GREEN INFRASTRUCTURE

TOOLBOX

APWA's Water Resources Management Committee, Asset Management Committee, and Sustainability and Resiliency Committee are dedicated volunteers who provide valuable education. The committees created the Green Infrastructure Toolbox. This toolbox is intended to be an overview for individuals new to this area of public works. It can also be used as education for residents and the governing body of your agency.

Green Infrastructure—A Critical Asset in our Communities

What is Green Infrastructure?

Green Infrastructure (GI) is a type of best practice that helps cities develop sustainably. GI practices reduce stormwater's negative impacts on local water quality, protect natural hydrology, and add curb appeal. GI practices help cities mimic how natural systems would have cleaned, cooled, and recharged groundwater, resulting in cleaner urban stormwater runoff.

GI is also known by various terms, including natural infrastructure, green stormwater infrastructure, low impact development (LID), and sponge city concepts. GI is a system that includes natural and human-made elements that provide ecological and hydrological functions and processes while also delivering multiple co-benefits. GI can include at a large scale: wetlands, stormwater ponds, ravines and streams; or in an urban context: street trees and stormwater tree trenches, urban forests, natural channels, permeable surfaces, and green roofs.

Communities rely more and more on GI such as plants, soil mixes, and wetlands to perform important environmental functions, such as filtering and infiltrating rainwater where it falls, removing pollutants from the air, and providing habitat to support biodiversity. While traditional grey systems such as pipes, dams, and stormwater control structures are still needed, communities are embracing the use of natural systems, often in combination with grey systems, to address environmental needs. Examples include:

- Clean Water Act compliance (MS4s, NPDES, TMDLs): Use of plant buffers, infiltration systems, rain gardens, rainwater harvesting, green streets, and natural stream restoration are all used in combination with grey systems to reduce the impacts of development and clean our waterways.
- Clean Air Act compliance: Community Climate Action Plans provide roadmaps to reduce greenhouse gas emissions to comply with Clean Air Act requirements. These plans often include conservation of green space, street trees, community gardens, and urban greening efforts to reduce heat islands and sequester carbon dioxide.
- Resiliency Measures (including coastal protection and urban flooding): These efforts seek to reduce the risk of coastal and urban flooding and include flood plain restoration and management, shoreline and stream buffers and plantings, restoration of reefs, and the protection of inland water resources such as marshes, mangroves, and wetlands.
- Community Quality of Life initiatives: Realizing the social, economic, and health benefits of GI, communities are investing in initiatives such as urban landscaping, tree cover, green space, and access to parks, streams, and open space for all members of their communities.

These natural systems are a critical component to protect the health, safety, and welfare of a community. Like other traditional infrastructure solutions, these systems need to be monitored, managed, and maintained.

Examples of Green Infrastructure

Man-made stormwater structures can never replace the benefits of high-quality existing natural systems. Examples of natural systems could include prairies, woodlands, wetlands, and other groundwater driven hydrologic systems. If your natural system is lower quality, invest in improving it! Investing in the health of a wetland, prairie, or woodland is always worth it. Protecting and enhancing natural areas is the first step in the development process and is the most fundamental part of designing with GI. Always see if you can design around existing systems instead of demolishing natural areas and adding man-made water quality or detention practices.

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Other GI practices include the use of bio-retention and porous paving systems, water harvesting and reuse, and underground water quality and quantity mitigation practices.

Bio-retention systems such as rain gardens, bio-retention cells, bioswales, stormwater planter boxes, or other practices utilize biological functions to reduce pollutants in stormwater.

Bio-retention cells line a 1.5 mile stretch of roadway in Coralville, Iowa.

Porous paving systems such as permeable pavement, concrete, asphalt, or grass-type pavement can sometimes interconnect with stormwater planter boxes or infiltration trenches. These systems function by filtering stormwater through underground rock chambers, soil media, and tree roots.

Porous paving patio in Coralville, Iowa. This practice is coupled with tree infiltration trenches which clean and infiltrate stormwater from the adjacent roof.

Natural systems such as woodlands, prairies, wetlands, or ponds are an important part of the hydrologic cycle, absorbing, cleaning, and cooling water before eventually discharging this improved runoff to the receiving water body.

One of the more challenging areas to deploy GI is within ultra-urban environments such as downtown metropolises. Designing for the implementation of GI within these areas can be done with creativity and a little ingenuity. Hard surfaces such as roadways, sidewalks, roofs, patios, rights-of-way or parking areas can be designed using porous surfaces such as green roofs, porous pavers, asphalt, or concrete. Planter boxes or tree infiltration trenches can be installed alone or in tandem with porous pavement systems. Underground water storage or rock chambers can also be added to allow a large volume of water to receive treatment or reduce peak stormwater flows. The key is to pair multiple practices to boost treatment and to use practices that offer multiple benefits and can have dual purposes. An example of this approach could include the use of a porous paving patio that functions as a GI practice and as an area for entertainment. Another example could be the use of an underground rock trench constructed within the right-of-way that is also used as a sidewalk for pedestrians.

Stormwater planter box in Coralville, Iowa. This practice is coupled with underground rock chambers to treat stormwater runoff from the roadway and sidewalks.

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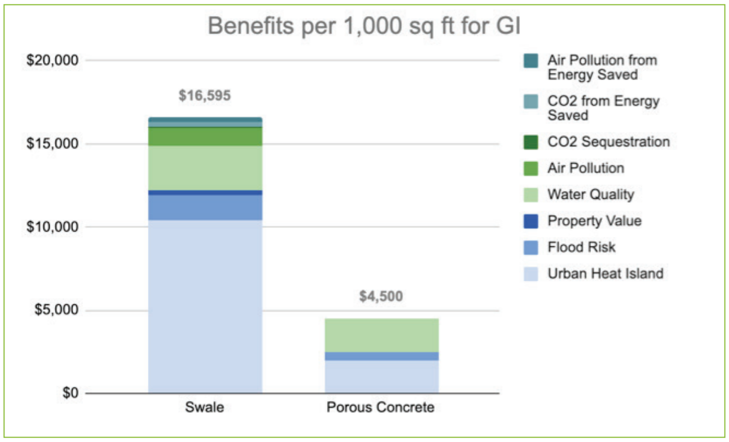
The Benefits of Green Infrastructure

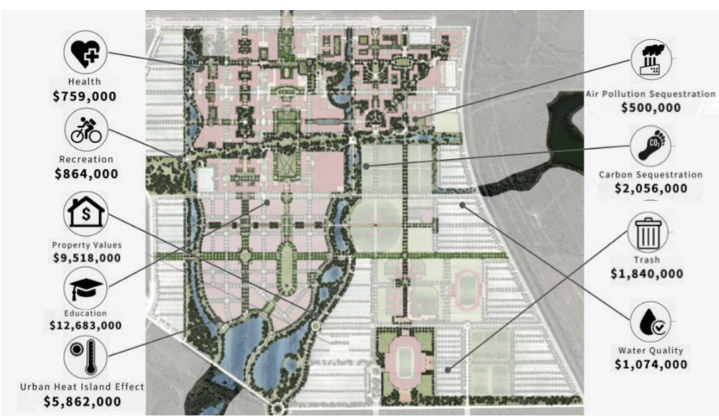
GI creates numerous financial, social, and environmental benefits. These projects build assets that provide advantages for years. The important thing to remember is that both size and location help to determine the value of GI.

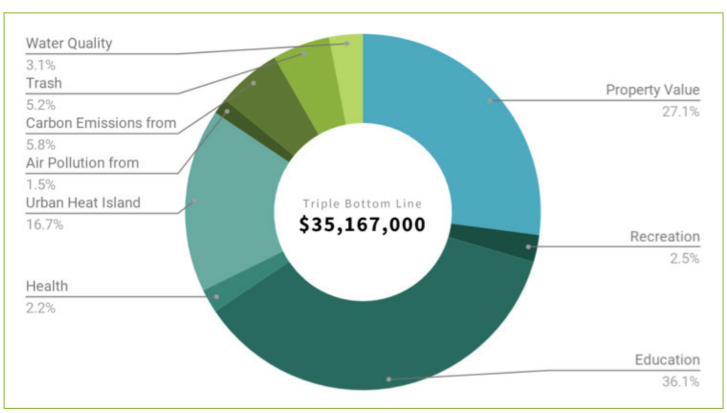
Some of the financial, social, and environmental impacts from GI are given below.

A study for the City of Phoenix, Arizona compared the benefits of various GI investments to asphalt on a per 1,000- square-foot basis and found that benefits varied by type of GI but could be as high as $16,600.



A recent project in San Antonio, Texas—conducted jointly with San Antonio River Authority, CDM Smith, Urban Ecoplan, and Autocase—found that a large urban redevelopment using GI would create an additional $35 million in benefits.





Public Works Role in Building a Successful GI Program

A core function of public works organizations is the management and maintenance of a community's infrastructure. A community relies on well maintained and operated water systems, roads, bridges, streetlights, trails, wastewater treatment plants, and facilities. There is a well-developed body of knowledge on how to best manage these assets. It is important to apply the same principles and approaches to these natural assets. The following sections provide guidance and resources to help develop successful GI asset management programs.

Asset Management. Integrating GI into asset management provides an opportunity to formally recognize the vital services and co-benefits that green assets provide. It also supports the allocation of resources to ensure that they are managed wisely.

Inventory. The importance of maintaining an accurate inventory of assets is critical for both grey and green asset types. Due to the relatively new nature of GI as assets, it's even more important to build a complete inventory—especially if these assets are located under the pavement or road surface, or unfamiliar to operations staff and other contractors. For example, a contractor might install a utility through a new stormwater tree trench, where most infrastructure is subsurface and not visible, or install a lateral through a bioretention bump out. Consider linking your assets to "One-Call" or other utility locates or incorporating a surface marker or asset ID.

Condition Assessments. Developing a current state of assets is a critical stage in asset management and information on asset condition is key data collected as part of the process. Many GI assets are newer assets, and this presents an opportunity to make sure operations and maintenance inspections are aligned with condition information needed for asset management. Municipalities can develop a condition scoring system (or rating scheme) and inspection program that is simple and repeatable and considers the multiple components of GI assets (e.g., horticulture, soil, and any gray infrastructure components such as distribution pipes or curb cuts).

Levels of Service. Unlike most gray infrastructure, GI can provide multiple services and co-benefits. It is important to account for co-benefits in defining levels of service (LOS), but this is not a standard approach in asset management practices. A solution can be to divide your LOS into two categories: core and secondary. Core services are the primary reason(s) an asset is built, and failure to deliver these services can result in an asset failure. Secondary services should cover those co-benefits that are important to a municipality but are not the primary reason for implementation. For GI, core services could relate to water quantity and quality, while secondary services might relate to public health, biodiversity, climate change, or aesthetics.

Case studies and tools on integrated grey and green asset management can be accessed here:

- Green Stormwater Infrastructure Asset Management Resources Toolkit
- SWEFC's Integrated Asset Management Framework
- Nature Conservancy Coastal Resilience

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Monitoring. Similar to measuring the capacity and performance of a pipe, GI must be measured in how it addresses different environmental functions. Questions must be asked and Key Performance Indicators (KPIs) developed specific to the objectives and implementation goals of the agency.

What do you monitor? And how do you measure? Based on regulatory requirements or compliance, some monitoring might be mandatory to ensure GI assets are meeting design objectives (for example validating volume capture targets and water quality performance) and provide information for Combined Sewer Overflow (CSO) volume reduction effectiveness and downstream water quality monitoring. Monitoring is also used to inform the maintenance management of the GI systems which includes determining the appropriate frequency or type of maintenance required. Ensure that monitoring infrastructure (monitoring wells, nylon basins) is incorporated into project design to enable monitoring. Not all assets need to be monitored at all times. Once an asset performance has been validated, consider rotating sensors to minimize costs and target specific assets.

Co-benefit estimating tools are also useful to demonstrate the impact of GI on other co-benefits such as urban heat island reduction, air quality improvements, or carbon sequestration.

https://www.itreetools.org/
These are free tools and technical support for students of all levels, homeowners, community advocates, corporate sustainability officers, urban foresters, and more!

https://gsiimpacthub.org/
Access a free GSI impact calculator among other great resources.

Design and Construction Standards. Updating design and construction standards along with other standard road cross sections to include GI enables easier implementation of nature-based solutions. Consistent implementation by qualified contractors is recommended along with integration of pre-qualifications into both consultant and contractor design and construction tenders. Ensuring appropriate care of plant material during delivery and construction as well as active maintenance is specified in the warrantee period is vital to establishing vegetated assets, which are ultimately assumed by an agency. Ensure operations staff are engaged in the design at an early stage to troubleshoot and coordinate GI maintenance with standard maintenance activities (e.g. routine winter maintenance).

States, counties, municipalities, and nonprofits across the United States and Canada have developed stormwater design manuals that emphasize GI approaches (also called “low impact development” or “environmental site design”).

https://www.epa.gov/green-infrastructure/green-infrastructure-planning-design-and-implementation

https://wiki.sustainabletechnologies.ca/wiki/Main_Page

https://guides.co/g/green-infrastructure-resources/192866

Maintenance Standards. Establishing standard lifecycle activities including preventative, corrective, and predictive maintenance can help ensure that maintenance activities can be planned and budgeted for as new assets come online. Maintenance indicators provide a platform for the assessment of the condition and functional performance of a GI system; they can be built into field inspection forms and tied to asset management systems.

https://www.epa.gov/green-infrastructure/green-infrastructure-installation-operation-and-maintenance

https://stormwater.pca.state.mn.us/index.php?title=Green_infrastructure_operation_and_maintenance_catalog_wiki_table