

# THE SUSTAINABLE SITES INITIATIVE™



## THE CASE FOR SUSTAINABLE LANDSCAPES

**American Society of Landscape Architects**

**Lady Bird Johnson Wildflower Center  
at The University of Texas at Austin**

**United States Botanic Garden**

*The Sustainable Sites Initiative is a partnership of the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center, and the United States Botanic Garden in conjunction with a diverse group of stakeholder organizations to establish and encourage sustainable practices in landscape design, construction, operations, and maintenance.*

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## EXECUTIVE SUMMARY

*This document, The Case for Sustainable Landscapes, is a companion volume to the much larger report titled The Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009. It provides background on the Sustainable Sites Initiative™; a set of arguments—economic, environmental, and social—for the adoption of sustainable land practices; additional background on the science behind the performance criteria in the Guidelines and Performance Benchmarks 2009; and a sampling of some of the case studies the Initiative has been following. For more information, or to download copies of either volume, please see [www.sustainablesites.org](http://www.sustainablesites.org).*

By aligning land development and management practices with the functions of healthy ecosystems, the Sustainable Sites Initiative believes that developers, property owners, site managers, and others can restore or enhance the ecosystem services provided by their built landscapes. Moreover, adopting such sustainable practices not only helps the environment but also enhances human health and well-being and is economically cost-effective. For the Initiative's purposes, "sustainability" is defined as design, construction, operations, and maintenance practices that meet the needs of the present without compromising the ability of future generations to meet their own needs. This definition embraces the definition of sustainable development first put forward by the United Nations World Commission on Environment and Development in 1987.

The Sustainable Sites Initiative, an interdisciplinary partnership of the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center, and the United States Botanic Garden, has spent several years developing guidelines for sustainable land practices that are grounded in rigorous science and can be applied on a site-by-site basis nationwide. These guidelines—*The Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009*—acknowledge that different regions of the country will have different requirements and therefore include performance levels appropriate to each region as needed.

The impetus for creating the guidelines came from the recognition that although buildings have national standards for "green" construction, little existed for the space beyond the building skin. Modeled after the LEED® (Leadership in Energy and Environmental Design) Green Building Rating System™ of the U.S. Green Building Council, the Initiative's rating system gives credits for the sustainable use of water, the conservation of soils, wise choices of vegetation and materials, and design that supports human health and well-being.

The term “ecosystem services” describes the goods and services provided by healthy ecosystems—the pollination of crops by bees, bats, or birds, for example, or the flood protection provided by wetlands, or the filtration of air and water by vegetation and soils. Ecosystem services provide benefits to humankind and other organisms but are not generally reflected in our current economic accounting. Nature doesn’t submit an invoice for them, so humans often underestimate or ignore their value when making land-use decisions. However, efforts to determine the monetary value of ecosystem services have placed that figure at an estimated global average of \$33 trillion annually (in 1997 dollars).

Increased understanding of the value of these services has led to acknowledgment of the way current land practices can imperil such essential benefits as air purification, water retention, climate regulation, and erosion control. As many communities have found, it is difficult, expensive, and sometimes impossible to duplicate these natural services once they are destroyed.

The good news is that we can model the creation of our landscapes after healthy systems and thereby increase the ecosystem services they provide after development—whether that development is a backyard garden, a housing development, or a state park. Water on the site can be managed to imitate natural water cycling, vegetation can be used strategically to cool the area and filter water, and soils can be restored to support healthy vegetation and filter pollutants.

The Initiative’s development of site-specific performance benchmarks is grounded in an understanding of healthy systems and natural processes. Achieving these benchmarks will help to maintain or support those natural processes and the services that they provide to humans. This volume, *The Case for Sustainable Landscapes*, is intended to provide readers with more background on the science underlying the guidelines for sustainable practices—to explain the connection, for example, between excessive use of nitrogen fertilizers and the increase in “dead zones” in coastal waters downstream, or between an increase in impervious cover and reduced base flow to creeks, streams, and rivers.

*The Case for Sustainable Landscapes* also offers evidence for the economic benefits that can accrue from adopting sustainable practices. For example, as a number of developers have found, bioswales, raingardens and other low-impact development strategies to reduce runoff not only help recharge groundwater but also can save developers anywhere from 15 to 80 percent in total capital costs. And as New York City has found, a long-term investment in protecting its watershed can save billions in avoided costs for a new water treatment plant—a cost saving passed on to rate payers.

The science demonstrates that humans are an integral part of the environment. As people acknowledge this link, they recognize that human decisions and behavior are in fact components of a global feedback loop: what people do affects the health and well-being of the rest of the natural world, which in turn affects human health and well-being—physical, mental, economic, and social.



Swan River Foreshore, Point Fraser  
Development, Perth, Western Australia

# 1 PURPOSE AND PRINCIPLES OF THE SUSTAINABLE SITES INITIATIVE

A little more than two decades ago, the United Nations World Commission on Environment and Development, headed by Gro Harlem Brundtland, then-Prime Minister of Norway, presented its report to the UN General Assembly. Titled *Our Common Future* but better known as the Brundtland Report, it made an eloquent argument for sustainable development, which it defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”<sup>1</sup>

*We came to see that a new development path was required, one that sustained human progress not just in a few places for a few years, but for the entire planet into the distant future.*

GRO HARLEM BRUNDTLAND, 1987

Over the intervening years, the Brundtland Report’s prescription for sustainability has gained wide acceptance. In corporate boardrooms and grade-school classrooms, at neighborhood gatherings and in councils of government, growing numbers of citizens are embracing the opportunity to live sustainably. As people acknowledge that humans are an integral part of the environment, they recognize that human decisions and behavior are in fact components of a global feedback loop: what people do affects the health and well-being of the natural world, which in turn affects human health and well-being—physical, mental, economic, and social.

The Sustainable Sites Initiative, founded in 2005, embraced the Brundtland Report's forward-looking definition of sustainability.<sup>2</sup> In the Initiative's words, "sustainability is defined as design, construction, operations, and maintenance practices that meet the needs of the present without compromising the ability of future generations to meet their own needs."

This definition guides the formulation of the Initiative's voluntary guidelines and performance benchmarks for sustainable land development and management. Presented in the document *The Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009*, these benchmarks are designed to preserve or restore a site's sustainability within the context of ecosystem services—the idea that healthy ecosystems provide goods and services of benefit to humans and other organisms.<sup>3</sup> As Dr. Brundtland put it, "the 'environment' is where we all live; and 'development' is what we all do in attempting to improve our lot within that abode. The two are inseparable."<sup>4</sup>

The benchmarks are meant to guide, measure, and recognize sustainable landscape practices on a site-by-site basis. They may also inform larger scale projects or planning efforts although they are not intended to be a tool for regional planning. Similarly, although the guidelines and benchmarks encourage edible landscapes and small-scale food production as components of a site, they do not address sustainable agricultural products or large-scale agricultural or farming practices; other organizations, such as the Leonardo Academy and the Rainforest Alliance, are developing or have already developed systems to do so. The U.S. Green Building Council anticipates incorporating the Sustainable Sites benchmarks into future versions of its LEED® (Leadership in Energy and Environmental Design) rating system.

### Roots of Sustainability

The word "sustainability" may be relatively new, but its underlying ethic has deep roots on the North American continent. Native Americans have historically held to the "seven generations" rule, meaning that all decisions should take into account the impact on seven generations into the future. Well aware that people have the power to manipulate the world around them, Native Americans use their ceremonies and traditions to help them to maintain respect for life and to remind them that, as one Native American proverb puts it, "We do not inherit the earth from our ancestors, we borrow it from our children."<sup>5</sup>

Another strand of sustainable resource use can be traced back more than a hundred years to Gifford Pinchot, the first head of the U.S. Forest Service. Pinchot coined the term "conservation ethic," and his philosophy "to provide the greatest amount of good for the greatest amount of people in the long run" infused the fledgling agency. Today, the stated mission of the Forest Service is to "sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations."<sup>6</sup>

## GUIDING PRINCIPLES

Throughout the life cycle of each site—from design and construction through operations and maintenance—sustainable performance benchmarks will enable built landscapes to support natural ecological functions by protecting existing ecosystems and regenerating ecological capacity where it has been lost. To that end, the Initiative's guiding principles (see page 9) not only inform its own work but should also inform all aspects of sustainable site development.



## GROWING AWARENESS

The Millennium Ecosystem Assessment, a United Nations study completed in 2005, highlighted the need for all development to address considerations in three key arenas: social, environmental, and economic.<sup>7</sup> Unless all three aspects are equally vibrant, true sustainability is not possible.

As with sustainable development in general, a sustainable site also needs to take into account the challenges on all three fronts. An environmentally sustainable site that does not engage its users on multiple levels—physical, aesthetic, cultural, spiritual—will lose crucial human stewardship. By the same token, creation and maintenance of the site must be economically feasible for the site to exist at all.

### Guiding Principles of a Sustainable Site

#### **Do no harm**

Make no changes to the site that will degrade the surrounding environment. Promote projects on sites where previous disturbance or development presents an opportunity to regenerate ecosystem services through sustainable design.

#### **Precautionary principle**

Be cautious in making decisions that could create risk to human and environmental health. Some actions can cause irreversible damage. Examine a full range of alternatives—including no action—and be open to contributions from all affected parties.

#### **Design with nature and culture**

Create and implement designs that are responsive to economic, environmental, and cultural conditions with respect to the local, regional, and global context.

#### **Use a decision-making hierarchy of preservation, conservation, and regeneration**

Maximize and mimic the benefits of ecosystem services by preserving existing environmental features, conserving resources in a sustainable manner, and regenerating lost or damaged ecosystem services.

#### **Provide regenerative systems as intergenerational equity**

Provide future generations with a sustainable environment supported by regenerative systems and endowed with regenerative resources.

#### **Support a living process**

Continuously re-evaluate assumptions and values and adapt to demographic and environmental change.

#### **Use a systems thinking approach**

Understand and value the relationships in an ecosystem and use an approach that reflects and sustains ecosystem services; re-establish the integral and essential relationship between natural processes and human activity.

#### **Use a collaborative and ethical approach**

Encourage direct and open communication among colleagues, clients, manufacturers, and users to link long-term sustainability with ethical responsibility.

#### **Maintain integrity in leadership and research**

Implement transparent and participatory leadership, develop research with technical rigor, and communicate new findings in a clear, consistent, and timely manner.

#### **Foster environmental stewardship**

In all aspects of land development and management, foster an ethic of environmental stewardship—an understanding that responsible management of healthy ecosystems improves the quality of life for present and future generations.



**Fig. 1.1 SUSTAINABLE DEVELOPMENT.** Of the three components of sustainability, the primary focus for the Sustainable Sites Initiative is the environment, including those aspects of economic feasibility and social equity that intersect with the environment.

In view of the pressing need for an economy less reliant on fossil fuels and more attuned to potential climate change, the Sustainable Sites Initiative hopes to encourage land design, development, and management professionals to engage in a re-evaluation of conventional practices—and a new valuation of ecosystem

services—so that built landscapes will support natural ecological functions throughout the life cycle of each site. Encouragingly, growing numbers of projects are adopting the philosophy of low-impact development (see Chapter 2) and many local and regional efforts now provide guidelines for improved land development and management practices. The Initiative is interested in information sharing and partnering with all interested parties. At the same time, the Initiative hopes that its products will be able to serve as stand-alone guidelines for anyone who wishes to embrace landscape sustainability.

Beginning in April 2010, a number of pilot projects will help test and refine the *Guidelines and Performance Benchmarks 2009* and its rating system over the course of two years. The Initiative expects to incorporate knowledge gained from working with the pilot projects into development of *The Sustainable Sites Initiative Reference Guide*.

Meanwhile, the Initiative has been following a number of case studies—projects that have incorporated sustainable practices in a wide variety of situations. A selection of those studies is presented in Chapter 4. The case studies pre-date the development of the *Guidelines and Performance Benchmarks 2009* and are separate from the Initiative's pilot program. For more information on the pilot program, please visit <http://www.sustainablesites.org/pilot/>.

## 1 Purpose and Principles of the Sustainable Sites Initiative

- <sup>1</sup> UN General Assembly, *Our Common Future: Report of the World Commission on Environment and Development*, 1987, chap. 2, "Towards Sustainable Development," <http://www.worldinbalance.net/agreements/1987-brundtland.html> (accessed October 11, 2009).
- <sup>2</sup> For a history of the Initiative, see <http://sustainablesites.org/history.html>.
- <sup>3</sup> G Daily, ed., *Nature's Services: Societal Dependence on Natural Ecosystems* (Washington, DC: Island Press, 1997).
- <sup>4</sup> *Our Common Future*, Foreword, <http://www.worldinbalance.net/agreements/1987-brundtland.html> (accessed October 11, 2009).
- <sup>5</sup> "In our every deliberation we must consider the impact of our decisions on the next seven generations." from the Great Law of the Iroquois Confederacy. For more information on the Great Law: <http://www.indigenouspeople.net/iroqcon.htm> (accessed September 26, 2009); "Native American communities are some of the most sustainable on earth because they live in balance with their environment. They follow the seven-generation rule: How will what we do today impact seven generations from now?" L Miller, "A Native American Teacher Talks About Biotechnology," Aldo Leopold Center, Iowa State University, <http://www.leopold.iastate.edu/pubs/nwl/2001/2001-2-leoletter/michael.htm> (accessed September 26, 2009); proverb from <http://www.quotegarden.com/environment.html>.
- <sup>6</sup> USDA Forest Service, "Sustainable Operations," <http://www.fs.fed.us/sustainableoperations/> (accessed September 26, 2009).
- <sup>7</sup> Millennium Ecosystem Assessment, *Ecosystems and Human Well-being: Message from the Board* (Washington, DC: Island Press, 2003), p.3.



The central message of the Sustainable Sites Initiative is that any landscape—whether the site of a large subdivision, a shopping mall, a park, an office building, or even one home—holds the potential both to improve and to regenerate the natural benefits and services provided by ecosystems in their undeveloped state. These benefits—such as the supply and regulation of clean air and water, the provision of food and renewable resources, and the decomposition of waste, to name only a small handful—are essential to the health and well-being of humans and all other life on the planet.

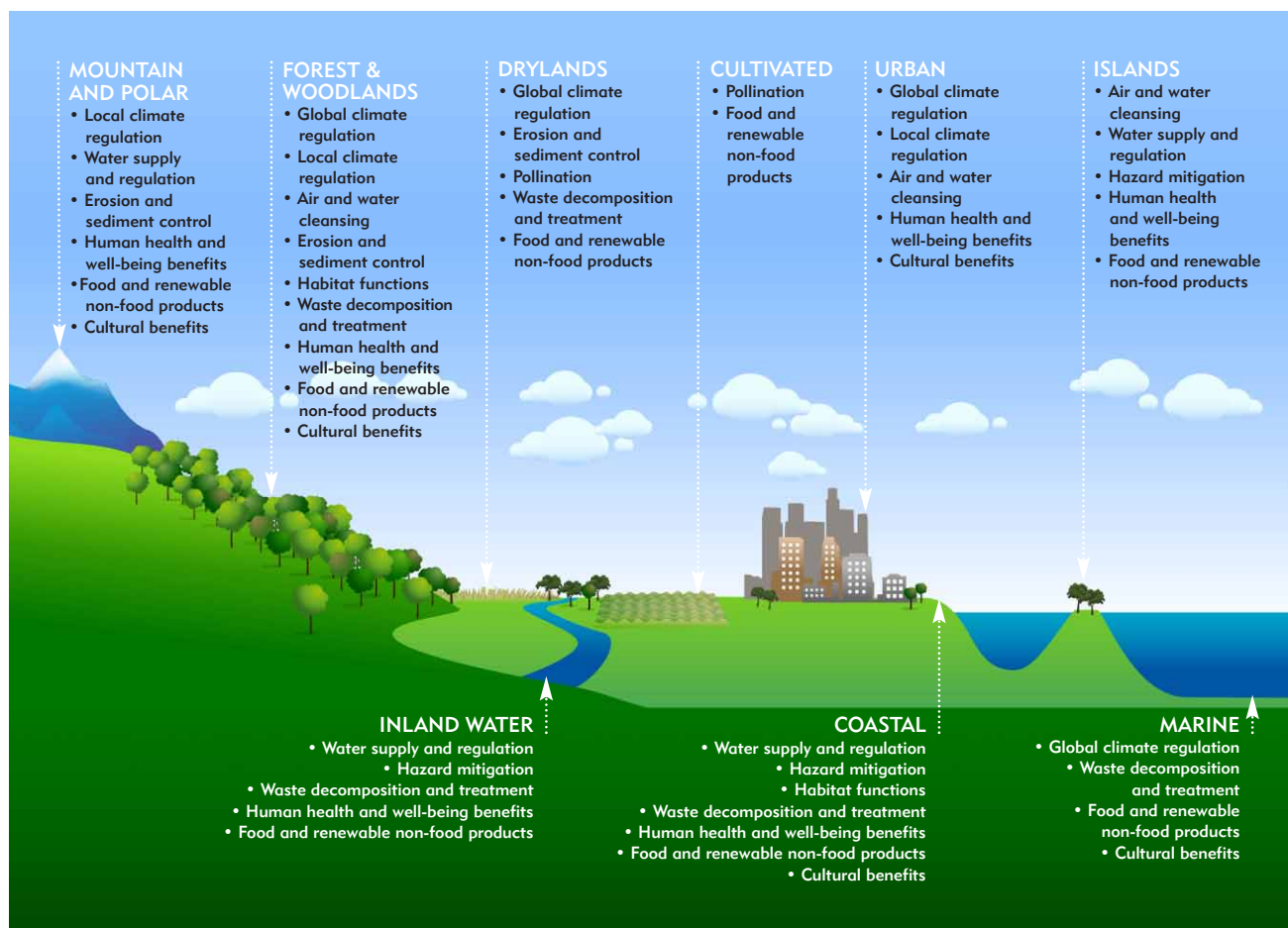
Because these ecosystem services occur largely in the background, governments and businesses until quite recently have not included them in conventional cost accounting. Although this situation is beginning to change, most people often underestimate or simply ignore these benefits and services when making land-use decisions—only to realize later how expensive and sometimes impossible it is to replicate them once they are lost.

*The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased, and not impaired, in value.*

PRESIDENT THEODORE ROOSEVELT

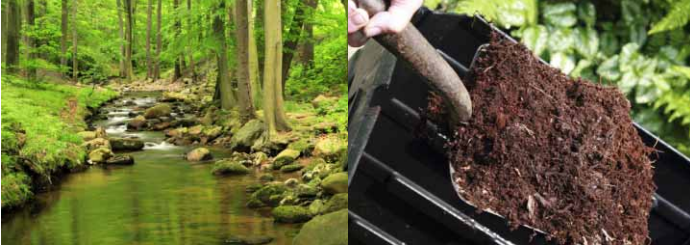
Yet efforts to build landscapes that preserve and restore healthy ecosystems face a significant challenge—namely, persuading decision-makers that the cost of changing conventional methods of landscape design, development, and maintenance is money well spent. Persuasion must begin, then, with an accurate accounting of what the benefits of ecosystems are worth to the economies of our cities and towns, to developers, and to individuals. One effort to calculate a global number placed an average price tag of \$33 trillion a year on these fundamental ecosystem services—nearly twice the value of the global gross national product of \$18 trillion (both figures in 1997 dollars).<sup>1</sup>

An accurate accounting must take into consideration how the adoption of sustainable practices can not only be cost effective for both public and private entities but also can often leverage additional costs and multiple benefits. This chapter offers a review of how certain conventional, accepted land practices affect the interrelated operations of functioning ecosystems and at what economic cost, followed by a description of the benefits of adopting sustainable practices, and some examples of the economic savings realized by a number of communities that have adopted them.



**FIG. 2-1. THE BOUNTY OF ECOSYSTEMS.** No one type of ecosystem has a monopoly on the goods and services it can provide, and the services listed here represent only a few of the many services available from each type. With sustainable practices, built landscapes can provide many of these same natural services. *Illustration adapted from The Millenium Ecosystem Assessment (2005).*





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## THE BENEFITS OF SUSTAINABLE PRACTICES

The elements in a functioning ecosystem are so highly interconnected (see Chapter 3) that unsustainable approaches to land development and management practices can have a devastating ripple effect throughout the system. The following examples of sustainable approaches demonstrate how thoughtful design, construction, operations, and maintenance can enhance and restore ecosystem services that would otherwise be lost.

### TREATING WATER AS A RESOURCE

Freshwater resources are under duress all over the world, and the United States is no exception. California and the arid Southwest have often dealt with water scarcity, and their challenges have only been exacerbated in recent years. Even the southeastern part of the country, which historically could rely on plentiful rain, has been experiencing drought conditions.<sup>2</sup>

Meanwhile, demand for water in the United States has tripled in the last 30 years, even though population has only grown 50 percent. Globally, demand for water is doubling every 20 years. As water rates rise, the imbalance between supply and demand has become so striking that investment bank Goldman Sachs has dubbed water “the petroleum for the next century.”<sup>3</sup>

Yet the following two practices, both traditionally accepted among land design, development, and management professionals, not only contribute to the imbalance but also ignore the looming crisis.

**Wasteful irrigation:** Irrigation of unsustainable landscapes accounts for more than a third of residential water use—more than 7 billion gallons of potable water *per day* nationwide.<sup>4</sup> With the compaction of soil a common condition in developed areas (see Valuing Soils, below), the infiltration rates of water are significantly reduced, causing much of the water used to irrigate lawns to end up as runoff or evaporation instead of filtering down to recharge the water table.

A sustainable approach to landscape design would minimize or eliminate the use of potable water or the drawing off of natural surface water or groundwater for landscape irrigation once plants are established.

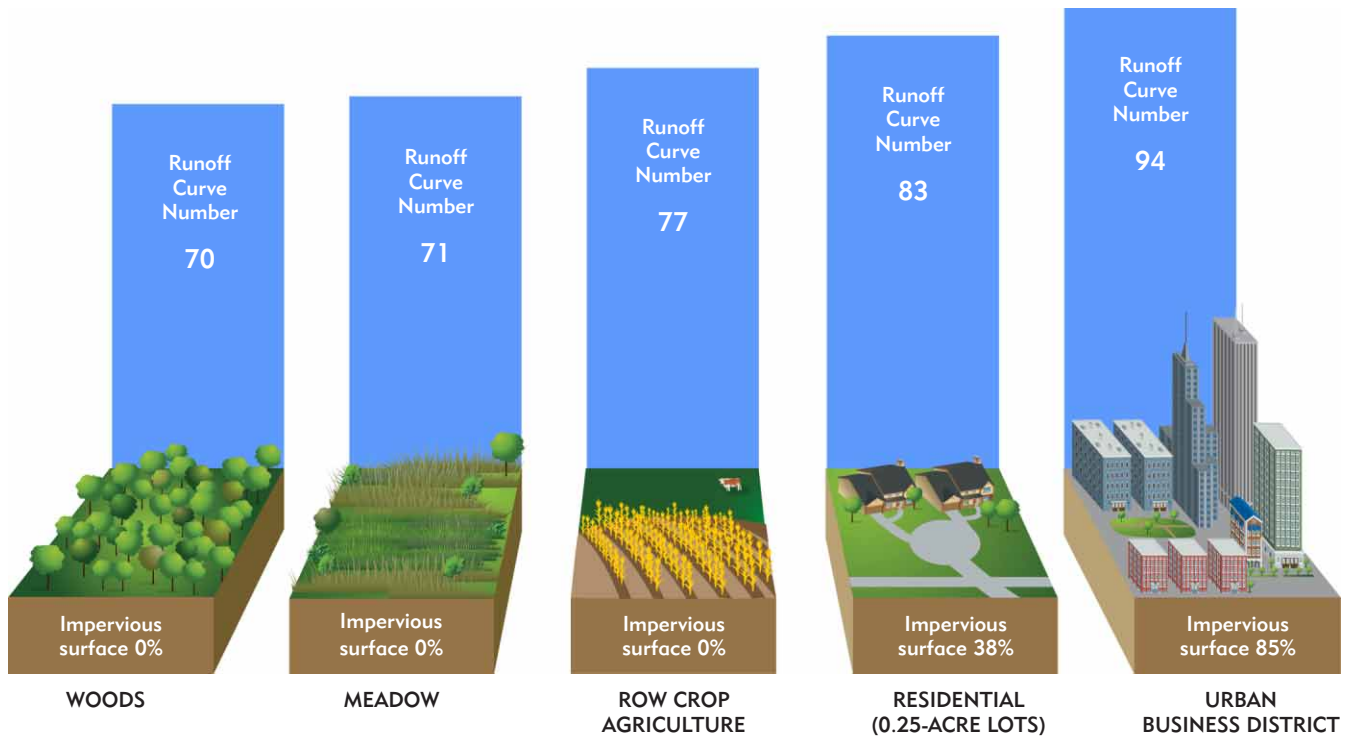
**Undervaluing rain:** In most cities and towns around the country, rainfall is treated as waste, to be funneled directly from roof gutters to sewers. In older cities this stormwater flows into combined sewer/stormwater systems that flow to water treatment plants, thus raising the cost of purifying drinking water. In heavy storms, these combined sewer systems can overflow, dumping raw sewage into fresh water.

Rather than getting rid of stormwater runoff as quickly as possible, a sustainable approach to stormwater management would find ways to capture it on site and use it for irrigation, ornamental water features, drinking water, and groundwater recharge.

### VALUING SOILS

The undervaluation of soils is one of the most significant failings of the conventional development approach. For example, a frequent consequence of standard construction practices is compaction of the soil, which seriously damages soil structure by shrinking the spaces between soil particles available for air and water. If not restored, compacted soil can start a spiral of degradation.





**FIG. 2-2. RUNOFF CURVE NUMBERS FOR DIFFERENT SITE TYPES.** The runoff curve number is a product of empirical data from many sites across the country. It takes into account the amount of rainfall that is intercepted by vegetation, stored in surface depressions, and infiltrated. Any rainfall not retained on site becomes runoff. All sites in the illustration above are assumed to have similar slopes and similar soils. However, as development increases—from woods to row crop agriculture to residential and urban landscapes—so does soil compaction. Compaction and increasing amounts of impervious area result in less water retained on site and more of it running off, thus raising a site's curve number. A higher curve number, in turn, corresponds to a greater predicted runoff volume (see Fig. 2-3).

**Damage to vegetation:** Compacted soil particles restrict a plant's root growth and its access to nutrients. If soil compaction continues, vegetation eventually dies and soils become vulnerable to erosion.

**Reduced infiltration:** Compacted soils are less able to absorb water, which reduces the recharge of groundwater and aquifers.

**Excess runoff:** Reduced infiltration leads to increases in the volume of runoff and the probability of flooding. On developed sites where there is widespread use of impervious material such as concrete and asphalt, even more runoff is likely.

**Water pollution:** Without a sustainable approach to managing water on site, excess runoff damages soils and vegetation in one area, and also creates further hazards downstream—exponentially so during heavy rains or storm events.

Water leaving developed sites can contain a host of pollutants, depending on the type of development. These pollutants may range from excessive nutrients, oil, grease, and heavy metals to contaminants such as *E. coli*, hepatitis A, and persistent bioaccumulative toxic (PBT) chemicals. Stormwater runoff is one of the leading sources of pollution for all water body types in the United States, with impacts that escalate with increased development and urbanization.<sup>5</sup>

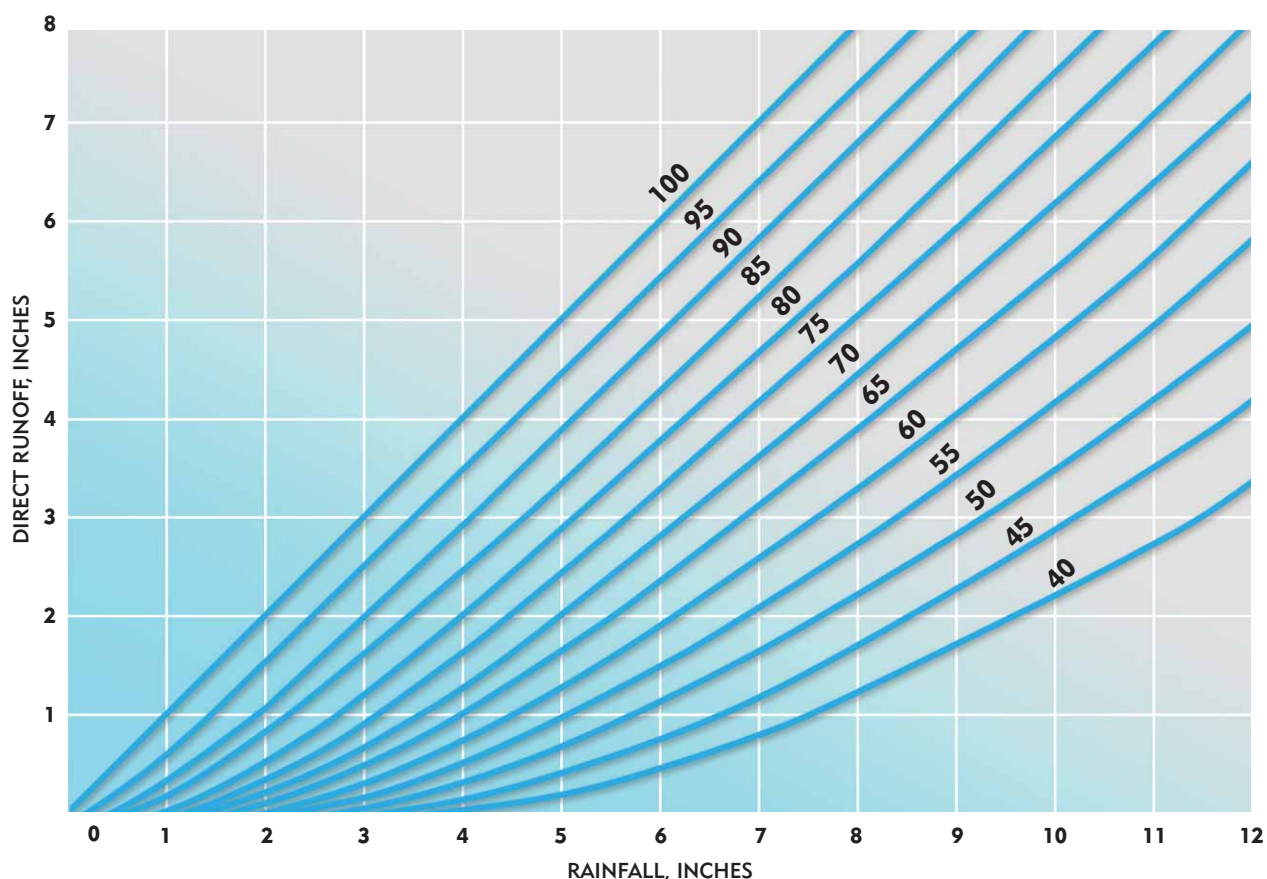
## 2 The Economics of Sustainable Landscapes

Although most pollutants and contaminants come from farming and agriculture runoff, or from combined sewage overflows, many pollutants leach into soil and water from materials and products used as part of conventional landscape development and management. Taken together such pollutant loads can be devastating to natural systems. Throughout the Mississippi River watershed, for example, increased surface runoff and nutrient delivery have created levels of dissolved oxygen that have caused fish and shrimp catches in parts of the Gulf of Mexico to drop to zero.<sup>6</sup>

Around the country, polluted and contaminated stormwater runoff accounts for 70 percent of

water pollution in urban areas and is the leading cause of poor water quality and the degradation of aquatic habitat.<sup>7</sup> According to the U.S. Environmental Protection Agency's Wadable Streams Assessment (WSA) in 2006, 42 percent of U.S. stream miles are in poor condition compared to the best available reference sites in their ecological regions. The WSA found that the most widespread stressors across the country are nitrogen, phosphorus, excess sedimentation, and riparian disturbance (i.e., evidence of human disturbance in or alongside streams).<sup>8</sup>

Ofentimes this pollution in water bodies stems from breaches in combined sewer overflow systems, when stormwater runoff overwhelms



**FIG. 2-3. PREDICTING STORMWATER RUNOFF.** The runoff potential of sites varies with their runoff curve numbers, which characterize a site's response to long-term patterns of precipitation. Sites with higher curve numbers will have more runoff than sites with lower curve numbers for the same amount of rainfall. For example, with 6 inches of rain, a site with a curve number of 40 yields just over 0.5 inch of runoff, while a site with a curve number of 90 loses nearly 5 inches as runoff.

sanitary sewers and raw sewage is released. In New York State in 2006, such instances caused a total of 1,280 combined beach closure or advisory days for all state beaches.<sup>9</sup>

In a sustainable approach to construction, a soil management plan communicated to contractors prior to construction would limit disturbance of healthy soil, assist soil restoration efforts, and define the location and boundaries of all vegetation and soil protection zones.

### **PRESERVING VEGETATIVE COVER**

Removing existing vegetation disturbs soils and has other consequences as well. Without vegetation, a site loses its natural capacity for stormwater management, filtration, and groundwater recharge. Reduced vegetative cover also affects soil health, because vegetation maintains soil structure, contributes to soil organic matter, and prevents erosion.

**Excess sedimentation:** Removing vegetation increases the likelihood of erosion, which contributes to increased sediment runoff. Sedimentation is a major cause of polluted rivers and streams in the United States, second only to pathogens.<sup>10</sup> Sediment runoff rates from construction sites can be up to 20 times greater than agricultural sediment loss rates and 1,000 to 2,000 times greater than those of forested lands.<sup>11</sup>

**Increased greenhouse gases:** Because so much organic carbon is stored in soils, significant amounts of carbon dioxide can be emitted when soils are disturbed. Disturbed soils also release substantial amounts of methane and nitrous oxide, both gases that trap heat even more effectively than carbon dioxide.<sup>12</sup> Although all of these greenhouse gases are emitted as part of natural nutrient cycling, the natural balance is upset by increased soil erosion and by activities such as tillage and fertilizer application, all of which increase the natural emission rates. (See

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The Carbon Cycle and The Nitrogen Cycle in Chapter 3.)

By adopting a plan with defined vegetation protection zones, a sustainable approach to site design and construction would preserve or restore appropriate plant biomass on the site as well as preserve native plant communities and mature trees.

### **CONSERVING MATERIAL RESOURCES**

Materials are natural resources that have been extracted, processed, and/or manufactured for human use. One way of evaluating a product's sustainability is to look at the energy and resource consumption involved, from the extraction of raw materials, through processing and manufacturing, to the product's use and disposal. However, conventional attitudes toward materials in society as a whole have not been focused on conserving either resources or energy. The land development and management industries are no exception.

**Yard waste:** Yard and landscape trimmings are a significant contributor to landfills, for example. In 2007, approximately 33 million tons of yard waste entered the municipal waste stream, representing 13 percent of total municipal waste in the United States.<sup>13</sup>

**Construction waste:** An estimated 170 million tons of building-related construction and demolition wood waste are generated each year in the United States.<sup>14</sup> Recoverable wood from construction and demolition could be reused in new applications, thereby reducing the need for virgin timber.

A sustainable approach to materials use in landscapes begins with an assessment of the existing site—both built and non-built features—and a design that seeks to incorporate and reuse as much of the existing site materials as practicable. Composting vegetation trimmings on site, for example, would provide an excellent source of soil nourishment. Similarly, recoverable wood from construction and demolition could be reused to become feedstock for engineered woods such as particle board and plywood, thereby reducing the need for virgin timber.

Careful materials selection can also reduce the energy used in both the production and the transport of the materials, thereby decreasing greenhouse gas emissions and the impact on global climate. For example, fly ash (a by-product of coal combustion) could be a substitute for energy-intensive portland cement in the production of concrete. Each ton of fly ash used to replace portland cement reduces greenhouse gas emissions by approximately one ton—equivalent to the emissions released by driving about 2,500 miles in an average car.<sup>15</sup> Selecting locally produced materials results in less transport, also reducing greenhouse gas emissions.

Ideally, sustainable products would be designed so that reuse and recycling could take place at each stage along the way, resulting in zero waste ending up in landfills. In this kind of “cradle-to-cradle” recycling, new, identical products (such as glass bottles from collected glass bottles) or different products (such as aluminum car parts from recycled aluminum cans) could be produced.

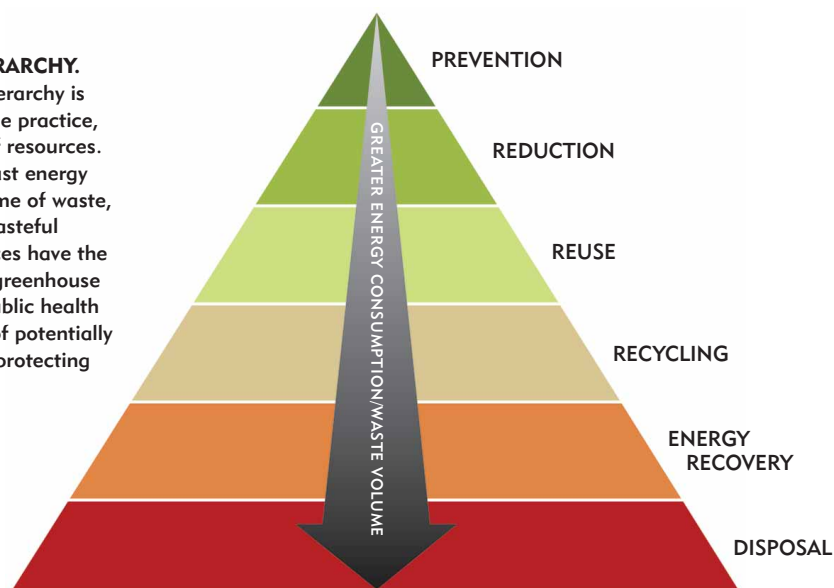
## VALUING THE HUMAN RELATIONSHIP WITH NATURE

Healthy ecosystems are the source of the many intangible—but no less real and measurable—benefits that humans derive from a relationship with nature. These benefits are especially important to the more than 80 percent of Americans who live in cities and towns.

For one thing, access to nature encourages physical activity, which can result in weight loss and overall improvements in health. With an estimated 32 percent of American children overweight—and with physical inactivity a contributing factor to this high proportion<sup>16</sup>—modifications to the built environment that are

**FIG. 2-4. THE WASTE HIERARCHY.**

The concept of the waste hierarchy is that the more sustainable the practice, the more efficient the use of resources. Prevention consumes the least energy and produces the least volume of waste, while disposal is the most wasteful practice. Sustainable practices have the added benefits of reducing greenhouse gas emissions, protecting public health through safe management of potentially hazardous substances, and protecting soils and groundwater.





likely to encourage more walking and biking among children are to be encouraged.<sup>17</sup> In a sustainable approach to community design, such modifications would include efforts to reduce risks associated with automobile traffic, such as bicycle networks and walking paths that link schools, parks, and residential neighborhoods.

Encouraging physical activity is not just for children. According to the U.S. Surgeon General's office, moderate physical activity, even taken in 10-minute increments, reduces the risk for adults of coronary heart disease, stroke, colon and breast cancer, osteoarthritis, high blood pressure and hypertension, non-insulin dependent diabetes, obesity, and fall-related injuries.<sup>18</sup> One study suggests that when inactive adults increase their participation in regular moderate physical activity, annual mean medical costs are reduced by \$865 per person.<sup>19</sup>

Access to nature has significant rewards in addition to physiological health. Research by social scientists and psychologists shows, for example, that for both adults and children, encounters with everyday nature—a green view from an office window, a lunchtime stroll through a nearby park, well-tended landscapes around schools—restore the ability to concentrate, calm feelings of anxiety, and reduce aggression.<sup>20</sup> Views of natural settings reduce the number of sick days taken by office workers and decrease hospital patient recovery time.<sup>21</sup> Furthermore, according to several studies in the United States and elsewhere, trees and green space generally increase property values, starting from around 4 percent to as much as 10 percent.<sup>22</sup>

### ACCOUNTING FOR DIRECT AND INDIRECT BENEFITS

Given the environmental cost of unsustainable land practices, a more sustainable approach is certainly desirable—but at what price? Those

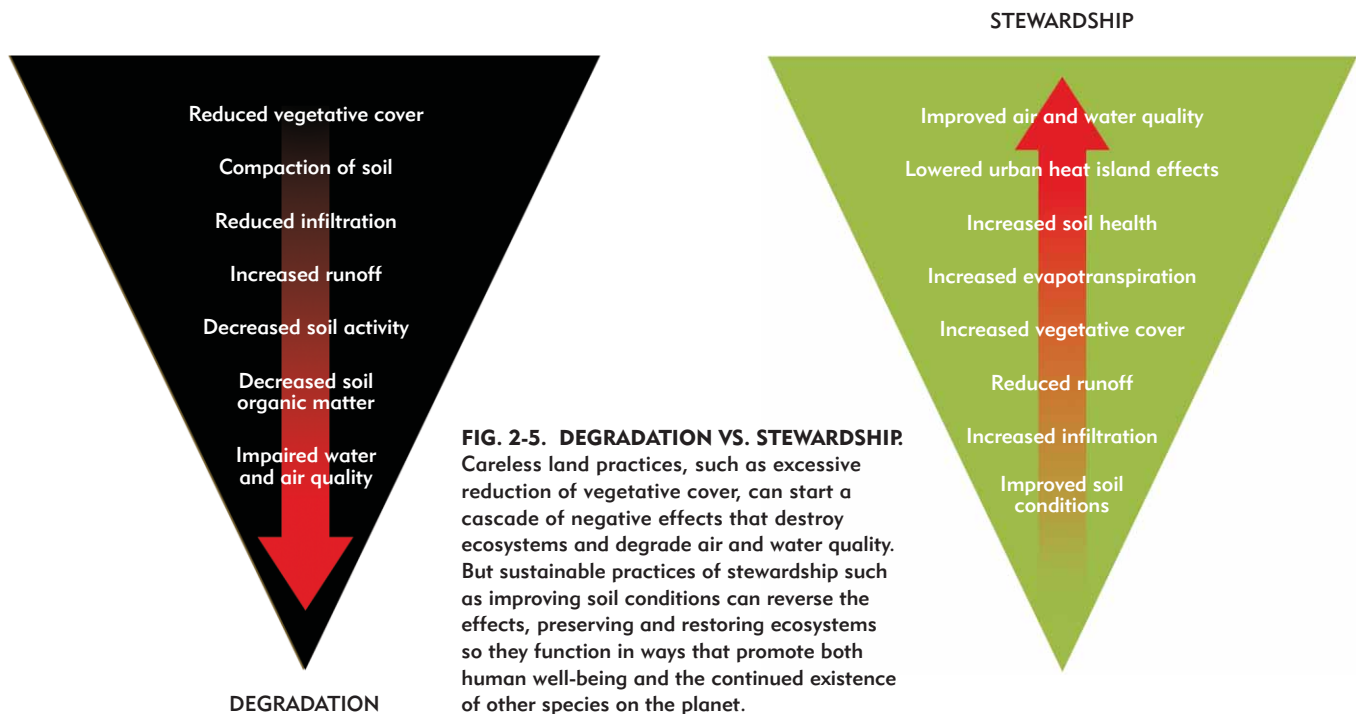


who make spending decisions—whether for governments, businesses, or individual households—are accustomed to looking at the trade-offs needed among economic, environmental, and social needs and constraints.

Often, however, these trade-offs are evaluated based on incomplete information. That is, the full direct and indirect economic value of the goods and services produced by a healthy environment—and the economic consequences of an impaired ecosystem—are not fully understood and not taken into account.

The economic value of benefits for which markets currently exist is relatively easy to quantify, as is the case with the commercial harvest of fish or timber, for example. However, even these relatively straightforward market prices do not usually include such external effects as the artificial price elevation for timber and agricultural products that results from government subsidies<sup>23</sup> or the cost of cleaning up resulting pollution, no matter who pays for it.

Measuring the economic significance of benefits for which markets do not exist is even more challenging. What is the economic value of an aesthetic or cultural or educational experience of nature, for example? Or the value of an endangered species? However, in recent decades economists have developed and tested techniques that can approximate the economic values of some of these benefits, with methods and results subjected to peer review in academic journals and presentations at scholarly conferences.<sup>24</sup>



**Energy savings:** Many ecosystem services have values that take the form of cost savings, which a number of studies have begun to quantify. The local climate regulation provided by shade trees, for example, results in an avoided cost for summertime electricity usage for the residence or commercial building cooled by that shade. Trees also block wind, potentially reducing demand for heating during the winter months.

When development results in an overall reduction in tree canopy cover, buildings are more exposed to both direct sunlight and wind. This exposure increases the demand for air-conditioning in the summer and for heating in winter. Studies conducted by American Forests found that tree canopy reduces residential home cooling costs, saving an average of between \$11 per household per year in Portland, Oregon, and \$28 per household per year in Atlanta, Georgia.<sup>25</sup> Multiplied across the region, this household benefit can add up: in the Atlanta region, savings in home cooling costs could amount to \$2.8 million per year with adequate tree canopy.

**Water treatment savings:** Similarly, when an urban forest prevents thousands of gallons of stormwater runoff from flowing into a municipal sewer system, that municipality saves money in water treatment. A study by the U.S. Environmental Protection Agency, for instance, found that a 2,500-acre wetland in Georgia saves \$1 million in water pollution abatement costs each year.<sup>26</sup> In New York City, urban trees intercept almost 890 million gallons of rainwater each year, preventing that much runoff from entering storm sewers and saving the city an estimated \$35 million annually in stormwater management costs alone.<sup>27</sup>

**Air cleansing:** Trees also provide an air-cleansing benefit. In the Chicago area, urban trees filter an estimated 6,000 tons of air pollutants each year, providing air cleansing valued at \$9.2 million.<sup>28</sup>

**Habitat and species preservation:** Along with habitat loss, exotic invasive species are a major cause of loss of biodiversity and species. Increasing the use of native plants in landscape design reduces the risk from invasive species and helps



bolster the wild native plant populations. This practice can also save considerable money: in the United States, exotic invasive species have been responsible for \$38 billion annual damage.<sup>29</sup> Efforts to control just one escaped, aggressive invasive—purple loosestrife (*Lythrum salicaria*)—cost \$45 million annually nationwide.<sup>30</sup>

### TAKING THE LONG VIEW

On a broader scale, New York City took a long-term ecosystem view of protecting its drinking water supply. Starting in 1992, the city began acquiring thousands of acres of watershed lands and working with communities in the watershed on the need for environmentally sensitive development.

The city's planned investment—approximately \$1.5 billion over the course of ten years—saved it anywhere from \$4 billion to \$6 billion in construction costs and an estimated \$300 million in annual operations costs for a new water filtration plant that it no longer had to build. The new treatment plant would have doubled or tripled rate payers' bills; by contrast, the provisions of the watershed protection plan increased the average residential customer's water bill by only \$7 per year.<sup>31</sup>

### RESPONDING TO THE CARBON ECONOMY

As the serious consequences of global climate change have become more apparent, the benefits associated with reducing atmospheric concentrations of carbon dioxide and other greenhouse gases have led markets to place an economic value on sequestered carbon. The Sustainable Sites Initiative urges sites to be carbon neutral, by eliminating net carbon emissions throughout the life of the site—that is, from design through construction, operations, and maintenance, including embodied energy in



materials and equipment operations. This goal may be achieved through decreased energy consumption, the use of renewable energy, and the provision of carbon sinks to effectively offset the site's carbon balance. When these options are unavailable or insufficient, another avenue is purchasing carbon credits from a legally binding trading system that provides independent third-party verification. The Initiative views buying carbon credits as an alternative after exhausting conservation, carbon sequestration, and renewable energy options.

Nature's methods of reducing carbon dioxide concentrations in the atmosphere also have other benefits. In the Chicago area alone, urban trees sequester roughly 155,000 tons of carbon a year. And by providing energy savings in residential heating and cooling, the same trees help reduce carbon emissions from power plants by about 12,600 tons annually.<sup>32</sup> In the continental United States, carbon sequestration alone provided by urban trees is estimated to be about 25 million tons per year,<sup>33</sup> which is equivalent to the carbon emitted by almost 18 million cars annually.<sup>34</sup>

### THE BOTTOM LINE

Direct comparisons of the cost of using sustainable land practices instead of traditional land practices are just beginning to be made. The case study on page 36—of two gardens in Santa Monica, California—is one project that attempts to track costs for both a sustainable site and a control site that uses traditional practices. Although initial

installation costs of the sustainable native garden were higher than the traditional garden, the native garden requires 77 percent less water, produces 66 percent less green waste, and costs 68 percent less for maintenance than the traditional garden.

Encouragingly, in recent years a number of state and local governments as well as private-sector developers have begun to move toward increased use of low-impact development (LID) to protect and restore water quality. LID approaches and practices are designed to reduce runoff by means of infiltration, evapotranspiration, and reuse of rainwater. Among the practices that achieve this goal are bioswales, green streets, raingardens, and pervious pavers; such practices are usually linked together into a cohesive system.<sup>35</sup>

By managing water and water pollutants on or close to the site where they are generated, LID techniques prevent or reduce the impact of development on groundwater, lakes, rivers, streams, and coastal waters. Moreover, according to a study by the U.S. Environmental Protection Agency (EPA), “in the vast majority of cases,” implementing thoughtfully selected LID practices saves money—for developers, property owners, and communities alike.<sup>36</sup>

The EPA study summarized 17 case studies of projects that included LID practices. With a few exceptions, total capital cost savings for the projects in the study ranged from 15 to 80 percent when LID methods were used.<sup>37</sup>

Beyond cost reductions and savings, these communities also experienced a number of associated amenities and economic benefits, including aesthetic amenities, improved quality of life, improved habitat, and enhanced property values. Although the EPA study did not attempt to monetize these additional benefits or consider them in its calculations of each project’s costs, it found the additional economic benefits to be “real and significant.”<sup>38</sup>

### Low-Impact Development Strategies: Examples of Best Practices for Developers

*From a 2008 forum on sustainable development co-sponsored by the American Society of Landscape Architects and the Urban Land Institute*

1. Preserving forested or natural areas can save up to \$10 per square foot or \$435,000 per acre over conventional landscape solutions.
2. Balancing cut and fill on site can save up to \$100 per cubic yard in haul costs.
3. Using raingardens and bioretention areas can save up to \$4,800 per residential lot over conventional engineered solutions (Sherwood Gap Creek, 2000).
4. Creating narrow streets (24 feet wide) versus wide streets (32 feet wide) can save up to \$30 per linear foot in street costs.
5. The use of on-lot bioretention areas can save up to \$4,000 per residential lot over standard stormwater management pond costs (Somerset, MD, 2005).
6. On-lot bioretention can save up to 75 percent of stormwater fees per residential lot (Kensington Estates, WA, 2001).
7. Shade trees on the south side of buildings can save up to \$47 per tree per year in energy costs (Peper, 2007).
8. Green roofs can retain more than 75 percent of rainfall annually, reducing downstream stormwater management costs (ASLA Green Roof, 2007).
9. Recycling construction waste can save tens of thousands of dollars in haul costs, dump fees, and material costs (Stapleton, 2006).

## 2 The Economics of Sustainable Landscapes

Studies such as this one offer on-going evidence of the satisfying return on investment to developers, communities, and individuals from adopting sustainable practices of land development and management. With the publication of *The*

*Sustainable Sites Initiative: Guidelines and Performance Benchmarks 2009*, the Initiative looks forward to increasing participation in the movement toward building sustainable sites across the country.

**Table 1.1. Summary of Cost Comparisons between Conventional and LID Approaches**

Project	Conventional Development Cost	LID Cost	Cost Difference	Percent Difference
2nd Avenue SEA Street	\$868,803	\$651,548	\$217,255	25%
Auburn Hills	\$2,360,385	\$1,598,989	\$761,396	32%
Bellingham City Hall	\$27,600	\$5,600	\$22,000	80%
Bellingham Bloedel Donovan Park	\$52,800	\$12,800	\$40,000	76%
Gap Creek	\$4,620,600	\$3,942,100	\$678,500	15%
Garden Valley	\$324,400	\$260,700	\$63,700	20%
Kensington Estates	\$765,700	\$1,502,900	-\$737,200	-96%
Laurel Springs	\$1,654,021	\$1,149,552	\$504,469	30%
Mill Creek	\$12,510	\$9,099	\$3,411	27%
Prairie Glen	\$1,004,848	\$599,536	\$405,312	40%
Somerset	\$2,456,843	\$1,671,461	\$785,382	32%
Tellabs Corporate Campus	\$3,162,160	\$2,700,650	\$461,510	15%

**Table 2.1. Summary of Cost Comparisons Between Conventional and LID Approaches.** The case studies shown here are from “Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices,” a study published by the U.S. Environmental Protection Agency in 2007. *Conventional development* cost refers to costs incurred or estimated for a traditional stormwater management approach, whereas *LID* cost refers to costs incurred or estimated for using LID practices. *Cost difference* is the difference between the conventional development cost and the LID cost. *Percent difference* is the cost savings relative to the conventional development cost. Negative values denote increased cost for the LID design over conventional development costs. *Note: Mill Creek costs are reported on a per-lot basis.*

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# 3

## AN INTRODUCTION TO ECOSYSTEM SERVICES

In the late 1990s, the general public became aware of the concept that healthy ecosystems provide goods and services that benefit humans and other organisms. Work by noted scientists such as Paul Ehrlich, Gretchen Daily, Donald Kennedy, Pamela Matson, and Robert Costanza did much to support this new groundswell of environmental awareness.<sup>2</sup> A few years later, the United Nations commissioned a global study called the Millennium Ecosystem Assessment, which was carried out by an international consortium of governments, non-profit groups, universities, and businesses. The group's report, published in 2005, established that "ecosystems are critical to human well-being—to our health, our prosperity, our security, and to our social and cultural identity."<sup>3</sup> The link between environmental well-being, human well-being, and economic prosperity continues to gain traction in mainstream political conversation.<sup>4</sup>

*Human needs and a healthy environment are not opposing claims that must be balanced; instead, they are inexorably linked by chains of cause and effect. We need a healthy environment because we need clean water, clean air, wood, and food.*

JARED DIAMOND, SCIENTIST AND AUTHOR, 2003<sup>1</sup>



## Ecosystem Services

Ecosystem services are goods and services of direct or indirect benefit to humans that are produced by ecosystem processes involving the interaction of living elements, such as vegetation and soil organisms, and non-living elements, such as bedrock, water, and air.

Researchers have come up with a number of lists of these benefits, each with slightly different wording, some lists slightly longer than others. The members of the Sustainable Sites Initiative's committees and staff have reviewed and consolidated the research into the list below of ecosystem services that a sustainable site can strive to protect or regenerate through sustainable land development and management practices.

### **Global climate regulation**

Maintaining balance of atmospheric gases at historic levels, creating breathable air, and sequestering greenhouse gases

### **Local climate regulation**

Regulating local temperature, precipitation, and humidity through shading, evapotranspiration, and windbreaks

### **Air and water cleansing**

Removing and reducing pollutants in air and water

### **Water supply and regulation**

Storing and providing water within watersheds and aquifers

### **Erosion and sediment control**

Retaining soil within an ecosystem, preventing damage from erosion and siltation

### **Hazard mitigation**

Reducing vulnerability to damage from flooding, storm surge, wildfire, and drought

### **Pollination**

Providing pollinator species for reproduction of crops or other plants

### **Habitat functions**

Providing refuge and reproduction habitat to plants and animals, thereby contributing to conservation of biological and genetic diversity and evolutionary processes

### **Waste decomposition and treatment**

Breaking down waste and cycling nutrients

### **Human health and well-being benefits**

Enhancing physical, mental, and social well-being as a result of interaction with nature

### **Food and renewable non-food products**

Producing food, fuel, energy, medicine, or other products for human use

### **Cultural benefits**

Enhancing cultural, educational, aesthetic, and spiritual experiences as a result of interaction with nature

## SUSTAINING LIFE

Ecosystem services are the absolute foundation of daily life (see above). In a healthy natural ecosystem, soils, vegetation, and water function together in processes that provide all the goods and services on which humans depend. Usually well below the awareness of people busy with their own lives is the inextricable connection among all the elements of a healthy ecosystem.

Plants could not perform their functions of creating food or regulating our breathable air if they were not supported in their growth by healthy soils and clean water—and water would not be cleansed without the filtering provided by healthy plants and soils. No element in the natural world can function well without the healthy functioning of the others, as the examples below suggest.



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- Water provides habitat for tens of thousands of species. Freshwater habitats are home to at least 45,000 described species, including 12,500 fishes, almost 5,000 mollusks, 5,700 amphibian species, and numerous other reptiles, insects, plants, and mammals. Perhaps as many as one million species in freshwater habitats have not yet been recorded by scientists.<sup>5</sup> Marine and estuarine systems are also valuable to wildlife, providing food, cover, migratory corridors, breeding grounds and nursery areas for coastal and marine organisms. Similarly, healthy streams and lakes are valuable to humans, who use them for recreational activities such as fishing and swimming and as sources of drinking water.

Keeping these bodies of water healthy requires healthy vegetation and soils to filter pollutants, prevent erosion, and optimize sedimentation. It also requires human stewardship to prevent or reduce man-made contaminants and pollution entering the watershed.

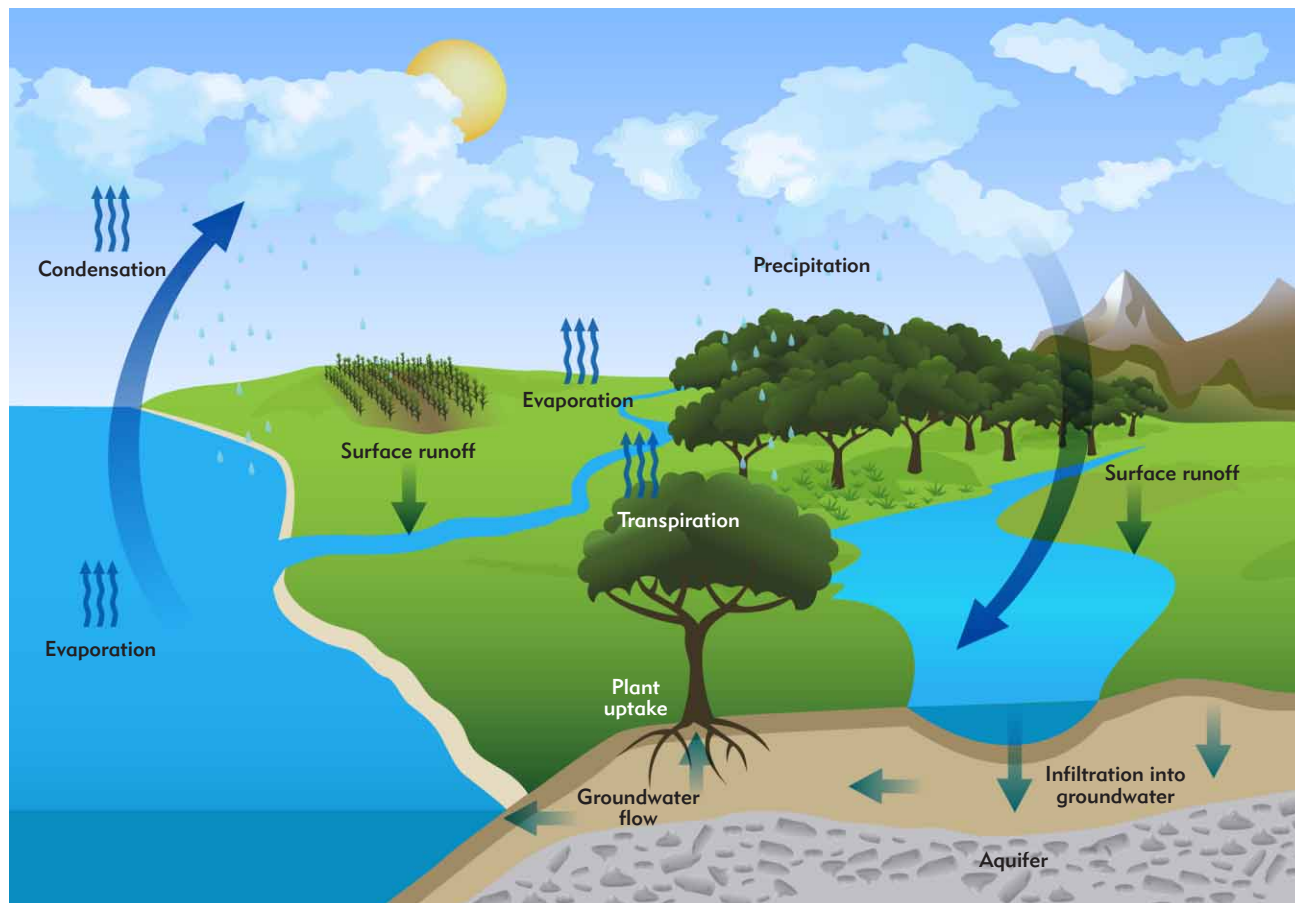
- Vegetation provides habitat for wild pollinator species, including insects, birds, and bats, which pollinate a wide range of plants. Eighty percent of the world's food plant species, including those produced by intensive agricultural systems, are dependent on pollination by animals.<sup>6,7</sup> Vegetation also provides refuge, breeding, and nursery habitat for resident and migratory species of fauna.<sup>8</sup>
- The biological habitats and gene reserves in soils are larger in quantity and quality than all aboveground biomass combined.<sup>9</sup> Soils are

habitat for such organisms as plants, worms, insects, arthropods, bacteria, fungi, protozoa, and nematodes. Indeed, the "soil food web" is responsible for decomposing organic matter, storing and cycling nutrients, maintaining soil structure and stability, and converting or attenuating pollutants.

- The diverse genetic resources in soil also are valuable in pharmaceutical development, agricultural research, and other new product development. For instance, the first antibiotic, penicillin, was originally derived from a soil fungus, and soil microorganisms provided the original source for, among other things, anticancer drugs, topical skin ointments, and tuberculosis treatments.<sup>10</sup>
- Plants also have contributed many chemical compounds that can be used directly or modeled to synthesize drugs and pharmaceuticals.<sup>11</sup> Substances derived from the Pacific yew tree, for example, are used to treat breast and ovarian cancers.<sup>12</sup> These resources are just a fraction of what may be available in the natural world. Scientists believe that the majority of plant-derived pharmaceutical resources remain undiscovered or unexplored.<sup>13</sup> In tropical forests, scientists believe that only 48 of an estimated 375 plant-based pharmaceuticals have been identified.<sup>14</sup> If natural systems and biodiversity are lost, the potential for future pharmaceutical discoveries will be lost with them.

## NATURAL CYCLES THAT PROTECT AND SUSTAIN

All of these essential functions and services, in turn, are the by-products of the workings of vast natural biogeochemical cycles, such as the hydrologic cycle, the carbon cycle, and the nitrogen cycle. Together and separately, water, carbon, and nitrogen move through the biosphere, atmosphere, and geosphere in a complex dance that preserves and sustains all life on the planet.



**FIG. 3-1. THE NATURAL HYDROLOGIC CYCLE.** Water exists on Earth as a solid, liquid, or gas and is in a frequent state of change. Surface water evaporates, cloud water precipitates, and rain infiltrates through the ground and into aquifers. Plants take up water and release water vapor during transpiration. Through all of these processes, the total amount of Earth's water remains constant as it is circulated and conserved in the hydrologic cycle. In the course of the cycle, rain collects pollutants from the atmosphere or from surface contamination. As rain falls on plants and infiltrates the ground, such pollutants can be removed by vegetation and soil biota, as well as by rock and sediment.

## THE HYDROLOGIC CYCLE

An enormous cycling of water through Earth's atmosphere, oceans, land, and biosphere shapes the world's weather and climate, supports plant growth, and makes life itself possible. On a well-vegetated site with healthy, open soils, rainwater is absorbed and transpired by vegetation, or it slowly trickles down and soaks into the soil. Undeveloped ecosystems absorb much of the precipitation that falls on them,<sup>15</sup> and only a small portion of rainfall is conveyed over the surface as runoff. In developed areas, by contrast, rainwater runs off into storm sewers and is lost to the

natural cycle (see Fig.2.3. Predicting Stormwater Runoff, page 16)

Plants slow the speed and intensity of runoff from precipitation, increase infiltration, and hold soil aggregates together. Vegetation stabilizes soil and slopes by making them resistant to erosion.<sup>16</sup> In turn, healthy, open soils allow rainwater to infiltrate, reducing not only runoff and erosion but also sedimentation and flooding. Soils also cleanse, cool, and store rainwater, recharge groundwater, and moderate the delivery of water to plants.

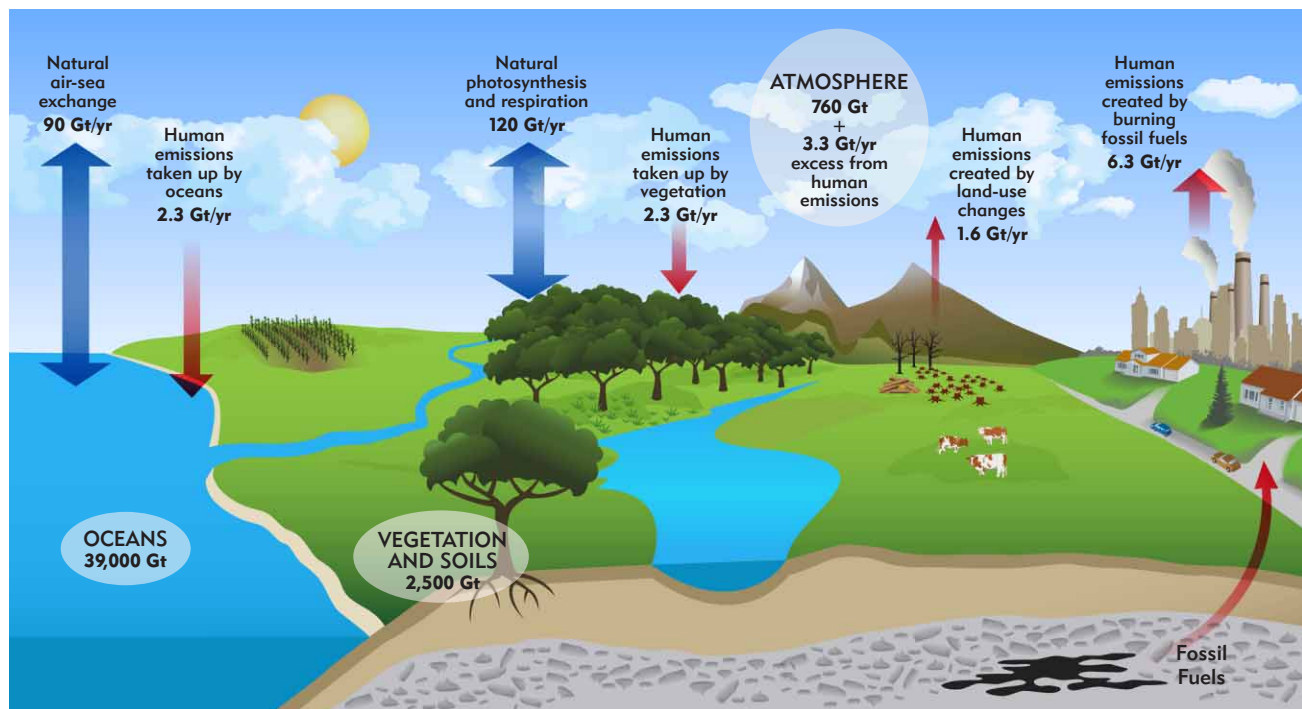
## THE CARBON CYCLE

All living things on Earth are built of carbon compounds, and carbon is an important component of many chemical processes. As carbon dioxide ( $\text{CO}_2$ ) in the atmosphere, it plays a large role in Earth's energy balance, acting like a blanket to trap radiation that would otherwise radiate away into space. An excess of emissions of carbon dioxide to the atmosphere and the inability of natural mechanisms to process it is contributing to global climate change.<sup>17</sup>

The geological component of the global carbon cycle operates on a time scale of millions of years. Over eons, carbon circulates through the atmosphere, land, and ocean, spending

significant portions of that time forming limestone (largely calcium carbonate) in ocean sediments. As tectonic forces draw the ocean floor deeper into the Earth, seafloor carbon is heated, melts, and eventually rises to the surface where it is released back to the atmosphere as carbon dioxide through vents, seeps, hot springs—or violent volcanic eruptions.<sup>18</sup>

The biological component of the carbon cycle operates on a scale ranging from days to thousands of years. Through photosynthesis and respiration, plants and animals play a key role in the circulation of carbon over this time frame. During photosynthesis, plants take in carbon dioxide from the atmosphere, along with water and light, to produce the carbohydrates needed



**FIG. 3-2. THE CARBON CYCLE.** Two-way blue arrows (above) indicate annual natural fluctuations as carbon moves from one carbon reservoir to another (ocean, atmosphere, vegetation, and soils); one-way red arrows represent fluxes due to human activity. All numbers are in gigatonnes (Gt,  $10^9$  tonnes). For millennia, atmospheric concentrations of  $\text{CO}_2$  were relatively stable. Since the late 18th century, carbon emissions from the burning of fossil fuels and land-use changes (e.g., deforestation, development, and agriculture) have increasingly outstripped the processing ability of natural mechanisms. An excess of about 3.3 Gt is added to the atmosphere each year—where it remains for as long as a century or more, thus contributing to global climate change. Humans can positively affect the carbon cycle by reducing the use of fossil fuels in industry, automobiles, and development, and by increasing carbon sequestration capacity through restoration of vegetation and soil. *Illustration adapted from U.S. EPA, "Carbon Sequestration in Agriculture and Forestry,"* <http://www.epa.gov/sequestration/cycle.html>.



for plant growth. In the process, plants also produce and release oxygen, thus helping to regulate the balance of oxygen and carbon dioxide required to maintain a livable atmosphere. Carbon taken up by plants eventually makes its way higher up the food chain. When plants and animals die, their carbon is returned to the atmosphere as they decompose. Dead organisms are sometimes trapped in places where decomposition cannot occur; eventually, that trapped carbon becomes fossil fuels such as petroleum or coal.

Meanwhile, the pool of organic carbon in the soil is approximately twice as large as that of the atmosphere;<sup>19</sup> soils can contain as much as or more carbon than living vegetation. For example, 97 percent of the 335 billion tons of carbon stored in grassland ecosystems is held in the soil.<sup>20</sup>

Since the beginning of the industrial revolution, the amount of carbon dioxide in the atmosphere has been steadily increasing, owing largely to the burning of fossil fuels and also to changes in land use. The warming effects of increased atmospheric CO<sub>2</sub> and other greenhouse gases have an impact on a host of environmental variables, including rising sea levels, extreme weather events, agriculture, habitat loss, and forest health. Furthermore, because carbon dioxide dissolves readily in water, increasing atmospheric CO<sub>2</sub> also increases the acidity of the oceans—with corrosive effects on the shells and skeletal material of many marine organisms. Because the natural mechanisms of erosion and sedimentation to process atmospheric CO<sub>2</sub> operate very slowly, the additional burden of carbon dioxide in the atmosphere will remain for thousands of years unless steps are taken.<sup>21</sup>

## THE NITROGEN CYCLE

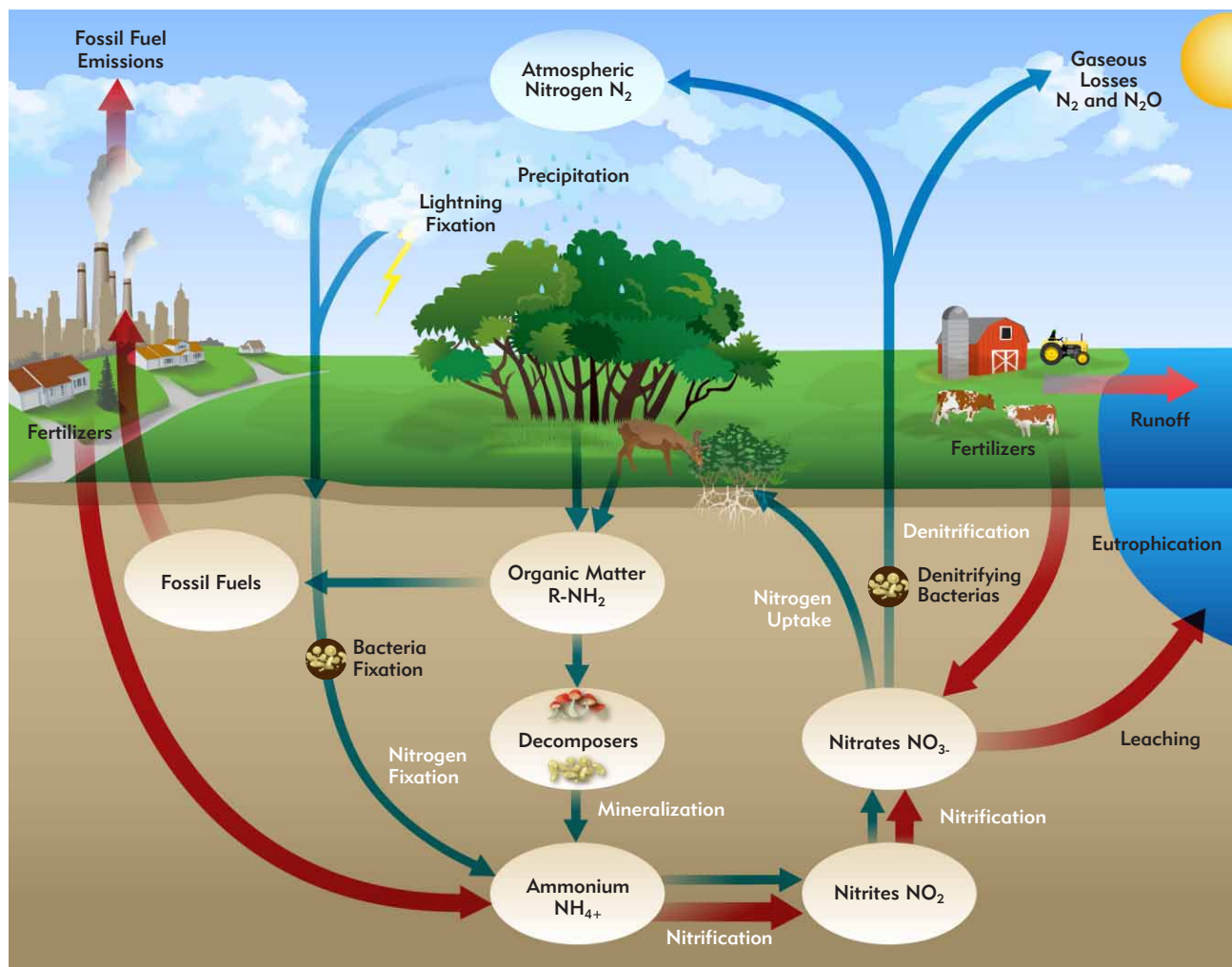
Nitrogen makes up 78 percent of Earth's atmosphere and is an essential component of



proteins, amino acids, chlorophyll, and other important organic molecules. It ranks fourth behind oxygen, carbon, and hydrogen as the most common chemical element in living tissue.<sup>22</sup>

The nitrogen cycle is thus one of the most important nutrient cycles in terrestrial ecosystems.<sup>23</sup> However, organisms cannot use the gaseous form of nitrogen (N<sub>2</sub>) directly from the air as they can carbon and oxygen. Because it is inert, gaseous nitrogen must first be “fixed”—that is, converted to a more chemically reactive form such as ammonium, nitrate, or organic nitrogen,<sup>24</sup> which plants can take up as a nutrient.<sup>25</sup> Fixation, which requires substantial amounts of energy, can occur through an industrial process, as in the production of commercial fertilizers or the burning of fossil fuel, or through a biological process, as occurs with legumes such as alfalfa and clover. Fixation can also occur in the atmosphere, during lightning storms.<sup>26</sup>

As with carbon, the nitrogen taken up by plants eventually makes its way into organisms higher up the food chain. When plants and animals die, decomposers (bacteria and fungi) consume the organic matter, converting some of the nitrogen back into ammonium, where it becomes available for plant use again or is converted to nitrate through the process of nitrification. Anaerobic bacteria convert nitrate into the gaseous form of nitrogen (N<sub>2</sub>), which escapes back into the atmosphere through the process of denitrification. Two by-products of that process are nitric oxide (NO), which contributes to smog, and nitrous



**Fig. 3-3. THE NITROGEN CYCLE.** In order to be used by living organisms, nitrogen must be “fixed”—converted to more chemically reactive forms such as ammonium and nitrate. In the illustration above, blue arrows indicate natural elements of the nitrogen cycle; red arrows indicate nitrogen entering the cycle through human activities. Along with fossil fuel combustion, the widespread use of nitrogen-based fertilizer in recent decades has introduced massive amounts of reactive nitrogen into the environment, causing it to accumulate in soil, water, the atmosphere and coastal waters. This excess reactive nitrogen contributes to the greenhouse effect, smog, acid rain, coastal “dead zones,” and stratospheric ozone depletion.<sup>31</sup>

oxide ( $N_2O$ ), a greenhouse gas that absorbs 310 times more heat per molecule than carbon dioxide.<sup>27</sup>

Human activities have greatly increased the amount of “fixed,” or reactive, nitrogen entering the nitrogen cycle—doubling it over the course of the past century. Some of those activities include:<sup>28</sup>

- Industrial processes that produce nitrogen fertilizers<sup>29</sup>
- Application of nitrogen fertilizers to crops
- Fossil fuel combustion and forest burning

- Cultivation of soybeans, peas, and other crops that host symbiotic nitrogen-fixing bacteria<sup>30</sup>
- Feed lots, which causes large amounts of ammonia to enter the soil system and then the hydrologic system through leaching, groundwater flow, and runoff.

The increase in fixed nitrogen to the global nitrogen cycle has serious consequences for the environment, including increased atmospheric concentrations of the greenhouse gas nitrous



oxide and of the nitrogen precursors of smog and acid rain. It also results in the acidification of soils and the loss of soil nutrients in many regions, as well as the acidification of streams and lakes in those regions.

Reactive nitrogen transported to estuaries and coastal waters results in eutrophication, one of the most serious human threats to the integrity of coastal ecosystems. In eutrophication, the increase in nutrient can cause algal blooms that consume oxygen, killing fish and shellfish and leading to significant declines in fisheries.<sup>32</sup> In these “dead zones,” the normal functioning of coastal ecosystems is disrupted, leading to loss of biodiversity.

Excessive nitrogen in inland freshwater lakes is also a serious health issue, especially in summer, when warmer waters are conducive to the growth of blue-green algae, or cyanobacteria, which thrive in waters rich in phosphorous and nitrogen. Some cyanobacteria produce toxins that can cause diarrhea, vomiting, nausea, skin rashes, and lesions, in both humans and pets. In 2005, officials in Illinois, Indiana, Iowa, Kansas,



Michigan, and Nebraska reported excessive growth of toxin-producing cyanobacteria. Nebraska issued health alerts on five lakes and cautioned people to avoid “full body contact” with lakes that were posted.<sup>33</sup>

According to environmental scientist James Galloway, nitrogen is in many ways “as big an issue as carbon.” Because the interactions of nitrogen and carbon, Galloway says, “providing food and energy to the world’s peoples without harming the global environment [is] a tremendous challenge.”<sup>34</sup> As is the case with carbon, humans can take steps to reduce excessive nitrogen by reducing the use of fossil fuels in industry, automobiles, and development and by reducing the use of nitrogenous fertilizers.<sup>35</sup>

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High Point, Seattle, Washington



# 4 CASE STUDIES: SUSTAINABLE PRACTICES IN ACTION

Often the best way to communicate an idea is to see it in practice. With this in mind, the Sustainable Sites Initiative has created a library of case studies that illustrate sustainable landscape practices at various stages of development. The projects were selected during the spring of 2008 when the Initiative announced its Call for Case Studies. The purpose was to document instances of sustainable land development and management practices to inspire and educate the public.

More than 130 projects submitted applications that monitored and documented the success or failure of sustainable land practices. A project was not required to be a sustainable site in all respects but rather to illustrate individual sustainable practices such as stormwater management, integrative design teams, habitat restoration, education, design for user health and well-being, and materials selection and management.

By showcasing projects representing different geographic regions, sizes, types, and stages of development, the Initiative hopes to demonstrate the feasibility of creating sustainable sites virtually anywhere. Whether on many acres of a former brownfield or in one family's front yard, a sustainable site has the capacity to regenerate many of the natural benefits and services provided by ecosystems in their undeveloped state and to conserve energy and resources for the larger community.

The projects on the following pages are a small sample. More can be found on the Initiative's website (<http://www.sustainablesites.org/cases/>).

# GARDEN\GARDEN

## A Comparison in Santa Monica

In 2003, the City of Santa Monica, CA, initiated a project called garden\garden, designed to encourage city residents and the local landscaping community to adopt sustainable garden practices. The city wished to promote practices that would, among other things, conserve water and energy, reduce waste and also decrease urban runoff, the single largest source of pollution in Santa Monica Bay. Although the city had been providing seminars and tours of local sustainable landscapes, as well as a large demonstration garden at City Hall, most residents were not moved to alter their gardening practices. Similarly, members of the landscaping community were still inclined to continue recommending and installing the traditional kinds of non-native plants with which they were most familiar.

The City of Santa Monica's challenge was to persuade both homeowners and landscape professionals that sustainable gardening was not only better for the environment than traditional gardening, but also was attractive and made good economic sense. To prove their case, the city created garden\garden—two gardens in adjacent residential front yards, one landscaped in the traditional manner and the other with a climate-appropriate, sustainable design, allowing residents to make a direct comparison. Using garden\garden as a model, the city has since awarded 51 Sustainable Landscape Grants for properties including single-family homes, multi-family buildings, and two schools. Sustainable landscape principles have been taught to more than a hundred residents and more than 120 landscape professionals since 2004. Garden\garden has served as a learning laboratory and working example for all of the workshop attendees, garden tour visitors, and for the general public who walk past the garden daily.



In the native garden (above), California native cultivars replicate the drought-tolerant chaparral of the Santa Monica Mountains and use 77 percent less water than required by conventional turf and exotic plants from the Eastern United States and Europe in the traditional garden (right).



### SIZE/TYPE OF PROJECT

Approximately 1,900 square feet in each garden

### SITE CONTEXT

Southern California's climate is coastal Mediterranean and is dominated by the Pacific Ocean. Average daily temperatures are mild and morning fog is common, with daily afternoon winds. The air tends to be salt laden and the average annual rainfall ranges from 11 to 20 inches. The soils are commonly alkaline and sandy in texture. The side-by-side bungalows are in an urban residential neighborhood. Each garden is approximately 1,900 square feet in area.

### ISSUES/CONSTRAINTS OF THE SITE

In both gardens the soil type was sandy loam (moderate permeability), poor in organic matter, and highly compacted from decades of turf. Tests also indicated high alkalinity and high levels of heavy metals, including zinc and copper. The existing landscape on both sites was completely removed to create an identical environmental base condition for study, with all waste exported for recycling. Soil amendments were applied as appropriate for the respective plant material. The intent was to bring the soil to a basic level of balance, facilitate a long-term development of healthy soil life, and to increase plant health. Both gardens also are exposed to unusually high vehicular traffic and resulting air pollution.

### SUSTAINABLE PRACTICES IN THE NATIVE GARDEN

- No chemical herbicides or insecticides (per Santa Monica City policy)
- Climate-appropriate California native cultivars, designed to replicate the chaparral of the Santa Monica Mountains
- Low-volume drip irrigation with a weather-sensitive controller
- System for capturing stormwater runoff for groundwater recharge
- Wildlife habitat for local and migratory fauna

### PRACTICES IN THE TRADITIONAL GARDEN

- No chemical herbicides or insecticides; occasional use of blood meal
- Exotic plants from northern Europe and the eastern United States
- Standard, user-controlled sprinkler irrigation system
- No provision for runoff mitigation

### CONSTRUCTION COSTS

Traditional garden      \$12,400

Native garden      \$16,700

The higher cost of the native garden included demolition and replacement of an existing access ramp, installation of permeable paving, and installation of a rainwater recovery system—rain gutters that tie into an underground infiltration pit. These figures do not take into account the costs and benefits to the larger community. Benefits may include, for example, water conservation, waste reduction, and improvements in human and environmental health.

### MONITORING

Construction was completed in March 2004. From 2004 to 2008, the city tracked costs, labor hours, plant growth, water consumption, green waste production, and other environmental factors for both gardens. The ever increasing costs of water, maintenance man hours, and the transporting costs of green waste disposal required to support a traditional landscape will determine the long-term dollar amount offset of costs for installation.

- **Water Use (gallons):** Each garden is separately metered. Water consumption was recorded at two-month intervals until November 2004, after which it was recorded monthly.
  - TG = 283,981 gallons/year
  - NG = 64,396 gallons/year
  - Difference = 219,585 gallons/year or 77% less water use for NG
- **Green Waste (pounds):**
  - TG = 647.5 pounds/year
  - NG = 219.0 pounds/year
  - Difference = 428.5 pounds/year or 66% less waste produced from NG
- **Maintenance Labor (U.S. dollars):**
  - TG = \$223.22/year
  - NG = \$ 70.44/year
  - Difference = \$152.78/yr or 68% fewer dollars spent on maintenance labor for NG

### LESSONS LEARNED

Collected site data have validated theories that a south California native landscape would yield significant reductions in resource consumption and waste production as compared to a traditional south California-style landscape.



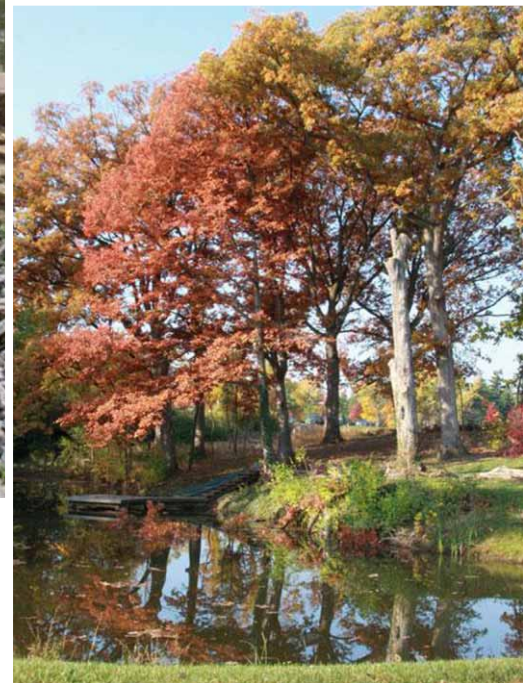
# JOHN BURROUGHS SCHOOL BIORETENTION SYSTEM

## A Commitment to Water Quality

John Burroughs School (JBS), a private college preparatory day school in Ladue, Missouri, is currently implementing a facilities master plan. As a result of the construction of a parking lot, theater, and a field hockey field, additional detention was required by the local agency. At the time of construction, water quality standards were not required and an existing small pond (0.38 acre) was to be used for the additional retention. As a direct result of an educational seminar on water quality, the school made a commitment to protect the pond and contribute to downstream flood protection. A three-cell bioretention system was designed and installed. The bioretention project successfully protected the pond, improved flood protection, and met new water quality requirements. As part of the science curriculum, students are participating in all aspects of the bioretention system—from selecting the appropriate plants to ongoing monitoring and maintenance. The integration of the facilities into the science curriculum provides hands-on learning opportunities for the students and the community.



Stormwater from the school driveway and parking lot passes through the three cells of the bioretention system (above) en route to the receiving pond (right).



### SIZE/TYPE OF PROJECT

10,156 square feet/school/greyfield and greenfield development

### SITE CONTEXT

The City of Ladue is a residential community located minutes from St. Louis, in the Interior River Valleys and Hills ecoregion, just north of the Ozark Highlands. The biome of the area is primarily midlatitude deciduous forest with rolling hills topography. The average annual precipitation of the St. Louis region is 39 inches per year and the average high temperature is 77.5° F while the average low temperature is 33.6° F.

### ISSUES/CONSTRAINTS OF THE SITE

- An established construction budget and schedule were substantial obstacles to this water-quality initiative, which arose late in the schedule. The project was accomplished thanks to the conviction of the client, who showed that it is never too late to do the right thing.
- Space constraints are not unique to many projects. However, a client with a landlocked campus needs to make careful choices about the allocation of land. John Burroughs School chose to allocate this land to a sustainable strategy instead of parking.

### FEATURED SUSTAINABLE PRACTICES

**Manage and cleanse stormwater:** The bioretention system is primarily a plant- and soil-based filtration facility for parking lot stormwater runoff. Stormwater runoff flows downhill from the driveway and south parking lot into the highest cell of the three cells, from which it slowly progresses into two lower cells until finally ending up in the pond. Before reaching the first cell, much of the water passes first through an underground vortex filter that spins under the power of the falling water. Debris and impurities removed from the water collect at the bottom of the filter and are pumped out once a year for disposal. Each cell of the bioretention basin has its own underground water holding chamber as well as aboveground plants and soil. Stands of native grasses and wildflowers in each cell help prevent evapotranspiration by shading the water, enhance soil composition, encourage biological activity, and promote the removal of pollutants before stormwater enters the pond.

### Promote sustainable awareness and education:

For this student-driven project, students researched and selected the appropriate native plants for each environment, including the bottom and sides of the retention basins and the adjacent slopes of the basin. Students were responsible for the labor involved in the planting, initial weeding, and future maintenance of the bioretention plantings. In addition, students documented the process by mapping the areas and collecting and analyzing data to assess the performance of the bioretention system.

### CONSTRUCTION COSTS

- \$267,479 for the bioretention system
- \$5 million for the total cost of Phase 1A of the project

### MONITORING

Students in the science department regularly monitor the bioretention system and pond. Because water chemistry testing and soil chemistry testing were already a part of the science curriculum, the school had the necessary equipment.

- Students are monitoring dissolved oxygen, water temperature, phosphorus and nitrate levels, pH, and turbidity. These factors were chosen in order to monitor the succession (aging) of the pond. Each test will also allow the students to analyze the overall pond health. Nitrogen and phosphorus levels are deemed to be the most important indicators for pollution and eutrophication.
- The soil is also being tested for nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur and soil pH. The students are mainly concerned with the top soil and its living and non-living role in supporting the plants in the bioretention system. Nitrogen, phosphorus, and potassium are considered most significant to promote healthy plant growth.

### LESSONS LEARNED

- Sustainable practices that are integral to a curriculum are the best outdoor classrooms.
- It is never too late to consider a sustainable strategy in a project or to retrofit a site for a sustainable strategy.



# CLINTON BEACH PARK

## A Sustainable Park for a Waterfront Community

Responding to community calls for public access to Puget Sound, the Port District of South Whidbey Island transformed a greyfield site next to the Clinton ferry terminal into a new beach park that promotes ecological awareness, resource efficiency, and stormwater management. The park accommodates the needs of diverse visitors with improved accessibility to the Port's Fishing Pier and small boat dock.



Much of the project included salvaged wood milled from tree stumps left over from old logging sites as well as cast-in-place concrete containing fly ash. The team removed all existing invasive plants and re-vegetated the area with drought-tolerant native and adapted species.

### SIZE/TYPE OF PROJECT

0.68 acre/greyfield redevelopment

### SITE CONTEXT

The site is adjacent to a busy commercial ferry terminal on Whidbey Island, Washington, 30 miles north of Seattle, at the northern boundary of Puget Sound. The island is partially in the rain shadow of the Olympic Mountains and has a variety of climate zones. The climate of the greater Seattle area is classified as marine west coast, with dry summers and cool wet weather during the rest of the year. A restaurant and parking lot were on the site when it was acquired.

### ISSUES/CONSTRAINTS OF THE SITE

No construction activities were permitted on the protected beach adjacent to the project.

### FEATURED SUSTAINABLE PRACTICES

**Materials reuse:** Existing footings and substructure were reused. Salvaged or recycled materials were used throughout the project, including salvaged wood from old logging sites, recycled plastic lumber, and concrete containing fly ash. Wood from deconstruction of the prior structure was sold to a local materials outlet to reduce landfill waste.

**Stormwater management:** By implementing several sustainable water management strategies, the team was able to avoid catch basins and detention ponds.

- All existing impervious surfaces were removed.
- The parking area consists of 3,100 square feet of porous pavers.
- The picnic shelter has an extensive green roof.
- A bioswale collects and filters excess stormwater.

**Native and adapted vegetation:** All existing invasive plants were removed and the park was re-vegetated with drought-tolerant native and adapted species. Turf areas were seeded with a special low-water mix that requires no irrigation or mowing once established and stays green throughout the year.

### CONSTRUCTION COSTS

The project's total cost was \$520,000.

### MONITORING

- Precipitation is infiltrating through the pavers; no evidence of flooding has been observed. This is consistent with the infiltration rate, which exceeds the average two-year storm event of 1.65 inches in 24 hours.
- Monitoring of the green roof determined that periodic watering is required during the summer months, but not at other times. Weeding has been required in late spring and midsummer. It is assumed that both watering and weeding can be phased out when the green roof is fully established.

### LESSONS LEARNED

- The sustainable strategies used in the project did not increase costs.
- Involving volunteers in design review and planting operations both reduced costs and engaged the community.
- Planned sustainable strategies need to be carefully reviewed with contractors in the planning phase to ensure that they can be achieved. Although the design team had identified a reuse for the existing building, which was to be relocated, the contractor was unable to find a means of moving the building across adjacent mudflats. The building was demolished, but heavy timbers and beams were salvaged and sold to a local outlet.



Made from recycled plastic lumber, the deck also used most of the existing footings and substructure from the restaurant building that originally occupied the site.



# KRESGE FOUNDATION HEADQUARTERS

## Historic Preservation and a Sustainable Future

The Kresge Foundation headquarters exemplifies environmental conservation—one of the foundation’s core values—along with sustainable building practices, environmental stewardship, and sound land-use planning, even as it inspires grantees to incorporate sustainable building systems and healthy habitats into their own facilities. For the new headquarters (certified LEED® Platinum), a compact building and parking footprint was designed to reduce negative environmental impacts. A historic farmhouse remains the cornerstone for the new building; other historic outbuildings were rearranged to maximize the site efficiency.

The combination of new construction, historic preservation, and landscape restoration provided an unusual mix of challenges resulting in a sustainable redevelopment prototype. The long-term potential for the Foundation headquarters goes beyond the restoration of ecological health on site. It demonstrates the Foundation’s mission to help create a sustainable future and will inspire other adaptive retrofit projects to be more sustainable.



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Existing structures (red buildings, left) at the Kresge Foundation headquarters were reused to preserve cultural heritage and reduce waste. By maintaining open communication with city officials, the project team was able to maintain natural landscaping (above) as well as to promote awareness of sustainable landscaping practices.



### SIZE/TYPE OF PROJECT

2.74-acre corporate campus redevelopment/greyfield

### SITE CONTEXT

Troy, Michigan, lies within the Detroit metropolitan area and the Clinton River watershed, in the southern Lower Peninsula. In summer the average temperature is in the 70s Fahrenheit; the average temperature in winter is in the 20s Fahrenheit. Average daily temperature ranges from 25° F to 75° F. The Kresge Foundation facility incorporates a historic farmstead that is surrounded by a mixed-use suburban landscape.

### ISSUES/CONSTRAINTS OF THE SITE

- Due to conflicts with seasonal timing, a specified “topsoil weed seed treatment” was not fully implemented, resulting in high levels of weeds in the native zones that required an intense period of weeding and spot herbicide treatment.
- Although limiting compaction during development was of utmost importance, virtually the entire project was affected due to the site’s compact size and the existing structures that remained.
- The client needed to move offsite during construction, and then moved back before the site improvements and landscape were complete.

### FEATURED SUSTAINABLE PRACTICES

**Site selection:** The Foundation explored alternative properties in the Detroit area, but ultimately chose to stay put for several reasons: (1) the Foundation treasured the historic farmhouse and wanted to remain caretaker of this cultural resource; (2) the site could accommodate the proposed expansion; (3) the site was well-located for the current staff.

**Minimize impacts during construction:** Care was taken throughout the construction process to avoid site compaction and to protect existing trees. The contractor and the landscape architect worked together during the submittal process to meet rigorous topsoil and amended bioswale soil requirements, and seed certification to prove native origins. Preservation of several trees required prudent location of the building site, tree protection during construction, and on-going tree care such as root pruning.

**Historic structure reuse:** Existing buildings were reused to preserve cultural heritage and reduce waste. The historic farmhouse was restored and incorporated as a cornerstone of the new headquarters building. Other historic outbuildings onsite were refurbished, relocated, and merged into the new campus design.

**Habitat restoration:** Approximately 64 percent of the total site area was restored to green space planted with ecologically appropriate vegetation, including more than 100 different adapted and native species.

**Human health and well-being:** The project’s primary objective was to create an environmentally sustainable workplace that promotes the well-being and productivity of staff and visitors. All views are designed to provide a strong connection to the living landscape immediately outside the building walls.

### CONSTRUCTION COSTS

Total site costs \$1,116,000

### MONITORING

Outdoor water use is estimated at 155,000 gallons/year. This assumes approximately 22,121 gallons/month during the growing season from March through September for irrigation for green roof plantings and makeup water for the constructed wetland pond. All of this is from harvested rainwater.

### LESSONS LEARNED

- Working with local agencies and governmental bodies throughout the design process is essential for success. The City of Troy was an invaluable partner, bringing innovation to the project and approving its design, because it was interested in having Best Management Practices and Low Impact Development tools implemented within the city. For example, although the City building code required grass to be kept no higher than 3 inches, the project team was able to maintain the plan for natural landscaping and promote awareness of green practices within their local government, thanks to open communication between project architects and city officials.
- Contractors and subcontractors with green experience still need regular communication and oversight to ensure that appropriate sustainable alternatives replaced standard practices.

# QUEENS BOTANICAL GARDEN

## Treating Rainwater as a Resource

The Queens Botanical Garden in New York City wanted its Visitor and Administration Center to be a highly visible model of sustainable solutions that are effective, practical, and attractive. The completed project harvests graywater and rainfall to virtually eliminate stormwater outflow and to minimize the demand for potable water throughout the facility.



© Jeff Goldberg/Esto

### SIZE/TYPE OF PROJECT

Approximately 4 acres of a 35-acre public botanical garden

### SITE CONTEXT

Queens Botanical Garden is located in downtown Flushing in Queens, the second most densely populated borough in New York City. Saltwater marshes, freshwater wetlands, prairie, and upland pine woodlands once thrived within a very short

The primary theme of the site design is the visible expression of water. A meandering water feature and fountain are kept full with cleansed rainwater that has been harvested from the site; no potable water is used, and any surplus rainwater or stormwater is absorbed in raingardens and bioswales.

distance of the site. Temperatures are generally mild, and average rainfall of about 46 inches is well distributed throughout the year. Contaminated portions of the site were remediated, qualifying the area as a brownfield site.

### ISSUES/CONSTRAINTS OF THE SITE

- Public access and facility operations had to be maintained throughout the entire period of construction.
- Because of the site's importance to the neighborhood, close communications with the community—in multiple languages—were required to promote neighborhood participation.

### FEATURED SUSTAINABLE PRACTICES

#### Rainwater (stormwater) treatment and reuse:

- Half of the roof is covered by a lightweight green roof.
- All other roof surfaces feed the site's rainwater harvest system.
- Harvested rainwater is cooled and cleansed with vegetation and a gravel substrate that is part of the landscape.
- Processed rainwater is stored in a cistern as the water source for the many ornamental water features.
- Overflow water is directed to a large raingarden.

**Graywater reuse:** Water from sinks, dishwashers, and showers is processed through a constructed wetland, where bacterial activity by selected plants treats the water naturally. It is then used for toilet flushing.

**Native and adapted vegetation:** Species native to New York or closely related cultivars make up the majority of plants; mature trees were preserved and integrated into the design.

**Soil restoration:** Nothing remains of the site's original soil structure; it is now comprised entirely of fill material (construction debris, fly ash, and other materials brought to the site over a period of about 80 years) covered with about 6 feet of imported soil. Specific soil mixes were prepared for all planted areas, and porous substrates were installed to support the efficiency of the raingarden and rain-filtering elements.

**Social and educational benefits:** The water creates a path that draws visitors through the building and landscape to the various garden spaces. Water conservation and reuse strategies are fully explained on multilingual touch screens in the building's lobby.

### CONSTRUCTION COSTS

Because the project was managed by the City of New York and was implemented by multiple contractors working on a variety of projects, cost details are not readily available for the project.

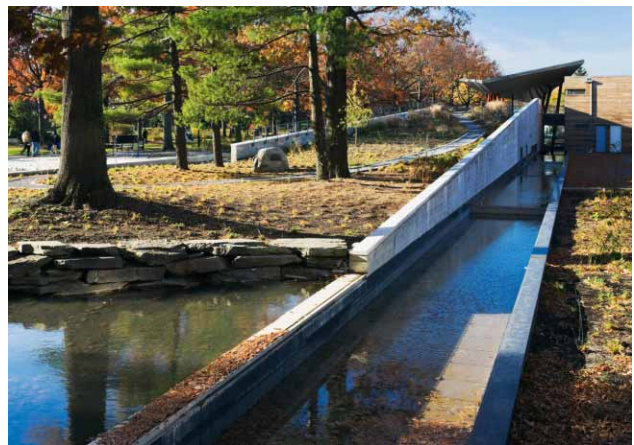
### MONITORING

Equipment has been installed on the green roof to monitor soil moisture, ambient air temperature, plant surface temperature, and growing medium temperature.

- A piezometer on the downstream edge of the roof captures water before it leaves the green roof.
- Other equipment will help to quantify the practical energy, longevity, climatic, and ecological attributes of the green roof, which can then be translated to other applications in New York.

### LESSONS LEARNED

- The procurement and management process required multiple and independent contracts issued to each trade specialty. Substantial project team effort was required to outline the responsibility of each trade and to ensure cooperation among the different disciplines involved.
- Because many techniques were new to the area, some costs escalated; the permit process required long lead times and regular dialogue with authorities.



A water channel, fed by rainwater that cascades off the roof canopy, weaves around the building and through the gardens. The process mimics the natural hydrology of the site, which originally contained low-lying streambeds that were tributaries of the Flushing River.

© Jeff Goldberg/Esto



# FLORIDA AQUARIUM PARKING LOT AND QUEUING GARDEN

## A Demonstration in Sustainable Stormwater Mangement

The Florida Aquarium in midtown Tampa partnered with the Southwest Florida Water Management District to build a stormwater research and demonstration area to evaluate the effectiveness of alternative low-impact parking lot design. The goal was to reduce runoff and improve the quality of water flowing into Tampa Bay, an Estuary of National Significance included in the National Estuary Program. This partnership was significant, given that all parties were aware from the outset that approximately one-third of the parking lot area would be eventually removed and redeveloped for a cruise ship terminal.

The fundamental goal of the project was to extend the environmental education objectives of the Aquarium to the parking lot and the Aquarium's shaded Queuing Garden near the entrance. The Aquarium uses its entire site to tell Florida's unique water story by following a drop of water from its underground source to the open sea.



Experiments with vegetated swales and pervious pavement in the parking lot (left) significantly reduced runoff and protected water quality. Runoff from the queuing garden was directed to a small pond (above).

### SIZE/TYPE OF PROJECT

11.25 acres/urban greyfield redevelopment

### SITE CONTEXT

Tampa sits in the Southwestern Coastal Plain (Southwestern Florida Flatwoods) ecoregion. In this humid subtropical climate, Tampa receives an annual precipitation of 46.3 inches, occurring primarily during the summer rainy season. The average high temperature is 82° F and the average low temperature is 65° F.

### ISSUES/CONSTRAINTS OF THE SITE

- The site contained two pre-existing ponds that met state stormwater regulations. Criteria to meet regulations do not account for the source of the runoff, which in this case, traveled from surrounding roadways and the Aquarium building rooftop, causing extremely high pollutant loadings. The project team had to retrofit these ponds in order to manage runoff and cleanse water properly.
- The site consisted of urban soils of poor quality. The lack of organics and the high pH of the soil

dictated the use of species native to coastal areas and those with a successful history of dealing with difficult sites. Soil conditions have improved with the growth of roots and the trapping of detritus in landscape areas.

### FEATURED SUSTAINABLE PRACTICES

**Stormwater treatment:** The 11.25-acre parking lot was the study site for the low-impact stormwater treatment system. The research was designed to determine pollutant load reductions measured from three elements in the treatment train: different treatment types in the parking lot, a planted strand with native wetland trees, and a small pond used for final treatment. In the study site, stormwater runoff was directed from the Aquarium roof and parking lot into a chain of bioswales, into smaller basins that converge into larger ones (i.e., strands), and finally, through a linear progression of vegetated filtering zones. The strands fed the parking lot pond before the pond discharged to the Ybor Channel. Runoff from the pedestrian areas is also redirected to help support vegetated areas

**Pervious pavement:** The experimental design in the parking lot allowed for the testing of three paving surfaces as well as vegetated swales (i.e. bioswales) to paved swales or pipes. Three types of paving were compared: asphalt, concrete, and pervious paving. The study was conducted to test the effectiveness of permeable pavers for reducing total suspended solids (TSS), nutrient, metal, and thermal loads.

**Site interpretation:** Aquarium visitors receive information about the project and the connection between rain, urban development, and water quality through brochures, signage, and at the research station.

### CONSTRUCTION COSTS

Base sustainable construction costs were \$1,091,000; with enhancements and research/education components, they totaled \$2,124,500.

### MONITORING

Southwest Florida Water Management District (SFWMD) measured rainfall and flow from eight of the subcatchments (i.e., test swales) in the parking area

and collected water-quality samples in a flow-weighted basis. Researchers collected samples from 59 storm events over a two-year period. The experimental design in the parking lot allowed for the testing of three surfaces as well as basins with vegetated swales and paved swales, creating four treatment types with two replicates of each type. The basins without swales still had depressions similar to the rest of the parking lot, but the depressions were covered over with asphalt. All basins had some landscaped garden areas providing opportunities for runoff to infiltrate. The data allowed comparisons among treatment techniques as well as among paving surfaces. The four treatment types included: (1) asphalt paving with no swale (typical of most parking lots), (2) asphalt paving with a swale, (3) concrete (cement) paving with a swale, and (4) porous (permeable) paving with a swale.

The extensive monitoring has demonstrated that the sustainable practices significantly reduced runoff volume and protected water quality. When the volume of water discharged from all the different elements to the treatment train (the swales, the strand, and the pond) were compared, calculations showed that almost all the runoff was retained on site. Basins paved with porous pavement had the best percent removal of pollution loads, with many removal rates for metals greater than 75 percent in the basin with a smaller garden area and greater than 90 percent with larger gardens.

### LESSONS LEARNED

- This project has opened up opportunities for new approaches to stormwater management in Florida. The project and associated research have also been used by others across the nation to promote sustainable practices. Florida regulatory agencies are now working to incorporate some of these elements in a proposed Unified State Stormwater Rule.
- Although the initial budget was insufficient to cover all the sustainable practices and research components envisioned, the project team and Florida Aquarium were able to obtain additional funding from grants (U.S. Environmental Protection Agency, the Florida Department of Environmental Protection, and the Southwest Florida Water Management District).



# CAYUGA MEDICAL CENTER MAIN CAMPUS

## A Healing Environment Indoors and Out

In response to the needs of a local, rapidly expanding medical facility, a master plan was created for the Cayuga Medical Center (CMC) to guide future development and identify major design and sustainability goals for the hospital. Cayuga Medical Center expressed a desire to create a comprehensive healing environment both indoors and out. Having a green building and a sustainable site was a central focus for the client and design team. The project purpose was to develop an overall architectural and site master plan, and to direct several years of building and site work in adherence with sustainability goals. The overall vision included creating seamless spaces between architecture and exterior garden spaces. The attention to the health and well-being of visitors and patients is exemplified in the outdoor garden environments, whether near entrances or as views from windows.



© Tom Watson, Tom Watson Photography

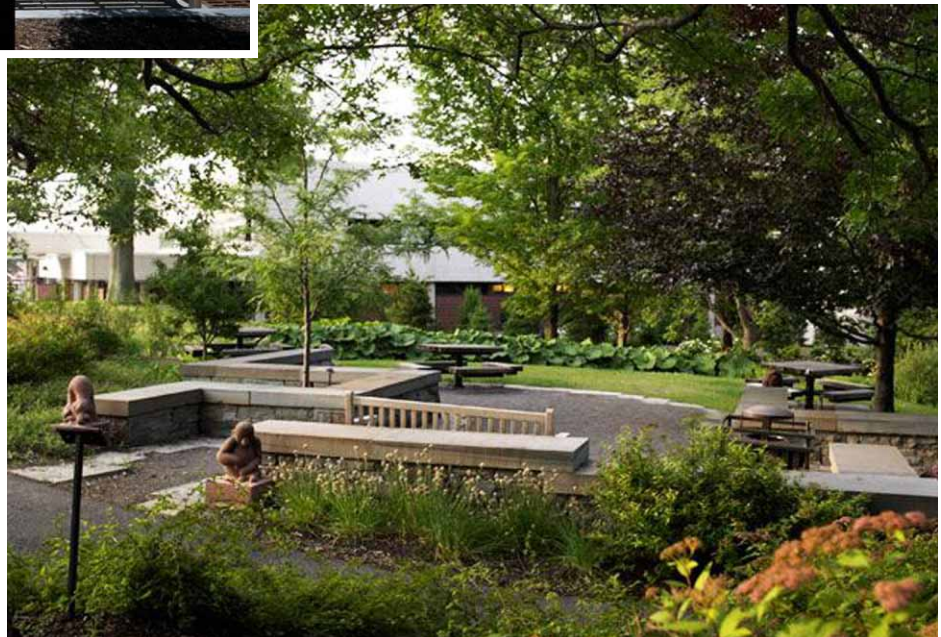
### SIZE/TYPE OF PROJECT

Approximately 24 acres/greyfield redevelopment

### SITE CONTEXT

Ithaca sits on the southern shore of Cayuga Lake, in central New York State. The natural vegetation of the Ithaca area, northern temperate broadleaf forest, is dominated by deciduous trees. Ithaca experiences a moderate continental climate, with cold, snowy winters and sometimes hot and humid summers.

An expansive restorative garden (right) offers a quiet place of respite for visitors, patients, and staff alike. All landscaped areas, including courtyards (above), feature native and adapted plants that do not require permanent irrigation systems.



© Tom Watson, Tom Watson Photography

### ISSUES/CONSTRAINTS OF THE SITE

- A unique constraint for this project was convincing the client, engineers, and local municipalities that a porous pavement lot could be successful in the cold climate. Many believed that the climate prohibited the success of porous pavement, and no local contractor or asphalt plant had ever produced or installed this type of pavement.
- Seamless transitions between phases of work while keeping the hospital accessible and operational at all times was a major component of the project. A great deal of planning, communication, organization and detail in the drawings were key to accomplishing this important goal.

### FEATURED SUSTAINABLE PRACTICES

**Providing restorative spaces and views of natural environments:** A belief that landscape experiences, even views from a window, benefit human health and well-being led to a commitment to develop a variety of garden spaces on the hospital campus.

- Close collaboration with the architect allowed inclusion of an outdoor garden space directly visible from each new waiting room or gathering space.
- Planted courtyards meet full-story glass curtain walls to allow the landscape to be experienced from the emergency department waiting room, main entrance atrium, and cafeteria (Garden Café).
- A roof garden was created along the entrance corridor to the Radiation Oncology Center, allowing patients views of green spaces from the treatment waiting room.
- An outdoor eating patio surrounded by lushly planted beds was also created directly adjacent to the Garden Café.
- A large restorative garden, more private than the other landscape spaces, was part of the medical center site plan. Complete with animal sculptures, a waterfall, walkways, eating spaces, and small-group and individual gathering areas, the restorative garden provides a soothing environment for visitors, patients, and staff.

#### Wayfinding and site circulation improvements:

New building additions and entries allowed for the development of clearer site circulation patterns and wayfinding cues. A comprehensive parking study and detailed parking management plan was developed to meet the needs of parking for the hospital while

minimizing the addition of paved surfaces and loss of green space.

**Use of porous pavement:** Over two-thirds of the additional parking spaces (69) were constructed in a porous pavement lot.

**Stormwater management:** Specific sustainable elements in stormwater management include the construction of a retention pond with a meadow planting, bioretention basin, a 700-square-foot intensive green roof, and a porous pavement parking lot.

### CONSTRUCTION COSTS

The cost was \$32.5 million (distributed among several building additions and phases), of which approximately \$6.7 million was used for site-related construction costs.

### MONITORING

- Project managers frequently evaluate the site and communicate with the client regarding the performance and effectiveness of the landscape elements.
- Because it is the first porous pavement parking lot installed in the greater Ithaca area, several local educational workshops have included site visits to the campus to see the lot firsthand.
- Formal monitoring of patients' recovery times or responses has not occurred. Anecdotally, it is clear that people use the outdoor spaces regularly and enjoy them.

### LESSONS LEARNED

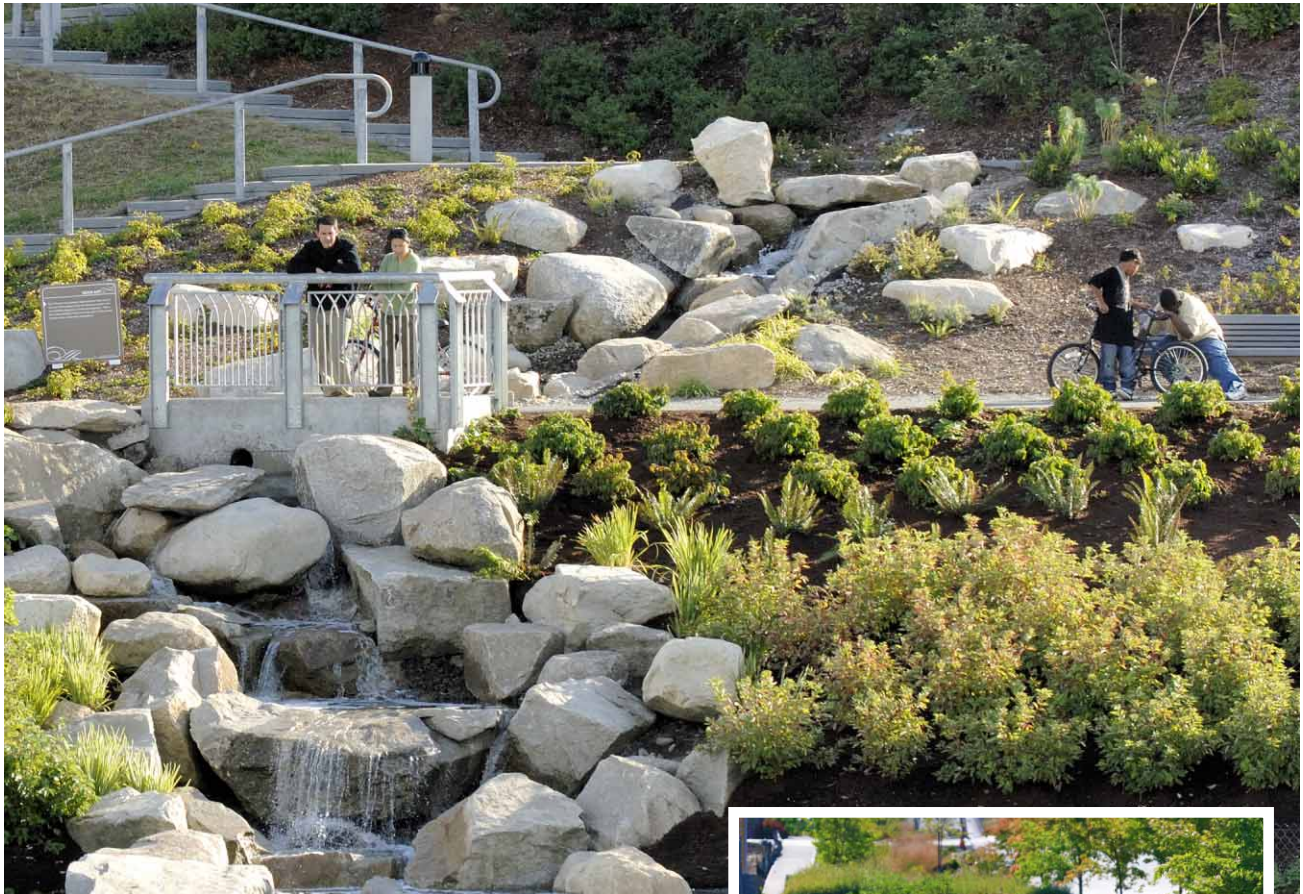
- Sustainable strategies can be about people as well as ecosystems. As a health-care facility, the well-being of staff, patients, and families is an important component. Including gardens on site provides restorative space for the whole campus community.
- Sustainable strategies can be about policy, which is essentially intangible. For example, such policies can involve a commitment to more effective use of resources (parking management plan).
- A cold climate is not a prohibitive factor for installing porous pavement.
- Keeping the hospital operational at all times during several phases of building and site construction was a special condition of the project and clear documentation and planning was needed.



# HIGH POINT

## Restoring Habitat in an Urban Neighborhood

Seattle's High Point project combines ecological and social goals to transform an isolated and distressed 34-block residential neighborhood into a vibrant, sustainable community. The redevelopment is in the Longfellow Creek watershed, one of four urban salmon-bearing streams remaining in the city. Seattle Public Utilities realized that the redevelopment of the 1940s-era site provided the potential to mitigate a significant area of contaminated urban runoff.



© Mithun, Juan Hernandez

High Point's natural drainage system provides clean water for 8 percent of the salmon-bearing Longfellow Creek Watershed, a mile-long urban creek system running through the heart of West Seattle. Overflow during extraordinary storm events is piped to an attractive detention pond (above). A vegetated median strip (right) collects and absorbs rainwater from the street, keeping it out of city storm sewers.



© Roger Williams

### SIZE/TYPE OF PROJECT

120 acres/residential greyfield redevelopment

### SITE CONTEXT

Seattle is in the Central Puget Lowland (or Puget trough) ecoregion. Its mild climate is classified as marine west coast, with dry summers and cool wet weather the rest of the year.

### ISSUES/CONSTRAINTS OF THE SITE

- The site topography slopes to the northeast with an elevation change of more than 170 feet in approximately 1 mile. The developed area drains to a single discharge point that is piped to Longfellow Creek.
- Residents did not want the stigma of “public housing” to continue in the new development. Connectivity to surrounding neighborhood was important.

### FEATURED SUSTAINABLE PRACTICES

**Stormwater management and protection of watershed and habitat:** Natural riparian corridors are an integral part of Seattle’s drainage system, with more than 20 percent of the city’s runoff flowing into local creeks. The project team focused on restoring and protecting the salmon habitat with systems to preserve and clean the watershed. Although the site is a greyfield developed in the 1940s, the design should allow the site to process stormwater as effectively as the pastures presumed to exist prior to the original development.

- Roof runoff is directed to splashblocks that drain to furrows, dispersion trenches, raingardens, and pervious pavements.
- Stormwater that does not infiltrate on housing sites is directed to a 22,000-foot system in which swales constructed with gravel and compost are graded with periodic berms to allow water to pond and filter into the soil.
- Overflow from the system during extraordinary storm events is piped to a single stormwater pond for detention.

**Native and adapted vegetation:** Native and adapted plants were used to reflect the local ecosystem and to minimize maintenance needs. More than 80,000 ground covers are planted in the streetscape, and the addition of more than 3,000 trees effectively tripled the number of trees on the site. Swale plantings vary to create an interesting year-round experience for residents.

**Irrigation efficiency:** Native, drought-tolerant, and site-suitable plants were used to minimize the need for irrigation and pesticides. Amended soils improve water retention, while a computerized irrigation management system adjusts water supply based on plant needs, solar orientation, and local weather information.

### CONSTRUCTION COSTS

Complete project costs are not available. For specific cost-saving aspects of the plan, see [www.sustainablesites.org/cases/](http://www.sustainablesites.org/cases/).

### MONITORING

Flow rate monitoring has begun but results were not yet available at time of publication. The Phase I area of the project did manage two 100-year storm events in the 2006-2007 season without flooding.

### LESSONS LEARNED

- Working with permitting agencies, interdisciplinary planning, collaboration, contractor education, public communication, and community celebrations were key to the project’s success.
- Protection of natural drainage system during construction needs to be emphasized for the contractor, as the whole system needs to be functioning successfully prior to issuance of the certificate of occupancy. This requirement has schedule implications for the contractor who must plan ahead.



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The High Point development team listened to the community’s desire for a number of small pocket parks (above) rather than one large park.



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