Bioretention Design Handbook

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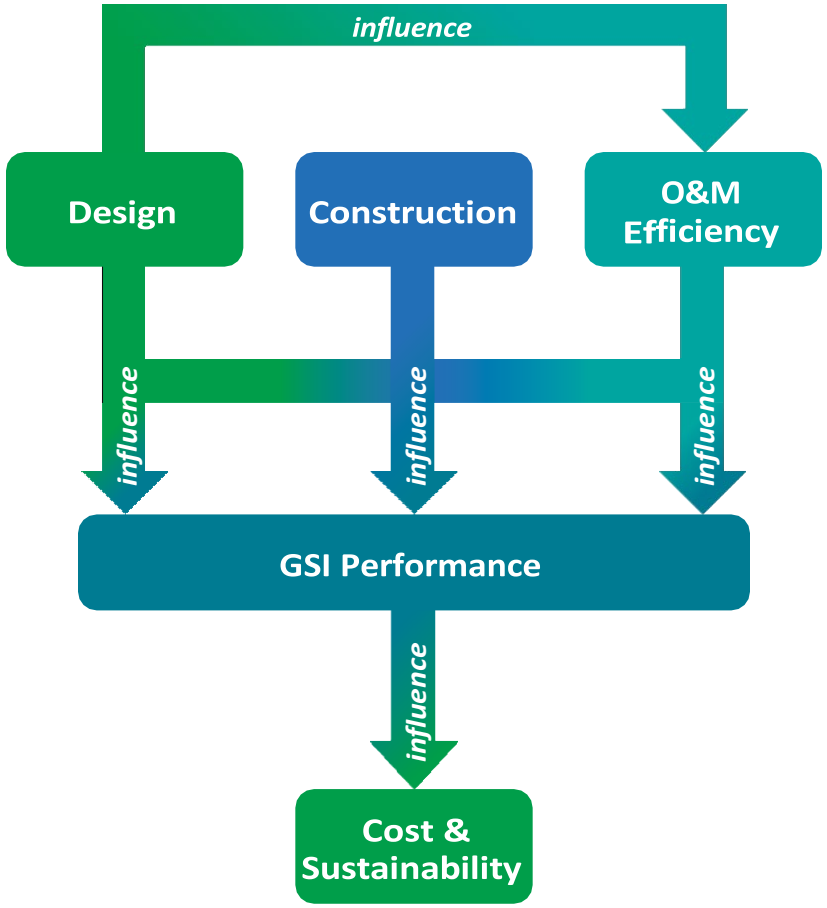
Municipal stormwater programs have been installing GSI for several decades. In contrast to gray infrastructure, which relies on piped networks and engineered components to convey stormwater, GSI instead depends on natural physical, chemical, and biological processes to manage stormwater quality and quantity.

GSI, the term used in this handbook, is synonymous with the term **green infrastructure** defined in the Clean Water Act[1] (CWA) as the range of measures that use plant or soil systems; permeable pavement or other permeable surfaces or substrates; stormwater harvest and reuse; or landscaping elements to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters. Some use other terms to reference the same practices as **green infrastructure for stormwater management**. Other terms include **low impact development**, **natural infrastructure**, and **nature-based solutions**. The definitions of these terms might vary slightly among organizations and industry professionals; however, these concepts are generally captured in the CWA definition of green infrastructure. GSI and green infrastructure are both terms used in planning and research to achieve various ecosystem services.

Bioretention is one of the most popular GSI practices implemented in urban areas. For example, as explained in the GAO's 2017 report, *Stormwater Management: EPA Pilot Project to Increase Use of Green Infrastructure Could Benefit from Documenting Collaborative Agreements*, a survey found that



Influence of design and post-design phases on GSI performance, cost, and sustainability

[1] Water Infrastructure Improvement Act, 2019. https://www.congress.gov/115/plaws/publ436/PLAW-115publ436.pdf

municipalities most frequently installed, encouraged, or required three main types of GSI: downspout disconnection, bioretention (also referred to as rain gardens), and permeable pavements (GAO 2017). A correctly designed, constructed, and maintained GSI practice can be a more effective, economical, and sustainable choice over its service life when compared to gray infrastructure (TNC and TX A&M 2021).

Despite the popularity of GSI, the 2017 GAO report noted that 15 of the 27 municipalities surveyed reported that less than 5% of the area subject to their municipal stormwater permit or consent decree drained into GSI. The remaining area drained into either gray infrastructure (i.e., combined or storm sewers) or directly into receiving waters. Municipalities indicated that implementing some GSI tasks were more challenging compared to gray infrastructure, including developing capital expenditure, identifying operation and maintenance (O&M) costs, and designing practices (GAO 2017).

The overarching goal of this bioretention design handbook—referred to as "the handbook" throughout this document—is to help you successfully implement bioretention projects. In addition to sharing lessons learned from across the country, the handbook offers recommendations for design, construction, inspection, and O&M practices that will help you achieve performance goals, reduce project costs, and effectively integrate bioretention into your built environments. We will highlight common obstacles that can cause a project to incur added expenses. For example, undersized inlets can lead to runoff bypassing the system and require reconstruction. The top photo shows an inlet that was constructed incorrectly without a drop in elevation; as a result, runoff ponds at the inlet. The bottom photo shows an inlet constructed with a change in grade between the roadside and the practice; it functions properly during a storm.

Darren Distefano

Incorrectly installed inlet.

NYC Department of Environmental Protection

A well-designed inlet.

Robert Goo

A street-side bioretention planter in Washington, DC.

The second overarching goal of the handbook is to promote adaptive management in GSI projects. Adaptive management is the process of observing how a system performs over time and using that knowledge to adapt O&M strategies, retrofits, or future designs. Applying adaptive management can also extend beyond the physical boundary of a GSI site. Incorporating lessons learned can improve future GSI implementation in public settings, enhancing social benefits such as green space.

This handbook is intended for a multidisciplinary audience of GSI professionals, including design professionals, municipal officials, developers, planners, contractors, and inspectors across states, territories, and Tribes.[2] This document compiles current knowledge from published resources detailing how to approach bioretention design and post-construction activities. As recognized in the acknowledgments, this handbook also conveys the experiences and expertise of many municipalities and GSI practitioners who generously shared information during interviews and site visits.

Bioretention facilities used throughout this document encompass bioretention, rain gardens, bioswales, bioretention planters/boxes, and tree pits. Design elements specific to each of these practices are called out when applicable. As highlighted later in the handbook, GSI offers benefits beyond stormwater control—it can also be implemented for programmatic reasons, such as traffic calming, urban greening, carbon sequestration, and heat island mitigation.

[2] For the purposes of this handbook, Tribe is used as a collective term encompassing Tribes, Nations, Pueblos, and other similar entities.

1.2 Handbook Organization

The handbook includes three parts, described in detail below. Chapters 1–3 offer background information. Chapters 4–12 describe the GSI design phase, and Chapters 13–14 discuss the GSI post-construction phase.

Part 1: Introduction – Provides background details:

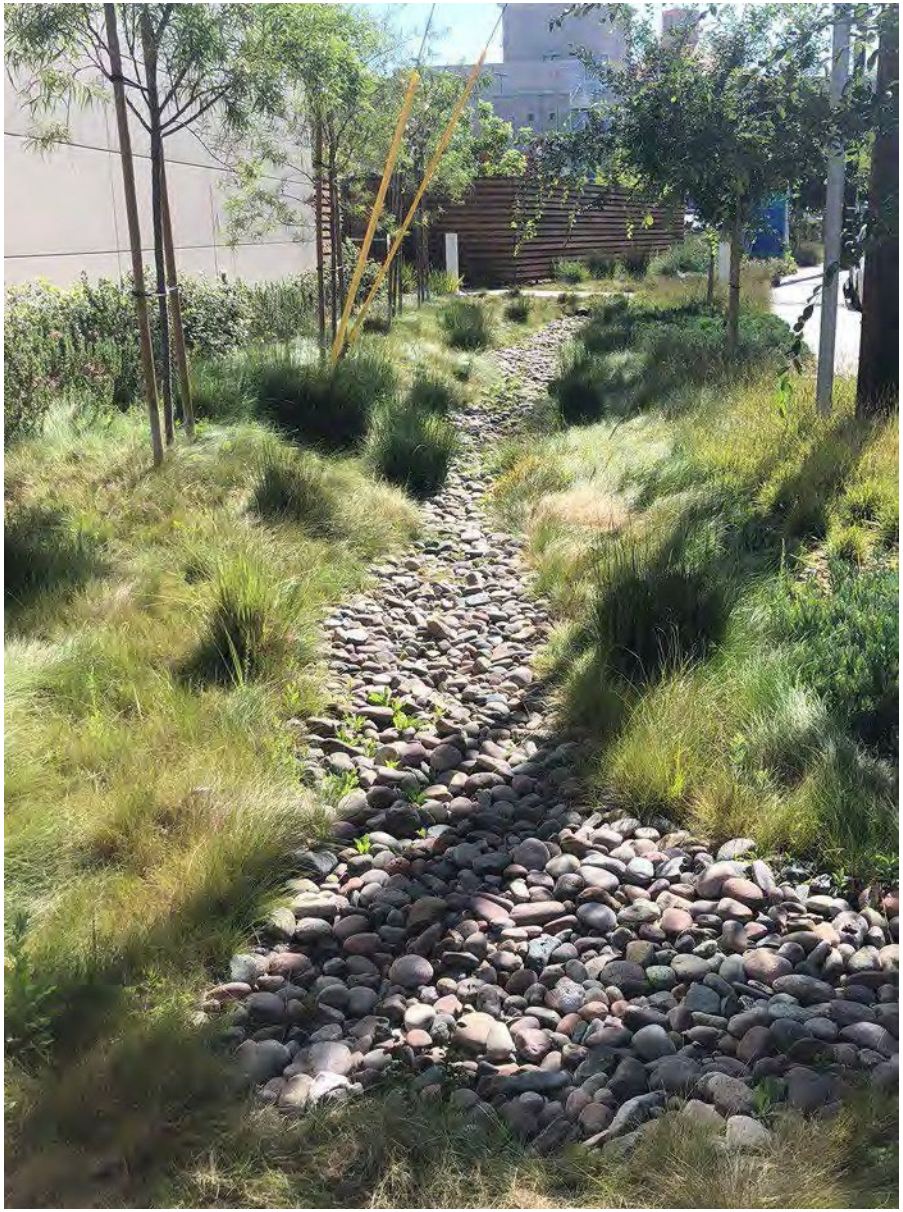
- Chapter 1: Handbook Introduction
- Chapter 2: Bioretention Design Elements
- Chapter 3: Holistic Design Concepts

Part 2: Design Phase – Describes various design considerations and lessons learned:

- Chapter 4: Managing Drainage Areas
- Chapter 5: Bioretention Geometry and Sizing
- Chapter 6: Runoff Capture
- Chapter 7: Pretreatment
- Chapter 8: Bioretention Media
- Chapter 9: Vegetation
- Chapter 10: Underdrains and Outflows
- Chapter 11: Multimodal Transportation and Public Safety
- Chapter 12: Promoting Community Acceptance

Part 3: Post-Construction Phase – Describes post-design considerations:

- Chapter 13: Managing the Construction Process
- Chapter 14: Long-Term O&M and Asset Management



Rhea Thompson

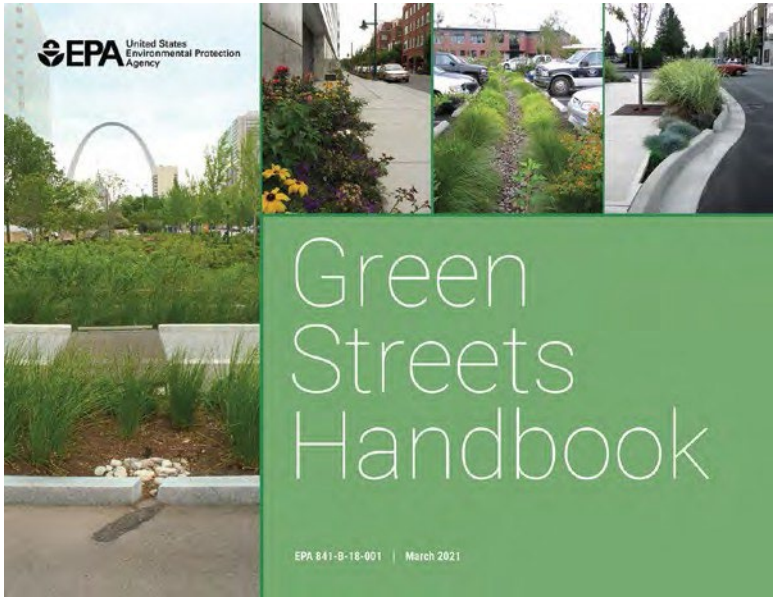
Bioretention in San Diego, CA.

1.3 Using the Handbook

This design handbook complements EPA's *Green Streets Handbook*, which guides state and local transportation agencies, municipal officials, tribal staff, designers, stakeholders, and others as they select, design, and implement site design strategies and GSI facilities for streets, alleys, and parking lots.

This design handbook focuses on efforts to implement bioretention in right-of-way (ROW) areas for stormwater management. Using ROWs for GSI alleviates concerns about access and O&M because these areas are already under the municipality's control. However, the *State of the Public Sector Green Stormwater Infrastructure 2022* surveyed 52 public sector entities and found that the GSI they implemented in the public ROW accounted for less than a third of acres they managed compared to projects implemented on parcels and redevelopment projects (Greenprint Partners 2022a). The report also notes that GSI in the public ROW is an expected growth area between 2022 and 2027. This handbook aims to expand the use of ROWs for GSI.

This document is not a design manual; instead, it provides recommendations and resources for bioretention design approaches—especially where technical expertise might be lacking. Furthermore, this document does not replace construction, inspection, or O&M manuals, which are necessary to ensure project success. Planning and design professionals are responsible for developing projects using sound judgment and following applicable laws and regulations. Always consult local or municipal specifications for design, construction, and O&M.



EPA's *Green Streets Handbook* focuses on GSI in transportation networks.

Portland Bureau of Environmental Services

Street-side bioretention in Portland, OR.

Purchase this course to see the remainder of the technical materials.