



Cascading Benefits

Designing Green Stormwater Infrastructure for Human Wellness

PREFACE

Wet, gray, and dreary, followed by several months of sparkling, brilliant sunshine. We know this cycle well; we grew up in the Pacific Northwest. The rains from the dreary months feed our rivers and nourish our forests, making the sunnier months all the more spectacular.

IN THE PACIFIC NORTHWEST, WE BOAST ABOUT HAVING ONE OF THE MOST LIVABLE CLIMATES (AND CITIES) IN THE COUNTRY, PERHAPS THE WORLD. But like other regions in the nation and world, our rainfall poses a particular, and important, challenge: stormwater runoff.

In recent years, our familiar, emerald green Salish Sea landscape has undergone remarkable changes. We are experiencing a shift not only in the quantity and pattern of rainfall, but also in where that rainfall goes once it splashes to Earth. Some of this shift is the consequence of human intention. For instance, in Washington State, our Growth Management Act encourages higher density development within existing urban areas. That means more paving and buildings, which concentrates rainfall and speeds its movement to drains and pipes. Some of the shift is due to broader climate patterns. It is predicted that future rainfall will be higher intensity cloudbursts, releasing greater volumes of water in shorter periods of time.

At the same time, human lifestyles have changed. We have seen a transition from natural resource related jobs, like fishing and agriculture, to a growing technology industry. Many of us are spending more time indoors.

While many people pursue the fantastic recreation opportunities of our region to recharge and rejuvenate, the presence of nature in our everyday surroundings and routines has declined. Access to nature, even in small amounts, has a significant positive impact on our well-being as humans.

Green infrastructure to the rescue! Natural areas have always been important to water management; the forests of the Cedar River Watershed have naturally cleansed Seattle’s drinking water for over a century. In recent years, nature has been integrated with streets, buildings, and entire developments in new strategies to work with rain. Trees and forests, landscape plantings, and soils are now part of the toolkit to help manage water quantity and quality in cities. This same toolkit can be used to enhance our quality of life.

This report provides a new perspective that merges recent innovations: nature for water management and nature for human health. High performance is the expectation of today’s workplace. Our landscapes can also achieve high performance. This report offers practical ideas about how to blend water infrastructure into built places in ways that create more livable communities. These strategies are useful not only in the Pacific Northwest, but can be used in cities everywhere...anywhere it rains.

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Tanner Springs Park welcomes people into a rain management amenity (Portland OR)

It’s one of those balmy spring days everyone has been waiting for. At a thoughtfully-planned apartment community, walkways overlook a creek that bubbles through the complex.

PARENTS CHAT AS THEIR KIDS EXPLORE A SMALL LANDSCAPED HIDEAWAY. Residents of the adjacent retirement home are enjoying benches on the patios that frame the creek. Birds are out too, flitting between small trees, to the delight of everyone.

This outdoor space isn’t large, but clearly, it’s precious. Primarily designed as green infrastructure for mitigating stormwater runoff, the space doubles as so much more: a deliberate and vital boost to residents’ well-being. The added cost over the original stormwater design? A few percent. The human health benefits: invaluable.

More than 80 percent of the U.S. population now lives in urbanized areas. *Research confirms that having even a small bit of nature near the everyday places of city life provides surprising social, psychological, and health benefits.* Just as our essential urban systems—water, energy, zoning, transportation—are designed for safety and efficiency, carefully planned parks, landscapes, and open spaces also improve quality of life for city residents.

Generally, green infrastructure is the conservation and creation of natural systems that are integrated with built systems to sustain ecological benefits

in urban landscapes. In many urban communities, green infrastructure is being used to improve the performance of traditional “gray” infrastructure. Within this broader concept is Green Stormwater Infrastructure, or GSI, which refers specifically to water management, especially runoff from rainfall.

In this report, we explore simple, and economical ways to add compelling outdoor spaces to urban environments by incorporating them into green stormwater infrastructure. Green stormwater infrastructure can reduce and filter runoff, improve water quality, and reduce flooding.

WHEN GREEN INFRASTRUCTURE IS DESIGNED TO INCLUDE COMPELLING NATURAL SPACES, NATURE AND PEOPLE BOTH BENEFIT. Thanks to decades of research from the social sciences, public health, and design professions, we know that even small outdoor spaces can serve to reduce particular health risks (e.g. skin cancer, obesity, asthma), encourage general wellness (e.g. reduced blood pressure, heart disease, and stress), and accomplish specific social or psychological benefits (improved cognition, mindfulness, improved social cohesion).

The purpose of this report is to explore how green infrastructure, especially GSI, can be co-designed to work not only for the environment, but for people as well. In particular, the report provides policy makers, designers and developers with research-backed facts and figures, strategies, and practices that help green infrastructure planning achieve those goals.

Green infrastructure is an emerging and important strategy for supporting healthy urban ecosystems. With a little extra attention to design, it can be used to promote healthier human communities too.



Urban spaces should be co-designed for water management and human comfort.

Over a century ago, Frederick Law Olmsted, who designed New York City’s Central Park, eloquently described the many benefits that urban residents gain from spending time in nature.

MORE RECENTLY, social science and public health research has confirmed those observations. Humans need nature experiences, even if it’s just in small doses.

Yet in some cities land may not be available for additional parks. In other cities land may be available, but there may not be the fiscal resources needed to create and manage new green spaces. In these and other cases, merging green stormwater infrastructure (GSI) and green space or parks systems is an ideal solution. GSI is a rapidly evolving innovation that combines engineered elements that are visible at the ground surface with the more traditional below-ground gray infrastructure of drains, pipes, and storage tanks. GSI is used to place small to large ecology-based water management features in both private and public spaces within communities.

GSI offers a variety of opportunities to bring more health-oriented greening into the everyday places where people live, work, learn and play. It can even be envisioned as a system of connected micro-parks that offer close-at-hand

contact with nature. Providing nature experiences across a comprehensive, connected system can generate a wider spectrum of benefit than site-by-site installations!

This report starts by explaining ‘why’ it is important to combine human health and water management goals in GSI design. Thousands of studies across recent decades reveal how nearby nature experiences improve human health, wellness and productivity, and these are summarized in Section 2. Then, Section 3 provides an overview about GSI and how it functions as a city system, along with a quick photo tour of GSI elements that can double as urban green spaces. Section 4 then integrates these two professional inputs, suggesting how landscapes that are meant to manage water can also become better human habitat. The Appendices provide additional technical resources.



GSI can be used to manage rain and create people welcoming spaces.

RESEARCH PROVES IT: PEOPLE NEED NATURE

How does having nearby nature—including trees, parks and gardens in our communities—contribute to well-being?

HERE ARE SOME EXAMPLES, and more details are in Appendix A:

ACTIVE LIVING

Our lives are more sedentary, with people spending increasing time in front of screens. Increased use of cars for transportation means fewer people walk to school or work or for errands. Over the last 30 years, adult obesity has doubled in the U.S., and childhood obesity has more than tripled. The U.S. Centers for Disease Control and Prevention report that moderate physical activity, such as brisk walking several times a week and taking the stairs, reduces health risks from obesity and related disease.

Active living, including active transit by walking or cycling, is a simple way to improve health. **Studies show that having neighborhood parks and green spaces can boost activity levels**

for people of all ages. Added benefit: Studies show that outdoor activity near our homes helps reduce depression, frustration, stress, and anxiety.

STRESS REDUCTION

Active living also ties directly into stress reduction. Being active prompts the brain to produce endorphins that improve mood and help reduce stress. When nature comes into play, a feedback loop kicks in: Research shows that being in a green environment enhances the restorative effects of exercise, potentially boosting how often a person exercises. That, in turn, promotes healthier behavior and reduces stress.²

Public health officials are seeing an increase in stress levels; a 2015 survey by

the American Psychological Association reported that **24 percent of U.S. adults experience “extreme stress.”** Other studies have established that stress is a major contributor to ill health, including higher heart rates and blood pressure, and increased levels of key hormones such as adrenaline and cortisol.

Recent research shows that low-grade, ever present stressors, such as commuting and job pressures, can lead to reduced immune function and a cascade of diseases. Studies show that the cumulative effect of chronic, low-grade stresses can have a greater impact on health and well-being than acute or extreme events.³

People can manage moderate and high stress levels for short periods of time, but chronic stress, with little

opportunity for recovery, can be worse. Even passive contact, meaning simply views of the outdoors, has been shown to effectively reduce stress,^{4,5} especially if initial stress levels are high. Views of nature in and around the places of our everyday activities provide important recovery experiences. The body’s positive response to being in nature is remarkably fast, occurring within a matter of minutes, as indicated by measures of cortisol levels, blood pressure, and heart rate.⁶

MENTAL HEALTH

Mental illness costs the U.S. an estimated \$150 billion annually. The U.S. Centers for Disease Control and Prevention report that approximately 22 percent of the U.S. adult population has one or more diagnosable mental disorders within a given year.⁷ About 20 percent of adults in the U.S. take medications for diagnosed mental illnesses, particularly antidepressants. In addition, an estimated one in 10 children in the U.S. has a mental disorder that causes some level of impairment.

It’s clear that being in nature can reduce adult depression. In one study, adults diagnosed with major depression took 50-minute walks a week apart in green versus highly built settings; walkers in green spaces improved both in mood and cognitive performance.⁸ In another study using mobile tools to measure brain activity, the subjects showed more calm, meditative mental states and lower frustration when they walked from a busy commercial district to green streets.⁹ Yet a third study found that a 90-minute walk in a natural



The complete street can include bioswales, and support walking and cycling.



Green infrastructure within residential areas offers stress reducing views, and recreation access.



setting decreased mental rumination—a damaging pattern of negative thinking about life—and reduced indicators of brain activity that mark sadness and behavioral withdrawal. A walk in more built settings did not show the same positive effects.¹⁰

Green settings within cities are also associated with reduced ADHD symptoms in children as well as adults.^{11,12} A study comparing 20-minute walks in parks versus downtown settings showed that walking in nature improved children’s attention and cognitive abilities, which could reduce the need for medication.¹³

IMPROVED MENTAL PERFORMANCE
Time spent in nature not only contributes to better mental health, but also improves our capacity to be productive. Today, people must focus on and process lots of essential information. It takes great cognitive effort to fend off and manage the competing demands for our attention. Always being “on” leads to mental fatigue as we work to meet schedules and finish tasks. The ability to maintain focus on what is most important

becomes difficult, and mental tiredness feeds feelings of frustration and irritability.

This cognitive overload is called “directed attention fatigue.” Attention Restoration Theory, as described by environmental psychologists, explains how nature can help.¹⁴ The theory proposes that “hard fascinations” such as watching a car race or a horror movie may give our mind respite from mental demands, but are not necessarily restorative. In contrast, “soft fascination” draws us in to a view or space without effort, but also leaves the mind with capacity for reflection. **Brief restorative experiences recharge our ability to concentrate,** and are positive influences on well-being, emotions, and mental states.¹⁵

CREATIVITY
Creativity, the remarkable process of experiencing inspiration and generating new ideas, is important for both success and well-being in one’s life. A study of creative professionals found that walking outside, compared to sitting or walking indoors, sparked

more new ideas, and helped people generate more novel ideas.¹⁶ Artists, designers, and other creatives reported that encounters with nature during the creative process supported more flexible thinking and helped recharge the ability to focus on tasks.¹⁷ They also reported that being outside was particularly helpful in the early preparation and idea incubation phases of a project.

HEALING AND THERAPY
Public health services are major expenses for individuals and households, as well as cities and our nation. Nature can help reduce costs. For example, hospital patients with views of nature display less severe pain, shorter hospitalization times, less anxiety, and higher hospital and room satisfaction.¹⁸ Gardens in dementia care facilities have been shown to contribute to reductions in medication use and in the number and severity of falls (a debilitating experience for elders).¹⁹ Guided participation in nature activities, for example horticulture therapy, is used in rehabilitation programs to help improve both mental

and physical outcomes. Hospitals are now exploring ways to retrofit more nature into their facilities, and new hospital designs often include ways for patients and staff to access safe and suitable outdoor spaces.

SOCIAL COHESION
To be healthy and resilient, people need social interactions. Everyday casual encounters with other people near where one lives helps build interpersonal relationships and supportive networks.²⁰ This dynamic of community connection is termed “social cohesion.” Good social connections are linked to fewer symptoms of depression,²¹ reduced risk of heart disease and stroke²² and greater willingness to walk for transport.²³ Social cohesion supports our health in these ways:²⁴

- Psychological, in developing relationships that promote a feeling of belonging with other people. Positive perceptions of security and personal safety are an outcome.

- Place attachment concerns the feeling of connection to physical place, and an ever-stronger desire to live in a specific community.

- Neighboring, or specific interactions between residents of a neighborhood and the support they may offer to each other. This can also include participation in events like festivals, or shared interests such as having children in the same schools.

Social cohesion emerges from the casual, informal encounters that often take place when people visit local parks.²⁵ Green streetscapes also enable the connections that are related to general health.²⁶ Over time and with increased familiarity we develop deeper relationships with the place where we live and other residents. Other opportunities to build social connections include community greening programs,²⁷ vacant lot cleanups, or shared community garden plots. What are the benefits? One is reduced crime in neighborhoods.^{28,29} And people who work together

to steward green spaces in their community develop greater personal and neighborhood resilience.³⁰

HEALTH SERVICES ECONOMICS
Health care costs now represent a staggering 18 percent of the U.S. annual gross domestic product—more than \$3 trillion every year.³¹ Does having nature nearby provide economic benefit that might help counter those costs? Trees and parks have traditionally been considered to be just ‘nice to have’ amenities. But what if health-oriented design of nearby nature could reduce medical costs by a small margin, even five to ten percent?³² The costs of nature investment would be well worth it.

Research about the economic value of nature benefits is relatively new. However, the answers we do have are encouraging. For example, studies show that, from infants to elders, access to nature can lead to annual savings of up to \$12 billion in avoided health care costs.³³ That includes savings from healthier infant birth weight, reduced ADHD symptoms, and reduced cardiovascular disease in older adults.³⁴



LEFT: Design a basin edge for workers to get away on breaks or for lunch. MIDDLE: Art and GSI express a sense of place and promote creativity. RIGHT: Access to nature in health care settings is linked to better response to treatment and therapy.

LEFT: Green infrastructure can be used to create social spaces. RIGHT: Having social connections is linked to reduced disease, faster healing and more active lifestyles for elders.

Water management innovations add nature to the spaces just outside our doors.



GREEN INFRASTRUCTURE SOLUTIONS

Stormwater management is a challenge in many U.S. cities. Green infrastructure is a general term for combined natural systems and engineered features that pair up to improve on the performance of traditional “grey” structures. Green infrastructure helps make urban environments more sustainable and more resilient. Increasingly, cities look to green infrastructure to also make cities more livable and appealing. This is especially true for green stormwater infrastructure (GSI), designed to manage stormwater runoff but also perfectly poised to provide co-benefits for human health and wellness.

THE GSI TOOLKIT

Across the nation and the world, cities increasingly look to green stormwater infrastructure to meet regulatory requirements, improve water management, and reduce costs. GSI performance and cost savings have been confirmed by post-construction evaluation, using tools to quantify ecological functions.³⁵ The U.S.D.A. Forest Service, for example, provides a suite of online tools called i-Tree that assess urban forest functions and benefits. Here is a quick tour of GSI elements that are often used to manage stormwater (additional technical information is provided in Appendix B):



BIOSWALES AND BIORETENTION

Small vegetated basins that collect, absorb, and filter runoff from adjacent paved areas.



RAIN GARDENS

Small scale bioretention features sized for yards or small public landscapes.



PERMEABLE PAVING

Porous pavement that permits vertical runoff and can support vehicle loads, such as parking and even light traffic.



DEPAVING

Removing underused or unnecessary pavement. Reduces heat islands, improves plant diversity, and decreases runoff.



GREEN ROOFS

Rooftop plantings using special growing media. Slows runoff, mitigates heat islands, and can reduce building energy use.



TREE CANOPY

Tree canopy and surrounding soils intercept, reduce and filter runoff, as well as improving shade, air quality, noise buffering, and wildlife habitat.



COMPOST AND MULCH

Protects soil from evaporation, slows stormwater infiltration, and improves soil quality.



TOP: Water management in urban landscapes can simply be a utility, or so much more!
BOTTOM & RIGHT: Bioswale planting design is flexible, from the wild to the manicured.



A COMPREHENSIVE APPROACH

GSI design elements are often installed as individual units. But a more effective approach is to place them as a collection of integrated components located close together within a drainage basin or watershed. Water is then increasingly managed by natural ecological functions over a larger area. They can be installed within public rights-of-way (near roads, sidewalks, and bike paths), in parking lots, alleys, yards, or even on walls and roofs.

And this provides other

opportunities, too. Integrated GSI can be used to customize urban spaces, and create a sense of place within neighborhoods and watersheds. This approach can readily incorporate co-design for human health co-benefits.

INSPIRING EXAMPLES

Some comprehensive, innovative examples from around the United States:

- In Baltimore, vacant lots are being transformed into urban green spaces for stormwater management by installing trees, rain gardens, and

permeable paving in parking areas.

- Targeting public rights of way, New York City installs bioswales along sidewalks throughout the city with a focus on high priority drainage areas.
- Other cities, such as Detroit, are converting little used alleys into linear parks that also process stormwater.
- Winslow, Washington, used stormwater management bioswales to create gardens within its downtown main street area, enhancing a walkable retail experience for users.



LEFT: Well-designed GSI invites people in and sparks curiosity about sustainable stormwater management. RIGHT: GSI can be the backdrop of appealing outdoor cafes.

How can outdoor environments more directly enhance human health and wellness?

THIS SECTION PROVIDES PRINCIPLES AND IDEAS FOR DESIGNING GSI, and suggests how to shape nearby nature in ways that contribute to human health and wellness.

These ideas build on research from environmental psychology, epidemiology, and public health, as well as best practices of landscape architecture. They also address the multiple goals that are important to many urban communities.

Let’s start with some basics.

Conditions that affect people’s comfort when they are outdoors:

- **Outdoor spaces should be a reasonable temperature** based on a balance of sun and shade, considering the season and local climate.
- **Noise levels should be as low as possible.** Excessive noise levels generate stress and other negative responses. Occupational health limits are set at 85 decibels, but the human comfort level is between 40 and 60 decibels.
- **Vegetation size and arrangement is important.** For example, studies of retail streetscapes found that vegetation that enclosed the pedestrian space, creating a series of outdoor rooms, was highly preferred to plantings where trees were simply lined up. Research has also found a

preference for large trees.

- **Built-to-nature balance is key.** Even within highly built settings, there can be the sense that one is interacting with nature, and that vegetation is a meaningful part of the experience, not just a decorative add-on.

There are many other characteristics that affect the appeal of places, and their impact on human health.³⁶ Research shows that even more nuanced characteristics are key to the aesthetics, appeal and use of city nature. Here is a collection of design goals and principles that can be integrated into GSI.

WALKABLE NEIGHBORHOODS

How might GSI improve walkability? Studies on neighborhood design and

walkability take into account both proximity and connectivity.³⁷ Proximity is the distances to destinations. Connectivity refers to how easy it is to walk continuously to a destination.

People who walk for transportation (to get to stores, a transit station, work or school etc.) are likely to take the most direct path to their destination, while recreational walkers often want opportunities to wander or choose routes away from busy roads. Good connectivity provides lots of route choices, and is supported by continuous sidewalks and streets in a grid pattern with few barriers.

Neighborhood greening affects walker perceptions of both proximity and connectivity. Positive perceptions of neighborhood aesthetics, and not having to contend with heavy traffic, encourages walking.^{38,39} Plants and

vegetation in the right-of-way soften and add greater interest to the built environment and provide visual connection. The presence of street trees, in particular, has been shown to improve walkability for recreational walkers.⁴⁰ Trees provide shade, screen cars, reduce noise, and can improve air quality. People prefer large trees, so preserving older trees is important.

SIDEWALKS AND THE RIGHT OF WAY

Sidewalk and right-of-way design is critical for walkability and safety. The optimal sidewalk has room for three zones:

- The frontage zone is adjacent to the building or a property line, and varies in width depending on its function (i.e. café chairs).
- The pedestrian zone should be at least six feet wide to accommodate people walking side by side, and have smooth

surfaces and little to no side slope.

- The furnishing zone (or planting strip) is closest to the road and is usually where a GSI element is installed.

While these three zones are usually distinct, design innovations can create an integrated sense of space. For instance, small bridges can connect the pedestrian zone through the furnishing zone to the curb edge. Benches and seating can be placed near the curb and within the GSI installation, and placement should reflect specific needs of the elderly or walkers with small children. Interpretive signs can explain how these connected bits of landscape are an effective alternative to street drains.

Swales that are enclosed by chicanes (S-shape curbs at intersections) or other curb extensions can calm traffic and create “safe zones” for pedestrians.

Narrower two-lane roads formed by such curb extensions are generally safer, since they provide shorter and quicker street crossings for pedestrians.⁴¹ The enclosed spaces can also provide enough room for street furniture or art.

PROSPECT AND REFUGE

People tend to settle or sit in open spaces, whether indoor or outdoor, in predictable ways. This is partly explained by the prospect-refuge theory. First suggested in the 1970s, this theory helped us to understand how people respond to and make choices within landscapes.⁴² Think about a large open area such as a park or plaza. People will tend to sit or stay near the edges, rather than being out in the open.

These choices relate to our ancient biological needs for survival and success. Even in the absence of imminent danger

LEFT: Co-design for co-benefits can help communities achieve a perfect blend of urban ecology and human wellness.
RIGHT: Green stormwater infrastructure treats rainwater, improving aesthetics and quality of life in urban places.



or need, people prefer places that offer a combination of enclosure and outlook. They will typically place themselves against a screen or backdrop (the “refuge”), yet in a position that provides a broader view of the space and activity within (the “prospect”).

Prospect and refuge is an important factor when designing. For example, place seating to optimize overviews and viewpoints. If there are surrounding walls or structures, walkways or benches can be placed to look out over a larger space or provide an opportunity for concealed people watching.

COMPLEXITY

The same curiosity that fueled the rapid rise in the use of smart devices, the internet, and social media can be seen in human relationships with landscapes. Generally speaking, people are information addicts. They constantly seek out new information to help understand their surroundings. No wonder it is simultaneously satisfying

to understand a space while feeling challenged by opportunities to learn more.

Complexity refers to the degree of information richness in a scene or situation. The amount of complexity of a place or space is directly related to the opportunity to understand, and thus the appeal of a space.⁴³ Too low, and people will quickly understand the available information and find it boring. Too complex, particularly when complexity is caused by multiple sensory inputs—visual, noise, and confusing layout—and people may feel frustration and agitation, even longer term stress and anxiety.

If we are unable to understand and navigate an outdoor space we find it uncomfortable or unwelcoming. Mid-level complexity is just right. It satisfies the desire to understand a place, but still provides opportunities to uncover more information and engage in more experiences by moving further into it.

COHERENCE

While complexity is about the amount

of information provided by a space, coherence refers to how well the information ‘hangs together’. Humans perceive their surroundings as visual arrays rather than focusing on individual objects.⁴³

A space that is pleasant to be in has internal physical and visual connectedness and general predictability. In other words, the elements within it relate to each other. A place that is coherent is innately understandable, and there is a promise of easy wayfinding. Coherence combined with complexity affects human behaviors in public spaces.

This idea is not limited to outdoor or even physical spaces. Digital spaces like web pages, graphic publications, and outdoor nature—each are easier to understand and navigate if there is a sense of coherence. Another version of this idea is “variety within unity,” meaning a sense of being able to explore the new and interesting within a broader sense of the whole.

Several ways to express coherence in or across outdoor spaces:

- Repeated features or patterns, symmetries, or a series of focal points serve as visual cues.
- A consistent planting palette within a neighborhood or project can provide spatial connections, clarify the edges of a place or district, and create a visual identity for a place.
- Art or cultural features can be placed intermittently to support coherence, leading to the sense of connectivity as one moves through and around a place.

Naturally, combining these elements bolsters spatial coherence. For instance, retail districts can plant bioswales using a repeated palette of ornamental grasses and flowering shrub species to create a sense of place.

MYSTERY

Mystery is another trait that boosts the appeal of a space.⁴³ Environmental

psychologists explain that mystery, in this sense, is not about being surprised or alarmed. Instead, it is the feeling that arises from moving through a landscape that is not entirely revealed all at once. A curving path, for example, suggests that there is more to be discovered as one continues through the space. This gradual reveal builds intrigue, drawing the viewer in.

At the same time, mystery should not compromise a sense of personal safety. Vegetation can be managed to maintain sightlines and promote other principles of Crime Prevention Through Environmental Design (CPTED). And of course, the better used a public space, the better the informal “eyes-on-the street” security.

BIODIVERSITY

Ecologists are concerned about the reduction of plant species diversity and wildlife habitat– from urban to rural and wildland areas. Good news—studies show that multi-species plantings can support remarkably complex ecosystems

in cities. These blends of native and horticultural species are now called ‘novel ecosystems’.⁴⁴ Even better, incorporating biodiversity principles can add both complexity and coherence in green infrastructure landscapes.

Using repeated patterns of mixed species plantings supports wildlife, including insects and birds. Wildlife in turn, greatly bolsters human appeal and stewardship. For example, the Pollinator Pathway program in Seattle encourages people to replace tree lawns along streets with plant collections that support pollinators. Those plantings provide routes for pollinator movement around the city, supporting pollination for both aesthetics and food production. This notion of repeating wildlife-friendly plantings could be reviewed for use in GSI installations.

CUES TO CARE

Some people prefer manicured landscapes. A landscape that is managed to achieve ecological goals is often



LEFT: People are less comfortable in places with complex vegetation arrangements, so clear navigation cues are needed.
RIGHT: Repeated plantings and pavings give a space the sense of coherence.

LEFT: A curving path welcomes visitors to enter and explore a landscape, and learn from it.
RIGHT: Biodiversity in urban landscapes achieves many goals, but should include attention to access and security.



Border materials (such as stones) or pavings tell the visitor that a ‘scruffy’ landscape is being cared for and not neglected.



Benches placed in and around a water feature encourage people to relax.

more naturalistic, more scruffy, and less preferred by some people. To encourage them to use a more natural looking space, it helps to include a cue that a landscape is actually a managed landscape and not neglected.

Environmental psychologists, working with ecologists, suggest framing more naturalistic landscapes with “cues to care”.⁴⁵ Those cues could be simple devices such as a simple fence, a mown edge, or a tidy ornamental plant border on the edges of a green space or along trails. The cues suggest that the disorder is intentional, and welcome people to enter and enjoy the more wild space.

RESTORATIVE LANDSCAPES

Modern lifestyles are busy, and our attempts to cope can introduce stress

and anxiety. Decades of research show that even brief experiences of nature can be both mentally and physically restorative. People of all ages and cultures consistently prefer natural to highly built settings, and neuroscience has linked this preference to pleasure centers in the brain.⁴⁶

What are the traits of restorative landscapes? Opportunities to experience soft fascination, mentioned earlier as important to mental health, is a key factor. Having views and features in our surroundings that hold our attention without effort help restore our cognitive ability to focus and pay attention to what is important. Think about what holds our interest in a park or garden: birds, bees moving about busily, the movement of clouds, the sound of the wind and

interesting plants—including foliage, flowers and seasonal color change. Water has high appeal for people, be it a stream, fountain, or stormwater feature. Taking time and slowing down to notice these things also encourages mindfulness, which helps people to take stock of what is important and set goals in their lives.⁴⁷ GSI can introduce nature-based opportunity for mental health benefits throughout a community.

Other conditions that support restorative experiences and can be incorporated into GSI design:⁴³

BEING AWAY: The sense of “being away” is the feeling of being removed from the sources of mental fatigue such as a busy office, crowded city street, or

long stretches of working on a computer. A small pocket of nature just outside a building can be adequate. A gateway or arch gives a distinct feeling of entry. Context-sensitive art or a water feature helps define a separate space.

EXTENT: A setting with extent should seem to have its own boundaries and definition, to create the restorative sense we get from being in “whole new world.” Paths, vegetation arrangements, and built elements can be designed so that a small area seems much larger. Water features such as fountains or streams are often used to define physical extent, while water sounds shape perceptual extent.

COMPATIBILITY: There should be a feeling of compatibility between the

environment and one’s purpose(s) in interacting with that environment. This includes considerations of comfort (suitable seating), safety (i.e. lighting and human presence), accessibility (such as for disabled or elderly users), and cleanliness (well managed with no litter). Offering a program of activities within the space—such as group walking, yoga, or community gardening—can foster compatibility.

DESIGNS FOR SOCIAL COHESION

Green infrastructure design can encourage the informal, spontaneous interactions that promote social cohesion. People encounter neighbors more often if outdoors spaces are appealing. If a neighborhood has a strong ethnic or cultural identity, the space can

be designed to reflect that and help strengthen social cohesion.

Some design elements that promote social encounters and resulting social cohesion:

- Benches, picnic tables, and games,
- Play areas for small children,
- Street furniture or art that promotes learning interactions,
- Plant choices that reflect the cultural or historic roots of people living in the neighborhood,
- “Pea patches” or community gardens where people may plant ethnically traditional produce not available in markets and share with others, and
- Farmers or produce markets in and around larger GSI installations.

When it comes to making designs of nearby nature more engaging, **don't forget the people.**

MANY ORGANIZATIONS AND AGENCIES ARE COMMITTED TO GETTING PUBLIC INPUT FOR GSI DESIGN. People often feel strongly about having input on the changes that shape the character of their own community. Successful public engagement programs promote wellness outcomes such as increased esteem, greater self-efficacy and pride, especially in young participants.

The planning process to design and install GSI at a neighborhood level should start early and include as many people as possible from the neighborhood. Reaching diverse segments of the population is necessary to form consensus around how people want to see their community developed.

Be sure to provide friendly, accessible channels for people to express their needs and concerns about how their neighborhood will be altered, and offer multiple options or alternatives.⁴⁸ If reasonable choices are provided, the chances of receiving useful feedback increases.

Finally, **provide opportunities for people to stay involved with**

their local landscape long after installation is completed. Agencies and organizations that install GSI often rely on local residents to help with ongoing management. That might take the form of work parties for renewal planting, weeding, and monitoring the effectiveness of the GSI elements. Jobs programs can sometimes provide youth and others paid positions for maintenance and installation.

People and organizations such as schools enjoy collaborating on projects as citizen scientists. Be creative in suggesting a variety of citizen scientist opportunities. Work up data collection activities that engage and excite children and adults to learn about and care for the new landscape in their midst.



Green infrastructure is typically used to provide environmental or ecosystems services in urban environments.

MEANWHILE, communities are searching for new solutions to a variety of challenges to human well-being. Green stormwater infrastructure is a specialized approach to better manage water quantity and quality. With guidance and creative design GSI can be designed to achieve a community's more human-centered goals as well.

If policy makers, developers, and the communities they serve can think in broader terms, they can create restorative “nearby nature” experiences and promote human wellness at many scales.

Once considered a curiosity, there is now robust research that documents the many instances of nature experiences in cities and human health outcomes. In just the past few years economic calculations indicate potential annual savings of billions of U.S. dollars.³⁴ The combined research findings and valuations are why communities are expanding programs that encourage people to go outside, helping prevent disease and promote health.

Some scientists refer to the emergence of “hyperfunctional” landscapes in cities.⁴⁹ Along those lines, this report is a unique effort to integrate the science findings of positive human response to nature with the practicalities of green infrastructure generally, and with GSI specifically. It offers a range of design principles and examples that are evidence-based.

Using the guidelines in this document, engineers, planners, and designers can make **small but important adjustments to GSI specifications to help achieve more healthful spaces and livable communities.**

APPENDIX A: NATURE & HUMAN HEALTH RESEARCH REVIEWS

The following are recent reviews of research literature that tie experiences of urban nearby nature to human health outcomes. Some resources address the entire spectrum of human health and well-being, while others focus on specific topics such as mental health, immune response, or nature dosage. These resources provide the scientific justification for the design principles offered in this report.

The [Green Cities: Good Health](#) website provides an indexed research review on urban nearby nature and human health response based on thousands of peer reviewed studies, as well as information about specific studies and health outcomes. The project is funded by the USDA Forest Service, Urban and Community Forestry Program; the USDA Forest Service, Pacific Northwest Research Station; and the University of Washington.

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APPENDIX B: GSI POLICY AND TECHNICAL RESOURCES

Many cities are adopting Green Stormwater Infrastructure (GSI) policies and best practices. It was not possible to include a detailed presentation of policy and technical background in this report. The list below is a sample of current publications and resources. There are many other examples; this list is not an endorsement of specific communities or products, but shows the range of efforts around GSI.

Ultra-Urban Green Infrastructure Guidelines (City of Denver, 2016): https://www.denvergov.org/content/dam/denvergov/Portals/705/documents/guidelines/PWF5-013.0-Ultra-Urban_Green_Infrastructure_Guide.pdf

Enhancing Sustainable Communities With Green Infrastructure (EPA, 2014): <https://www.epa.gov/smartgrowth/enhancing-sustainable-communities-green-infrastructure>

Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure (EPA, 2010): <https://nepis.epa.gov/Exe/ZyPDF.cgi/P10QFTFM.PDF?Dockey=P10QFTFM.PDF>

Green Infrastructure Design and Implementation (EPA, clearinghouse website): <https://www.epa.gov/green-infrastructure/green-infrastructure-design-and-implementation>

Green Infrastructure Opportunities that Arise During Municipal Operations (EPA, 2015): https://www.epa.gov/sites/production/files/2015-09/documents/green_infrastructure_roadshow.pdf

Green City Clean Waters Stormwater Plan (Philadelphia, program website): http://phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan

Making Cities Liveable: Blue-Green Infrastructure and Its Impact on Society (Ramboll, 2016): https://issuu.com/ramboll/docs/bgi_new?e=4162991/34845282

Green Stormwater Infrastructure in Seattle: Implementation Strategy 2015-2020 (Seattle, 2015): https://www.seattle.gov/Documents/Departments/OSE/GSI_Strategy_Nov_2015.pdf

Harvesting the Value of Water: Stormwater, Green Infrastructure and Real Estate (Urban Land Institute, 2017): <https://americas.uli.org/wp-content/uploads/sites/125/ULI-Documents/HarvestingtheValueofWater.pdf>

Green Infrastructure in Parks: Resource Guide for Planning, Designing and Implementing Green Infrastructure in Parks (2017): <http://www.nrpa.org/contentassets/0e196db99af544bbba4f63f480c1316b/gupc-resource-guide.pdf>

Manual De Lineamientos De Diseño De Infraestructura Verde: Para Municipios (2017): http://www.cocof.org/desarrollo-de-capacidades/publicaciones-e-informes/manual-de-lineamientos-de-dise-no-de-infraestructura-verde-para-municipios-mexicanos#Wozg44JG3_8

Harvesting the Value of Water: Stormwater, Green Infrastructure, and Real Estate (Urban Land Institute, 2017): <https://americas.uli.org/wp-content/uploads/sites/125/ULI-Documents/HarvestingtheValueofWater.pdf>

New Jersey Developers' Green Infrastructure Guide (2017): <https://www.akrf.com/documents/159/NJ-Developers-Green-Infrastructure-Guide.pdf>

Great Lakes Green Streets Guidebook: A Compilation of Road Projects Using Green Infrastructure (2013): https://www.semco.org/Reports/GLGI_Guidebook/index.html

Green Infrastructure For Desert Communities (2017): <https://watershedmg.org/document/green-infrastructure-manual-for-desert-communities>

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