# Green Parking Lot Resource Guide

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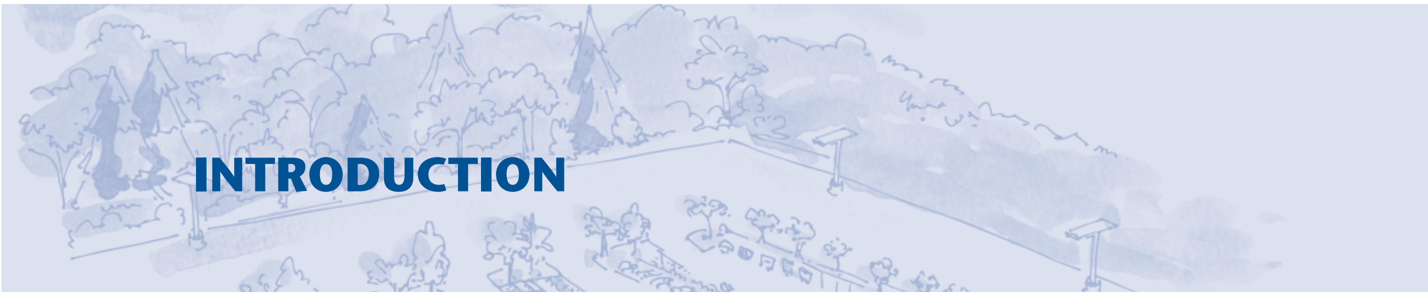


# INTRODUCTION

"Green" parking lot is a term increasingly used to describe parking lots that may incorporate a variety of environmentally preferable features, including a minimized footprint and/or impervious surfaces, stormwater best management practices (BMPs), and alternative parking surface materials. To date, however, information on green parking lots has been scattered across planning, construction, stormwater, engineering, and landscaping resources. The goal of this resource guide is to present the fundamental planning and design concepts of a green parking lot and connect readers to existing resources on the environmental benefits and cost effectiveness of green parking approaches. This document is expected to be particularly useful for local government officials involved in planning and development activities, as well as construction industry professionals (developers, project managers, facility managers and other decision makers) interested in green parking lot technologies.

The guide is organized into seven chapters:

- Chapter 1 describes the environmental and cost impacts associated with conventional parking lots.
- Chapter 2 provides an overview of the benefits of green parking lot development techniques, briefly describing major planning, design, and material considerations.
- Chapters 3 through 6 provide detailed information on specific elements of sustainable parking lot approaches including planning and design approaches (Chapter 3), sustainable stormwater management techniques (Chapter 4), alternatives to asphalt parking surfaces (Chapter 5), and water efficient landscaping and irrigation (Chapter 6).
- Chapter 7 discusses how green parking lots can help municipalities reduce future stormwater infrastructure and utility maintenance costs.

Case studies are included throughout the guide to provide real world examples of green parking lot techniques.

Key resources consulted in developing this guide are listed in the back of the document.

# CHAPTER 1

# Impacts of Parking Lots

Parking lots are a ubiquitous feature of the American landscape. Perhaps because they are so commonplace, the significant environmental and cost impacts associated with parking lots are often overlooked. In this chapter, we provide an overview of these impacts.

## Environmental Impacts of Parking Lots

The prevailing low-density American development pattern (i.e., urban sprawl) necessitates reliance on automobiles, along with the construction of parking lots to accommodate, and many times overaccomodate, demand for parking. As parking lots have become a dominant feature of urban and suburban landscapes, their environmental impacts have also become increasingly apparent.

Most parking lots are made of pavement—a combination of asphalt concrete, the most widely used paving material in the United States, and aggregates such as sand, gravel, or crushed stone. Pavement is an impervious, heat absorbing material that collects stormwater on its surface and does not allow it to filter into the soil, inhibiting the natural water cycle. With this in mind, parking lots have traditionally been built with the primary goal of channeling stormwater into receiving water bodies as quickly as possible, via means such as gutters, drains, and pipes. As a result, runoff that is contaminated with many types of petroleum residues, fertilizers, pesticides, and other pollutants from parking surfaces enters receiving waters at an unnaturally high rate and volume, negatively impacting the surrounding ecosystem. Hence, parking lots degrade water quality, strain stormwater management systems, consume large amounts of land and resources, and enable urban sprawl. Furthermore, materials used to construct parking lots have a variety of impacts on air, water, and biodiversity throughout their life cycle. Some of the major environmental impacts of traditional parking lots are described below.

### Water Quality Impacts

Parking lot runoff is a major contributor to non-point source pollution of our waterways. Conventional parking lots quickly move stormwater into receiving water bodies. As it flows across pavement, the water picks up pollutants from the surface. This results in large volumes of polluted runoff entering surface water and groundwater resources, negatively affecting water quality.

Contaminants in parking lot runoff can originate from a variety of sources, including the paving materials used to build them. Recently, the U.S. Geological Survey (USGS) pinpointed parking lot sealants as a significant source of non-point source pollution, specifically polycyclic aromatic hydrocarbons (PAHs), a known carcinogen that can be toxic to fish and wildlife.[1] Automobiles are also a major source of pollutants in parking lot runoff, including antifreeze, oil, hydrocarbons, metals from wearing brake linings, rubber particles from tires, nitrous oxide from car exhausts, and grease.

## Water Supply Impacts

Conventional parking lots consist of large areas of impervious surfaces that do not permit the infiltration of water into the soil. Unlike natural conditions where rainwater filters into the ground, impervious surfaces halt this process, inhibiting a watershed's natural hydrological cycle and preventing groundwater recharge. As a result, water tables are lowered, reducing streamflow during dry periods, depleting water supplies, and exacerbating the negative impacts of droughts.

## Stormwater Management Impacts

According to the USGS, an impervious, man-made surface will generate two to six times more runoff than a natural surface. In addition to the direct impact of paving, conventional parking lots also typically include pipes, curbing, gutters, and drains to help speed water off of parking surfaces. These systems cause runoff to move even faster downstream, increasing the risk of stream flooding. Sewer systems often become overwhelmed by the rapid runoff of stormwater, causing them to overflow and, in the case of combined sewer and stormwater systems, discharge raw sewage into receiving waterways. In addition to the human health risks related to combined sewer overflows, these discharges can cause algal blooms to form, depleting aquatic oxygen levels and altering a waterbody's habitat.

## Air Emission Impacts

Pollutant air emissions occur throughout the lifecycle of a parking lot. Asphalt cement plants emit particulate matter, nitrogen oxides ($NO_X$), sulfur oxides ($SO_X$), carbon monoxide (CO), volatile organic compound (VOCs), polycyclic aromatic hydrocarbons (PAHs), and carbon dioxide ($CO_2$) during the manufacturing process. The activities associated with the construction and maintenance of parking lots also generate emissions, typically in the form of dust, fumes, and equipment and vehicle exhaust. For example, the use of hot mix asphalt, a common process where the asphalt is heated to extremely high temperatures prior to application, can cause health problems for workers including headache, skin rash, fatigue, throat and eye irritation, breathing problems, and coughing. Diesel emissions from on-site equipment can also cause similar health effects.[2] In addition, the typical after effects of parking lot construction, such as fewer trees and less vegetation due to clearing, as well as heat island effect (see below), also lead to higher amounts of $CO_2$ in the air.

## Heat Island Effect

Heat island effect (HIE) occurs in urban areas where materials that have heat-absorbing properties, such as asphalt, are prevalent. In urban areas, the combined effect of such surfaces can cause a change in the energy (temperature) balance, leading to hotter air and surface temperatures. Recent research indicates that urban areas are 2 to 8ºF hotter in summer due to this increased absorbed heat.[3]

Parking lots contribute significantly to HIE. Asphalt, one of the most common paving materials used in parking lots, is a dark, heat absorbing material.[4] When asphalt cools at night, all the heat it has absorbed during the day is released into the air, slowing the rate of nighttime cooling. This hot surface, combined with stormwater runoff from the parking lot also affects surrounding waterbodies. When water is forced to flow quickly off the lot's surface, not enough time is allowed for evaporation to occur, again limiting natural cooling of the air. In addition, the land clearing needed to create space for parking lots diminishes tree cover and other natural vegetation that can help shade land and moderate temperatures.

The environmental impacts of the HIE are varied. Hotter temperatures can lead to more $CO_2$ emissions due to increased energy demand to cool neighboring buildings.[5] HIE can also increase smog, and subsequently exacerbate pulmonary and cardiovascular health problems. During rain events, paved surfaces can transfer heat to runoff, increasing the temperature of receiving waters. This warmer water can be detrimental to the natural habitats of fish and other aquatic life.

## Waste Impacts

The traditional production and application of asphalt relies heavily on the use of virgin stone and aggregate and non-renewable, petroleum-based materials. Use of fresh asphalt in parking lot construction creates a lost opportunity for reusing waste products, such as recycled asphalt, which would reduce the amount of material sent to landfills and increase the amount of virgin materials conserved. The use of recycled asphalt is common in the construction of roads, but has yet to become prevalent in parking lot construction.

## Disturbance of Habitat and Local Ecology

Traditional parking lots can have a host of negative impacts on adjacent habitat and fauna. The velocity and volume of runoff from parking lots can damage plant, fish and invertebrate habitat. During storm events, runoff can erode stream banks and alter the natural shape of a waterway. Stream edge habitat and stream channel protection removed during the construction of the parking lot increases the potential for erosion. Sediments entering the waterway as a result of erosion can smother habitat and stress aquatic organisms. The turbidity created from the sedimentation can disrupt an aquatic ecosystem by diminishing light transmission, reducing plant growth, altering food supplies, interfering with navigation, decreasing spawning habitat, and reducing shelter.

The contaminants in parking lot runoff also pose a risk to wildlife. Toxic substances from contaminated ground and surface water supplies have the potential to bioaccumulate in the tissue of fish and other organisms in the wildlife food chain. They can also accumulate in sediments, posing risks to bottom feeding organisms and their predators.

The impact of parking lots on water supplies affects local ecology. Unnaturally low stream flows as a result of decreased infiltration can negatively impact deep water and swift flowing habitats. Impaired water quality, and increased volume and velocity of runoff, can lead to habitat loss, stress aquatic species, and have an overall negative effect on biological diversity in abutting areas.

## Decrease In Greenspace

Greenspace is a finite resource with a wide range of intrinsic values, including conservation, recreation, and agricultural purposes, as well as its scenic qualities and contribution to the overall character of a city or town. Proper management of greenspace is essential to achieving and maintaining sustainable communities. Nevertheless, greenspace areas are commonly paved to accommodate demand for parking. For example, it is estimated that 30 to 40 percent of a typical American downtown is used for parking spaces.[6]

Ineffective local government zoning restrictions also result in the creation of larger areas of paved surface than necessary to meet the parking demand. Many municipalities require a minimum number of parking spaces per development project, often forcing developers to build more spaces than needed to meet actual demand. For instance, commercial parking lots frequently have 60 to 70 percent vacancy rates.[7] Parking stall sizes required by zoning can also be larger than necessary, eliminating opportunities to alter parking lot configuration designs to achieve higher car capacity and minimize impervious surface area.

Conventional parking lots are often viewed as unattractive, hostile, and sometimes unsafe areas. In contrast, green parking lots with urban greenscaping provide aesthetic benefits, including privacy and noise reduction, to landowners and to communities. These benefits are lost when conventional parking lot construction and paving techniques are used.

### Urban Sprawl

Urban sprawl and prevailing low-density development patterns characterized by free, plentiful parking reinforce dependence on automobiles for commuting to work, shopping, and social activities. Thus, conventionally designed parking is an enabler of urban sprawl. Conventional parking creates barriers to alternative transportation, including walking and bicycling, and encourages automobile travel, disconnecting communities and decreasing the habitability of cities and towns. The resulting increase in vehicle miles traveled and the associated high levels of mobile source air emissions exacerbate air quality issues, and contribute to global climate change.

## Costs of Parking Lots

Beyond their environmental impacts, parking lots have economic and social costs related to their construction—costs that are often much higher than consumers realize. Moreover, parking costs are shouldered by many stakeholders, including developers, local governments, parking users, and community members. Below we describe the types of costs related to parking lot construction, as well as who pays.

### On-site Costs

On-site costs include the construction, operation, maintenance, and disposal of materials needed to develop and maintain parking lots, including paving materials and infrastructure such as gutters and curb cuts. In addition, on-site costs include the cost of parking lot landscaping that, depending on the shrubs, trees, and turf chosen, vary in their need for mowing, pruning, and irrigation. These costs are typically paid by developers, although local governments sometimes subsidize infrastructure costs. HIE can add to parking lot user costs, by decreasing an automobile's value by quickening the deterioration of the vehicle's paint, plastics, and tires while on the lot. HIE can also shorten the life of the pavement, causing it to become brittle and weak (a cost to parking lot owners); and can increase the energy costs of adjacent buildings due to the hotter air temperatures (a cost to the building owner and potentially to third parties).

### Infrastructure Costs

Local governments bear the brunt of infrastructure costs related to parking. The high volume and velocity of polluted run-off from parking lots can stress stormwater management systems and hasten the need for repairs, upgrades, and expansions to handle water flow and treat runoff. Flooding caused by runoff can also degrade bridges, roads, and other parts of a city's infrastructure. Additionally, groundwater shortages due to disruption of the water cycle can increase the frequency, and thus cost, of pumping groundwater.

### Opportunity Costs

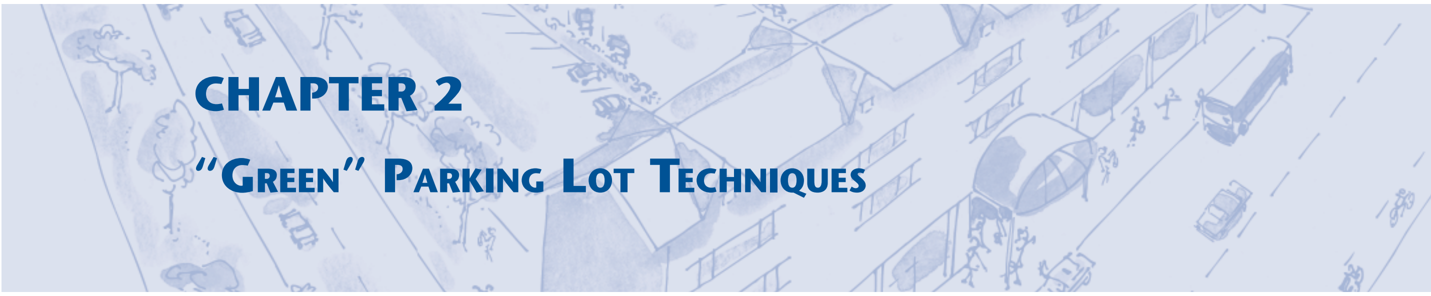
Parking lots consume large areas of open space that could otherwise be used for alternative, higher value purposes, such as parks, wildlife habitat, recreation, agriculture, housing or other businesses. Building parking instead of other types of development could reduce the property tax base, a cost to local governments and local taxpayers. Enforced minimum parking requirements do not benefit developers either. They limit the development potential of land; the more parking spaces that are required, the less land available for more profitable uses. This can be costly because parking is relatively expensive to construct and yields little return, or no return where parking is free.

### Distributional Issues

Parking lots provide a value to consumers who use them, but result in negative impacts for neighbors and other community members who do not use them. Community members would be better served by almost any other land use, particularly in cases of excessive sizing of paved areas, which can reduce adjacent property values.

### Community Development Costs

Parking lots and associated sprawl decrease a community's habitability, livability, and sense of identity, a cost to all community members. Unattractive expanses of pavement placed in front of buildings create voids and disconnectedness, discouraging pedestrian-friendly communities and alternative methods of transport. The presence of multiple conventional parking lots can also signal developers that a community accepts urban sprawl development. This signal can create a cyclical effect on a community's future development patterns. Subsequent developments in these areas are far more likely to have a similar pattern of urban sprawl, further disconnecting the link with any older non-sprawl development, and eroding or precluding unique characteristics that establish a community's sense of place.



# CHAPTER 2

## "Green" Parking Lot Techniques

Innovative approaches to planning and design can greatly mitigate many of the negative impacts of parking lots, including diminished recharge of groundwater, high rates of stormwater runoff, and non-point source pollution, by decreasing impervious surface area, protecting water quality, reducing stormwater management and maintenance costs, and increasing aesthetic value. Below, we introduce green parking lot techniques, many of which are described in detail in subsequent chapters.

### Planning Aspects

Local planners regularly reinforce car dependence through zoning bylaws that, although meant to meet a community's parking needs, can result in an oversupply of parking. As a result, cities and towns are increasingly trying new approaches to parking management that allow for greater flexibility and adaptability by determining parking space numbers on a project-specific basis, rather than through a one-size-fits-all regulation.

One such technique is to ***reduce minimum parking requirements*** based on project location or demographics. For example, local governments can encourage projects that are located near public transportation to reduce the demand for parking spaces. Adaptations of this technique include municipalities allowing a reduction in the minimum parking requirements in return for a developer/employer agreeing to implement a transportation demand management program to encourage employees to use alternative modes of transport, through company support or subsidies. Another alternative is for municipalities to institute an optional fee that developers can pay towards an appropriate municipal fund, such as a traffic mitigation fund, in lieu of meeting minimum parking requirements.[8]

Depending on the site, developers may not opt for constructing less parking because it may make a site less marketable. A technique applicable in this case would be to set ***parking maximums and/or area wide parking restrictions***, which would limit the number of spaces allowed across a larger area, evening the playing field for the marketability of sites in the area.

Beyond reducing the number of parking spaces required, municipalities and developers can also encourage practices that ***reduce stall dimensions*** by creating more compact car spaces and realistic stall size requirements. Some local zoning laws currently require unnecessarily large stall dimensions that are bigger than even the largest SUV.[9] In many cases smaller, more realistic, stall sizes would be sufficient while reducing the amount of disturbed land and impervious surface associated with a project.

Improving the aesthetic of the parking lot is also a central technique in green parking lots. For instance, placing a parking lot behind a building rather than in front of it creates a more inviting and pedestrian-friendly environment. Reducing the number of curb cuts also decreases the frequency of pedestrian/

traffic interaction, thus making for a more pedestrian-accessible area. These practices aim to improve the character of the development while maintaining accessibility to the lot. Additionally, parking lots can be divided into two or more parking areas, again projecting a more visually welcoming appearance.

The impact of locating a parking lot at the front of a building can be mitigated by providing ample space between the lot and the road, and then creating a buffer with landscaping, fencing, or a wall. Landscaping inside the parking lot is also an important technique. Beyond making the parking lot more visually pleasing, vegetation and landscaping (including trees) around and inside the parking lot reduce HIE and help to absorb $CO_2$ emissions. Landscaping is discussed below.

Chapter 3 provides detailed information on green parking planning.

## On-Site Stormwater Management

Innovative stormwater management strategies are increasingly being incorporated into parking lot design as part of the overarching concept of Low Impact Development (LID). LID stormwater techniques (also known as Best Management Practices, or BMPs) manage stormwater on-site, reducing negative impacts on receiving waters and municipal stormwater management systems, and decreasing the need for costly infrastructure such as pipes, gutters, and curbs. Done on a small-scale, these controls attempt to mimic the pre-development ecological and hydrological processes of an area and can reduce stormwater and site development design, construction, and maintenance costs by 25-30 percent compared to conventional approaches.[10]

*Strategically sloped vegetated strips are a better option than conventional grassy parking islands for collecting and filtering runoff.*

Stormwater BMPs include structural controls and bioengineering techniques designed to facilitate natural water cycling processes (i.e. evaporation, transpiration, and groundwater recharge) by capturing, filtering, infiltrating, and/or storing stormwater. Components of these soil- and plant-based systems can carry out one or more of the aforementioned functions, including some that store water for various durations (from 24 hours to permanent storage). Examples of BMPs include swales, vegetated buffer strips, and bioretention areas.

Unlike traditional stormwater management systems designed only for efficiency in stormwater removal, which can lead to negative downstream effects, BMPs represent a shift towards a sustainable approach to stormwater management. Thus, in the context of parking lots, BMPs add value by minimizing environmental impacts of runoff, and often lower site development costs while improving aesthetics.

Chapter 4 provides detailed information on greener stormwater management and BMPs.

## Parking Surface Material Selection

The negative impacts associated with large impervious surface areas in parking lots can be reduced through the use of new permeable materials as substitutes for pavement. A number of paving substitutions have been developed to reduce the range of environmental impacts associated with the use of pavement. Types of permeable and semi-permeable alternative pavers include gravel, cobble, concrete, wood mulch, brick, open jointed pavers filled with turf or aggregate, turf blocks, natural stone, and pervious concrete.

Based on a site's characteristics (i.e. traffic volume, soil type, climate etc.), alternative pavers may not be an option for the entire surface of primary parking areas.[11] However, in many cases, the aisles and driveways can be constructed using conventional pavement, while alternative pavers can be used in parking stalls, crosswalks, and overflow lots. Alternative pavers slow the flow of runoff, allowing it to filter into the soil, sustaining an area's natural hydrological cycle, and in some cases, allowing microbes to break down contaminants before entering the soil layer.

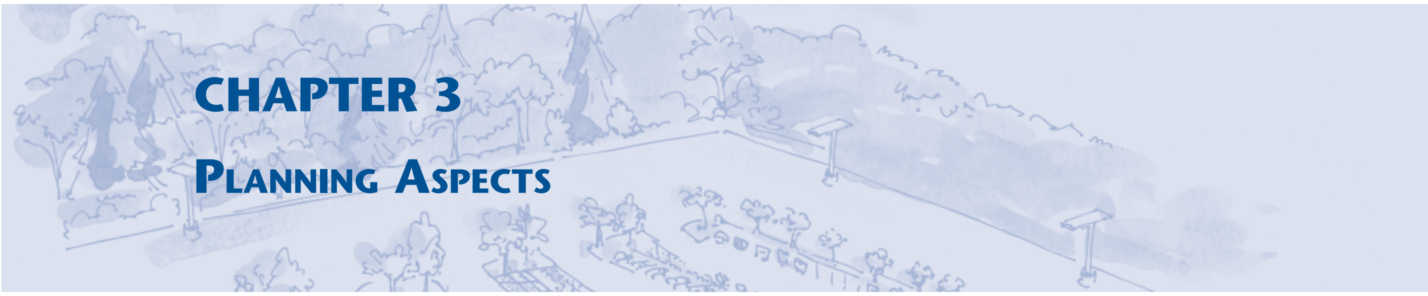
Opportunities for materials recycling exist in the management and construction of parking lots. For example, the use of recycled asphalt in parking lot construction is not only environmentally beneficial, but can make economic sense. Other environmentally preferable materials, such as recycled rubberized asphalt, may also be used in parking lot construction. Recycling materials can be more economical for developers than incurring the rising costs in some states for disposal of construction, demolition, and clearing debris in landfills.

Chapter 5 provides detailed information on greener choices for parking surface materials.

## Landscaping and Irrigation

Green parking lot techniques work to minimize the amount of land cleared for construction, conserving as much of a site's natural vegetation and open space as possible, and retaining habit for local wildlife. When designing a parking lot area, landscapers can use native trees and shrubs rather than non-indigenous species, which are more suitable to local climates and, therefore, require less irrigation. The benefits of increasing the amount of greenscape in and around parking areas include reduction of $CO_2$ in the air; improved stormwater runoff management including water storage; increases aquifer recharge and flood protection; and increased human comfort through mitigation of HIEs. Wetlands preservation or creation is particularly beneficial, as they can act as natural bioretention basins, providing water quality improvements, flood protection, and erosion control. Wetlands also provide excellent habitat for local avian and fish species, and are invaluable for water storage; one acre of wetlands can store over million gallons of water.[12]

Chapter 6 provides detailed information on green parking lot landscaping and irrigation.



# CHAPTER 3

# Planning Aspects

Parking lot design and parking availability are vital to transportation management throughout the United States. Parking availability may determine a customer's willingness to visit a business, and it is often a sought after feature in urban residential areas. However, parking lots should be designed efficiently so that spaces are used frequently and not left empty a majority of the time. When developing a parking lot, a number of factors combine to determine the lot's size, layout, and design. These decisions, made during the planning stages of a development, can transform a parking lot from a sparsely landscaped expanse of impervious paving to a space that is more aesthetically pleasing, land efficient, and community and environmentally friendly.

Local governments can use better parking planning as a tool to promote infill and smart growth developments while reducing the direct environmental impact of parking. In many cases, revisions to zoning and other parking ordinances may be needed to achieve better parking planning. This chapter provides a summary of parking planning considerations that have environmental implications, including municipal parking lot regulations, parking lot aesthetics and design, and the connection between parking and smart growth.

## Municipal Parking Requirements

In most urban and suburban areas, a number of zoning laws govern the layout and quantity of spaces in a parking lot. It is these regulations that manage a community's parking capacity, and thus a large amount of its impervious surface area.

Zoning requirements for developers to provide off-street parking first began in the 1930s as a solution to an on-street parking shortage. Over the years, off-street parking requirements expanded in response to the population's dependence on automobiles. Today, according to the U.S. Department of Transportation, 87 percent of trips of less than 50 miles are made by personal motor vehicles.[13] Americans have become accustomed to the availability of free parking and automobile travel, rather than public transit or other alternative methods, even for very short distance trips. Increased parking availability encourages more driving, more driving requires more parking, and so on.

One of the most important local parking ordinances addresses minimum space requirements, or *parking ratios*. Typically, local governments require developers to construct the minimum number of parking spaces needed to satisfy peak demand. These minimum parking regulations often result in an oversupply of parking. One study found that the average parking supply at worksites is 30 percent greater than peak parking demand.[14] In many instances, minimum parking requirements are inflexible to adaptation or variances. Also, the methods to determine these minimum parking requirements are often excessive and over-generalized, leading to an oversupply of parking.[15] In addition, although municipalities regulate the minimum number of parking spaces, they typically do not put a cap on the maximum. Thus, developers can frequently construct even more than the required minimum, which is often the case at large retail developments, leading to a further surplus in supply.

In addition to requirements for the number of spaces in a parking lot, regulations for the size of each space are also common. Some local zoning laws require unnecessarily large stall dimensions that are bigger than even the largest SUV.[16] In many cases, smaller stall sizes would satisfy parking needs while reducing impervious surface, and the entire footprint, of the parking lot.

## Re-thinking Municipal Parking Requirements

There are a number of planning alternatives to minimum parking requirements that leading local governments throughout the United States are implementing to minimize land dedicated to parking. These include reducing minimum parking requirements; assessing parking needs on an individual project basis rather than using a generic formula; encouraging shared parking; and establishing parking maximums, area wide parking caps, in-lieu parking fees, and reduced parking space dimensions.

- **Reduced minimum parking requirements—**Parking requirements should be determined on a project-by-project basis instead of by formula, taking into consideration how a project's location can shape parking needs. This approach may decrease the required parking capacity where there is accessibility to public transportation and/or a high level of foot and bike traffic. Such was the case for the City of San Francisco, where city planners eliminated minimum parking requirements for development within a half mile of train stations and one-quarter mile of major public transit routes.[17]

  Municipalities can also consider the land uses in the surrounding area. For instance, it is possible that existing nearby development and parking may already provide some of the parking necessary to support a new development. Mixed used developments often have natural parking flexibility; an office where peak parking demand occurs during the day can share the same parking spaces with restaurants, entertainment venues, or residential units that have peak parking demands at night and on weekends. Shared parking is also an option for single use developments in mixed-use areas.[18]

- **Maximum Limits on Parking—**The opposite of parking minimums, parking maximums limit the number of spaces that a developer can construct, which is often determined by the development's square footage. Portland, Oregon is one city that has successfully implemented the use of parking maximums. Benefits of such a policy include open space preservation, reduction in impervious surface area, traffic congestion reduction, promotion of alternative transport, and the development of pedestrian-friendly urban design. For developers, such limits mean lower parking lot construction costs.[19] Similar policies include setting both a parking minimum and maximum, or determining a median parking ratio.

- **Area wide parking caps—**Municipalities can control the amount of parking by setting limits on the total amount of parking spaces allowed in a certain area. This strategy is being used in major U.S. cities including Boston and San Francisco. Such regulations require greater research and planning efforts by the city or town to ensure that the parking cap is appropriate and reasonable, but if done properly, it can be very successful in minimizing the land area used for parking and encouraging use of public transportation. This option is appropriate for areas with adequate access to public and alternative transportation, as well as desirable location that would outweigh the perceived drawbacks of more limited parking.[20]

- **In-Lieu Parking Fees—**Towns such as Berkeley, California, Lake Forest, Illinois and Orlando, Florida incorporated systems of in-lieu parking fees. This optional fee is offered to developers by municipalities in-lieu of meeting minimum parking requirements. This fee is typically allocated to an appropriate municipal fund, such as a traffic mitigation fund.[21] An alternative under the in-lieu system is that in return for the developer's fee, the city provides existing centralized, off-site parking to the new development's tenants and visitors.[22]

- **Reduced stall size requirements—** Adjusting a local government's stall size requirements may reduce impervious surface coverage as well. Alternatives include creating a certain number of compact car spaces and/or limiting stall dimensions to feasible sizes. For example, in the town of Needham, Massachusetts, up to 50 percent of off-street parking can be reduced dimension spaces designed for compact cars.[23] If possible, developers can also adapt the layout and angle of parking stalls to achieve the greatest car capacity, again reducing the amount of land necessary for the lot.

## Parking Lot Placement and Aesthetics

Parking lots have been described as "sterile, unattractive environments that deaden city and suburban streets alike, further isolate users and preclude lively pedestrian-friendly streets."[24] Although all parking lots do not match this description, many are eyesores that inhibit the usability and walkability of an area. Several techniques can be incorporated into the design and layout of a parking lot to improve aesthetics and help connect parking lots to community design. This not only benefits the user, but also the organization or business adjacent to the lot, as a more pleasing atmosphere will help draw in the public. Plantings around the perimeter, especially trees and shrubs, can screen the lot from passer-bys and break-up the otherwise continuous strip of asphalt and cars from the street to the parking lot. This can also be achieved through the use of fencing or a wall. Vegetation can also be used to divide one large lot into two or more smaller lots, again increasing the site's visual appeal. Equally important, landscaping within the lot provides an environmental benefit by decreasing dust, wind, noise, glare and air pollution; and minimizing heat island effect.[25]

The placement of a parking lot is a simple, yet fundamental feature that can improve a development's attractiveness. A majority of parking lots are placed in the front of buildings, between buildings and streets, requiring pedestrians and bicyclists to cross expanses of parking in order to enter a building. Alternatively, parking lots could be placed at the rear of a building, increasing the interconnectedness between pedestrians and the built environment. This simple zoning change is incredibly effective in shifting the orientation of a streetscape from cars to pedestrians. This also helps give the community a greater sense of place and interconnectedness. In recognition of such benefits, the City of Fort Collins, Colorado requires that no more than 50 percent of the parking for a retail development be located between the principle building and the primary abutting street.[26] Limiting the number of curb cuts also makes a parking lot more pedestrian friendly and inviting. Furthermore, by minimizing the number of vehicular entries to parking areas, pedestrian mobility is improved, and pedestrian/traffic is minimized.

## Linking Parking to Smart Growth

Smart Growth is a state and local government planning movement aimed at improving the long-term habitability and sustainability of cities and towns by minimizing environmental impacts, improving human health, building a sense of community, creating walkable neighborhoods, promoting traditional and alternative transport, and preserving open space. Most fundamentally, smart growth entails moving away from the urban sprawl development pattern common in the United States, and promoting sustainable land use patterns. With many cities designed around use of the automobile, planners are often presented with the conflicting challenge of promoting smart growth development while supporting the parking needs of a population. Green parking planning approaches support smart growth by creating more sustainable land use patterns and decreasing the environmental impacts of conventional parking lot development. By promoting and supporting alternative transport and commuting, local governments may reduce the parking needs.

A concept linked to smart growth is "transit-oriented development," defined as development placed within close proximity of public transportation, designed to create walkable communities and alleviate traffic congestion and environmental impacts caused by urban sprawl. When building parking lots, local governments can encourage or require developers to incorporate features that help reduce automobile reliance, such as bicycle racks. Employers can support use of alternative transport options by subsidizing the cost of public transit, encouraging participation in a commuting program, and/or providing shower facilities on-site so that staff can bike to work.

# CHAPTER 4

## Stormwater Management

A pivotal component of green parking lots is the inclusion of innovative stormwater management techniques, often referred to as stormwater "best management practices" (BMPs). BMPs are practices, techniques, and measures that prevent or reduce water pollution from non-point sources (i.e. runoff) using the most effective and practicable means available.[27] Stormwater management BMPs often include engineered, on-site systems that, when coupled with reduction of impervious surface area, can help significantly reduce detrimental environmental effects and infrastructure burden from stormwater runoff.

Increased development and conventional stormwater systems have significantly changed the characteristics of stormwater flow from land into receiving waters. According to the Natural Resources Defense Council, the amount of rain converted to runoff under natural conditions is less than ten percent of the rainfall volume.[28] However as more development occurs, rainwater or snow melt that would have infiltrated into the soil, evaporated into the air, or been absorbed by plants, instead flows quickly off of the pavement as stormwater runoff. Moreover, conventional stormwater management exacerbates this problem. Conventional parking lot stormwater management typically consists of costly systems of man-made drains, pipes, gutters, storm ponds, and paved channels that direct runoff from impervious lots into storm drains and neighboring waterbodies. The environmental ramifications of one development project alone can be minimal, but multiplied by the current, and growing, number of commercial and residential parking lots, the combined effect of stormwater runoff has become the leading cause of non-point source pollution to our waterbodies.[29]

As discussed in Chapter 2, the environmental effects of increased volume and velocity of stormwater include not only diminished water quality in surrounding waterbodies, but also:

- Degradation of stream channels resulting erosion and sedimentation;
- Minimized groundwater recharge, which can diminish water flow in the dry weather, and lead to poorer water quality during low flows;
- Higher water temperatures, which negatively impact aquatic organisms and plants; and
- More frequent and severe flooding.[30]

This chapter provides an overview of green parking lot stormwater management BMPs that can help mitigate these impacts, including information on pollutant removal efficiency and cost considerations.

### Green Parking Lot Stormwater Management Techniques

Green parking lots offset environmental impacts of parking by using on-site stormwater infrastructure that more closely mimics the natural water cycle, and manages stormwater through effective rainfall retention, pollutant removal, and water infiltration. Although still in the early stages of wide-spread implementation, cities and towns are recognizing the benefits of stormwater BMPs, and many have introduced both voluntary and mandatory policies for their inclusion in development projects.[31]

Some of the most commonly used structural BMPs are described below. It also should be noted that incorporating BMPs is not limited to new development. As illustrated by the case study of building a rain garden at Bloedel Donovan Park in this chapter, existing parking lots can be retrofitted to include them.

- **Swales**

  Swales are open channels or depressions with dense vegetation used to transport, decelerate, and treat runoff. In parking lots, they are designed to help direct water into bioretention areas. Swales can come in the form of a grassed channel, dry swale, or wet swale. They can be used in most climatic regions of the United States, but may be unsuitable for densely urban areas as they require a large amount of pervious surface area.[32]

- **Vegetated Filter Strips/Riparian Buffers**

  Vegetated filter strips are flat pieces of land with low slopes, which are designed to encourage natural sheet flow of stormwater as opposed to channeled runoff. Vegetated filter strips are well suited for low-density development or areas with less concentrated amounts of runoff.[33] They function by using soil and vegetation to remove pollutants from stormwater runoff, and often are incorporated to pre-treat and remove sediment before water enters infiltration devices such as bioretention areas.[34] Other benefits include protection of riparian areas, habitat creation, and streambank stability.

  Vegetated filter strips are frequently used in combination with riparian buffers, another common BMP, to increase pollutant removal effectiveness. Riparian buffers are vegetated strips along waterways that trap and filter contaminants, encourage infiltration, and slow stormwater flow. They also help to preserve streambank stability.

- **Bioretention Areas (Rain Gardens)**

  One of the more well-know BMPs, bioretention treatment areas (a.k.a., rain gardens) consist of a grass buffer strip, shallow ponding area, organic layer, planting soil, and vegetation. These areas are typically used in parking lot islands. Unlike swales, bioretention areas are well-suited for parking lots in denser, urban areas with less available open space.

- **Dry Detention Basins**

  A dry detention basin is a vegetated basin with controlled outlets, designed to detain runoff (lowering flows and reducing velocity) for a short amount of time (e.g. 24 hours or less), partially removing pollutants before the water is discharged. This helps limit flooding and other stormwater impacts, such as stream channel erosion and wildlife habitat destruction. Dry extended detention basins are better suited for pollutant removal than standard dry detention basins because they retain the water for an "extended" period of time (i.e., up to 48 hours). They are effective at treating certain runoff contaminants, particularly those contained in spring and winter runoff in colder climate areas. However, because water temperature increases while in this type of system, dry detention basins discharge warmer than natural water into waterbodies, which should be taking into consideration. Both dry detention and dry extended detention basins are normally dry between storm events, thus giving them their name.[35]

- **Wet Retention Basins**

  Wet retention basins are designed to capture, filter, store, and infiltrate storwmater, and have storage capacity adequate for flood volumes of water. Because they have the capacity to store a permanent pool of water, wet basins can be very effective for water control, and can provide the benefits of aesthetic value and wildlife habitat, both terrestrial and aquatic. Although not suitable for smaller areas because of their size, when applicable, retention basins are a very effective BMP.[36]

- **Infiltration Systems**

  Infiltration systems are designed to capture and retain stormwater runoff, allowing water to gradually infiltrate into the ground over a period of hours or days, depending on the design.[37] Two common infiltration systems used in green parking lots are infiltration basins and infiltration trenches. An infiltration basin is an open depression that covers a relatively large area. It is constructed to work in conjunction with filter strips or swales, which help direct runoff from a parking surface into the basin. Infiltration trenches are shallow excavated ditches lined with filter strips and filled with stone to form a subsurface basin, where water is stored until it infiltrates into the soil. This system greatly reduces the volume of runoff, and is particularly good for groundwater recharge as it allows a significant amount of rainwater to infiltrate. Both of these BMPs are considered effective for pollutant removal when used in conjunction with a pre-treatment BMP such as a swale. However, potential drawbacks include higher failure rates due to improper design and maintenance, limited site applicability, and increased sediment clogging.[38]

  Porous pavement is another type of infiltration technique used in green parking lots; as it is also an asphalt alternative, it is discussed in Chapter 5: Parking Surface Materials.

- **Constructed Wetlands**

  Constructed wetlands are designed to capture, filter, and store stormwater similar to a wet retention basin. However, they also contain a large quantity of wetland vegetation and have wetland channels. Although they are not built to replicate all of the ecological functions of wetlands, constructed wetlands help simulate the natural water cycle, recharge groundwater, remove pollutants, reduce erosion, and provide wildlife habitat. They are considered to be a very effective pollutant removal option.[39] Constructed wetlands have a few limitations; they are not applicable in arid climates and, due to their large size, they are not suitable for dense urban areas.

It is not necessary for developers to incorporate all available green stormwater techniques into a project; rather, they should determine those useful for specific site conditions. Considerations should include all factors that affect the amount, speed, and pollutant loadings of runoff: soil type, the slope and landscape of the site, amount of impervious surface, local precipitation patterns, and rainfall surface retention.[40] Carefully choosing the appropriate BMP(s) is important to avoid any secondary environmental impacts caused by the use of an inappropriate BMP. BMPs should address peak discharge, runoff volume, infiltration capacity, base flow levels, ground water recharge, and maintenance of water quality, so that they are ideally managed in the pre-development stormwater filtration conditions of the site.[41]

It should be noted that BMPs are helping to meet the Clean Water Act's mandate to "restore and maintain the chemical, physical and biological integrity of the Nation's waters".[42] By 2025 the U.S. population is predicted to grow 22 percent, which could mean an additional 68 million acres of development, a good fraction of which will be dedicated to parking.[43] Thus, BMPs may play a larger role in the future to mitigate non-point water pollution.

## BMP Pollutant Removal and Effectiveness

Stormwater can carry a number of harmful pollutants, and is the prime contributor to non-point source pollution. Runoff contaminants can originate from a variety of sources, including the paving materials used to build the parking lots. Recently, the USGS pinpointed parking lot sealants as a large source of non-point source pollution, specifically polycyclic aromatic hydrocarbons (PAHs), a known carcinogen that can be toxic to fish and wildlife.[44] Automobiles are also a major source of pollutants in parking lot runoff, including antifreeze, oil, hydrocarbons, metals from wearing break linings, rubber particles from tires, nitrous oxide from car exhausts, and grease. Other polluting materials include pesticides, fertilizers, litter, pet waste, dirt, and sand.[45]

One of the main goals of a green parking lot is to decrease pollutant levels in stormwater runoff as much as possible before it enters a waterbody. Exhibit 1 shows a range of pollutant removal efficiencies for selected BMPs. Understanding the effectiveness of each BMP for pollutant removal is a complex undertaking because pollutant removal is affected by a large number of variables. Fundamentally, removal effectiveness depends on: 1) BMP type, 2) the quantity of runoff treated, and 3) the type of pollutant being removed.[46] Variation in one of these factors can affect a BMP's efficiency. For example, infiltration trenches show a high pollutant removal efficiency for pathogens, but much lower for phosphorus. However, these effectiveness ranges can vary based on the climate, soil, and land type of a particular site. Infiltration trenches may be less effective in colder climates when surface waters freeze and cannot allow runoff to flow into them, a limitation that can be partially remedied through proper design and maintenance, but may still reduce pollutant removal effectiveness.[47]

As seen in Exhibit 1, not all BMPs have a high level of pollutant removal effectiveness. Instead, they serve other roles in controlling the impacts of runoff. This is the case for dry detention basins, which serve to reduce peak discharges of stormwater to neighboring waterbodies, as well as limit erosion and downstream flooding.

## Exhibit 1: BMP Effectiveness

| BMP Type | Typical Pollutant Removal Efficiency (percentage) | | | | |
|---|---|---|---|---|---|
| | Suspended Solids | Nitrogen | Phosphorus | Pathogens | Metals |
| **Dry Detention Basins** | 30-65 | 13-45 | 15-45 | <30 | 15-45 |
| **Retention Basins** | 50-80 | 30-65 | 30-65 | <30 | 50-80 |
| **Constructed Wetlands** | 50-80 | <30 | 15-45 | <30 | 50-80 |
| **Infiltration Basins** | 50-80 | 50-80 | 50-80 | 65-100 | 50-80 |
| **Infiltration Trenches/ Dry Wells** | 50-80 | 50-80 | 15-45 | 65-100 | 50-80 |
| **Grassed Swales** | 30-65 | 15-45 | 15-45 | <30 | 15-45 |
| **Vegetated Filter Strips** | 50-80 | 50-80 | 50-80 | <30 | 30-65 |

Source: U.S. EPA, 1993, Handbook Urban Runoff and Pollution Prevention Planning, EPA-625-R-93-004, taken from Purdue University Engineering Department's Long-Term Hydrologic Impact Assessment (L-THIA): http://cobweb.ecn.purdue.edu/~sprawl/LTHIA7/lthia/lthia_index.htm.

## BMP Cost Considerations

Innovative structural stormwater BMPs are more effective than conventional stormwater management in removing pollutants and maintaining the environmental quality of a site. However, because some of these techniques are relatively new and have not achieved market penetration, it is not clear their costs compare to conventional stormwater management approaches.[48] Calculating the cost-effectiveness of a stormwater BMP is a very site-specific endeavor, and current cost information is limited and inconsistent. The main factors affecting the relative costs of BMPs include the cost of land, engineering and design, permitting, construction, and operation and maintenance. These costs can vary greatly due to individual site characteristics such as climate, topography, government regulations, soil type, time of year of construction, drainage, accessibility of equipment, and economics of scale. For instance, very rocky soils may increase the cost of constructing a BMP considerably because of excavation costs.

Another significant variable in the comparative cost of BMPs is the value of land; in areas where real estate prices are high, constructing a BMP may take up too much space to be cost effective.[49] BMPs operation and maintenance costs can also be significant. The long-term cost to maintain certain, more complex, stormwater BMPs over a 20-25 year period can be close to its initial construction cost.[50]

However, some BMPs, such as swales and bioretention areas, are less expensive to build than their conventional counterparts of pipe and gutter systems. These BMPs can decrease development costs by reducing or eliminating the high cost of conventional stormwater infrastructure such as piping, gutters, and drains, as well as reduced long-term maintenance costs for such systems. Furthermore, some BMPs, such as constructed wetlands, may increase the property value by creating a water feature and vegetation that has high aesthetic value. Developers may also gain from local government incentives that encourage incorporating structural stormwater BMPs. For instance, the City of Portland, Oregon will give up to a 35 percent discount off its stormwater utility fee to properties with on-site stormwater management.[51] In addition, some costs are tax deductible, and operating costs may be fully deductible as expenses in the year they are incurred.[52]

Although the costs of BMPs vary by site and type, they are almost always a good investment from the perspective of local governments and taxpayers, not only because they protect the health of waterbodies, but also because they can avoid long-term costs. Without stormwater BMPs, many waterbodies and water infrastructure may deteriorate. Taxpayers bear the cost burden to slow or repair damage caused by downstream flooding, stream and aquatic habitat deterioration, and repairs and upgrades to worn town stormwater infrastructure systems, all of which are very expensive and time-consuming.[53] Infrastructure costs associated with stormwater management and how green parking can help mitigate these costs are discussed further in Chapter 7.

# CASE STUDY 1: Stormwater Best Management Practices (BMP) Bloedel Donovan Park, Bellingham, Washington[54]

Stormwater runoff in Bellingham, Washington, like much of the U.S., is a foremost water quality issue. The Washington Department of Ecology estimates that roughly one-third of the state water bodies with pollution related problems are impaired because of stormwater runoff impacts. In an effort to protect the receiving waters of nearby Lake Whitcom from such impacts, City of Bellingham officials chose to retrofit stormwater management at the heavily used Bloedel Donovan Park parking lot. Rather than choosing a conventional technique, they elected to build an innovative rain garden to manage stormwater on-site.

*The raingarden in Bloedel Donovan Park helps protect the water quality in nearby Lake Whatcom, and recharge groundwater supplies.*

## Design and Construction

Designed on a 550 square-foot section of the parking lot near the catch basin, the park's rain garden supports runoff from 80 parking spaces and two parking lanes. To meet water quality guidelines, the rain garden was also designed to treat 91 percent of the runoff from a 50-year storm event. Aspects of its construction included:

- **Site excavation—**From site topography and soils logs, the city determined the maximum allowable depth for water to pond in the rain garden. Under a 50-year storm event, the depth should be no more than six-feet. Thus, the site was excavated three to four feet.
- **Layering of materials—**The rain garden is composed of three layers of non-woven geotextile fabric alternated with six inches of drain rock, and topped with a layer of fabric to constrain the sand and restrict any plants from growing through. An 18- to 24-inch layer of sand composed of twenty percent organic materials is the top layer .
- **Landscaping—**For landscaping, the city chose native plants that could survive the year-round climatic conditions of the site. This included plants that prefer wet soil, but could also tolerate drought.

## Exhibit 2: Case Study Initial Cost Comparison

| | |
|---|---|
| **Conventional stormwater technique (4,400 ft$^3$ wet vault)** | $52,800 |
| **Rain Garden** | $12,820 |
| **Cost Savings** | **$39,980** |

## Cost and Pollutants Removal Effectiveness

The benefits from incorporating this rain garden are numerous. It adds aesthetic value to the site, increases wildlife habitat, and is a highly effective BMP for treating stormwater runoff. According to officials at the Bellingham Public Works Department's, monitoring shows that approximately 80 percent of total runoff is captured by the rain garden, with overflows running through media filtration and then another infiltration bed. Furthermore, Bellingham saved 70 percent in initial costs compared to installing a conventional in-ground storage and treatment stormwater system (see Exhibits 2 and 3). This was achieved through reduced construction and equipment costs, as well as reduced labor costs from the relative ease of installation, some of which was accomplished by volunteer landscaping help. These costs savings do not include future regular maintenance costs.

A more detailed case study of the city of Bellingham's rain garden can be found on the Puget Sound Action Team's Web site at www.psat.wa.gov/Publications/Rain_Garden_book.pdf.

### Exhibit 3: Cost for Bloedel Donovan Park Raingarden

| | |
|---|---:|
| **Labor** | $3,600 |
| **Vehicle use** | 1,900 |
| **Amended soil** | 1,650 |
| **Concrete** | 1,200 |
| **Asphalt** | 1,200 |
| **PVC/grates/catch basins/fabric/other misc.** | 1,000 |
| **Washed rock** | 805 |
| **Excavator rental (1.5 days)** | 500 |
| **Plants** | 400 |
| **Debris Removal** | 300 |
| **WCC crew planting time** | 265 |
| **Total Cost** | **$12,820** |

# CHAPTER 5

# Alternative Parking Surface Materials

The majority of parking lots are made of a combination of asphalt concrete, the most widely used paving material in the United States, and aggregates such as sand, gravel, or crushed stone. Conventional pavement is an impervious, heat absorbing material that collects stormwater on its surface, and does not allow it to filter into the soil, inhibiting the natural water cycle. As a result, parking lots must be designed to quickly remove the water that gathers during storms by channeling it off the lot via means such as gutters, drains, and pipes. The stormwater is directed into receiving water bodies at unnaturally high rates, causing a number of adverse impacts including increased downstream flooding, combined sewer overflow events, diminished groundwater supplies, streambank erosion, and non-point source water pollution from runoff contaminated by vehicular residues and other pollutants.

To combat several of the negative impacts of conventional parking lot paving, developers are increasingly incorporating modest changes, such as using light colored concrete instead of asphalt to reduce heat-island effect, or using recycled rather than virgin asphalt to reduce emissions and natural resource consumption. For example, 80 percent of asphalt pavement removed each year during widening and resurfacing projects is reused, with contractors typically incorporating up to 20 percent recycled material in concrete mixes.[55, 56] However, these changes do not address the fundamental problem of parking lot impermeability.[57]

Permeable pavements provide a sustainable alternative to the conventional asphalt and concrete parking materials widely used today. Permeable pavements are a broadly defined group of pervious paving options that allow natural infiltration rates of stormwater into the soil through certain design techniques and material substitutions.[58] For this reason, like many of the techniques mentioned in Chapter 4, permeable pavements are considered a best management practice (BMP) for stormwater management. However, permeable pavement should be used in combination with other BMP techniques to magnify benefits and provide back-up systems in case of BMP failure.[59] Two basic types of permeable paving designs exist: 1) porous pavement and 2) alternative pavers. This chapter describes these permeable pavement alternatives, considering their functionality, infiltration and pollutant removal effectiveness, and cost implications.

## Porous Pavement

Porous pavement is a permeable pavement surface, often built with an underlying stone reservoir, which temporarily stores stormwater before it infiltrates into the underlying soil.[60] Porous pavement works by eliminating the finer aggregates typically used in conventional paving, and binding the remaining aggregates together with an asphalt or Portland cement binder. By eliminating finer aggregates, a less dense material is created that allows stormwater to seep through. The underlying stone bed is designed with an overflow control structure, helping to ensure that water does not rise to the pavement level. Stormwater settles in the empty spaces of the storage bed, infiltrating over time into the subgrade soils—a process similar to an infiltration basin.[61]

The most common types of porous pavement are porous asphalt and pervious concrete, which are very similar in their design and applicability.

- **Porous Asphalt—**Developed by the Franklin Institute in the 1970s, porous asphalt consists of an open-grade coarse aggregate, bonded together by a typical asphalt cement in which fine aggregates have been reduced or eliminated, allowing water to move through the small voids created.[62] Porous asphalt can be used in all climates where conventional asphalt is suitable.[63]

- **Pervious Concrete—**Pervious concrete was developed by the Florida Concrete Association. It typically contains a mixture of Portland cement; uniform, open-graded coarse aggregate; and water. There is at least 15 percent more void space in pervious concrete compared to conventional pavements.[64] Pervious concrete can be more durable than porous asphalt, particularly in hot weather. However, the State of Pennsylvania's Department of Environmental Protection has noted that in colder northern and mid-Atlantic climates, porous concrete parking lots should always be designed with a stone subbase for stormwater management, and should not be placed directly onto a soil subbase.[65]

The manufacturing process for porous pavement has the same environmental and health impacts as the process for conventional paving materials, but porous pavement exhibits significant downstream benefits.[66] Although porous pavement looks very similar to conventional pavement, it is a far more sustainable alternative, considered by experts to be the most effective and affordable technique for addressing stormwater management from development.[67]

Porous pavements typically have a greater spectrum of uses than alternative pavers (discussed below), as porous pavement can be applied to both low vehicular traffic areas and some medium traffic areas. Porous pavements also have been used in a few high traffic areas, including some highway applications, because the product can provide better traction than conventional pavement and reduce hydroplaning.[68] Ongoing research is working to improve its highway applicability through the use of additives and binders.[69] In addition, porous asphalt may help reduce noise levels from tires on pavement. In a study measuring acoustical properties of pavement types, porous asphalt was shown to have lower noise levels than conventional hot mix asphalt.[70]

## Alternative Pavers

Alternative pavers, also known as permeable pavers or unit pavers, are interlocking concrete blocks or synthetic fibrous grids with open areas filled with grass, sand, or gravel. Unlike concrete or asphalt poured-in-place paving surfaces, alternative pavers are separate units laid out on a prepared base.[71] When built with a storage bed infiltration system, alternative pavers function similarly to porous paving systems. The voids between the interlocked pavers allow stormwater from a parking lot's surface to collect and then seep into the storage bed, which is made of sand or crushed stone. The water then gradually infiltrates over time into the subgrade soils. In addition to stormwater management, the storage bed also provides added structural support to the pavers.[72] As with porous pavements, the most beneficial element of alternative pavers is the reduction or elimination of stormwater impacts.[73]

A number of alternative paver options are on the market, including but not limited to: Turfstone®, UNI Eco-Stone®, Checkerbox®, Grasspave2®, and Gravelpave2®. Of the alternative paver options, grass paving systems are the most permeable. However, they have more limited applicability because grass cannot survive daily traffic; thus, grass-based systems are typically used for emergency fire lanes or temporary overflow parking areas.[74] Pavers should be filled with fine gravel or other permeable materials when more frequent parking is expected.[75] It should also be noted that certain types of alternative pavers, including block, grid pavers, and gravel, are not always suitable for handicap accessible areas.[76]

## Design and Installation Considerations

A number of uses for permeable pavement exist beyond new, whole parking lot construction projects. One option for high traffic parking lots is to design a hybrid parking lot combining permeable pavement parking spots with more conventional paving in the aisles.[77] In addition, permeable pavements can be used during parking lot retrofits and replacements.

According to the U.S. Department of Transportation, permeable pavements must be properly sited, designed, and installed in order to function fully over their life span. If planned correctly, permeable pavements can last 15 to 20 years, a length similar to conventional asphalt concrete pavement, which requires resurfacing after 20 years on average.[78] However, a number of factors need to be assessed when determining whether a site is suitable for a permeable paving system, including: slope, traffic volume, subgrade, land use, soil, infiltration and drainage characteristics, and groundwater conditions.[79]

Compared to conventional asphalt surface installation and design, features such as subgrade, soil type, and installation requirements are more complicated for permeable paving systems.[80] For example, soil, including its type, porosity, and stability, is considered one of the most important factors to determine site suitability. According to the New York State Stormwater Design Manual, developers must ensure that soils are permeable enough to carry out adequate infiltration by considering the natural qualities of a soil type as well as past land uses, because previous grading, filling, compaction, and other disturbances of the land can alter soil infiltration qualities. Underlying soils should have a minimum infiltration rate of 0.5 inches per hour to accommodate stormwater volumes, and knowledge of the organic matter content of the soil is also important in determining its pollutant removal capabilities.[81]

Permeable pavement is meant to treat small storm events, which can range from 0.5 to 1.5 inches. A site must be designed with an adequate ratio of infiltration area to impervious area, and the soil should have a permeability of between 0.5 and 3.0 inches per hour in order to adequately handle stormwater.[82] Occasionally, exceptions can be made to allow for permeable paving when sites do not meet certain criteria. For instance, permeable pavement can be used in soils with low porosity if a discharge pipe is installed to run from a storage area to a conventional stormwater system. This modified system will still treat stormwater from small and medium storms, but also will prevent flooding during large storm events.[83]

Porous pavement and alternative pavers alone are not an appropriate BMP to combat extreme flooding events in channels and riverbanks. It is recommended that a BMP designed specifically to control high waterflows, such as a dry detention pond, should be used in conjunction with porous pavement. This approach is required by some local governments as part of flood protection design criteria.[84]

Permeable pavement should not be used in parking lot areas with high volumes of sediment-laden runoff, high traffic volume, high dust areas, and/or heavy equipment traffic.[85] Clogging is the main cause of a system malfunction that can result from poor siting of the permeable pavement system. During construction, developers can prepare for possible clogging by installing a perimeter trench connected to the stone reservoir to treat overflow should the surface clog.[86] Other common problems to avoid include:

- Compaction of underlying soil, such as through the use of heavy equipment.
- Contamination of stone sub-base with sediment.
- Tracking of sediment onto pavement.[87]

Like other best management practices, when permeable paving systems fail, it is frequently due to mistakes made during the design and construction process. Recent studies note that if properly installed, success rates for a permeable paving system, particularly porous asphalt, can be much higher than earlier installations using these materials.[88]

## Maintenance of Permeable Pavement

In the past, studies indicated that permeable pavement applications had a high failure rate, due not only to improper siting, but also poor maintenance. Failure of a permeable paving system means that the surface becomes impervious and behaves like conventional asphalt, yet typically without the fully developed system of piping and gutters used to manage runoff on conventional parking surfaces. However, with correct maintenance, permeable pavement can retain its permeability, and be a successful stormwater management option.[89]

The level of maintenance necessary to maintain permeable pavement lots varies. Alternative pavers such as concrete grid pavers and plastic modular blocks will require less maintenance because they do not clog as easily as porous asphalt and permeable concrete. Location also impacts the amount of maintenance, as areas receiving more sediment will require more maintenance. For example, a parking lot with higher traffic volumes will tend to require more maintenance because of the resulting increased quantities of soil and particulates brought onto the lot. Although the new soil alone will not necessarily clog the pavement's voids, if ground in repeatedly by tires, clogging can occur.[90,91]

Regular maintenance can avoid clogging of permeable paving systems. Facilities managers are generally advised to high pressure hose and then vacuum porous pavement a minimum of two to four times a year, depending on the system. This should remove any dislodged sediment and particulate matter from the site.[92] Exhibit 4 provides an example of typical permeable pavement maintenance activities.

### Exhibit 4: Maintenance Activities for Permeable Pavement Parking Lots

| Maintenance Activity | Scheduling |
|---|---|
| **Ensure paved area is clear of sediments** | As needed |
| **Mow upland and adjacent areas, and seed bare areas** | Monthly |
| **Ensure paved area is clear of debris** | Monthly |
| **Monitor that paved area dewaters between storms** | Monthly and after storms >0.5 inches |
| **Vacuum sweep routinely to keep surface free of sediments** | 3 to 4 times a year |
| **Clean inlets draining to the subsurface bed** | Biannually |
| **Inspect the paved surface for deterioration** | Annually |

Source: Adapted from New York State Department of Environmental Conservation, (2007), New York State Stormwater Design Manual—Chapter 9, : www.dec.ny.gov/chemical/29072.html.

Clogging can also be avoided through monitoring activities on and around the lot, including:

- Never using sand or gravel to address icy conditions on porous pavements, although salt may be used on porous asphalt, and commercial deicers may be used on porous concrete.[93]
- Ensuring that the surface is not sealed or repaved with a non-porous material.
- Maintaining planted areas adjacent to porous pavement to prevent soil washout onto the pavement.[94]

Signs should also be posted around the lot to prevent harmful activities such as resurfacing, the use of abrasives, and any activities that may lead to contamination of the groundwater. This includes prohibiting construction vehicles or hazardous material carriers from using the lot.[95] Finally, because these types of parking lots have unique maintenance needs, land owners must ensure that individuals responsible for parking lot maintenance, such as the facilities manager, are properly trained and prepared to handle the lot's maintenance needs.

## Cold Climate Considerations

In cold weather regions, specific activities are necessary to properly maintain a permeable pavement parking lot. The underlying stone bed of permeable paving systems often absorbs and retains heat, causing faster snow melt which leads to less snow accumulation. However, snow may still accumulate, especially during heavier storms. When treating it, abrasive materials such as sand should not be used on or near the pavement, as it will quickly clog the surface. As noted above, salt can be used as a deicer on the porous pavement, though nontoxic, organic deicers are preferable because the chlorides in salt can migrate into the groundwater.[96] With porous pavement, some sites have found that light plowing reduces the need for salt, as the remaining snow quickly drains into the material.[97] When plowing snow, operators should set the blade slightly higher than usual (i.e., one inch), as to not damage the material. This will avoid the blade catching the edge of a block or paving and damaging its surface. Signs should be posted to reinforce plowing requirements.[98] Finally, frost heave can occur if infiltrating runoff freezes below the surface, however porous pavement can be designed to avoid this issue.[99]

### Repairs

According to Cahill Associates, a leading sustainable stormwater management design firm, potholes in porous pavement are very rare. However, settling might occur if any soft spots in the subgrade are not addressed during construction. Even after 20 years, a well-maintained porous surface can show little if any cracking or potholes.[100] Many alternatives are available for repairing damaged porous pavement and alternative pavers. In general, areas less than 50 square feet can be patched by using either a porous mix or standard pavement because the loss of porosity to a small spot is insignificant to the overall stormwater management function. If an area greater than 50 square feet is damaged, an engineer should be consulted to design an appropriate patch.[101]

## Infiltration & Pollutant Removal Effectiveness of Permeable Pavements

Permeable paving coupled with a subsurface storage bed can capture and manage stormwater from small, frequent rainfall events, which accounts for between 30 and 50 percent of annual precipitation on average.[102] In addition, this combination can be very effective at removing stormwater pollutants.

### Infiltration Effectiveness

Permeable pavement, when properly designed and maintained, can eliminate almost all surface runoff from low intensity storms.[103] As mentioned before, proper siting and maintenance of permeable parking areas are critical to maintaining high surface infiltration rates.[104] Data on infiltration rates vary widely according to design characteristics and underlying soils, however, research indicates that an average of 50 percent of annual rainfall on porous pavement infiltrates, with reported infiltration rates reaching as high as 80 percent.[105] Infiltration rates can decline to a certain extent over time, again depending on design, installation, maintenance, and site characteristics such as sediment loads.[106]

### Pollutant Removal Effectiveness

Limited data indicate that permeable pavement systems have high removal rates for many pollutants, including total suspended solids, metals, oils, and grease.[107] However, pollutant removal is not effective for larger storms with rainfall greater than one-inch, or with high rainfall intensity.[108]

## Porous Pavement

Studies of porous pavement performance show that they can effectively trap soluble pollutants, which are then absorbed or broken down in the underlying soil layers. Exhibit 5 depicts the range of pollutant removal effectiveness for porous pavement, showing a removal effectiveness of at least 65 percent for suspended solids, nitrogen, pathogens, and metals; and at least 30 percent of phosphorus.[109]

## Exhibit 5: Porous Pavement Pollutant Removal Efficacy

| BMP Type | Typical Pollutant Removal (percentage) | | | | |
|---|---|---|---|---|---|
| | Suspended Solids | Nitrogen | Phosphorus | Pathogens | Metals |
| **Porous Pavement** | 65-100 | 65-100 | 30-65 | 65-100 | 65-100 |

Source: U.S. EPA, 1993, Handbook Urban Runoff and Pollution Prevention Planning, EPA-625-R-93-004, taken from Purdue University Engineering Department's Long-Term Hydrologic Impact Assessment (L-THIA): http://cobweb.ecn.purdue.edu/~sprawl/LTHIA7/lthia/lthia_index.htm.

## Alternative Pavers

Alternative paver systems have been shown to be just as effective as porous pavement in removing pollutants. A study from the University of Washington conducted to determine the long-term effectiveness of permeable pavements as a stormwater management strategy showed significant pollutant removal rates. Researchers compared the effectiveness of four permeable pavement types and conventional asphalt over six-years.[110] They found that runoff from the conventional asphalt had significantly higher concentrations of measured pollutants (i.e. motor oil, copper, zinc) compared to the alternative paver surfaces. Concentrations of copper in runoff from alternative pavers were roughly 80 percent lower than those found in the runoff from conventional asphalt, and zinc concentrations were at least 40 percent lower. Also, motor oil was detected in 89 percent of the runoff samples from conventional asphalt, while no motor oil was detected in any samples that infiltrated through sections of alternative pavers.[111]

Another study researched driveways constructed of conventional asphalt versus permeable pavers to compare their runoff depths, infiltration rates, and pollutant concentrations over two years. The study found that the mean weekly runoff rate for conventional asphalt was over three times that of the permeable pavers. In addition, they found that pollutant concentrations in runoff from the permeable pavers were substantially less than from the conventional asphalt, as shown in Exhibit 6.[112]

As with other stormwater infiltration BMPs, developers must take measures to mitigate any possible groundwater contamination at a permeable pavement site. Permeable paving should not be used to treat stormwater "hotspots," areas where land uses or activities have the potential to generate highly contaminated runoff. These areas include: commercial nurseries, auto recycling and repair facilities, vehicle service and maintenance areas, fueling stations, high-use commercial parking lots, and marinas.[113]

## Exhibit 6: Study Example: Stormwater Runoff Comparison in Jordan Cove, CT

| Pollutant | Conventional Asphalt (mg/l) | Permeable Pavement (mg/l) |
|---|---|---|
| TSS | 47.8 | 15.8 |
| $NO_2$-N | 0.6 | 0.2 |
| $NH_3$-N | 0.18 | 0.05 |
| TP | 0.244 | 0.162 |
| Cu | 18 | 6 |
| Pb | 6 | 2 |
| Zn | 87 | 25 |

Source: Hinman, C., (2005), Low Impact Development Technical Guidance Manual for Puget Sound, Puget Sound Action Team, publication number PSAT 05-03: www.psat.wa.gov/Publications/LID_tech_manual05/lid_index.htm.

## Cost Considerations

The costs for permeable pavement systems vary depending on site specifications and the type of system being used. In general, the cost to install alternative pavers or porous pavements alone are higher than conventional asphalt paving, which costs between $0.50 to $1.00 per square-foot. Sources disagree on the average initial costs for permeable pavement. Exhibit 7 provides an initial cost comparison of pavement options from the NY State Stormwater Design Manual. However, another source notes that porous asphalt, with additives, costs from 10 to 20 percent more than conventional asphalt paving.[114] Finally, Cahill Associates maintains that the cost of a porous pavement installation is roughly the same as the cost of a conventional asphalt parking lot.[115] The costs for alternative pavers are more difficult to estimate, as they fluctuate widely depending on type and manufacturer.[116] In general, larger parking lots utilizing alternative pavers will incur a lower overall unit cost per space.

The overall cost-effectiveness of permeable pavement can only be fully assessed by considering its typical use in concert with other stormwater BMPs. Specifically, the cost-

## Exhibit 7: Parking Surface Initial Cost Comparison Chart

| Pavement Type | Cost per $Ft^2$ (Installed) |
|---|---|
| Conventional Asphalt | $0.50 to $1.00 |
| Permeable Concrete | $1.50 to $5.75 |
| Grass/Gravel Pavers | $2.00 to $6.50 |
| Interlocking Concrete Blocks | $5.00 to $10.00 |

Source adapted from New York State, New York State Stormwater Design Manual: www.rpi.edu/~kilduff/Stormwater/permpaving1.pdf.

competitive nature of permeable pavement systems lies in their success when combined with other BMPs or subsurface drainage to create a well-designed and sustainable stormwater management system. Properly designing and installing such a system requires a high level of labor and expertise, as well as material costs, including excavation for deep underlying stone bed and the use of geotextile fabric. However, these higher initial costs are offset by reductions in the need for expensive traditional "hard" stormwater management of pipes, gutters, and drains relative to parking lots made of conventional asphalt pavement. When these savings are incorporated, overall project costs are often reduced.[117] Also, when used in combination with other smaller techniques, such as bioretention cells, vegetated swales, or vegetated filter strips, permeable pavement reduces the need for land-intensive BMPs such as dry extended detention or wet retention ponds. This fact produces additional cost advantages for permeable pavement over conventional asphalt in locations with high land prices.[118]

Maintenance costs should also be factored in when considering the costs of a permeable paving system. If not designed and maintained properly, porous pavement's effective lifespan may be shortened due to potentially high risks of clogging.[119] Some studies suggest that the cost of vacuum sweeping on a new permeable lot may be considerable if the landowner does not already perform vacuum sweeping operations. However, one study estimates the annual maintenance cost for a porous pavement parking lot at $200 per acre annually, which includes regular inspections, as well as jet hosing and vacuum sweeping.[120]

## CASE STUDY 2: Parking Surface Alternatives
## Heifer International, Little Rock, Arkansas

In 2006, Heifer International, a non-profit sustainable community development organization located in Little Rock, Arkansas, designed an environmentally-friendly parking plaza to complement their new green building headquarters. A first of its kind in Arkansas, this project serves as a model for other organizations considering a green parking lot. Heifer's parking plaza encompasses numerous green parking lot techniques including the use of more sustainable materials to minimize impervious surface, reduce runoff, reduce virgin water use, and incorporate recycled content.

*Heifer International's World Headquarters: a green building with a green parking lot.*

Heifer evaluated a variety of paving options when selecting materials for their green parking lot. Unlike a conventional lot, which most likely would be constructed primarily of asphalt, Heifer chose three types of paving materials that provide environmental benefits over asphalt.

- **Concrete—**The high traffic aisles and driveway of the Heifer lot are paved with concrete rather than asphalt. Overall, it covers an 86,000 square-foot area, at a cost of $5.75 per square foot, or $494,500. The concrete base contains 90 percent recycled cement and its top layer is made of locally produced concrete.[121] Because it is a light colored and highly reflective surface, concrete helps minimize heat island effect (HIE) at the Heifer site. Coupled with the extreme humidity in the Little Rock region where Heifer is located, this HIE can be stifling. However the use of concrete for paving has been shown to produce a 20°F reduction in surface temperatures compared to asphalt.[122]
- **Gravel Pave system—**Used for the parking stalls, thirty thousand square feet of Heifer's parking plaza are covered by a gravel pave system. The stalls are constructed using 100 percent recycled material (90 percent post-industrial and 10 percent post-consumer). At a unit cost of $4.75 per square foot, this gravel pave portion of the lot cost a total of $142,500. Maintenance is minimal, requiring roughly eight hours a month at a cost of $160 per month.
- **Brick pavers—**Recycled brick pavers were used to form a decorative driveway centerpiece, and cover the smallest part of the lot (2,500 $ft^2$) at a total cost of $34,418. Heifer minimized the cost for the pavers by reusing bricks from buildings that previously occupied the site. Heifer employees also volunteered to help clean a number of the bricks so they could be reused. The total cost for the pavers includes additional labor, beyond the volunteer hours, to clean bricks and construct the centerpiece. Heifer has yet to incur any maintenance costs for this area.

All of the parking lot materials used in the Heifer lot were purchased from local dealers within 500 miles of the site, supporting the local economy and reducing emissions associated with transportation of purchased materials.

## Upstream Benefits

Upstream environmental benefits were realized through Heifer's use of recycled concrete and other recycled materials, instead of using virgin asphalt, in the construction of their lot. These benefits include reduced air emissions (associated with the production of asphalt), reduced transportation emissions (from purchasing locally produced materials), reduced energy use, and reduced hazardous waste generation related to the production of virgin materials.

Modeling was used to estimate any upstream benefits from the construction of Heifer's lot.[123] The resulting analysis (see Exhibit 8) shows a clear overall positive net benefit from the construction of Heifer's lot, although results for some individual metrics indicate a net increase in emissions or resource use. For instance, Heifer's green parking lot used more water than an asphalt parking lot would have because of the greater water inputs required in the recycling of concrete pavement compared to the production of asphalt pavement.

By applying estimates of the economic value of reduced human health and ecological impacts from avoiding emissions, these upstream benefits were then monetized. Reliable estimates of economic value are not available for carbon dioxide ($CO_2$) emissions. However, by applying estimates for the value of reducing sulfur dioxide ($SO_2$) and particulate matter ($PM_{10}$) emissions, a range of monetary values related to Heifer's reductions can be shown (see Exhibit 9).[125]

Heifer's goal in building its parking plaza was to minimize impacts to the environment while handling a large volume of site traffic.

A more detailed case study of Heifer International's green parking lot can be found on the U.S. EPA's Web site at www.epa.gov/earth1r6/6sf/bfpages/bfheifer.html.

### Exhibit 8: Upstream Benefits of the Heifer Parking Lot[124]

| Energy (MMBtu) | Water Use (gallons) | Tons | | | | |
|---|---|---|---|---|---|---|
| | | $CO_2$ | $NO_x$ | $PM_{10}$ | $SO_2$ | Hazardous Waste Generated |
| 668.3 | -116 | 20.9 | -0.89 | 0.72 | 25.3 | 20.7 |

### Exhibit 9: Value of Upstream Air Emissions Benefits for Heifer Lot

| Air Emission | Monetized Upstream Benefit | |
|---|---|---|
| | Low | High |
| $SO_2$ | $43,044 | $455,760 |
| $PM_{10}$ | $7,170 | $71,700 |

# CASE STUDY 3: PARKING SURFACE ALTERNATIVES
## UNIVERSITY OF RHODE ISLAND, KINGSTON, RHODE ISLAND[126]

### OVERVIEW

In 2002 and 2003, the University of Rhode (URI) constructed two parking lots at their Kingston, Rhode Island campus to meet parking demands from new University development and commuting students. The parking lots were located within the town's groundwater protection overlay district, the University's wellhead protection area, and also within the Pawcatuck sole source aquifer. These lots would increase parking capacity by 1,000 spaces, spread over seven acres of land (see areas highlighted in red in Photo 1). However, because the lots were located in an ecologically sensitive area already covered by an estimated thirty percent impervious surface, the University desired an environmentally protective option than would combat stormwater issues more effectively than conventional paving surfaces. The University's main stormwater concern was to decrease runoff quantities to protect a nearby stream considered impaired due to low water flows.


URI's permeable parking lots - The two original permeable asphalt parking lots built in 2002 and 2003 are outlined in red. The 2005 parking lot extension is outlined in green.

Rainwater infiltrates the porous asphalt (left), but accumulates on adjacent road paved with conventional material (right).

In addition, project managers were also interested in avoiding any potential impacts to groundwater supplies.[127] The University determined that a permeable asphalt surface would help control runoff quantities as well as potentially limit pollutants entering surface and groundwater supplies.

In addition to using permeable asphalt, landscaped islands were designed as biofiltration areas to provide a secondary route of infiltration during large storm events or pavement clogging. Also, the University took precautions to avoid clogging the permeable pavement by planting trees and grass around the parking lot perimeter, which limits wind-blown dust from nearby agricultural areas and controls soil erosion. An emergency spillway was also constructed to direct overflow to recharge beds in the extremely unlikely event that the permeable asphalt and biofiltration areas both clog.

## Cost Considerations

The total construction costs for the two parking lots was just over $3 million, or $3,000 per parking space, which is considered comparable to conventional parking lots of equal size. Costs included site preparation, barn demolition, materials, lighting, drainage, landscaping, monitoring wells, post-construction inspections, and design fees that were roughly ten percent of the total cost. URI's costs included non-typical items such as removal of stone masonry walls, and installation of security cameras and emergency telephones. Without these additions, installation would have been cheaper. On average, installation runs between $2,200 and $2,750 for porous pavements such as permeable asphalt.

## Incorporating Lessons Learned

In the few year since they constructed the two permeable asphalt parking lots, URI has been monitoring their success in managing and filtering stormwater. As a new technology, they noted several areas for improvement.

- **Clogging**

  Overall, these parking lots were successful from a hydrological perspective. However, some clogging was observed in the higher traffic areas of the lot. Clogging also occurred in one corner of the lot where plowed snow was stockpiled during the winter, which reduced infiltration due to sediment build-up. This is an indication that plow blades were not raised to the required height, an issue that also caused surface defects to the lot.

  Excavation of the lot during construction of a sidewalk also revealed that the permeable asphalt layer was not infiltrating properly because the binder had become separated from the asphalt. Project consultants recommended an improved polymer mixture, new to the market, that would prevent the separation and eliminate the infiltration problem.

- **Pollutant removal**

  The University is currently monitoring the pollutant removal and runoff level from the lots. They found a 90 percent retention of zinc and copper. However, the permeable asphalt was not as effective in capturing other pollutants, including organic pollutant such as PAHs, and inorganic pollutant such as nitrate and phosphate. This is due to clogging, as well as the type of geotextile fabric used in the project, which was found to prevent an even flow of water into the subsurface.

In the summer of 2005, the larger of the two permeable asphalt parking lots was expanded by another 800 spaces. When planning this expansion, the University was able to incorporate improvements to their design based on lessons learned from the original two parking lots. Design changes included use of the polymer mixture to prevent separation of the binder, fewer and wider biofiltration islands, and curb cuts for water entry to the biofiltration islands. Maintenance issues regarding snow removal were also addressed.

Further information on the University of Rhode Island's permeable asphalt parking lots can be found at www.uri.edu/ce/wq/NEMO/Publications.

# CHAPTER 6

# Landscaping and Irrigation

In the majority of parking lots across the country, landscaping does not vary according to geographic location. It is typically designed using conventional turf grass, such as Kentucky Bluegrass, and common popular ornamental plantings. However, because these plants are often not native to areas where they are being used, regular maintenance is required to keep them healthy. Sustaining this greenery requires irrigation systems and potable water use to supplement rainfall, chemical applications of pesticides and fertilizers, and ongoing lawn maintenance (e.g., mowing).[128] Irrigation and chemical use contribute to degradation of water quality and aquatic habitat in receiving waters, decreased water supplies, increased stormwater runoff, declining biodiversity, and air pollution. Mowing and other maintenance activities are a significant air pollution concern; for example, in one hour a lawn mower emits as much pollution as a car driving 350 miles.[129] With proper planning, landowners can avoid these impacts by utilizing "natural landscaping" approaches.

Natural landscaping involves creating a low-maintenance landscape in and around a parking lot using native plants and water-efficient irrigation techniques. A vital component of green parking lots, natural landscaping can:

- Reduce landscape installation and maintenance costs,
- Limit harmful chemical pollution (i.e. pesticides, fertilizers),
- Reduce potable water use and pollutant air emissions,
- Reduce damage from stormwater, and
- Improve habitat and increase biodiversity.[130]

This chapter provides an overview of natural landscaping and irrigation techniques suitable for green parking lots. It describes the difference in irrigation and maintenance requirements for natural landscaping compared to conventional landscaping, the benefits of natural landscaping, and cost considerations.

## Overview of Natural Landscaping and Irrigation

### Natural Landscaping Considerations and Vegetation Conservation

Natural landscape design, sometimes referred to as native or sustainable landscaping, uses plant species indigenous to a region pre-European settlement. Because these native plant species have evolved in the local environment, maintaining them is relatively easy—they are more resistant to local pests, they are better suited to survive on natural rainfall, and they are adapted to live in local soil types. These heartier plants also provide habitat for local native wildlife species that they co-evolved with—a symbiotic relationship that is the foundation for our native ecosystems and biodiversity.[131]

A feasible and intelligent approach for most development sites, natural landscaping also supports sustainable development strategies such as Low Impact Development (LID) and Smart Growth, and is a vital component to many stormwater Best Management Practices (BMPs). For example, some of the bioretention approaches described in Chapter 4, such as vegetated swales and rain gardens, are based on natural systems and intended to function as they would have in absence of development.[132] BMPs rely on native plants for added efficiency in retention, infiltration and transpiration, and cleansing.[133] See Chapter 4 for more information on BMPs.

Developers must take a number of factors into consideration when planning and designing natural landscaping. Natural landscaping involves more than new plantings of native species; an important step to consider before construction even begins is retaining as much of the existing native landscaping as possible at a site. By preserving existing vegetation, developers can minimize the need for new landscaping, and limit site disturbance. If the location of existing vegetation is not suitable, it is preferable to relocate it on-site rather than dispose of it during construction. Another option is to remove native plants from sites scheduled for construction; some volunteer organizations will retrieve plants from construction sites to later replant at other locations.[134]

Landscaping choices should be compatible with individual site characteristics including topography, soil, drainage patterns, and sun exposure.[135] It is important to select site-appropriate plants when bringing native landscaping in from off-site; as such, consulting a local landscape designer with native plant knowledge is recommended.

Although native landscaping is feasible for most sites, in cases where it is not feasible or is otherwise not utilized, developers should choose low-water use plants and limit the amount of turf to only those areas necessary for practical purposes.

## Irrigation Requirements for Natural Landscaping

As mentioned above, a key difference between conventional and natural landscaping is water use requirements. Conventional landscaping consumes large quantities of water to sustain non-native species, which typically cannot withstand local conditions as well as native varieties. For instance, the popular turf species Kentucky Bluegrass typically requires in excess of 40 inches a year of precipitation to thrive.[136] This is above annual rainfall levels for many states, particularly in Western parts of the country. According to the U.S. Department of Energy, native and other climate appropriate landscaping can reduce irrigation water use by at least 50 percent.[137] This was the case for Heifer International's green parking lot (see case study at the end of the chapter), where the landscaping requires no additional irrigation under normal conditions. Typically, native plants require irrigation only when they first take root.[138]

In most cases the water source for conventional irrigation is the same potable drinking water used inside buildings, applied generously by inefficient spray irrigation systems. In many developments, these irrigation systems are programmed to turn on automatically, and do not take fluctuating rainfall amounts or soil moisture into account. In contrast, natural landscaping fosters smarter irrigation practices, through water-efficient planting, mulching, rainwater harvesting, and water-efficient irrigation technology.

## Efficient Irrigation Technology[139]

Efficient irrigation technology is essential to conserving water, and a number of options are available to help landowners save money through less wasteful practices. A fundamental problem of conventional irrigation is over-watering. Not only does over-watering reduce water supplies and increase runoff amounts, but it also can result in plant diseases such as fungus, and in the excessive growth of weeds and pests. Over-watering also results in weak plant growth that in turn precipitates the need for additional maintenance.[140]

If landscaping is watered at a less frequent and more appropriate rate, plants will develop deeper roots and become healthier overall.[141] Recommended alternatives to the traditional sprinkler method, which often over-waters landscaping, include soaker hose, drip, or subsurface irrigation.

Drip irrigation in particular is a water conservation technology that is gaining popularity. Used in the past to conserve water in arid areas, its use has expanded with heightened awareness of resource conservation and environmental sustainability. Drip irrigation is a system of tubing with small holes that allows water to drip out onto the root zone of plants, providing more targeted and uniform irrigation. Such systems can run on recycled water, and can be an option for temporary use to establish native plants. Should a sprinkler system be selected, low-flow sprinkler systems that release water slowly and close to the ground are preferable to sprinklers that emit mist, which easily evaporates.[142]

Other examples of efficient irrigation technology include soil tensiometers, which determine when the soil is dry and gauge water needs; rain or moisture sensors that can shut off automated irrigation systems during rain; irrigation timers with manual overrides to properly schedule sprinkler use; and zoning systems that focus on the water needs of each plant grouping.[143]

## Efficient Irrigation Procedures

The basic practices of landscaping, including plant layout and irrigation scheduling, are also vital to natural landscaping.

- **Seasonal influences—**When scheduling irrigation, it is important to understand the seasonal variations and changing weather conditions. In some regions of the country, water requirements can vary considerably depending on the season.
- **Time of day—**It is also important to consider the time of day when irrigation is taking place. Watering is more effective during early morning hours or early in the evening, when temperature and wind speeds are typically lower, thus reducing evaporation water loss.[144]
- **Weather conditions—**Weather conditions and weather forecasts should be incorporated into irrigation planning. Use system override devices when it is raining, and try to program irrigation to avoid days when rain is forecast. In addition, watering on windy days means that the water may not reach targeted areas or may be blown onto paved areas.

Mulching helps keep moisture in the soil and allows rainfall and irrigation water to better penetrate the root system. Landscapers recommend that roughly three inches of organic mulch be applied over trees and shrubs roots, and in plant beds. This also helps moderate soil temperature, minimize evaporation, and reduce erosion and weeds. In addition, when mulch decomposes, it increases the organic content of the soil.[145] Lastly, the layout of natural landscaping is important to efficient irrigation. By grouping plants with similar water needs together, a dedicated irrigation line or valve can be used to apply the appropriate amount of water at the correct frequency.[146]

### Rainwater Harvesting and Recycled Water[147]

To conserve water, natural landscaping also includes the use of collected rainwater or recycled wastewater for irrigation. These are both preferred alternatives to using potable water, which is a finite natural resource. Moreover, potable water treatment management requires energy use for desalting, pumping, pressurizing, groundwater extraction, conveyance, and treatment.[148]

Reuse of rainwater is a good option because it is "not chlorinated and is mildly acidic, which helps plants take up important minerals."[149] Containers, such as cisterns or rain barrels, can be used to collect and store water from roof catchment areas. Rainwater can also be harvested from an underground storage system, which is then pumped to the irrigation system. In addition to rainwater harvesting, certain types of non-potable water, if treated properly, can be used as well for irrigation. For instance, water recycled from wastewater, also known as irrigation quality or reclaimed water, can be treated and, although not suitable for drinking, is very useful for irrigation.

## Environmental Benefits of Using Natural Landscaping and Associated Irrigation

Compared to conventional landscaping design, natural landscaping can offer substantial environmental benefits by minimizing irrigation and maintenance needs once plants are established. The primary environmental benefits of incorporating natural landscaping into parking lots are described below.

### Decreased Non-Point Source Pollution

The U.S. EPA's 2004 Conference on Landscaping with Native Plants found that landscaping with native plants may help reduce non-point source pollution reduction in the following ways:

- The need for fertilizers and pesticides to maintain conventional landscapes (i.e. turf grass) can often be eliminated with native vegetation.
- Through direct uptake of nutrients, native plants may reduce the impact of fertilizer elements (i.e. nitrogen and phosphorous) that would otherwise contaminate water sources.[152] Fertilizer contributes to approximately 80 percent of nutrient loads in the springtime.[153]
- Native plants may create sub-soil conditions that help reduce levels of nitrate entering water supplies via facilitation.[154]
- Native plants are capable of filtering other impurities from stormwater runoff, such as salt and automobile deposits (i.e., oil).

The over-application of fertilizers and pesticides can lead to other detrimental environmental impacts beyond non-point source pollution. Less than 10 percent of insects actually harm plants, yet inappropriate pesticide use harms non-target insects that are beneficial to the environment, it can also harm wildlife.[155] Overuse of fertilizers can exacerbate insect diseases as well as promote unnecessary plant growth, which in turn increases maintenance needs.[156]

An innovative natural landscaping approach to pest management, called "integrated pest management," is a low chemical approach to landscape maintenance. Rather than emphasizing the use of harsh chemicals, it incorporates materials composed of naturally occurring compounds, and promotes natural landscaping design and maintenance practices. According to the U.S. Department of Energy, integrated past management "demonstrably creates a better environment for plants as time passes."[157]

### Water Conservation

Water conservation is one of the primary benefits of a natural landscaping approach. Using native plants in landscaping helps conserve water because once established, native plants often do not need supplemental watering beyond local rainfall amounts.[158] This is not the case for conventional landscaping where, for instance, the watering schedule for turf landscaping is estimated at 1 inch of water over the entire area, for 30 applications per year.[159] The water conservation benefits become even greater when harvested rainwater or recycled wastewater are used for irrigation rather than potable water.

With water shortages seen in many communities throughout the country, native landscaping is a sensible approach to preserving water. Local governments in states such as North Carolina, Texas, and California have adopted natural landscaping ordinances, innovative rate structures, and wastewater reuse plans to address water shortages. For example, Santa Monica, California requires the use of a particular water-efficient landscaping strategy called "xeriscaping" for all landscapes installed in new commercial and industrial developments. Xeriscaping is a collection of sustainable landscaping design principles incorporating the use of native or other water efficient plants.[160] Another example is Las Vegas, Nevada, where a city ordinance limits the amount of turf on new landscapes to no more than 50 percent.[161]

### Reduced Air Pollution

Reduced maintenance from native landscaping can improve air quality:

- Locally, through reduced smog and air toxics;
- Regionally, through the reduction of acid rain caused by nitrogen oxide ($NO_X$) and sulfur dioxide ($SO_2$) emissions; and
- Globally, by combating greenhouse gas emissions.[162]

It is estimated that for every 10 days of maintenance required for a traditional turf landscape area, a natural designed area only requires one day.[163] This greatly minimizes the need to run maintenance equipment such as lawn mowers, leaf blowers, and weed wackers, which typically run on gasoline and emit carbon dioxide ($CO_2$) and other air pollutants. For example, the use of lawn equipment in just the Chicago region produces 50 tons of volatile organic compounds (VOCs) every day in the summertime.[164]

### Reduced Erosion and Sedimentation

Natural landscaping in parking lots also helps minimize the erosion and sedimentation impacts of development. The deep root systems of native plants stabilize soils and help prevent wind and water erosion along detention basin edges and streambanks.[165] This is particularly true of plants that were on-site pre-construction and preserved. Native plantings can also help remove sediments from runoff through filtration, again helping to preserve water quality and aquatic habitat.[166]

### Reduced Heat Island Effect

As discussed in Chapter 1, heat island effect (HIE) occurs in urban areas when the combined effect of heat-absorbing surfaces, such as asphalt, leads to higher air and surface temperatures. HIE can increase temperatures between 2 to 8ºF on average during the summer.[167] The greatest temperature increases are typically seen in areas with less vegetation and high amounts of urban development. Vegetation, especially trees, can help reduce HIE, by providing shading to paved areas. For example, a NASA study on the Madison Square Mall in Huntsville, Alabama found that the temperature in the middle of the parking lot on a summer day was 120ºF, while the temperature at a small tree island in the parking lot was only 89ºF. For every additional tree canopy cover temperatures can often be reduced by 1º F. Vegetation can also indirectly cool parking areas though transpiration, and soil also cools through water evaporation.[168]

Because of its cooling capabilities, landscaping also plays a role in reducing building energy use and associated $CO_2$ air emissions. Hotter temperatures from HIE can lead to increased energy demand to cool buildings located near heat absorbing surfaces such as parking lots. By reducing HIE, it is estimated that plantings close to buildings can reduce air conditioning costs by 5 to 20 percent.[169]

### Enhanced Biodiversity

Biological diversity, or biodiversity, is literally the variety of life. Defined as "the variability among living organisms from all sources including…terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part," biodiversity is the diversity within species, between species and of ecosystems.[170] Conventional landscaping can negatively affect biodiversity of species at various levels when native plants species are replaced with homogenous, exotic, ornamental species. This "monoculture" limits genetic, species, and ecosystem diversity.

The diversity of our flora and fauna is an invaluable resource from an environmental and human health perspective. Ecosystems that contain a diversity of native plant and animal species better provide "ecosystem services" to humans, such as water and air purification.[171] Native plants also support a healthier environment by providing food and shelter for wildlife. In addition, some exotic plants can become invasive species, smothering native plants or overrunning their habitat, again affecting the plant population and the chain of species dependent upon it.

## Cost Effectiveness of Using Natural Landscaping

A common perception is that natural landscaping is more costly than conventional landscaping. However, cost/benefit modeling and case studies have shown that natural landscaping can be more cost-effective in the long term—for both communities and land owners.[172] Reduced costs result from decreased energy use, forestalled infrastructure upgrades, and lower land maintenance costs. For example, one study found that landowners can save between $270 and $640 dollars per acre by preserving the native landscape of their open land instead of creating a conventional, tuft-based, landscape. Savings can also be realized during the installation of natural landscaping. It can be between $4,400 and $8,850 less expensive per acre for the installation of natural landscaping than for turf grass.[173]

Of all the potential sources of costs savings from natural landscaping, reduced maintenance leads to the greatest savings. As discussed throughout this chapter, natural landscaping requires less maintenance and labor expenditures, such as less irrigation, mowing, weeding, and fertilizer/pesticide application. Decreased irrigation is a major part of these savings, as is seen in the case of Heifer International (see following case study).

sustainable landscaping versus conventional landscaping.

By using a simple payback calculation, the above example demonstrates that the costs for the native landscaping are recovered within the first year because of significantly lower maintenance costs.[174] As a general rule, annual maintenance costs for natural landscaping are approximately 10 percent of conventional landscaping.[175]

Other economic benefits of natural landscaping include local government and community cost-savings from avoided infrastructure and/or water supply upgrades associated with stormwater runoff, which can lead to flooding, pollution, groundwater recharge

### Exhibit 10: Installation, Maintenance, and Incremental Costs of Sustainable vs. Conventional Landscape Area (landscape area = 8,000 square feet)

| | Site Design and Implementation | Installation | Total Maintenance ($/year) |
|---|---|---|---|
| **Native Planting** | $3,673 | $184 | $272 |
| **Traditional Turf** | $1,224 | $61 | $3,318 |
| **Cost Difference (Native minus Traditional)** | $2,449 | $123 | -$3,046 |

Source:

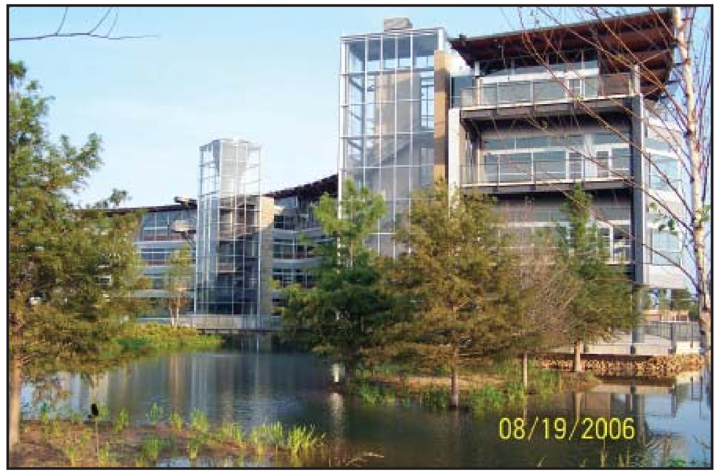
Estimate of landscape area includes 1-acre (43,560 ft$^2$) lot with 25,200 square foot parking area and 10,082 ft$^2$ building footprint. For more information see U.S. Department of Energy, (2003), The Business Case for Sustainable Design in Federal Facilities—Appendix D, http://www1.eere.energy.gov/femp/sustainable/sustainable_federalfacilities.html.

An example of the *overall* maintenance savings, including water savings, is presented in the following comparison produced by the U.S. Department of Energy. In this example, costs are compared for a one-acre site (including a 50 to 75 space parking area) using

deficits, and damage to stream ecology.[176] Reduced infrastructure burden is discussed in Chapter 7. In addition, communities often pay to eradicate algae blooms caused by excess fertilizing, a cost avoided by widespread use of native landscaping.[177]

## CASE STUDY 4: Landscaping and Irrigation
## Heifer International, Little Rock, Arkansas

In 2006, Heifer International, a non-profit sustainable community development organization located in Little Rock, Arkansas, designed an environmentally-friendly parking plaza to complement their new green building headquarters. A first of its kind in Arkansas, this project serves as a model for other organizations considering utilizing green parking lot techniques. One highlight is Heifer's use of native landscaping and irrigation methods, which reduce potable water use and provide habitat for local species.




*By using native landscaping around its parking lot, Heifer International supports the local ecosystem and conserves water.*

The innovative landscaping and irrigation surrounding Heifer International's parking lot provides a variety of environmental benefits. The grasses, plants, trees, and wildflowers used throughout much of the site are indigenous, and do not require pesticides. They also offer food and shelter to native wildlife, and help create a more visually pleasing aesthetic. Under natural rainfall events, the species planted in the lot should be able to sustain themselves with little irrigation. In fact, in a normal rainfall year, the landscape will require irrigation only once a week.

Because Heifer used a combination of native seeding and sod, their parking lot requires less irrigation than a conventional lot using all sod and non-native landscaping. In a typical, non-drought year, Heifer's closed loop stormwater system will provide 100 percent of the water necessary to irrigate vegetation throughout the lot, eliminating use of municipal water for this purpose. Heifer uses approximately 5,000 gallons of irrigation water per week, or 260,000 gallons annually, to irrigate its grounds. According to their landscape architect, this represents a two-thirds reduction in water demand compared to a conventional parking lot scenario with standard landscaping. By using recycled water, native plants, and water conserving irrigation, Heifer is conserving 520,000 gallons of potable water, and saving $65,343, annually.

Currently Heifer has six irrigation zones, four that use drip irrigation and two that use conventional sprinkler irrigation.

- **Drip Irrigation—**Heifer has four drip-zones for irrigating native trees and shrubs on the site. Each releases 0.9 gallons per hour, using a total of approximately 2,000 gallons of water per week. The total cost for the drip irrigation system was $79,000.
- **Sprinkler Irrigation—**Heifer has two spray-zones for irrigating the sod portions of the lot. These conventional pop-up spray heads produce approximately 25 gallons of water per minute per zone, using a total of approximately 3,000 gallons of water per week. The total cost for the sprinkler irrigation system was $42,000.

Heifer supported this sustainable landscaping by amending the soil with compost, which helps increase nutrient retention, decrease irrigation needs, and improve soil and plant health. They went beyond the City of Little Rock's parking ordinance by planting 80 trees (63 more than the city requires) and landscaped a far larger area within the lot than required. These actions improved the aesthetics of the parking lot, reduced heat island effect, and supported wildlife habitat.

For more information on Heifer International's green parking lot, including their sustainable landscaping techniques, please vist the U.S. EPA's green building Web site at: www.epa.gov/earth1r6/6sf/bfpages/bfheifer.html.

# CHAPTER 7

## Reduced Infrastructure Burden

This resource guide has explored how components of a green parking lot, including stormwater best management practices, innovative planning policies, and native landscaping, can be used in combination to sustainably manage stormwater at individual sites. The ultimate potential of these practices, however, lies in scaling them up to the neighborhood, town, or regional level, to reduce burden on the current stormwater management infrastructure, and plan for sustainable future growth. This "green infrastructure" approach encompasses planning for parking lots, housing developments, roads, and other stormwater related infrastructure. Defined by the EPA as techniques that "utilize natural systems, or engineered systems that mimic natural landscapes, to capture, cleanse, and reduce stormwater runoff using plants, soils, and microbes," green infrastructure is an approach that is being endorsed by U.S. federal, state and local government entities, including:

- **The U.S. Environmental Protection Agency (EPA) and national stakeholders**

  In 2007, EPA and four major national groups (National Association of Clean Water Agencies, Natural Resources Defense Council, Low Impact Development Center, and Association of State and Interstate Water Pollution Control Administrators) signed an agreement to promote the use of green infrastructure to reduce stormwater runoff and sewer overflows.[178]

- **The Environmental Council of States (ECOS)**

  In 2007, ECOS' Green Infrastructure Resolution (07-10) encouraged the use of green infrastructure to mitigate sewer overflows and protect public health and the environment.[179]

- **The U.S. Conference of Mayors**

  A 2006 Green Infrastructure Resolution from the U.S. Conference of Mayors recognized that "green infrastructure naturally manages stormwater, reduces flooding risk and improves air and water quality, thus performing many of the same functions as traditional building infrastructure, often at a fraction of the cost."[180]

The need for scaling up green infrastructure is pressing. It is estimated that nearly 25 million acres of impervious surface cover the continental United States, and that approximately 70 million acres of land will be newly developed in the United States by the year 2025. By 2030, 50 percent of the built environment will have been constructed since 2000.[181] Such growth will increase strain on existing municipal stormwater management systems by adding more impervious surface area and higher volumes of runoff. In many areas of the country, these systems are already critically strained and are saddled with a backlog of deferred maintenance. A green infrastructure approach can minimize runoff volumes, and reduce the combined burden on municipal stormwater and wastewater infrastructures.[182]

## Regional Stormwater and Wastewater Impacts

As outlined in previous chapters, stormwater runoff can cause a number of serious problems including water pollution, flooding, groundwater recharge deficits, and damage to stream ecology.[183] These impacts translate into high costs to municipalities, and using conventional methods alone to control them can be an expensive use of public funds. This is particularly true in regions of the country with older infrastructure, including the Pacific Northwest, Northeast, and Great Lakes. In these regions, stormwater is often channeled into the same pipes as sewage (i.e., combined sewers). With large areas of impervious surface and development, heavy rain events can push these combined pipes beyond capacity, causing them to overflow. These "combined sewer overflows," or CSOs, result in large amounts of untreated waste overflowing into waterways, making them a primary source of pollution for many water bodies. The Clean Water Act requires that combined sewer systems be updated to prevent CSOs, however, these upgrades are cost prohibitive for many cities and towns.[184] The EPA's 2000 Clean Watersheds Needs Survey estimates that $56 billion in capital investment nationally was needed for CSO controls.[185]

The regional impact of stormwater runoff and CSOs cannot be properly controlled by sporadic site-by-site controls, or large end-of-pipe conventional stormwater treatment alone. A coordinated, area-wide planning effort is required. Major cities throughout the country, including Portland (Oregon), Seattle, Chicago, and Philadelphia, have started to invest in land use planning and infrastructure development with green infrastructure as a major component.[186] For example, Portland, Oregon is a leader in integrating innovative environmental technology into its city planning and policies. The city's building codes require on-site stormwater management for all new construction projects, and their stormwater manual encourages the use of best management practices.[187] A number of smaller cities and towns have also started to embrace green infrastructure planning. In Kansas City, Missouri, planners are implementing the 10,000 Rain Garden Initiative, which will create 10,000 such gardens to help the city achieve its 20-year Wet Weather Solutions Program. This is one of the largest infrastructure projects in the city's history.[188]

## Cost Effectiveness

Looking at stormwater management from a regional or watershed scale is important when considering costs. The piping, channels, and treatment plants of a traditional stormwater infrastructure are expensive to build, operate, and maintain, and are not the most effective way of controlling stormwater.[189] The EPA's Assistant Administrator for Water has stated that:

> *"Green infrastructure may save capital costs associated with digging big tunnels and centralized stormwater ponds, operations and maintenance expenses for treatment plants, pipes, and other hard infrastructure; energy costs for pumping water; and costs of wet weather treatment and repairing of stormwater and sewage pollution impacts, such as stream bank restoration."*[190]

Potential cost savings are important to communities throughout the United States that are working to comply with federal stormwater management regulations. According to an 2007 report evaluating the potential of a major storm water minimization program, "the use of green infrastructure can help communities meet their overall water resource management goals and reduce the costs (or free up funding for other uses such as land purchases) of constructing and maintaining engineered infrastructure including pipes and treatment systems."[191] For example, in Kane County, Illinois, researchers estimated economic benefits of downstream stormwater management through green infrastructure practices implemented upstream would save approximately $4 million, money that would otherwise have been spent on culvert replacement or upgrades for stormwater diversion. When both flood reduction and infrastructure savings are considered, the green infrastructure practices were found to be approximately $300-$700 less expensive per developed acre.[192] Portland, Oregon estimates its Green Streets stormwater infrastructure design saves 40 percent in costs compared to conventional stormwater infrastructure (also see Green Streets case study at the end of this chapter).[193]

Green infrastructure can be a cost effective replacement or complement for other water quality improvement strategies. For example, for 10 years, a demonstration project in the Rouge River area of Michigan has been utilizing 14 acres of wetlands (two thirds of which are constructed) along the river's banks to naturally treat stormwater before it enters the water body, rather than piping it directly into the river. They found that, at a cost of less than $50,000 per year, the wetlands not only diminished stormwater flows, but also successfully removed pollutants from runoff, including 80 percent of suspended solids, 70 percent of phosphorus, and 60 percent of oxygen depleting compounds and heavy metals. The high efficacy of the wetlands made them a cost-effective strategy for improving the river's water quality.[194] In Portland, Oregon, the City has found that adopting a variety of green infrastructure techniques over the course of a 10 year period has avoided over 1.2 billion gallons of runoff and has reduced CSO events by 10 percent.[195]

It is clear that stormwater management must be elevated to a key urban planning and policy issue as local governments seek to reduce stormwater impacts cost-effectively. Promoting green infrastructure regionally or watershed-wide will help control the cumulative impact that stormwater from multiple sources has on stormwater infrastructure. Even in cases where green infrastructure investments are not more cost-effective in the short-term, the long-term environmental and social benefits can be quite significant to livability and sustainability on a regional scale. These benefits have been explored throughout this guide, and include enhanced groundwater recharge, pollution prevention, increased carbon sequestration, HIE mitigation, improved air quality, and increased green space and wildlife habitat.[196]

## CASE STUDY 5: Reduced Infrastructure Burden
## Green Streets Program—Portland, Oregon

For over a decade, the City of Portland, Oregon has been pursuing new approaches to stormwater management. Known for its wet weather with the third highest number of rainy days annually in the U.S., Portland typically averages 37 inches of rain a year.[197] Approximately 66 percent of the resulting stormwater runoff comes from streets and rights of way.[198] For this reason, the City created "Green Streets," a city-wide land use planning effort for stormwater management focused on transportation-related development (i.e. parking lots, streets). Defining a Green Street as "one that uses vegetated facilities to manage stormwater runoff as its source," this program is part of a concert of initiatives that the city is undertaking to help them reach their goal of removing 60 million gallons of stormwater annually by 2011.[199, 200]

*One of many rain gardens being built throughout Portland as part of the city's Green Streets program.*

Although city officials have been promoting a green streets theme for a number of years, in 2005 an interdisciplinary team of area experts, including government officials, engineers, planners, landscape architects, and watershed managers refocused the program by taking a fresh look at opportunities for its implementation. This multi-disciplinary approach provided the breadth of knowledge necessary to properly address comprehensive stormwater management, and was invaluable to successfully implementing the Green Streets program.

In revamping the Green Streets program, Portland focused on learning through demonstration projects. This includes a project on the Portland State University campus built in 2005 to treat 8,000 square-feet of street surface runoff through the use of infiltration basins. In 2006, this project was recognized with the national American Society of Landscape Architects Design Award.[201] By starting with demonstration projects, the City was able to monitor results and incorporate lessons learned into more effective stormwater designs that could be replicated on a city-wide scale.[202]

In April 2007, the Portland City Council officially endorsed the enhanced Green Streets program by approving an innovative stormwater management plan comprised of a resolution, report, and policy. The overarching goal of this program is to "comprehensively address numerous city goals for neighborhood livability, sustainable development, increased green spaces, stormwater management, and groundwater protection."[203] The city council articulated several objectives for achieving this goal, including a neighborhood planning initiative, further stakeholder outreach, the pursuit of more funding mechanisms, and ultimately the establishment of even more Green Streets. As a short term objective, the City is planning on developing 500 additional Green Street projects to address combined sewer overflow issues.[204]

For more information on the Portland, Oregon Green Streets program, please visit the Green Streets Web site at: www.portlandonline.com/BES/index.cfm?c=44407&.

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