature and CO_2 is visible as far back as 400,000 years (Petit et al., 1999).

Scientists attribute observed global and regional temperature rises to the increase of GHG concentrations in the atmosphere, including CO_2. A warming atmosphere can hold greater amounts of water vapor, which in turn influences both the increase in average precipitation as well as the associated increase in the frequency of large precipitation events (Solomon et al., 2009).

NATURAL AND HUMAN INFLUENCES

At both the national and regional scale, yearly fluctuations in weather patterns occur that do not reflect the longer term trends seen in temperature or precipitation. Such fluctuations can be influenced by cyclical changes in ocean current temperatures or the eruption of volcanoes. Recently, scientists conducted a modeling experiment simulating GHG concentrations and the resulting impacts on temperature over the last century under a scenario without human influences. The modeling results indicated that by removing human influences, the atmosphere would have experienced cooling, rather than the observed rise in global temperatures due to anthropogenic sources (Hegerl et al., 2007).

EVIDENCE OF A CHANGING CLIMATE

The long record of climate evidence found in ice cores, tree rings, and other natural records show that Earth's climate patterns have undergone rapid shifts from one stable state to another within as short of a period as a decade. The occurrence of abrupt changes in climate becomes increasingly likely as human disturbance of the climate system grows (Meehl et al., 2007).

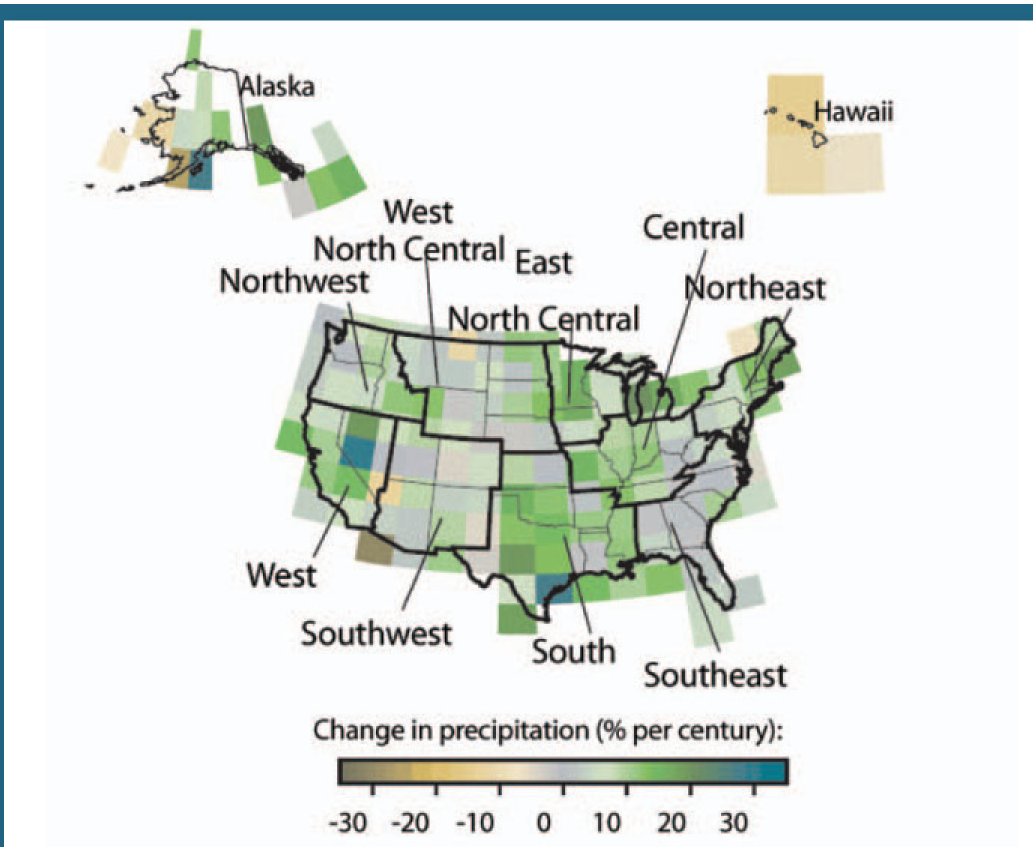
The NASA Goddard Institute for Space recently released a report which considers the climate close to a "tipping point," which is defined as a concentration of GHG in the atmosphere which can have disastrous impacts worldwide due to abrupt and dramatic changes in the climate (NASA, 2010).

Increases in Precipitation, Storm Intensity and Temperature

Paralleling the rise in global and regional temperatures are increases in the associated average precipitation and the number of extreme storm events across the U.S.'s northern latitudes. According to NOAA climatic records for the U.S., which has been collected from stations across the 48 contiguous states, average precipitation has increased 6.1 percent since the early 20th century. Figure 4-2, from

FIGURE 4-2
Average Precipitation Changes for the US

(NOAA Climatic Data Center)



the NOAA Climatic Data Center, shows where the greatest increases in average precipitation have occurred across the country. As depicted, the Midwest, North Central, South, and Northeast regions have experienced increases in precipitation of 10 to 20 percent since the early 20th century (Figure 4-2).

In looking at a more recent time frame, researchers from Antioch University New England analyzed weather records for specific locales in New England from 1979 to 2000. Over this time span, there was a 20 to 28 percent increase in the average amount of rainfall in a twenty-four hour period (Stack et al., 2005; Simpson et al., 2008).

Additional localized data analyzed in the northern states has shown similar trends over the last few decades that are associated with rising global temperature and precipitation changes. These include:

- Warmer winters
- Decreased snowfall
- Fewer days with snow on the ground
- Earlier spring runoff
- Lake ice out 9-16 days earlier
- Earlier lilac and honeysuckle bloom dates
- Shifts in U.S. Department of Agriculture plant Hardiness Zones
- More frequent summer drought periods

(Hodgkins et al., 2002, 2006; Wolfe et al., 2005; Wake and Markham, 2005; Hayhoe, 2006; Frumhoff et al., 2008; Backlund et al., 2008)

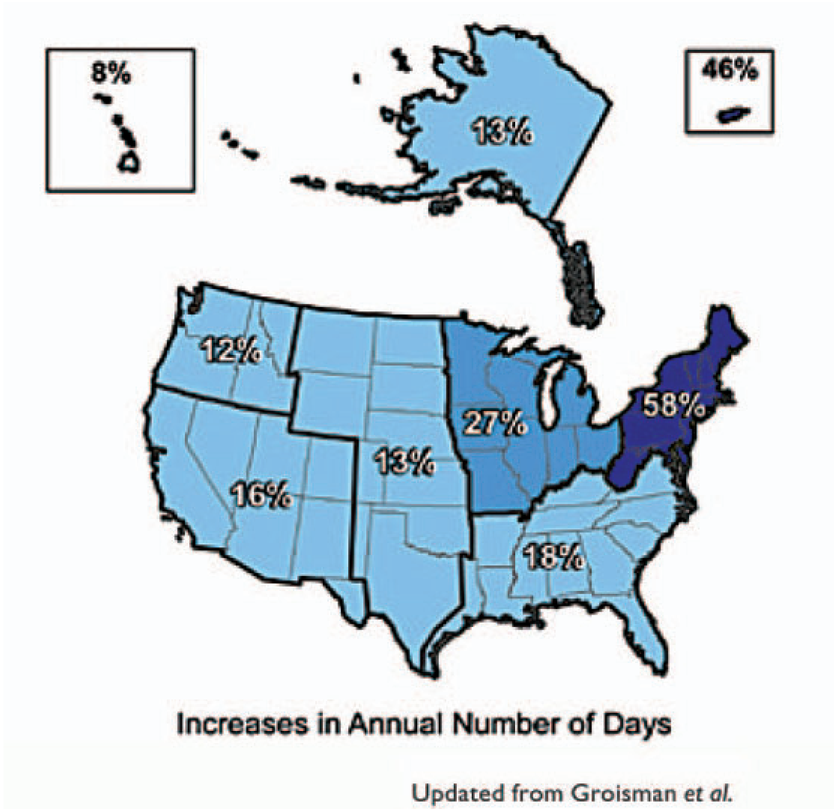


FIGURE 4-3
Increase in the Heavy Rainfall Events 1958-2007

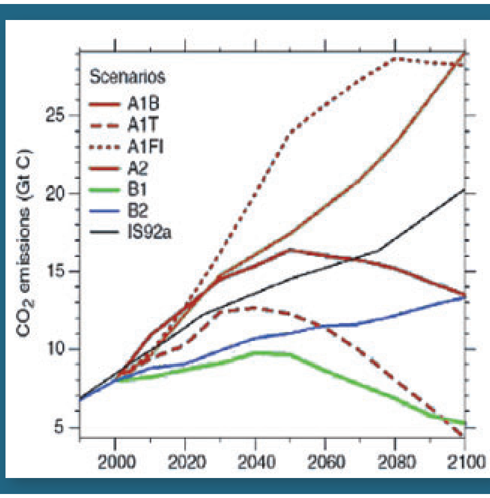
(Karl 2009)

Steadily rising average and extreme temperatures observed in the record of historical data, combined with increases in average precipitation and the number of extreme storm events (especially rain storms in the Northeast and Midwest regions), provide strong evidence of measureable changes in climate. The World Meteorological Organization (WMO) states that no single storm can be attributed directly to the increase in overall global temperatures. However, in looking at recent trends in New England data, there is a higher frequency of storms with greater amounts of precipitation which parallels trends over the same time period for increases in regional average temperatures and associated average rainfall. Figure 4-3 shows the percent increase of the largest one percent of all storm events in the U.S. over the last 50 years.

Since 2005, researchers in New England have documented 6 major storms crossing the states of New Hampshire, Vermont and Maine that have all exceeded the amount of rainfall expected for the 100-Year Storms, based on historical precipitation records. Two of those storms, one in the fall of 2005 and another in the spring of 2006, caused more than $1,300,000 in related property damage from associated flooding. Since 2005, record breaking storm events with associated flooding have also occurred in the Midwest, Great Lakes, and Northeast regions (Simpson, 2008; Wake, 2009; Karl, 2009).

FIGURE 4-4
IPCC Future Scenarios

(Nakicenovic et al. 2000)

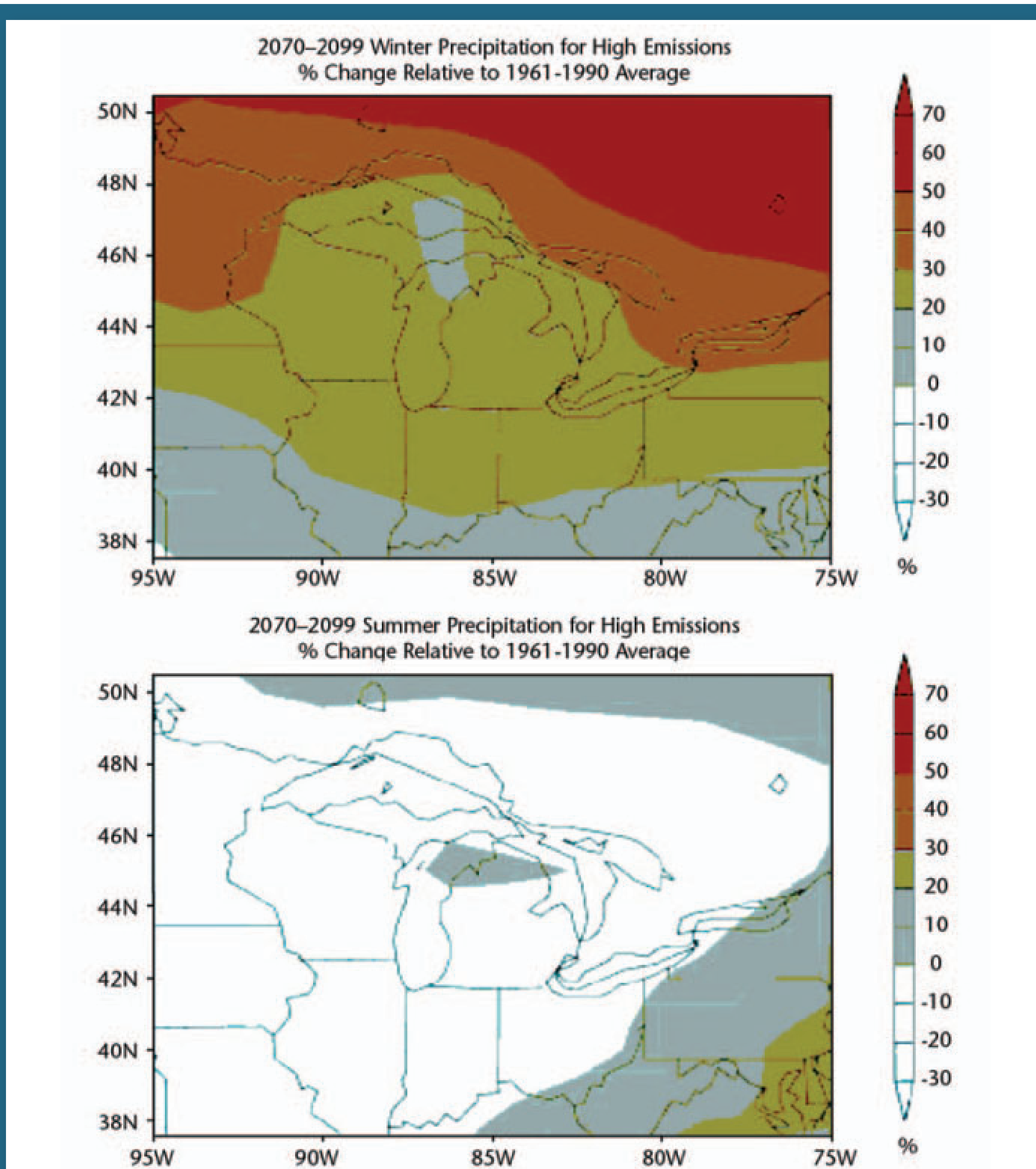


PROJECTED CHANGES IN CLIMATE

The IPCC considered a series of possible future outcomes in regards to energy, technology and land use in concert with various economic and population growth scenarios. (Nakicenovic et al. 2000) The following graph shows how these future scenarios would influence the release of CO_2 (Figure 4-4). A1Fi is considered "business as usual" or the

FIGURE 4-5
Midwest Shift in Seasonal Precipitation, Late 21st century

(Kling et al., 2003)



"fossil fuel-intensive" economic growth scenario, and projects CO_2 concentrations reaching 940 ppm by the end of this century – three times today's levels. B1 is also a high economic growth scenario but also includes economic shifts to less intensive fossil fuel use as well as introductions of resource efficiency strategies and technologies. Under this scenario, CO_2 atmospheric concentrations are projected to be at 550 ppm by 2100 (NECIA 2006).

The Kling et al. and the Union of Concerned Scientists determined the projected rainfall changes in the Great Lakes states, under a highly fossil fuel intensive scenario, is likely to bring wetter winters with more precipitation as rain by the second half of the century(Kling et al, 2003). Figure 4-5 shows that while the total annual average precipitation levels are unlikely to change, the seasonal distribution of rainfall amounts will shift. The projections include increasing precipitation as rainfall during winter seasons and summer months are forecasted to experience decreasing rainfall.

Overall, the Great Lakes region may eventually grow drier because increases in rain or snow are unlikely to compensate for the drying effects of increased evaporation and transpiration in a warmer climate. Under a high CO_2 emissions scenario, the Union of Concerned Scientists projects a 30 percent reduction in soil moisture as well as lower long-term average levels of surface and ground water. The paradox is that even in a considerably drier summer climate, the frequency of 24-hour and multi-day downpours, and thus flooding, may continue to increase (Kling et al., 2003).

Figure 4-6 depicts possible future scenarios developed by the IPCC in relation to precipitation patterns for the northern tier of the U.S. through the year 2099. As shown, this region will experience significant increases in

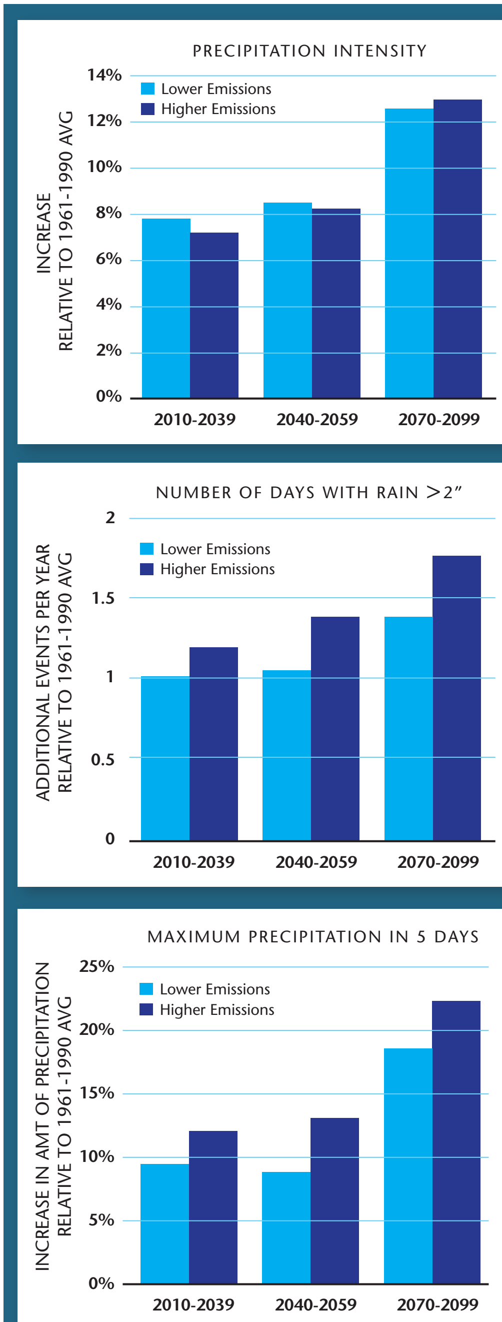
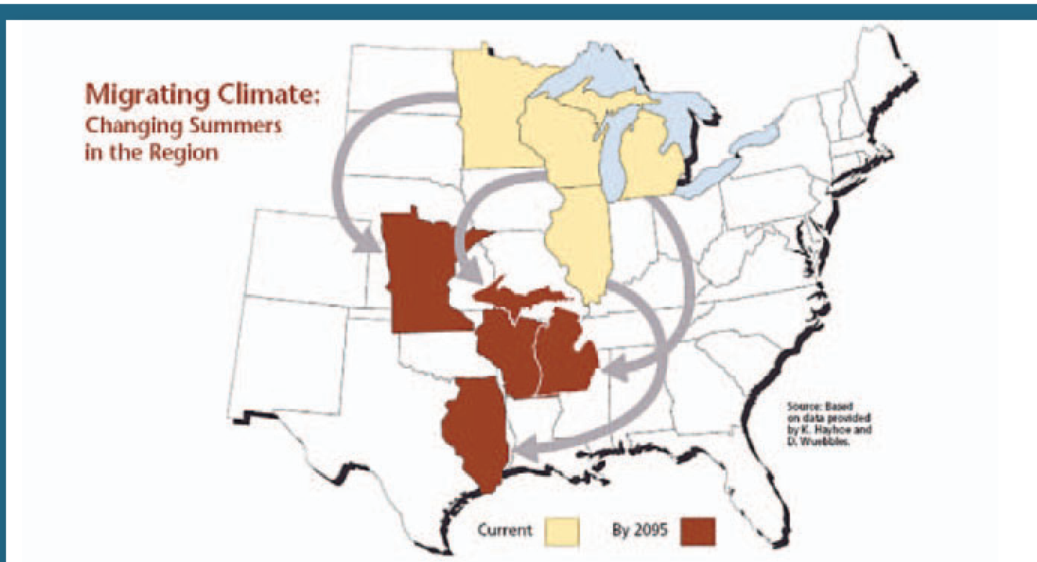


FIGURE 4-6
Midwest US
Precipitation Scenarios

(Bates, 2008)

FIGURE 4-7
Minnesota's Migrating Climate

(Kling, 2005)



the frequency and intensity of extreme precipitation events, especially under a higher emissions scenario.

The possible effects of a changing climate also include the potential for climate migration. According to a study by Kling, et al. using the IPCC scenarios, summer weather patterns characteristic of the North Central region are anticipated to have migrated south by the year 2095. As such, and illustrated in Figure 4-7, summer temperature and precipitation levels normally representative of Michigan could eventually be found in Arkansas (Kling et al, 2003).

CONCLUSIONS

Climate research provides evidence that, by mid-century across the northern tier and other parts of the U.S., the following can be expected to occur:

- Temperatures will rise, with winters warming the fastest.
- The number of summer days exceeding 90 degrees F will increase. In cities, which are heat-sinks, the number of summer days exceeding 100 degrees F will increase.
- Winter precipitation will increase with more precipitation falling in the form of rain as compared to snow, increasing the likelihood of high flow events in the winter months.
- Summer precipitation will remain similar.
- Snow-pack will not last as long and will melt earlier in the spring, resulting in increasing spring-runoff.
- Higher summer temperatures and corresponding increases in evaporation rates will result in extended low-flow conditions in streams.
- The frequency of intense storms and storms with greater amounts of precipitation will increase.
- Rising temperatures will cause evaporation rates to increase, reducing soil moisture in summer.
- The frequency of short-term summer droughts will increase.
- The combination of sea-level rise and increasing storm intensities will result in a greater frequency of coastal flooding.

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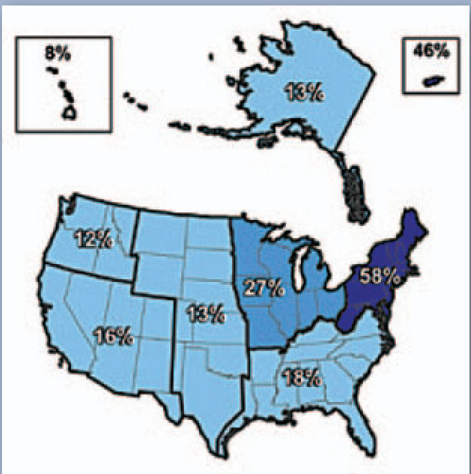
FACT SHEET

LID as a Climate Change Adaptation Tool

Low Impact Development can play an important role in climate adaptation planning for municipalities. Through the use of LID practices, resiliency can be planned into a watershed.

Through this century, climate projections show an increased frequency of larger precipitation events. This projected increase in higher rainfall events must be considered in the context of continued development of a watershed.

NOAA indicates that average precipitation has increased by approximately 6% in the lower 48 contiguous states. In regions of the Northeast and Midwest, the increase has been 10-20% since the beginning of the 21st century. Research has shown that an increase in average precipitation translates to a disproportional increase in frequency of larger precipitation events.



Increase in Heavy Rainfall Events: Annual Number of Days, 1958-2007

RESILIENCE

The ability of a system to absorb and rebound from weather extremes and climate variability and continue to function.

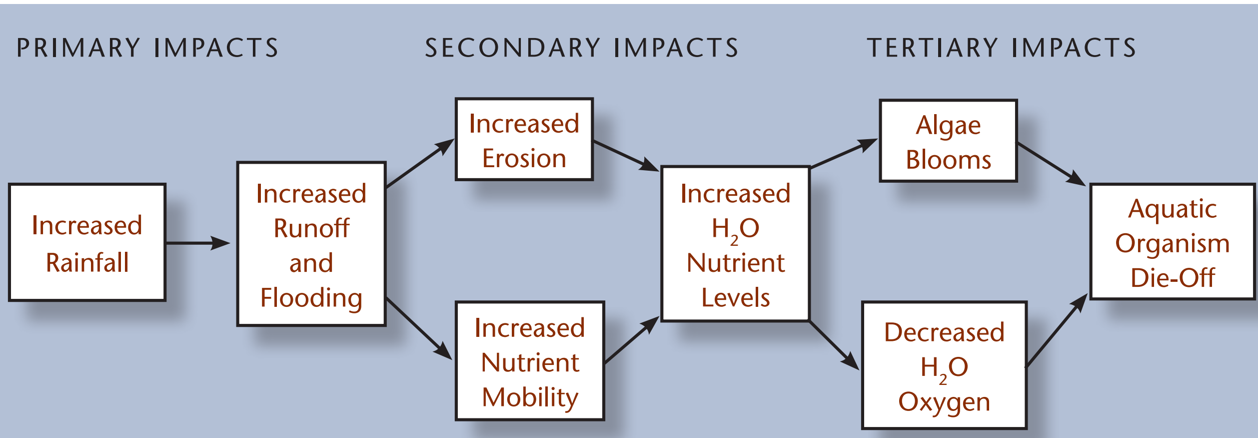
ADAPTATION

Any action or strategy that reduces vulnerability to the impacts of climate change. The main goal of adaptation strategies is to improve local community resilience.

As watersheds are developed, the increase in impervious surfaces results in a decrease in the ability of precipitation to infiltrate into soils. The addition of the dynamics of climate change to watershed build-out will result in increased runoff and in more frequent and higher flood waters, which can threaten both natural systems and built infrastructure.

At the municipal level, planning decisions should incorporate design capacities that can assimilate these projections. The option of not doing anything to prepare for climate change will increase risk to the community.

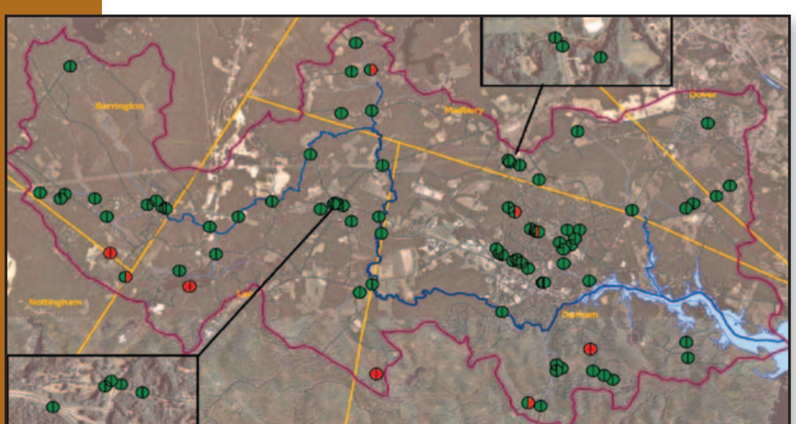
FORGING THE LINK



Primary, Secondary, and Tertiary Impacts Due to Climate Change Effects on Rainfall and Runoff

One study in New England provided an analysis of the changes in climate and related impacts to culverts, whose capacity had been designed based on historic designs storms. The study examined the use of LID to mitigate future impacts from increased runoff caused by both climate change and watershed development.

> LID systems can mitigate impacts from increased precipitation by
> - increasing infiltration,
> - reducing runoff volumes, and
> - delaying the runoff peak.



Culverts Analyzed Within the Oyster River Basin; red symbols indicate vulnerability.

The implementation of LID practices reduced the number of culverts determined to be undersized by 29 to 100 percent. Additionally, when considering the marginal cost increase to replace such undersized culverts, LID approaches were projected to reduce the total marginal cost increase across the watershed by one-third.

Per-Culvert Marginal Costs by Land-use Scenario, with Recent Precipitation Amount

Land Use	Marginal Cost Per Culvert	% Increase Over Current Land Use
Current	$2,952	—
Build-Out	$3,596	22%
LID	$3,372	14%

These results indicate that in addition to the water quality benefits of LID, wide-scale implementation can also build community resiliency and reduce the economic impacts from build out and increased precipitation trends.

FORGING THE LINK: Linking the Economic Benefits of Low Impact Development and Community Decisions • www.unh.edu/unhsc/forgingthelink
Chapter 5: LID as a Climate Change Adaptation Tool

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CHAPTER 5

LID as a Climate Change Adaptation Tool

Low Impact Development approaches are one type of adaptation tool that can be used to mitigate increases of runoff from changes in the intensity of extreme storm events. Projected changes in climate through this century and their impacts should be considered when planning for development and increased impervious surfaces in a watershed. LID stormwater management can add storage to the built landscape and maintains robustness of natural systems and contributes to the resiliency of the built infrastructure. LID approaches can play a key role to reduce the scale of impact of this projected increase in runoff.

INTRODUCTION

The state of the earth's climate has been a topic of extreme debate. However, there is near consensus that climate change is expected to continue through the 21st century, and that the magnitude of warming will disproportionately impact rainfall rates closer towards the poles, as opposed to the equatorial latitudes. For many regions of North America, projections are for an increase in the depth, frequency and duration of precipitation events. Concurrently, there are projections indicating sea level rise. Both of these projected changes can translate into significant environmental impacts to natural and human built systems (NRC, 2001).

There is near consensus that climate change is expected to continue through the 21st century, and that the magnitude of warming will disproportionately impact rainfall rates closer towards the poles, as opposed to the equatorial latitudes.

One reason for the debate about this issue is the misperception that climate change refers solely to human induced change. Rather, climate change is defined as: "*…changes in long-term trends in the average climate, such as changes in average temperatures*". The Intergovernmental Panel on Climate Change (IPCC) defines climate change as *"…any change in climate over time, whether due to natural variability or as a result of human activity"* (Pew Center on Global Climate Change). Climate change scenarios run by peer reviewed scientific research suggests that if current water resource management policies remain unchanged, the risk of flooding, infrastructure collapse, and damaging erosion will increase greatly over time (Miller and Yates, 2006; Simpson, 2006; Backlund et al., 2008; Falco et al., 2009; Brekke et al., 2009). Many municipalities are currently facing decisions about the construction or reconstruction of water resource infrastructure that will have a profound impact on the size, scope, cost of drainage, and relative risk years into the future. Many communities are looking for information as to how to allocate funds and how to implement guidance for incorporating climate change projections into their planning.

Hydrologic response from land use and climate change can vary from year to year and are often hard to differentiate. While land use change patterns are progressing towards higher percentages of impervious cover, historic climate change patterns have shown variation from decadal to thousands of years. However, the future changes being projected by scientists through the 21st century have implications to community water resource planning today. For most water resource planning, infrastructure development has a fixed design life. The concern is whether the capacity of this design will be adequate to assimilate the rapid changes in precipitation being currently projected by scientists.

Many municipalities are currently facing decisions about the construction or reconstruction of water resource infrastructure that will have a profound impact on the size, scope, cost of drainage, and relative risk years into the future.

Stormwater infrastructure is usually designed to safely pass the flows generated from a design watershed area for a 10-, 25-, 50- or 100-year storm event depending on the degree of importance of the site and the local regulations. The return interval for a given storm, within a specific geographical location, has an associated depth of rainfall. Specific storm sizes have a given possibility of occurrence in any one year, and are determined statistically based on regional historic precipitation records. Since any choice of a storm to drive water infrastructure decisions is based on probability, such a choice means designers are accepting a given amount of risk of failure with respect to the design capacity. The probability of having a storm event equaling or exceeding the design storm in a 24-hour period is known as a return period (T) and is associated with theories of acceptable risk. For example, driveway culvert installation may require designers and contractors to consider rainfall amount associated with a design storm with a 10-year return period. Often such requirements are incorporated in subdivision regulations at the municipal level. In this instance, the probability of a storm event equaling or exceeding the 10-year design storm in a 24-hour period in any given year is 1/T or 10 percent. If the infrastructure was associated with an arterial road and a culverted stream crossing with a large population center downstream, the risk associated with that same 10-year storm would not be acceptable and a larger design storm would be required such as a 50- or 100-year event.

NOAA Rainfall Frequency Atlases have not been updated for the northeastern United States since 1963, thus infrastructure design today relies on precipitation records that do not account for the last half century of rainfall patterns. However, Cornell University has begun to include rainfall data for this time period and has concluded that many of the design storms are significantly under estimating the actual volume of rainfall (Wilks, 1993).

Comparing the precipitation data from the first and second half of the last century in the Chicago area, Angel and Huff (1997) concluded that the rainfall intensities for the storm durations of interest would require statistically significant changes to infrastructure design. Increases of 28, 36, 43, 50, and 60 percent were observed based on modeling for return periods of 2-, 5-, 10-, 25-, and 50-years, respectively, when recent rainfall data was used over older data sets (Guo, 2006). According to Stack et al. (2005), who studied rainfall data for southwest New-Hampshire, and based on conservative climate change projections, the 10- and 25-year storms of the late 20th century (1970-2000) will become 25- and 100-year storms, respectively, by mid-21st century (2075).

Predictions of change in the design storm depths for the mid-21st century as well as changes observed from precipitation data over the half century from presently available literature are summarized in Figure 5-1.

NOAA Rainfall Frequency Atlases have not been updated for the northeastern United States since 1963, thus infrastructure design today relies on precipitation records that do not account for the last half century of rainfall patterns.

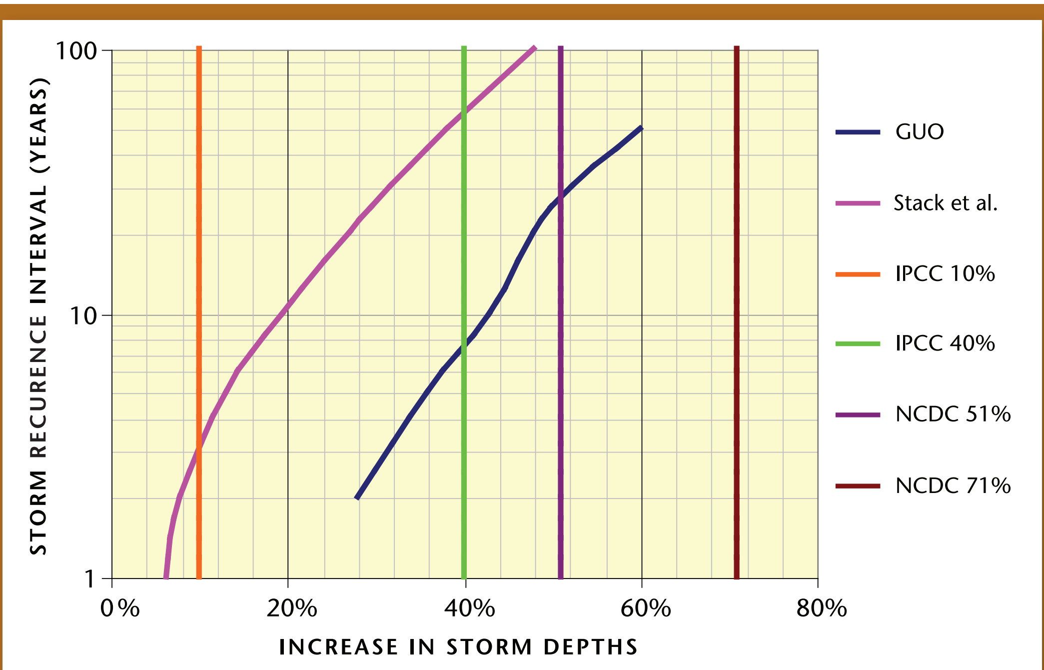


FIGURE 5-1
Changes in design storm depths predicted from different models of climate change

At the municipal decision-making level, local decisions should incorporate design capacities that can accommodate future rainfall projections, doing otherwise leaves a community unprepared. Scheraga (2003) noted that climate change adaptation need not wait for "perfect" science. Community leaders are adept at decision-making under conditions of uncertainty; indeed this is a defining characteristic of leadership.

CLIMATE CHANGE ADAPTATION, RESILIENCY AND VULNERABILITY

Adaptation is defined as any action or strategy that reduces vulnerability to the impacts of climate change. Resilience is defined as the ability of a system to absorb and rebound from weather extremes and climate variability and continue to function. This applies to natural systems as well as institutional structures (ASCE 2007; Moser et al., 2007). The main goal of adaptation strategies is to improve local community *resilience*, or the ability of a community to bounce back quickly from climate impacts. For society, the projected changes to climate will directly affect water supply and water quality and will require community preparation. Such preparation requires an assessment of the critical natural resource assets that should be preserved in order to mitigate potential future impacts. Additionally, infrastructure vulnerability studies and planning assessments of both institutional and technical options should be prepared

DEFINITION

Resilience

The ability of a system to absorb and rebound from weather extremes and climate variability and continue to function.

Major cities such as New York City, Chicago, and Seattle are assessing where their water supply, sewer, and waste water systems are vulnerable, while smaller cities, including Keene, NH and Alexandria, VA, have developed plans that reflect short and long term goals (Georgetown Climate Center, 2010). State and community initiatives are also expanding to address potential impacts to water supply and water quality as a result of sea level rise. Communities that choose not to plan for and institute adaptation strategies potentially accept a higher risk for their citizens into the future.

The initial step to any community adaptation plan is to identify the natural features that may provide resiliency for specific projected impacts. For example, increasing runoff has secondary and tertiary impacts to natural habitats, water quality, and built infrastructure. An assessment of the watershed properties that contribute to mitigating runoff should be identified and preserved. This may include recommendations that range from limiting development on steep slopes, to preserving wetland systems, to conserving areas with permeable soils and forested cover.

In addition to assessing the resiliency of natural systems, communities should determine infrastructure vulnerabilities.

This requires community leaders and citizens to work with scientists to understand the scale of the potential impacts. For example, this could include a determination of the capacity of a combined sewer system to handle increasing flows due to a higher number of rainfall events (Johnson 2008). In other instances, the variability of the climate may require communities to reassess the capacity of their reservoirs to withstand longer periods of drought or to determine the ability of their agricultural networks to support specific crops due to decreased water tables (USGS, 2009).

Vulnerability also translates into economic viability. Due to potential changes in climate on the timing and lengths of seasons, specific economic activities may be vulnerable. For example, 71 ski areas in 21 states have voiced concern to congress in regards to climate change-related impacts to their operations including lower natural snow bases, a decreased ability to create snow, as well as a reduction in operating days (NSAA 2010). The projection for a changing climate indicates that maple, beech, and birch forest types will be shifted further north. This will have a major impact to areas in New England where Maple sugar products contribute to local and state economies (Frumhoff et al., 2008). Trout, salmon and other cold water fishes are especially vulnerable to climate change, and the ecotourism and food industries dependent on these species may see a decrease in revenue coupled with increased costs over time (Williams, 2007).

> Communities that choose not to plan for and linstitute adaptation strategies potentially laccept a higher risk for their citizens into the future.

The projected impacts to natural systems, human infrastructure, and

FIGURE 5-2
Mill Pond Road after dam failure at Nottingham Lake, Nottingham, NH, 4/18/2007. Hanging in the picture is the guard rail and support posts for the washed-out road.

economic viability necessitates the need for a concurrent process of stakeholder education, networking, and coordination of efforts from the science, business, and community-level sectors to address adaptation planning and implementation. This adaptation planning must be in parallel with efforts to reduce emissions. The former effort is responding to impacts from past behavior, the latter is to mitigate how extreme those impacts will be into the future.

To assist communities with the challenges of climate change, the International Council of Local Environmental Initiatives (ICLEI): Local Governments for Sustainability developed the Cities for Climate Protection, a curriculum that outlines a framework for creating local climate protection plans. As part of this effort, the U.S. Department of Commerce, NOAA supported the development of the Climate Resilient Communities as a network to help local governments develop capacity to identify and reduce vulnerabilities from the threats of climate change.

Successful adaptation requires:

- Strong political leadership
- Institutional organization and coordination
- Active stakeholder involvement, including cross-cutting advisory groups
- Education and outreach programs
- Citizen engagement
- Appropriate and relevant climate change information
- Decision making tools, including consideration of barriers and challenges to adaptation approaches
- Funding for implementation of adaptation planning and actions
- Research into future impacts
- A continuous adaptive management approach

Municipalities, with their focus on health, safety, and welfare, can consider three main response options when approaching changes in climate and the resultant impacts to the community. These include:

1. Protect resources/systems from changes
2. Accommodate/adapt to expected changes
3. Abandon or retreat when accommodation or protection is not feasible.

The ICLEI Climate Resilient Communities report identifies milestones necessary for municipalities to achieve in order to establish a successful climate adaptation planning process. These include:

1. Study and assess climate information and resilience—collect local climate and weather data to determine if the community is capable of adjusting to changes in climate
2. Establish a community vision for future climate adaptation strategies.
3. Develop and implement an action plan—one that describes the actions and policies to be carried out including the timing, financing, and responsible parties
4. Monitor the efforts and re-evaluate the plan

Several communities have begun the process to create climate resiliency plans; focusing on the impacts to water resources and community response. The cities of Milwaukee, WI., Chicago IL., and New York City, NY., focused many of their efforts on stormwater infrastructure and invested in options that included increased Green

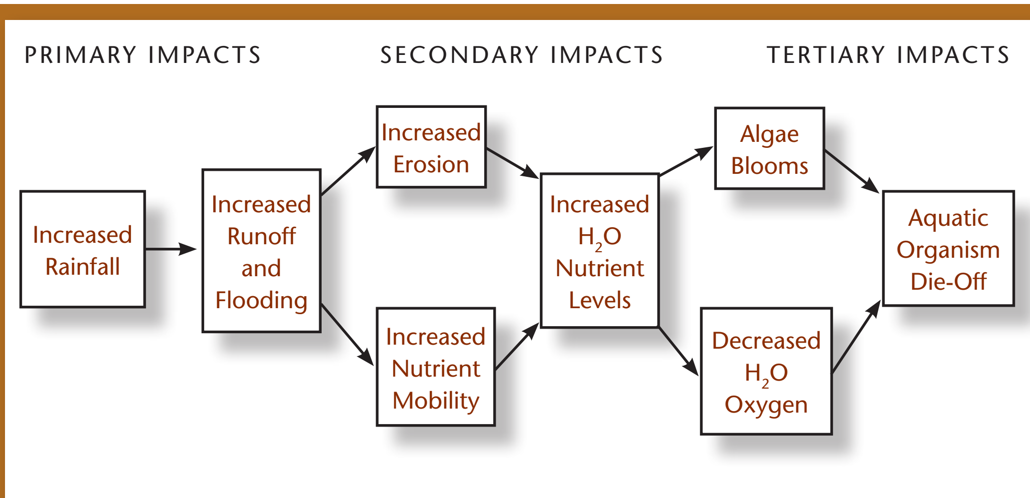


FIGURE 5-3
Primary, Secondary, and Tertiary Impacts Due to Climate Change

Infrastructure, additional storage for their Combined Sewer Overflow (CSO), and inlet control to reduce the volume of water entering the CSO.

CLIMATE CHANGE IMPACTS UPON WATER RESOURCES

A changing climate will alter the timing, duration, and frequency of extreme events. These changes will be of concern to municipal planners and local officials due to the resulting impacts to infrastructure and ecological health, as well as the associated financial costs to the community.

For example, as shown in Figure 5-3, increasing rainfall due to climate change will result in increased runoff. This, in turn, will lead to secondary impacts including increased erosion potential and a higher mobility of nutrients, such as nitrogen and phosphorus, into water bodies. Tertiary impacts may include an increase in nutrients, leading to algae blooms, reduced dissolved oxygen levels, and the possible loss of sensitive aquatic species.

Increasing Runoff, Erosion and Decreasing Water Quality

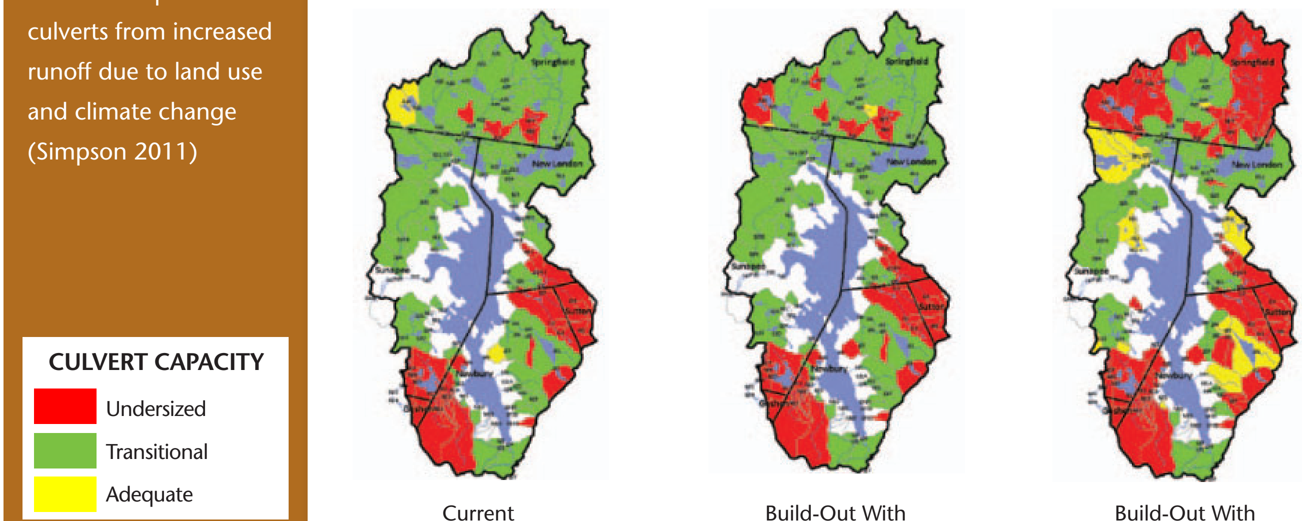
Runoff is an obvious immediate impact from an increase in rainfall and winter precipitation. Based on projections for certain regions of the country, there will be larger flows overland, as well as higher stream and river flows during storm events. This increased runoff will have secondary and tertiary impacts on both natural systems and man-made infrastructure.

As watersheds are developed, there is a corresponding increase in impervious surfaces and a decrease in the ability of precipitation to infiltrate into soils. Increased impervious surface results in an increase in runoff, larger stream flows, and a greater potential for

A changing climate will alter the timing, duration, and frequency of extreme events. These changes will be of concern to municipal planners and local officials due to the resulting impacts to infrastructure and ecological health, as well as the associated financial costs to the community.

FIGURE 5-4
Potential impact to culverts from increased runoff due to land use and climate change (Simpson 2011)

Culvert Catchments Vulnerability to Change in Landuse and Increased Precipitation
Lake Sunapee, NH Watershed, 2011



Current Conditions | Build-Out With Current Rainfall | Build-Out With Future Projected Rainfall

more frequent and higher flood waters associated with intense storms.

Figure 5-4 shows potential impacts to culvert and road crossings from increased runoff from impervious surfaces and climate change. Red areas indicate catchments where culverts are inadequately sized to handle projected increases in runoff. The figure on the left indicates those catchments that drain into culverts for current conditions of land use and current rainfall amounts, in this case for the 25yr-24hr storm event. The middle figure indicates vulnerable catchments draining into culverts when the watershed is built out to 75% of its capacity with current rainfall amounts. The figure on the right indicates which catchments become vulnerable with both a 75% build-out and projected mid-century rainfall amounts for the 25yr-24hr storm event.

Undersized culverts at road crossings can be impacted by an increase in erosion and sedimentation, which can affect downstream aquatic organisms and wetland habitat. Undersized culverts also contribute to road and associated infrastructure damage during large precipitation events because of the inability to convey increased volumes of water. In some cases, this may result in life threatening flash flooding events (Simpson, 2008).

Another secondary impact from increasing runoff from climate change is a greater amount of sediment from erosion. Where rainfall is projected to increase, the corresponding increase in erosion will be greater, and even in areas with projected decreases in precipitation, there will be a greater susceptibility to erosion due to increased storm intensity (Pelzhen et al., 2001; Yang et al., 2003; Nearing et al., 2004). Increased runoff causes stream instabilities, most notably incision and bank failures. This then causes property loss, loss of aquatic habitat, loss of aquatic passage, and impairments to infrastructure. Most of these will need to be addressed when they happen, often with public funds, making the case for resiliency all the more important.

The primary affect of increased soil erosion includes direct impacts upon natural habitats and associated sensitive species as a result of higher levels of scouring and sedimentation. There is a strong correlation between the movement of sediment and the mobility of nutrients and pollutants. The transport of nutrients and other pollutants into surface and ground water can have ecological and human health.

As the potential for erosion increases, so will nutrient and pollutant transport to the waters of the United States. Coping with the resulting physical, chemical and biological damages are anticipated to bring substantial financial costs to communities. One estimate, attributed to sediment impact, included financial costs of $16 billion to the country as a whole for addressing issues such as property damage, fish deaths, and degradation of drinking water sources. Sediment-related impacts will only increase with higher levels of precipitation into the future (Osterkamp et al., 1998).

LAND USE AND CLIMATE CHANGE RUNOFF HYDROLOGY

The design and planning community is becoming aware of the need to update design criteria information for municipal infrastructure. Changing storm depths, longer periods of record, and improved statistical evaluation of the frequency and duration of rainfall events is prompting updates in absence of information from the National Weather Service.

The Southeastern Wisconsin Regional Planning Commission recently updated design storm data (depth, duration, and frequency) after only 10 years of a previous update in recognition in part of the need to incorporate extreme rainfall events. The update provides information that in general increases design storm depths for use in stormwater and floodplain management and in the design of water infrastructure.

As the potential for erosion increases, so will nutrient and pollutant transport to the waters of the United States. Coping with the resulting physical, chemical and biological damages are anticipated to bring substantial financial costs to communities.

The City of Alexandria, Virginia has completed a study as part of their Storm Sewer Infrastructure Planning Program. Alexandria has experienced increasingly frequent flooding attributable in part to old infrastructure, and extreme rainfall events reflective of a changing climate. The city has commissioned a study to develop a flood control program which includes updated design storm data, evaluation of climate change risk, and identification of solutions that includes a combination of planning and Gray and Green Infrastructure.

An example of a Green Infrastructure project and climate change resiliency is Boulder Hills. This site is a low impact development (LID) adult condominium community in Pelham, New Hampshire which incorporates widespread infiltration measures including the state's first porous asphalt road and rooftop infiltration. With widespread sandy soils, the 14-acre site is ideal for infiltration and includes 5 buildings, a community well, and a private septic system, with a portion of the site containing wetlands in a 100-year flood zone. The roadway, all driveways, and sidewalks in the development are composed of porous asphalt, while the fire lanes, which consist of crushed stone, serve as infiltration systems for rooftop runoff. Prior to this LID design, a conventional site drainage plan was first proposed. These two designs (Figure 5-5) were compared side to side in order to perform an engineering costing study as well as model runoff hydrology. The modeled runoff hydrology is presented below to compare the impacts upon stormwater runoff for both post-development and for

FIGURE 5-5
Comparison of Two Site Drainage Designs, LID Design (top) and Conventional (bottom) for Boulder Hills, Pelham, NH

(SFC, 2009)

increased storm depths under potential climate change scenarios.

With Boulder Hills, LID planning and structural controls were used to minimize increases in runoff volumes due to development. However, this approach can also be used to manage increased storms size due to climate change. The same strategies that are used to provide infiltration and storage for land use changes can be used to mitigate impacts from changing storm depths. The usage of Green Infrastructure to add distributed storage and infiltration throughout a project has a cumulative effect on a watershed and can be used as an adaptation tool for building resiliency to extreme events. As will be illustrated here, increased resiliency can be achieved affordably by a combination of planning and structural controls.

Modeling

A conventional, event-based engineering hydrology analysis was performed for the pre-development, conventional, and LID designs. The hydrologic models are typical of standard civil engineering site design, and were used as part of the project design and permit. The authors are cognizant of the limitations of event based models, which are not intended to be reflective of the highest level of accuracy that is possible with continuous simulation, but rather, are indicative of engineering tools common to the permitting and design process.

The results in Figure 5-6 demonstrate both volume of runoff (blue) and volume infiltrated (orange). For the Boulder Hills site design, the recharge volumes for pre-development and the LID design are very similar, whereas the conventional design demonstrates a tremendous increase in storm runoff volumes. For the water quality volume (in most regions equivalent to the 1-inch, 24 hour rainfall event), many LID designs yield no additional runoff replicating pre-development conditions.

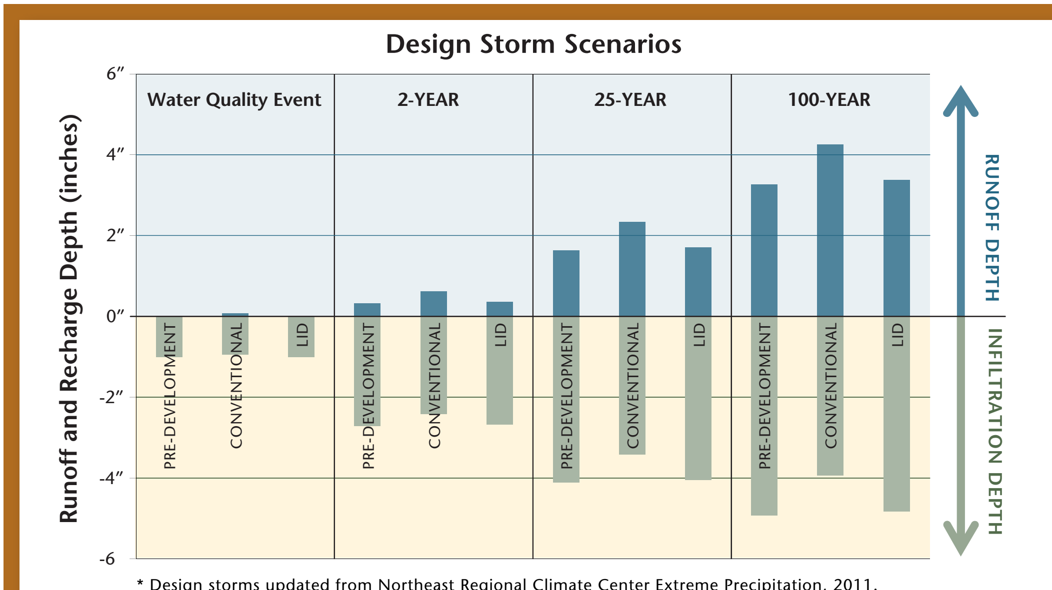


FIGURE 5-6
Benefits of LID as an adaptation measure. Comparing runoff and recharge depths for Pre-Development, Post-Development and Low Impact Development, Boulder Hills, Pelham, NH

TABLE 5-1
Values of design storm depths for present conditions and those predicted for the climate change scenario.

Design storm (year)	2	10	100
Climate Change Depth Increase (%)	17	28	45
Current depth in cm (in)	7.53 (3.01)	10.86 (4.35)	15.75 (6.3)
Increased depth in cm (in)	8.8 (3.52)	13.93 (5.57)	22.85 (9.14)

This is significant because in the New Hampshire region, 92 percent of the storms are less than 1-inch from which no runoff would be generated. For larger storms, runoff is observed, and it is notable that the volume retained with the LID condition is actually greater than pre-development. This impact is most notable with increasing storm depth, and in part, is due to added infiltration and storage built into the LID landscape as well as the tremendous lag time that occurs using porous pavements. These effects will be proportional to the storage provided. For example, using systems with less storage (i.e. rain gardens) would result in proportionally less storage.

Through the use of structural and nonstructural LID practices, the hydrologic characteristics of the Boulder Hills site were improved over that of a conventionally designed site by providing for additional storage in the LID systems, increasing infiltration, reducing runoff peaks, and delaying the runoff peak. The longer residence time of water in the stormwater systems allows groundwater recharge over a longer period, which in turn results in higher total volumes recharged per storm event. This is in contrast to conventional stormwater management practices, which are meant to collect, concentrate, and convey runoff off site. LID systems are commonly designed to retain, treat, and infiltrate the first inch of rainfall runoff while higher storm depths are by-passed. However, the use of porous pavement systems adds substantial storage capacity because they are usually designed to serve for transportation function (load capacity and resistance to frost depth in cold climate zones) as well as for stormwater management. In most cases, the sub-base designed for these structural criteria allows for retention of as much as 10 inches of direct rainfall for the pavement surface. This represents additional resiliency and explains why the peak flow rates and runoff volumes for the LID site are lower than pre-development conditions. Similar improvements could also be expected to a varying degree for higher density sites with similar system and site characteristics.

The modeling results shown here have not been calibrated, as the site is not monitored. The site appears to function at least as well as modeled. With the exception of a small swale on the perimeter of the site, no runoff from the site has been observed since its installation in the fall of 2009. This includes storm events exceeding 3 inches over a 24 hour period.

CASE STUDIES

CLIMATE CHANGE ADAPTATION & WATER RESOURCES MANAGEMENT

The following examples are two New England communities faced with addressing the challenges of changes in climate: Keene, NH and the Oyster River basin in New Hampshire's Great Bay watershed.

KEENE, NH

Piloting the ICLEI Local Governments for Sustainability, Climate Resilient Communities Program

FIGURE 5-7
Keene , NH

Photo by
Michael Hussey

The Town of Keene, NH is a community of approximately 23,000 residents in the southwestern portion of the state and is home to both Keene State College and Antioch University New England. Keene has a total land area of approximately 38 square miles and is in the Connecticut River valley between the Green Mountains of Vermont and White Mountains.

The Town of Keene signed on to pilot the ICLEI Cities for Climate Protection Campaign in April of 2000 to develop a Local Action Climate Plan and was the first of five U.S. cities to participate in the ICLEI Climate Resilient Community (CRC) Program. The Plan is intended to address changes in climate that will continue to affect the community, and to identify the necessary steps that are needed to mitigate and adapt to those changes. ICLEI's CRC Program partnership with Keene provided valuable technical assistance to the

ICLEI - Local Governments for Sustainability is an international association of local governments as well as national and regional local government organizations who have made a commitment to sustainable development.

ICLEI provides technical consulting, training, and information services to build capacity, share knowledge, and support local government in the implementation of sustainable development at the local level. The basic premise is that locally designed initiatives can provide an effective and cost-efficient way to achieve local, national, and global sustainability objectives.

community to conduct the process necessary to develop their plan.

The Town of Keene felt it was their responsibility to address community health, safety, and welfare issues associated with changes in climate and identified their plan to include areas that would affect short and long-term energy security, food security, air quality, public health, employment, and economic welfare. The town accomplished the first step of the resiliency plan by initiating the plan development effort.

The Town of Keene followed the CRC plan development process by conducting a vulnerability and risk analysis of the existing community resources. This included identifying community resource assets of the built social and natural environments. Community participation was very important in the development of these categories and in determining relative importance.

The town followed with an assessment to determine the vulnerability of each category to changes in climate, and defined a set of goals, targets, and actions relevant to each. To establish ranked priorities for actions and begin the formal goal setting process, the town and stakeholders placed each target against a series of criteria to determine relative value. Upon completion, the ranking permitted the development of the actual plan, which identified the actions and policies needed to establish the town as a climate resilient community. The final stages of the process included the implementation of the plan (with identified roles and responsibilities) and the monitoring of progress of implementation.

Overall, the plan addressed a wide range of categories for the community to address over time to become a climate resilient community. The plan included the categories of: the Built, the Natural, and the Social Environments with detailed targets respective to each. The category relevant for the purpose of this case study was the considerations to the Built Environment in the areas of Buildings, Transportation Infrastructure, and Stormwater and Wastewater Infrastructure. The recommendations (specifically identified below) include language supporting the implementation of increased stormwater capacity, LID, Green Infrastructure, smart growth principles, and LEED standards.

SECTOR 1: THE BUILT ENVIRONMENT

OPPORTUNITY: Building and Development

GOAL: Reduce the likelihood of structural damage resulting from predicted increases in severe weather events.

TARGET: Identify a 200-year floodplain and prevent future development in these areas.

GOAL: Make all new development in Keene "green" (i.e. sustainable)

TARGET: Incorporate sustainable stormwater design and management techniques to lessen the ecological footprint of new development, and take into account the potential for greater storm loads, by 2012.

GOAL: Lower the ecological footprint of existing buildings.

TARGET: Update City code to include green building standards for all major renovations, in a fashion consistent with Goal A outlined above, by 2012.

Update the City's Infrastructure Standards to ensure public safety in the event of major flooding or severe storm events.

GOAL: Reduce sprawl and promote infill development/redevelopment.

TARGET: Identify areas within the City that have infill or redevelopment potential and are outside an area of potential significant impact to flooding. Aim to have 50 percent of these areas developed by 2027. Adopt smart growth principles in the comprehensive master plan to support this goal, which provide for growth boundaries to avoid new or continued development in areas that are deemed high risk through a vulnerability assessment.

TARGET: Revise conservation subdivision regulations to create incentive for the developer to provide greater densities and community services in this type of development, while achieving open space conservation. Devise incentives to foster infill development in areas within the City that have been identified as being at low risk for flooding.

OPPORTUNITY: Transportation Infrastructure

GOAL: Design and reconstruct roadways to handle changes in temperature and precipitation as a result of a change in climate.

TARGET: Change design requirements for new or refurbished roadways to include different pitches combined with stormwater design and/or use of more permeable surfaces to effectively remove water from the roadway.

OPPORTUNITY: Stormwater Systems

GOAL: Safely and efficiently remove stormwater from the built environment.

DEFINITION

A Green Street is a street right-of-way that, through a variety of design and operational treatments, gives priority to pedestrian circulation and open space over other transportation uses. The treatments may include sidewalk widening, landscaping, traffic calming, and other pedestrian-oriented features. The purpose of a Green Street is to enhance and expand public open space, and to reinforce desired land use and transportation patterns on appropriate City street rights-of-way.

TARGET: Work with the Regional Planning Commission to create a regional management plan for future stormwater runoff levels. Aim to develop and have all municipalities endorse or adopt the plan by 2015.

Research, create, and begin the implementation of a green streets and a sustainable infrastructure program in Keene, similar to those developed by the City of Portland, Oregon and the City of Seattle, Washington by 2012.

Adequately assess the need for new culvert capacity in the City; identify where capacity and infrastructure upgrades are needed; and begin a replacement program.

Include the reassessment of stormwater infrastructure into the City's Comprehensive Master Plan and Capital Improvement Program to replace failing or antiquated infrastructure (inclusive of Three Mile Reservoir, Ashuelot River, Surry Mountain, and Otter Brook dams).

Approach Army Corps of Engineers for reassessment, using climate change scenarios, of the capacity of existing dams and recommend changes to ensure the ability of these systems to withstand increases in precipitation by 2009.

Devise and implement a process for coordination of stormwater, utility, and streetscape improvements to occur in sync with the City's capital improvement schedule for road repairs by 2009.

Identify stormwater treatment and management standards to minimize discharge from private property and from public improvement projects.

GOAL: Decrease stormwater runoff and flash flooding.

TARGET: Foster innovative storm water design requirements (on and off site) and include these in site plan requirements.

Adopt a Net Zero Runoff site plan requirement.

Identify areas where increased infrastructure capacity is needed to hold/divert water and include replacement or upgrade in Capital Improvement Program.

OYSTER RIVER BASIN

An Analysis of the Cost Impact to Water Conveyance Infrastructure

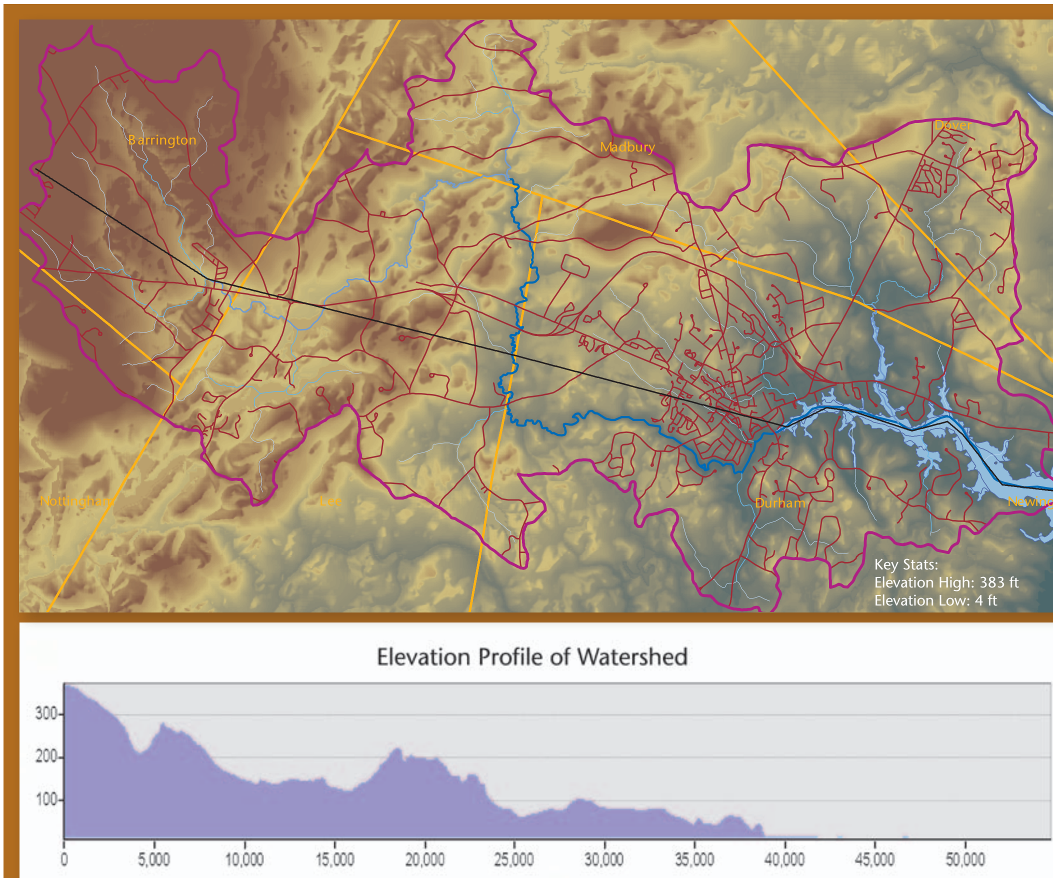


FIGURE 5-8
Relief of Oyster River Basin

The Oyster River Watershed is a 19,857-acre watershed and is a significant source of freshwater for the Great Bay estuary on the New Hampshire coast. The watershed is within coastal New Hampshire, and includes portions of six townships, although only four have significant land area within the watershed.

In 2000, the population density was 304 persons per square mile (United States Census Bureau, 2010). Population growth, at 8.6 percent, has been vigorous, for the eight years ending 2008, equaling 10.8 percent per decade. This exceeds the growth rate through the 1990s of 0.8 percent per decade. At this rate, the population will be 40 percent greater by 2046, the beginning of the thirty-year climate-changed period modeled in this study, and 70 percent greater by 2075, the end of the thirty-year climate-changed period.

Durham has the largest population among towns in the watershed. The Durham 2000 Master Plan projects that full build-out will occur by 2028 (Town of Durham, 2000). The negative impact of recent growth on hydrology is indicated by the change in percentage of impervious surface from 1990 to 2005. This increase signifies significant impacts for the installed drainage system,

FIGURE 5-9
Oyster River Watershed, New Hampshire

elevating the importance of quantifying these impacts and investigating the potential for techniques such as LID to mitigate increased runoff.

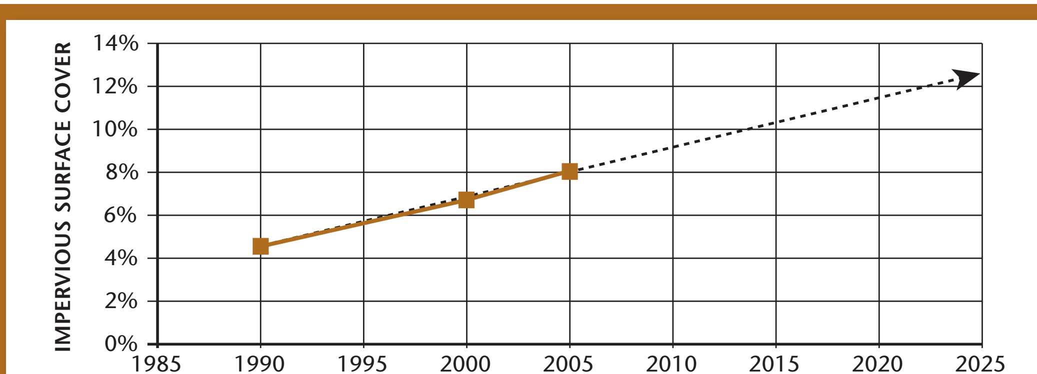
Antioch University of New England initiated a study in order to provide an analysis of the changes in climate and related impacts to stormwater conveyance infrastructure. In collaboration with the UNH Stormwater Center the project examined land use impacts and the use of Low Impact Development as an adaptation tool. The University worked with the towns within the watershed to develop a climate change scenario, which included costing estimates for improving the conveyance system to compensate for the changes in hydrology. Two dams on the Oyster River have insignificant storage capacity and little impact on river hydrology. However, the lower dam creates a boundary between freshwater and tidal portions of the river.

PROJECT DESIGN

The study utilized a geographic information system (GIS)-based watershed modeling approach to examine the hydrological impact on existing culvert infrastructure of several climate change and land use scenarios. Field data was collected on culvert capacity, vegetation cover, slope, soils, permeability, roads, and land use. The project applied standard hydrological assessment methods, including the Natural Resources Conservation Service (NRCS) NRCS Curve Number and TR-55 methods, to estimate runoff volumes and peak flows under current and projected future precipitation and land-use patterns (Stack et al., 2010).

The project consisted of five separate analyses: runoff/peak-flow under current

FIGURE 5-10
Actual and Projected Imperviousness in Oyster Basin



conditions; recent and climate-changed design storm; culvert reverse-engineering and required future capacity; 100 percent build-out under current and LID influenced zoning standards; and replacement cost analysis.

Two full build-out analyses were developed to form the basis for the scenarios, both of which were based on current zoning ordinances. The first scenario assumed future development consistent with existing construction practices that minimally limit runoff and impervious surfaces. The second scenario factored in a built-out condition based on the application of a realistic set of LID methods to the existing zoning ordinances.

Changes to runoff rates were estimated from a build-out analysis of the study area to the current minimum zoned lot size, and from a build-out based on the application of a realistic set of LID methods. To estimate drainage system functioning, these results were measured against the present capacity of the existing system of culverts. For culverts identified as undersized, a simple modeled approach that used standard civil engineering principles was conducted to achieve the estimated runoff rate and construction costs.

Because up-sizing of drainage systems has been shown as the most costly method for managing increased runoff from climate change, a second build-out scenario applied a set of realizable LID techniques to determine the capacity of runoff management methods for reducing adaptation costs (Blankensby et al., 2003).

Replacement and marginal costs were developed using standard construction cost estimating procedures and unit cost rates. Individual culverts were ranked according to vulnerability and potential hazard to the community, in order to provide leaders with a prioritized schedule for guiding the planning of LID ordinances and culvert upgrades.

PRECIPITATION

The adequacy of the existing drainage system is a function of several hydrological variables, including the precipitation intensity-duration-frequency (IDF) relationship. This relationship is specified by New Hampshire Department of Public Works and Highways regulations (NHDPWH, 1996) and states the design storm must meet the 4 percent probability (once-in-25-year) of rainfall to be received within 24 hours.

Table 5-2 indicates the design rain-fall depths used in the runoff model for current conditions (baseline) as well as projections for climate change (A1b–Balanced Growth and

TABLE 5-2 Rainfall Design Depths from Climate Change for Oyster River Infrastructure Vulnerability Assessment

25-YEAR, 24-HOUR PRECIPITATION (IN.)				
	TP-40	1971-2000 (Baseline)	2046-2075 (A1b)	2046-2075 (A1fi)
+95% c.i.	5.1	7.46	9.53	12.22
"most likely"		5.37	6.86	8.35
-95% c.i.		3.85	4.92	5.66

A1Fi–Fossil Fuel Intensive Growth) in the Northeast.

For the study site, 25-year, 24-hour precipitation for recent and climate-changed scenarios (A1b & A1Fi) were modeled. As seen in the previous table, the Baseline is the actual recorded data from 1970 to 2000 illustrating an increase in precipitation, and also demonstrates the A1b and A1fi projected changes to both volume of rainfall and rate of increase.

CULVERT DATA

Culverts are designed to convey flows of water through (usually) manmade obstructions, such as roadways or railway embankments. Typically, a culvert is designed to convey the maximum or peak flow (QP) from a specified design storm, established by New Hampshire standards as the once-in-25-year, 24-hour precipitation amount.

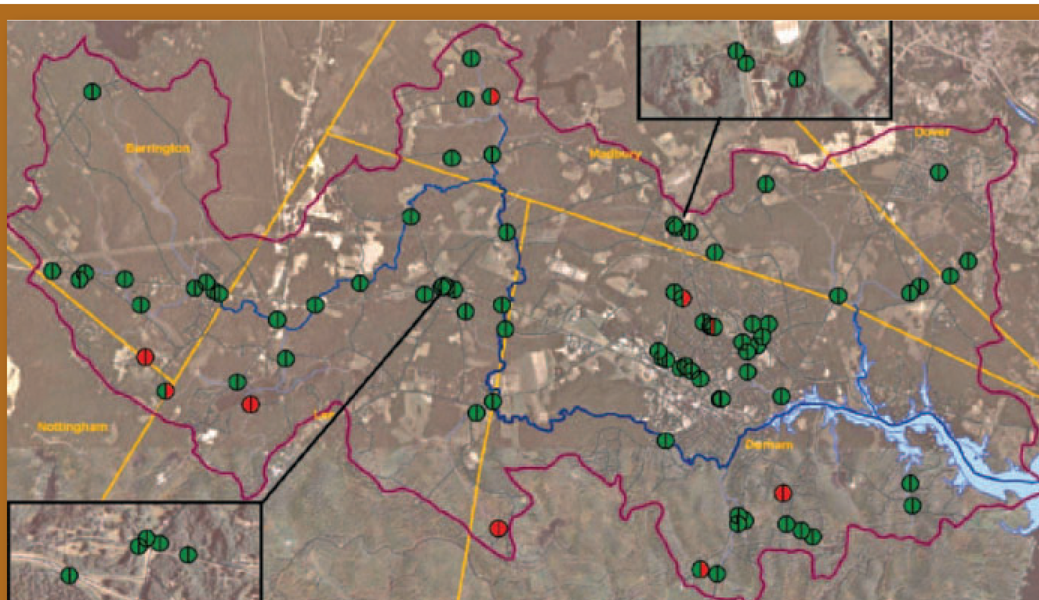
An inventory of culverts in the Oyster River was conducted to determine the model culvert capacity. For each catchment in the watershed and each precipitation and land-use scenario, the culvert model estimated the minimum required cross-sectional area needed to safely pass estimated QP. The required cross-section was compared with the actual cross-section of the culvert currently in place in order to determine the adequacy of the current culvert.

BUILD-OUT PROJECTION

Population growth is evident on the landscape as demonstrated by the increase in development of commercial and residential real estate. The future development condition is determined by zoning plans and regulations enacted at the municipal level. By referencing the existing zoning map, a community build out scenario may be developed.

To better understand the impact of population growth on hydrology, a modeling effort was performed using a complete build-out of the Oyster

FIGURE 5-11
Culverts Analyzed Within the Oyster River Basin; red symbols indicate vulnerability



River watershed to current zoning standards. This scenario permitted the development of an estimate for the adequacy of the existing culvert system to accommodate projected impacts from population growth. Additionally, it allowed the creation of a baseline standard development to which LID methods for new development could be applied.

Utilizing a combination of GIS and aerial photo interpretation, current building practices were determined to establish the typical development conventions within the various zoning density districts. These photos had enough resolution to identify key features associated with each land-cover attribute, including the footprint of primary and secondary structures on a site, impervious surfaces (e.g. patios, driveway, etc), semi-impervious surfaces (e.g. unpaved driveways), lawns, as well as forests. Landscape and building features identified by these analyses were mapped to standard land cover categories and combined with soil hydrologic classification. The output was the curve number calculation, which drove the calculation of runoff for particular rainfall depths.

LOW IMPACT DEVELOPMENT ANALYSIS

In order to study the capacity of runoff reduction methods for mitigating impacts of climate change and population growth, results from the standard build-out were modified by applying LID principles.

In essence, the incorporation of LID at the parcel level for each zoning district within the study area effectively changes the curve number that dictates

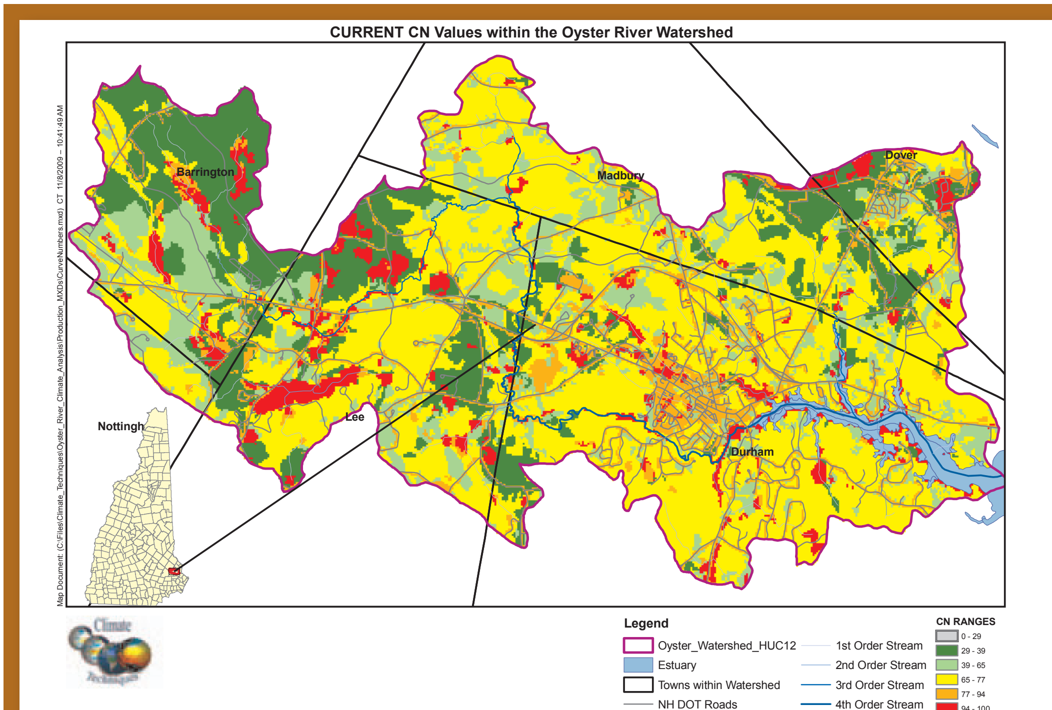


FIGURE 5-12
Curve Number Spacial Analysis for a Built-out Watershed

TABLE 5-3
Estimated Runoff Coefficients with LID

		Curve Numbers by Soil Group			
Zoning District	Lot Size (sq ft 000)	A	B	C	D
Commercial/Business		62	74	83	88
Industrial		62	74	83	87
Residential Acres:					
1/8	5.4	61	74	82	85
1/4	10.9	50	68	78	82
1/3	14.5	48	66	77	82
1/2	21.8	44	63	75	80
1	43.6	43	62	74	80
2	87.1	42	61	74	80
5	212.8	42	61	74	80

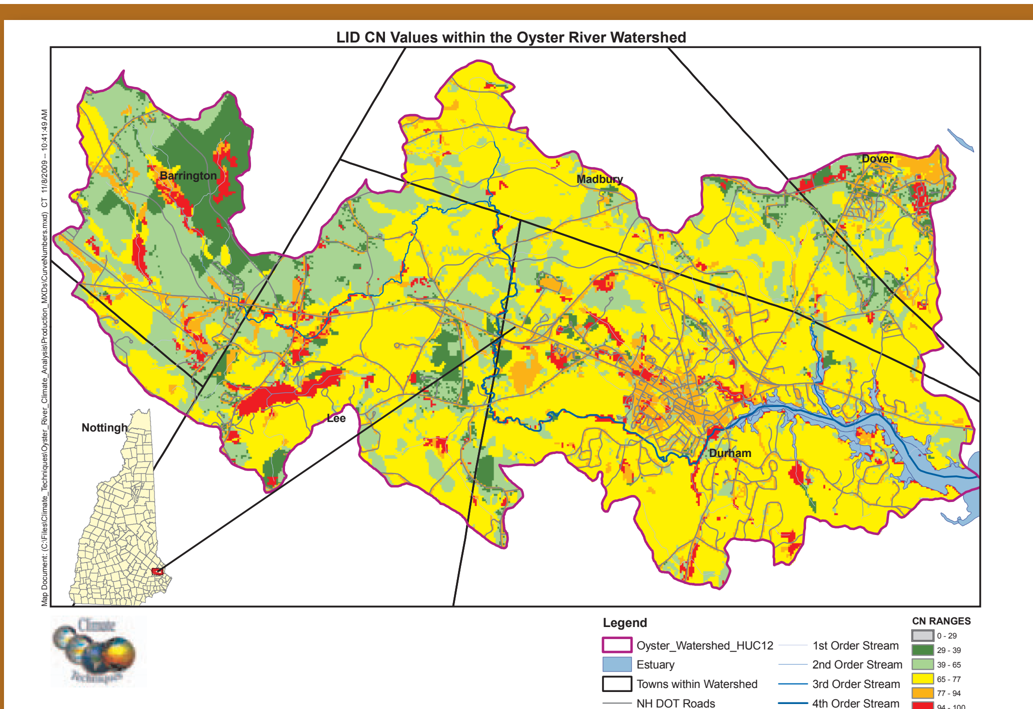
how much runoff occurs for different precipitation amounts.

The goal was to assume a set of LID techniques with a realistic expectation of adoption within the economic and political constraints of the community. In most cases, a set of LID regulations likely to be enacted by towns in the study site will be constrained by resource limitations and political realities.

For the different sized parcels specified by zoning districts, a set of LID practices was created that achieved this standard. The impact of these practices on the curve number (CN) value for each catchment was computed and served as an input to the precipitation-runoff model.

The reduction in runoff and resulting QP were compared for scenarios

FIGURE 5-13
Curve Number Adjustment for a Built-out Watershed with LID



	UNDERSIZED CULVERTS			
	BUILDOUT SCENARIO			
Scenario	Standard	w/LID	Difference	% Difference
LATE SPRING				
Baseline, AMC II	4	0	4	100%
A1b, AMC II	4	2	2	50%
A1fi, AMC II	7	5	2	29%
A1b, AMC III	10	7	3	30%
A1fi, AMC III	15	12	3	20%
FALL				
Baseline, AMC II	8	6	2	25%
A1b, AMC II	16	12	4	25%
A1fi, AMC II	19	18	1	5%
A1b, AMC III	20	19	1	5%
A1fi, AMC III	25	23	2	8%

TABLE 5 -4
Impact of LID on Culvert Capacity under Built-Out Conditions

of build-out with and without the application of LID techniques. The difference between the number of undersized culverts with and without LID was used as an indicator of the value of LID methods.

CLIMATE CHANGE

Table 5-15 summarizes the impact of realizable LID methods on the rates of undersized culverts for the various climate change precipitation scenarios as well as for normal and wet antecedent

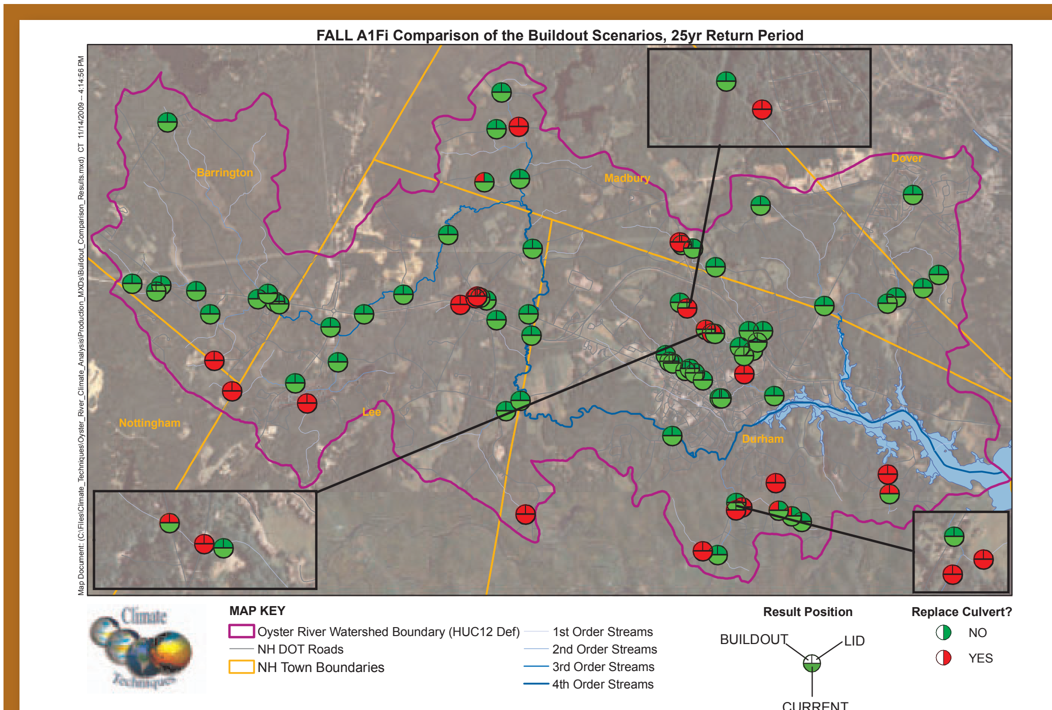


FIGURE 5-15
Culvert Capacity under Different Land-use Scenarios without Climate Change; red symbols indicating vulnerability

> Upgrading existing drainage systems is considered to be the most expensive means of accommodating increased peak flow resulting from climate change. More economical adaptation strategies reduce peak flow through application of LID, Best Management Practices, Sustainable Urban Drainage methods, or Smart Growth lot designs.

moisture conditions. When soils are saturated (or frozen), as given by Type III antecedent moisture conditions (AMC III), the efficacy of LID is reduced. However, even for the most pessimistic precipitation projections, the Fall A1fi (Fossil Fuel Intensive scenario)/AMC-II, A1b (Balanced growth scenario)/AMC-III, and A1fi/AMCIII conditions still had a 5 to 8 percent reduction in projected undersized culverts as a result of LID practices. With the more moderate precipitation increases, the potential benefit of LID methods is greater, ranging from 25 to 100 percent.

COST ANALYSIS

Based upon the analysis that identified undersized culverts for the various climate change and build-out scenarios, the goal of this analysis was to determine the cost of removing the existing culvert and replacing it with one that is adequately-sized. The quantities of materials required for each upgrade were calculated based on field data that established existing culvert type, cross-sectional area, length, elevation below the road, and road and shoulder dimensions.

For the purposes of this study, the costing results are intended to be indicative, and for planning purposes only. For more accurate estimates sufficient to support capital budgeting it would be essential to conduct a formal engineering design process for each culvert. To maximize the accuracy of results, costs were estimated only for tasks and components with a high degree of predictability. Therefore, total estimated replacement costs per culvert likely understate actual replacement costs. Excluded were costs for engineering design, excavation of the stream course, bank stabilization that may be incurred from culvert enlargement, and headwall demolition and replacement.

The additional cost resulting from upgrading a culvert to a larger size rather than replacing it with one of equal size is referred to as marginal cost. For the pessimistic A1fi scenario with build-out, marginal costs averaged an additional 49 percent per culvert. For individual culverts, the factors that most influence marginal cost are the extent of increase in culvert cross-section, the height-to-road-surface, and the culvert length.

When the data in Table 5-5 are aggregated by a land-use scenario (Table 5-6), the cost differential between build-out and build-out with LID is apparent. The additional runoff from build-out increases the per-culvert marginal cost by 22 percent. The additional runoff from build-out with LID also increases the per-culvert marginal cost, but only by 14 percent. LID methods reduce the marginal cost per culvert by 8 percent, or one third.

TABLE 5-5 Summary of Cost Analysis across Precipitation, Land-use and Antecedent Soil Conditions

Moisture Condition	Precipitation Scenario	Land-Use Scenario	Precipitation (in)	Undersized Culverts	Replacement Cost	Upgrade Cost	Marginal Cost	% Difference	Cost per Culvert
AMC II	Baseline	Current	5.4	4	16,824	24,582	7,758	46%	1,940
		Build-Out	5.4	8	56,542	88,264	31,722	56%	3,965
		LID	5.4	6	28,894	50,446	21,553	75%	3,592
	A1b	Current	6.9	9	75,621	101,184	25,562	34%	2,840
		Build-Out	6.9	16	145,786	204,293	58,507	40%	3,657
		LID	6.9	12	110,832	152,590	41,757	38%	3,480
	A1fi	Current	8.3	17	147,118	203,726	56,608	38%	3,330
		Build-Out	8.3	19	171,521	234,356	62,835	37%	3,307
		LID	8.3	18	160,695	222,267	61,572	38%	3,421
AMC III	A1b	Current	6.9	18	151,344	208,859	57,516	38%	3,195
		Build-Out	6.9	20	175,746	239,488	63,742	36%	3,187
		LID	6.9	19	164,921	227,400	62,479	38%	3,288
	A1fi	Current	8.3	22	191,817	273,192	81,375	42%	3,699
		Build-Out	8.3	25	224,761	321,339	96,578	43%	3,863
		LID	8.3	23	200,912	269,803	68,891	34%	2,995
							+95% c.i.:	48%	3,565
							Mean:	42%	3,317
							-95% c.i.:	37%	3,070

TABLE 5-6 Per-Culvert Marginal Costs by Land-use Scenario, with Recent Precipitation Amount

Land Use	Marginal Cost Per Culvert	% increase Over "Current" Land Use
Current	2,952	—
Build-Out	3,596	22%
LID	3,372	14%

SUMMARY

For the study site, climate change is estimated to have a profound impact on the precipitation intensity-duration-frequency relationship, resulting in undersized culverts, increased flooding, increased hazard to life and property, and an increase in maintenance costs. The study estimates that the "most likely" 25-year event for the mid-21st century A1b (Balanced Growth) scenario will be 35 percent greater than the 25-year TP-40 event, while the "most likely" 25-year A1fi (Fossil Fuel Intensive) scenario will be 64 percent greater than the 25-year TP-40 event. For comparison, the TP-40 100-year precipitation event for a 24-hour duration was 24 percent greater than the 25-year event.

This study found that existing culverts in the study site vary widely in their adequacy for a given precipitation event, with 5 percent of culverts currently undersized based on the TP-40 design storm to which they presumably should have been constructed. When build-out is considered, an additional

7 percent are already undersized for the "most likely" 25-year, 24-hour event experienced during the 1971-2000 interval. Thirty-five (35) percent of culverts are undersized under full build-out with no LID methods, and with the most pessimistic precipitation estimate.

Upgrading existing drainage systems is considered to be the most expensive means of accommodating increased peak flow resulting from climate change (Blankensby et al., 2003). More economical adaptation strategies reduce peak flow through application of LID, Best Management Practices, Sustainable Urban Drainage methods, or Smart Growth lot designs (Coffman, 2005; Urbonas and Starhre, 1993; Butler, 2000; Daniels, 2001). Although LID methods can potentially maintain pre-development runoff rates, the set of methods that are likely to be achievable in the near future in the study site can be expected to be limited. Based on current development patterns, a set of achievable LID methods was generated and the impact of this set on post build-out rates of peak flow was measured.

Study findings indicate that a set of LID methods that is modest but achievable can significantly mitigate the impacts of climate change and population growth. Across all modeled catchments, the mean curve number increases from 67 to 72 due to build-out, but decreases from 72 to 70 with the incorporation of achievable LID methods. For moderate precipitation increases and "average" antecedent moisture conditions, achievable LID methods reduce the number of culverts undersized due to build-out by 25 to 100 percent. For more extreme precipitation increases, or "wet" antecedent conditions, achievable LID methods reduce the number of undersized culverts due to build-out by 5 to 8 percent.

The effect of LID methods can also be seen in the cost of adaptation. Under recent precipitation (1971-2000) conditions, LID methods reduced the marginal upgrade cost per culvert by 8 percent as compared to the build-out with no LID scenario. The marginal upgrade cost for the A1b scenario with LID ($41,757), is 29 percent less than the marginal cost for the A1b scenario without LID methods ($58,507).

Due to the extent of land cover, zoning regulations, and catchment hydrology, catchments do not respond equally the application of LID treatments. LID may be more effective for certain catchments as compared to others, based on existing land cover and land use. For two culverts in the study, the application of LID treatments were shown to be adequate for mitigating impacts from the most pessimistic climate change precipitation scenarios, specifically, the upper-95 percent confidence limit A1fi scenario for the mid-century.

Combining the results of the LID analysis with the risk-prioritized upgrade schedule, certain culverts benefit more from the application of LID methods, either due to the extent of mitigation provided by LID, or due to the relatively higher risk assigned to a culvert in relation to other culverts.

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FACT SHEET

Overcoming the Barriers to the Implementation of LID

A survey of local decision makers provided important insight into the barriers to implementation of low impact development practices in communities.

In 2009, Project Investigators conducted a market survey of over 700 local decision makers representing localities in Minnesota, Ohio, Massachusetts, New Hampshire and Maine to understand the common barriers to implementing low impact development in their communities. The surveys showed that there were similar barriers in all of the communities.

THE FOUR MOST COMMON BARRIERS

1. The perceived costs associated with LID practices.
2. The need for additional education on specific topics directed to local officials and secondarily the general public.
3. Lack of political will to implement LID.
4. Concerns with long-term function and maintenance.

COST

LID is often perceived as a more expensive option than traditional stormwater management. LID can be a cost-effective solution to a community's stormwater management challenges due to the treatment of runoff at the source helping reduce the downstream infrastructure impacts during flooding events. LID can also reduce the development costs due to reductions in curbing and clearing for large detention basins and can introduce significant cost savings when separating storm sewers.

Connections between high levels of development and declining water quality are well established, and can result in financial impacts through the loss of natural resources within the community if they are not controlled or mitigated.

EDUCATION AND TRAINING

Many local officials identified the need to be informed as an important component to making good decisions for their community. Valuable outreach in innovative and cost effective stormwater management can be conducted by Nonpoint Education for Municipal Officials (NEMO), Coastal Training Programs (CTP), Extension Programs, Universities or NGOs. Consider hands-on exercises, field activities or planning charrettes.

FORGING THE LINK

LANGUAGE

The translation of technical materials for local officials is a key component to successful outreach activities. The backgrounds of local officials are often varied, and their understanding of stormwater management is not often equal between officials. Using terminology and communication formats that reach a broader audience improves comprehension of the outreach activity. Consider testing the message or materials with the intended audience to confirm understanding.

Local officials tend to obtain most of their environmental information through the use of the Web and from direct trainings or presentations.

POLITICAL WILL

Local officials are representatives of their communities and need the support of their constituents when making decisions. Public outreach campaigns assist in the development of the political will necessary to implement innovative or alternative approaches.

While many educators would hope that local decisions are made based upon factual, logical information, many decisions are influenced by emotional and personal bias.

LACK OF CAPACITY TO BUILD SOCIAL CAPITAL

Environmental educators are tasked with informing wide ranging audiences on ground breaking information regarding resource protection. However, those educators are often limited in their ability to lead group discussions to develop local policy changes in favor of innovative approaches. Consider improving the capacity to lead and nurture group process.

CREDIBILITY

Environmental educators are provided a short window of time to inform local decision makers about new information that could assist in their role. Providing information that is timely, relevant and unbiased are means to ensure successful delivery. Universities, NEMO, CTP, Sea Grant Cooperative Extension, and NGOs can be effective tools for implementing local change.

MAINTENANCE AND OPERATION PLANS

Stormwater management structures, both traditional and innovative require regular maintenance to be performed to maximize performance during their life span. Effective maintenance and operation plans outline the specific steps necessary to keep stormwater practices operating to the maximum benefit.

ADDITIONAL BARRIERS

- negative perceptions of "new technologies"
- concerns over long-term performance and liability
- doubt as to the performance and function of the technology.

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CHAPTER 6

Overcoming the Barriers to the Implementation of LID

Water pollution associated with increasing development is perhaps the most pressing problem facing our surface waters today. During the last census, many coastal communities experienced as much as 25 percent population growth. This tremendous growth pressure is forcing municipalities and other watershed stakeholders to develop strategies for managing growth while maintaining watershed health. Population growth also corresponds to an increase in demands on infrastructure. In challenging economic times, revenue reductions can significantly impact a municipality's ability to implement innovative approaches to managing stormwater. To overcome many of the challenges at the local level, education of local officials and key decision makers is a critical element to successful implementation of innovative practices (Goodwin, 2008).

To overcome many of the challenges at the local level, education of local officials and key decision makers is a critical element to successful implementation of innovative practices.

IDENTIFIED BARRIERS AND RECOMMENDATIONS TO OVERCOME

In 2009, Project Investigators conducted a market survey of over 700 local decision makers from different coastal regions to determine the barriers to implementing LID. Participants were from Minnesota, Ohio, Massachusetts, New Hampshire, and Maine and represented elected and appointed officials, volunteer board members, and municipal staff. Data collection also came from a series of focus groups that included representatives from each region. The focus groups were comprised of a subset of the survey participants in order to obtain more detailed information than the survey could provide. Participation in the focus group was requested through the survey and through direct contact. Despite geographic and demographic differences, consistent topics came into view in the identification of barriers as well as suggestions for solutions.

The primary barriers to implementing LID were identified as:

1. The perceived costs associated with the practices;
2. the need for education, training, or resources on the subject, primarily for the focus group participants, but secondarily for the general public;
3. a lack of political will to implement LID strategies due to the previous two points; and
4. concerns with respect to long-term function and maintenance.

COST

Cost is often identified as a significant barrier to the implementation of LID. Local governments are facing decreasing revenues and are seeking solutions for addressing water resource management concerns on a community-wide scale. The up front costs of designing an LID system are often seen as one of the primary hurdles to implementation, especially when several redesigns may be necessary to obtain a final design. However, those costs may get recouped by the developer through the leaseholder or the end consumer. The education of costs should extend beyond the up-front initial costs and include a discussion on the cost benefits of specific LID practices as well as the savings that can be realized through the elimination of structures such as pipes and catch basins.

Connections between high levels of development and declining water quality are well established, and can result in financial impacts through the loss of natural resources within the community if they are not controlled or mitigated.

Often, demonstrating the cost savings of implementing LID on a land development scale, as opposed to single practice costs, permits the audience to realize the savings in specifics aspects of the development process. For example, a development project in the mid-Atlantic region was able to demonstrate considerable cost savings by implementing LID principles (ACB, 2005). Numerous case studies present cost savings from both commercial, residential, and municipal implementation of LID. Life cycle costs are rarely considered in development plans.

Connections between high levels of development and declining water quality are well established, and can result in financial impacts through the loss of natural resources within the community if they are not controlled or mitigated. Over time, communities will need to bear the costs of restoration and clean up, or risk federal fines. Even worse, they risk their economic vitality through lost revenue as a result of declining fishing, tourism, and other water-dependent industries.

EDUCATION AND TRAINING

The 2009 market survey and direct interviews indicated many local officials voiced their need of information and training to better perform their role for the municipality, and indicated that they are likely to incorporate what they have learned into their decision making process. Based on the results of a market survey, local officials tend to obtain most of their environmental information through the use of the Web and from direct trainings or presentations. Additional research has identified other communication mediums such as radio or television as the most effective means to inform an audience as opposed to topic specific workshops (CWP, 2000). While the use of television may be most effective at behavior change, it can be cost prohibitive and is often generalized to meet the needs of a larger and more diverse audience. However, that audience may include key stakeholders that support locally elected officials. Intensive training through workshops conveys detailed information to a smaller audience that is seeking more complex information. The workshops can also be tailored to the specific needs of the immediate audience, though this requires more dedicated time from the trainer. Partner organizations such as the Nonpoint Education for Municipal Officials (NEMO), Coastal Training Programs (CTP) at the National Estuarine Research Reserves, and the Sea Grant Marine Extension provide detailed workshops on water quality programs and integrating land conservation strategies. These organizations are experienced in providing various approaches to communicating the science of LID to various audiences.

Often, local officials have a vision for what they hope their community will look like, but may be focused on immediate issues such as declining budgets, road maintenance, and new school construction. One tool to assist in communicating the future is visual representation of a community built out in differing future scenarios based upon input from community leaders. These future scenarios provide the community an immediate ability to see the affects of local decisions.

> Local officials tend to obtain most of their environmental information through the use of the Web and from direct trainings or presentations.

Other types of engagement strategies may involve leading local officials, staff, and the public through a charrette process. Planning charrettes are collaborative processes in which a group of stakeholders develops a solution to a challenging problem. Planning charrettes utilize various scenarios to communicate possible outcomes and reach solutions through the exchange of dialogue between participants. These structured, hands on activities provide an opportunity for a group of people with a diverse background to share their perspective and provide solutions.

Additionally, the use of field activities for local officials provides an opportunity to dispel misunderstandings about LID through an outdoor classroom.

FIGURE 6-1
Discussion Group

Basic functional properties and the aesthetics of LID practices are often key factors that prevent local officials and the public from accepting and implementing LID (Nowacek, 2003). By offering a site-based experience for local officials that is less formal from their typical setting, the ability to communicate some of the aspects of LID can be successful. Understanding the design, functional features, and expectations for performance can be very effective for local officials.

LANGUAGE

During the direct interviews with Municipal decision makers, it became apparent that there was a misunderstanding of how LID is typically defined. Focus group participants indicated that LID was not an applicable technique because the community had completely built out its jurisdictions with no "new developments" planned. LID, as defined, is a stormwater management strategy that emphasizes conservation and the use of existing natural site features integrated with distributed, small scale stormwater controls to more closely mimic natural hydrologic patterns in residential, commercial, and industrial settings (Goodwin, 2008). Upon further conversation and clarification, the techniques of LID were determined to be completely applicable in a built out scenario and are now currently being used as a water quality protection strategy. Using information and language that is relevant to the audience is the most effective method to being understood by local officials and managers, often referred to as science translation (TNC, 2009). Science translation moves the conversation to the core values that individuals share, and permits the acceptance of the information more readily. While many educators would hope that local decisions are made based upon factual, logical information, many decisions are significantly influenced by emotional and personal bias (Feurt, 2006). In the case of the confusion as to the definition of LID, the relevant point was that despite the technical terminology, it was an approach to maintain clean water. Clean water, in this example, is the root interest of most communities, but for reasons more personal than practical.

POLITICAL WILL

A barrier often limiting the implementation of LID at the local level is a lack of political will by local officials. Leaders are often reluctant to support a new concept without proper knowledge of the issue and backing from constituents. Many leaders may not understand the topic or have a misperception of it based upon limited or false information. Educational programs directed towards them can help clarify the issue but educational programs directed towards the general public are important, as elected officials are representatives of their constituents. This is the beginning of the development of social capital, a concept that Robert Putnam (2000) catalyzed as a means for public discussions around policy issues. Social capital is built upon community networks that each individual has established and recognized, such as community assets. The development of social capital builds communities by allowing individuals to begin functioning as a group to form a social fabric, and not operate as a single individual. The process builds the ability for a community to share common values and ideas, furthering the growth of that community and enabling it to solve collective challenges. Social capital builds trust between those within a community because community members begin to see that their perspective is similar to those around them. To create political will, local officials need their constituents to support their decisions, and good, informed decisions require local officials to support collaborative public discourse.

While many educators would hope that local decisions are made based upon factual, logical information, many decisions are significantly influenced by emotional and personal bias.

LACK OF CAPACITY TO BUILD SOCIAL CAPITAL

Building social capital requires a dedication to process and willingness to expend the time to reach the desired outcome. Social capital can be fostered through the use of public workshops, public dialogues, or collaborative problem solving activities that encourages public participation and discourse around specific issues or policy development relevant to the community. It also requires local decision makers to support and request the concept of public engagement. Stakeholder participation can bring about delays and new challenges to in the decision making process, which can be costly and cause tension when discussing a specific policy or action.

The success of stakeholder participation is predicated upon the invitation of participants with ranging viewpoints to participate in structured, facilitated dialogues to reach an outcome that is relevant to the community.

Advocates, extension agents, education and outreach staff need to consider building their repertoire by facilitating collaborative public discourse processes. The concept of public issues education is a commonly accepted approach for engaging the public around public policy issues. The success of stakeholder participation is predicated upon the invitation of participants with ranging viewpoints to participate in structured, facilitated dialogues to reach an outcome that is relevant to the community. A successfully led public issues education process requires an approach somewhat dissimilar to traditional educational programs. A typical outreach or educational program will present technical information followed by a question and answer session that relies upon the presenter to provide responses to directed requests for additional information. While this approach is successful for improving the comprehension of the material presented, it limits the audience's opportunity to understand various perspectives from their neighbors. A public issues educational approach establishes ground rules for participants and outlines expectations for their participation in a dialogue regarding the topic. Following the presentation and brief questioning session, a series of questions to the audience begins the dialogue between the participants. This process may require the organizer of the session to obtain the assistance of an objectively removed facilitator. Or, the organizer may accept the additional role to facilitate the process and dialogue. In either case, the organizer has accepted the role of convener and program planner.

There is not a single means to build social capital and foster stakeholder participation. The tools used are based upon the desired outcome. If the outcome is to reach a policy decision, consensus or democratic-based voting may be the best approach. However, if the intent is to further the policy changes necessary and advance local change, the use of a facilitated discussion following the presentation may be useful to actively recruit participation. The Canadian Institute for Cultural Affairs developed a guide entitled *The Art of Focused Conversation*, which identifies several engagement strategies and processes. Several of these outcome-based processes are identified which seek to obtain workgroup participation through thorough questioning that follows a four level process framework. The intent is to employ the whole framework as a single tool approach to obtain community buy-in in the development of a solution.

CREDIBILITY

The results of the market survey which asked local officials who they most trusted in terms of providing credible environmental information, identified universities as the top choice for reliable information. The survey placed relative equal value on state agency personnel and non-governmental organizations (NGOs). Upon further discussion with the focus groups, the consensus held that universities provide scientific, peer-reviewed information, but that the same level of information could also be delivered through other educational organizations. The groups identified previously, NEMO, CTP and the NEPs, were recognized by local officials as credible and reliable.

MAINTENANCE AND OPERATIONS PLANS

Stormwater management practices often fail due to a lack of maintenance because the expense of maintaining most stormwater BMPs is relatively significant when compared to original construction costs. Improper maintenance decreases the efficiency of BMPs and may also detract from the aesthetic qualities of the practice. Proper operation and maintenance language within a stormwater ordinance can ensure that designs facilitate and require regular maintenance. However, here is often a disconnection between the requirements of the ordinance and what actually happens in the field. Some important elements of effective stormwater operation and maintenance ordinance language include specification of an entity responsible for long-term maintenance, as well as reference to regular inspection visits. The ordinance should also address design guidelines that can help ease the maintenance burden, such as maintenance easements, pretreatment forebays, minimum side slopes (3:1), and clean-out processes. Other information that is in support of the ordinance, such as maintenance agreements and inspection checklists, are equally important to ensuring that stormwater BMPs perform well over time.

OTHER IDENTIFIED BARRIERS

Additional barriers have been identified through survey results and feedback from the focus group process. These barriers include: negative perceptions of "new technologies"; concerns over long-term performance and liability; as well as reasonable doubt as to the performance and function of the technology.

Overcoming the negative perception of new technologies is a major challenge. Culturally, we often question new approaches because they are seen as untested or unproven. On a development project in the Town of Greenland, NH, local officials felt challenged by their lack of knowledge and experience with LID. The local officials and municipal staff considered requiring long-term performance bonds to be posted by the developer and held by the leaseholder to ensure performance of the technologies. This scenario raises the issue of whether or not to hold innovative practices to a higher standard than existing practices. Volumes of data exist confirming the failure rates of conventional practices for protecting water quality, yet many local governments require long-term performance bonds for innovative practices. However, with the case in Greenland, NH, after the developers/engineers illustrated a performance record that consisted of over a decade of in-the-field application and research verifying the performance of LID, the community agreed to proceed without performance bonds. The community also requested an indemnification of responsibility for the town, despite the fact that the LID application was being implemented on private property. Liability remains a concern for many local decision makers. For example, after acceptable winter performance data was established for a project in Pennsylvania incorporating porous pavement, the subject of reducing the need for deicing was raised. In order to reduce their legal responsibility in case of slip and fall accidents, the locality and the property leaser agreed to a limited liability waiver. Implementing proper designs, appropriate engineering oversight, and adequate long-term operations and maintenance plans can help overcome liability-based challenges and ensure success.

Additional barriers include negative perceptions of “new technologies”; concerns over long-term performance and liability; and reasonable doubt as to the performance and function of the technology.

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Appendix A

CFW PROTECTION CODE AND ORDINANCE WORKSHEET

Codes & Ordinance Worksheet (COW)

This is one of several tools designed to assist local stormwater managers with the development of their post-construction stormwater program. The tools are a companion to the Post-Construction Guidance Manual (www.cwp.org/postconstruction). The following tools are available:

Tool #1: Post-Construction Stormwater Program Self-Audit

Tool #2: Program & Budget Planning Tool

Tool #3: Post-Construction Stormwater Model Ordinance

Tool #4: Codes & Ordinance Worksheet (COW)

Tool #5: Stormwater Manual Builder

Tool #6: Plan Review, BMP Construction, and Maintenance Checklists

Tool #7: Performance Bonds

Tool #8: BMP Evaluation Tool

For more information on the Post-Construction Guidance Manual, contact the Center for Watershed Protection, 8390 Main Street, 2nd floor, Ellicott City, MD 21046, 410-461-8323

center@cwp.org

www.cwp.org.

CODE AND ORDINANCE WORKSHEET

The Code and Ordinance Worksheet allows an in-depth review of the standards, ordinances, and codes (i.e., tl development rules) that shape how development occurs in your community. You are guided through a system comparison of your local development rules against the model development principles. Institutional framework regulatory structures and incentive programs are included in this review. The worksheet consists of a series of questions that correspond to each of the model development principles. Points are assigned based on how we the current development rules agree with the site planning benchmarks derived from the model development principles.

The worksheet is intended to guide you through the first two steps of a local site planning roundtable.

Step 1: Find out what the Development Rules are in your community.

Step 2: See how your rules stack up to the Model Development Principles.

The homework done in these first two steps helps to identify which development rules are potential candidates change.

PREPARING TO COMPLETE THE CODE AND ORDINANCE WORKSHEET

Two tasks need to be performed before you begin in the worksheet. First, you must identify all the developmer rules that apply in your community. Second, you must identify the local, state, and federal authorities that actu administer or enforce the development rules within your community. Both tasks require a large investment of time. The development process is usually shaped by a complex labyrinth of regulations, criteria, and authoritie A team approach may be helpful. You may wish to enlist the help of a local plan reviewer, land planner, land u attorney, or civil engineer. Their real-world experience with the development process is often very useful in completing the worksheet.

Identify the Development Rules

Gather the key documents that contain the development rules in your community. A list of potential documents look for is provided in Table 1. Keep in mind that the information you may want on a particular development ru is not always found in code or regulation, and maybe hidden in supporting design manuals, review checklists, guidance document or construction specifications. In most cases, this will require an extensive search. Few communities include all of their rules in a single document. Be prepared to contact state and federal, as well a local agencies to obtain copies of the needed documents.

Table 1: Key Local Documents that will be Needed to Complete the COW
Zoning Ordinance
Subdivision Codes
Street Standards or Road Design Manual
Parking Requirements
Building and Fire Regulations/Standards
Stormwater Management or Drainage Criteria
Buffer or Floodplain Regulations
Environmental Regulations
Tree Protection or Landscaping Ordinance
Erosion and Sediment Control Ordinances
Public Fire Defense Masterplans
Grading Ordinance

Code and Ordinance Worksheet

Identify Development Authorities

Once the development rules are located, it is relatively easy to determine which local agencies or authorities are actually responsible for administering and enforcing the rules. Completing this step will provide you with a better understanding of the intricacies of the development review process and helps identify key members of a future local roundtable. Table 2 provides a simple framework for identifying the agencies that influence development in your community. As you will see, space is provided not only for local agencies, but for state and federal agencies as well. In some cases, state and federal agencies may also exercise some authority over the local development process (e.g., wetlands, some road design, and stormwater).

USING THE WORKSHEET: HOW DO YOUR RULES STACK UP TO THE MODEL DEVELOPMENT PRINCIPLES?

Completing the Worksheet

Once you have located the documents that outline your development rules and identified the authorities responsible for development in your community, you are ready for the next step. You can now use the worksheet to compare your development rules to the model development principles. The worksheet is presented at the end of this chapter. The worksheet presents seventy-seven site planning benchmarks. The benchmarks are posed as questions. Each benchmark focuses on a specific site design practice, such as the minimum diameter of cul-de-sacs, the minimum width of streets, or the minimum parking ratio for a certain land use. You should refer to the codes, ordinances, and plans identified in the first step to determine the appropriate development rule. The questions require either a yes or no response or specific numeric criteria. If your development rule agrees with the site planning benchmark, you are awarded points.

Calculating Your Score

A place is provided on each page of the worksheet to keep track of your running score. In addition, the worksheet is subdivided into three categories:

- Residential Streets and Parking Lots (Principles No. 1 - 10)
- Lot Development (Principles No. 11 - 16)
- Conservation of Natural Areas (Principles No. 17 - 22).

For each category, you are asked to subtotal your score. This "**Time to Assess**" allows you to consider which development rules are most in line with the site planning benchmarks and what rules are potential candidates for change.

The total number of points possible for all of the site planning benchmarks is 100. Your overall score provides a general indication of your community's ability to support environmentally sensitive development. As a general rule if your overall score is lower than 80, then it may be advisable to systematically reform your local development rules. A score sheet is provided at end of the Code and Ordinance Worksheet to assist you in determining where your community's score places in respect to the Model Development Principles. Once you have completed the worksheet, go back and review your responses. Determine if there are specific areas that need improvement (e.g., development rules that govern road design) or if your development rules are generally pretty good. This review is key to implementation of better development: assessment of your current development rules and identification of impediments to innovative site design. This review also directly leads into the next step: a site planning roundtable process conducted at the local government level. The primary tasks of a local roundtable are to systematically review existing development rules and then determine if changes can or should be made. By providing a much-needed framework for overcoming barriers to better development, the site planning roundtable can serve as an important tool for local change.

Code and Ordinance Worksheet

Table 2: Local, State, and Federal Authorities Responsible for Development in Your Community				
Development Responsibility		**State/Federal**	**County**	**Town**
Sets road standards	Agency:			
	Contact Name:			
	Phone No.:			
Review/approves subdivision plans	Agency:			
	Contact Name:			
	Phone No.:			
Establishes zoning ordinances	Agency:			
	Contact Name:			
	Phone No.:			
Establishes subdivision ordinances	Agency:			
	Contact Name:			
	Phone No.:			
Reviews/establishes stormwater management or drainage criteria	Agency:			
	Contact Name:			
	Phone No.:			
Provides fire protection and fire protection code enforcement	Agency:			
	Contact Name:			
	Phone No.:			
Oversees buffer ordinance	Agency:			
	Contact Name:			
	Phone No.:			
Oversees wetland protection	Agency:			
	Contact Name:			
	Phone No.:			
Establishes grading requirements or oversees erosion and sediment control program	Agency:			
	Contact Name:			
	Phone No.:			
Reviews/approves septic systems	Agency:			
	Contact Name:			
	Phone No.:			
Review/approves utility plans (e.g., water and sewer)	Agency:			
	Contact Name:			
	Phone No.:			
Reviews/approves forest conservation/ tree protection plans	Agency:			
	Contact Name:			
	Phone No.:			

Development Feature	**Your Local Criteria**

1. Street Width

What is the minimum pavement width allowed for streets in low density residential developments that have less than 500 daily trips (ADT)? ______ feet

*If your answer is between **18-22 feet**, give yourself **4** points* ☞ [ ]

At higher densities are parking lanes allowed to also serve as traffic lanes (i.e., queuing streets)? YES/ NO

*If your answer is **YES**, give yourself **3** points* ☞ [ ]

Notes on Street Width (include source documentation such as name of document, section and page #):

2. Street Length

Do street standards promote the most efficient street layouts that reduce overall street length? YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Notes on Street Length (include source documentation such as name of document, section and page #):

3. Right-of-Way Width

What is the minimum right of way (ROW) width for a residential street? ______ feet

*If your answer is **less than 45 feet**, give yourself **3** points* ☞ [ ]

Does the code allow utilities to be placed under the paved section of the ROW? YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Notes on ROW Width (include source documentation such as name of document, section and page #):

4. Cul-de-Sacs

What is the minimum radius allowed for cul-de-sacs? ______ feet

*If your answer is **less than 35 feet**, give yourself **3** points* ☞

*If your answer is **36 feet to 45 feet**, give yourself **1** point* ☞ [ ]

Can a landscaped island be created within the cul-de-sac? YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Are alternative turnarounds such as "hammerheads" allowed on short streets in low density residential developments? YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Notes on Cul-de-Sacs (include source documentation such as name of document, section and page #):

Code and Ordinance Worksheet *Subtotal Page 5* [ ]

Development Feature	Your Local Criteria

5. Vegetated Open Channels

Are curb and gutters required for most residential street sections? — YES/ NO

*If your answer is **NO**, give yourself **2** points* ☞ [ ]

Are there established design criteria for swales that can provide stormwater quality treatment (i.e., dry swales, biofilters, or grass swales)? — YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞ [ ]

Notes on Vegetated Open Channel (include source documentation such as name of document, section and page #):

6. Parking Ratios

What is the minimum parking ratio for a professional office building (per 1000 ft^2 of gross floor area)? — _______ spaces

*If your answer is **less than 3.0 spaces**, give yourself **1** point* ☞ [ ]

What is the minimum required parking ratio for shopping centers (per 1,000 ft^2 gross floor area)? — _______ spaces

*If your answer is **4.5 spaces or less**, give yourself **1** point* ☞ [ ]

What is the minimum required parking ratio for single family homes (per home)? — _______ spaces

*If your answer is **less than or equal to 2.0 spaces**, give yourself **1** point* ☞ [ ]

Are your parking requirements set as maximum or median (rather than minimum) requirements? — YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞ [ ]

Notes on Parking Ratios (include source documentation such as name of document, section and page #):

7. Parking Codes

Is the use of shared parking arrangements promoted? — YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Are model shared parking agreements provided? — YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Are parking ratios reduced if shared parking arrangements are in place? — YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

If mass transit is provided nearby, is the parking ratio reduced? — YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Notes on Parking Codes (include source documentation such as name of document, section and page #):

Code and Ordinance Worksheet *Subtotal Page 6* [ ]

Development Feature	***Your Local Criteria***

8. Parking Lots

What is the minimum stall width for a standard parking space? _______ feet

*If your answer is **9 feet or less**, give yourself **1** point* ☞ [ ]

What is the minimum stall length for a standard parking space? _______ feet

*If your answer is **18 feet or less**, give yourself **1** point* ☞ [ ]

Are at least 30% of the spaces at larger commercial parking lots required to have smaller dimensions for compact cars? YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Can pervious materials be used for spillover parking areas? YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞ [ ]

Notes on Parking Lots (include source documentation such as name of document, section and page #):

9. Structured Parking

Are there any incentives to developers to provide parking within garages rather than surface parking lots? YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Notes on Structured Parking (include source documentation such as name of document, section and page #):

10. Parking Lot Runoff

Is a minimum percentage of a parking lot required to be landscaped? YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞ [ ]

Is the use of bioretention islands and other stormwater practices within landscaped areas or setbacks allowed? YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞ [ ]

Notes on Parking Lot Runoff (include source documentation such as name of document, section and page #):

Code and Ordinance Worksheet *Subtotal Page 7* [ ]

Development Feature	**Your Local Criteria**

Time to Assess: Principles 1 - 10 focused on the codes, ordinances, and standards that determine the size, shape, and construction of parking lots, roadways, and driveways in the suburban landscape. There were a total of **40** points available for Principles 1 - 10. What was your total score?

Subtotal Page 5 ____ + Subtotal Page 6 ____ + Subtotal Page 7 ____ = [ ]

Where were your codes and ordinances most in line with the principles? What codes and ordinances are potential impediments to better development?

____

____

____

____

11. Open Space Design

Are open space or cluster development designs allowed in the community? — YES/ NO

*If your answer is **YES**, give yourself **3** points* ☞

*If your answer is **NO**, skip to question No. 12*

Is land conservation or impervious cover reduction a major goal or objective of the open space design ordinance? — YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞

Are the submittal or review requirements for open space design greater than those for conventional development? — YES/ NO

*If your answer is **NO**, give yourself **1** point* ☞

Is open space or cluster design a by-right form of development? — YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞

Are flexible site design criteria available for developers that utilize open space or cluster design options (e.g., setbacks, road widths, lot sizes) — YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞

Notes on Open Space Design (include source documentation such as name of document, section and page #):

Code and Ordinance Worksheet — *Subtotal Page 8* [ ]

Development Feature	Your Local Criteria

12. Setbacks and Frontages

Are irregular lot shapes (e.g., pie-shaped, flag lots) allowed in the community?	YES/ NO
*If your answer is **YES**, give yourself **1** point* ☞	
What is the minimum requirement for front setbacks for a one half (½) acre residential lot?	_______ feet
*If your answer is **20 feet or less**, give yourself **1** point* ☞	
What is the minimum requirement for rear setbacks for a one half (½) acre residential lot?	_______ feet
*If your answer is **25 feet or less**, give yourself **1** point* ☞	
What is the minimum requirement for side setbacks for a one half (½) acre residential lot?	_______ feet
*If your answer is **8 feet or less**, give yourself **1** points* ☞	
What is the minimum frontage distance for a one half (½) acre residential lot?	_______ feet
*If your answer is **less than 80 feet**, give yourself **2** points* ☞	

Notes on Setback and Frontages (include source documentation such as name of document, section and page #):

13. Sidewalks

What is the minimum sidewalk width allowed in the community?	_______ feet
*If your answer is **4 feet or less**, give yourself **2** points* ☞	
Are sidewalks always required on both sides of residential streets?	YES/ NO
*If your answer is **NO**, give yourself **2** points* ☞	
Are sidewalks generally sloped so they drain to the front yard rather than the street?	YES/ NO
*If your answer is **YES**, give yourself **1** point* ☞	
Can alternate pedestrian networks be substituted for sidewalks (e.g., trails through common areas)?	YES/ NO
*If your answer is **YES**, give yourself **1** point* ☞	

Notes on Sidewalks (include source documentation such as name of document, section and page #):

14. Driveways

What is the minimum driveway width specified in the community?	_______ feet
*If your answer is **9 feet or less (one lane) or 18 feet (two lanes)**, give yourself **2** points* ☞	

Code and Ordinance Worksheet *Subtotal Page 9*

Development Feature	Your Local Criteria
Can pervious materials be used for single family home driveways (e.g., grass, gravel, porous pavers, etc)?	YES/ NO
*If your answer is **YES**, give yourself **2** points* ☞	
Can a “two track” design be used at single family driveways?	YES/ NO
*If your answer is **YES**, give yourself **1** point* ☞	
Are shared driveways permitted in residential developments?	YES/ NO
*If your answer is **YES**, give yourself **1** point* ☞	

Notes on Driveways (include source documentation such as name of document, section and page #):

15. Open Space Management

Skip to question 16 if open space, cluster, or conservation developments are not allowed in your community.

Does the community have enforceable requirements to establish associations that can effectively manage open space?	YES/ NO
*If your answer is **YES**, give yourself **2** points* ☞	
Are open space areas required to be consolidated into larger units?	YES/ NO
*If your answer is **YES**, give yourself **1** point* ☞	
Does a minimum percentage of open space have to be managed in a natural condition?	YES/ NO
*If your answer is **YES**, give yourself **1** point* ☞	
Are allowable and unallowable uses for open space in residential developments defined?	YES/ NO
*If your answer is **YES**, give yourself **1** point* ☞	
Can open space be managed by a third party using land trusts or conservation easements?	YES/ NO
*If your answer is **YES**, give yourself **1** point* ☞	

Notes on Open Space Management (include source documentation such as name of document, section and page #):

16. Rooftop Runoff

Can rooftop runoff be discharged to yard areas?	YES/ NO
*If your answer is **YES**, give yourself **2** points* ☞	
Do current grading or drainage requirements allow for temporary ponding of stormwater on front yards or rooftops?	YES/ NO
*If your answer is **YES**, give yourself **2** points* ☞	

Notes on Rooftop Runoff (include source documentation such as name of document, section and page #):

Code and Ordinance Worksheet *Subtotal Page 10*

Development Feature	***Your Local Criteria***

Time to Assess: Principles 11 through 16 focused on the regulations which determine lot size, lot shape, housing density, and the overall design and appearance of our neighborhoods. There were a total of **36** points available for Principles 11 - 16. What was your total score?

Subtotal Page 8 ____ + Subtotal Page 9 ____ + Subtotal Page 10 ____ = [ ]

Where were your codes and ordinances most in line with the principles? What codes and ordinances are potential impediments to better development?

____

____

____

____

____

17. Buffer Systems

Is there a stream buffer ordinance in the community? — YES/ NO

If your answer is ***YES****, give yourself* ***2*** *points* ☞ [ ]

If so, what is the minimum buffer width? — _______ feet

If your answer is ***75 feet or more****, give yourself* ***1*** *point* ☞ [ ]

Is expansion of the buffer to include freshwater wetlands, steep slopes or the 100-year floodplain required? — YES/ NO

If your answer is ***YES****, give yourself* ***1*** *point* ☞ [ ]

Notes on Buffer Systems (include source documentation such as name of document, section and page #):

18. Buffer Maintenance

If you do not have stream buffer requirements in your community, skip to question No. 19

Does the stream buffer ordinance specify that at least part of the stream buffer be maintained with native vegetation? — YES/ NO

If your answer is ***YES****, give yourself* ***2*** *points* ☞ [ ]

Does the stream buffer ordinance outline allowable uses? — YES/ NO

If your answer is ***YES****, give yourself* ***1*** *point* [ ]

Code and Ordinance Worksheet — *Subtotal Page 11* [ ]

Development Feature	Your Local Criteria

Does the ordinance specify enforcement and education mechanisms? YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Notes on Buffer Systems (include source documentation such as name of document, section and page #):

19. Clearing and Grading

Is there any ordinance that requires or encourages the preservation of natural vegetation at residential development sites? YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞ [ ]

Do reserve septic field areas need to be cleared of trees at the time of development? YES/ NO

*If your answer is **NO**, give yourself **1** point* ☞ [ ]

Notes on Buffer Maintenance (include source documentation such as name of document, section and page #):

20. Tree Conservation

If forests or specimen trees are present at residential development sites, does some of the stand have to be preserved? YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞ [ ]

Are the limits of disturbance shown on construction plans adequate for preventing clearing of natural vegetative cover during construction? YES/ NO

*If your answer is **YES**, give yourself **1** point* ☞ [ ]

Notes on Tree Conservation (include source documentation such as name of document, section and page #):

21. Land Conservation Incentives

Are there any incentives to developers or landowners to conserve non-regulated land (open space design, density bonuses, stormwater credits or lower property tax rates)? YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞ [ ]

Is flexibility to meet regulatory or conservation restrictions (density compensation, buffer averaging, transferable development rights, off-site mitigation) offered to developers? YES/ NO

*If your answer is **YES**, give yourself **2** points* ☞ [ ]

Notes on Land Cons. Incentives (include source documentation such as name of document, section and page #):

Code and Ordinance Worksheet *Subtotal Page 12* [ ]

Development Feature	*Your Local Criteria*

22. Stormwater Outfalls

Is stormwater required to be treated for quality before it is discharged? YES/ NO

If your answer is ***YES****, give yourself* ***2*** *points* ☞ [ ]

Are there effective design criteria for stormwater best management practices (BMPs)? YES/ NO

If your answer is ***YES****, give yourself* ***1*** *point* ☞ [ ]

Can stormwater be directly discharges into a jurisdictional wetland without pretreatment? YES/ NO

If your answer is ***NO****, give yourself* ***1*** *point* ☞ [ ]

Does a floodplain management ordinance that restricts or prohibits development within the 100-year floodplain exist? YES/ NO

If your answer is ***YES****, give yourself* ***2*** *points* ☞ [ ]

Notes on Stormwater Outfalls (include source documentation such as name of document, section and page #):

Code and Ordinance Worksheet *Subtotal Page 13* [ ]

Time to Assess: Principles 17 through 22 addressed the codes and ordinances that promote (or impede) protection of existing natural areas and incorporation of open spaces into new development. There were a total of 24 points available for Principles 17 - 22. What was your total score?

Subtotal Page 11 ____ + Subtotal Page 12 ____ + Subtotal Page 13 ____ = [ ]

Where were your codes and ordinances most in line with the principles? What codes and ordinances are potential impediments to better development?

____

____

____

____

____

To determine final score, add up subtotal from each **Time to Assess**

Principles 1 - 10 (Page 8) __________

Principles 11 - 16 (Page 11) __________

Principles 17 - 22 (Page 13) __________

TOTAL [ ]

Code and Ordinance Worksheet

SCORING (A total of **100** points are available):		
Your Community's Score		
90- 100	☞	Congratulations! Your community is a real leader in protecting streams, lakes, and estuaries. Keep up the good work.
80 - 89	☞	Your local development rules are pretty good, but could use some tweaking in some areas.
79 - 70	☞	Significant opportunities exist to improve your development rules. Consider creating a site planning roundtable.
60 - 69	☞	Development rules are inadequate to protect your local aquatic resources. A site planning roundtable would be very useful.
less than 60	☞	Your development rules definitely are not environmentally friendly. Serious reform of the development rules is needed.

Appendix B

USEPA WATER QUALITY SCORECARD


EPA
United States
Environmental Protection
Agency

EPA 231B09001 | October 2009 | http://www.

WATER QUALITY
SCORECARD

Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales

Table of Contents

1 Executive Summary

Many communities across the United States face the challenge of balancing water quality protection with the desire to accommodate new growth and development. These cities and counties are finding that a review of local ordinances beyond just stormwater regulations is necessary to remove barriers and ensure coordination across all development codes for better stormwater management and watershed protection. Local policies, such as landscaping and parking requirements or street design criteria, should complement strong stormwater standards and make it easier for developers to meet multiple requirements simultaneously.

EPA's Water Quality Scorecard was developed to help local governments identify opportunities to remove barriers, and revise and create codes, ordinances, and incentives for better water quality protection. It guides municipal staff through a review of relevant local codes and ordinances, across multiple municipal departments and at the three scales within the jurisdiction of a local government (municipality, neighborhood, and site),[1] to ensure that these codes work together to protect water quality goals. The two main goals of this tool are to: (1) help communities protect water quality by identifying ways to reduce the amount of stormwater flows in a community and (2) educate stakeholders on the wide range of policies and regulations that have water quality implications.

The scorecard is for municipalities of various sizes in rural, suburban, and urban settings, including those that have combined sewers, municipal separate storm sewers, and those with limited or no existing stormwater infrastructure. It can help municipal staff, stormwater managers, planners, and other stakeholders to understand better where a municipality's[2] land development regulations and other ordinances may present barriers or opportunities to implementing a comprehensive water quality protection approach. The scorecard provides policy options, resources, and case studies to help communities develop a comprehensive water quality program.

1 While the watershed scale is the best scale at which to look regionally at water quality protection strategies, it can be difficult to align policies, incentives, and regulations across political boundaries. For purposes of implementation, the largest scale the scorecard uses is the municipality.

2 The term "municipality" as used by the International City/County Management Association (ICMA) refers to local government at both the city and county levels.

2 Background

Growth and development expand communities' opportunities by bringing in new residents, businesses, and investments. Growth can give a community the resources to revitalize a downtown, refurbish a main street, build new schools, and develop vibrant places to live, work, shop, and play. The environmental impacts of development, however, can make it more difficult for communities to protect their natural resources. The U.S. Census Bureau projects that the U.S. population will reach 400 million people by about 2040, which will add continued development pressure on local communities and the environment. Many communities are asking where and how they can accommodate this growth while maintaining and improving their water resources.

Land development directly affects watershed functions. When development occurs in previously undeveloped areas, the resulting alterations to the land can dramatically change the transportation and storage of water. Residential and commercial development creates impervious surfaces and compacted soils that filter less water, which increases surface runoff and decreases groundwater infiltration. These changes can increase the volume and velocity of runoff, the frequency and severity of flooding, and peak storm flows.

Mixed use developments, like main street in Cedar Falls, Iowa, allow for the co-locating of land uses, which decreases impervious surfaces and stormwater runoff problems.

Many communities are already struggling with degraded water bodies and failing infrastructure. For example, *EPA's National Water Quality Inventory: 1996 Report to Congress* indicated that 36 percent of total river miles assessed were impaired.[3] In EPA's 2004 Report to Congress, that percentage increased to 44 percent.[4] Further, a report by the National Academy of Sciences found urban stormwater is estimated to be the primary source of impairment for 13 percent of assessed rivers, 18 percent of lakes, and 32 percent of estuaries—significant numbers given that urban areas cover only 3 percent of the land mass of the United States.[5]

Urban runoff also affects existing wastewater and drinking water systems. EPA estimates that between 23,000 and 75,000 sanitary sewer overflows occur each year in the United States, releasing between 3 and 10 billion gallons of sewage annually.[6] Many of these overflow problems stem from poor stormwater management. Many municipalities—both large and small—must address the impact of existing impervious areas, such as parking lots, buildings, and streets and roads, that have limited or no stormwater management while at the same time trying to find effective and appropriate solutions for new development.

These water quality impairments exist, in part, because historically stormwater management—and indeed stormwater regulation—has focused primarily at the site level. The reasoning was sound: manage stormwater well at the site, and water bodies in the community will be protected. However, as the findings of EPA's National Water Quality Inventory demonstrated, this strategy has not been effective for two main reasons.

First, the site-level approach does not take into account the amount of off-site impervious surfaces. During the development boom from 1995-2005, rain-absorbing landscapes, such as forests, wetlands, and meadows, were transformed into large areas of houses, roads, office buildings, and retail centers. This development created vast areas of impervious cover, which generated significant increases in stormwater runoff. However, the amount of development in the watershed is not simply the sum of the sites within it. Rather, total impervious area in a watershed is the sum of sites developed plus the impervious surface of associated infrastructure supporting those sites, such as roads and parking lots.

Second, federal stormwater regulations focus on reducing pollutants in the runoff—the sediments from roads, fertilizers from lawns, etc.—and not on the amount of stormwater coming from a site. Nevertheless, the increased volume of runoff coming into a municipality's water bodies scours streams, dumps sediments, and pushes existing infrastructure past its capacity limits. Failure to consider the cumulative impact—this loss of natural land, increased imperviousness, and resulting stormwater runoff volumes— on regional water quality and watershed health has led communities to seek stormwater solutions that look beyond site-level approaches.

Communities are recognizing the importance of managing water quality impacts of development at a variety of scales, including the municipal, the neighborhood, and site levels. A range of planning and development strategies at the municipal and neighborhood scales is necessary to address stormwater management comprehensively and systematically. At the same time that stormwater management is moving beyond the site level, it is also evolving beyond hardscaped, engineered solutions, such as basins and curb-and-gutter conveyance, to an approach that manages stormwater through natural processes.

A green infrastructure approach provides a solution to thinking at all three scales as well as addresses the need to change the specific types of practices used on the site. Green infrastructure is a comprehensive approach to water quality protection defined by a range of natural and built systems that can occur at the regional, community, and site scales. At the larger regional or watershed scale, green infrastructure is the interconnected network of preserved or restored natural lands and waters that provide essential environmental functions. Large-scale green infrastructure may include habitat corridors and water resource protection. At the community and neighborhood scale, green infrastructure incorporates planning and design approaches such as compact, mixed-use development, parking reductions strategies and urban forestry that reduces impervious surfaces and creates walkable, attractive communities. At the site scale, green infrastructure mimics natural systems by absorbing stormwater back into the ground (infiltration), using trees and other natural vegetation to convert it to water vapor (evapotranspiration), and using rain barrels or cisterns to capture and reuse stormwater. These natural processes manage stormwater runoff in a way that maintains or restores the site's natural hydrology.

3 U.S. EPA National Water Quality Inventory: 1996 Report to Congress: ***http://www.epa.gov/305b/96report/index.html***

4 U.S. EPA National Water Quality Inventory: 2004 Report to Congress: ***http://www.epa.gov/owow/305b/2004report/***

5 Urban Stormwater Management in the United States, National Research Council of the National Academy of Sciences, 2008: ***http://dels.nas.edu/dels/rpt_briefs/stormwater_discharge_final.pdf***

6 U.S. EPA National Water Quality Inventory: 2004 Report to Congress: ***http://www.epa.gov/owow/305b/2004report/***

2

At the municipal scale, decisions about where and how our towns, cities, and regions grow are the first, and perhaps most important, development decisions related to water quality. Preserving and restoring natural landscape features (such as forests, floodplains, and wetlands) are critical components of green infrastructure. By choosing not to develop on and thereby protecting these ecologically sensitive areas, communities can improve water quality while providing wildlife habitat and opportunities for outdoor recreation. In addition, using land more efficiently reduces and better manages stormwater runoff by reducing total impervious areas. Perhaps the single most effective strategy for efficient land use is redevelopment of already degraded sites, such as abandoned shopping centers or underused parking lots, rather than paving greenfield sites.

At the intermediate or neighborhood scale, green infrastructure includes planning and design approaches such as compact, mixed-use development, narrowing streets and roads, parking reduction strategies, and urban forestry that reduce impervious surfaces and better integrate the natural and the built environment.

At the site scale, green infrastructure practices include rain gardens, porous pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting for non-potable uses such as toilet flushing and landscape irrigation.

Street retrofits can integrate green infrastructure, like this bioswale along Sandy Boulevard in Portland, Oregon, into standard roadway maintenance and upgrades.

These processes represent a new approach to stormwater management that is not only sustainable and environmentally friendly, but cost-effective as well.

Municipalities are realizing that green infrastructure can be a solution to the many and increasing water-related challenges facing municipalities, including flood control, combined sewer overflows, Clean Water Act requirements, and basic asset management of publicly owned treatment systems. Communities need new solutions and strategies to ensure that they can continue to grow while maintaining and improving their water resources. This Water Quality Scorecard seeks to provide the policy tools, resources, and case studies to both accommodate growth and protect water resources.

3 The Water Quality Scorecard

EPA worked with numerous water quality experts, local government staff, developers, urban designers, and others working on land use and water quality issues to develop this Water Quality Scorecard. The purpose of the scorecard is to address water quality protection across multiple scales (municipality, neighborhood, and site) and across multiple municipal departments. This scorecard can help municipal staff, stormwater managers, planners, and other stakeholders to understand better where a municipality's land development regulations and other ordinances may present barriers or opportunities to implementing a comprehensive green infrastructure approach. The tool's two main goals are to: (1) help communities protect water quality by identifying ways to reduce the amount of stormwater flows in a community and (2) educate stakeholders on the wide range of policies and regulations that have water quality implications.

Communities throughout the U.S. are implementing stormwater regulations that require or encourage the use of green infrastructure for managing stormwater on site. These cities and counties are finding that, to better manage stormwater and protect watersheds, green infrastructure policies require a review of many other local ordinances to remove barriers and ensure coordination across all development codes. Local policies, such as landscaping and parking requirements or street design criteria, should complement strong stormwater standards and make it easier for developers to meet multiple requirements simultaneously. At the same time, if these policies support water quality goals, they can independently reduce and better manage stormwater runoff.

How to Use the Scorecard

This scorecard is a locally controlled self-assessment and guide for better incorporating green infrastructure practices at the municipal, neighborhood, and site scales. While one department or agency could complete the tool, the effectiveness of this tool will increase if an interagency process is established to review all local codes and policies that might affect water quality.

Completing the Water Quality Scorecard requires different documents, plans, codes, and guidance manuals. While the legal structure for stormwater management and land development regulation varies among municipalities, the following list contains the most common and relevant documents to complete this scorecard and describes how they can create impervious cover.

- *Zoning ordinances* specify the type and intensity of land uses allowed on a given parcel. A zoning ordinance can dictate single-use low-density zoning, which spreads development throughout the watershed, creating considerable excess impervious surface.

- *Subdivision codes* or ordinances specify development elements for a parcel: housing footprint minimums, distance from the house to the road, the width of the road, street configuration, open space requirements, and lot size—all of which can lead to excess impervious cover.

- *Street standards or road design guidelines* dictate the width of the road, turning radius, street connectivity, and intersection design requirements. Often in new subdivisions, roads tend to be too wide, which creates excess impervious cover.

- *Parking requirements* generally set the minimum, not the maximum, number of parking spaces required for retail and office parking. Setting minimums leads to parking lots designed for peak demand periods, such as the day after Thanksgiving, which can create acres of unused pavement during the rest of the year.

- *Setbacks* define the distance between a building and the right-of-way or lot line and can spread development out by leading to longer driveways and larger lots. Establishing maximum setback lines for residential and retail development will bring buildings closer to the street, reducing impervious cover associated with long driveways, walkways, and parking lots.

- *Height limitations* limit the number of floors in a building. Limiting height can spread development out if square footage is unmet by vertical density.

- *Open space or natural resource plans* detail land parcels that are or will be set aside for recreation, habitat corridors, or preservation. These plans help communities prioritize their conservation, parks, and recreation goals.

- *Comprehensive plans* may be required by state law, and many cities, towns, and counties prepare comprehensive plans to support zoning codes. Most comprehensive plans include elements addressing land use, open space, natural resource protection, transportation, economic development, and housing, all of which are important to watershed protection. Increasingly, local governments are defining existing green infrastructure and outlining opportunities to add new green infrastructure throughout the community.

An initial step in using this tool is to convene appropriate staff to review various sections of the tool and coordinate to both identify opportunities for change and address the potential inconsistencies between policies. The approaches described in this scorecard may be under the control of a number of different local government agencies, including:

- Parks and Recreation
- Public Works
- Planning
- Environmental Protection
- Utilities
- Transportation

The scorecard's review of land use and development policies provides guidance for implementing a range of regulatory and non-regulatory approaches, including land use planning elements, land acquisition efforts, and capital investment policies that can help various municipal agencies integrate green infrastructure into their programs. Internal agency policies and practices, such as maintenance protocols or plan review processes, may be potential barriers as well.

Each policy or approach is described in the context of its potential for providing water quality benefits, although most of the policies have many additional benefits for community livability, human health, air quality, energy use, wildlife habitat, and more. This tool does not provide model ordinance language. It emphasizes best practices and helps municipalities understand the incremental steps for changing specific policies and internal agency practices. The scorecard divides the tools and policies into four categories:

1. Adopt plans/Educate
2. Remove barriers
3. Adopt incentives
4. Enact regulations

These four categories provide greater structure to the compiled tools by organizing the policies or approaches as incremental changes and updates. These categories may help municipal staff prioritize which tools to work on based on local factors like resources, time, and political support. For example, an appropriate first step in the process of updating local regulations may be to remove a barrier rather than enacting a new regulation. Most policy options avoid specific performance guidance so that the tool is useful to a range of municipalities in different contexts. However, the case studies and resources provide locally appropriate performance measures where possible.

To highlight the diverse nature of green infrastructure approaches, as well as the fact that oversight over these policies resides in various municipal agencies, the scorecard has five sections:

1. Protect Natural Resources (Including Trees) and Open Space
2. Promote Efficient, Compact Development Patterns and Infill
3. Design Complete, Smart Streets that Reduce Overall Imperviousness
4. Encourage Efficient Provision of Parking
5. Adopt Green Infrastructure Stormwater Management Provisions

The five sections organize green infrastructure approaches based on drivers of impervious cover at the municipal, neighborhood, and site scales. Yet all three scales may be in any single section. For example, the parking section will have questions that address the municipal, neighborhood and site level considerations.

The scorecard describes alternative policy or ordinance information that, when implemented, would support a comprehensive green infrastructure approach, and will allow the municipality to determine where, in the broad spectrum of policy implementation, their policies fall.

A Note about the Point System

The tool includes a point system to make it easier to evaluate and improve local programs. The municipality can decide whether to use the point system at all. If the point system is used, municipalities can set locally appropriate thresholds and goals.

Governments could choose to use the point system in many different ways, including:

- State governments could require municipalities to complete the Water Quality Scorecard and establish measures for improvement over different permit cycles. For example, a municipality might have to improve its score by some number of points before the next permit cycle.

- Local governments could determine a score based on existing programs and policies and then set goals from this baseline. Local targets may include incremental yearly improvements or achieving additional points in a particular section, such as "Encourage Efficient Parking Supply" or "Protect Natural Resources and Open Space."

- Stakeholders such as watershed groups or environmental organizations could complete the scorecard and then provide feedback and information assistance to the local government about sections within the scorecard that received few points and might be an area for improvement.

- The total score or scores in certain sections could educate elected officials, decision makers, and others about the importance of these issues and the role of local policies in addressing them.

- A lack of points in one section may alert a municipality that a certain area, such as parking, lacks local ordinances that support green infrastructure and may be ripe for improvement.

- Variation in the number of points achieved across the five sections may help a municipality to better assess local sources of impervious cover and potential for the introduction of green infrastructure.

Because the scorecard is intended for use by a range of community types and sizes in locations throughout the U.S., please note that no single municipality will be able to receive every point. Some questions and points may only be

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A green roof located on the Friends Center in downtown Philadelphia, Pennsylvania provides stormwater management capacity and adds aesthetic value to this dense urban environment.

available to urban municipalities while others may only be available to those in a suburban or rural setting.

Tips for Building Relationships Between Stormwater Managers, Land Use Planners, and Other Local Officials

Effective stormwater management requires coordination and collaboration across many different municipal departments and processes. Below are some ideas for incorporating stormwater management in traditional planning processes and programs.

- Include both land use planners and stormwater managers in pre-concept and/or pre-application meetings for potential development projects.
- Use local government sites (e.g., schools, regional parks, office buildings, public works yards) as demonstration projects for innovative land use strategies and stormwater management. Form a team that includes land use planners, stormwater managers, parks and school officials, etc. to work out the details.
- Include stormwater managers in the comprehensive plan process to incorporate overall watershed and stormwater goals.
- Make sure that both land use planners and stormwater managers are involved in utility and transportation master planning.
- Allow stormwater managers to be involved in economic development planning, especially for enterprise zones, Main Street projects, and other projects that involve infill and redevelopment. Encourage stormwater managers to develop efficient watershed-based solutions for these plans.
- Develop cross training and joint activities that allow land use planners, stormwater managers, and transportation, utility, and capital projects planners to explore the improved integration of various land use and stormwater processes.
- Hold staff trainings with speakers that are knowledgeable about smart growth and stormwater management. Alternately, encourage land use planners, stormwater managers, and other local officials to attend trainings on this topic as a team.

Table 1: Water Quality Scorecard Quick Reference Guide

Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales (SUMMARY)

	Policy Question	Goal
PROTECT NATURAL RESOURCES (INCLUDING TREES) AND OPEN SPACE		
1A.	**NATURAL RESOURCE PROTECTION**	
	Are development policies, regulations, and incentives in place to protect natural resource areas and critical habitat?	Protect natural resource areas (e.g., forests, prairies) and critical habitat (e.g., conservation corridors, buffer zones, wildlife preserves) from future development.
	Are no-development buffer zones and other protective tools in place around wetlands, riparian areas, and floodplains to improve/protect water quality?	Protect critical areas such as wetlands, floodplains, lakes, rivers, and estuaries with a mandatory no-development buffer.
	Does the community have protection measures for source water protection areas through land use controls and stewardship activities?	Protect source water areas from current or potential sources of contamination.
1B.	**OPEN SPACE PROTECTION**	
	Does the jurisdiction have adequate open space in both developed and greenfield areas of the community?	Create open networks throughout a community that serve a dual function of providing recreational areas and assisting in management of stormwater runoff.
1C.	**TREE PRESERVATION**	
	Does the local government have a comprehensive public urban forestry program?	Protect and maintain trees on public property and rights-of-way and plant additional trees to enhance the urban tree canopy.
	Has the community taken steps to protect trees on private property?	Preserve trees on private property and require replacement when trees are removed or damaged during development.
	Do local codes encourage or require street trees as part of road and public right-of-way capital improvement projects?	Leverage existing capital funds to plant more street trees and add multiple benefits to the public right-of-way.
PROMOTE EFFICIENT, COMPACT DEVELOPMENT PATTERNS AND INFILL		
2A.	**INFILL AND REDEVELOPMENT**	
	Are policy incentives in place to direct development to previously developed areas?	Municipalities implement a range of policies and tools to direct development to specific areas.
2B.	**DEVELOPMENT IN AREAS WITH EXISTING INFRASTRUCTURE**	
	Is the jurisdiction directing growth to areas with existing infrastructure, such as sewer, water, and roads?	Adopt policies, incentives, and regulations to direct new development to areas that have infrastructure, such as water and sewer.
2C.	**MIXED-USE DEVELOPMENT**	
	Are mixed-use and transit-oriented developments allowed or encouraged?	Revise codes and ordinances to allow for the "by right" building of mixed-use and transit-oriented developments.

7

Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales (SUMMARY) continued

	Policy Question	Goal
DESIGN COMPLETE, SMART STREETS THAT REDUCE OVERALL IMPERVIOUSNESS		
3A.	**STREET DESIGN**	
	Do local street design standards and engineering practices encourage streets to be no wider than is necessary to move traffic effectively? Do policies allow narrow neighborhood streets designed to slow traffic and create safer conditions for pedestrians and bicyclists?	Appropriate street widths allow narrower lanes for certain street types, thereby reducing overall imperviousness.
	Are shared driveways, reduced driveway widths, two-track driveways, and rear garages and alleys encouraged for all single-family developments?	Encourage alternative forms and decreased dimensions of residential driveways and parking areas.
3B.	**GREEN INFRASTRUCTURE ELEMENTS AND STREET DESIGN**	
	Are major street projects required to integrate green infrastructure practices as a standard part of construction, maintenance, and improvement plans?	Formally integrate green infrastructure into standard roadway construction and retrofit practice.
	Do regulations and policies promote use of pervious materials for all paving areas, including alleys, streets, sidewalks, crosswalks, driveways, and parking lots?	Build and retrofit these surfaces with pervious materials to reduce stormwater runoff and its negative impacts.
ENCOURAGE EFFICIENT PROVISION OF PARKING		
4A.	**REDUCED PARKING REQUIREMENTS**	
	Does your local government provide flexibility regarding alternative parking requirements (e.g., shared parking, off-site parking) and discourage over-parking of developments? Do parking requirements vary by zone to reflect places where more trips are on foot or by transit?	Match parking requirements to the level of demand and allow flexible arrangements to meet parking standards.
4B.	**TRANSPORTATION DEMAND MANAGEMENT ALTERNATIVES**	
	Does the municipality allow developers to use alternative measures such as transportation demand management or in-lieu payments to reduce required parking?	Provide flexibility to reduce parking in exchange for specific actions that reduce parking demands on site.
4C.	**MINIMIZING STORMWATER FROM PARKING LOTS**	
	Are there requirements for landscaping designed to minimize stormwater in parking lots?	Require substantial landscaping to help reduce runoff.
ADOPT GREEN INFRASTRUCTURE STORMWATER MANAGEMENT PROVISIONS		
5A.	**GREEN INFRASTRUCTURE PRACTICES**	
	Are green infrastructure practices encouraged as legal and preferred for managing stormwater runoff?	Make all types of green infrastructure allowed and legal and remove all impediments to using green infrastructure (including for stormwater requirements), such as limits on infiltration in rights-of-way, permit challenges for green roofs, safety issues with permeable pavements, restrictions on the use of cisterns and rain barrels, and other such unnecessary barriers.
	Do stormwater management plan reviews take place early in the development review process?	Incorporate stormwater plan comments and review into the early stages of development review/site plan review and approval, preferably at pre-application meetings with developers.

Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales (SUMMARY) continued

	Policy Question	Goal
	Do local building and plumbing codes allow harvested rainwater use for exterior uses such as irrigation and non-potable interior uses such as toilet flushing?	Ensure that the municipality allows and encourages stormwater reuse for non-potable uses.
	Are provisions available to meet stormwater requirements in other ways, such as off-site management within the same sewershed or "payment in lieu" of programs, to the extent that on-site alternatives are not technically feasible?	Allow off-site management of runoff while still holding developers responsible for meeting stormwater management goals.
5B.	**MAINTENANCE/ENFORCEMENT**	
	Does your stormwater ordinance include monitoring, tracking, and maintenance requirements for stormwater management practices?	Incorporate monitoring, tracking, and maintenance requirements for stormwater management practices into your municipal stormwater ordinance.

Appendix C

COUNTY OF YORK, VA OVERLAY DISTRICT

County of York, VA

ARTICLE III. DISTRICTS

DIVISION 7. OVERLAY DISTRICTS

Sec. 24.1-376. WMP-Watershed management and protection area overlay district.

(A). **Statement of intent.**

In accordance with the objectives of the comprehensive plan, the Watershed Management and Protection Area Overlay regulations are intended to ensure the protection of watersheds surrounding current or potential public water supply reservoirs. The establishment of these regulations is intended to prevent the causes of degradation of the water supply reservoir as a result of the operation or the accidental malfunctioning of the use of land or its appurtenances within the drainage area of such water sources.

(B). **Applicability**.

The special provisions established in this section shall apply to the following areas:

(1) Areas designated on the Watershed management and protection area overlay district map, dated May 15, 1991, and made a part of this chapter by reference. (See Map III-2 in Appendix A)

(2) Such other areas as may be determined by the zoning administrator through drainage, groundwater and soils analyses conducted by the department of environmental and development services to be essential to protection of such existing or potential reservoirs from the effects of pollution or sedimentation.

(C). **Definitions**.

For the purposes of this section, the following terms shall have the following meanings:

Bulk storage. Storage equal to or exceeding 660 gallons [2500L] in a single aboveground container

Development. Any construction, external repair, land disturbing activity, grading, road building, pipe laying, or other activity resulting in a change in the physical character of any parcel or land.

Reservoir. Any impoundment of surface waters designed to provide drinking water to the public.

Tributary stream. Any perennial or intermittent stream, including any lake, pond or other body of water formed therefrom, flowing either directly or indirectly into any reservoir. Intermittent streams shall be those identified as such on the most recently published United States Geological Survey Quadrangle Map, or the Soil Conservation Service Soil Survey of James City and York Counties and the City of Williamsburg, Virginia, or as determined and verified upon field investigation approved by the zoning administrator.

Watershed. Any area lying within the drainage basin of any reservoir.

(D). Use regulations.

Permitted uses, special permit uses, accessory uses, dimensional standards and special requirements shall be as established by the underlying zoning district, unless specifically modified by the requirements set forth herein.

The following uses shall be specifically prohibited within the WMP areas:

(1) Storage or production of hazardous wastes as defined in either or both of the following:

a. Superfund Amendment and Reauthorization Act of 1986; and

b. Identification and Listing of Hazardous Wastes, 40 C.F.R. §261 (1987).

(2) Land applications of industrial wastes.

(E). **Special requirements.**

(1) Except in the case of property proposed for construction of an individual single-family residential dwelling unit, any development proposal, including the subdivision of land, in WMP areas shall be accompanied by an impact study prepared in accordance with the requirements set forth in subsection (f) below.

(2) A two hundred foot (200’) [60m] wide buffer strip shall be maintained along the edge of any tributary stream or reservoir. The required setback distance shall be measured from the centerline of such tributary stream and from the mean high water level of such reservoir. Such buffer strip shall be maintained in its natural state or shall be planted with an erosion resistant vegetative cover. In the case of tributary streams located upstream from a stormwater management facility designed to provide water quality protection, no buffer shall be required if such facility has been designed to accommodate and manage the quality of runoff from the subject site.

The zoning administrator may authorize a reduction in the two hundred foot (200’) [60m] wide buffer down to an absolute minimum of fifty feet (50’) [15m] upon presentation of an impact study, as defined herein, which provides documentation and justification, to the satisfaction of the zoning administrator, that even with the reduction, the same or a greater degree of water quality protection would be afforded as would be with the full-width buffer. In granting such authorization, the zoning administrator may require such additional erosion control and runoff control measures as deemed necessary.

Except as provided below, all development shall be located outside of the required buffer strip.

a. The buffer strip requirement shall not apply to development which is appurtenant to the production, supply, distribution or storage of water by a public water supplier.

b. Encroachment into or through the required buffer by roads, main-line utilities, or stormwater management structures may be permitted by the zoning administrator provided the following performance standards are met:

1. Road and main-line utility crossings will be limited to the shortest path possible and that which causes the least amount of land disturbance and alteration to the hydrology of the watershed.

2. Stormwater management facilities located within the buffer must be designed to be apart of a watershed stormwater management program.

3. No more land shall be disturbed than is necessary.

4. Indigenous vegetation shall be preserved to the maximum extent possible.

5. Wherever possible, disturbed areas shall be planted with trees and shrubs.

6. The post-development non-point source pollutant loading rate shall be no greater than ninety percent (90%) of the pre-development pollutant loading rate.

7. Non-essential elements of the road or utility project, as determined by the zoning administrator, shall be excluded from the buffer.

c. When the property where an encroachment is proposed is owned by the entity owning and operating the water supply reservoir being protected, and such entity specifically and in writing authorizes and approves the encroachment, it shall be allowed.

(3) In the case of permitted non-residential uses within the WMP areas, performance assurances shall be provided to guarantee that all runoff control and reservoir protection measures proposed in the impact study shall be constructed, operated and maintained so as to meet the performance criteria set forth in the study. The form of agreement and type of letter of credit or other surety shall be approvedby the county attorney. The amount of the letter of credit or other surety and designated length of completion time shall be set by the zoning administrator.

(4) The following uses shall not be permitted within the buffer strip required above or within five hundred feet (500') [150m] of the required buffer strip:

a. septic tanks and drainfields;

b. feed lots or other livestock impoundments;

c. trash containers and dumpsters which are not under roof or which are located so that leachate from the receptacle could escape unfiltered and untreated;

d. fuel storage in excess of fifty (50) gallons [200L];

e. sanitary landfills;

f. activities involving the manufacture, bulk storage or any type of distribution of petroleum, chemical or asphalt products or any materials hazardous to a water supply (as defined in the Hazardous Materials Spills Emergency Handbook, American Waterworks Association, 1975,as revised) including specifically the following general classes of materials:

1. oil and oil products;

2. radioactive materials;

3. any material transported in large commercial quantities (such as in 55-gallon [200L] drums), which is a very soluble acid or base, causes abnormal growth of an organ or organism, or is highly biodegradable, exerting a severe oxygen demand;

4. biologically accumulative poisons;

5. the active ingredients of poisons that are or were ever registered in

accordance with the provisions of the Federal Insecticide, Fungicide, and Rodenticide Act, as amended(7 USC 135 et seq.); or

6. substances highly lethal to mammalian or aquatic life.

(F). **Impact study.**

(1) The impact study shall be performed or reviewed by a registered professional engineer who shall certify that the study has been conducted in accordance with good engineering practices. The study shall address, at a minimum, the following topics:

a. Description of the proposed project including location and extent of impervious surfaces; onsite processes or storage of materials; the anticipated use of the land and buildings; description of the site including topographic, hydrologic, and vegetative features.

b. Characteristics of natural runoff on the site and projected runoff with the proposed project, including its rate, and chemical composition including phosphorus concentration, nitrogen concentration, suspended solids, and other chemical characteristics as deemed necessary by the zoning administrator to make an adequate assessment of water quality.

c. Measures proposed to be employed to reduce the rate of runoff and pollutant loading of runoff from the project area, both during construction and after.

d. Proposed runoff control and reservoir protection measures for the project and performance criteria proposed to assure an acceptable level and rate of runoff quality. Such measures shall be consistent with accepted best management practices and shall be designed with the objective of ensuring that the rate of surface water runoff from the site does not exceed predevelopment conditions and that the quality of such runoff will not be less than pre-development conditions. Special emphasis shall be placed on the impacts of proposed encroachments into the required buffer.

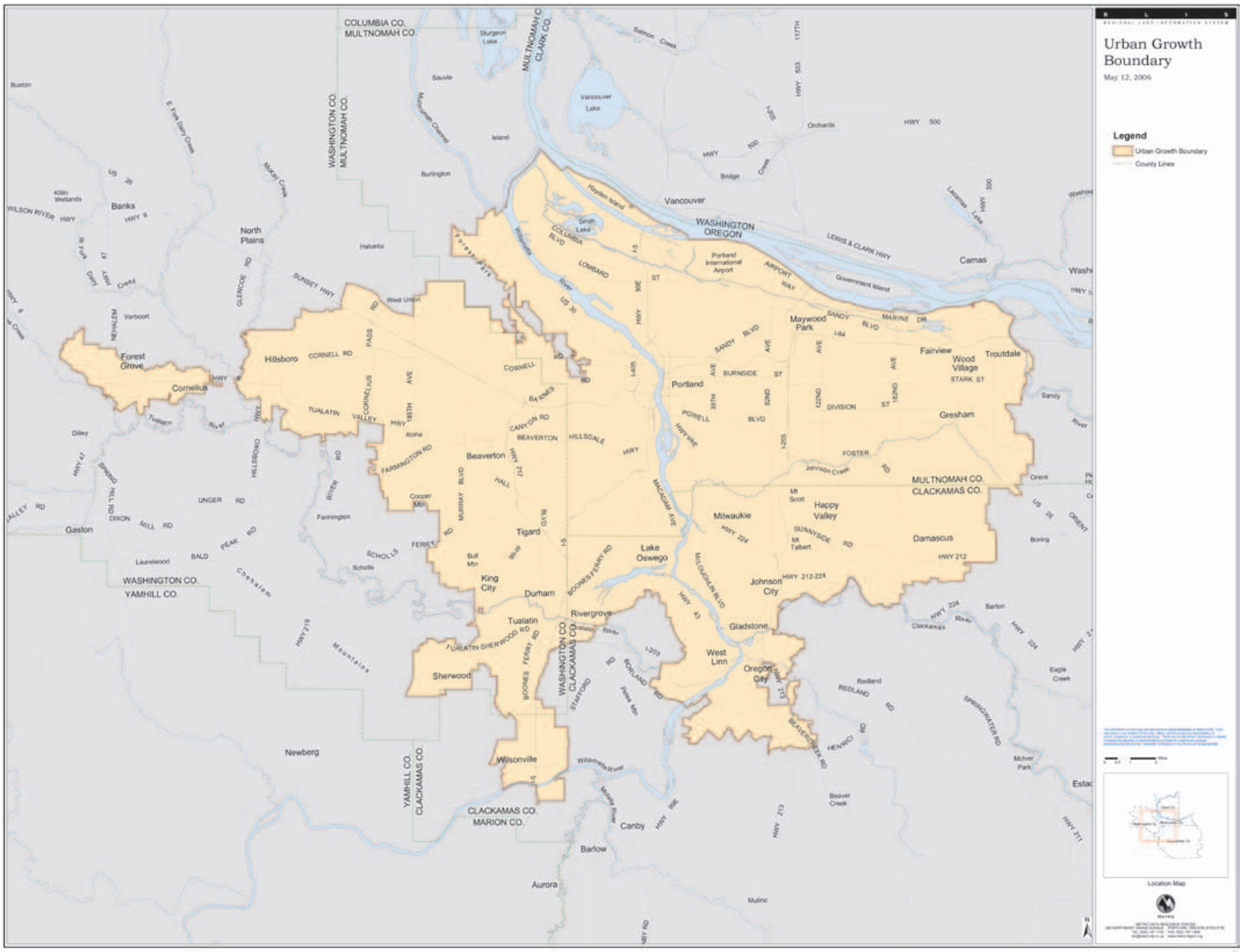
e. Proposed methods for complete containment of a spill or leaching of any materials stored on the property which would or could cause contamination of drinking water sources.

f. Where the developer of property which is subject to the terms of this overlay district desires to utilize existing or planned off-site stormwater quality management facilities, the developer shall provide a written certification to the zoning administrator that the owner of the off-site facilities will accept the runoff and be responsible for its treatment to a level of treatment acceptable to the county and consistent with the requirements of this chapter.

(2) Such study shall be submitted to the zoning administrator for review and approval concurrent with the submission of applications for review and approval of site or subdivision plans or applications for land disturbing or erosion and sediment control permits. A copy of the impact study shall also be forwarded to the agency which owns or manages the subject watershed for review and comments.

Appendix D

CITY OF PORTLAND, OR URBAN GROWTH BOUNDARY



SC
UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

VCU
Virginia Commonwealth University

ANTIOCH UNIVERSITY
NEW ENGLAND

UNIVERSITY of NEW HAMPSHIRE

ERG

CICEET

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE