BOSTON PARKS AND RECREATION

GREEN STORMWATER INFRASTRUCTURE
DESIGN AND IMPLEMENTATION GUIDE

BOSTON PARKS & RECREATION

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Overview

Boston Parks and Recreation Department operated and maintained facilities:

217 city parks, playgrounds and athletic fields, two golf courses, 65 squares, 17 fountains, 75 sports courts, 16 historic and three active cemeteries, approximately 209 acres of urban wilds and natural areas, four High School Athletic Fields, and approximately 125,000 trees.

The City of Boston is the home to some of the oldest parks in the United States. The Public Garden is the country's first public botanical garden, and the Boston Common is the first public park. Frederick Law Olmsted's Emerald Necklace park system passes through many Boston neighborhoods and can be considered the city's first green stormwater infrastructure (GSI) project. His brilliant stormwater management system has connected people to nature for over 100 years and serves as a prime example of the importance of incorporating GSI into parks and vice versa.

The types of properties managed by the Boston Parks and Recreation Department (BPRD) are diverse. Parks vary by scale, use, age, and surrounding contexts and communities. They also represent many things to those communities such as places to gather, play, exercise, recreate and to connect to nature. Such an assorted set of public spaces creates challenges as well as opportunities to create multi-functional parks.

As climate change introduces new constraints and threats to Boston, resiliency has been identified as a city-wide goal. BPRD is looking to advance the implementation of GSI strategies to meet resiliency, livability and health goals. These efforts support recommendations in BPRD's Open Space & Recreation Plan 2015-2021, as well as the 2014 Climate Action Plan and on-going Climate Ready Boston Planning Initiative.

Photo credits on cover, left to right: Central Square in East Boston (KMDG), Hernandez Boston Public School (HWG), Fisher Hill Reservoir Park (KMDG). Photo credits on opposite page, clockwise starting top left: Boston Commons, Millennium Park (BRR), Basketball Courts (BRR), Franklin Square, children playing (BRR), Soldiers and Sailors Monument, George Wright Golf Course, and Brighton Common.

HOW TO USE THIS GUIDE

The GSI Implementation and Design Guide (the Guide) is intended to assist BPRD staff, as well as partnering city agencies and park consultants, to design, implement and maintain more resilient, multi-functional parks that maximize benefits to park users and the environment. To accomplish this goal, the Guide is divided into the following four sections: Background, Goals & Benefits, Design Process and Implementation.

Background

GSI can help reach city-wide environmental protection and equity goals, cultivate partnerships, and provide inter-agency and community co-benefits.

Existing Boston-specific policies, plans and studies that include GSI strategies were reviewed to identify shared inter-agency goals related to resiliency and GSI. This first section also includes a case study review and assessment of existing GSI park programs in similar cities, including NYC, Philadelphia, Seattle, Chicago and Portland (Oregon).

Goals & Benefits

GSI can be used as an "engine" to meet park goals and provide multi-functional benefits in future park improvement projects.

Based upon the information gathered from the precedent case studies, relevant document review, and BPRD staff input, GSI goals and multi-functional benefits were identified, specific to implementation within Boston parks. These goals and benefits should be considered when beginning any park improvements project.

Design Process

GSI design must be adapted to different park environments as well as address the opportunities and challenges of implementing GSI in a variety of park contexts.

Both the background information and the identified goals are used as the framework for the development of a park-specific GSI selection and design process. This section includes five steps to guide the location, selection, design, and construction of the most applicable GSI practices for BPRD-managed properties.

Step 1: Determine the GSI Objectives

Step 2: Identify the Park Context

Step 3: Perform a Site Analysis

Step 4: Select a Pretreatment and GSI Practice(s)

Step 5: Design and Construct

To assist with the design process, this section also includes information sheets and reference matrices for 21 typical GSI practices suitable for parks.

Lastly, a system of icons and maintenance tiers is used throughout this section for quick reference between steps. Icons are provided for Context, GSI Practices, and Pretreatment Types.

Implementation

GSI designers and BPRD staff must assess the capacity for financing, designing, building, and maintaining these projects, as well as conducting thorough outreach and engagement. If there are resource gaps within agencies, other government agencies or existing partners may be able to contribute.

To help guide the implementation of GSI within Boston parks, potential partnerships between city agencies and funding sources are identified in this section. Public outreach is encouraged to better connect people to GSI and educate the public on its importance and function.

A GIS-based prioritization and mapping analysis of the BPRD-managed parks within the city is provided to identify priority parks for GSI implementation.

Appendices

A. Plant Matrix

A plant matrix to assist with selecting species that can tolerate various site conditions for different GSI practices.

B. Sample Maintenance Plan

A sample plan that includes GSI maintenance tasks and schedules.

C. Precedent Study

Relevant literature and case studies initially compiled to help frame the guiding principles for the GSI goals and Guide.

Community members learn about different kinds of permeable surfaces at the "Discover Moakley" park festival.

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Background

INTRODUCTION

On average, Boston receives approximately 44 inches of rain per year, much of which becomes stormwater runoff that moves across impervious surfaces and flows untreated into our waterways, degrading the city's natural resources.

The decline in water quality to the city's waterways led to a legal consent decree settlement between the U.S. Environmental Protection Agency (EPA), the Department of Justice (DOJ), Massachusetts Department of Environmental Protection (MassDEP), Conservation Law Foundation (CLF) and Boston Water and Sewer Commission (BWSC). As a result of this settlement, BWSC requires reconstruction projects connected to the city's drainage network to retain and infiltrate the runoff from small, frequent storm events (currently, the target is 1 inch) on site prior to discharging to a storm drain or a combined sewer system.

To meet this requirement, BWSC encourages the use of GSI practices. GSI captures the stormwater at its source and mimics natural processes to store, infiltrate, and/or filter stormwater in large and small, surface and subsurface spaces.

"Under this settlement, the City of Boston will use green infrastructure and low-impact techniques to control pollutants being discharged in its stormwater to local beaches, rivers and streams, benefiting all residents of Boston who enjoy outdoor recreation in the Hub."

Curt Spaulding EPA, Dept. of Justice, Settlement Press Release, Aug. 2012

Climate projections indicate that average annual precipitation in the Northeast will rise as the intensity and frequency of extreme storms increase and produce large quantities of rain in a short period of time. Not only will this increase flooding in low lying areas and decrease water quality within the city, but it will also impact the quality of the city's cherished parks and open spaces.

To add to this challenge, Boston's population is increasing. According to Imagine Boston 2030, projections indicate a population of 724,000 by 2030, up from 656,000 in 2014. Adding more people to the city's already dense urban spaces raises complex planning questions and places additional demands on limited infrastructure funds and usable open space.

"From 1958 to 2010, there was a 70% increase in the amount of precipitation that fell on the days with the heaviest precipitation. This increase is greater in the Northeast than for any other region of the country."

Climate Ready Boston (2016)

This increased demand on the use of available open space, coupled with the threats from climate change and the associated sea level rise, places a significant burden on the current open spaces within the city. BPRD seeks opportunities to expand the capacity and open space benefits of the park system to improve the quality of life and well-being of all city residents. GSI can contribute to this by ensuring that parks are well-drained and usable, adding vegetation to increase ornamental value, biodiversity and shade, introducing new landscape types for beautification and education, and engaging constituents in understanding and stewarding their local open spaces. Landscape diversification and layering of uses maximizes open space value and allows GSI to be integrated into parks in ways that don't take away from other uses or limit future flexibility of park programs.

The Boston Water and Sewer Commission in collaboration with other city departments, including Boston Public Works, Boston Public Schools, Boston Transportation, Boston Parks and Recreation, and the Boston Planning & Development Agency has undertaken several GSI projects throughout the city to demonstrate "green" alternatives to traditional "grey" stormwater management.

Boston Water and Sewer Commission website

CITY-WIDE GSI IMPLEMENTATION

The first task in the development of the Guide was to review relevant City of Boston reports on climate change, resiliency and open space plans. Table 1 summarizes the reports reviewed and topics covered, specifically related to GSI planning, implementation, and maintenance.

In general, the documents from BPRD's partner agencies indicate that GSI is an important part of the city's climate change adaptation and resiliency plans. GSI has been identified as a priority across the various departments and agencies; in particular, as GSI relates to increasing the city's resilience to climate change and extreme weather.

Throughout these reports, BPRD is identified as a key partner to help increase the city's resilience. Currently, stormwater management in Boston parks is implemented on an ad-hoc basis. As the department responsible for the management of over 2,000 acres of land in the city, it is essential that BPRD look for ways to increase stormwater management and infiltration within these properties.

As a manager of over 2,000 acres of land within the city, BPRD has been identified as a key partner to help meet the city's resilience initiatives. While implementation of park GSI has previously been ad hoc, future implementation should carefully balance stormwater management with BPRD's current mission of providing open space and recreational opportunities for the public. With this in mind, accepting non-park stormwater within park properties becomes a challenge for not only current park capacities but also for meeting the Department's primary mission. As Boston moves towards city-wide resiliency, it becomes even more critical for interdepartmental collaboration, resource sharing and establishing sustainable solutions.

Table 1. Reviewed City of Boston Reports

Relevant Report	GSI Topic and BPRD Roles
City of Boston Climate Vulnerability Assessment	*Discussion of Boston's most significant vulnerabilities/hazards: extreme heat, stormwater flooding, and coastal/riverine flooding.*
Enhancing Resilience in Boston: A Guide for Large Buildings and Institutions - Feb 2015	*GSI and other resilience fact sheets; case studies included.*
Boston Green Links Map	*GIS data relevant for current, planned, and future greenspace projects.*
Boston Complete Streets Report	*Significant discussion of BPRD's role in GSI, planning and maintenance.*
Boston Open Space and Recreation Plan	*BPRD goals and objectives related to GSI in parks, improvements, and interconnections with other City-department led projects.*
Greenovate Boston – 2014 Climate Action Plan Update	*Discussion of GSI as it relates to climate preparedness, flood protection and improved water quality.*
City of Boston Climate Resilience Initiatives	*GSI's role in managing stormwater and mitigating urban heat. BPRD's role in using GSI to improve aesthetics and stormwater management in the public right-of-way and on public lands.*
Imagine Boston 2030	*Creating and planning for increased population in Boston's waterfront areas.*
CRWA Green Street Guidelines for Allston Brighton	*Park accessibility and equity; references to BPRD street tree requirements.*

PARK GSI CASE STUDIES

As part of the development of the Guide, and to better understand the programmatic structure and implementation of GSI in parks and open spaces, park GSI implementation in five U.S. cities was analyzed – New York City, Philadelphia, Seattle, Portland, and Chicago. A summary of this analysis is included in Appendix C. The lessons learned from these case studies should help guide GSI not only in the Boston park system but throughout the city, as discussed further below.

Lessons Learned and Recommendations

Some lessons learned were consistent throughout the case study research and report reviews. As BPRD discusses a comprehensive GSI network in Boston with other agency partners, the following lessons learned and recommendations can be applied.

Understand Intended Park Uses

Understanding how community members and neighbors utilize park space is a critical consideration when siting a GSI project. Park GSI designers must first understand current use in order to effectively design GSI to ensure continued appropriate use of the space.

Connect People with GSI

Public outreach to educate park users on the benefits of GSI can increase public support and acceptance. Implementing GSI in parks and public rights-of-way (ROWs) is a departure from what many people traditionally view as stormwater management. Traditional or grey infrastructure practices have historically been "out of sight" or underground. Using GSI to manage stormwater brings the system closer to the public view and requires strong communication.

Through public meeting processes and interpretive signage, the benefits of GSI to the community can be communicated to the public. Fostering a better understanding of natural, hydrologic processes and re-connecting the urban population with nature can have long lasting effects. Once the public understands the correlation between GSI and visible improvements in habitat, biodiversity, and water quality, they may be more likely to support funding for future projects and may also be interested in volunteering to maintain the GSI practice. Public outreach can also be a resource in the form of accessing community expertise and knowledge and building relationships to solve future problems.

City staff from Portland and Chicago indicated that public acceptance and even a sense of ownership of GSI projects is attributable to public education and outreach and suggested that outreach occur long before construction of a GSI practice even begins.

Leverage Partnerships

Strategic partnerships and cooperation among different agencies with shared goals were identified as essential to long-term success. Therefore, the current effort by the city to have a GSI working group to share information and knowledge, comprised of the Boston Planning and Development Agency, Boston Transportation, Environment and Public Works Departments, BWSC, Boston Public Schools, as well as BPRD, should be continued and expanded to develop standardized GSI details, specifications, and comprehensive maintenance protocols. A GSI network encourages the various participating agencies to seek partnerships for GSI design, implementation, and maintenance. Those partnerships can also be used to leverage funding for park improvements and maintenance.

GSI projects can be expensive. The case study cities found that the most cost-effective way to implement GSI is to integrate it with other planned or needed public improvements (e.g., park renovations, street repairs, ADA accessibility upgrades, utility repairs, etc.). Often times, this requires the inter-department partnerships discussed above and results in a win-win for everyone involved. Not only can this greatly reduce total GSI costs, but it will directly tie GSI to improved neighborhoods, access, safety, and overall public experience.

Partnering with agencies can also be used to share the long-term maintenance responsibilities for GSI. Too often, however, GSI practices are installed, but the finer details regarding who will maintain them, what type of equipment is needed and how much and how often maintenance should occur, are not always clearly defined. A common lesson learned from the case study cities was that while benefits of improved stormwater management are often obvious for these shared projects, financial obligations and maintenance responsibilities need to be clarified and agreed upon before any project begins to avoid issues down the road.

Consider Creative Funding and Financing

Both funding and financing strategies should be considered for GSI implementation. Funding for GSI can be complicated, and cities often rely on grant funding from agencies like EPA in order to supplement funding for construction. NYC in particular has succeeded in leveraging grant funding for GSI projects when they are tied to monitoring the improvements (e.g., better water quality, improved drainage). Most of the case study cities paid for GSI through their general funds, but some cities have stormwater fees or a "stormwater utility" to provide an additional funding source to help with both construction and long-term maintenance costs.

Large-scale GSI construction often needs not only a long-term funding source but also short-term financing. Financing strategies include utilizing subsidized loans (e.g., state revolving funds), municipal bonds/non-subsidized loans, and public private partnerships such as impact investment.

Portland's Bureau of Environmental Services (BES) has a stormwater utility that funds both green and grey infrastructure projects. The estimated average single-family monthly stormwater fee is $30 and pays for stormwater treatment, operation, and maintenance of stormwater management facilities. The annual revenue from this fee is approximately $140 million[2]. This funding is dedicated for BES projects, but it can be used for park projects when the parks department partners with BES.

2 *City of Portland Bureau of Environmental Services Fiscal Year 2019-20 Requested Budget*

Based on the research and case study findings, the Guide is structured to address BPRD shared goals and incorporate the recommendations into the Goals & Benefits, Design Process and Implementation sections. The Guide was developed by applying past lessons learned to help BPRD and city partners address design, maintenance, construction, monitoring, partnering and funding considerations for GSI practices.

Goals & Benefits

BPRD GSI GOALS & BENEFITS:

1. ***Improve climate resiliency***
    - Promote rainwater reuse and recharge
    - Adapt to increased flooding
    - Reduce impervious cover & heat islands
2. ***Improve livability and health***
    - Connect people to nature
    - Improve drainage and water quality within parks
    - Increase green spaces and aesthetics
    - Improve air quality
    - Improve habitat value

INTRODUCTION

The two main goals identified for the implementation of GSI within Boston parks are based upon the shared interest, benefits, and recommendations from the following documents and sources:

- Boston Open Space and Recreation Plan
- Climate Ready Boston
- Imagine Boston 2030
- Greenovate Boston
- Boston Complete Streets
- Trust for Public Land Climate-Smart Cities Tool
- Boston Green Links Map

All of these documents share similar goals to improve flood resiliency, prepare for climate change, and protect and enhance the public's access and use of the city's open spaces and natural resources.

The list on the left outlines the stated BPRD GSI goals and their benefits addressed by this Guide. As discussed throughout this document, the benefits of GSI can vary based on the intended uses of the space and the type of pretreatment and practices selected. Maximizing the ability to achieve multiple goals and benefits can help guide practice selection. A matrix comparing the BPRD benefits to each practice is found in the GSI Pretreatment and Practices section of this document.

Keeping these goals in mind throughout the GSI design process will help create multi-functional landscapes that maintain park uses, while providing benefits that overlap with inter-agency goals of improving climate resiliency, livability, and health throughout the city. How these benefits can be layered onto parks is discussed in greater detail below.

GOAL 1. IMPROVE CLIMATE RESILIENCY

Promote rainwater reuse and recharge infiltration

GSI can be part of a rainwater reuse or recharge system. By using GSI instead of grey infrastructure, stormwater is diverted or kept out of closed pipe networks and directed into both surface and subsurface systems that can store and/or infiltrate water into the ground.

To help facilitate rainwater reuse, GSI storage practices, such as rain barrels and cisterns, can be used to hold a variety of water volumes, dependent upon the intended use. Captured rainwater can be used for lawn and garden irrigation, or toilet flushing which, in turn, helps reduce depletion of our water resources.

Many GSI practices can be designed to infiltrate depending on the site conditions (see Site Analysis under the Design Process). Whether the practice filters the water above ground in the landscape (surface), or stores the water below ground (subsurface), groundwater recharge is a common GSI benefit.

Adapt to increased flooding

The integration of GSI within park designs presents opportunities to create new vibrant spaces that store and infiltrate runoff which can reduce the frequency of flooding. From entire parks designed to store rainwater or absorb rising water elevations, to a series of more discreet landscaped GSI storage practices, utilizing both existing and proposed open spaces to facilitate resiliency does not need to compromise active or passive recreational uses.

Thoughtful and properly designed GSI can provide and enhance valued public open space, recreational opportunities, and improve resiliency. GSI practices can be integrated into existing or new park features and have a range of storage volumes from a small landscape depression to a large series of underground storage chambers. (See Stormwater Park under Implementation.)

Reduce impervious cover & heat islands

Impervious cover includes paved surfaces (i.e., roads, parking lots, paths, walks, plazas, etc.) and the roofs of all buildings and structures. The stormwater runoff created by impervious surfaces can lead to flooding and water pollution.

Impervious cover is also the leading cause of the "urban heat island" effect. Urban heat islands are areas of the city with unnaturally high surface temperatures due to the amount of dark, impervious surfaces that absorb heat. The impacts of this effect include: increased energy consumption from air conditioning, heat-related discomfort and compromised health, and impaired water quality due to elevated temperatures of stormwater runoff.

Reducing both existing and proposed impervious cover can be a cost-effective way to decrease runoff and flooding, improve water quality, increase infiltration and recharge, reduce the heat island effect, open up space for trees to provide additional shade and cooling, as well as improve habitat value.

As pavement reduction often has minimal impact to the overall park design as well as provides multiple benefits, it is considered a GSI practice for the purposes of this Guide. Some park contexts are better suited to pavement reduction than others as discussed in Step 3 of the Design Process.

GOAL 2.
IMPROVE LIVABILITY AND HEALTH

Connect people to nature

GSI provides increased visibility and community engagement opportunities that can better connect park users to their environment and improve their understanding of stormwater management, hydrologic cycles, climate change, and water quality issues.

Converting a wide vehicular road to a smaller pedestrian path in Roger Williams Park created additional green space, a linear wet swale for treating road runoff, an increased vegetated buffer and reduced geese habitat. (Credit: HWG)

Plantings and signage engage visitors with the rain garden at the Rose Kennedy Greenway. (Credit: HWG)

GSI can also be designed as new landscape features, which celebrate and highlight rainwater. Design elements such as stones, weirs, grates, and pavers, as well as a diverse plant palette, can be used to create visually pleasing spaces that allow users to interact with the landscape in new ways.

Educational opportunities that can connect park users with GSI practices include: interpretive and educational signage, natural play areas within and around the GSI practices, pilot restoration projects, tree planting events, and volunteer cleanups. Involving and educating the public about GSI practices helps create support for GSI projects and builds community connections.

Improve drainage and water quality within parks

There are many GSI practices that can be used to improve the drainage within parks by decreasing impervious surfaces and promoting infiltration. Improved drainage has the additional benefit of reducing the maintenance and cleanup required after storm events and increasing access by reducing ponding and flooding that can make areas impassable or even unusable.

Untreated stormwater pollutes the city's valuable water resources such as lakes, ponds, streams and rivers with bacteria, nutrients, and other pollutants. Waterbodies that cannot support desired uses because of poor water quality are designated as impaired. These impaired waterbodies pose health risks to the community and can become unusable. GSI can help to improve and restore these resources, improving the livability and general health of the community.

Instead of piping runoff straight into water resources, GSI practices can intercept polluted stormwater and treat it prior to discharge, improving water quality. Surface GSI practices use plants and soil as filters, which maximize the benefits of a multi-functional space as noted below. GSI practices enhance the quality of the water bodies in parks and other areas in and around the city, improving public health.

Increase green spaces and aesthetics

Green space refers to land that is vegetated. Pavement reduction and the use of permeable surfaces that supports plant growth can increase green space around the city. Though some GSI practices may only take up a minimal amount of area, by incorporating them throughout the city, a substantial amount of additional green space can be created.

GSI can also be used to improve aesthetics by adding plants, tree canopy, and buffers that create healthy plant communities and wildlife habitats along the water's edge, around ball parks and even within parking lots and ROWs.

GSI also presents a unique opportunity to partner with other city agencies to identify and acquire new properties that are designed to provide both stormwater management and additional green space. By helping to provide the city's residents beautiful, multi-functional parks, GSI promotes physical and mental health and community connectivity.

Improve air quality

Trees and other plants help reduce air pollution by sequestering carbon dioxide via photosynthesis and intercepting and absorbing gaseous air pollution. Protecting and increasing the tree canopy/urban forest utilizes the benefits of trees for public health.

GSI can result in the reduction of pavement and an increase in plantable areas, in particular in ROWs and parking lots. Although space may be limited, these areas can be amenable to growing a diverse selection of plants, appropriate to the context. Plants can be specifically selected to help mitigate air pollution as well as provide stormwater treatment.

Some GSI practices can be located in underutilized lawn areas within a park and eliminate or decrease the need to mow, thereby reducing air pollution caused by equipment exhaust.

Improve habitat value

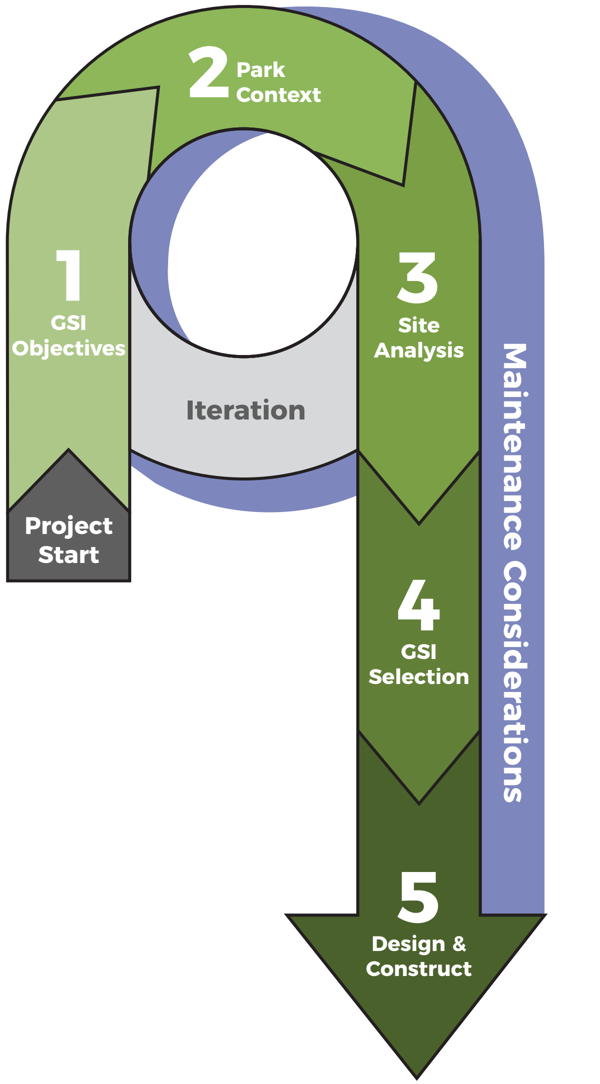
GSI can be designed to support a variety of plant communities that improve the habitat value for different species, such as pollinators and birds. Habitat improvements can also be attributed to the GSI benefits of improved water quality, a reduced urban heat island, and habitat connectivity. For more information, see the planting recommendations in Appendix A.

Canopy trees create a welcoming environment with shade and buffers from the street for visitors to the Farmer's Market at Adam's Park in Roslindale. Not only do they increase aesthetics, they improve air quality, habitat value and soak up stormwater. (Credit: KZLA)

Design Process

(Credit: KMDG)

STEPS



INTRODUCTION

GSI selection and design is based on a five step process developed to ensure that current park use, BPRD goals, GSI objectives, and maintenance capabilities are considered throughout the design process. These steps were developed based on BPRD staff input and priorities as they relate to the implementation of GSI within the parks. It is important to remember that GSI design, like all good design, is iterative and objectives can change based upon information gathered during the process.

Given that BPRD manages such diverse public spaces, the design process is not intended to be prescriptive, but rather to encourage creative, multi-functional design solutions specific to each project's needs and budget. Guidance pertaining to sizing criteria, engineering formulas, construction details, and regulatory requirements specific to each practice are not included in the Guide. Refer to the Massachusetts Stormwater Handbook and Stormwater Standards, BWSC Stormwater Best Management Practices: Guidance Document as well as other local regulatory documents and resources for specific design, details, and engineering requirements.

"There is a growing need for parks to accommodate a variety of activities, purposes, and user groups. Parks are increasingly being designed or redesigned to allow for flexible, multi-purpose program space."

NRPA Resource Guide for Planning, Designing and Implementing Green Infrastructure in Parks

DESIGN PROCESS STEPS

STEP 1: Determine GSI Objectives

In order to maximize the multi-functionality of park spaces, the Goals and Benefits as outlined in this Guide should be reviewed at the start of every project. Project-specific objectives and GSI opportunities should then be discussed with and determined by BPRD staff. During this first step, clear design objectives (e.g., potential partnerships, the project budget, fixing existing drainage problems) and maintenance responsibilities and expectations are established.

STEP 2: Identify the Park Context

The park context and use need to be considered on a project-specific basis to determine where GSI may be best suited and ensure that desired recreational uses are not compromised by the addition of GSI.

Park context, as it relates to this Guide, refers to areas within a park that have a specific function, user experience, and environment. Depending upon the park size and location, some parks may be comprised of one or more contexts.

GSI is most successful when it is integrated into the surrounding context and the corresponding uses and aesthetics are considered. Implementing GSI does not necessitate changing the program or character of a site; in fact, proper siting of GSI can enhance the park experience by providing additional benefits beyond stormwater treatment such as habitat creation, healthier plant communities, and improved aesthetics. Understanding the required maintenance for the park context(s) can also help guide practice selection.

For the purpose of this Guide, 12 park contexts have been identified (see Icons section below). Specific GSI considerations for each of the contexts are described in this step.

STEP 3: Perform a Site Analysis

A comprehensive site analysis is critical to proper GSI selection and design. The following factors should be considered before the final selection and design of any GSI practice:

- Watershed and Receiving Waters
- Contributing Drainage Area
- Water Table
- Soils
- Vegetation
- Utilities
- Topography
- Buildings

This step also requires identifying special conditions, additional constraints, and potential opportunities unique to working within parks, such as:

- Trees
- Historic Parks
- Floodable Areas
- Natural Depressions
- Golf Courses

STEP 4: Select the Pretreatment & GSI Practice(s)

The information gathered in steps 2 and 3 is used to refine the GSI objectives in step 1, helping to ensure the most appropriate practice(s) are selected for that project. Most projects will have multiple GSI options. For final GSI practice selection, those options should be filtered based on the updated objectives and data gathered in steps 1-3.

In this step, information is provided for each of the 21 recommended GSI practices and 4 pretreatment types. Factors such as level of effort for maintenance can be compared to the GSI objectives to further refine the selection. Each information sheet provides a quick summary of the following:

- Advantages and Limitations
- Existing Conditions
- Companion Practices
- Context
- Planning
- Maintenance
- Function
- Design and Implementation

STEP 5: Design & Construct

The last step involves developing design plans and details sufficient for construction. This step reinforces the importance of maintenance considerations throughout the project; from planning all the way to the operation and maintenance after installation. Careful planning and analysis of GSI options and siting can be undone by flawed design details or poor construction workmanship.

MAINTENANCE

The design process steps all play a critical role in GSI practice selection and design, but addressing maintenance is perhaps the most important for long-term success. Too often GSI practices are advanced all the way through design and construction without enough thought given to maintenance along the way. GSI in a public park setting or urban area often needs to be incorporated into an existing specific or designated use and maintenance program. The GSI may be "front and center" in the public eye and located in well-loved spaces. Due to these factors, extra attention needs to be given to maintenance and the impact it will have on both the long-term functionality and appearance of the practice(s). As such, this Guide integrates how to design for maintenance throughout the design process steps.

The level of effort for GSI maintenance can vary and has been classified in this Guide into two tiers:

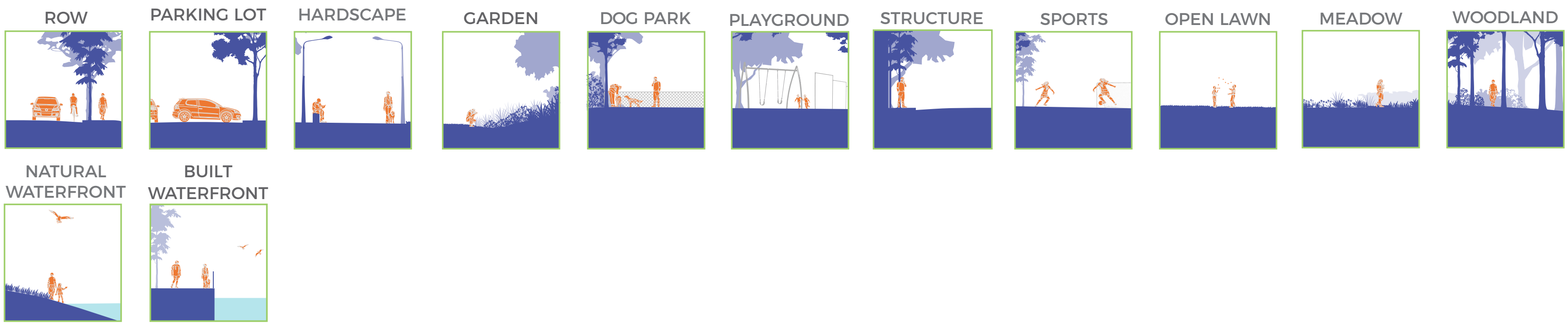
Tier 1. Low to Moderate level of effort (typically done in-house by BPRD staff)

Tier 2. Moderate to high level of effort (typically requires training, an independent contractor, or partners)

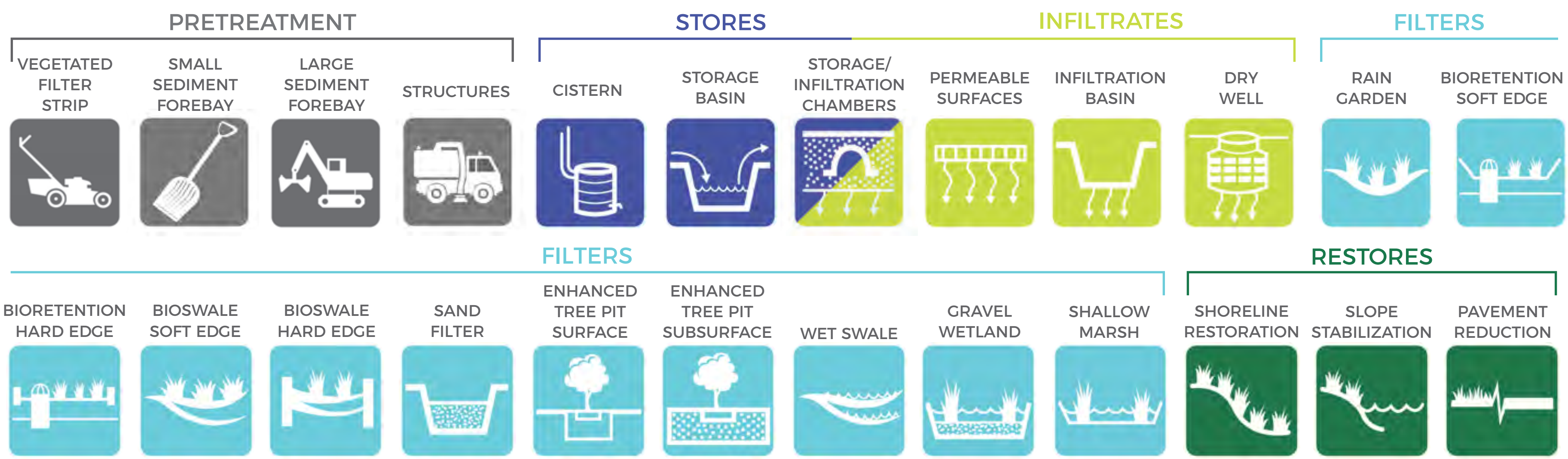
ICONS

Icons are used throughout the design process section for quick reference between the steps. They are categorized by: Park Contexts, Pretreatment, and GSI Practices. The icons are shown below and are described in further detail in Step 2: Park Context, starting on page 24 and Step 4: Pretreatment and GSI Selection, page 62.

Park Contexts



GSI Practices



(Credit: HWG)

STEP 1:

GSI Objectives

STEP 1: GSI Objectives

Bioswale at the Jackson Mann Boston Public School. (Credit: HWG)

Prior to beginning the GSI design, the first step is to meet with BPRD staff, agency partners, identified stakeholders, and any volunteer groups to collaborate on design objectives, maintenance responsibilities, and expectations. Though these GSI objectives may evolve during the design process, the intent of the meeting is to consider the following issues:

DESIGN

- What are the project and GSI priorities?
- Do existing drainage problems exist?
- Are there multi-functional benefits and/or partnering opportunities?
- How much budget is available for GSI and what are the funding sources?
- Is the project area connected or adjacent to a larger city drainage network?
- What type of permitting is necessary (BWSC, DCR, Boston Conservation Commission, Boston Landmarks Commission, others) and is stormwater treatment required?
- How might the park use impact GSI selection and maintenance? (e.g., soil compaction, erosive forces, sedimentation and trash/debris)
- How might the practice and maintenance affect the park user? (e.g., limit activities, impact circulation, create educational opportunities)
- Is there a preferred location(s)?
- How much space is available for GSI?
- Should stormwater be managed at the surface or subsurface?
- Is the project area highly visible and suitable for educational outreach?

MAINTENANCE RESPONSIBILITIES AND EXPECTATIONS

- Who will provide the maintenance?
- What are the maintenance capabilities? (budget, staff, and equipment)
- What are the maintenance and aesthetic expectations? (naturalistic, manicured, mowed)
- Is a maintenance funding partner needed? If so, has one been identified?
- How and where should maintenance access be provided?

- Will snow removal, storage, and de-icing be required? If so, what equipment/materials are preferred/allowed?
- Is monitoring required or desired?

As the design process evolves with each step, the answers to some of these questions may change or become more clear. The outcome of this first step and meeting provides the framework for the GSI design and anticipated maintenance. The objectives should be refined and used by the project team to guide the design decisions and manage expectations.

From top left, clockwise: maintenance of sediment forebay, vacuuming catch basin, educational signage, cleaning out an inlet into a swale. (Credit: HWG)

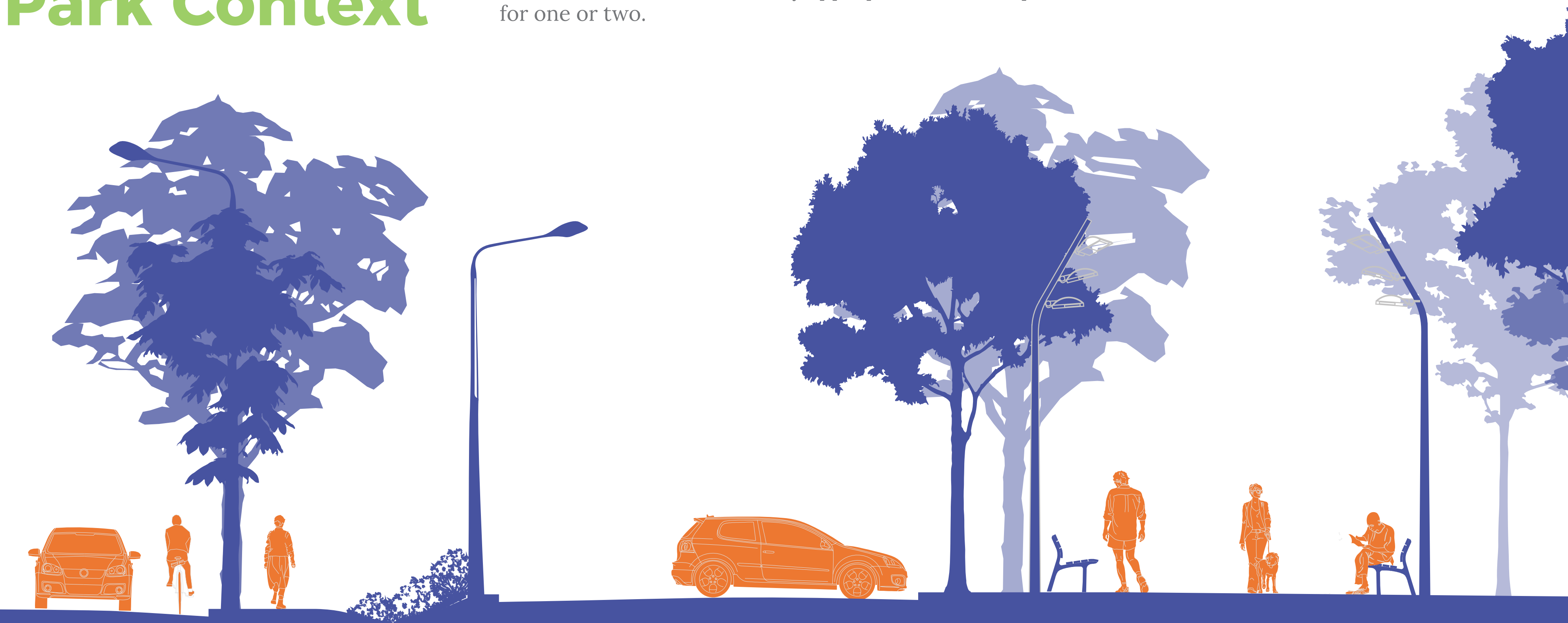
STEP 2:

Park Context

STEP 2:
Park Context

Identifying the context provides valuable information about existing or future uses and considerations for the implementation of GSI. Some practices may fit into many different contexts, while others are only appropriate for one or two.

A park may be categorized as having one context or multiple contexts. To meet BPRD GSI implementation goals, the continued function of various park contexts is imperative.



RIGHT-OF-WAY

Right-of-ways (ROWs) exist along small residential streets to large boulevards or arteries. ROWs can include street curbs, sidewalks, street trees, and landscape edges.

PARKING LOT

Parking lots provide vehicular access and can vary in size and frequency of use. They are usually paved and can include lighting and pedestrian and bicycle infrastructure.

HARDSCAPE

Hardscapes are paved surfaces and include plazas, seating areas, and pathways. These areas typically include amenities such as benches, trash receptacles, bike racks, and lighting.

Acknowledging the context of the park and thinking about how the particular site may evolve sets the stage for making GSI selection and design decisions. Layering functionality enhances the park space and maximizes its potential. Integrating, instead of inserting, GSI into a park will create a more environmentally, economically, and socially sustainable park.

GARDEN

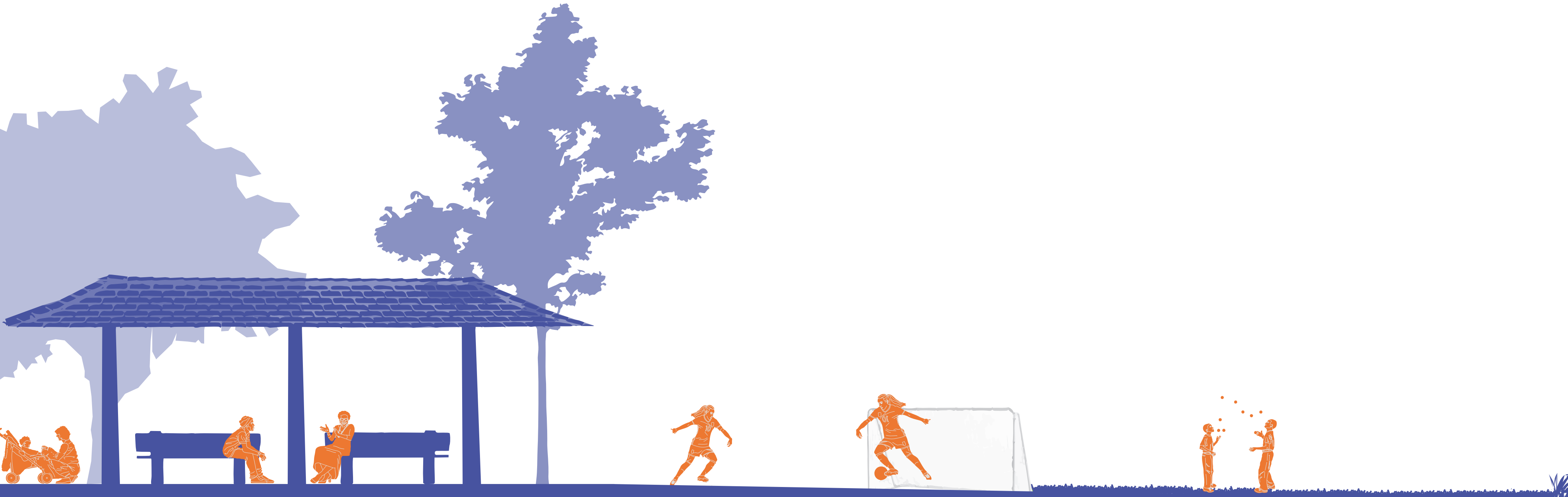
Gardens consist of designed and maintained planting areas. These spaces can include perennial beds, shrubs and woody plantings, or community gardens. They are typically mulched and sometimes irrigated.

DOG PARK

Dog parks are enclosed areas where dogs can play in a secure off-leash environment. Areas vary in size and surface material.

PLAYGROUND

Playgrounds are designated areas for children that can include a wide array of play equipment or splash pads. Areas vary in size and number according to the specific park.



STRUCTURE

Structures are often incorporated into park landscapes as covers for visitor amenities such as shade, seating, or restrooms. They can also include maintenance buildings or structures of historical interest.

SPORTS FACILITIES

Sports facilities are fields and courts that are designated areas for playing a sport or game, such as soccer, baseball, softball, basketball and are typically covered with turf-type grasses (fields) or hardscaped (courts).

OPEN LAWN

Open lawns are typically medium to large areas within a park where visitors participate in passive recreation and informal activities like kite-flying, games, and event gatherings.

MEADOW

Meadows are areas of diverse grass species that are maintained by seasonal or infrequent mowing. They can cover large areas or serve as edge conditions between other spaces.

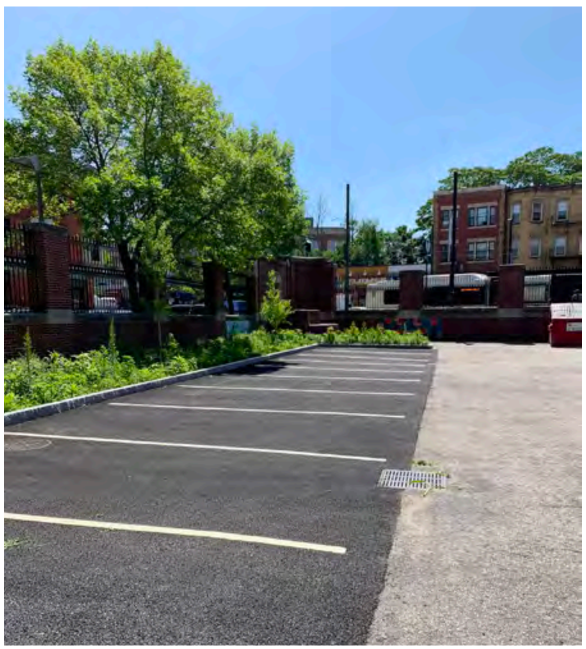
WOODLAND

Woodlands are defined by areas of dense tree plantings, typically with high, closed tree canopy and a sparse understory.

WATERFRONT

Waterfronts are the interface between parks and rivers, ponds, lakes, or the ocean. This context can be further divided into more natural or built environments.

Parking and sidewalks for McConnell Park and Malibu Beach (Credit: HWG)



Porous pavement and enhanced tree pits at Kennedy Academy High School in Boston (Credit: HWG)

The following context sheets (pages 30-42) discuss the GSI considerations unique to each of the 12 park contexts. However, it is important to note that there are some GSI considerations that can be applied to all park contexts. Below is a list of these general overarching considerations for GSI implementation in parks. When the consideration is particularly important to a specific context it is also included on that context page.

General Considerations

Constraints/opportunities

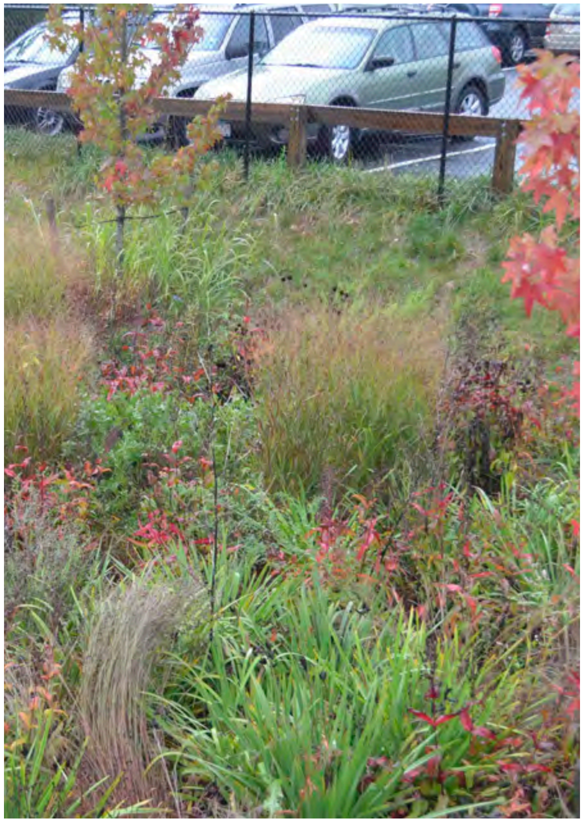
- GSI can be incorporated into any context. Whether it's more appropriate to use filter, store, infiltrate or restore practice(s) depends on the project goals, GSI objectives, and site conditions.
- See Climate Ready Boston and check with local neighborhood officials about existing or forthcoming reports on resiliency planning or other local planning and research reports that may inform decision making on designing the coastal edge.
- Maintain safe pedestrian and vehicular access and circulation when siting GSI.
- For paved areas, select GSI practices that filter prior to infiltration, as many paved surfaces can have high concentrations of salt and contaminated runoff.
- When space is limited for surface practices, consider enhanced tree pits that filter runoff, reduce the urban heat island effect, and provide area for tree roots while using limited surface space.
- When adding new or replacing old paved surfaces, consider permeable surfaces for areas such as sidewalks, multi-use paths, and parking spaces to reduce surface runoff and help move water into the soil or into tree pits or trenches.
- If existing paved surfaces are underutilized, consider reducing the paved areas through parking re-organization, reduced path widths, or elimination of unnecessary pavement.
- Large flat areas such as parking lots and fields can be used for subsurface storage or infiltration to hold and treat a large quantity of water while not altering the existing uses or aesthetics.
- Plan snow storage areas and consider the materials and equipment used for winter maintenance for the hardscapes areas when selecting the GSI practice.
- Consider the potential number of visitors and required access when choosing practices that influence how people move through the space.
- Design for shallow water depth for surface practices to ensure it is not a safety concern or a perceived danger and eliminate the need for fences.

Plants

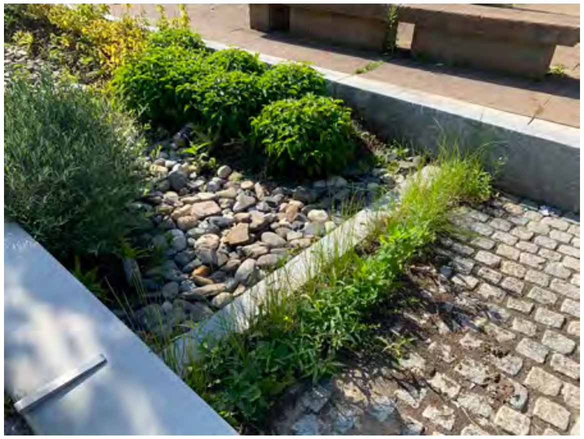
- In general, all plant selection should rely heavily on native, hardy, low maintenance plantings with a demonstrated tolerance for salt, heat, pollutants, and periods of drought.
- Always take into account the mature size of plants and root network to properly address safety, visibility, sight lines, and above and below ground utility conflicts.
- Incorporate trees to best reduce the heat island effect while also providing a buffer, habitat, beautification, and stormwater management. Design for adequate soil volume for mature trees (see the Special Conditions section in Step 3: Site Analysis for more information).
- Within paved areas and hardscapes, consider incorporating structural soils or suspended pavement systems to provide space for tree root growth.
- Water flowing from paved surfaces can be hot and have high levels of pollutants and salt. Use plants in the GSI practice but limit their use in the pretreatment system to avoid the need for frequent replacement.
- Plants can be used to highlight the GSI or blend in with the surrounding area.
- Consider using plants and seed mixes that attract various pollinators when appropriate.
- See Step 3: Site Analysis, Step 5: Design & Construct and Appendix A for more information on plant selection.

Pretreatment & Maintenance

- Consider the sediment and pollutant loading from the contributing impervious areas and existing maintenance practices when selecting and sizing pretreatment.
- Adapt GSI to existing BPRD maintenance practices used within each context.
- GSI is not typically designed for snow storage since de-icing materials can increase the maintenance burden by damaging plants due to salt, or clog the system with sand.
- Provide appropriate access for maintenance vehicles to both surface and subsurface pretreatment and practices.



Plants in a parking lot bioretention area (Credit: HWG)



Sediment forebay at bioswale in front of Jackson Mann Boston Public School (Credit: HWG)

DESIGN PROCESS 2

RIGHT-OF-WAY

Western Ave, Cambridge (Credit: HWG)

Recommended GSI includes:

See page 62 for icon descriptions.

Right-of-ways (ROWs) include paved roads and sidewalks that can produce high volumes of polluted stormwater runoff and are often the interface between the park and the public realm. Due to the limited space within these linear corridors, ROWs can present many GSI design challenges, but can also provide opportunities for creative, effective stormwater management.

Considerations

Constraints/opportunities

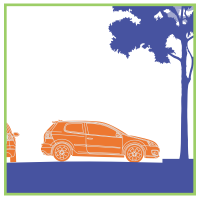
- Integrating GSI into ROWs increases the resiliency of city streets while also increasing livability by the creation of more comfortable, safe, and beautiful corridors for circulation.
- Provides a great opportunity to filter and infiltrate road and/or sidewalk runoff.
- Use GSI to create cooler, comfortable spaces within the ROW and address drainage problems.
- Consider surface GSI such as swales, stepped bioretention areas, or landscaped road bump-outs to create multi-functional areas that can filter, store, and infiltrate runoff as well as provide traffic calming and beautification (See also the *Boston Complete Streets Guidelines*).
- Utility conflicts are often encountered in ROWs and should be identified early in the design process. Consider using a ground penetrating radar (GPR) survey to accurately locate utilities.

Plants

- Along roadway edges consider highly salt and drought tolerant plants, low mow seed mixes, and the use of plugs to allow for infrequent mowing.
- Along streetscapes, consider shorter mature perennial and shrub heights (3' or lower) to maintain pedestrian clearance/access and sight lines.
- Depending on maintenance partners, ROWs provide an opportunity for plant diversity.
- Provide adequate soil volume in tight spaces (structural soils or suspended pavement).
- Coordinate with Public Works when there are existing utilities, especially street lights.

Pretreatment & Maintenance

- Runoff has higher sediment and pollutant loading from vehicles and road salt/sanding.
- Pretreatment can include small sediment forebays that require safe access (Tier 1) or catch basin sumps that include oil/grit separators (Tier 2). Both require regular maintenance.
- Maintenance can vary from simply mowing along a road edge (Tier 1) to hand weeding and cleanup for streetscape practices (Tier 2).
- Relies on partnerships with other city agencies or resident/volunteer groups.



PARKING LOT

Parking lot bioswale at Washington Irving school in Boston (Credit: HWG)

Recommended GSI includes:

See page 62 for icon descriptions.

Parking lots include paved and unpaved surfaces that allow visitor vehicular access to parks. BPRD parks have very few parking lots, but where they exist they can be one of the largest impervious areas within the park, a significant source of pollutants and sediment loading, and increase the heat island effect.

Considerations

Constraints/opportunities

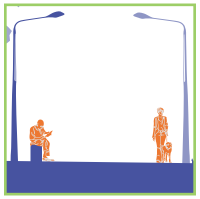
- Surface GSI can be used to add/expand parking lot islands or planting beds, create cooler, more comfortable spaces for park users, and address existing drainage problems.
- Subsurface GSI can be used to store or infiltrate off-site runoff beneath the parking lot.
- When possible, reconfigure parking lot layouts for more efficient use to reduce impervious cover and create additional landscape and/or GSI areas.
- Both impervious and pervious surface materials can be integrated into the parking lot design (e.g., impervious aisles and pervious spaces).
- Consider the overhang of cars and trucks and pedestrian circulation when locating GSI in parking lots.

Plants

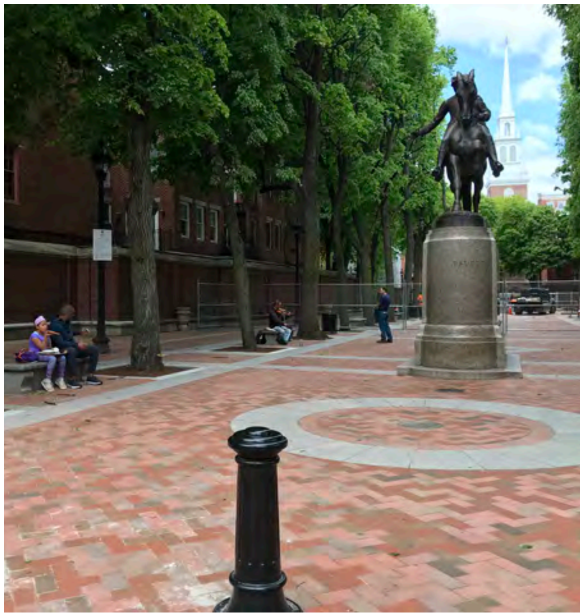
- Use trees along the perimeter and in islands for increased tree canopy cover to intercept rainfall and add shade, reducing the heat island effect.
- For less maintenance, incorporate a naturalized plant palette which can tolerate a harsh environment and mowing and weed-whacking.
- Similar to ROWs, select plants that are highly tolerant of salt, heat, pollutants and long periods of drought.
- Consider the facilities or context the parking lot is serving when selecting plants (e.g., historic, formal building, sports facilities, etc.).

Pretreatment & Maintenance

- Pretreatment can include shovel-ready forebays that require safe access (Tier 1) or catch basin sumps that include oil/grit separators (Tier 2). Both require regular maintenance.
- Runoff has higher sediment and pollutant loading from vehicle tires, leaks, and road salt/sanding, requiring more frequent forebay cleaning.
- Identify snow storage areas to minimize impacts to the GSI practice and lessen maintenance burdens.



HARDSCAPE



Hardscape at Paul Revere Park

Recommended GSI includes:

See page 62 for icon descriptions.

Hardscapes include high pedestrian traffic areas within a park such as paths, plazas, and entryways. These areas are often made up of impervious surfaces with little to no formal on-site stormwater management. Creating multi-functional hardscapes integrates them into park-wide resiliency and beautification efforts.

Considerations

Constraints/opportunities

- Many GSI practices can be utilized with hardscapes, and the surface itself can be designed or retrofitted with permeable surfaces.
- Look for opportunities to reduce paved surfaces to create landscape areas and reduce runoff.
- Highly visible areas that are desirable for public gathering provide the perfect opportunity for demonstration projects, public education, and outreach.
- Blending the site aesthetics into surface GSI practices can be relatively easy in this context through the repetition of hardscape materials and plants.
- Convert existing non-stormwater planters and tree pits into filter practices.
- Subsurface GSI can be used to store or infiltrate runoff beneath the hardscape.
- Use GSI to provide water to trees and shrubs by directing it to their roots or storing it for irrigation.

Plants

- Depending upon existing maintenance, more colorful or showy plantings may be appropriate in this context.
- In general, mature perennial and shrub height should be kept low (3' or lower) to maintain sight lines throughout the space and provide a safe environment.
- Look for opportunities to incorporate trees into the GSI to increase canopy and shade.

Pretreatment & Maintenance

- When selecting a pretreatment type, consider accessibility and vehicular loading requirements for Tier 1 or Tier 2 maintenance.
- Identify snow storage areas to minimize impacts to the GSI practice and lessen maintenance burdens.
- Large accumulation of sediment in forebays can be unsightly, therefore, provide smaller forebays with more frequent cleaning.

GARDEN

Bremen Community Garden *(Credit: BRR)*

Cornell Plantation Bioswale (Credit: HWG)

Recommended GSI includes:

See page 62 for icon descriptions.

Gardens are designed landscape areas that include planting beds of annuals, perennials, or woody vegetation. Typically, these areas are designated by mulched beds, edging or fencing, and have coordinated planting strategies. They are often concentrated around the most highly used or highly visible areas of a park and typically require a higher level of maintenance.

Considerations

Constraints/opportunities

- GSI systems for these areas require careful design to fit into the existing aesthetic and uses but can provide beneficial water reuse, filtering, restoration, and education.
- Incorporate naturalistic shapes such as soft edged swales and rain gardens in informal gardens, while more formal gardens can consider geometric shapes and hard edges.
- Filtering practices should be used since gardens may receive high levels of fertilizer, impacting the quality of the runoff.
- Convert impervious pathways to permeable surfaces.
- Cisterns can be used to collect nearby roof and surface runoff for reuse as irrigation.
- Gardens often provide great opportunities to incorporate GSI interpretative signage for outreach and connecting people to stormwater and nature.

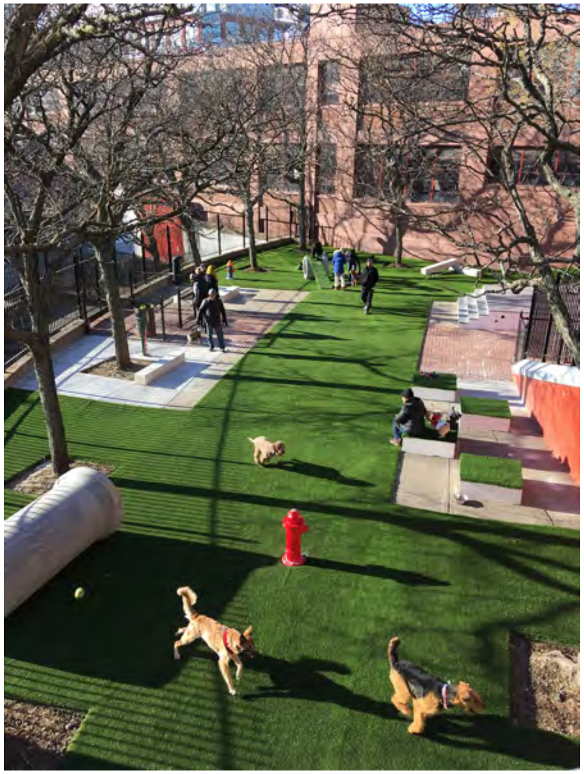
Plants

- Consider the existing species/plant palette and what GSI plants would blend into or enhance the garden's aesthetic.
- The existing maintenance program may allow for a more showy, complex, and diverse plant composition.
- Existing irrigation may increase the range of plants available for use (i.e., less drought tolerant.)

Pretreatment & Maintenance

- To reduce disturbing the existing garden the types of maintenance vehicles may be limited.
- Coordination with BPRD staff and their input is critical to understand the existing maintenance regime.
- The higher level of care and maintenance for gardens may require help and coordination from a volunteer or friends group.
- Depending on the users and type of garden, the visibility of the pretreatment system may be of concern.

DOG PARK



DeFilippo Dog Park

Recommended GSI includes:

See page 62 for icon descriptions.

Dog parks are "off-leash spaces" that provide a safe environment for dog owners to let their dogs play. These spaces help to control conflicting use and sanitation issues often encountered in parks that have high popularity for canines and their owners. Due to the intense concentrated use, dog parks can often be a source of high nutrient and bacteria pollutants. Reducing and/or capturing and filtering stormwater runoff can improve water quality and help keep these spaces healthy for their users.

Considerations

Constraints/opportunities

- Special consideration should be given to grading and incorporating on-site infiltration because the drainage from dog park sites can present significant challenges to water quality.
- Subsurface pretreatment structures can be utilized to avoid damages from dog use.
- Reducing any existing impermeable surfaces and designing to repair and prevent compaction and erosion can help to contain and infiltrate runoff.
- Wet practices are not recommended in areas accessible to dogs to reduce the chance of dogs interacting with ponded stormwater. However, wet practices that are fenced to deter canine and human interaction can be useful in providing treatment for the dog park runoff.
- Due to the potential pollutant loading, water collection and reuse for irrigation should not be used.
- Dog parks are an excellent place for a highly visible practice and signage to educate dog-owners about the effects of dog waste in runoff, what they can do to help, and about GSI.

Plants

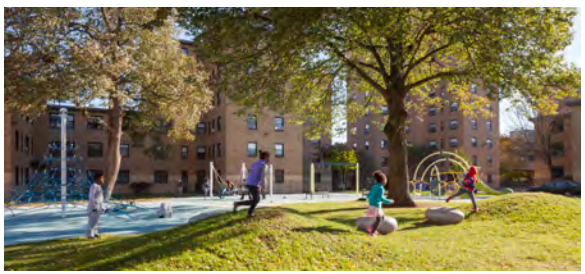
- Use low-growing plants that maintain visibility throughout the park.
- Select plants that are tolerant of the salt, high levels of ammonium in canine urine and that are not poisonous to animals.
- Consider trees for GSI in and around the park for shade and beautification.

Pretreatment & Maintenance

- Provide users clear and easy access to disposal bags and receptacles for dog excrement.
- Due to the odors associated with pet waste and the potential high frequency of maintenance, below ground pretreatment practices (Tier 2) are most applicable.
- Maintenance crews will need to check the waste receptacles and GSI practices frequently to guard against odor and health concerns.

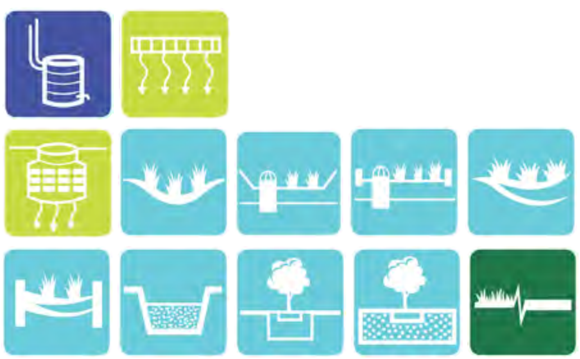
PLAYGROUND

Bremen Spray Fountain (Credit: BRR)



Monsignor Reynolds Playground

Recommended GSI includes:



See page 62 for icon descriptions.

Playgrounds are highly valued by communities and attract many people to a relatively small space. They provide great opportunities for outreach; but must be functional, safe and accessible. Many GSI practices can be appropriately integrated into playgrounds to provide treatment as well as serve as natural play areas.

Considerations

Constraints/opportunities

- Considerations for safety and access can be different in playgrounds than other contexts. Ensure the GSI is built for children to play in or around it, or create appropriate barriers.
- GSI can be incorporated into landscape beds and features beyond the equipment fall zone surfacing material.
- Consider replacing impervious surfaces with a permeable playground surfacing material, or design the site to direct stormwater towards other GSI.
- Runoff from water play areas and fountains can be captured, stored, and treated for reuse. Water treatment may be required prior to reuse.
- Playgrounds are a great opportunity to connect people to GSI. Add signage about the GSI and design systems that children can interact with and learn from.
- GSI can create an opportunity for natural play areas where users can see the path of the stormwater in surface GSI practices and learn about the filtering capabilities of plants.
- To ensure safety, surface GSI practices should not hold more than 6” of water and drain within 24 hours.

Plants

- Use native species that attract butterflies and other pollinators for observation or to teach visitors about native plants. Consider proximity to play areas if plants attract bees.
- Choose plantings that maintain visibility throughout the park and that are not poisonous.
- Protect and/or add trees to reduce stormwater impacts and provide shade.
- Select trees that do not produce messy litter and that can be easily pruned to maintain clearance, visibility, and safety.

Pretreatment & Maintenance

- Design pretreatment to avoid standing water and clean frequently to limit user interaction with sediment, pollutants or debris. Consider subsurface pretreatment when applicable.
- Tier 1 maintenance approach is preferred due to limited equipment access.

STRUCTURE

Constitution Beach

Green roof on bus stop

Recommended GSI includes:

See page 62 for icon descriptions.

Structures in parks offer a unique opportunity to collect roof runoff during storm events. Roofs, and the associated gutters and downspouts, can direct water to a variety of GSI practices. Aboveground cisterns and other highly visible GSI practices offer an opportunity to create educational moments and connect humans with natural systems.

Considerations

Constraints/opportunities

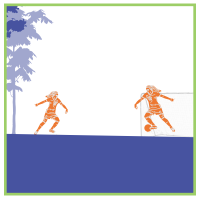
- GSI selection should fit the use and design of the structure as well as the surrounding context. GSI for a shade shelter in a park with mostly lawn will differ from GSI for a maintenance building roof that may be surrounded by hardscape.
- In general, GSI practices should be located a minimum of 10 feet away from structures with basements to avoid flooding or moisture-related deterioration over time. If the site has limited space, an impermeable liner can be installed to impede the lateral movement of water.
- Cisterns and underground chambers can provide storage options for water reuse for bathrooms or surrounding landscape irrigation.
- Although not included in the Guide, options for blue or green roofs can be considered for new roofs or for retrofitting existing ones. Blue roofs store water and let it evaporate; green roofs can have either shallow or deep profiles and be used to filter water. The design of blue and green roofs depends on the structural integrity of the roof and involves maintenance by trained crews. For more information on blue and green roofs, consult the American Society of Landscape Architecture as well as local industry specialists.
- GSI practices near structures create educational opportunities by highlighting the system and vegetation with the design itself or with signage or both.

Plants

- Plant selection should consider the building architecture and the surrounding landscape.
- Consider the sun/shade relationship of the building to the GSI practice.
- Consider the soil volume available and the root system in relationship to the foundation(s).

Pretreatment & Maintenance

- Roof runoff is typically low in sediment, and pretreatment can be kept simple or eliminated.
- Access to the pretreatment and GSI systems should not interfere with clear and safe building access. See the related context pages around the building for additional considerations.



SPORTS FACILITY

Swale at edge of field

Artificial turf field at Washington Irving school (Credit: HWG)

Recommended GSI includes:

See page 62 for icon descriptions.

Sports facilities include outdoor fields and courts used for organized sports and active recreation. They are important park programming centers for the surrounding communities. Typically, highly used and highly visible, these areas often offer a structured and enduring invitation for the public to interact with parks.

Considerations

Constraints/opportunities

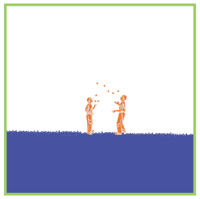
- Sports facilities provide a unique opportunity to both infiltrate and store runoff in subsurface structures under fields and courts as part of new construction or renovation projects.
- Due to their size and generally flat topography, they have the ability to hold and/or infiltrate large volumes of water both above (floodable courts) and below ground (fields).
- To avoid use conflicts, surface GSI practices are not the preferred option.
- GSI can be used to improve field drainage.
- Vegetated/grass swales should be located well beyond the zone of play.
- Consider porous pavement for courts.
- GSI must be integrated to maintain sports-specific standards, proper grading, drainage, and addressing soil compaction (on fields). Wet conditions make fields unusable.
- Consider using GSI along the perimeter to create transition zones to reduce mowed turf and irrigation needs.
- Provide underdrains for GSI to ensure proper drainage if poor soils are present.

Plants

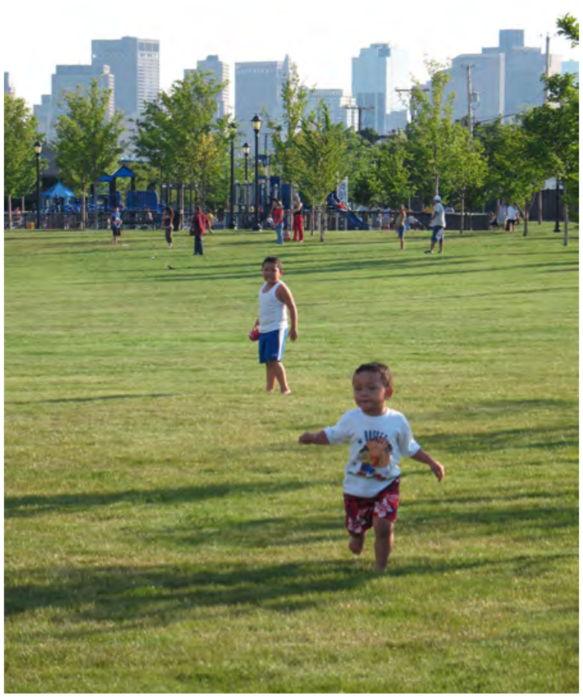
- Protect and/or add shade trees to the sides of fields and courts to provide shade for users in hot weather. Trees should be located in respect to spectators and sightlines.
- Plants for perimeter GSI practices should be mowable.

Pretreatment & Maintenance

- Select pretreatment that does not compromise use of the facilities.
- The maintenance plan should clearly address differences between facility upkeep and GSI upkeep (mowing regimes).
- Addressing soil compaction issues is critical to the effectiveness of sports fields as GSI systems. This includes: temporarily closing the field after storm events, annual aeration, and reseeding as necessary.



OPEN LAWN



Bremen Street Park

Recommended GSI includes:

See page 62 for icon descriptions.

Open lawns are flexible and highly utilized spaces for active and passive recreation, various programming, and creating iconic park views. GSI can be used to store, filter, and infiltrate water as well as help irrigate and provide stabilization. The selected systems must be designed to ensure integration with existing and future lawn use.

Considerations

Constraints/opportunities

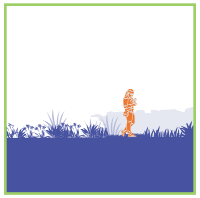
- Avoid the use of hard armoring such as stone/rip rap for outlets and spillways. Consider soft armoring such as reinforced turf/geotextiles. When space allows, use earthen check dams between pretreatment and practice area.
- Surface GSI should be underdrained to maintain dry lawns.
- Subsurface GSI practices located high in the soil profile can provide water for grass roots.
- Grading of side slopes should be subtle (5:1 or greater), blend in with the surrounding lawn, maintain existing use and maintenance.
- Storage depth for surface practices should consider existing uses and safety.
- GSI practices can be located along the edges or the entire lawn area can serve as the practice. For example, vegetated swales can be incorporated along the sides to filter or direct runoff to other GSI while maintaining the central, open lawn.
- Similar to sports facilities, open lawns are also ideal places for subsurface storage.
- Consider converting unused lawn area to a meadow during the GSI design process.

Plants

- Select grass species that require less fertilization and irrigation to help reduce water quality issues and the maintenance needed.
- Fertilizer should not be used in open lawns with GSI practices.

Pretreatment & Maintenance

- Often lawns are highly accessible areas of a park, and GSI can be maintained by various sizes of equipment. However, lawns themselves should only be driven on by equipment with appropriate loading for lawns (mowers) to reduce compaction.
- Do not mow surface practices after storm events to protect against compaction.
- Addressing issues of soil compaction can be critical to the effectiveness of these areas as functioning GSI systems.



MEADOW

Wet Swale at Roger Williams Park (Credit: HWG)

Millennium Park (Credit: BRR)

Recommended GSI includes:

See page 62 for icon descriptions.

Meadows are infrequently mowed, low-use areas with grasses and non-woody plants. The plants provide wildlife biodiversity and habitat. With minimal, but well-timed maintenance regimes, meadows can be relatively simple to create or to retrofit to incorporate store, infiltrate, filter or restore GSI practices without changing the aesthetic or passive uses.

Considerations

Constraints/opportunities

- Adding GSI to meadows requires sensitive grading for aesthetics and maintenance.
- Surface GSI in meadows can be wet or dry. If a dry meadow is desired, consider underdrains.
- Meadows can serve as landscape transitions to provide filtration of stormwater runoff.
- Mowing needs should be considered during the grading design to ensure safe mower access.
- If the maintenance plan varies for the GSI versus the surrounding landscape, incorporate visual indicators for edge definition of the GSI, either with planting cues or site-appropriate hardscape elements, such as boulders or granite markers.
- Creating meadows versus lawns enhances water filtration with their looser soil and plants with extensive root systems. They also reduce the amount of fertilizers used, reduce the impact of mowing on the environment, and provide wildlife habitat and visual diversity.

Plants

- Seed mixes for meadows are a flexible tool as they allow the most suitable species to establish themselves in any given environment. Species mixes must take into account the projected frequency and duration of storm events and levels of inundation as well as ensuring plant layering that provides year round interest and soil stabilization.
- Using plant plugs can help establish particular species at the site. They also act as a seed-bank while seed mixes get established, which can take over a year depending on the species.
- Consider mowing frequency when selecting plant species and desired aesthetics.
- Consider using species that provide pollen, nectar, and habitat for pollinators.

Pretreatment & Maintenance

- Depending on the practice, the pretreatment area can be mowed or maintained by hand.
- In general, maintenance of GSI in meadows should be kept to infrequent mowing.
- Over-mowing will limit the diversity of the planting and under-mowing can result in the eventual establishment of a forest. Mowing GSI on edges of meadow paths more frequently creates a buffer that can add comfort for users.

WOODLAND

Franklin Park (Credit: HWG)

A natural depression in a woodland (Credit: HWG)

Recommended GSI includes:

See page 62 for icon descriptions.

Woodlands are areas with canopy trees and understory growth that provide many environmental benefits. People are drawn to them for relaxation, shade, and a change of scenery. If properly implemented in appropriate locations, GSI practices in woodlands can store and filter large quantities of water and restore slopes and areas of erosion, without creating disruptive changes to the canopy, circulation patterns, or the experience of walking in the woods. Urban wilds or areas without sensitive ecological communities are best suited for implementing GSI to manage stormwater naturally, without concern for unwanted alterations to more historic or sensitive woodland ecosystems.

Considerations

Constraints/opportunities

- In general, the design of GSI practices should minimize disturbance and look to use existing landforms. Using undisturbed natural depressions can save on construction and installation cost. See Natural Depressions: Things to Consider on page 58.
- Minimal disturbance of the existing canopy and healthy plant communities is critical. Existing plant specimens and communities to be preserved should be identified and located (surveyed) prior to design to minimize impact.
- Consider converting impervious paths to permeable surfaces.
- Identify restoration opportunities as part of the design approach.

Plants

- The plant species chosen for woodland practices must be shade tolerant and typically moisture tolerant. They should work with the existing plant communities and be species resistant to deer browse.

Pretreatment & Maintenance

- Place pretreatment outside of the woodland area, easily accessible by foot or small vehicle, to minimize disturbance during construction and to provide easy access for maintenance. This approach is critical in order to keep the practice functioning without needing to disturb the trees or soil for future maintenance.
- Pretreatment should be designed to contain sediments and trash so that they do not move from the pretreatment system into the GSI practice and so that leaf litter does not impede functionality.
- Thinning growth of any woody species in the GSI maintains the designed capacity for stormwater but requires a different level of maintenance.
- Woodlands can also be managed by foresters and maintained by arborists for safety and disease to ensure healthy succession.

WATERFRONT (NATURAL)

Boardwalk at Malibu Beach (Credit: HWG)

Jamaica Pond stormwater swale (Credit: HWG)

Recommended GSI includes:

See page 62 for icon descriptions.

Natural waterfronts allow park users access to the water's edge while maintaining a natural vegetated buffer. People enjoy the views as well as the multitude of recreational activities such as picnicking, boating, and fishing. GSI for natural waterfronts often includes shoreline restoration, stabilization, or filtering practices with the goal of improving water quality, reducing erosion, enhancing habitat, and creating a pleasant park experience for visitors.

Considerations

Constraints/opportunities

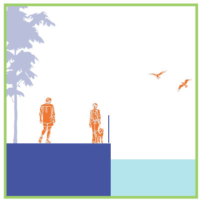
- Similar to the woodland context, the design of GSI practices should minimize disturbance to protect healthy plant communities and the shoreline.
- Depending on the water table and park uses, both wet and dry GSI practices are well suited.
- Specific waterfront site conditions such as: sea level rise, storm surge, wave action, freeze/thaw conditions, seasonal water level fluctuation, erosion, waterfowl use, and the potential for high pedestrian traffic must be addressed in the design.
- When applicable, identify opportunities to restore and increase floodplains. See Special Conditions: Floodable Areas on Page 56.
- Consider issues of soil compaction in popular areas. Controlling access to the water is critical to preserving the quality of the shoreline.
- Shoreline and buffer restoration can be an effective approach to GSI in this context as well as eliminate invasive Canada Geese habitat.

Plants

- Consider enhancing any existing plant communities or create ones that will help stabilize the shoreline and provide habitat and beauty.
- Select plants based upon: the type of water body (fresh or salt), wind and sun exposure, seasonal or tidal water levels, sea level rise, storm surges, and destructive water fowl.
- Consider mature plant heights to maintain desired views.

Pretreatment & Maintenance

- Pretreatment design should consider that the natural waterfront context can have heavier sediment loads (debris, sand, etc.) and a higher potential for erosive forces. More frequent maintenance may be required in these areas.
- Maintenance access should be designed to minimize disturbance.
- Selective pruning for view-management, removal of woody species, and invasive species management may be required.



WATERFRONT (BUILT)

The built waterfront is located in densely developed areas, and the waterfront edges are often hardened or reinforced in order to minimize detrimental effects of storm surges, tidal influence, and sea level rise. GSI includes filtration practices recommended for hardscape contexts as well as hard/soft restoration practices, with the goal of maintaining controlled public access to the water's edge and improving aesthetics, resiliency, and livability for the park users.

Malibu Beach (Credit: HWG)

Lopresti Park

Recommended GSI includes:

See page 62 for icon descriptions.

Considerations

Constraints/opportunities

- With rising sea levels, the waterfront edge in coastal or tidally influenced zones is almost always subject to coastal flooding or storm surge and should be designed accordingly, with design accommodations for periodic saltwater inundation.
- In freshwater zones, such as ponds, streams, and rivers, the edges will be subject to seasonal water level fluctuations.
- The elevation of walls and structures should be considered with regard to anticipated flood levels.
- Selection of durable materials that will not be damaged or corrode easily is critical.
- Where appropriate, consider integrating natural shorelines and restored floodplains into built waterfronts.
- See Special Conditions: Floodable Areas on page 56 for information on creating open spaces designed to accept waters from flooding, sea level rise, and associated storm surges.

Plants

- Where plants can be introduced, select species based upon: the type of waterbody (fresh or salt), wind and sun exposure, seasonal or tidal water levels, sea level rise, storm surges, and destructive water fowl.

Pretreatment & Maintenance

- Built waterfronts typically provide greater access for maintenance than natural waterfronts and can have fewer erosive forces.
- Sediment, water spray (fresh or salt), and wind should be considered.
- Subsurface structures are well suited for pretreatment in this context.

STEP 3:

Site Analysis

STEP 3: Site Analysis

A thorough site analysis prior to practice selection ensures that the GSI:

- Mimics the surrounding natural environment
- Is properly located
- Functions as designed
- Minimizes the maintenance burden

Understanding and adapting to site constraints and opportunities early in the design process is a critical step to the successful implementation of a GSI project. Some existing and special site conditions may limit the use of certain GSI practices but would not exclude the use of GSI altogether.

EXISTING SITE CONDITIONS

Watershed and Receiving Waters

Identify the targeted pollutant

The Boston park system is located in two watersheds, which have the following Total Maximum Daily Loads (TMDLs):

Boston Harbor

- Final TMDL of Bacteria for Neponset River Basin

Charles River

- Final Pathogen TMDL Report for the Charles River Watershed
- Final Phosphorus TMDL Report for the Lower Charles River Basin

A TMDL establishes the maximum amount of a pollutant allowed in a waterbody and serves as the starting point or planning tool for restoring water quality.

EPA.gov

Prior to GSI selection and design, it is important to identify the watershed and understand the water quality objectives and regulatory requirements of the proposed project area. Consider GSI practices which address targeted pollutant removal within the watersheds to meet city-wide goals.

Contributing Drainage Area

Observe the surrounding area

The type of land cover, specifically the amount of roofs and pavement (impervious cover) within the contributing drainage area, determines the quantity and quality of the runoff. Simply stated, more impervious cover means more runoff and typically dirtier water. If the practice will be receiving runoff from a large area or surrounding runoff, the design must take into consideration the following:

- Both land cover and land use are directly related to the type, size, location, and plant selection of the GSI practices.
- Land uses with higher pollutant loading, such as large parking facilities, roadways, equipment or storage facilities, and landscape yards may require larger or specialized pretreatment.
- The selection of pretreatment type and frequency of maintenance are also directly related to land cover and use.
- Obvious sediment sources, such as eroded slopes and unstabilized or bare soil, should be addressed during design and construction to reduce future maintenance and prevent clogging.

Example: Road runoff may produce more pollutants, sediment, road salt and debris when compared to a paved multi-use path or plaza. Therefore, the runoff may require larger pretreatment and a hardier plant palette, which would include plants that can tolerate road salt, pollutants, grease and urban conditions.

Water Table

Determine the depth to groundwater

Online soil survey sites such as NEsoil and Web Soil Survey[1] or available data from surrounding wells can be used to estimate the water table during preliminary planning. As the designs are advanced, a site soil evaluation is recommended.

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1 NEsoil: *www.nesoil.com*

Web Soil Survey: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

- At least one test pit or boring evaluation should be performed by a Massachusetts licensed soil evaluator in the location of the proposed GSI.
- Additional test pits may be required depending upon the size of the practice.

The Massachusetts Stormwater Standards require a minimum of 2' of separation from the estimated seasonal high water table (ESHWT) for infiltrating practices.

A high water table can present unique design challenges, but it should not exclude the use of GSI. In areas where a minimum separation to groundwater cannot be maintained consider the following options to meet estimated seasonal high water table (ESHWT) separation requirements and increase the versatility of filtering practices:

- Impermeable liners (clay or geomembrane) with an underdrain system may be incorporated into the design to allow for temporary storage or filtration.
- Underdrains can be installed just below or in the filter media, in lieu of a liner, to discourage direct infiltration.

In locations where the water table is close to the ground surface, a "wet" practice which intercepts the groundwater and maintains a permanent pool can be used to not only provide stormwater treatment but also establish a healthy wetland micro-ecosystem.

Soils

Classify the soils

Identifying the existing soils goes "hand and hand" with determining the depth to groundwater. A site soil evaluation not only determines the ESHWT, it also provides site-specific information about the soil classification, textures, infiltration rates, and limiting soil layers or depth to bedrock. This information is critical to not only the GSI selection and design but also to help inform the plant selection.

Soil Type

The general site soil type and Hydrologic Soil Group (A, B, C, D) should be determined early in the GSI selection process. A double ring infiltrometer test should also be performed as part of the site soils evaluation to obtain a site-specific infiltration rate. The soil texture along with the infiltration rate determines how efficiently the GSI practice can infiltrate or drain the water into the underlying soil.

Bedrock & Hardpan

If bedrock or hardpan is encountered, GSI selection will be limited to a low-profile practice, with a shallow plantable soil depth and underdrain(s).

Contaminated Soils

If there is a history of industrial use or urban fill at the site, soil testing for potential contamination may also be necessary prior to advancing the designs. In general, sites with contaminated soils are:

Double ring infiltrometer test (Credit: HWG)

Measuring the soil layers and depth to groundwater (Credit: HWG)

- Suitable for filter and storage practices with liners and underdrains or contaminants that are not water soluble.
- Not suitable for infiltration practices on sites with water soluble contaminants.
- Can require costly off-site disposal of excavated material.

Soil Types

A & B: Well to moderately drained soils

- Includes sands, coarse sands, sandy loam, loamy sand and loam
- Infiltration rates of ½ in. /hr. or greater
- Suitable for infiltrate and filter practices
- Not suitable for wet filters without a liner

C & D: Poorly drained soils

- Includes silt loam, fine silts and clays
- Infiltration rates less than ½ in. /hr. or less.
- Suitable for store and filter practices with underdrains.
- Suitable for wet filter practices without underdrains
- Not suitable for infiltrate practices

Plants

Assess the surrounding plant communities

Assessing the existing plant communities early in the design process is critical to:

- Preserve historical landscapes.
- Protect existing native plant communities and cherished trees.
- Develop a suitable plant palette.
- Identify wetland species, poor drainage or other environmental constraints.
- Identify areas to increase plant diversity or with potential maintenance problems due to weeds, invasive species or erosion.
- Identify important wildlife habitat.

When invasive species are identified at a GSI site, a management strategy should be developed and implemented prior to or during construction. Invasive plants close to or within the area of a proposed GSI practice are often inadvertently spread during construction, which contributes to their propagation and can cause long-term plant establishment and maintenance problems for both the GSI and the park landscape.

Utilities

Locate the existing utilities

In dense urban areas and ROWs, above and below ground utilities can present significant challenges. Utilities encountered may include gas, electric, cable, telecom, sewer, water and stormwater. Early in the design process, coordinate with utility providers to identify existing utilities including pipe sizes, material, depth and age, and potential conflicts.

Japanese Knotweed at different stages of growth (Credit: HWG)

Smartweed growing in a landscape bed (Credit: HWG)

A utility survey should be performed prior to the design. If information is limited, use an underground utility locations service (ground penetrating radar) or other method to accurately determine utility locations and depths.

When possible, avoid locating a GSI practice directly over utilities. If working within close proximity to underground utilities is unavoidable, be sure proper access is provided within the GSI area. Often, utility easements may exist that may limit the installation of GSI practices or incur future costs to the project if utilities repairs are required.

The specific utility providers should be contacted to determine the acceptable limits of the design. Collaborative decisions with the providers can be made to relocate the utility, add waterproofing measures, and evaluate structural support requirements. Making conservative assumptions and building flexibility into the design will help alleviate problems during construction.

Also consider the impacts of planting on top of existing utilities, in particular, the mature height of trees and the depth of the root system. Select and locate plants to avoid conflict with overhead wires and underground utilities.

General Guidelines for Utilities:

- **Sewer:** Consider the age and condition of a nearby sewer when designing a GSI practice. Working near older pipes should be avoided or the pipes should be replaced.
- **Drainage:** Drainage pipe depths can vary and accurate drainage network information is critical when designing GSI to intercept or tie back into existing systems.
- **Water Line:** Water lines are typically buried approximately 4 feet below grade to the crown of the pipe. With careful excavation, BWSC does not typically prohibit a water line in the vicinity of a GSI practice. Working within close proximity of older pipes should be avoided or the pipes should be replaced.
- **Gas Lines:** High-pressure gas lines should be avoided, but low-pressure shallow lines are of less concern, though they can create problems with plant health if leaks exist.
- **Single Conduit Utilities:** Single conduit utilities, including electrical, telephone, fiber optic, and cable, are typically buried 18 inches below grade in a watertight conduit and can be re-located if necessary.
- **Lighting:** Consider locations of above or in-ground lighting and associated electrical boxes and wiring which can contribute to space constraints when locating GSI, especially in the ROW.
- **Concrete Support Structures:** Due to the cost of relocating or disturbing utilities such as duct banks, steam, etc., utilities with concrete support structures should be avoided.

Utilities found during construction run along the bottom of the GSI. Orange fencing delineates the limit of work (Credit: HWG)

Topography

Minimize excessive disturbance

The topography of a site is an important part of a park's character and often dictates the site use. Often the focus is on the immediate grading required for the GSI and the surrounding topography is overlooked. Degraded, steep slopes near the practice can become a continuous source of sedimentation creating long-term maintenance issues. Eroded slopes beyond the immediate project area should be addressed in the design and stabilized during construction

The existing topography of both the surrounding area and the location of the GSI practice should be assessed during the design to:

- Adapt the design to the existing topography to reduce site disturbance, earthwork, and long-term maintenance.

A stepped system was built into the slope at Roger Williams Park in Providence (Credit: HWG)

Limited space for trees and GSI in Boston

- Estimate anticipated sediment accumulation for pretreatment sizing and maintenance requirements.

Gentle Slopes (0-5%)

GSI practices are most adaptable to gentle sloping sites (0-5%) with gradual topographic change.

- Most versatile, minimizes earthwork, and can reduce construction and maintenance costs.
- Suitable for both large and small, surface storage, infiltrate, and filter practices of varying shapes and sizes.

Moderate Slopes (5-10%)

Smaller and narrower infiltrate, filter, and store practices are generally more adaptable and can be incorporated into moderate slopes.

- Limitations, more earthwork and can increase construction and maintenance costs with stabilization and erosion.
- Suitable for swales or bioswales that can run perpendicular to the slope to capture and direct runoff to less steep areas that are more suitable for a larger GSI practice.

Swales on grades steeper than 5% should be avoided unless check dams are used to "step" the practices and lessen the slope and depth of the practices.

Steep Slopes (>10%)

In general, storage, infiltrate and filter practices are not suitable for slopes 10% and greater. Restore practices to reduce erosion and sediment sources may be the better approach along steeper slopes.

- Can require significant earthwork, which increases both the construction and maintenance costs.
- Suitable only for stepped or "tiered" practices parallel or perpendicular to hillside with multiple check dams.

If working on steeper slopes is unavoidable, it is critical that proper erosion control, scour protection, and slope stabilization is provided.

Buildings

Protection of structures

When installing GSI practices in dense urban environments, existing structures such as building foundations and basements must be protected. Because these structures are often older, they may be susceptible to stormwater flooding or damage from nearby construction.

- A 10' or greater setback should be provided.
- If providing less than 10 feet or basement flooding concerns exists, an impermeable liner can be installed to limit the lateral movement of water.
- If a liner or non-infiltrating practice is used, sufficient foundation setbacks should still be provided to avoid structural problems.

Check dams in a sloped bioswale (Credit: HWG)

3 DESIGN PROCESS

(Credit: BRR)

SPECIAL CONDITIONS

The following special conditions, unique to parks, also need to be considered during the site analysis to properly select and design GSI practices within the park system.

Trees

Why is this important?

The benefits provided by trees help to meet many of the BPRD GSI goals of improving climate resiliency, livability and health as discussed in the Goals & Benefits section. Trees play a significant role in mitigating extreme heat events, and creating an action plan to increase the tree canopy is one of Climate Ready Boston's initiatives. The benefits of planting and protecting trees should not be overlooked during the design process. Opportunities to preserve and enhance the urban tree canopy should be identified during the site analysis.

Shade and Cooling

Trees provide relief to park users in warmer months and mitigate the urban heat island effect caused by solar heat absorbed by large amounts of impervious, dark surfaces, such as roofs and pavement.

Stormwater Management

Trees intercept rainfall, "absorb" stormwater runoff, filter pollutants, and provide water storage, thereby acting as a GSI system unto themselves.

Air Quality

Trees absorb carbon dioxide from the air and release oxygen. They can also remove various pollutants from the atmosphere through absorption and adhesion.

Aesthetics

Trees create context and frame views. A healthy urban forest gives the sense that the place is well cared for, provides a harmonious environment, and contributes to improved quality of life.

Education and Interaction

Trees provide a physical and visual connection to nature for urban dwellers as well as indicators of seasonal changes.

Habitat

Trees create and enhance habitat in the city, providing a home, refuge, and food source for wildlife.

Adding Green

A tree's canopy can provide a lot of "green" in a small footprint. By providing an adequate soil volume for healthy trees to grow, trees can be planted in areas that may have limited space for other types of GSI, such as plazas, parking lots, and streetscapes.

A general rule of thumb for calculating adequate soil volume in Boston is at least 1 cubic foot for every square foot of area under the drip line of the expected mature tree canopy.

Based on soil volume calculations for various tree species according to the methodology in "Trees in the Urban Landscape" by Peter J. Trowbridge and Nina L. Bassuk, 2004.

Economic Value

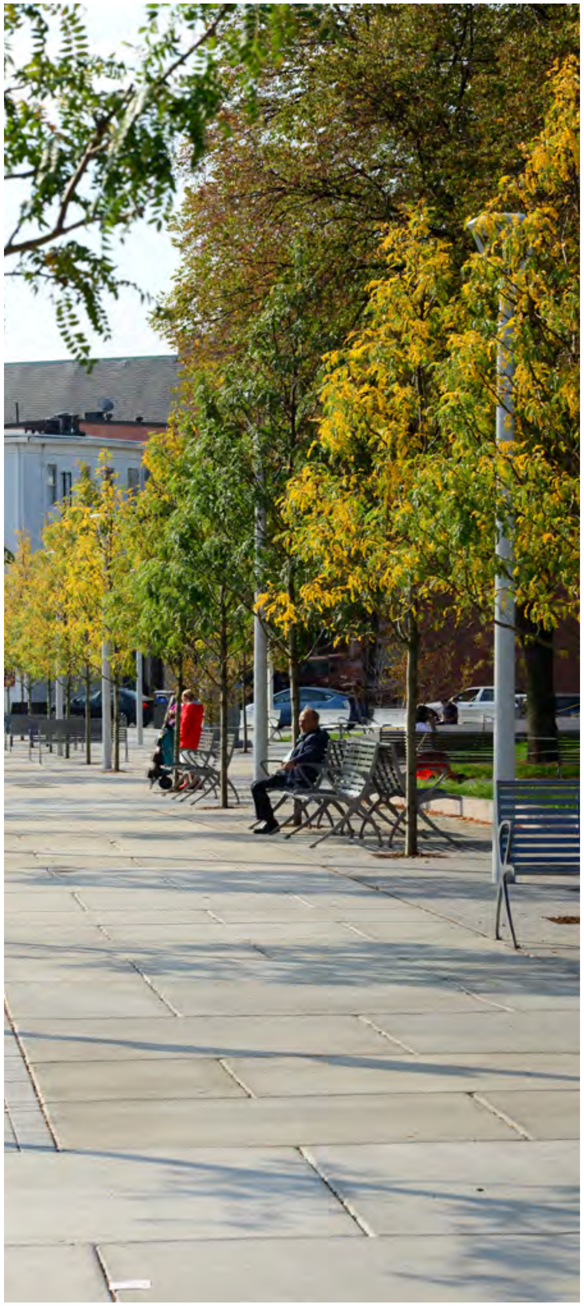
Trees create economic value for cities. By providing stormwater management, air pollution mitigation, cooling effects, and aesthetic value, the benefits of trees all add up.

> **"Trees in New York City currently store about 1.2 million tons of carbon... valued at $153 million. In addition, these trees remove about 51,000 tons of carbon per year...($6.8 million per year) and about 1,100 tons of air pollution per year ($78 million per year). New York City's urban forest is estimated to reduce annual residential energy costs by $17.1 million per year and reduce runoff by 69 million cubic feet/year ($4.6 million/year). The compensatory value of the trees is estimated at $5.7 billion."**
>
> *"The Urban Forest of New York City" U.S. Forest Service, 2018.*

Things to consider:

Many GSI practices support the planting of trees; some, such as enhanced tree pits, even rely on it. Care should be taken to incorporate and protect trees during the design and construction process. Sometimes the best GSI for a site can be simply ensuring trees are protected instead of removed or compromised during construction. In order to preserve and enhance the existing urban forest, the following should be considered:

- When planning tree protection, ensure the entire root zone of the trees is sufficiently protected from disturbance and the largest possible soil volume for the tree roots is available.
- In areas where space is limited, consider specifying structural soils or modular suspended pavement systems to increase volume.
- When designing GSI close to existing mature trees, ensure minimal disturbance of the root system.
- Trees can also benefit from GSI by the reduction of impervious surfaces and increasing infiltration for stormwater runoff into the root zone.



Central Square, East Boston (Credit: KMDG)

Historic Parks

Why is this important?

The Boston Landmarks Commission is the city's historic preservation agency. It is charged with preserving landmarked historic properties and districts in the city. The Commission is responsible for reviewing proposals that involve any type of change to designated parks. All GSI projects in historic parks will need to be reviewed by the Commission.

Some parks in Boston are designated Landmarks such as the Boston Common, the Public Gardens, and the Emerald Necklace. There are also historic parks, parks with historic elements, and public squares in the city that are not designated landmarks but still deserve thoughtful treatment during any GSI project. When working within these landscapes, a thorough understanding of the original design intent, historic integrity, and character of the park should guide GSI selection and design.

It is important to note that historic parks should not be treated as landscapes frozen in time but dynamic landscapes that naturally change over time. Trees grow, plants die, slopes erode, and ponds build up with sediment. In those circumstances where the parks need to be adapted or altered to accommodate stormwater and rising sea level, changes can be undertaken with sensitivity to both history and context. Respect the park's historical aesthetic, context, and character-defining features, while adapting them for today's users and uses.

Jamaica Pond, part of the Emerald Necklace (Credit: BRR)

Things to Consider:

In order to develop GSI that is compatible with the park, BPRD and the designer should reference *The Secretary of the Interior's Standards for the Treatment of Historic Properties*[1] to determine whether the site should be preserved, rehabilitated, restored, or reconstructed. The standards provide guidance for decision-making for any work on a historic property or landscape.

The four options range from preservation, where the least amount of work is done, to reconstruction, a historically accurate rebuilding of what was once there. More often than not in the case of parks, 'rehabilitation' is needed.

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1 Birnbaum, Charles A., ed., *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for the Treatment of Cultural Landscapes (Washington, D.C.: U.S. Department of Interior, National Park Service, Cultural Resource Stewardship and Partnerships, Heritage Preservation Services, Historic Landscape Initiative, 1996).*

Preservation

Work will sustain existing form, integrity, and materials of an historic property. Protect and stabilize what is there. Repair historic materials and features.

Rehabilitation

Project will have a compatible use for a property through repair, alterations, or additions while preserving those portions or features which convey its historical, cultural, or architectural values.

Restoration

Project recommendations will depict form, features, and character of a property as it appeared at a particular period of time by removal of features from other periods of its history and reconstruction of missing features from the restoration period. Limited and sensitive upgrading of drainage systems to make parks functional is appropriate within a restoration project.

Reconstruction

New construction of the form, features, and details of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location.

The following guidelines are intended to foster appropriate GSI treatments for historic parks:

- Retain and maintain historic features and materials.
- Choose materials that are appropriate to their historic setting and complement what is historic.
- Respect and work with the existing topography.
- Minimize soil disturbance and maximize stabilization of adjacent land.
- Look for opportunities to disconnect and/or reduce impervious cover.
- Continue the use of existing open drainage systems, where feasible.
- Meet the aesthetic goals of the particular park and its context.
- For paved swales, replace with stone spaced to allow some infiltration or recharge to groundwater, or, if maintenance can be provided, plant low height turf species to allow more stormwater to infiltrate.
- Where storing or holding of water is required to manage stormwater peak flows or fix drainage problems, consider store or infiltrate practices constructed underground where soils are suitable instead of detention/retention basin systems that detract from historic settings.


Franklin Park Cobble-Edged Roads (Credit: HWG)


Paul Revere Mall


Boston Public Garden Pond (Credit: BRR)

Floodable Areas

Why is this important?

For the purposes of this Guide, Floodable Areas are defined as areas that can provide additional temporary flood storage from large rain events, sea level rise, and associated storm surge to minimize the impacts to the city. These areas are often part of a larger climate resilient strategy to adapt to climate change and sea level rise. Although not designed specifically as a stormwater practice, they provide a natural defense within at-risk communities by allowing the temporary storage of floodwaters from large storm events.

Floodable Areas within parks should be identified and, if necessary, expanded or created as part of the GSI design to improve climate resiliency within the park system. As storm intensities increase, maintaining and/or expanding these areas is critical to lessen the overall impacts to the city from future flooding and predicted sea level rise.

Things to Consider:

Floodable Areas are intended to store stormwater overflow from extreme fluctuations in water levels as well as maintain the existing open space and recreational uses. This overlap of uses presents unique design challenges and requires an innovative approach. Applicable BPRD managed areas may include the following:

- Open space, parks, and natural areas in close proximity to the waterfront (harbor and rivers).
- Inland open spaces, sports fields, and courts located in low lying areas or near streams or wetlands.

When working within these areas, the design should strive to meet the following objectives[1]:

- Meet the community and park needs by addressing both resiliency and recreational uses.
- Maintain or increase flood storage and allow for the waters to efficiently and safely rise and recede.
- Create new bulkheads, walls, or berms as additional barriers against flooding and storm surge.
- Remove invasive plant species and restore buffers, floodplain and wetland habitat and establish resilient native plant communities.
- Consider relocating park uses beyond the floodable areas to improve public accessibility and safety.

Gowanus Canal Sponge Park (Credit: DLANDstudio Architecture+ Landscape, "Gowanus Canal Sponge Park Masterplan", *Architect Magazine*, March 2017, Web. Jan. 2020*)*

Resilience initiatives that produce multiple benefits generate more resources to support their implementation and sustainability. Flood barriers that also provide recreational open space, developable land, or upgraded roadways represent examples of multiple-benefit solutions.

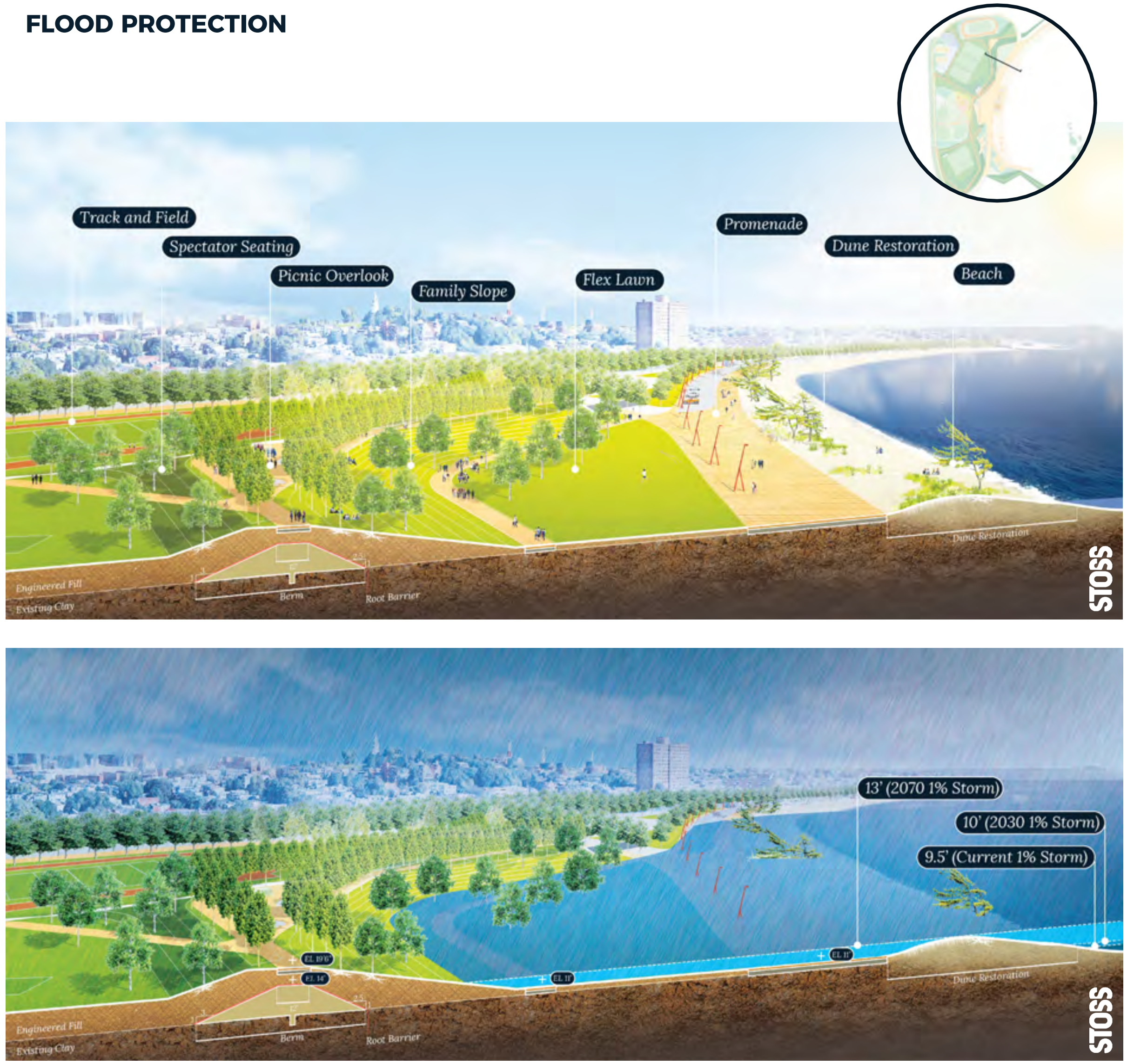
Climate Ready Boston

1 *Designing and Planning for Flood Resiliency: Guidelines for NYC Parks* and *Climate Ready Boston*

- Minimize damage and long-term maintenance through the siting and use of resilient materials, site furnishing, and plants.
    - Locate amenities requiring utility services (fountains, lighting, etc.) outside of floodable areas
    - Consider solar lighting to reduce electrical requirements
    - Assess site amenities to minimize floatable debris and corrosion
    - Use PVC-coated or hot-dipped galvanized metals, recycled plastic, boulders, granite blocks, and rot-resistant woods
- Provide sufficient access for the collection of debris after each flooding event
- Select plants and seed mixes able to withstand variable water levels including inundation and saltwater as needed

> **...account for "the norm, not the storm." In other words, waterfront parks should facilitate everyday public use during typical weather conditions while still including elements meant to face the risk.**
>
> *Designing and Planning for Flood Resiliency: Guidelines for NYC Parks*

FLOOD PROTECTION



Graphics showing plans for Flood Protection in Moakley Park (Credit: Stoss)

Natural Depressions

Why is this important?

Existing unused natural depressions in the landscape can be incorporated into stormwater management as a natural, less invasive GSI approach. Utilizing large or small depressions can take advantage of existing topography and drainage patterns and intercept runoff prior to, or instead of, being directed into pipes and discharging to other GSI or an existing outfall.

The biggest benefit to using natural depressions are:

- Minimizing the disturbance of the designed landscape
- Limiting the disruption to park uses and maintaining the current park use areas
- Utilizing unused areas
- Reducing the need to construct other, potentially larger stormwater management areas
- Cost savings by reducing the need for machinery mobilization, earthworks, and additional materials

Things to Consider:

- Depressions that do not get frequent use are best.
- The existing soils, plant community, and current use of the area must be able to accommodate the desired stormwater treatment (store, infiltrate or filter).
- The design of appropriate pretreatment practices to capture sediment and other debris prior to discharging into the depression.
    - Ideally, pretreatment is located in areas that are easy to access and maintain.
    - To minimize disturbance, the pretreatment system must be large enough to hold the sediment and easy to access to allow regular maintenance.
    - Rely on existing circulation infrastructure for access.
    - Subsurface pretreatment structures located outside the depression can be a good option.
- The amount of runoff sent into a natural depression should be in proportion to the receiving area in order to protect and maintain the existing ecological system and the additional water and not result in plant die-back from the inundation, velocities, or salt and pollutant levels from the runoff.
- Depending on the depth to groundwater, the depression can function as either a wet or dry practice.
- Some plant communities are more sensitive to fluctuations in water levels, pollutants, and salts associated with stormwater runoff and may not tolerate receiving the additional stormwater.
- When natural depressions are used, any existing invasive species should be removed and replaced with plants that are appropriate for the existing context, improve the surrounding plant community, and add habitat value.
- The outlet into the depression should be properly designed to minimize disturbance while attenuating velocities from large storm events to prevent scouring and erosion. Various sizes of stone, plants, and other materials, as well as stepped or swale systems can be utilized to dissipate energy and reduce velocities.

Jamaica Pond Park depression (Credit: HWG)

Golf Courses

Why is this important?

Golf courses are a popular public amenity that provide valuable open space to the community and embrace the surrounding naturalistic environment(s). However, certain areas within the course require intensive landscape maintenance (watering and mowing) as well as frequent turf fertilization. These maintenance practices can adversely impact local water quality.

GSI can be integrated into golf courses to provide better stormwater management and improve the course aesthetics, sustainability (water reuse), plant diversity, and habitat value. GSI also provides educational opportunities to promote the use of GSI and highlight sustainable landscape management strategies within BPRD.

Things to Consider:

Golf courses consist of varying contexts as well as varying topography. The undulating landforms inherent to the game can be integrated with GSI practices. The topography is composed of naturalistic depressions that provide areas to filter, store, and infiltrate stormwater.

Besides adding specific GSI practices, the overall maintenance of the golf course must be considered in order to meet resiliency, livability, and health goals. The following strategies can be used to implement GSI and create a more environmentally sustainable course.

- Discuss and manage expectations of golf course aesthetics in order to meet GSI and maintenance goals.
- Direct runoff from impervious surfaces such as parking lots and roofs to GSI practices.
- Provides a great outreach opportunity to use educational signage to inform golfers about the design.
- Consider water reuse for course irrigation.
- Ensure maintenance requirements for GSI is communicated and understood by the maintenance team.
- Restore and maintain vegetated buffers around water features and resources (ponds and wetlands) to filter course runoff, protect the feature, and increase habitat. These buffers can increase the challenge and beauty of the course and reduce destructive waterfowl populations.
- Minimize the amount of turf and expand naturalized areas where possible to reduce water needs and maintenance. Naturalized areas can create interest and have always been an integral part of some of the oldest courses around the world.
- Integrate seed mixes that require lower maintenance and less fertilization and watering.
- When possible, utilize golf courses to conduct seed "test" plots to learn which mixes meet aesthetic, use, and benefit goals.
- Create nutrient management plans, conduct soil testing, and utilize Precision Turfgrass Management (PTM) if possible to minimize unnecessary irrigation and nutrient inputs.
- Manage grass clippings as needed and use them as natural fertilization by leaving them in place, spreading them into the rough, or by composting them.
- Limit any use of pesticides and use Integrated Pest Management techniques (IPM) as possible.
- Reference and implement Audubon International's "*Environmental Management Practices for Golf Courses*" (*www.auduboninternational.org*) as possible.

STEP 4:

Pretreatment & GSI Selection

STEP 4: Pretreatment & GSI Selection

The successful integration of GSI within the Boston Parks requires the use of a variety of practices. This Guide helps users narrow down the options through matrices and information sheets. Although 21 of the most applicable GSI practices and four pretreatment types are identified, there may be other creative stormwater solutions that are well suited for a particular site. In many instances, the best GSI solution for a site may include multiple practices designed as a system to provide multi-functional park benefits.

PRETREATMENT TYPES

Four pretreatment types are provided to improve efficiency and reduce maintenance before stormwater discharges into the GSI practices. Pretreatment should be combined with GSI and are not considered a standalone practice. The pretreatment types are grouped into the following two categories:

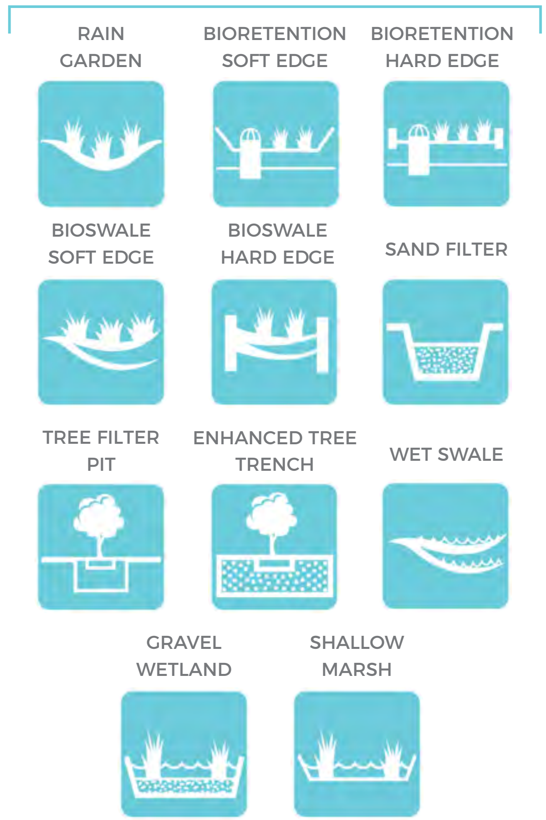
SMALL: Surface pretreatment for small drainage areas that are easily cleaned and maintained by hand tools and manual labor.

LARGE: Surface and subsurface pretreatment devices for larger drainage areas that require excavating or specialized equipment for cleaning and maintenance.

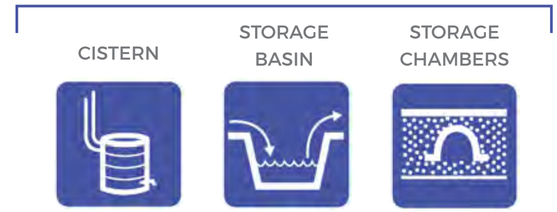
GSI PRACTICES

The practices are grouped into four categories: filters, stores, infiltrates, and restores. The icons depict the 21 types of practices recommended in this Guide. The icons are found on the relevant context pages and on the GSI practice sheets as companion practices.

FILTERS: Subsurface and surface practices that use plants and/or soil to clean the stormwater prior to discharge.



STORES: Subsurface and surface practices that temporarily hold stormwater and slowly release it out of the system.



INFILTRATES: Subsurface and surface practices that enable stormwater to infiltrate into underlying soils.

RESTORES: Surface practices that restore areas to healthy soils and vegetation by reducing erosion or pavement.

SUBSURFACE VS. SURFACE

Before selecting a practice, the pros and cons of subsurface (below ground) or surface (above ground) practices will also need to be considered. The practices categorized as Stores, Infiltrates, and Filters each have subsurface and surface options.

Subsurface

GSI subsurface practices:

Advantages (+):

- Maximizes space by placing the practice under the landscape (e.g. fields) or hardscape (e.g. parking)
- Well suited for large quantities of runoff
- Requires less frequent maintenance as long as proper treatment is provided
- Great as a combination with surface practices

Limitations (-):

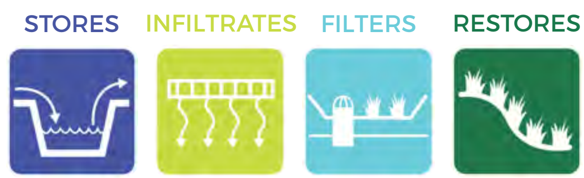
- Requires special equipment to provide proper maintenance, which can be costly
- Extensive excavation
- Significant earthwork increases construction costs (material and labor)
- Not easily adaptable to utility conflicts
- Often neglected: "Out of sight, out of mind"
- Nearly impossible to clean if clogged
- Limited stormwater treatment

General Use:

- Areas with limited surface space
- Parking lots
- Sports facilities
- Sidewalks, roads, and paths
- Plazas
- Roof runoff
- General drainage projects
- Combined with surface practices to provide additional volume

Surface

GSI surface practices:



Advantages (+):

- Highly adaptable to various conditions and budgets
- Used for multiple purposes (e.g. floodable courts)
- Creates habitat and microecosystems
- Creates native landscapes/buffers
- Reduce heat island effect
- Adds trees and plant diversity
- Provides landscape aesthetic
- Provides educational and partnership opportunities
- Typically less earthwork and lower costs
- Volunteers can maintain

Limitations (-):

- Most require plant knowledge for maintenance
- May require partnerships
- Costs can vary greatly
- Greater commitment to more frequent maintenance
- If unmaintained, can be become unsightly and a nuisance
- Uses/converts surface space

General Use:

- Adaptable to most landscape areas of various shapes and sizes
- Highly visible sites such as entrances, plazas, streetscape, etc.
- Buffer Zones/Restorations
- Partnership or landscape improvement projects
- Roof runoff
- Edge of parking lots, roadways, and paths
- Combine with subsurface practices to store, infiltrate and filter

MATRICES

The following three matrices compare the GSI practices with Goals and Benefits (right), Context (page 65), and Existing Conditions (page 66) to assist with GSI selection.

GSI Practices and Park Benefits

GSI Practices	Improve Climate Resiliency			Improve Livability & Health				
	Benefits			Benefits				
	Promote rainwater reuse & recharge	Adapt to increased flooding	Reduce impervious cover & heat islands	Connect People to Nature	Improve drainage and water quality	Increase green spaces and aesthetics	Improve air quality	Improve habitat value
Stores								
Cistern	✓				✓			
Storage Basin		✓			✓	✓		
Storage Chambers	✓	✓			✓			
Infiltrates								
Infiltration Chambers	✓	✓			✓			
Permeable Surfaces	✓		✓		✓			
Infiltration Basin	✓	✓		✓	✓	✓		✓
Dry Well	✓				✓			
Filters Wet/Dry								
Rain Garden	✓			✓	✓	✓	✓	✓
Bioretention (Soft)	✓			✓	✓	✓	✓	✓
Bioretention (Hard)	✓			✓	✓	✓	✓	✓
Bioswale (Soft)	✓			✓	✓	✓	✓	✓
Bioswale (Hard)	✓			✓	✓	✓	✓	✓
Vegetated Sand Filter	✓				✓	✓		
Tree Pit (Surface)	✓		✓		✓	✓	✓	✓
Tree Pit (Subsurface)	✓		✓		✓	✓	✓	✓
Wet Swale		✓		✓	✓	✓	✓	✓
Gravel Wetland		✓		✓	✓	✓	✓	✓
Shallow Marsh		✓		✓	✓	✓	✓	✓
Restores								
Shoreline Restoration				✓	✓	✓	✓	✓
Slope Stabilization				✓	✓	✓		✓
Pavement Reduction	✓		✓		✓	✓		

GSI Practices and Context

GSI Practices	Contexts												
	Water-front (natural)	Water-front (urban)	Wood-land	Meadow	Open Lawn	Sports Facilities	Play-ground	Dog Park	Garden	Hard-scape	Parking Lot	ROW	Struc-ture
Stores													
Cistern					■	■	■		■	■	■		■
Storage Basin				■	■						■	■	
Storage Chambers				■	■	■		■		■	■	■	■
Infiltrates													
Infiltration Chambers					■	■		■		■	■	■	■
Permeable Surfaces	■	■				■	■			■	■	■	
Infiltration Basin				■	■					■	■	■	■
Dry Well					■		■			■	■	■	■
Filters Wet/Dry													
Rain Garden	■			■			■	■	■	■			■
Bioretention (Soft)	■			■			■	■	■	■	■	■	■
Bioretention (Hard)		■					■		■	■	■	■	■
Bioswale (Soft)	■		■	■	■	■	■	■	■	■	■	■	■
Bioswale (Hard)		■					■		■	■	■	■	■
Vegetated Sand Filter	■			■	■		■	■		■	■	■	■
Tree Pit (Surface)							■	■	■	■	■	■	
Tree Pit (Subsurface)							■	■	■	■	■	■	■
Wet Swale	■		■	■					■		■	■	
Gravel Wetland	■	■									■		
Shallow Marsh	■		■	■									
Restores													
Shoreline Restoration	■	■											
Slope Stabilization	■	■	■	■				■	■			■	
Pavement Reduction	■	■					■	■	■	■	■	■	

GSI Practices and Existing Conditions

GSI Practices	Existing Conditions							
	Contributing Drainage Area			High water table	Well drained soils (A&B)	Poorly drained soils (C&D)	Suitable for steep slopes	Adapt-able to utility conflicts
	> 1 acre	.25-1 acre	< .25 acres					
Stores								
Cistern								
Storage Basin								
Storage Chambers								
Infiltrates								
Infiltration Chambers								
Permeable Surfaces								
Infiltration Basin								
Dry Well								
Filters Wet/Dry								
Rain Garden								
Bioretention (Soft)								
Bioretention (Hard)								
Bioswale (Soft)								
Bioswale (Hard)								
Vegetated Sand Filter								
Tree Pit (Surface)								
Tree Pit (Subsurface)								
Wet Swale								
Gravel Wetland								
Shallow Marsh								
Restores								
Shoreline Restoration	N/A	N/A	N/A					
Slope Stabilization	N/A	N/A	N/A					
Pavement Reduction	N/A	N/A	N/A					

PRETREATMENT & GSI INFORMATION SHEETS

The following information sheets are not intended to be comprehensive and should serve as companion information to the Massachusetts Stormwater Policy BWSC Stormwater Management Practices: Guidance Document and other reference documents. GSI selection and design should be park specific. The following eight categories are used to describe each GSI and pretreatment option to compare between practices:

Advantages (+) & Limitations (-) identifies the specific advantages and limitations for each individual practice.

Existing Conditions are site specific, best suited conditions for each practice:

- Drainage Area
- Water Table
- Soils
- Utilities
- Topography

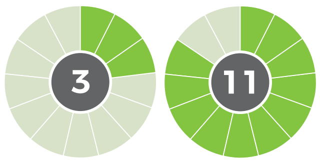
Companion Practices icons identify specific pretreatment or GSI practices that work well together as a treatment train or system.

Context icons identify the specific park context most applicable.

Planning provides the following information to assist with practice selection early in the design process. Some of the information is represented by info-graphics.

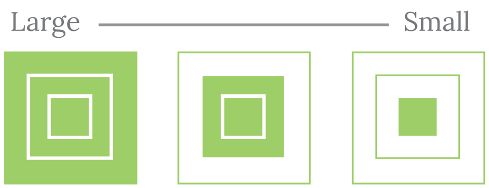
Versatility (not provided for pretreatment)

Versatility visually indicates how many park contexts may be applicable for that practice.



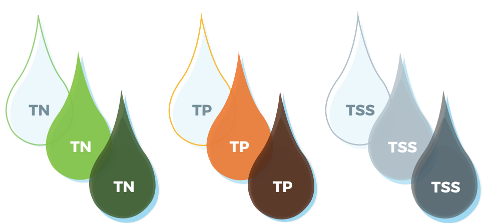
Footprint

Footprint indicates the typical surface and subsurface space required for the practice relative the contributing drainage area.



Treatment

This category indicates how effective each practice is at removing total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS). The drops are shown in shades indicating high, medium, and low levels of treatment. The lighter the color of the drop, the more treatment for that pollutant. This assumes pretreatment for all practices.



Install Cost

The practices are considered to be a low, medium or high implementation cost as they relate to each other.

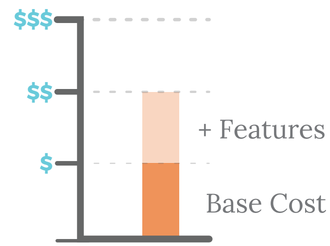
Planning level costs for surface practices are:

Low Cost ($) < $15.00 per square foot

Medium Cost ($$) = $16.00 - $25.00/sf

High Cost ($$$) > $26.00/sf

The graph includes the cost of using more expensive materials or fine detailing with a lighter color above the base construction cost.



Uses

This information identifies specific locations where a particular practice may be applicable.

Maintenance includes general maintenance specific to the practice as well as frequency guidelines. A maintenance "tier" is provided for each practice indicating the level of effort.

Maintenance Tiers

The size, location, pretreatment and practice type may dictate that certain practices require a greater level of effort and additional maintenance. Based upon these factors, the level of effort required for maintenance has been classified into two tiers:

Tier ① Level of Effort: Low to Moderate. Typically includes small pretreatment types and more frequent maintenance, handled in-house by BPRD staff. Work may include mowing or weed-whacking, minor pruning and sediment/debris removal by hand or small equipment.

Tier ② Level of Effort: Moderate to High. Typically includes larger pretreatment types with less frequent but more extensive maintenance; requires either training for maintenance staff, hiring an independent contractor, or partnership with another agency or organization. In addition to Tier 1 tasks, work may include plant removal and replacement, and sediment removal with larger equipment.

Maintenance Cost

This information is based upon equipment and the level of effort. The same info-graphic is used for both planning and maintenance cost comparisons. Note: The costs provided are based on average planning level assumptions for comparison purposes only. However, true cost comparisons early in the design process can be difficult and are not always an effective way to select a practice. The costs can vary significantly due to the project goals, location, site constraints, and materials used.

Function provides a graphic illustration of the practice and the various parts of the system in order to call out specific materials and to visually explain how it works.

Design & Implementation includes both requirements and recommendations specific to the particular GSI practice related to its use within a park setting.

VEGETATED FILTER STRIP

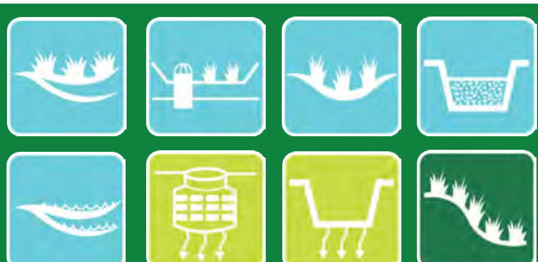
Advantages (+) & Limitations (-)

- \+ Can be naturalized or mowed
- \+ Unmowed strips can provide habitat
- \+ Adds green space
- \+ Low visual impact & no excavation
- \- Not good for concentrated flow
- \- Prone to erosion & frequent clogging
- \- Not suitable for high sediment volumes

Existing Conditions

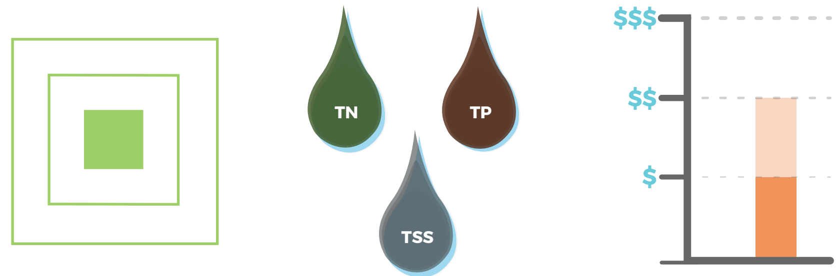
- Drainage Area: small
- Water Table: > 2 feet
- Soils: poor to well drained (A-D)
- Utilities: low level of conflict
- Topography: 1% min. - 6% max.

Companion Practices



: *turf or planted surfaces used to slow runoff and trap sediments between paved area and GSI*

Planning



Footprint
Small, linear
Minimal Disturbance

Treatment
TSS = low
TP = low
TN = low

Installed Cost
Inexpensive to construct

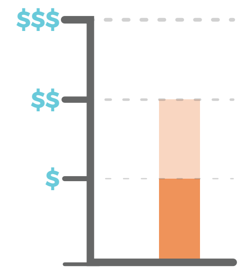
Uses: limited to low-use perimeters around sports fields or courts, pathway shoulders, and flat transitional landscapes. Can be used as a buffer for natural resource areas.

Maintenance

Typically requires mowing. Frequency varies based upon desired appearance and seed mix selection.

- Keep offline until grass is established. Minimum mowing height of 2 inches.
- Erosion may require frequent reseeding.
- Remove all trash and debris.
- Remove accumulated sediment along the edge to avoid creating concentrated flows.
- Inspections should occur during regularly scheduled mowing or at a minimum quarterly.

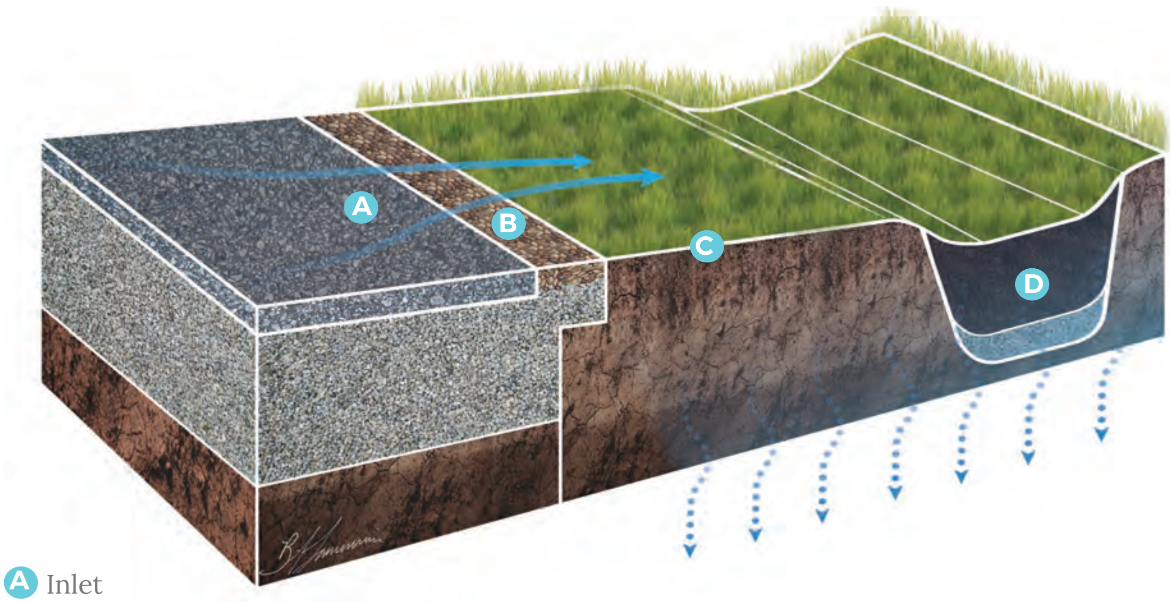
Tier ①



Maintenance Cost

Manual labor for sediment, trash and debris removal. Routine mowing, minor slope stabilization, and reseeding.

Function



- **A** Inlet
- **B** Level Spreader
- **C** Vegetated Filter Strip
- **D** Treatment Area (GSI)

Design & Implementation

- Consider park context and spatial limitations to determine filter width and applicability.
- Improper grading can cause concentrated flow and runoff may "short-circuit" the filter. Provide a level spreader (curb, etc.) to distribute runoff across the entire length.
- Width of filter and density of vegetation will directly impact function and performance.
- Typical widths is between 25 – 50 feet. Smaller widths can be considered for small drainage areas.
- Remove existing, under utilized paved surfaces to increase filter width when applicable.
- Do not use on slopes greater than 5%, and drainage areas greater than 1 acre.
- Use turf reinforcement matting for areas with higher runoff velocities.
- Use of low maintenance, salt, and drought tolerant plants/seed mixtures.
- Transitional slope from a paved surface to filter should not exceed 3%.

Vegetated Filter Strip for Wet Swale and buffer (Credit: HWG)

Vegetated Filter Strip for a Wet Swale (Credit: HWG)

Vegetated Filter Strip for a Bioswale (Credit: HWG)

SMALL SEDIMENT FOREBAY

Advantages (+) & Limitations (-)

- \+ Effective small scale sediment/debris capture
- \+ Easy access and maintenance
- \+ Highly adaptable to most contexts and designs
- \+ Naturalized, mowed, or hardscape
- \- Requires excavation and disturbance
- \- High visibility and can become unsightly

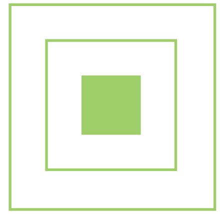
Existing Conditions

- Drainage Area: small to medium
- Water Table: > 2 feet
- Soils: poor to well drained (A-D)
- Utilities: low level of conflicts
- Topography: 0% min. - 5% max.

Companion Practices

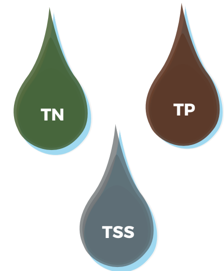
: depression with check dams designed to capture sediment and debris prior to flowing into GSI

Planning



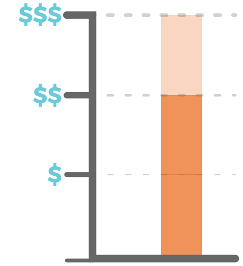
Footprint

Small
Minimal Disturbance



Treatment

TSS = low
TP = low
TN = low



Installed Cost

Cost varies based upon materials and practice

Uses: Highly adaptable and versatile surface pretreatment for small to medium sized Stores, Infiltrates, Filters practices. Not ideal for playgrounds.

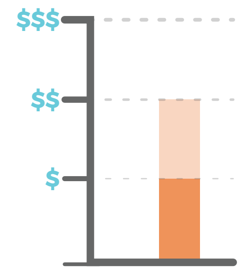
Maintenance

Frequency varies based upon size, materials, the contributing drainage area and park context. Typically, hardscape forebays are associated with a lower level of maintenance, and vegetated are associated with higher maintenance.

- Remove sediment, leaf litter, and trash in early spring and late fall or when sediment accumulation is equal to 1/2 the depth.
- Ensure inlet is clear and working properly.
- Inspect check dam to prevent runoff from “short-circuiting” around the edges. Repair and re-plant all eroded areas.
- If planted, cut and remove biomass during fall clean-up. Replace plants as needed.

Tier

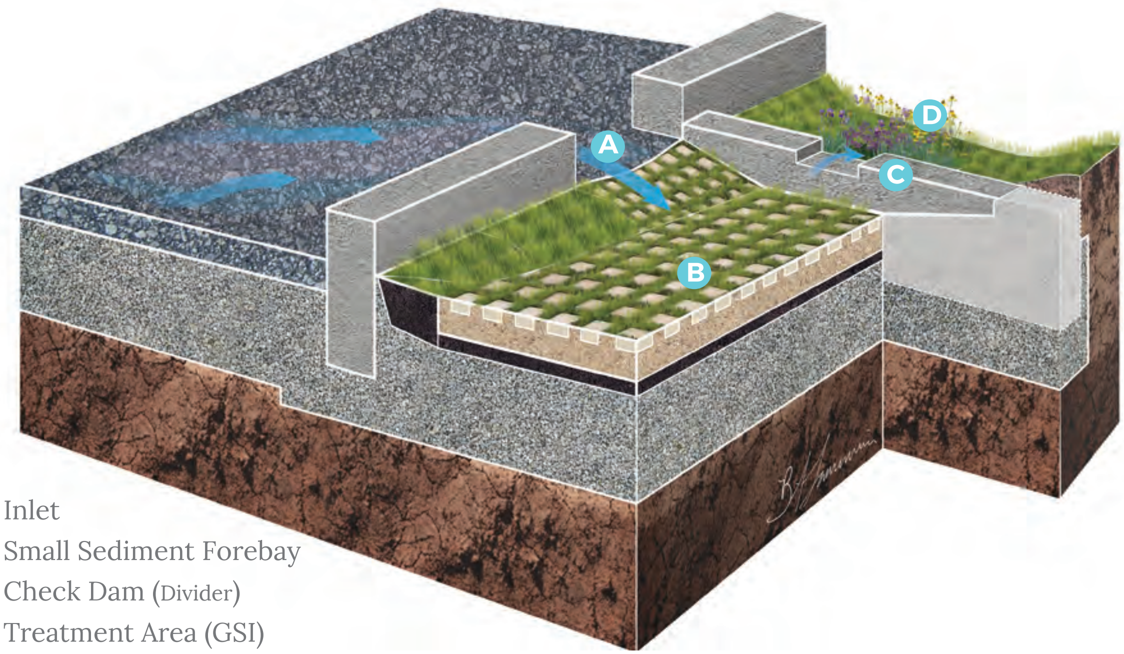
1



Maintenance Cost

Manual labor for weeding and sediment/debris removal. May include routine mowing if vegetated. Cost varies depending on size and frequency

Function



A Inlet
B Small Sediment Forebay
C Check Dam (Divider)
D Treatment Area (GSI)

Design & Implementation

- Provide easy maintenance accessibility and confirm capabilities prior to design.
- Consider the location and visibility of all pretreatment areas during design and material selection.
- Design forebays to allow sediment to be easily removed with a standard shovel.
- Smaller or undersized forebays require a greater frequency of maintenance.
- Consider smaller sediment forebays into the overall design as an artistic design element.
- Provide a minimum ponding depth of 3”-6” and a flat level bottom for settling.
- Set check dam level and provide an overflow weir and stone splash pad on downstream side.
- Surface bottoms should be porous to allow for proper drainage. Use plants, seed mixes, pavers, cobbles, reinforced turf, gravel or a combination of materials.
- If planted, use hardy, low maintenance, salt, and drought tolerant species and seed mixes.
- Avoid rip-rap or dumped stone on the bottom as it is difficult to clean and stones can be moved or thrown.

Small Sediment Forebay for a Bioretention Area at Washington Irving Boston Public School (Credit: HWG)

Small Sediment Forebay for a Bioretention Basin at Heritage Gardens (Credit: HWG)

PRETREATMENT

LARGE SEDIMENT FOREBAY

: *large depression designed to capture sediment and debris prior to flowing into GSI*

Advantages (+) & Limitations (-)

+ Storage for large volumes of sediment/debris capture
+ Infrequent cleaning
+ Can provide wildlife habitat
- Significant disturbance to clean
- Often neglected which can become unsightly
- Prone to invasive plant propagation

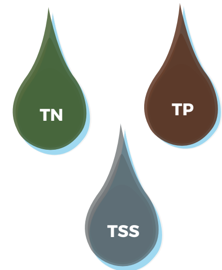
Existing Conditions

- Drainage Area: large
- Water Table: adaptable and varies by practice
- Soils: poor to well drained (A-D)
- Utilities: moderate to high levels of conflict
- Topography: 0% min. - 5% max.

Planning

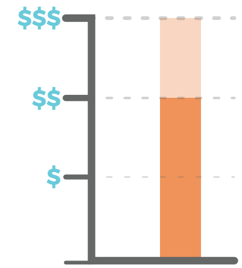
Footprint

Large
Significant disturbance



Treatment

TSS = low
TP = low
TN = low



Installed Cost

More expensive due to earthwork

Uses: large parking lots and long stretches of roads exceeding 10 acres. Suitable for large "end of pipe" GSI practices such as constructed wetlands or storage/infiltration basins.

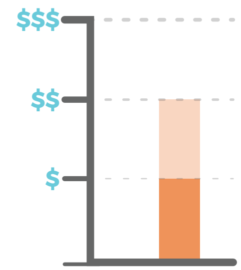
Maintenance

Less frequent, but earthwork can be significant when removing sediment.

- Keep offline until grass is established.
- Inspect annually.
- Ensure inlet is clear and working properly.
- Inspect check dam/overflow spillway to prevent runoff from "short-circuiting" the system. Repair and re-plant all eroded areas.
- Mow as needed. Maintain an average mowing height of 3" - 4" to protect perennials and eliminate woody plants.
- Identify and remove all invasive plants.

Tier

②

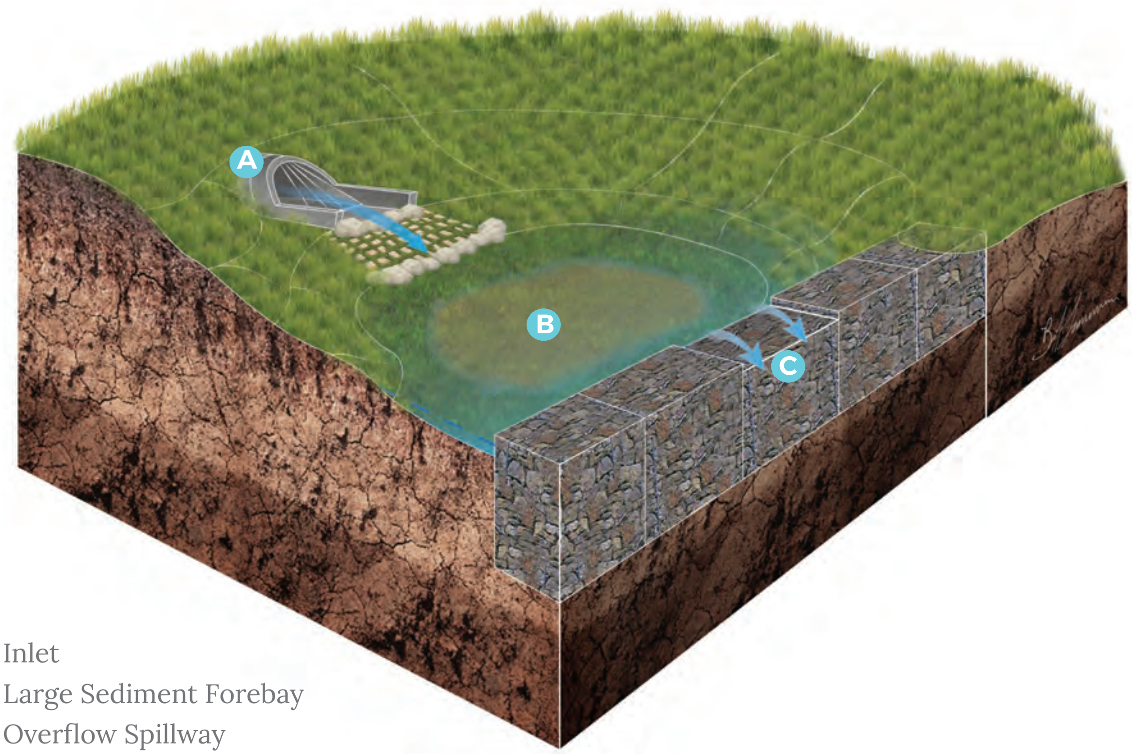


Maintenance Cost

Large equipment for sediment, trash and debris removal. Routine mechanical mowing and weed removal/cutting. Cost varies depending on size and frequency. Sediment removal can be infrequent, but costly.

Companion Practices

Function



- **A** Inlet
- **B** Large Sediment Forebay
- **C** Overflow Spillway

Design & Implementation

- Integrate maintenance access into the design for larger equipment. 10’ wide maintenance access around the perimeter is required for large equipment.
- Prone to becoming unsightly if not properly maintained and may require partnering with other city departments depending on maintenance regimen.
- Typically sized to hold large quantities of sediment over an extended period of time.
- Design for 24-hour drawdown to avoid stagnant water, except for wet GSI practices.
- Surface bottoms should be porous to allow for proper drainage. Use plants, seed mixes, pavers, cobbles, reinforced turf, gravel or a combination for the bottom surface.
- Provide proper scour protection at all inlet and outlet locations. Side slopes 3:1 max.
- Overflow spillway is typically reinforced earthen dam/stone check dam with control weirs.
- Costly maintenance may be required for high visibility sites.
- Due to significant disturbance, avoid using large forebays in wooded or natural areas.

Large Sediment Forebay for a Gravel Wetland (Credit: HWG)

Large Sediment Forebay in Wappingers Falls, NY (Credit: Renewage LLC)

Post-Construction in Wappingers Falls, NY (Credit: Renewage LLC)

STRUCTURES

: *prefabricated, subsurface structures of various sizes designed to capture sediment and debris*

Advantages (+) & Limitations (-)

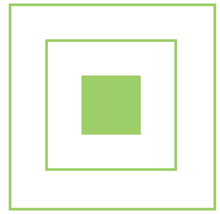
- \+ Ideal for sites with space constraints
- \+ Many options for different applications
- \+ Other city agencies are familiar with maintenance requirements
- \+ Low visual impact
- \- Special equipment for maintenance
- \- Little to no benefits beyond sediment removal
- \- Often neglected and prone to clogging- “out of sight, out of mind”

Existing Conditions

- Drainage Area: small to large
- Water Table: 0 ft (can be in the WT)
- Soils: poor to well drained (A-D)
- Utilities: moderate to high level of conflicts
- Topography: suitable for most slopes

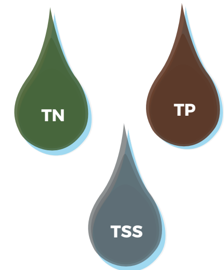
Companion Practices

Planning



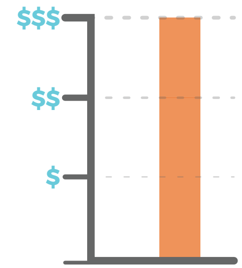
Footprint

Small pretreatment options



Treatment

TSS = low
TP = low
TN = low



Installed Cost

More expensive due to earthwork and fabrication

Uses: adaptable to many applications for both large and small impervious drainage areas with limited surface space. Parking areas, roadways, ROWs, sport courts, and fields.

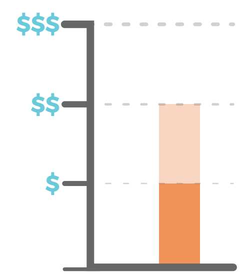
Maintenance

Annual maintenance is typical, but could require more frequent cleaning depending upon contributing drainage area (i.e. roads, parking lots, etc.)

- Inspect quarterly and after heavy rains, prone to clogging due to lack of maintenance. (“out of sight, out of mind”).
- Ensure inlet is clear and working properly. At a minimum, remove sediment and debris once a year. Spring is preferred.
- Maintain proper access to accommodate large equipment.
- See manufacturer’s requirements.

Tier

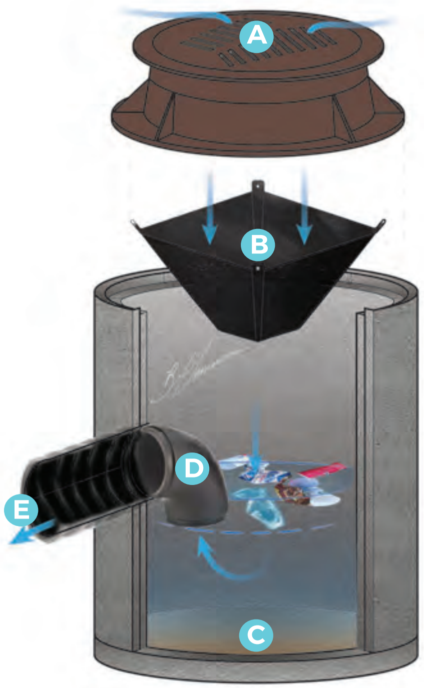
②



Maintenance Cost

May require partnering with other city agencies for equipment/maintenance. Vacuum or clam shell truck is required for sediment/debris removal. Cost can vary depending upon size. Larger structures can be costly may require confined space entry.

Function



- **A** Inlet Grate
- **B** Filter Bag (Optional)
- **C** Deep Sump
- **D** Outlet Hood
- **E** Outlet Pipe

High-Flow Sediment Filter Bag in Catch Basin (Credit: ACF Environmental)

Design & Implementation

- Structures can include deep sump catch basins, diversion structures, oil/water separators, water quality units, hydrodynamic separators, and small PVC drain basins.
- Requires planning and coordination with underground utilities.
- Provide maintenance access for larger equipment into the design.
- Consider buoyancy when installing structures within the water table.
- Provide outlet pipe hoods to capture floating debris (e.g. litter, debris and oil/grease) within the structure.
- Use a low profile structures if high invert connections are required.
- Consider the location and material of manhole covers and grates in lawn or play areas.
- For structures with closed pipe connections, avoid using in wooded or natural areas. Consider locating away from the GSI practice to minimize disturbance and provide access.
- Consider high-flow, sediment filter bags at the inlet grate to capture sediment for ease of maintenance and additional pretreatment.

Oil / Water Separator Structure (Credit: Mohr Separations Research, Inc.)

CISTERNS

: *Surface or subsurface structure that captures and stores water for reuse*

Advantages (+) & Limitations (-)

- \+ Reduces potable water use for irrigation
- \+ Interesting design element
- \- Limited storage
- \- Water reuse only

Existing Conditions

- Drainage Area: small
- Water table: 0 ft (can be in the WT)
- Soils: NA
- Utilities: conflicts when below ground
- Topography: 0%

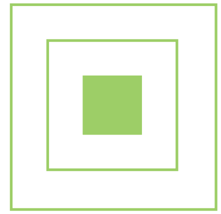
Companion Practices

Context

Planning

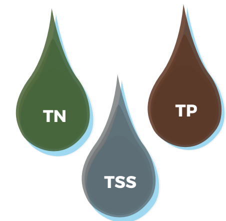
Versatility

Site specific & adaptable products to suit location



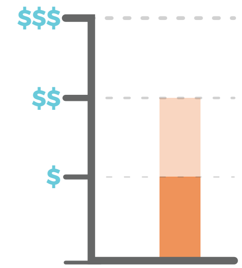
Footprint

Small footprint, minimal (surface)to moderate (subsurface) disturbance



Treatment

TSS = low
TP = low
TN = low



Installed Cost

Aboveground is less expensive than below ground

Uses: capture runoff for reuse in small gardens, lawn irrigation, design features and spray parks. Applicable for educational elements and playground feature. Also suitable for water feature recapture and reuse.

Maintenance

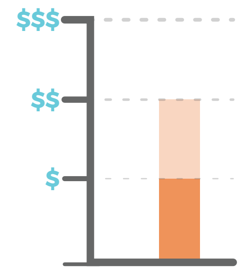
Typically requires a low-level of maintenance including: cleaning gutters and downspouts, draining water, dirt and debris removal, cistern walls disinfection.

- Inspect annually and repair leaks as needed.
- Maintenance frequency varies depending upon intended water reuse.
- Check during spring and summer for stagnant water and possible mosquito breeding. Drain aboveground cisterns and winterize to prevent freezing.
- Sample and test water quality as needed depending on intended water reuse.

Tier

1

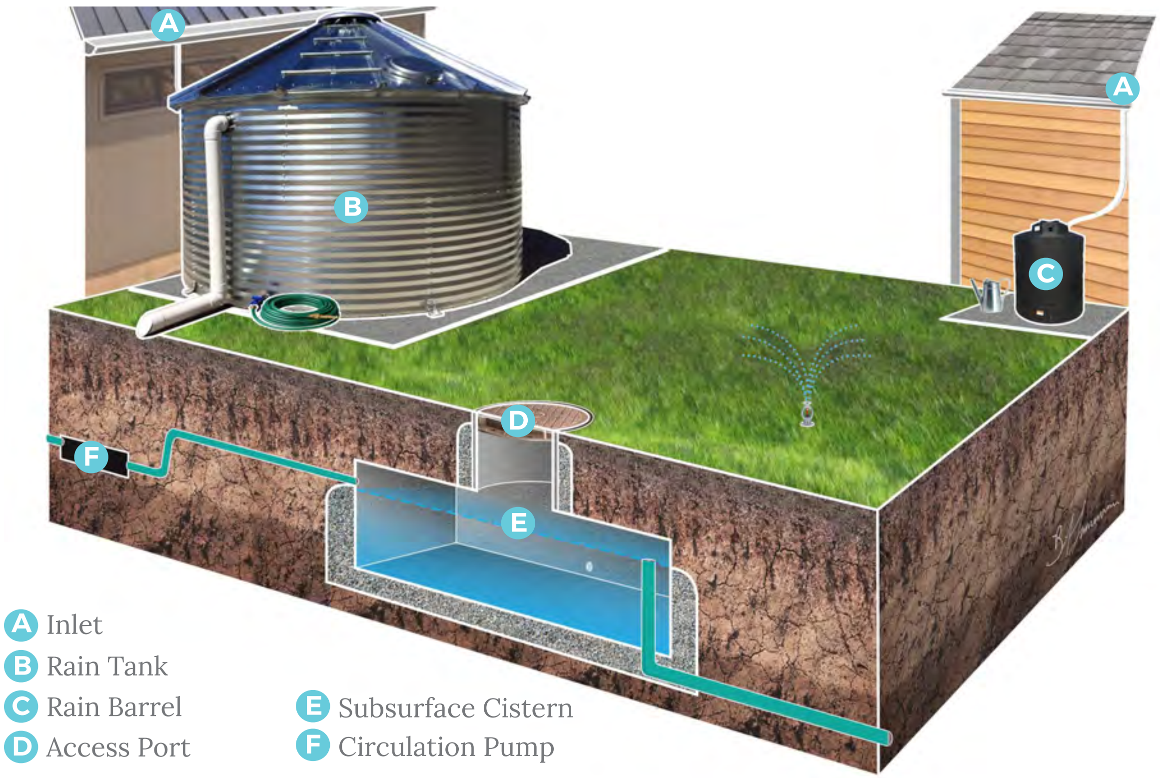
2



Maintenance Cost

Dependant upon type and intended grey water reuse. May require routine water sampling and cleaning frequency varies.

Function



Design & Implementation

- Identify intended water reuse prior to design and locate cistern(s) for convenient reuse access.
- Design foundation to support the weight of full cistern for above ground applications.
- Design for gravity flow to reduce costs or identify a power source if pumping is required.
- Locate a minimum of 10' from the building. Do not locate in areas with utility conflicts or place on top of subsurface structures.
- Do not locate in direct sunlight and areas with long periods of sun to prevent algae growth. Consider health and safety issues related to water quality and treatment requirements for reuse.
- Provide an overflow during large rain events which may exceed storage capacity.
- Cisterns and rain barrels should be covered at all times to prevent mosquitoes breeding.

Cistern takes roof runoff at Hernandez Boston Public School (Credit: HWG)

STORAGE BASIN (DRY)

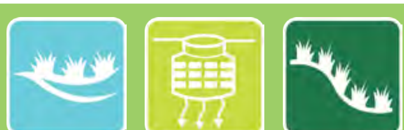
Advantages (+) & Limitations (-)

+ Reduces flooding
+ Adaptable to multi-functional spaces
+ Can be naturalized or mowed
- Limited water quality treatment
- Only provides water storage

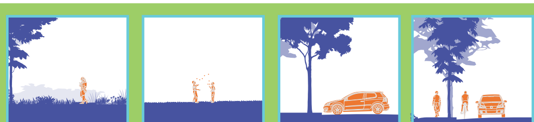
Existing Conditions

- Drainage Area: large
- Water Table: > 5 feet
- Soils: well drained to poor soils (A-D)
- Utilities: high level of conflict
- Topography: 0% min. - 5% max.

Companion Practices



Context

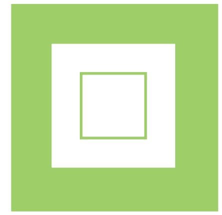


: depression to store large quantities of water during storm events and slowly release over time.

Planning

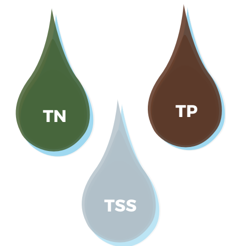
Versatility

Limited due to size, depth and overflow



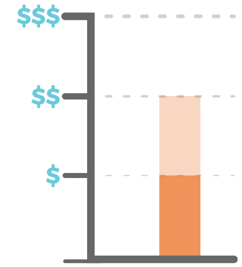
Footprint

Large footprint with significant disturbance



Treatment

TSS = medium
TP = low
TN = low



Installed Cost

Mostly earthwork

Uses: large grass areas, sports courts, plazas and stormwater parks designed to reduce peak flows and flooding. Can be programmed for multi-functional park use when dry. See Implementation (page 132) for more info on Stormwater Parks.

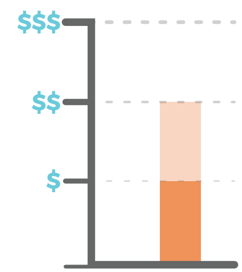
Maintenance

Typically requires frequent mowing.

- Inspect twice a year for sediment accumulation and signs of erosion.
- Mowing frequency should be based upon site context and seed mix selection.
- Establish and maintain vegetation.
- Repair and stabilize slopes.
- Remove debris/litter from outlet structures and/or spillways.
- Bag and remove grass clippings from storage basins to reduce nutrient loading.

Tier

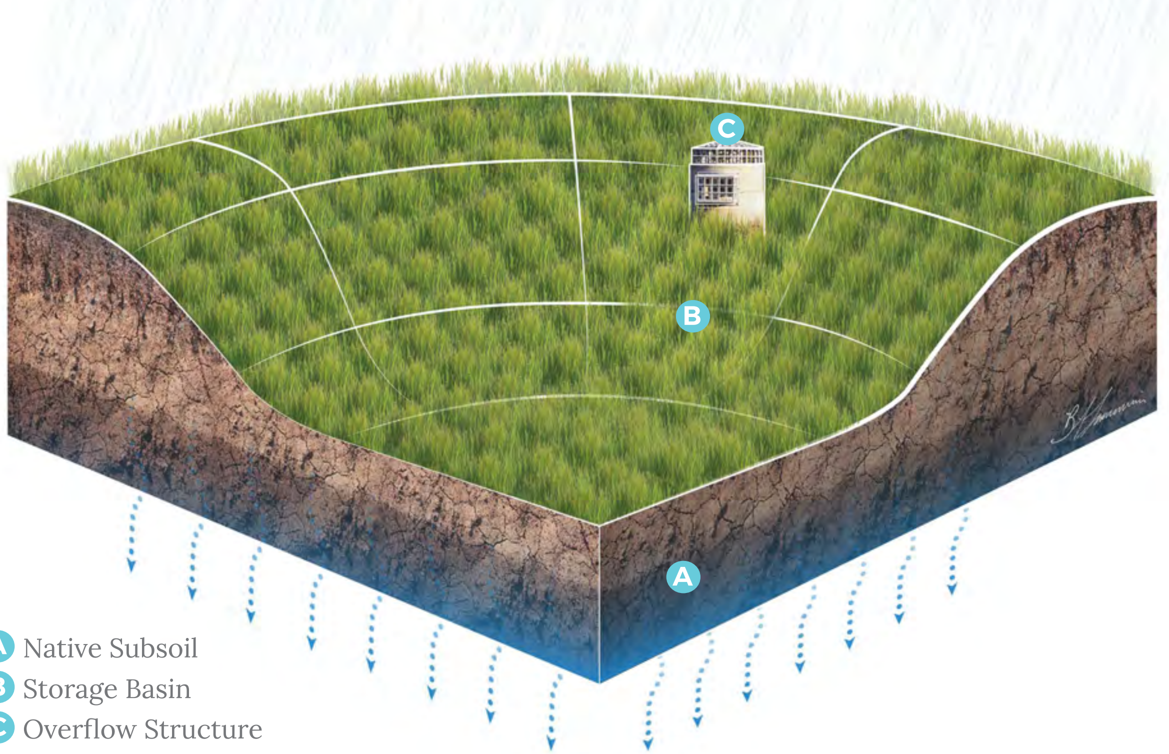
1



Maintenance Cost

Regular mowing, slope stabilization, and sediment, trash, and debris removal. Sediment removal and pretreatment maintenance may require larger equipment (Tier 2).

Function



A Native Subsoil
B Storage Basin
C Overflow Structure

Design & Implementation

- Take advantage of the existing topography where possible and design natural, organic shapes. Consider low-mow areas using native grasses to reduce mowing frequency and water demands.
- Design for multi-functional park space when dry. Ensure adequate safety and access.
- Design gentle side slopes (5:1) for ease of mowing or slope stabilization on slopes exceeding 3:1.
- If required, use walls and/or terraces as design elements to minimize steep slopes.
- Consider a tiered bottom with varying depths to accommodate diverse plant communities.
- Creatively integrate overflow/outlet structure(s) into the site to minimize eyesores and clogging.
- Provide a maximum drawdown time of 24 hours to avoid stagnant water and soggy soils.
- Provide maintenance access to avoid unplanned vehicular damage/worn paths

Storage Basin at Manassas Park Elementary School
(Credit: Prakash Patel Photography)
(Project Team: O'Shea Wilson Siteworks & VMDO)

STORES/INFILTRATES

UNDERGROUND CHAMBERS

: stores and infiltrates small to large volumes underground while maximizing usable surface space

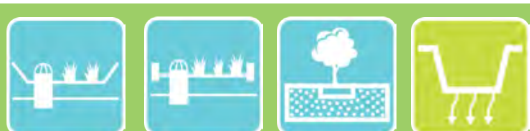
Advantages (+) & Limitations (-)

- \+ Adaptable to multi-functional spaces
- \+ Low impact to existing park use
- \+ Reduces flooding
- \- No aesthetic value
- \- Special equipment for maintenance
- \- Often neglected and prone to clogging- “out of sight, out of mind”
- \- Best combined with surface practices

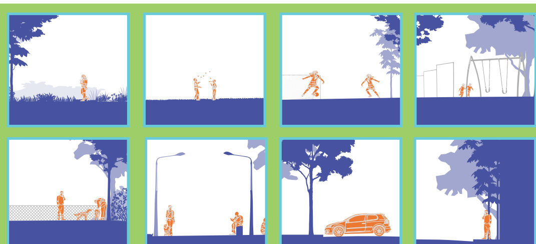
Existing Conditions

- Drainage Area: large to small
- Water Table: > 5 feet
- Soils: poor to well drained (A-D)
- Utilities Conflicts: high
- Topography: 0% min. - 10% max.

Companion Practices



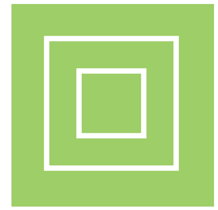
Context



Planning

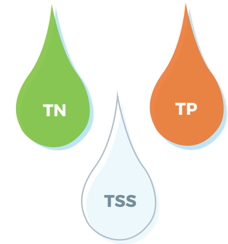
Versatility

Highly adaptable for multi-functional park spaces



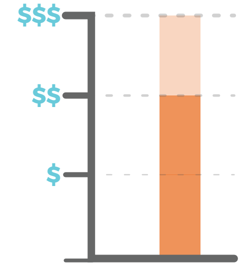
Footprint

Large and small spaces with moderate site disturbance



Treatment

TSS = high
TP = medium
TN = medium



Installed Cost

Requires excavation and materials.

Uses: ideal for below (subsurface) parking lots, sport fields and courts, playgrounds, plazas/ hardscapes and open fields without trees or utility conflicts. Can be used to infiltrate direct roof runoff.

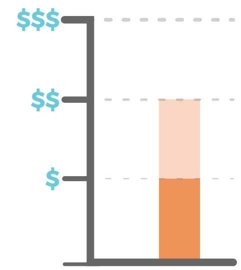
Maintenance

Maintenance should occur within surface pretreatment areas. Cleaning underground chambers requires special equipment.

- Pretreatment is critical to minimize maintenance and failure.
- Inspect inlets, inspection ports, chambers, diversion structure and overflow at least twice annually.
- Proper pretreatment and regular maintenance is critical.
- Refer to product manufacturer’s maintenance requirements and guidelines.

Tier

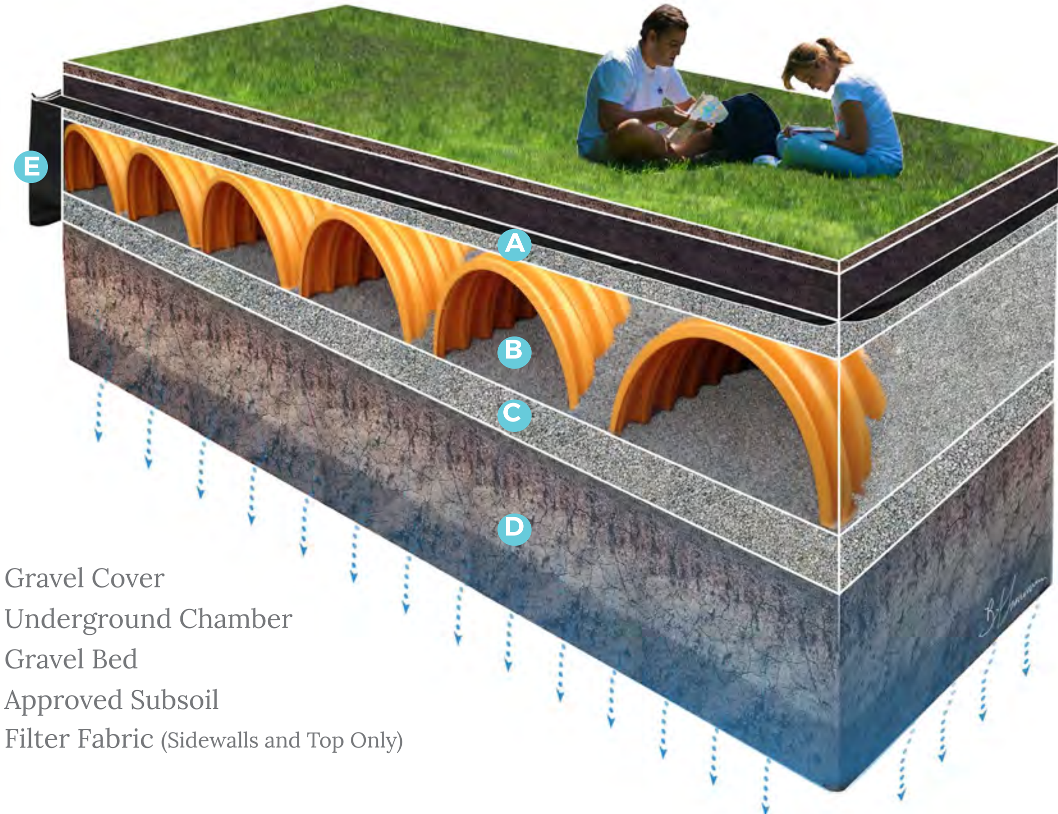
②



Maintenance Cost

Vacuum truck and specialized equipment is required for sediment removal. Maintenance should be minimal if pretreatment is properly designed and maintained.

Function

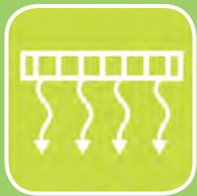


- **A** Gravel Cover
- **B** Underground Chamber
- **C** Gravel Bed
- **D** Approved Subsoil
- **E** Filter Fabric (Sidewalls and Top Only)

Design & Implementation

- Underground chambers are most successful when combined with other GSI practices.
- Design for redundancy in pretreatment sediment capture to prevent clogging and combine chamber fields with companion practices to capture sediment above ground.
- Provide cleanouts/inspection ports (> 6” diameter) for routine inspection and maintenance.
- An impervious liner is required for sites with a high water table or contaminated soils.
- Perforated underdrains and an overflow structure are required for drawdown in poor soils.
- Design for H-20 loading beneath vehicular areas (roads, parking lots, fire lanes, etc.).
- Designer or BPRD staff should observe subsoils, subbase, and chamber install prior to backfill.
- Design and install the system per the specific product manufacturer’s requirements.

Underground Chambers at Fisher Hill Reservoir (Credit for three images above: KMDG)



PERMEABLE SURFACES

Advantages (+) & Limitations (-)

- \+ Adaptable to multi-functional spaces
- \+ Low impact to existing park use
- \+ Hardscape aesthetic value
- \+ Reduces need and/or size of additional/off-site stormwater areas
- \- Prone to clogging without sufficient maintenance
- \- Requires special maintenance
- \- Not suitable for off-site runoff, suitable for direct infiltration only

Existing Conditions

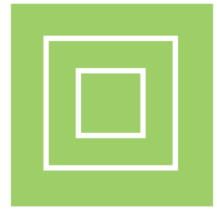
- Drainage Area: small to large
- Water Table: > 3 feet
- Soils: well drained (A&B)
- Utilities: shallow depth can accommodate some utilities
- Topography: 0% min. - 3% max.

Context

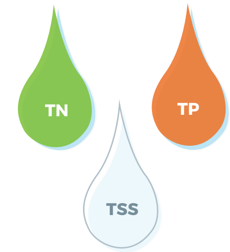
: open voids in the surface and subbase allow water to drain while still providing a rigid surface

Planning

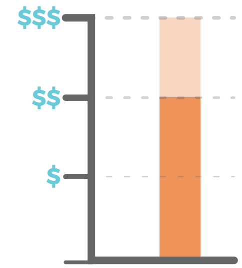
Versatility
Alternative surface for existing impervious areas



Footprint
Customizable to serve specific applications



Treatment
TSS = high
TP = medium
TN = medium



Installed Cost
Requires earthwork and materials

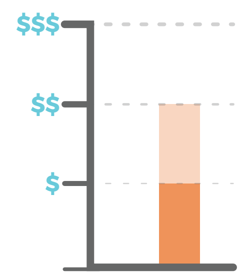
Uses: retrofit existing impervious areas, alternative for parking lots, pathways, sidewalks, plazas, playgrounds, tree pits, and forebays. Many products available allow for highly-adaptable designs.

Maintenance

Frequent inspections and maintenance is required to sustain the surface porosity.

- Requires annually vacuuming or pressure washing to reduce clogging. Do not sweep.
- Winter sanding is not allowed, and the reduction of deicing salts is required.
- Provide signage or stencils to identify areas for the maintenance providers.
- Patch repairs with the same material.
- A rubber plow edge may be required for snow removal
- Refer to the product manufacturer's specific maintenance requirements.

Tier ②

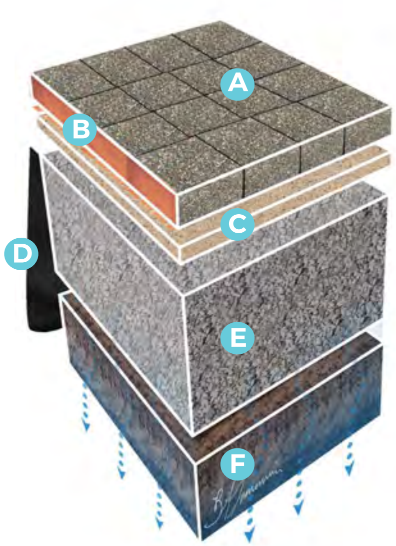


Maintenance Cost

Vacuuming surface and sediment/debris removal. Cost varies depending on size and frequency.

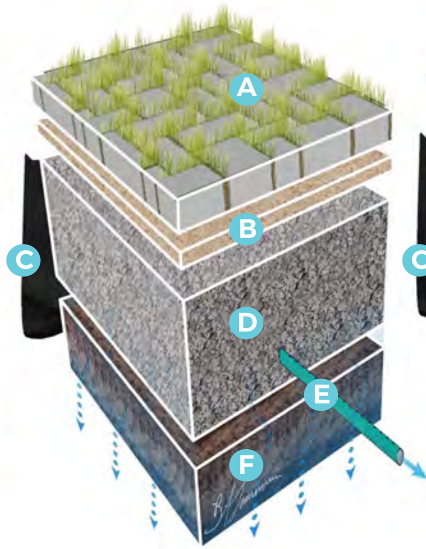
Function

Ⓐ Pervious Pavers



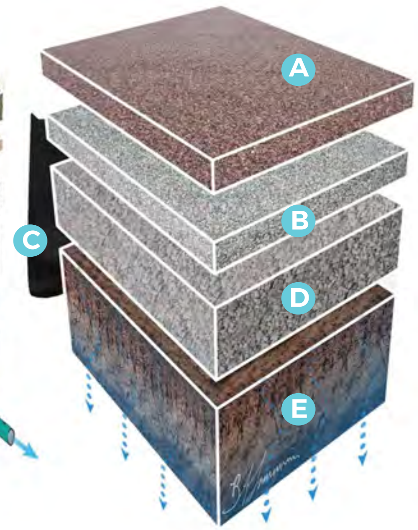
Ⓑ Edging (Per Manufacturer)
Ⓒ Bedding Course
Ⓓ Filter Fabric (Sidewalls Only)
Ⓔ Gravel Reservoir
Ⓕ Approved Subsoil

Ⓐ Grass Pavers



Ⓑ Bedding Course
Ⓒ Filter Fabric (Sidewalls Only)
Ⓓ Gravel Reservoir
Ⓔ Perforated Underdrain
Ⓕ Approved Subsoil

Ⓐ Porous Pavement



Ⓑ Choker Course
Ⓒ Filter Fabric (Sidewalls Only)
Ⓓ Filter Course
Ⓔ Approved Subsoil

Design & Implementation

- Critical to perform infiltration testing in the proposed location to ensure proper drainage.
- Consider use and loading to select proper surface material and subbase requirements.
- Surface slope not to exceed 5%, and underdrains may be required to properly drain with 72 hours.
- Do not direct surrounding runoff to permeable surfaces. Provide conveyance swales to intercept runoff at the perimeter where necessary.
- Select low albedo permeable pavement/paver colors to reduce heat island effect.
- Can provide additional storage for larger storms or off-site runoff (piped) with an extended stone reservoir.
- Consider impact to surrounding tree roots.
- Designer or BPRD staff should observe subsoils, subbase, and surface material installation.

Interlocking pavers, BAC Green Alley (Credit: HWG)

Grass pave, Rose Kennedy Greenway (Credit: HWG)

Polymer bond with open-graded pavement (Credit: HWG)

INFILTRATION BASIN

: *landscape space that stores and infiltrates large or small volumes, but remains dry most of the time*

Advantages (+) & Limitations (-)

- \+ Adaptable to multi-functional spaces
- \+ Can be programmed for multi-functional park use when dry.
- \+ Can be naturalized or mowed
- \+ Can have minimal visual impact
- \- Open space required
- \+ Pretreatment required to reduce clogging

Existing Conditions

- Drainage Area: small to large
- Water Table: > 5 feet
- Soils: well drained (A & B)
- Utility Conflicts: high
- Topography: 0% min. - 5% max.

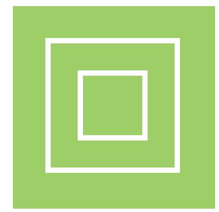
Companion Practices

Context

Planning

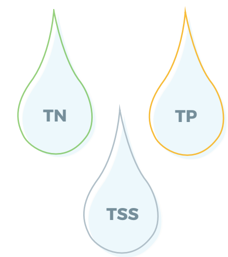
Versatility

Adaptable to multi-functional park spaces



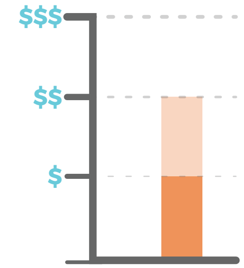
Footprint

Small to large, moderate to significant disturbance



Treatment

TSS = high
TP = high
TN = high



Installed Cost

Inexpensive to construct. Mostly earthwork

Uses: underutilized open lawn and field areas to accept surrounding park runoff. Suitable for edge of parking lots, roads, paths, Can be part of Floodable Areas (see Special Conditions, page 56) and Stormwater Parks (see Implementation, page 132).

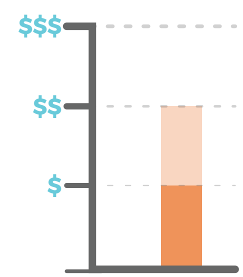
Maintenance

Maintain as a mowed lawn for relatively low effort maintenance.

- Inspect inlets and outlet after heavy rains.
- Mowing frequency should be determined by park context and selected seed mix.
- Pretreatment is critical as sediment accumulation may require large equipment and disturbance for removal.
- Stabilize slopes and repair eroded areas.
- Remove sediment from pretreatment device and inspect bottom of basin for trash and debris to prevent clogging.

Tier

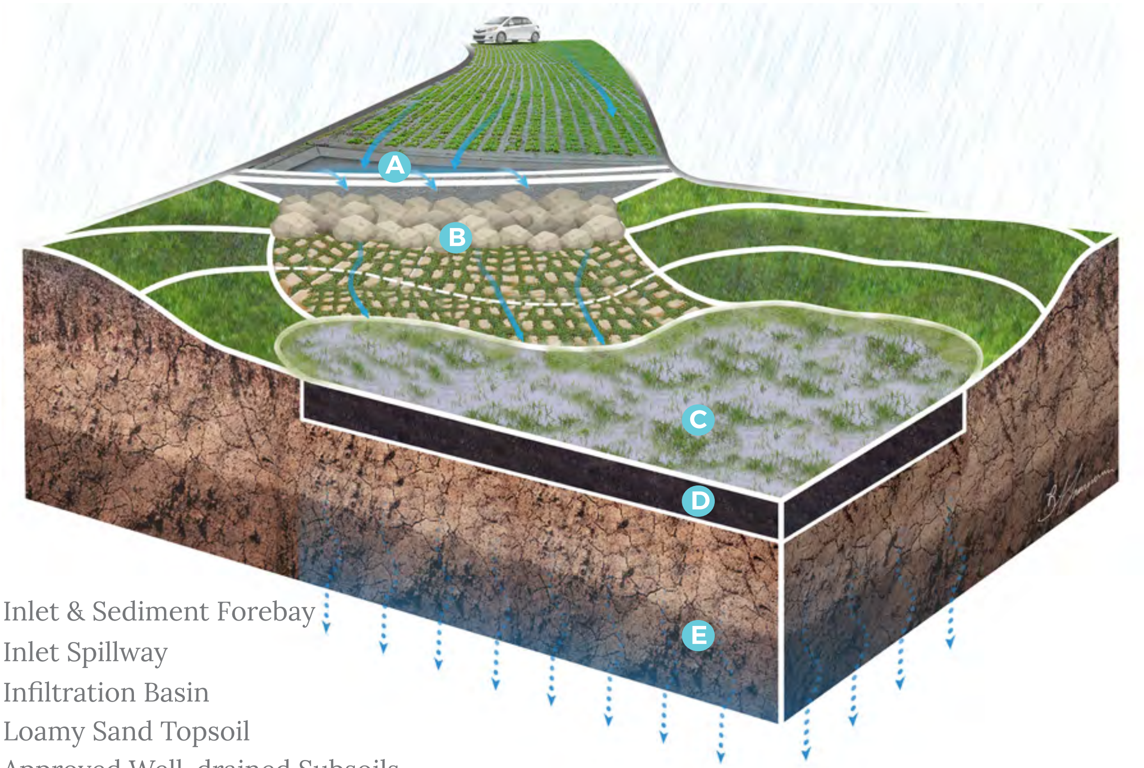
1



Maintenance Cost

Regular mowing, slope stabilization, and sediment, trash, and debris removal. Sediment removal and pretreatment maintenance may require larger equipment (Tier 2).

Function



- **A** Inlet & Sediment Forebay
- **B** Inlet Spillway
- **C** Infiltration Basin
- **D** Loamy Sand Topsoil
- **E** Approved Well-drained Subsoils

Design & Implementation

- When designing for a multi-functional spaces, maintain shallow depths (2 feet or less).
- For multi-functional spaces provide a maximum drawdown time of 24 hours.
- Provide gentle sides slopes for ease of mowing and to accommodate park uses/safe access.
- Avoid heavy equipment and over-compaction along the bottom during construction.
- Consider low-mow grasses or other native plants that reduce maintenance and water demand.
- Combine with companion GSI, such as dry wells to increase capacity and draw down time.
- When selecting plants, consider total basin depth and ponding depth.
- Designer or BPRD staff should observe subsoils, subbase and chamber install prior to backfill.
- See also Storage Basin - Design & Implementation.

Infiltration Basin at Heritage Museums & Gardens (Credit: HWG)

Infiltration Basin off Crane Farm Road, MA (Credit: HWG)

Infiltration Basin (Credit: City of Thousand Oaks)

DRY WELL

: *pre-fabricated subsurface structure designed to infiltrate runoff into native subsoils*

Advantages (+) & Limitations (-)

- \+ Low impact to existing park use
- \+ Highly adaptable to existing park uses
- \- Provides no value to the natural environment
- \- Often neglected and prone to clogging- "out of sight, out of mind"
- \- Pretreatment required to reduce clogging

Existing Conditions

- Drainage Area: small
- Water Table: > 6 feet
- Soils: well drained (A&B)
- Utility Conflicts: moderate
- Topography: no restrictions

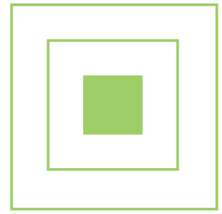
Companion Practices

Context

Planning

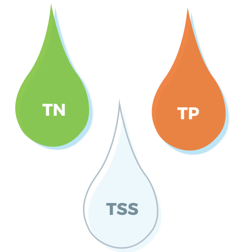
Versatility

Adaptable to different sites and companion practices



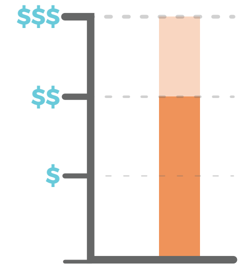
Footprint

Small for tight spaces with moderate disturbance



Treatment

TSS = high
TP = medium
TN = low



Installed Cost

Earthwork and structure costs

Uses: roofs, roadways, paths, parking lots, lawns. etc. Best when combined with other GSI practices to provide pretreatment, additional storage and infiltration capacity. Not recommended to be used as a stand alone catch basin.

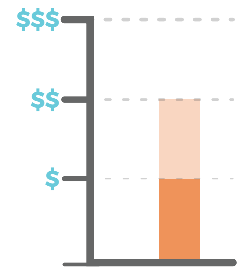
Maintenance

Relatively low maintenance, but requires specialized equipment to clean.

- Prone to clogging, inspect bi-annually (spring and fall) and after large rain event
- Clean and remove sediment annually
- Keep the inlet clean to prevent ponding, flooding, or erosion
- Leaf litter can cause clogging problems and leaves should be removed later fall before the winter
- When using in grass or landscaped areas, consider a bee-hive grate to prevent clogging.

Tier

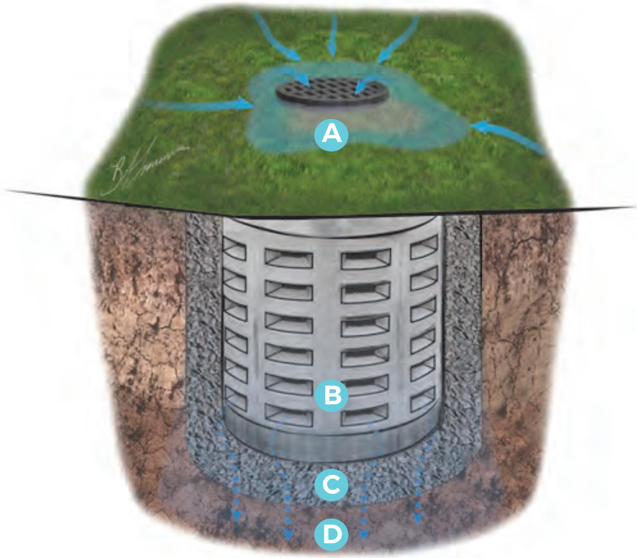
①

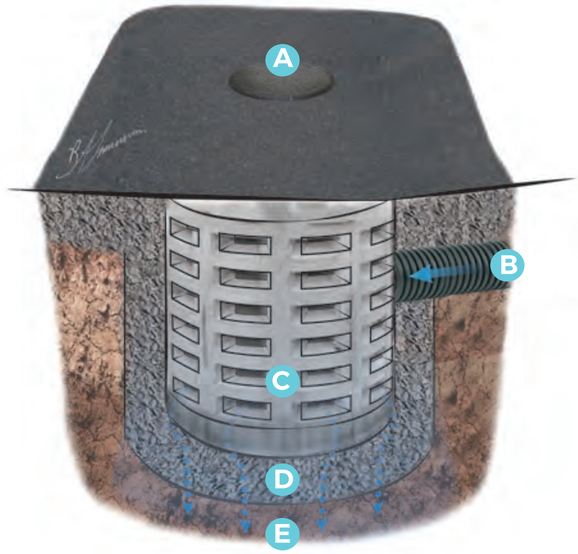


Maintenance Cost

May require partnering with other city agencies for equipment/maintenance. Vacuum or clam shell truck is required for sediment/debris removal. Low cost and low level of effort.

Function





- **A** Grate set higher than Shallow Depression
- **B** Dry Well (Perforated Structures)
- **C** Washed Stone
- **D** Approved Subsoils

- **A** Cover
- **B** Inlet Pipe (from deep sump catch basin)
- **C** Dry Well (Perforated Structures)
- **D** Washed Stone
- **E** Approved Subsoils

Design & Implementation

- Provide deep sump catch basin for pretreatment or at a minimum provide a high-flow, sediment filter bag at the inlet grate to capture sediment for ease of maintenance.
- Can also be used at the end of the treatment train with GSI surface practices to provide additional overflow storage and improve infiltration capacity.
- As possible, provide a piped overflow connection to the drainage network for larger storms.
- Do not install dry wells within the water table and maximize separation to groundwater from the bottom of the structure. 2 foot minimum required.
- Provide H-20 loading for all paved surface applications and wherever vehicles are anticipated.
- Set rim slightly higher in landscaped surface applications to provide pretreatment.
- Use low-profile structures, frames,and grates to provide flexibility for high inverts or to maintain separation from groundwater.

Dry Wells (perforated structures) (Credit: HWG)

Dry Wells during installation (Credit: HWG)

Dry Wells combined with Infiltration Basin (Credit: HWG)

RAIN GARDEN

: shallow depressions that temporarily hold and filter water through existing or amended soils

Advantages (+) & Limitations (-)

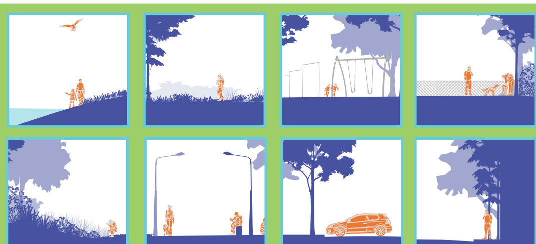
- \+ Simple design and installation (no structures, shallow earthwork)
- \+ Uses existing soil
- \- Requires larger footprint compared to bioretention and bioswales
- \- Not suitable for high pollutant areas
- \- Best for small site applications
- \- Can be prone to extended periods of ponding

Existing Conditions

- Drainage Area: small
- Water Table: > 3 feet
- Soils: well drained (A&B)
- Utilities: low level of conflict
- Topography: 0% min. - 3% max.

Companion Practices

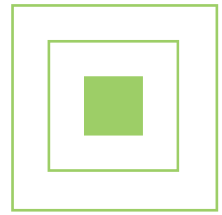
Context



Planning

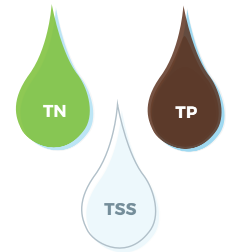
Versatility

Adaptable in shape and size, useful as a retrofit



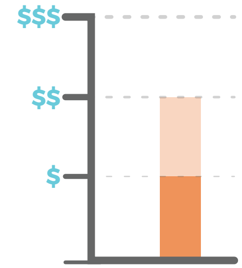
Footprint

Small sites, minimal disturbance



Treatment

TSS = high
TP = low
TN = medium



Installed Cost

Inexpensive, can be done by hand

Uses: roofs, pathways, sidewalks, small plazas/hardscapes, and playground runoff. Convert existing planting beds for stormwater treatment and create pollinator gardens. Great for demonstration training and educational outreach programs.

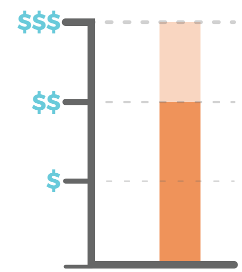
Maintenance

Depending upon objectives and plant selection can required higher level of maintenance.

- Inspect quarterly for invasive plant species and drainage patterns.
- Maintain and cut back vegetation.
- Weed frequently as part of bi-monthly landscape maintenance routine
- Cut and remove dead biomass to improve aesthetics and prevent clogging in late fall.
- Stabilize slopes and repair eroded areas.
- Maintain flat bottom for even infiltration and to avoid scouring.

Tier

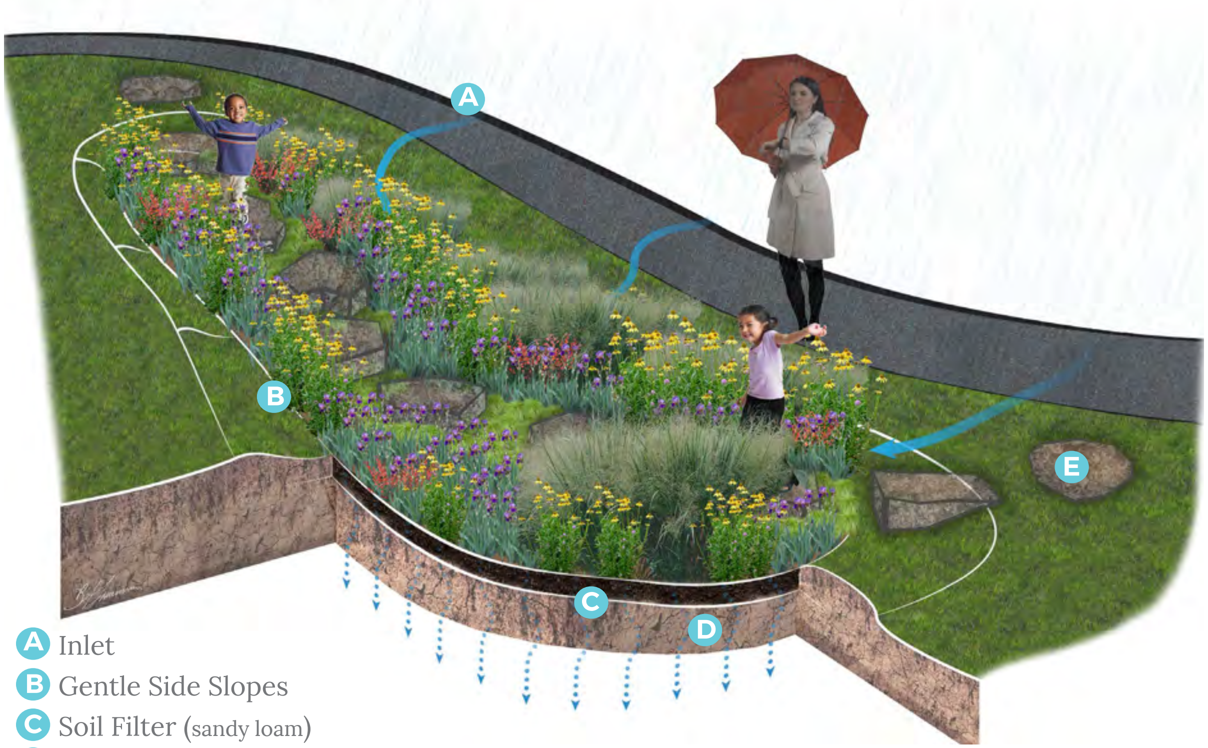
②



Maintenance Cost

Manual labor for sediment and debris removal. Requires plant knowledge for weeding. Cost varies by size and plant palette.

Function



- **A** Inlet
- **B** Gentle Side Slopes
- **C** Soil Filter (sandy loam)
- **D** Well-drained Native Soil
- **E** Stepping Stones

Design & Implementation

- Depending on contributing drainage area, rain gardens may not require pretreatment.
- Convert the existing landscape (lawns, planting beds, etc.) into depressed landscape areas to accept runoff. Work with the existing topography and locate at low points.
- Create natural, organic shapes in less formal areas.
- 5:1 side slopes or greater are preferred, 3:1 side slope maximum.
- Shallow ponding depth of 3 inches – 6 inches. Amend soils if necessary to avoid standing water for more than 24 hours.
- Integrate into the overall site design for high visibility and to encourage public interaction.
- Provide an overflow spillway to control and convey excess stormwater during large storms.

Rain Garden on the Rose Kennedy Greenway (Credit: HWG)

Rain Garden on the East Boston Greenway (Credit: HWG)

FILTERS

BIORETENTION (SOFT EDGE)

Advantages (+) & Limitations (-)

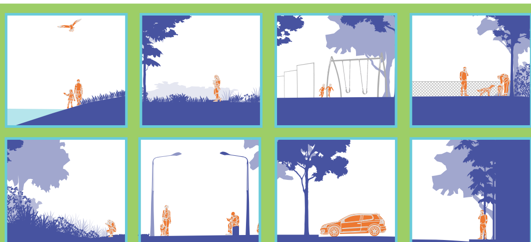
+ Highly adaptable to many sites
+ Ideal for naturalized areas
+ Can be designed as a landscape amenity or feature
+ Better treatment than a rain garden
- Requires greater construction oversight (engineered soils, underdrains and structures)

Existing Conditions

- Drainage Area: small to medium
- Water Table: > 3 feet (without liner)
- Soils: poor to well drained (A-D)
- Utilities: medium level of conflict
- Topography: 0% min. - 10% max.

Companion Practices

Context

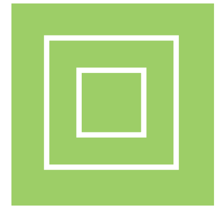


: holds and filters water through a side slope depression and amended soils, pipes, and structures

Planning

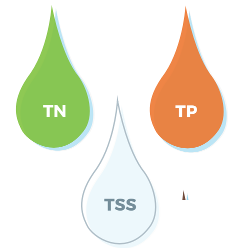
Versatility

Adaptable in shape and size, useful as a retrofit



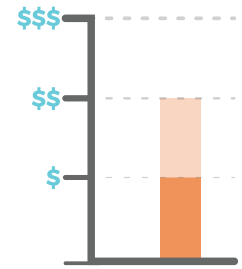
Footprint

Adaptable to meet available space, moderate disturbance



Treatment

TSS = high
TP = medium
TN = medium



Installed Cost

Cost varies based on complexity, materials, and plantings

Uses: parking lots islands, road medians, edge of paths, integrated into plazas/hardscapes, and playground. Used to convert existing planting beds for stormwater treatment and create pollinator gardens. Locate in underutilized areas such as lawns and planting beds.

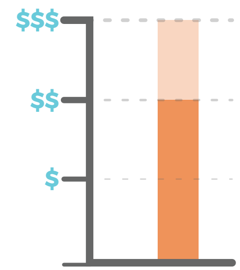
Maintenance

Moderate to high level of plant maintenance.

- Inspect quarterly and after heavy rains.
- Weed frequently as part of bi-monthly landscape maintenance.
- Maintain vegetation. Prune and replace plants as needed.
- Stabilize slopes and repair eroded areas to prevent clogging.
- Clean overflow structure and emergency spillway bi-annually to prevent failure. Consider beehive grates to prevent clogging.
- Use groundcovers vs. mulch to suppress weeds and reduce clogging.

Tier

②



Maintenance Cost

Manual labor for weeding, sediment, trash and debris removal, slope stabilization. Requires plant knowledge for pruning and weeding. Cost varies by size, complexity, and plant palette.

Function

Design & Implementation

- Includes amended soil media, overflow structures connections to a drainage network and spillways. An underdrain is required for poor draining soils and sites with shallow water table separation.
- Natural and organic in appearance. Integrate into the landscape, avoid placement at the edge or perimeter of spaces prone to neglect.
- Embrace existing topography and create natural, organic shapes. Consider terracing on steep slopes.
- Consider placing in highly visible areas. Provide gentle, varying side slopes to blend into the landscape and to encourage public interaction. 5:1 side slopes or greater are preferred, 3:1 side slope maximum.
- Recommended ponding depth is between 3 inches – 6 inches. Design to avoid ponding water for more than 24 hours to improve multi-functional use.
- Integrate overflow structure into side slope to limit visibility.

Bioretention at Heritage Museums & Gardens (Credit: HWG)

Bioretention on Cape Cod (Credit: HWG)

Bioretention at Heritage Museums & Gardens (Credit: HWG)

FILTERS

BIORETENTION (HARD EDGE)

: holds and filters water through a hard edged depression with amended soils, pipes and structures

Advantages (+) & Limitations (-)

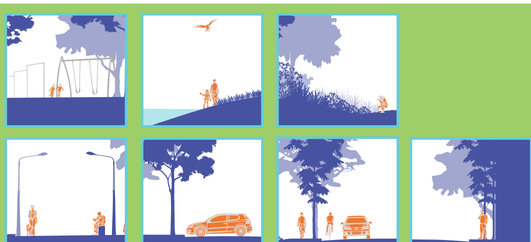
- \+ Great for urban spaces
- \+ Formal/structured appearance
- \+ Adds landscape interest in hardscapes
- \- Interior curb reveal 12" or greater
- \- 6" curb reveal or short fences may be required for safety in streetscapes
- \- Requires greater construction oversight (engineered soils, underdrains and structures)

Existing Conditions

- Drainage Area: small to medium
- Water Table: > 3 feet (without liner)
- Soils: poor to well drained (A-D)
- Utilities: medium level of conflict
- Topography: 0% -10%

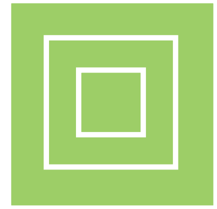
Companion Practices

Context

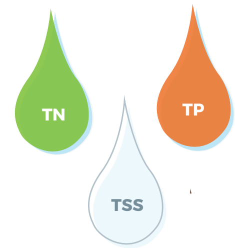


Planning

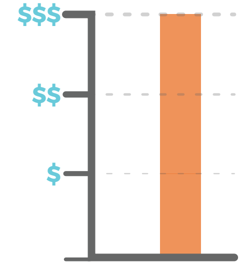
Versatility
Adaptable in size, shape for linear sites



Footprint
Adaptable for tight spaces, moderate disturbance



Treatment
TSS = high
TP =medium
TN = medium



Installed Cost
Higher cost due to formal edging and urban environment

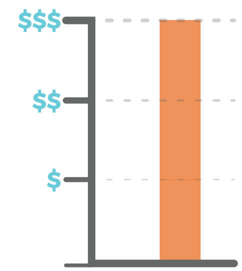
Uses: tight urban spaces with limited area including plazas/hardscapes, parking lots, playgrounds, and sidewalk/streetscapes. Can be used to create visual and physical buffers between spaces and replace formal planters.

Maintenance

Moderate to high level of plant maintenance.

- Inspect quarterly and after heavy rains.
- Weed frequently as part of bi-monthly landscape maintenance.
- Establish and maintain vegetation. Prune and replace plants as needed.
- Repair eroded areas.
- Clean pretreatment area, overflow structure and emergency spillway to prevent clogging and overtopping. Consider beehive grates to avoid clogging.
- Use groundcovers vs. mulch to suppress weeds and reduce clogging.

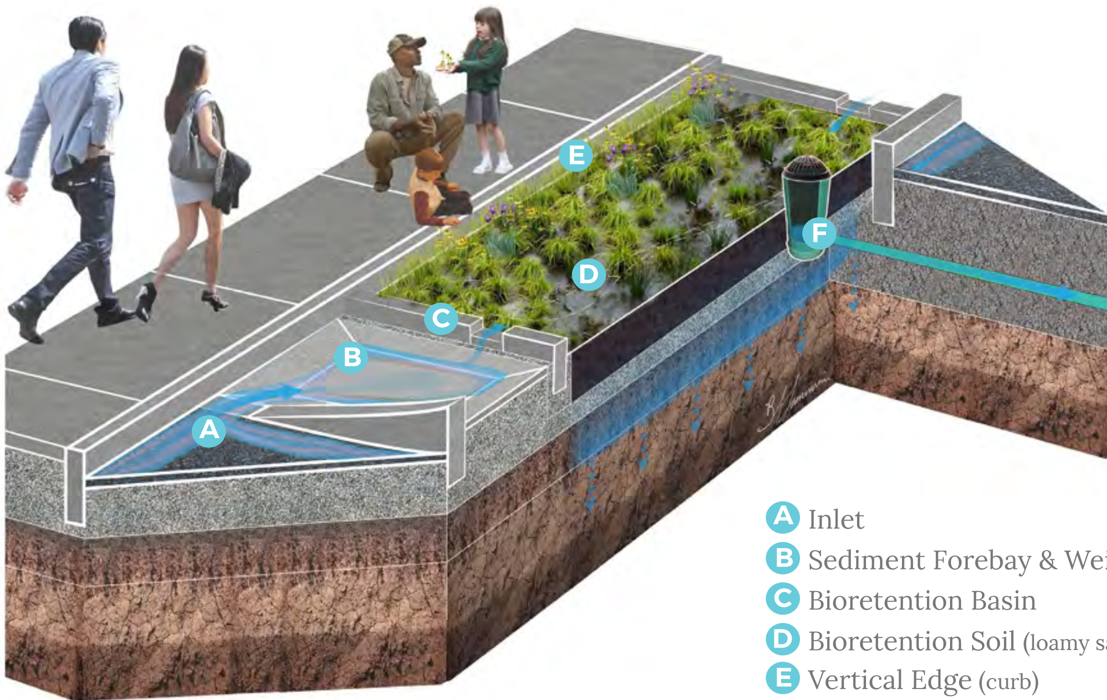
Tier ②



Maintenance Cost

Manual labor for weeding, sediment, trash and debris removal, slope stabilization. Requires plant knowledge for pruning and weeding. Cost varies by size, complexity, and plant palette.

Function



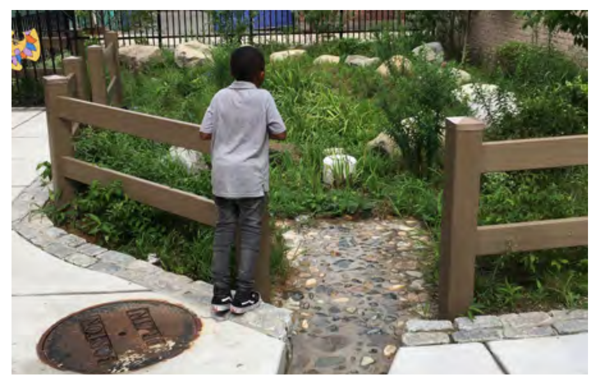
- **A** Inlet
- **B** Sediment Forebay & Weir
- **C** Bioretention Basin
- **D** Bioretention Soil (loamy sand)
- **E** Vertical Edge (curb)
- **F** Overflow Structure

Design & Implementation

- Includes amended soil media, overflow structures connected to a drainage network, and curbs/hard edge. Underdrains are required for poor draining soils and sites with shallow water table separation.
- Use granite curbing or other vertical element to create a hard edge in lieu of side slopes.
- Formal, structured appearance with geometrical shapes to fit urban environment and minimize grading requirements.
- Typically located in an urban landscapes with area limitations or sites with grading challenges (steep side slopes). Work with the topography and "step" with check dams to maintain flat bottom & proper depth when necessary.
- Shallow ponding depth of 3 inches – 6 inches. Design to avoid ponding water for more than 24 hours. Try to maintain a maximum depth of 12" from top of curb to bottom.
- Integrate into the overall site improvements to provide visibility, access ,and circulation.

Bioretention at Fisher Hill, Brookline (Credit: KMDG)

Streetscape Bioretention, Cambridge (Credit: HWG)



Outdoor classroom Bioretention, Boston (Credit: HWG)

BIOSWALE (SOFT EDGE)

: moves and filters water through a linear landscape swale with amended soils

Advantages (+) & Limitations (-)

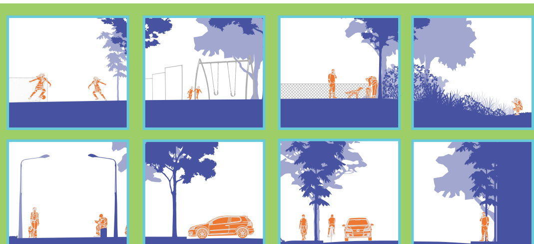
- \+ Both moves and filters water
- \+ Can be simpler design than bioretention with no structures
- \+ Can be naturalized or mowed
- \- Prone to erosion (bottom & slopes)

Existing Conditions

- Drainage Area: small
- Water Table: > 3 feet (without liner)
- Soils: poor to well drained (A-D)
- Utilities: medium level of conflict
- Topography: 0% min. - 5% max.

Companion Practices

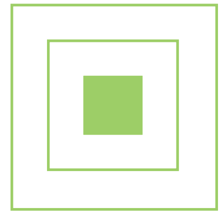
Context



Planning

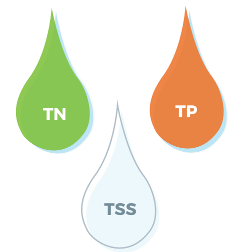
Versatility

Adaptable in size, shape and as a retrofit



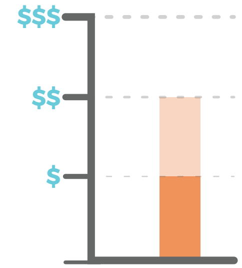
Footprint

Linear and narrow spaces, moderate disturbance



Treatment

TSS = high
TP = medium
TN = medium



Installed Cost

Cost varies based on complexity, materials, and plantings

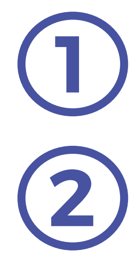
Uses: edge of parking lots, roads, plazas, playgrounds, open fields, sports fields, courts, and pathways. Can be used to create visual and physical buffers between conflicting uses. Located in underutilized landscape areas.

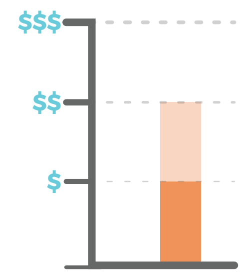
Maintenance

Moderate to high level of plant maintenance.

- Inspect quarterly and after heavy rains.
- Weed frequently as part of bi-monthly landscape maintenance.
- Establish and maintain vegetation. Prune and replace plants as needed.
- Stabilize slopes and repair eroded areas.
- Clean overflow structure and emergency spillway to prevent clogging and overtopping.
- Use groundcovers not mulch to suppress weeds and reduce clogging.

Tier

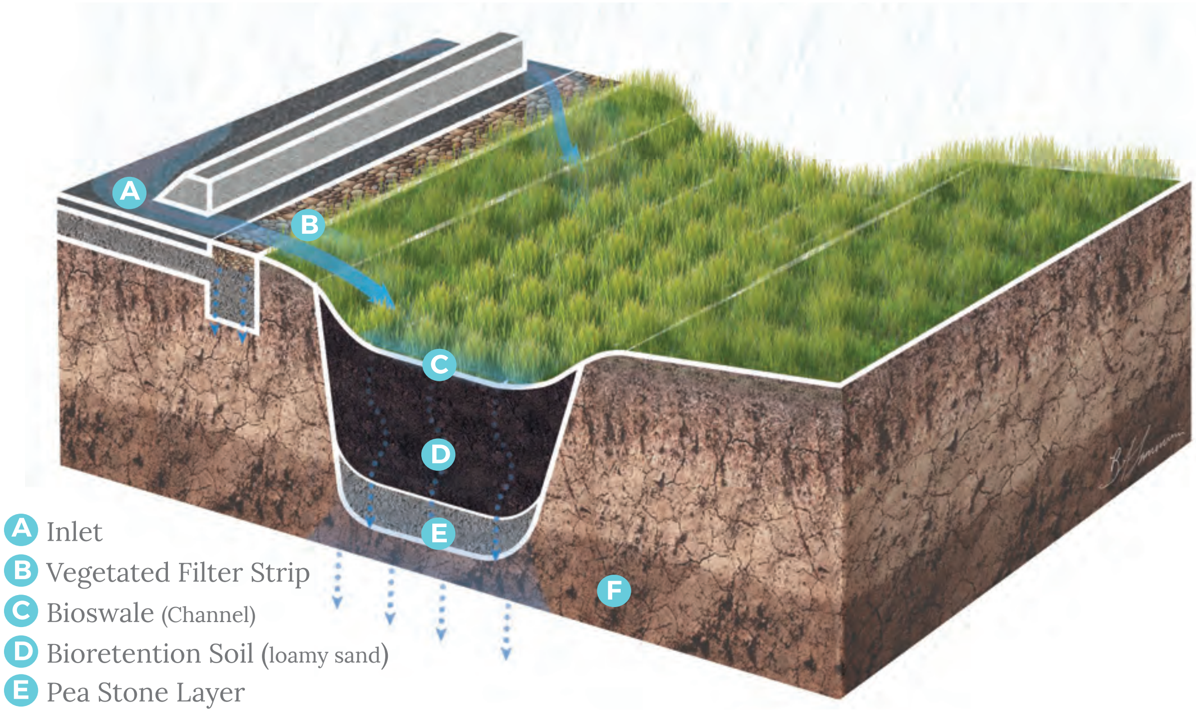




Maintenance Cost

Manual labor for weeding, sediment, trash and debris removal, stabilization. Use seed mixes for mowing (Tier 1). Cost varies by size, complexity, and plant palette.

Function



- **A** Inlet
- **B** Vegetated Filter Strip
- **C** Bioswale (Channel)
- **D** Bioretention Soil (loamy sand)
- **E** Pea Stone Layer
- **F** Approved Subsoils

Design & Implementation

- Typically requires a low level of effort to convert underutilized perimeter landscape areas (lawns, planting beds, and degraded edges, etc.) to bioswales.
- Keep swales shallow with total bed depth of 6 inches – 12 inches. Work with the topography and provide check dams to maintain ideal slope gradients. Ideal running slope of the conveyance channel is between 1% - 5%.
- Provide scour protection such as permeable hardscape or turf reinforced matting to prevent erosion (>2%).
- Provide gentle side slopes (5:1 or >) for ease of mowing and maintenance (3:1 max.).
- For well drained soils, design for stormwater to flow in and out to eliminate outlet structures and piped connections.
- Perforated underdrain with an outlet structure is required for poor draining soils. Can be located in the bioretention soil layer for sites with shallow water table separation.
- Can be integrated into the park as a landscape feature and to buffer incompatible uses.

Bioswale at Roger Williams Park, RI (Credit: HWG)

Orr's Pond, MA (Credit: HWG)

Roger Williams Park, RI (Credit: HWG)

FILTERS

BIOSWALE (HARD EDGE)

: *moves and filters water through a linear hard edged channel with amended soils, and pipes*

Advantages (+) & Limitations (-)

+ Great for linear urban spaces
+ Formal/structured appearance
+ Adds landscape interest in hardscapes and streetscapes
- Increased material and installation cost
- More advanced design, see bioretention

Existing Conditions

- Drainage Area: small to medium
- Water Table: > 3 feet (without liner)
- Soils: poor to well drained (A-D)
- Utilities: high level of conflict
- Topography: 0% min. - 6% max.

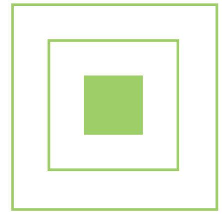
Companion Practices

Context

Planning

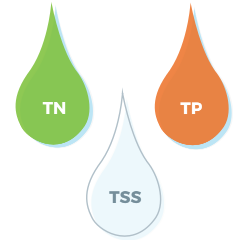
Versatility

Multiple uses and creative design potential



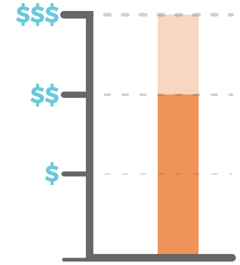
Footprint

Linear and narrow spaces, moderate disturbance



Treatment

TSS = high
TP = medium
TN = medium



Installed Cost

Cost varies based on complexity, materials and plantings

Uses: tight, linear spaces within streetscapes, road medians, and edge of playgrounds, plazas, pathways, and parking lots. Used to convert existing spaces such as narrow landscape strips or existing hardscapes to intercept stormwater runoff.

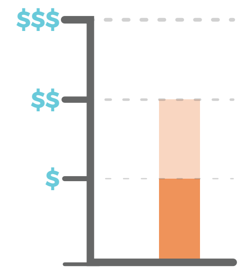
Maintenance

Moderate to high level of plant maintenance.

- Inspect quarterly and after heavy rains.
- Weed frequently as part of bi-monthly landscape maintenance.
- Establish and maintain vegetation. Prune and replace plants as needed.
- Clean overflow structure and emergency spillway to prevent clogging and overtopping.
- Use groundcovers vs. mulch to suppress weeds and reduce clogging.

Tier

2

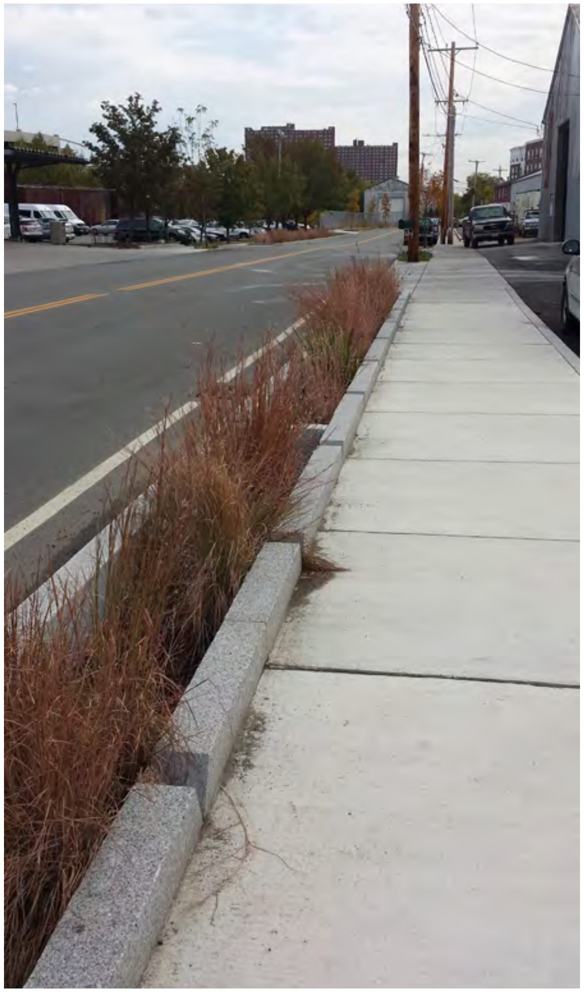


Maintenance Cost

Manual labor for weeding, sediment, trash and debris removal, slope stabilization. Hard edges typically prohibit mowing. Requires plant knowledge for pruning and weeding. Cost varies by size, complexity, and plant palette.

Function

Bioswale island, Chelsea, MA (Credit: HWG)



Streetscape bioswale, Cambridge (Credit: HWG)

Design & Implementation

- Includes amended soil media, overflow structures connected to a drainage network, and curbs/hard edge. Underdrains are required for poor draining soils and sites with shallow water table separation.
- Design as a "flow in and out" or provide an outlet structure for overflow. Work with the existing topography to minimize slopes and use vertical elements (curbs, walls, or timbers) along the edges to eliminate steep side slopes.
- Swale longitudinal slope is between 1% - 5%. Install check dams to maintain minimum slopes.
- Typical ponding depth of 3 inches – 6 inches.
- Minimize interior curb reveal and provide barrier or short fences for safety in streetscapes as necessary.
- Design should allow circulation (vehicular/pedestrian) where needed for park/street access.

FILTERS

VEGETATED SAND FILTER

: *landscape depression that filters and infiltrates water through a subsurface sand filter*

Advantages (+) Limitations (-)

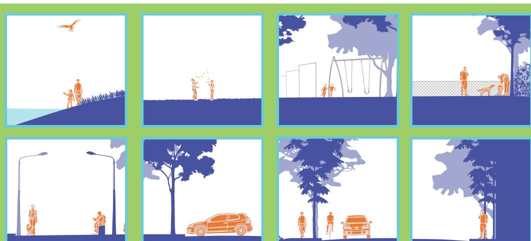
- \+ Adaptable to multi-functional spaces
- \+ Can be planted but best suited as a mowed lawn surface
- \+ Requires less space than bioretention
- \+ An alternative to bioretention
- \- Little aesthetic value
- \- Adds more lawn and not plant communities

Existing Conditions

- Drainage Area: small to medium
- Water Table: > 3 feet
- Soils: well drained to poor (A-D)
- Utilities: moderate level of conflict
- Topography: 0% min. - 3% max.

Companion Practices

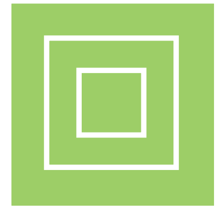
Context



Planning

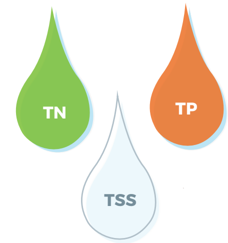
Versatility

Multiple uses and creative design potential



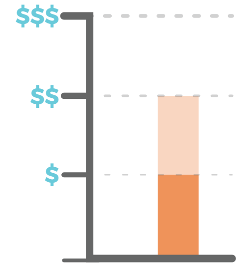
Footprint

Adaptable for various spaces, moderate disturbance



Treatment

TSS = high
TP = medium
TN = medium



Installed Cost

Moderate cost depending on size and plantings

Uses: parking lots, road medians, edge of paths, fields/meadows, and playgrounds. Used to convert existing lawns for stormwater treatment and create multi-functional space. Locate in underutilized lawns.

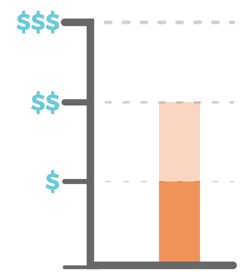
Maintenance

Frequently mowed lawn areas with a relatively low level of maintenance.

- Inspect annually, identify, and remove invasive plant species prior to mowing.
- Regularly mow to a height of 3" along with other scheduled mow areas/routines.
- A low-mow meadow aesthetic requires less mowing.
- Establish and maintain vegetation.
- Re-seed bare patches as required.
- Remove trash and debris to maintain proper function and to avoid overtopping.

Tier

1



Maintenance Cost

Manual labor for sediment, trash and debris removal. Routine mowing, stabilization. Cost varies by frequency of mowing.

Function

- **A** Inlet
- **B** Vegetated Surface
- **C** Topsoil
- **D** Sand Filter
- **E** Gravel Reservoir
- **F** Approved Subsoils

Design & Implementation

- Design for recreational use when dry and ensure public safety when wet.
- Recommend gentle sides slopes with a 5:1 max. for ease of mowing and to blend into the surrounding landscape.
- Provide a ponding depth between 3 inches – 6 inches. Design for a drawdown time of 24 hours after a rain event or less to avoid standing water.
- Provide an outlet structure and emergency spillway for overflow during larger rain event.
- Integrate overflow structure/spillway into the design to minimize eyesore and clogging.
- Create low-mow areas using native grasses to reduce mowing frequency and water demand.

Sand Filter at Sandy Neck Beach, MA (Credit: HWG)

Dry sand filter, Roger Williams Park, RI (Credit: HWG)

Same sand filter (after rain event) (Credit: HWG)

ENHANCED TREE PIT (SURFACE)

: *filters water through a tree pit with well-drained, amended planting soil*

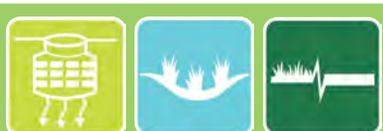
Advantages (+) Limitations (-)

+ Adds trees
+ Provides surface water for trees
+ Adaptable to sites with limited area
- May impact tree health/growth
- If clogged, tree may need to be removed
- Not ideal for road or parking lot runoff

Existing Conditions

- Drainage Area: small
- Water Table: > 6 feet
- Soils: well drained (A&B)
- Utilities: high level of conflict
- Topography: 0% min. - 5% max.

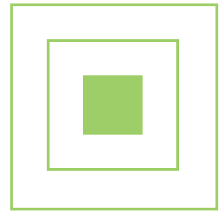
Companion Practices



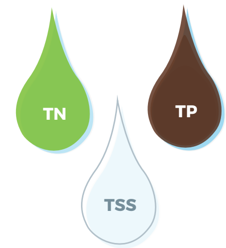
Context

Planning

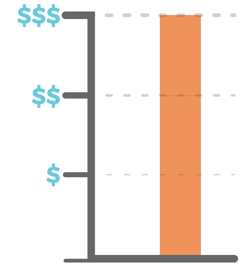
Versatility
Limited use with expensive SF install and upkeep costs



Footprint
Small footprint, minimal to moderate disturbance



Treatment
TSS = high
TP = low
TN = medium



Installed Cost
Expensive structures, excavation, and materials

Uses: streetscapes, playgrounds and plazas, to treat surrounding sidewalk and hardscape runoff where available surface space for GSI is limited. Not recommended for parking lots or road runoff.

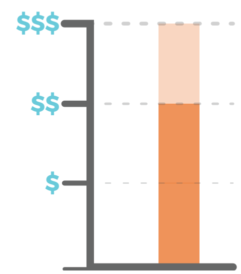
Maintenance

Requires a medium level of effort. Regular maintenance is critical to avoid clogging and costly rehabilitation.

- Inspect quarterly – once per season.
- Remove sediment, trash and debris in the bi-annually.
- Restrict winter salt use or plan for spring flush of soils with clean potable water
- Routine landscape maintenance of street trees also required.
- See manufacturer's requirements for proprietary products.

Tier

②



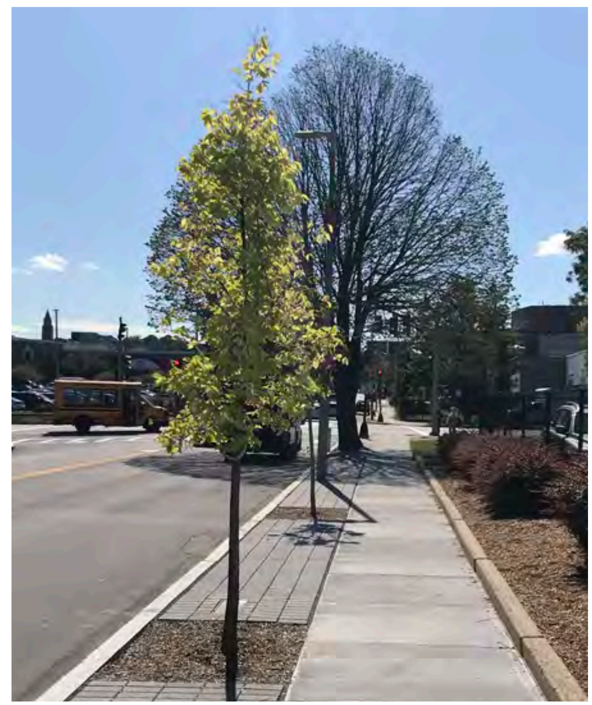
Maintenance Cost

Requires vacuum truck for sediment removal. Manual labor for routine street tree maintenance and monitoring for diseases/ insects.

Function

- **A** Inlet
- **B** Cleanout
- **C** Mulch
- **D** Amended Planting Soil
- **E** Pea Stone Layer
- **F** Gravel Reservoir
- **G** Structural Soil
- **H** Perforated Underdrain (As Needed)

Enhanced Tree Pit, downtown Boston (Credit: HWG)



Enhanced Tree Pit at BWSC office (Credit: HWG)

Design & Implementation

- Can be a proprietary product or custom designed. Do not use closed box type structures.
- Sides and bottom of pit should be open to promote healthy root growth.
- Typically used when runoff has less salt and pollutants to reduce stress on tree.
- Consider combining with structural soils, modular suspended pavement systems, or other method for improved root growth and long-term tree health.
- Tree species must tolerate urban runoff and all site-specific climatic constraints. Routine maintenance and accessibility is critical to properly care for the tree.
- Provide pretreatment to capture sediment such as small sediment forebays.
- If filter media clogs or needs to be replaced, the tree has to be removed and replaced as well.
- Reduced sidewalk salt is recommended to reduce detrimental impact on soil and tree health.

FILTERS

ENHANCED TREE PIT (SUBSURFACE)

: stores and infiltrates water in the subsurface gravel reservoir below tree planting soil

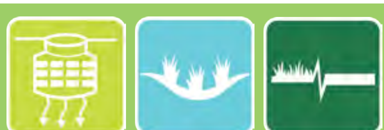
Advantages (+) Limitations (-)

- \+ Adds trees
- \+ Provides subsurface water within the tree root zone
- \+ Less impact to trees from winter salt
- \+ Adaptable to sites with limited area
- \- If clogged, tree needs to be removed/ replaced

Existing Conditions

- Drainage Area: small to medium
- Water Table: > 5 feet
- Soils: well drained (A&B)
- Utilities: high level of conflict
- Topography: 0% min. - 5% max.

Companion Practices

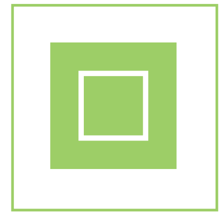


Context

Planning

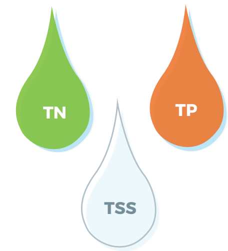
Versatility

Promotes healthy growing conditions with extra space



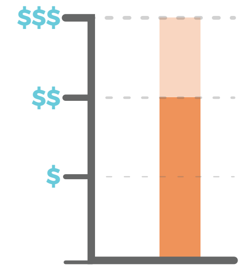
Footprint

Small to medium, moderate disturbance



Treatment

TSS = high
TP = medium
TN = medium



Installed Cost

Cost varies depending on length

Uses: parking lots and ROWs, as well as streetscapes, playgrounds and plazas to treat surrounding sidewalk and hardscape runoff where available surface space for GSI is limited.

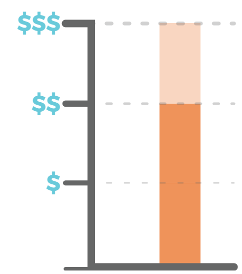
Maintenance

Requires a medium level of maintenance. Regular maintenance is critical to avoid clogging and costly rehabilitation.

- Inspect quarterly – once per season. Clean inlet quarterly.
- Remove sediment, trash, and debris in the pretreatment area bi-annually.
- Routine landscape maintenance of street trees.
- With proper pretreatment and routine maintenance, the planting soil should not need to be flushed or replaced.

Tier

②

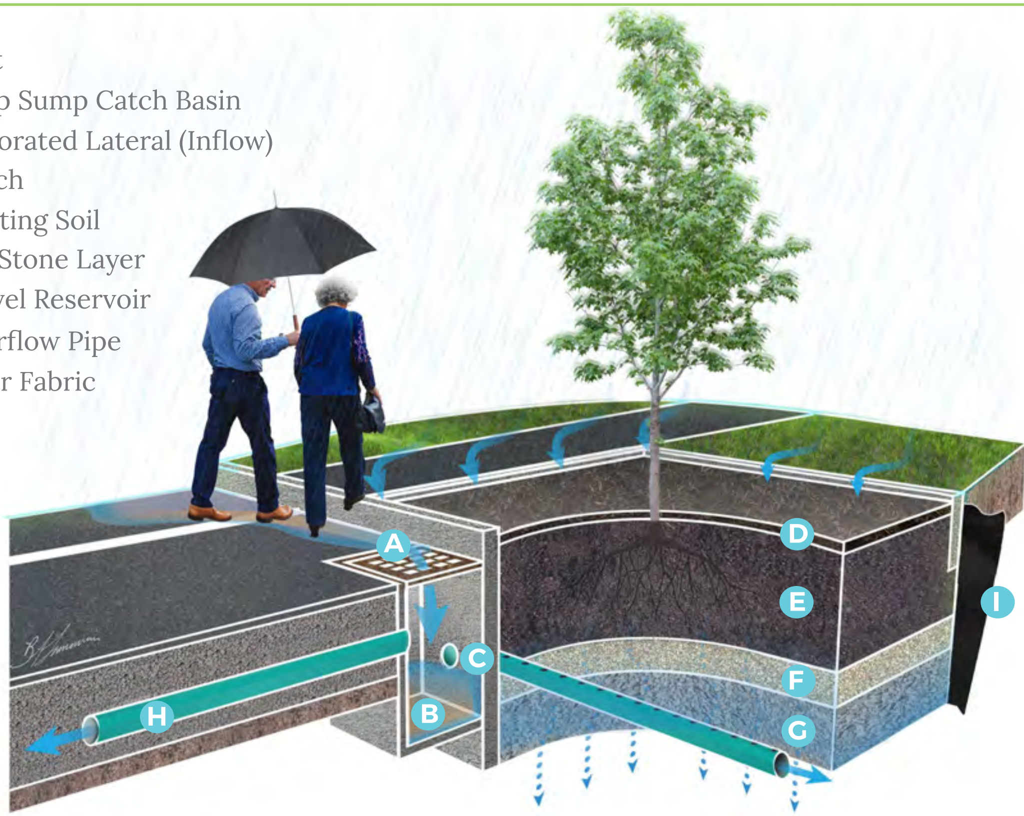


Maintenance Cost

Requires vacuum or clamshell truck for sediment removal for catch basin. Manual labor to clean lateral lines as necessary, and routine street tree maintenance and monitoring for diseases/insects.

Function

- **A** Inlet
- **B** Deep Sump Catch Basin
- **C** Perforated Lateral (Inflow)
- **D** Mulch
- **E** Planting Soil
- **F** Pea Stone Layer
- **G** Gravel Reservoir
- **H** Overflow Pipe
- **I** Filter Fabric



Design & Implementation

- Pit width, length, and depth can vary based on site-specific constraints (e.g. available area, depth to groundwater, utilities, etc.). Consider multiple trees in one long pit.
- Direct water to the subsurface gravel reservoir via a 4"-8" perforated lateral pipe. Set lateral pipe invert below the overflow invert (no deeper than 4' from rim).
- Provide overflow to the existing drainage system and set the overflow invert as high as possible to maximize storage depth and root zone saturation.
- Application can be limited due to depth of existing stormwater inverts. Use low profile catch basins if applicable.
- Match surrounding grades at the surface and consider opportunities for additional plantings. Surrounding surface can be pervious pavers, mulch, grass, or plantings.
- Consider using structural soils, modular suspended pavement systems, or other method to improve root growth.

Deep sump catch basin for Enhanced Tree Pit (Credit: HWG)

Gravel reservoir for Enhanced Tree Pit (Credit: HWG)

Completed Enhanced Tree Pit installation in Chelsea (Credit: HWG)

WET SWALE

: *intercepts groundwater creating a permanent pool, micro-wetland system to move and filter water*

Advantages (+) Limitations (-)

- \+ Self sustaining plant community
- \+ Great natural resource buffer
- \+ Micro ecosystem adaptable to small spaces
- \+ Integrates natural systems into the urban setting more than other GSI
- \- Does not provide traditional park use

Existing Conditions

- Drainage Area: small to medium
- Water Table: < 2 feet
- Soils: poorly drained (C&D)
- Utilities: low level of conflict
- Topography: 0% min. - 10% max.

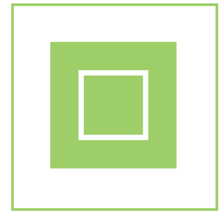
Companion Practices

Context

Planning

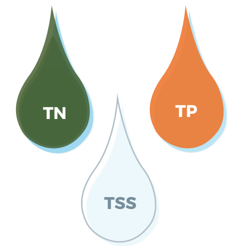
Versatility

Best suited for sites with a high water table



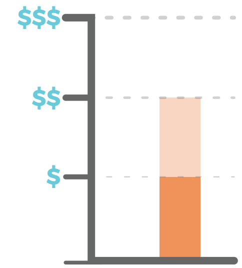
Footprint

Small to medium, moderate disturbance



Treatment

TSS = high
TP = medium
TN = low



Installed Cost

Inexpensive to construct, mostly earthwork

Uses: sites with high water tables, Floodable Areas, naturalized buffers to protect natural resources, along the edge of water, connecting to the waterfront, habitat creation, and education/outreach.

Maintenance

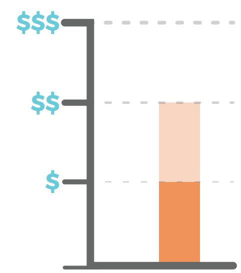
Often a self-sustaining wetland plant community requiring low maintenance once established.

- Inspect annually and remove trash, debris, and sediment.
- Monitor plant health. Identify, remove, and properly dispose of invasive wetland species.
- Maintain ponding volume and remove plants as necessary to avoid overcrowding.
- Maintain stabilize slopes and repair eroded areas.

Tier

1

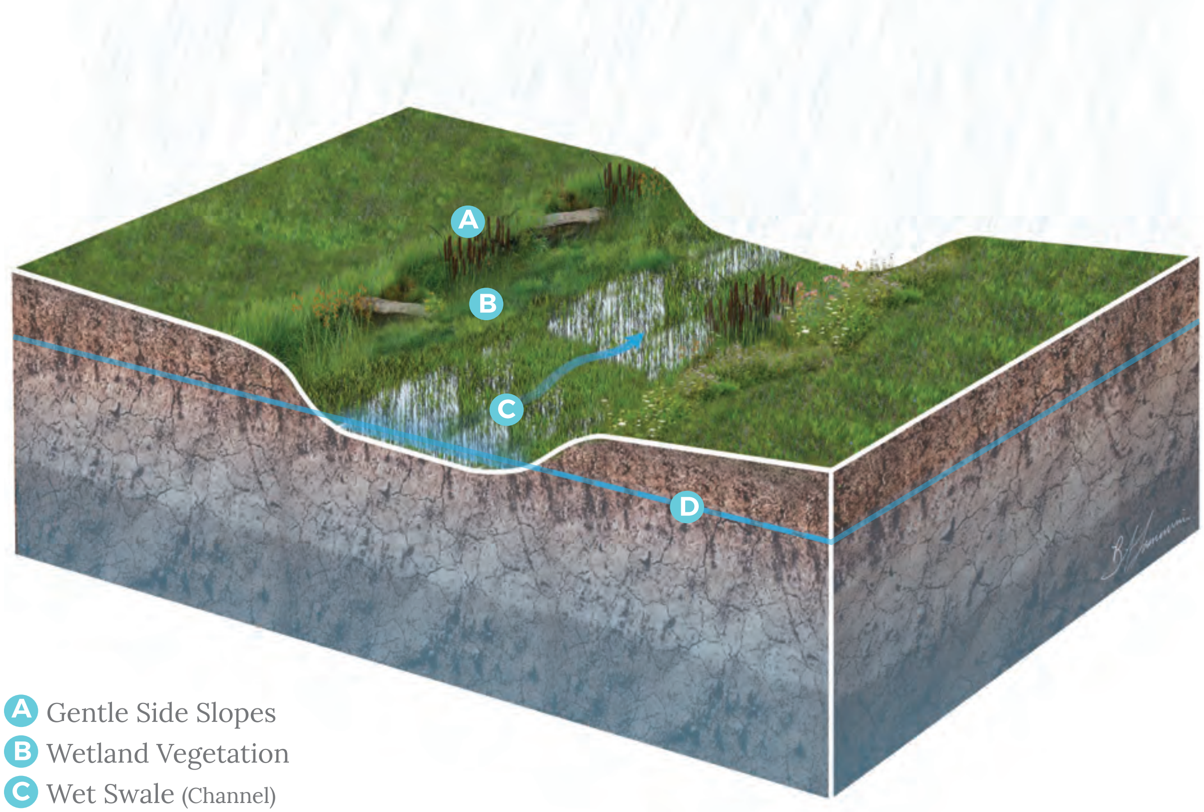
2



Maintenance Cost

Manual labor for weeding and sediment and debris removal. Depending on size may require small equipment to remove sediment. Note Tier 2 maintenance may be required in the beginning consider including in contractor bid.

Function



- A Gentle Side Slopes
- B Wetland Vegetation
- C Wet Swale (Channel)
- D Permanent Pool

Design & Implementation

- Design to mimic nature. Bottom width can vary where appropriate to improve visual interest. The flow path should follow the natural topography with a longitudinal slope of 2% or less. Select and locate plants based upon ponding depths and elevations.
- Blend into the landscape and consider integrating pedestrian circulation with boardwalk crossing(s) to bring park users closer to nature.
- Provide permanent pools of various depths to improve treatment and habitat value.
- Water table depth is critical. Determine water table elevation using test pits and, if necessary, leave a perforated pipe in place to take wet and dry season readings.
- Provide proper maintenance access to avoid vehicular damage/worn maintenance paths.

Wet Swale at Roger Williams Park, RI (Credit: HWG)

Roger Williams Park, RI (Credit: HWG)

Bare Hill Pond, MA (Credit: HWG)

GRAVEL WETLAND

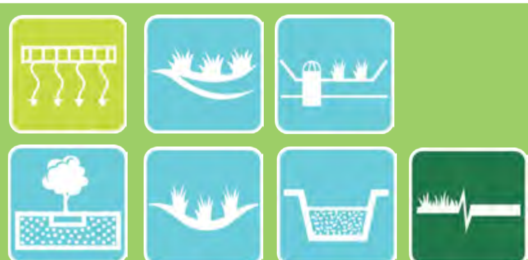
Advantages (+) Limitations (-)

- \+ Self sustaining plant community
- \+ Great natural resource buffer
- \- Slightly less natural and more structured
- \- Less habitat value than other wet practices
- \- Does not provide traditional park use

Existing Conditions

- Drainage Area: small to large
- Water Table: < 4 feet
- Soils: poorly drained (C&D)
- Utilities: low level of conflict
- Topography: 0% min. - 5% max.

Companion Practices

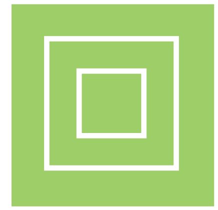


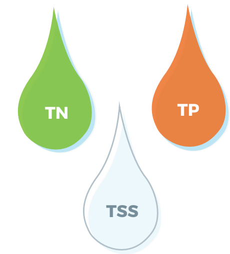
Context

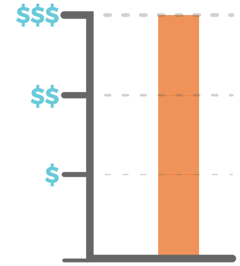
FILTERS

: stores and filters water through a saturated gravel bed and designed wetland system

Planning







Versatility
High water table and more structured in appearance

Footprint
Adaptable for tighter spaces, significant disturbance

Treatment
TSS = high
TP = medium
TN = medium

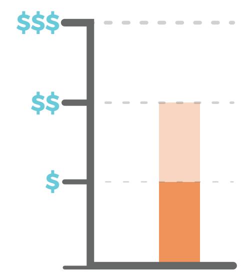
Installed Cost
Expensive to construct, materials, and excavation

Uses: sites with high water tables, naturalized buffers to protect natural resources, along the edge of water, retrofit of existing basins, edge of parking lots, and roads.

Maintenance

A self-sustaining wetland plant community requiring relatively low maintenance once established. Maintenance of the subsurface features requires a higher level of effort.

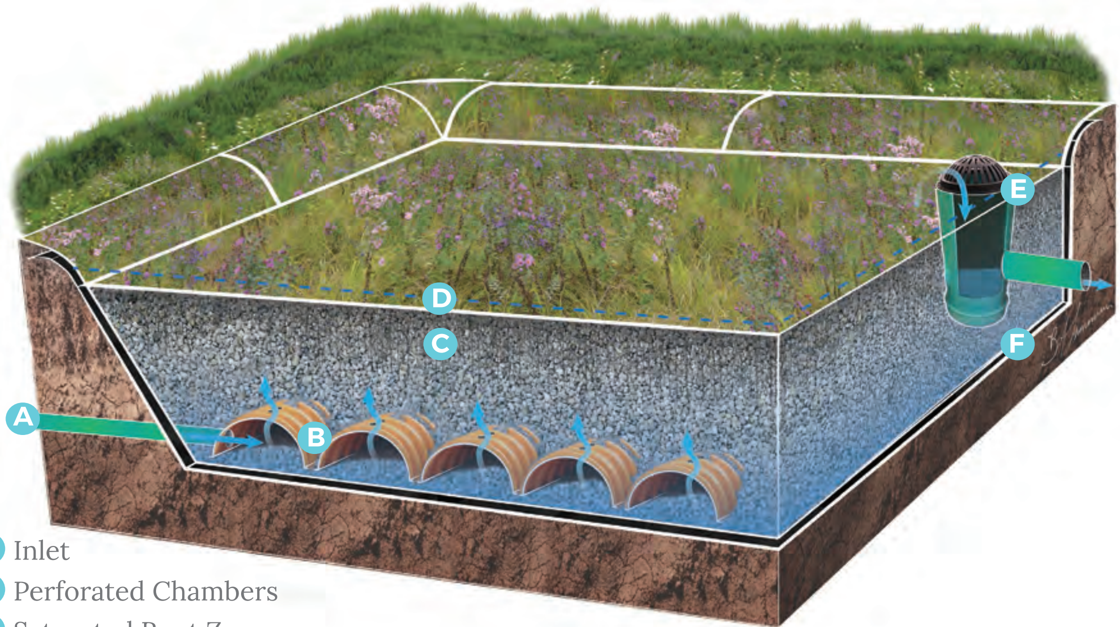
- Inspect annually and remove trash, debris, and sediment.
- Monitor plant health. Identify, remove, and properly dispose of invasive plant species.
- Monitor water levels and watch for “floating plants” after heavy rains.
- Establish and maintain vegetation. Stabilize slopes and repair eroded areas.
- Replace plants in the gravel as necessary.



Maintenance Cost

Requires a vacuum truck for sediment removal from subsurface pipes or storage chambers (Tier 2). Manual labor for periodic trash removal and outlet cleaning. Invasive species management may be required.

Function



- **A** Inlet
- **B** Perforated Chambers
- **C** Saturated Root Zone
- **D** Controlled Water Height
- **E** Overflow Structure
- **F** Impermeable Liner (Optional: based upon specific site conditions)

Design & Implementation

- Shapes can vary from rectangular or hard geometric shapes to natural, organic shapes.
- Provide gentle, varying side slopes for plant establishment and ease of maintenance.
- Thoughtfully integrate shape, depth, and size into the surrounding topography.
- Standing water should only be present during storm events. Design to maintain the water level just below the gravel surface to provide sufficient root zone saturation.
- Systems are meant to mimic nature; utilize native, wetland plant communities. See Appendix A.
- Surface of gravel bed must be set level with a 0% slope.
- Overflow structures are required to regulate water height.
- Provide access to all structures to avoid vehicular damage/worn maintenance paths.
- An impervious liner is required for well-drained soils to maintain subsurface water levels.

Gravel Wetland, South Portland, ME (Credit: HWG)

Gravel Wetland Year 1 (Credit: HWG)

Gravel Wetland Year 3, Bare Hill Pond, MA (Credit: HWG)

FILTERS

SHALLOW MARSH

: *moves and filters water through large, permanent pools with varying depths and wetland plants*

Advantages (+) Limitations (-)

+ Self sustaining plant community
+ Great natural resource buffer
+ Large ecosystem & habitat
+ Integrates natural systems into the urban setting more than other GSI
- Requires a large area of under utilized space
- Does not provide traditional park use

Existing Conditions

- Drainage Area: large
- Water Table: < 2 feet
- Soils: poorly drained (C&D)
- Utilities: low level of conflict
- Topography: 0% min. - 5% max.

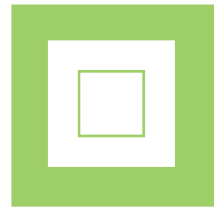
Companion Practices

Context

Planning

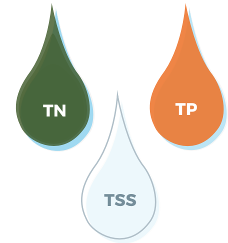
Versatility

Limited due to space requirements and defined aesthetic



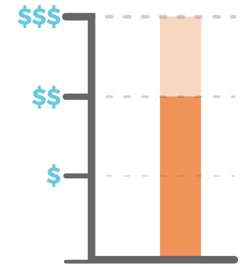
Footprint

Large area, significant disturbance



Treatment

TSS = high
TP = medium
TN = low



Installed Cost

Moderately expensive to construct with earthwork and plants

Uses: sites with a high water table and transition zone to natural areas, Floodable Areas, stormwater parks, wetland habitats, along the waterfront, and as an educational feature.

Maintenance

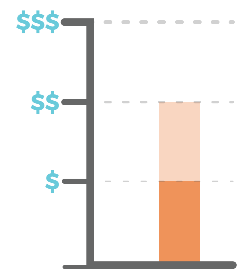
A self-sustaining wetland plant community requiring relatively low maintenance once established.

- Inspect annually and remove trash, debris, and sediment.
- Monitor plant health. Identify, remove, and properly dispose of invasive plant species.
- Monitor water levels and watch for "floating plants" after heavy rains.
- Establish and maintain vegetation.
- Stabilize slopes and repair eroded areas.

Tier

1

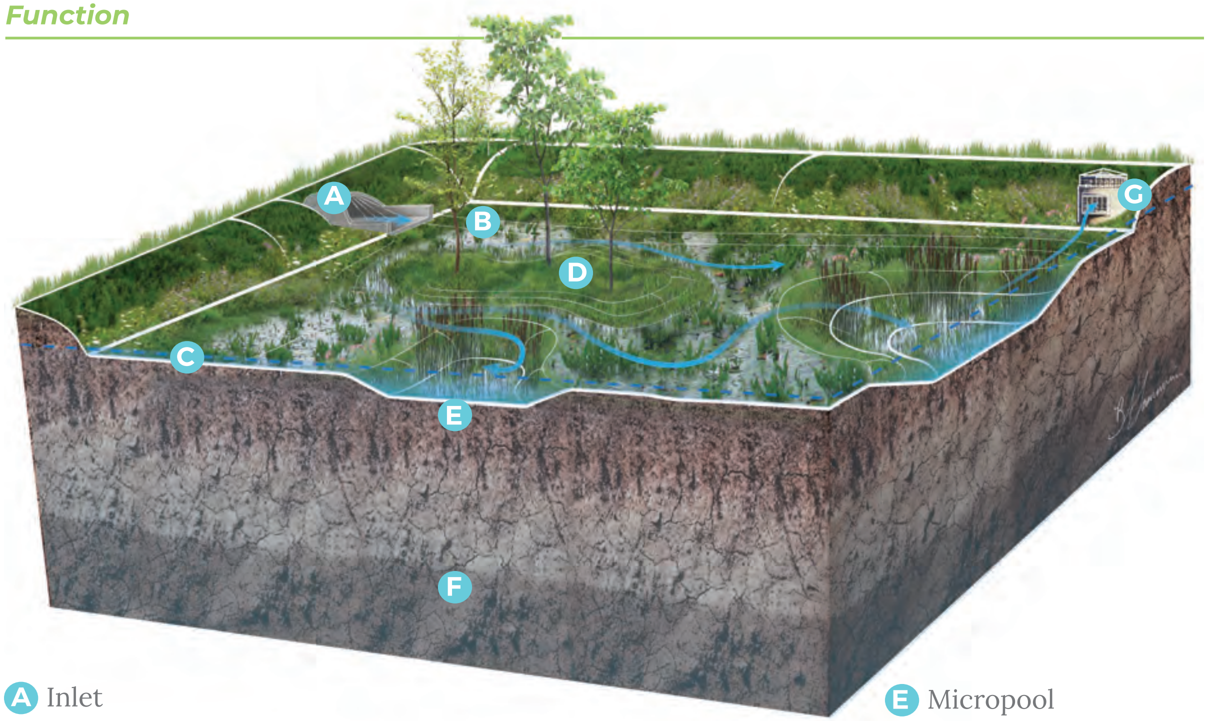
2



Maintenance Cost

Very infrequent manual labor for periodic trash removal, and outlet cleaning. Pretreatment maintenance may require larger equipment (Tier 2). Invasive species management may be required.

Function



A Inlet
B Sediment Forebay
C Permanent Pool/Low Marsh
D Internal Island
E Micropool
F Native Hydric Subsoils
G Outlet Structure

Design & Implementation

- Design to mimic nature. Create a meandering flow path with gentle slope. Provide gentle, varying side slopes for plant establishment and ease of maintenance.
- Select and locate plants based upon ponding depths to create sustainable native wetland plant communities.
- Water table depth is critical. Determine water table elevation using test pits. If necessary leave a perforated pipe in place to take wet and dry season readings.
- Blend into the landscape and consider the integration of pedestrian circulation with boardwalks and overlooks to bring park users closer to nature.
- Provide a low marsh area with permanent pools of various water depths to improve treatment and habitat value.
- Provide proper maintenance access to avoid vehicular damage/worn maintenance paths.

Shallow Marsh construction, Chepachet, RI

Same marsh year 4

Same marsh year 6 (Credit for all three photos: HWG)

RESTORES

SHORELINE RESTORATION

Advantages (+) Limitations (-)

- \+ Reduces sedimentation
- \+ Promotes the conservation of existing soils.
- \+ Improves park aesthetic and habitat
- \+ Opportunity to increase waterfront access
- \- Does not provide direct treatment of stormwater runoff

Existing Conditions

- Drainage Area: not applicable
- Water Table: variable
- Soils: well drained to poor (A-D)
- Utilities: low level of conflicts
- Topography: 0% min. - 33% max.

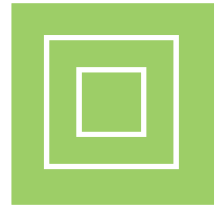
Context

: restores shoreline buffers with native plant communities and can create additional floodplain

Planning

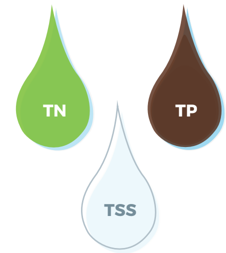
Versatility

Suitable for all waterfront areas



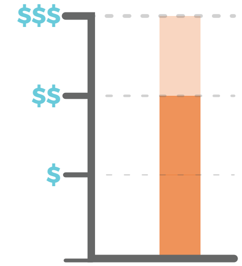
Footprint

Size and disturbance varies depending on project



Treatment

Reduces sediments by filtering overland flow



Installed Cost

Varies depending on project-specific techniques

Uses: waterfront restoration, trails, Floodable Areas, resource buffers, multi-functional passive recreational spaces and as an educational tool.

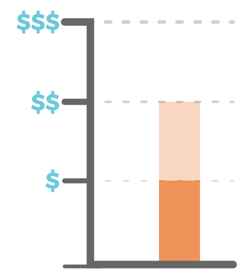
Maintenance

Create a self-sustaining riparian plant community requiring low maintenance once established.

- Inspect monthly during the first year.
- Monitor plant health.
- Establish and maintain vegetation, including periodic mowing or weed whacking.
- Stabilize slopes and repair eroded areas especially after storm events.
- A 3-year contractor commitment is recommended when invasive species management is required.

Tier

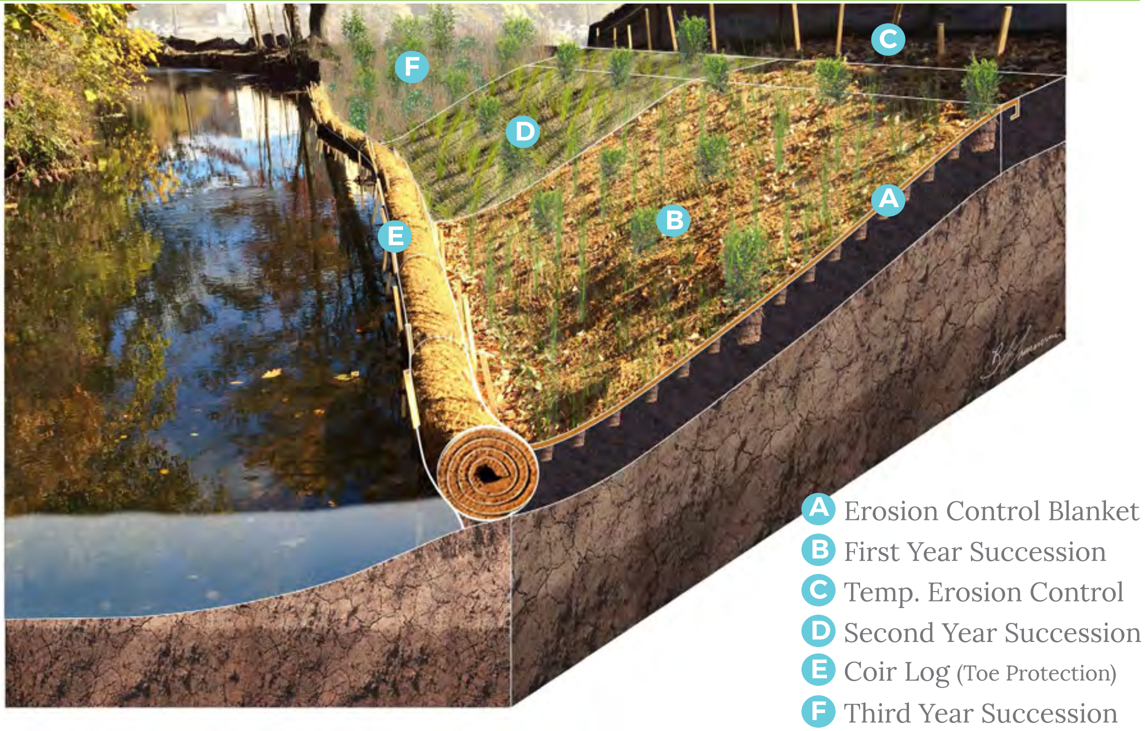
① ②



Maintenance Cost

Depends on scale of the project. Includes manual labor for hand weeding, erosion control/repairs and mowing. Monitoring and invasive species management may be required. (Tier 2).

Function



Design & Implementation

- Correct existing shoreline erosion and stabilize slopes with native plantings.
- Assess upgradient existing drainage patterns to divert runoff from slope to protect stabilization efforts. Remove erosion controls upon adequate surface stabilization.
- Identify and develop an invasive species removal and management plan.
- When possible, cut back man-made or armored slopes to create a living shoreline with gentle, varying slopes at 4:1 max to increase riparian resiliency.
- Remove urban fill to create additional floodplain for storage during extreme storm events.
- Take into account sea level rise when working within the coastal context.
- Consider earthen berms to improve resiliency and flood protection.
- Provide controlled access points to minimize shoreline degradation from pedestrian traffic.
- Relocate active recreational areas out of flood-prone areas and create new Floodable Areas.
- Use biodegradable materials for temporary stabilization during plant establishment.
- Consider temporary, perimeter fencing to protect restoration areas until fully established.

Shoreline Restoration at Joseph Finnegan Park (Credit: Halvorson Design Partnership)

Shoreline Restoration at Grays Beach Park, MA (Credit: HWG)

SLOPE STABILIZATION

: *restores degraded or unsafe slopes with a variety of techniques and native plants*

Advantages (+) Limitations (-)

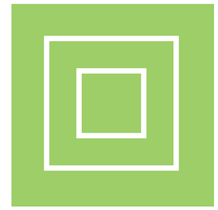
- \+ Reduces sedimentation
- \+ Promotes the conservation of existing soils.
- \+ Improves park aesthetic and habitat
- \- Does not provide direct treatment of stormwater runoff

Existing Conditions

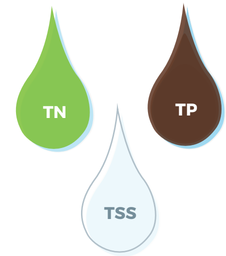
- Drainage Area: not applicable
- Water Table: variable
- Soils: well drained to poor (A-D)
- Utilities: low level of conflicts
- Topography: 20% min. - 50% max.

Planning

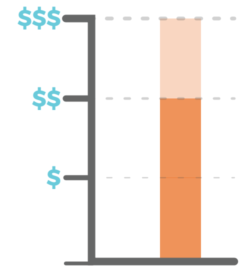
Versatility
Suitable for sites with steep and degraded slopes



Footprint
Size and disturbance varies depending on project



Treatment
Reduces sediment loss by stabilizing soils and slopes



Installed Cost
Varies depending on project specific techniques

Uses: upland areas, habitat creation, living walls, biodegradable materials for ecologically sensitive areas, and near passive recreation areas.

Maintenance

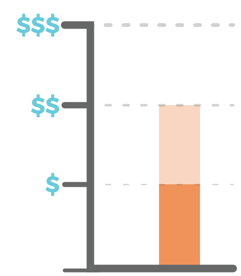
Restored slope and self-sustaining plant community requiring low maintenance once established.

- Inspect slope conditions monthly during the first year for signs/sources of erosion.
- Monitor plant health.
- Establish and maintain vegetation, including periodic mowing or weed whacking.
- Stabilize slopes and repair eroded areas.
- A 3-year contractor commitment is recommended when invasive species management is required.

Tier

1

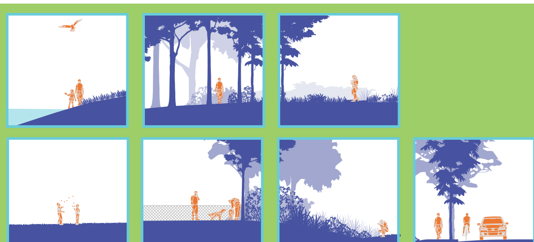
2



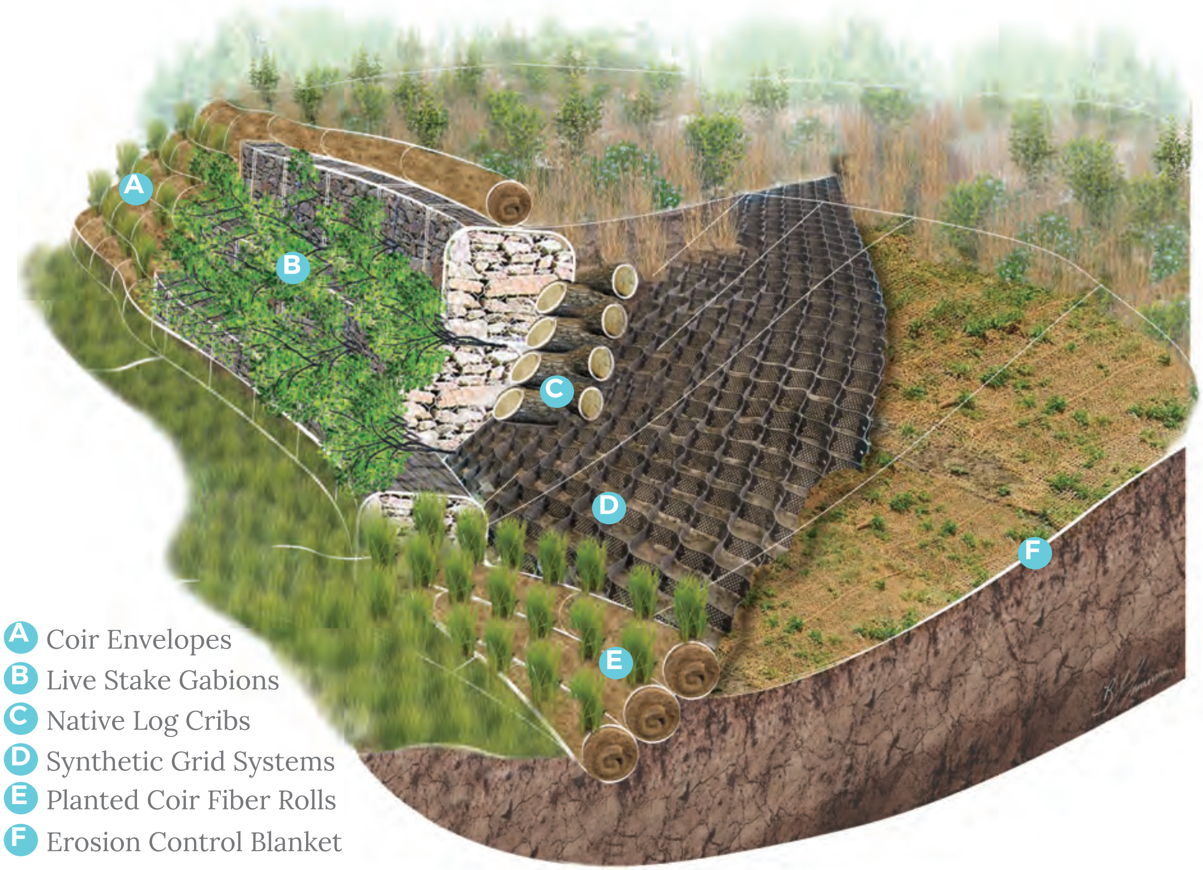
Maintenance Cost

Includes manual labor for hand weeding, erosion control/repairs and mowing. Monitoring and invasive species management may be require (Tier 2).

Context



Function

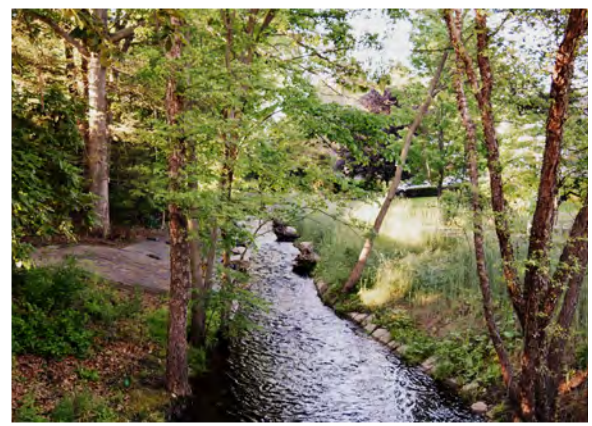


Design & Implementation

- Assess up-gradient drainage patterns to divert runoff from the project area to minimize erosion.
- Correct existing erosion and stabilize steep embankments prior to seeding or planting. If possible, regrade to reduce long runs of steep slopes.
- Disturbed slopes are susceptible to invasive species. Identify and develop an invasive species removal and management plan, if necessary, prior to construction.
- Use biodegradable materials for temporary stabilization during plant establishment. If runoff is directed onto the slopes, consider permanent stabilization with geotextile matting.
- Consider perimeter fencing and signage to protect restoration areas from foot traffic until fully stabilized.

Erosion control blanket at Ten Mile River, MA (Credit: HWG)

Coir fiber rolls and live stakes (Credit: HWG)



River rock and reclaimed logs at Fuller Brook, MA (Credit: HWG)

PAVEMENT REDUCTION

Advantages (+) Limitations (-)

- \+ Reduces stormwater runoff
- \+ Adds usable park space
- \+ Improves park aesthetics.
- \+ Reduces pavement maintenance costs
- \- Does not provide direct stormwater treatment

Existing Conditions

- Drainage Area: not applicable
- Water Table: >2' feet
- Soils: well drained (A&B)
- Utilities: low level of conflict
- Topography: 0% min. - 3% max.

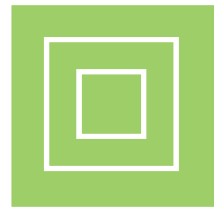
Context

: restores and infiltrates water through the reduction of impervious cover to a permeable surface

Planning

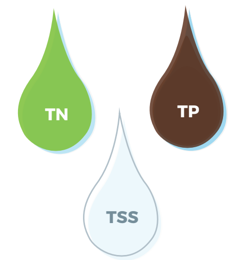
Versatility

Removal and/ or replacement of impervious cover



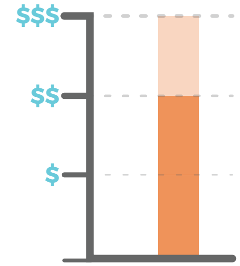
Footprint

Size and disturbance varies depending on project



Treatment

Provides treatment through runoff reduction



Installed Cost

Varies depending on project-specific goals

Uses: area where underutilized impervious pavement exists. Parking lots, walkways, plazas, sports courts, waterfronts, gardens, playgrounds, and especially within resource buffers.

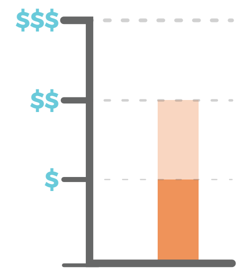
Maintenance

Pavement reduction is often part of a larger project and the level of maintenance must be determined on a site-by-site basis relative to the surface replacement.

- Consider future maintenance capabilities and desired level of effort when removing and planting large paved surfaces.
- Inspect at a minimum once per year.
- Maintenance can include general landscape to GSI practices. See individual GSI sheets.
- Mowing, weeding, and watering may be required for seeded or planting areas. Similar to other BPRD landscape improvement projects.

Tier

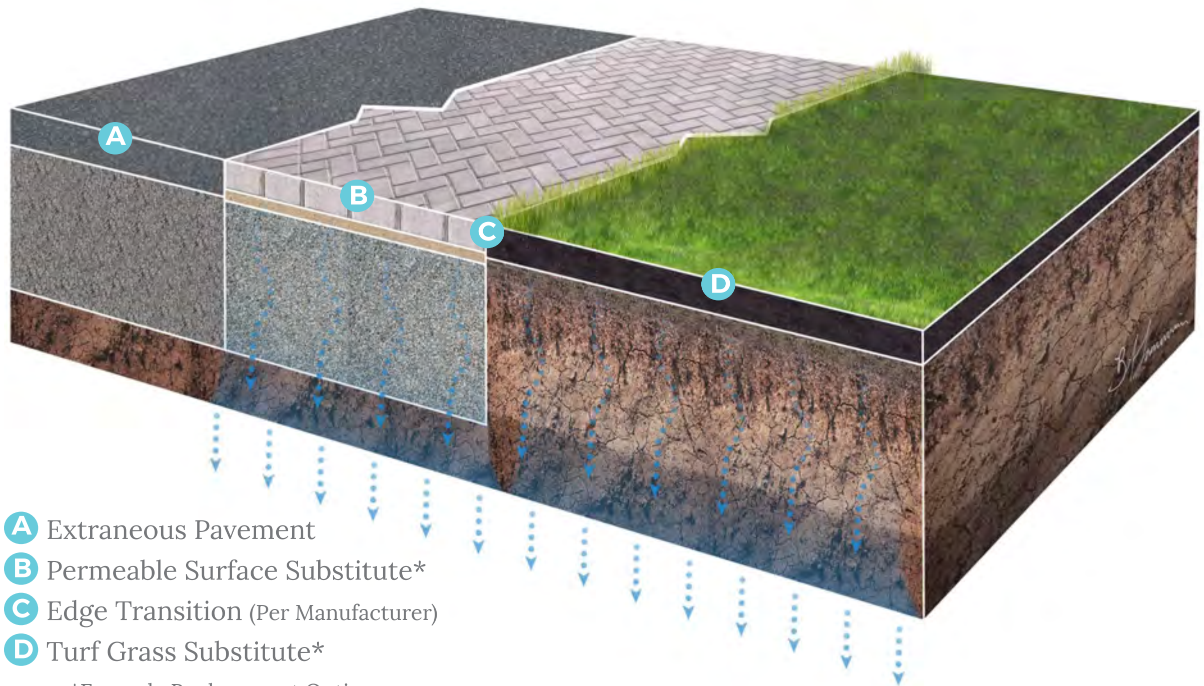
① ②



Maintenance Cost

Varies by project and can include general landscape to full GSI maintenance.

Function



Design & Implementation

- Pavement reduction should be considered as part of any site improvement project and prior to re-paving of degraded paved surfaces, consider removal, reduction or conversion to a permeable surface.
- Re-organize parking areas to reduce pavement. Remove unnecessary drive aisle and parking spaces and/or reduction in path or road widths. Use reinforced turf to replace overflow paved parking areas to create new multi-functional green space.
- Assess underlying soils for potential contamination before considering pavement reduction.
- Replace impervious sport courts with permeable surfaces when applicable. May reduce or even eliminate the need for additional GSI practices.
- Consider drainage impacts (e.g. structure and pipe relocation) when considering pavement removal.
- Slope and accessibility should be factored into approach and surface material selection.
- Recycle removed pavement for future road base or pathway material.

Sidewalk retrofit to permeable paver (Credit: KMDG)

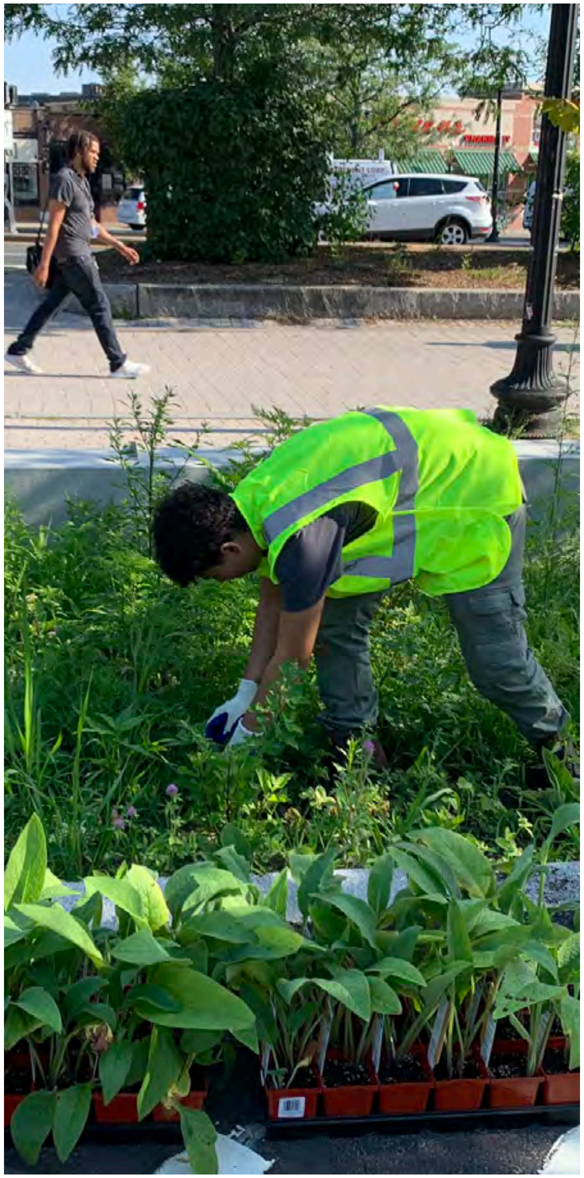
Plaza retrofit to permeable pavers (Credit: KMDG)

Excess pavement retrofit, Washington Irving Boston Public School (Credit: HWG)

STEP 5:

Design & Construct

STEP 5: Design & Construct



Maintaining bioretention, Boston school (Credit: HWG)

DESIGN FOR MAINTENANCE

GSI is not a "one size fits all" approach. The design plans and details must incorporate and rely on the information gathered in STEPS 1-4.

Unlike traditional closed pipe drainage, most GSI is located above ground and within public view. Designs that are complex typically require a higher level of maintenance and can lead to unmaintained practices that not only underperform but can become an eyesore or nuisance. This problem is magnified when working in a public park setting or urban space. To properly address this issue, designers should work closely with BPRD staff and discuss design and maintenance options as the designs advance to ensure, at a minimum, the designs accomplish the following:

- Meet the GSI objectives identified in Step 1.
- Are based on realistic maintenance expectations and BPRD capabilities.
- Maintenance can and will continue long after construction is complete.

The simplest way to minimize maintenance is to ensure the GSI design itself is not the maintenance problem. Often much of the design and construction is focused on the practice area, and not enough attention is given to how the water is collected, moves through the GSI space, and how sediment is captured. The following design approach will reduce costs and practice failure by addressing both design and maintenance (see the GSI Selection section for general design information for each practice).

Collect Water (Inlets)

Collecting the water is the first design element in the GSI practice. This may include the following:

- Modified curb inlets
- Paved or cobble flumes
- Catch basins or drop inlets

Improperly designed, constructed, and maintained inlets are a leading cause of GSI failure.

- The inlet needs to be set at a well-defined low point with an exaggerated drop into the pretreatment practice. Often the low point is not clearly defined on the plans or properly graded and constructed.

This curb inlet and flume collect and direct stormwater into the forebay. (Credit: HWG)

- Water can easily bypass poorly designed or built inlets and cause long-term erosion and sediment problems.
- Unmaintained, blocked inlets also lead to ponding and over-topping, which contributes to erosion and clogging.

Move Water (Conveyance)

Once the water is collected, it may need to be "moved" or conveyed to the pretreatment or GSI practice location. Vegetated swales and pipes are often used to move water from an inlet to the sediment forebay.

- Swales and pipes should be designed to convey the maximum flow (cfs) or velocity (fps) for the site. Improper designs can lead to overtopping and/or scouring, causing excessive sediment accumulation in the practice.
- The use of placed stone or rip rap in flumes and swales should be carefully considered as it will trap sediment between the aggregate and accumulate over time. This can lead to blockages that prevent runoff from flowing into the GSI.
- Turf reinforced matting and mortared cobbles are the preferred option for conveyance swales.
- Long runs along steeper grades (5% or greater) should be avoided and check dams used to "step" the swale and lessen the slope and depth.

Capture Sediment (Pretreatment)

Design the pretreatment practices to capture sediment and debris prior to the water entering the GSI practice.

- Poorly designed, constructed, and unmaintained pretreatment leads to poor infiltration, compromises plant health, promotes weeds and invasive species, and ultimately creates an eye sore.
- Material selection should match the identified context.
- Sediment accumulation in loose stone/rip rap is difficult to remove, can become an eyesore, and should be avoided.
- Pervious pavers, reinforced turf, or mortared stones are the preferred surface option.
- Ensure checkdams/spillways are keyed into the side slopes and do not promote side slope erosion.

A mortared swale moves water into a forebay and bioretention practice. (Credit: HWG)

A cobble forebay captures sediment. (Credit: HWG)

Infiltration chambers installed in a parking lot at a school (Credit: HWG)

This domed grate minimizes clogging from debris. (Credit: HWG)

Treat and Manage (Filter, Infiltrate, or Store)

This is where the stormwater storage and/or treatment occurs. Failure to properly (1) collect, (2) move the water, and (3) capture sediment and debris prior to reaching the practice, greatly increases the annual maintenance and likelihood for failure. If properly designed, the regular maintenance should be limited to the following:

- Slope stabilization
- Flushing (subsurface practices
- Mowing and/or pruning
- Weed removal

Excessive grading and the creation of steep slopes (3:1 or greater) should also be avoided.

- Work with the existing topography
- Do not design a practice that requires unnecessary and/or costly earthwork.
- Steeper slopes also present construction and maintenance challenges for stabilization, plant establishment, and maintenance as well as erosion.
- If 3:1 side slopes or greater are necessary, protect with erosion control blankets or matting.

Overflow (Structures and Spillways)

If the GSI practice is intended to be "online" (i.e., runoff from large storm events is also directed to the GSI practice), an overflow structure is required. This typically includes a combination of catch basins or other overflow structures connected to existing drainage network and/or emergency spillways.

- Spillways should be designed to convey the maximum flow (cfs) or velocity (fps) for the 100-yr storm and include a level spreader.
- Improper design and construction can lead to frequent over-topping and scouring causing downstream sedimentation.
- Spillways can use turf reinforced matting, mortared cobbles, or hand-placed stone.
- The design and material selection should blend into the surrounding context.
- Consider accessibility for maintenance
- Use domed grates on overflow structures to minimize clogging where applicable.

Restore

Although Restore practices are not intended to collect, move, capture, and treat or manage stormwater, like other GSI practices, a similar design approach should still be applied. They improve both the landscape and water quality through the removal of pavement and/or the restoration of degraded landscapes to reduce pollutant loading and sedimentation as well as create new healthy plant communities. They can be combined with other GSI or serve as a standalone project. To assist with the successful design and construction of these practices, the following general guidelines should also be considered:

- Upgradient drainage problems and proper stormwater management should be addressed during the design process.
- Manage existing unwanted vegetation, including weed seedlings, prior to seeding.

- For grass, consider low-mow seed mixes such as blends with a variety of fescues.
- Include a quick germinating cover crop for initial establishment such as spring oats or grain rye, depending on the intentions and context.
- Test existing soil and amend or provide suitable planting soil to establish and sustain the intended plant growth.
- When working on slopes, minimize the length of steep slopes.
- Select proper biodegradable erosion control blankets/stabilization product suitable for the intended use on all slopes 3:1 or greater.
- Consider the use of small trees and shrubs to create a healthy root zone to stabilize slopes or when working within a buffer.
- Avoid the use of rip rap and stone to the maximum extent practicable unless site conditions require hard armoring.
- Avoid excessive wholesale removal of existing vegetation that may further destabilize steep slopes. Phase construction as needed.

Plants

Plant requirements vary by practice and site. Store, Filter, and Infiltrate practices that drain quickly and do not hold water in the soil require drought-tolerant plants that can also handle periods of inundation during storm events. Some "wet" Filter practices (wet swale and constructed wetlands) require wetland plant species that can endure "wet feet" at all times.

See Appendix A for a list of plants found to thrive in GSI systems in eastern Massachusetts. The plants are suggestions only and should be supplemented as necessary. Consult the additional plant resources on the following page for a more comprehensive view on what species may thrive in the site-specific environment.

Plant selection considerations include:

Water inundation

It is important not only to consider moisture tolerance but the depth of ponding, and the duration of inundation.

Sun/Shade

Plant selection should consider sun exposure due to existing or future site elements and tree cover as well as the time of the year.

Salt tolerance

Designers should consider whether the plants will be growing in salty soils or enduring salt spray. Depending on snow management practices, salt from paved surfaces may enter the practice. Dog urine is another source of salt to consider.

Snow Management

Coordinate the snow removal and stockpiling plan with the planting plan or consider whether the GSI location is a likely place for snow piles. This may damage woody plant species that do not easily regenerate. Protect GSI from snowplowing as necessary.

Pollinators

Consider using native plants that provide habitat for pollinators.

Slope stabilization on a streambank (Credit: HWG)

A bee pollinating asters

Plant Resources

For Massachusetts Plant Communities:

https://www.mass.gov/service-details/classification-of-natural-communities

The City of Boston's Street Tree list:

https://www.boston.gov/departments/parks-and-recreation/caring-bostons-urban-forest

NEMO Rain Garden Plant Selector Tool:

http://nemo.uconn.edu/raingardens/plants.php

RIDOT Salt Tolerant Trees & Shrubs:

http://www.dot.ri.gov/documents/about/research/RIDOT_Salt_Tolerant_Tree_and_Shrub_Guide_August2010.pdf

Recommended Urban Trees and more from Cornell's Urban Horticulture Institute:

http://www.hort.cornell.edu/uhi/

Pollutant Tolerance

Often plants in GSI receive water high in nutrients or pollutants due to fertilizers, pet and landscape waste, and car oils. Some plants can handle higher nutrient levels, and some are uniquely suited to take up or break down pollutants through phytoremediation.

Sight Lines and Spatial Constraints

Look for species and cultivars that fit the spatial constraints of the particular site. Many plants have compact or disease/pest resistant cultivars that may be more appropriate for the context and design.

Soils

The texture of the existing, imported or engineered soil impacts moisture content and can effect plant growth. Choose plants for their ability to thrive in these conditions.

Plants require a particular soil volume in order to thrive and grow to their mature size. In urban areas, the available soil volume is often limited. When possible, design to maximize soil volume for the desired species (see Special Conditions, page 52). When space is limited, choose plants that are smaller or that can tolerate minimal soil volumes.

Trees

The best tree species for urban parks in Boston are typically tolerant of seasonal temperature fluctuations, road salt, drought, pollution, and elevated levels of soil compaction. Often, trees in GSI practices also need to endure periods of inundation as well as drought and increased pollutant loading. Proper selection is important as many species cannot survive these variable and sometimes harsh environments.

When choosing species, the following should be considered:

- the context
- the proximity and relationship to other trees and plants
- nearby utilities
- current or proposed uses in and around the tree

How the root system grows, and the mature size of the tree is important to plan for as well, especially in areas with less space or that abut active park spaces or circulation routes. Roots can cause pavement to heave or create tripping hazards.

Approach to Ground Cover

Consider what type of ground cover is best suited for the long-term aesthetics, functionality, and maintenance of a practice. Mulch can float and potentially clog GSI practices. Seeding or using a dense groundcover planting approach as a "green mulch" layer are alternative solutions.

Protection from Destructive Waterfowl

Choose design and construction techniques to dissuade waterfowl. Options include:

- Barriers such as dense vegetated strips at the water's edge, hedges, fencing, and netting over seeded areas until establishment.
- Design and educate to discourage feeding.

For more information go to: https://www.in.gov/dnr/fishwild/3002.htm

Maintenance

Always consider the level of maintenance that will be available after installation when choosing plants. Tier 1, mowing and spring/fall clean-ups may be all that is possible.

Adopting a more natural look and creating micro plant communities can help with weed suppression.

CONSTRUCTION

Successful implementation of GSI relies not only on good design, but also proper installation.

- Plans must provide sufficient detail for proper installation and clearly identify and address the design components described above.
- The specifications should be well coordinated with the design plans, planting requirements, and the products specified must be readily available.
- When applicable, the designer should work with BPRD staff to identify opportunities to use reclaimed or recycled material.
- The importance of proper grading and slope stabilization during seed/plant establishment must be addressed both in the construction drawing and during construction.
- Provide a silt fence or silt sock at the toe of the GSI practice slope prior to planting to protect from sedimentation during establishment.
- Requirements for designer and/or BPRD staff field visits for installation quality control should be provided on the plans and made known to the contractor prior to construction.
- Require proper testing and submittal of soil samples.

Many contractors are unfamiliar with GSI practices, do not fully understand how they work, and fail to realize how little tolerance there can be in design deviations. An inch off in elevation or inaccurate layout can separate success from failure. Designers and/or BPRD staff must be engaged throughout the construction process to ensure the design is properly installed. Far too many GSI installations have failed because of errors not properly addressed and corrected during construction. To avoid these pitfalls, the following approach is recommended:

- Use qualified or pre-qualified bidders for GSI work (list requirements in bid docs).
- A pre-construction meeting should be conducted on site prior to starting construction. This meeting provides an opportunity to review the design, explain how the practice works, and answer contractor questions.
- The contractor should be encouraged to ask questions throughout construction.
- Establish clear lines of communication between the contractor and BPRD to avoid costly errors and long-term maintenance problems.
- The designers should provide construction oversight services to not only review submittals and answer questions, but provide periodic field visits during installation to ensure the design is built per the plans.

A bioretention installation training (Credit: HWG)

Planting an Enhanced Tree Pit (Credit: HWG)

Cleaning out a catch basin with a vacuum truck (Credit: HWG)

Removing debris from a swale (Credit: HWG)

- Provide the contractor with field visit reports identifying deficiencies and required corrections.
- Assign a project manager familiar with GSI (BPRD staff or contracted).
- Require as-built progress forms to be completed during construction by the contractor and prior to the completion of the as-built plan. Too often as-built plans identify errors that could have been easily addressed during construction, but may be costly to fix post construction.

OPERATION & MAINTENANCE

Although the approach, as described above, is critical for proper function, regularly scheduled post-construction maintenance must be implemented to ensure the project's future success. Therefore, the "design for maintenance" approach is intended to accomplish the following objectives to make long-term maintenance possible:

- Keep designs simple.
- Design GSI practices based on BPRD expectations.
- Ensure an acceptable level of effort for maintenance consistent with BPRD capabilities.
- When possible, simplify maintenance requirements to allow for more frequent, less labor-intensive Tier 1 maintenance visits, which can be completed by BPRD staff.
- Clearly identify the GSI system through signage to communicate functionality and maintenance.
- Agency partnership agreements like Memorandum of Understandings (MOUs) or contracts with outside providers should be in place for Tier 2 maintenance upon completion of design.

The designer should work with BPRD staff to develop a simple Operation and Maintenance (O&M) Plan for all Tier 1 and Tier 2 maintenance. Although the O&M Plan is frequently required during permitting, the plan should be updated upon completion of construction to ensure that any design changes are addressed in the plan. This also provides an opportunity to include actual photos of the design elements.

Successful maintenance requires that BPRD staff (Tier 1) or outside providers (Tier 2) understand how the practice works, where the components are located, and what is required to keep it functioning. At a minimum, the O&M plan must include the following:

- The name and contact for the provider.
- Location of the practice(s).
- Graphic/photos of each practice identifying location of the 5 components and explaining how it works.
- Maintenance checklist or form which corresponds to the graphic and provides a brief description of the following:
  - Maintenance at each component such as sediment/litter/debris removal, weeding, pruning, and erosion control
  - Frequency (after rain event ¼" or greater)
  - Any corrective measure requirements

- Vegetation maintenance schedule for weeding, pruning, and plant cutback
- Seasonal considerations, such as fall leaf removal or spring clean up
- Additional regulatory requirements that may be required
- Estimate of annual maintenance costs
- Copies of plans, proprietary product information, etc. as appendices.

In general, the O&M plans should be light on text and heavy on images and graphics. A few options that can also be considered with BPRD input are:

- Quick reference cards or checklist for staff to use in the field
- Incorporation of maintenance requirements onto interpretative signage
- Reference video(s) made available online with the designer describing the practice and demonstrating maintenance.

Monitoring

Monitoring should be discussed with BPRD staff early in the design process. If a monitoring program can be properly funded, it can be used as an effective tool to improve future designs and the long-term maintenance and leverage additional funding.

Subtle field adjustments can also be made to the design based upon monitoring results to improve performance and maintenance.

Monitoring can be as simple as observing plant health, sediment accumulation rates, drawdown after rain events, and overall performance. Data collected can be applied to future designs for cost savings and to reduce maintenance costs.

If partnering with other agencies, additional monitoring could include sampling and testing for flow reduction, pollutant removal performance, or soil infiltration rates. If sampling and testing for pollutant removal, a method for sampling both the inflow and outflow (after treatment) will need to be designed into the practice.

Roles & Responsibilities

Even with a "design for maintenance" approach and a user-friendly O&M Plan in place, the project can still fail if the maintenance provider and responsibilities are not clearly defined.

While the maintenance requirements may be well defined during the design process, it is just as important that the financial obligations and the responsibilities be clarified and agreed upon prior to beginning the project.

When a project includes partnering with other departments or organizations, the responsibilities for the design, construction, long-term funding, and operation and maintenance should be agreed upon early in the design process. Each department's roles and responsibilities should be documented using an MOU to clarify who is responsible for inspecting and maintaining the practice. The MOU can include a maintenance schedule to ensure that all parties know what is needed to ensure the long-term function of the GSI system and require periodic "check-ins" or updates from the responsible party (See also Section 4 Implementation).

An MOU is an important tool to clearly identify each department or agency's roles and responsibilities. Parks and stormwater departments or agencies are not the only ones that might be involved. If the GSI project overlaps or affects the ROW, transportation and public works departments and the public improvement commission might also need to be included to ensure that their input is sought and their objectives, responsibilities, and requirements are documented.

Elements of an MOU:

- **Describe the property and features for which responsibility is shared.**
- **Detail funding sources and costs for design/construction and maintenance, including requirements for each.**
- **List each department's objectives, roles and responsibilities, and legal requirements.**
- **Define methods of communication or collaboration.**
- **State the term of agreement, e.g., from date of signature until completion or expiration.**
- **Outline procedures for modifying, extending, or severing the agreement.**

Implementation

Parkman Bandstand in the Boston Commons

INTRODUCTION

This section serves as a guide for the implementation of GSI in Boston parks. These recommendations build on the lessons learned from the case studies and various city documents discussed in the Background of this Guide, as well as BPRD staff input, to assist with the establishment and management of a BPRD GSI program.

In addition, to help focus GSI efforts, a comprehensive desktop analysis of existing BPRD-managed properties was performed to assess and prioritize where the greatest park GSI implementation opportunities exist. The section includes the following topics:

- Partnerships & Funding
- Connect People to GSI
- Maintenance & Monitoring
- Stormwater Parks
- Prioritization
- Highlight Co-Benefits

There is currently a GSI working group to share information and knowledge, comprised of the Boston Planning and Development Agency, Boston Transportation, Environment and Public Works Departments, BWSC and Boston Public Schools, as well as BPRD. While this section is primarily intended for BPRD staff for a park GSI program, it should also be used to inform the GSI working group as they work toward the development of a comprehensive city-wide GSI network.

> **"Engaging with partners from the outset of the project will ensure that the necessary expertise is available to guide the project from an idea through its implementation."**
>
> *The EPA Green Infrastructure in Parks: A Guide to Collaboration, Funding, and Community Engagement*

PARTNERSHIPS & FUNDING

Meeting the goals of improved climate resiliency and livability and health within the city will require a city-wide effort and the collaboration between multiple city, state, and federal departments as well as local community groups, non-profits and volunteer organizations. Strategic partnerships with these various entities can lead to additional funding for design and construction as well as shared resources and maintenance capabilities. For example, some departments may be better equipped and staffed to maintain certain GSI practices or landscaped spaces while others may be able to apply for grant funding. To strengthen city inter-department partnerships and agency collaborations, and hopefully result in a city-wide GSI network, the following recommendations should be considered.

- Continue to support the city GSI Working Group with members from city departments, organizations, and other stakeholders. A more unified effort within existing GSI programs, or as a part of a city-wide GSI network, will help streamline the process, remove barriers, and make the best use of available funds.

- Schedule regular meetings between city departments to assess co-benefits, future projects, potential teaming opportunities, funding, and maintenance capabilities.
- Leverage grant funding for GSI projects tied to monitoring for improvements (e.g., better water quality, improved drainage).
- Continue to implement GSI projects within priority park capital renovations.
- Explore new revenue sources to create a city department dedicated to GSI implementation and maintenance. The use of one shared maintenance staff could create cost-savings among all agencies and provide consistency in the maintenance program. This may be the most effective way to implement a long-term collaborative approach.

The following is a summary of potential partners and funding sources.

BWSC

As part of their consent decree, BWSC has adopted a new "green" approach to stormwater management. This presents an opportunity to partner on projects with BWSC to not only share the construction costs and maintenance burden, but to provide park improvements through the implementation of stormwater management within existing parks and to acquire new land for additional open space and stormwater management.

Effective communication and coordination between BPRD and BWSC on specific GSI projects is critical to ensure the following:

- The design meets both BPRD and BWSC goals.
- The intended use of the public space has not been altered or compromised.
- Maintenance responsibilities and financial obligations have been clearly defined.

Public Works Department (PWD)

The Boston Public Works Department (PWD) provides core basic services essential to neighborhood quality of life. PWD oversees the general construction, maintenance, and cleaning of approximately 802 miles of roadways and associated sidewalks and streetlights throughout the city. However, BPRD often provides the maintenance of the green space within the ROW.

Thus, if GSI is proposed within these spaces, coordination between BPRD, BWSC, and PWD is critical to ensure the project will meet the goals of all three departments and to clearly define the maintenance responsibilities and financial obligations. Sharing of resources between all three agencies will greatly increase the success of a city-wide GSI program.

Department of Conservation and Recreation (DCR)

Certain parks within the city share space or may abut the Massachusetts Department of Conservation and Recreation (DCR) lands. Improvement projects in these areas by one department may adversely impact or be directly related to the other; however, DCR projects may benefit from improvements on BPRD land and vice versa. Shared drainage problems should be identified in advance of specific projects and prioritized for future park improvements. Too often the departments' budgets, priorities and timing of the projects do not coincide. Communication and coordination should be improved between these two departments as part of a more comprehensive city-wide GSI program.

> **"The health and happiness of people across Massachusetts depend on the accessibility and quality of our green infrastructure - our natural resources, recreational facilities, and great historic landscapes. The DCR continues to improve the vital connection between people and the environment."**
>
> *DCR*

Watershed Associations

BPRD should continue to strengthen and build upon existing relationships with local watershed associations and other environmental advocacy groups. These organizations can apply for grants to implement GSI projects that benefit downstream waters, create wildlife habitat, reduce urban heat, and expand the tree canopy.

Below is a list of the potential watershed teaming partners within the city:

- Charles River Watershed Association
- Mystic River Watershed Association
- Neponset River Watershed Association

Regional Land Trusts

As demonstrated in BPRD's use of TPL data within the park assessment, non-profit regional land trusts can also be another valuable resource for GSI implementation. The Nature Conservancy (TNC), TPL and other conservation organizations may provide opportunities to share resources or provide potential funding opportunities for restoration projects. Sharing of GIS data between these agencies may also help to create a city-wide GIS-based tracking and monitoring program.

Community Groups and Volunteer Organizations

Partnerships between city departments are imperative to planning and implementing GSI as discussed above; however, partnerships with volunteer organizations, friends groups, and youth programs are just as important for creating and maintaining a beautiful and functional project in the long-term. These partnerships can contribute to the community acceptance of GSI projects and provide opportunities to educate the public about water quality, the value of GSI, and environmental stewardship as well as train volunteers and youth groups to assist with long-term maintenance.

Community Group examples include:

- YouthBuild Boston
- Park Conservancies
- "Friends of" organizations (e.g. Friends of Christopher Columbus Park or Friends of Peters Park)
- Community-based volunteer organizations
- Housing Authorities

Strategic partnerships can create a sense of ownership or stronger connection to nature. This in turn creates more "stewards" who volunteer to help by providing both manual labor as well as serving as monitors, notifying the responsible agency when the system does not appear be functioning properly or when maintenance is required.

All of these benefits in turn provide lower levels of effort required for BPRD maintenance staff. Partnering with these types of organizations is an integral part of connecting people with nature and community outreach as discussed below.

Other Partners

Climate resiliency and improvements to livability and health don't stop at the city limits. Contributing impacts to a specific site, such as flooding and erosion, may extend beyond city boundaries. Looking at the bigger picture and teaming with regional agencies such as the Metropolitan Area Planning Council (MAPC), as well as neighboring cities and towns, can promote design that work toward a shared vision of a regional resiliency network.

> **"There are opportunities for Boston and adjacent municipalities to work together with Metropolitan Area Planning Council (MAPC) and the Commonwealth on waterfront and riverfront planning, linear parks, green infrastructure, alternative transportation, social equity, and climate change on a regional level and between adjacent municipalities. The opportunity exists for the City of Boston to be partners with its neighbors over shared resources and environmental issues that exist beyond the boundaries of the city."**
>
> *Boston Open Space and Recreation Plan*

CONNECT PEOPLE TO GSI

Forming partnerships with community groups and volunteer organizations as discussed above also goes "hand and hand" with connecting people to GSI. Parks are well loved community spaces and proposed changes can often elicit an emotional responses and resistance. If not properly explained and communicated early in the design process, GSI can often be misunderstood and perceived to be a nuisance. By connecting people to GSI the public is more likely to support funding for future projects and may also become involved in maintaining the GSI practice. Public engagement and education along with successful high visibility projects lead to a successful GSI program.

Engage

Engage the public early and often during the design process. The most successful GSI projects keep the public well informed throughout the design process and offer opportunities to review and comment. This helps build trust and is the first step in "creating stewards" and identifying future volunteers and partners or a project "champion". Engaging the community increases feelings of pride, ownership, and willingness to take part to help plan, build, and maintain these systems.

Use public meetings, charrettes, and workshops to engage the community throughout the design process to provide meaningful feedback, not just initial ideas or general desires.

Reach out to partners such as the local housing authority to maintain community involvement and volunteers. Work with other agencies to create stewardship programs such as Portland, Oregon does with their Green Street Stewards program[1].

Use and/or develop online social media applications to reach a wider, more inclusive audience for more comments and feedback.

Educate

Clearly explaining to the community how GSI works and why it is important leads to wider general acceptance and creates community advocates and stewards. It also can raise awareness on environmental and public health issues and reinforce the idea that GSI is part of the larger solution.

Education should include the following:

- Educational signage at GSI practices
- Online educational and maintenance videos
- "Rain garden" installation training sessions and educational programs for the general public within the parks

Be Visible

Create high visibility pilot projects to demonstrate the effectiveness of GSI within a community park. Documenting the success of these projects helps to evaluate and showcase how investing in GSI can also be effectively used to improve park aesthetics and increases human understanding and interaction with nature.

Successful demonstration projects help build momentum and gain stakeholder and community acceptance. It is also an effective way to create interest and educate park staff, designers, engineers, and the community on methods that deviate from conventional approaches.

1 *https://www.portlandoregon.gov/bes/article/319879*

MAINTENANCE AND MONITORING

Volunteers

After learning about GSI in their neighborhood or favorite park, local residents and park users may become interested in maintaining or monitoring the practice. Friends of the Park type organizations may also volunteer to "adopt a practice."

Partnering with local high schools, colleges, or universities for both maintenance and performance monitoring can often be a cost-effective approach to implementing a monitoring program.

Training program

To build and advance in-house GSI capacity, a BPRD staff training program should be developed to address the following:

- Review how different GSI practices function
- Provide construction oversight training for BPRD project managers
- How to troubleshoot problems and causes
- Typical maintenance requirements
- Good housekeeping measures

Grant funding through EPA is available for training programs. The training should include both classroom time and hands-on training. Training can include other agency staff or can be combined with a public outreach event (e.g., a rain garden installation).

Signing in at a block party for a neighborhood park in Hyde Park (Credit: HWG)

Maintaining a bioswale in Chelsea (Credit: HWG)

Online videos to describe the required maintenance at each site should also be considered as part of the Operation and Maintenance Plan for both training and as a long-term maintenance solution.

GSI tracking system

As the use of GSI increases throughout the city, BPRD should work with other city departments to develop a city-wide GIS based GSI tracking system. At a minimum the tracking should include the following information:

- Practice Type
- Location
- Installation date
- Warranty period
- Observations
- Scheduled field visits/inspections
- Required Maintenance
- Maintenance completed

Monitoring sensors in a biorention area (Credit: HWG)

Monitoring

An internal BPRD monitoring program should be considered for the following GSI elements over time:

- Plant health and growth
- Performance (e.g., overall appearance, meets design expectations, functioning properly, etc.)
- Sediment accumulation

Additional monitoring, such as pollutant removal performance, can also be performed through strategic partnerships with BWSC or local schools and universities.

As identified in the case study review and discussed in the Partnerships and Funding section above, monitoring can often be leveraged for additional funding. Monitoring and data collection on GSI performance can be valuable information for improving future designs as well as be used to improve maintenance and performance of existing practices.

STORMWATER PARKS

The creation of new "Stormwater Parks" within the city on existing city-owned vacant or newly acquired land provides a unique opportunity to add new open space within the city, provide multi-functional/resilient spaces, and to partner with other agencies to construct and maintain the new facilities. By identifying co-benefits between city agencies, this approach can encourage agencies such as BPRD and BWSC to work together to purchase land specifically for stormwater management during rain events and usable as public open space when dry. As part of this collaboration, the maintenance burdens could also be shared between the multiple agencies.

Stormwater Parks are most applicable:

- When degraded or vacant land is available or parcel acquisition possible and a maintenance agreement is worked out between the partnering agencies
- As shared solutions with multiple city agencies in vulnerable low-lying areas that experience frequent flooding
- With complementary active and passive uses of the park that can support stormwater
- To consolidate stormwater management in one location when the implementation of smaller practices dispersed throughout the surrounding neighborhood is not practical

Stormwater Parks are specifically designed to provide traditional park uses, when not raining, and creatively filter, infiltrate, and/or store off-site neighborhood runoff within the same space, when raining. They are typically located in "downstream" locations where it is relatively easy to intercept neighborhood runoff or where localized flooding occurs. These parks can transform the community's perceptions by celebrating the rainwater as a resource rather than as waste. During heavy rain, the open space is often flooded and not used for recreational purposes. After the water subsides, the area once again becomes available for recreational use. This multi-functional approach can also be used to improve resiliency and be part of a climate-resilient neighborhood plan.

At a minimum, the design of Stormwater Parks should strive to meet the following objectives:

- Create vibrant and accessible public open space
- Address localized flooding problems and improve flood resiliency
- Maximize flood storage and allow for the waters to be efficiently and safely collected and drained
- Provide stormwater treatment and improve water quality
- Use resilient materials, site furnishings, and plants to minimize stormwater damage and long-term maintenance (see Special Conditions, Floodable Areas, page 56).

As the park is designed to function as a large GSI system, understanding the contributing drainage area and potential pollution sources is critical. Depending on the scale of the project, the pretreatment may require a higher level of design when compared to other GSI practices. Subsurface pretreatment structures may be the most practical option. Due to the increase in sediment, debris, and pollutants associated with the larger contributing urban drainage area, ease of maintenance will be a critical factor. Depending upon the available area, the park design may need to include an option to take the park "off-line" during extreme storm events to protect the park and minimize long-term damage.

PRIORITIZATION

A total of 283 park properties were assessed to prioritize GSI implementation within the park system. The GSI analysis and assessment of BPRD properties was performed using the available Open Space and Recreation Plan's GIS data and staff knowledge of the existing park system. Using this information along with the BPRD GSI goals and benefits (see page 8), GSI criteria were established. The GSI criteria were then layered with data from the Trust for Public Land's (TPL) Climate-Smart Boston Decision Support Tool to ensure additional co-benefit opportunities were included in the BPRD prioritization.

BPRD Criteria

As the first step, BPRD staff developed a criteria point system to assess the individual properties. A total of eight criteria were selected based on the goals and staff input. Point values were then assigned to the criteria listed below in order of priority:

Flooding

Properties with existing flooding problems that would benefit from improved drainage and GSI.

Highly Suitable for GSI

Suitability is based on the property's location, use, ease of implementation, and minimal permitting requirements.

Water Resources

Properties with ponds, wetlands, streams, buffers, and other water resources that would benefit from water quality improvements.

Water Features

Properties with designed water features that would benefit from water reuse and water quality improvements (e.g., fountains and spray parks).

Tree Canopy

Properties with less than 20% tree cover that would benefit by increasing tree canopy with GSI.

Partnerships

Properties with the following partnership opportunities that could assist with funding and/or maintenance and outreach:

- Existing shared maintenance with other departments or potential for shared maintenance opportunities
- Existing or future partnership, private donor, or other funding sources
- Strong volunteer groups to help with maintenance

Capital Funding

Properties targeted for future funding/improvements in the city Capital Plan.

Equity/Economic/Environmental Justice (EJ) Communities

Properties located within EJ communities.

TPL Climate Smart Boston Data

Once BPRD's criteria were established, the TPL Climate-Smart Boston Decision Support Tool[2] data was added to the criteria ranking and assigned point values. The TPL Tool's data is based on the following four strategies for climate resiliency:

Absorb

Areas of the city where features of the landscape are particularly vulnerable to or at risk of flooding as a result of major storms.

2 *http://web.tplgis.org/Storymaps/CSC_Boston/cascade/index.html*

Protect

Areas of the city that are particularly vulnerable to coastal flooding based on current flood risk and the projected rise in sea levels.

Cool

Areas of the city with unnaturally high surface temperatures and designated as urban heat island hotspots.

Connect

Areas of the city where additional connections are needed (e.g., expanding walk-bike corridors).

All four of the TPL strategies were added to the BPRD criteria. Each strategy was assigned a sliding point value for high, medium, and low.

> **"While using green infrastructure to manage runoff mitigates flooding and pollution downstream, it also improves air quality, cools the city, and provides green spaces that make our cities more livable, beautiful, and climate-resilient. Urban greenery has also been proven to improve mental health and well-being."**
>
> *Trust for Public Land*

Park Prioritization Ranking

Using these criteria, a weighted ranking exercise was performed to prioritize BPRD-managed properties for potential GSI implementation. The suitability of each property was then determined by assigning a "GSI suitability score."

By prioritizing the park properties, each site can be compared to find the highest priority and most advantageous sites for early GSI implementation. Based on the "GSI suitability score," the properties were ranked for comparison and grouped into the three GSI suitability categories:

Highly Advantageous

Properties that ranked highest and met most of the higher-ranking criteria. (50 properties)

Advantageous

Properties that were in the middle of the pack and typically did not meet the highest BPRD criteria. (155 properties)

Less Advantageous

Properties that ranked lowest and met the lower ranking criteria. (78 properties)

This list was developed to categorize the parks based upon their level of suitability for GSI implementation. It is important to note that most park improvement projects provide opportunities to incorporate varying levels of GSI, and each park should be considered for GSI implementation regardless of their final rank.

The ranking did not include BPRD-managed ROWs, but this by no means should exclude them from consideration for GSI.

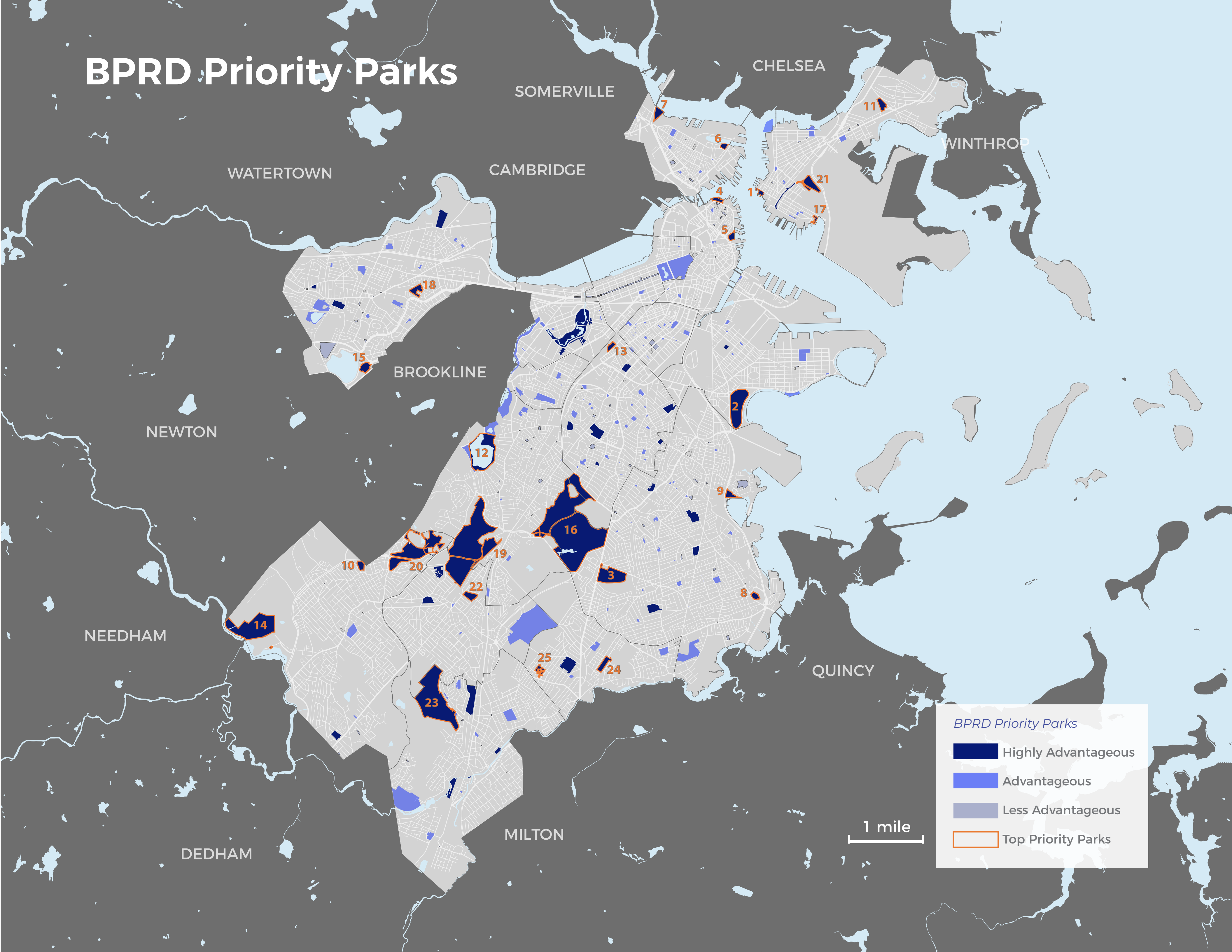
Top Priority Sites

Based upon the top weighted scores, the following 25 parks were identified as the Highest Priority:

1. LoPresti Park
2. Moakley Park
3. Harambee Park
4. Langone Puopolo
5. Christopher Columbus Park
6. Barry Playground
7. Ryan Playground
8. Garvey Playground
9. McConnell Park
10. Hynes Playground
11. Noyes Playground
12. Jamaica Pond Park
13. Carter Playground
14. Millennium Park
15. Cassidy Playground
16. Franklin Park
17. Porzio Park
18. Ringer Playground
19. Arnold Arboretum: Bussey Brook
20. Allandale Combined
21. East Boston Memorial Park
22. Healy Playground
23. George Wright Golf Course
24. Gladeside Urban Wild
25. Mattahunt Woods

BPRD Priority Parks Map

On the following page is a map that shows all Boston parks included in the final ranking from highly advantageous to less advantageous as described above. The top 25 highest priority parks are also highlighted.



BPRD Priority Parks
SOMERVILLE
CHELSEA
WINTHROP
CAMBRIDGE
WATERTOWN
BROOKLINE
NEWTON
NEEDHAM
QUINCY
MILTON
DEDHAM
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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16
17
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19
20
21
22
23
24
25
1 mile
BPRD Priority Parks
Highly Advantageous
Advantageous
Less Advantageous
Top Priority Parks

Moakley Park (Credit: HWG)

HIGHLIGHT CO-BENEFITS

Additional information from other city agencies was reviewed and included on the neighborhood maps in this section to identify parks where GSI would be beneficial according to multiple agencies' priorities. This is referenced below as co-benefit opportunities.

Climate Ready Boston (CRB)

The CRB final report identifies 11 BPRD parks, listed below, that are in vulnerable areas due to future flood progression and exposure, making them prime candidates for climate resilience initiatives such as GSI. Although this data is not included in the ranking method, these parks are marked with a green circle (●) on the maps to highlight potential co-benefits of GSI at BPRD properties. See CRB for specific recommended improvements.

Potential District-Scale Flood Protection:

- LoPresti Park
- Brophy Park
- Porzio Park
- Moakley Park
- Christopher Columbus Park

Flood Progression:

- Ryan Playground
- East Boston Greenway

Coastal Flooding:

- Boston Common
- Public Gardens

Climate Hazard:

- Malcolm X Park

Infrastructure Exposure:

- Union Park

BWSC Priority Parcels for GSI

BWSC recently completed a ranking exercise of all parcels in the city for GSI suitability. Their analysis focused on areas with high phosphorus loading, impervious cover, land use, terrain, good soils/sufficient depth to groundwater, and parcels with open space, including BPRD properties. A total of 69 BPRD-managed properties were included in the final ranking. Similar to TPL, BWSC uses a weighted ranking method using the identified data layers to create a composite ranking. In discussions with BWSC staff, it was determined that phosphorus reduction was the main co-benefit factor between the departments. BWSC scored areas within the city for phosphorus reduction from 0 to 5. For the purpose of highlighting the co-benefits of GSI in parks, the scores were divided into the three phosphorus reduction categories and are indicated with blue circles beside the park names on the maps as follows:

- Low: 0-3 ○
- Medium: 4 ●
- High: 5 ●

In addition to phosphorous reduction, BWSC identified 13 parks to prioritize for GSI implementation based on recent tributary studies and a "low lying areas" analysis. These parks are indicated on the maps with a dark blue outline around the BWSC phosphorus reduction circles (e.g. ●).

The parks listed below were identified by BWSC as priority parks for GSI based on the recent BWSC tributary studies:

- Olmsted Park (Daisy Field)
- Franklin Park
- Harambee Park
- Moakley Park
- Fallon Field
- Dimock and Amory Street Park

The parks identified for possible flood reduction, based upon the BWSC "low lying areas" analysis are:

- Allandale Combined
- Sherrin Woods
- George Wright Golf Course
- Franklin Park
- Gladeside Urban Wild
- Roslindale Wetland Urban Wild
- Arnold Arboretum: Bussey Brook

The following maps illuminate the overlapping priorities and goals between departments. This helps to identify partnership opportunities for future teaming projects and shared funding to create multi-functional spaces that improve both climate resiliency and the livability and health of the city.

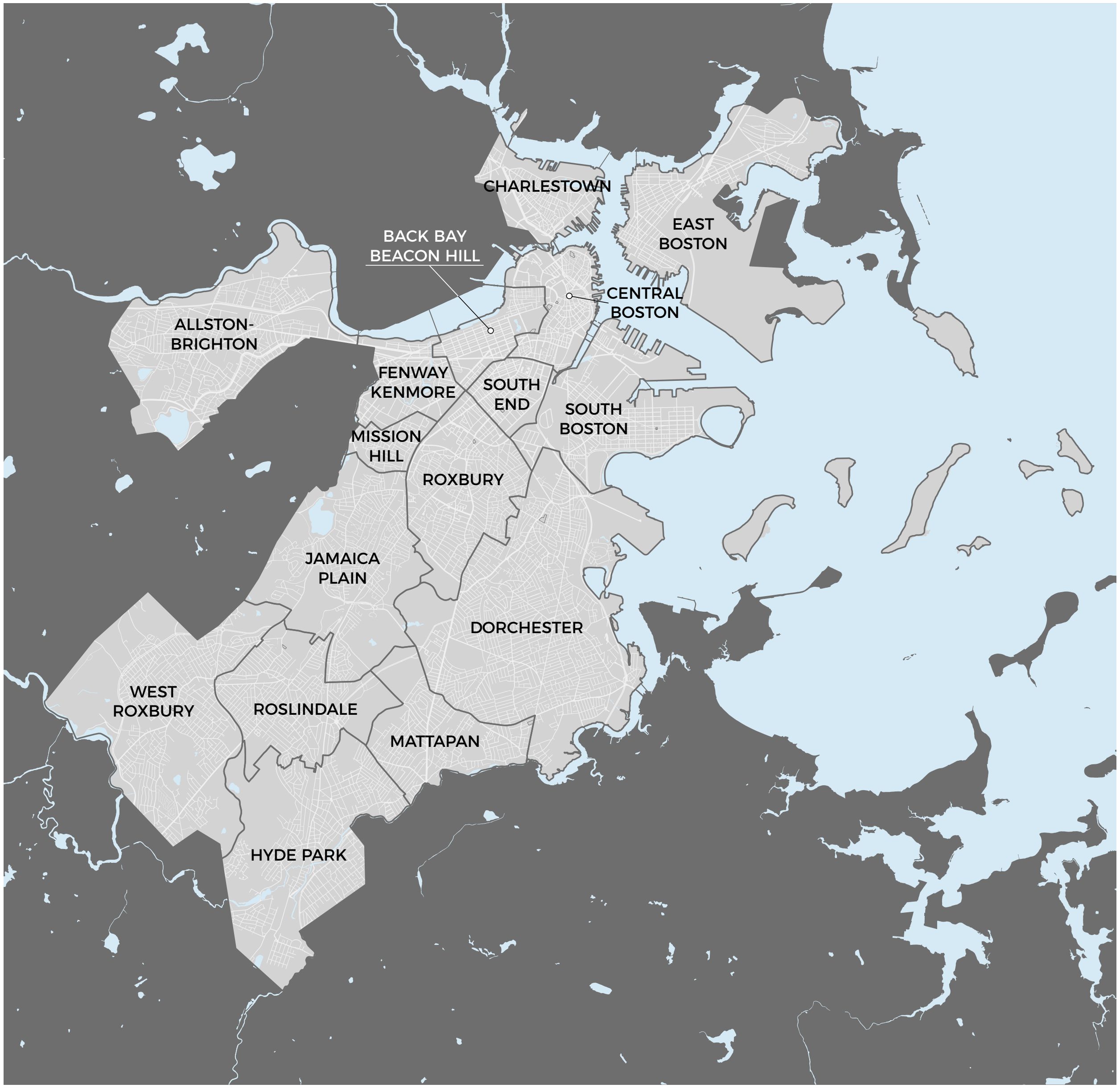
Franklin Park (Credit: HWG)

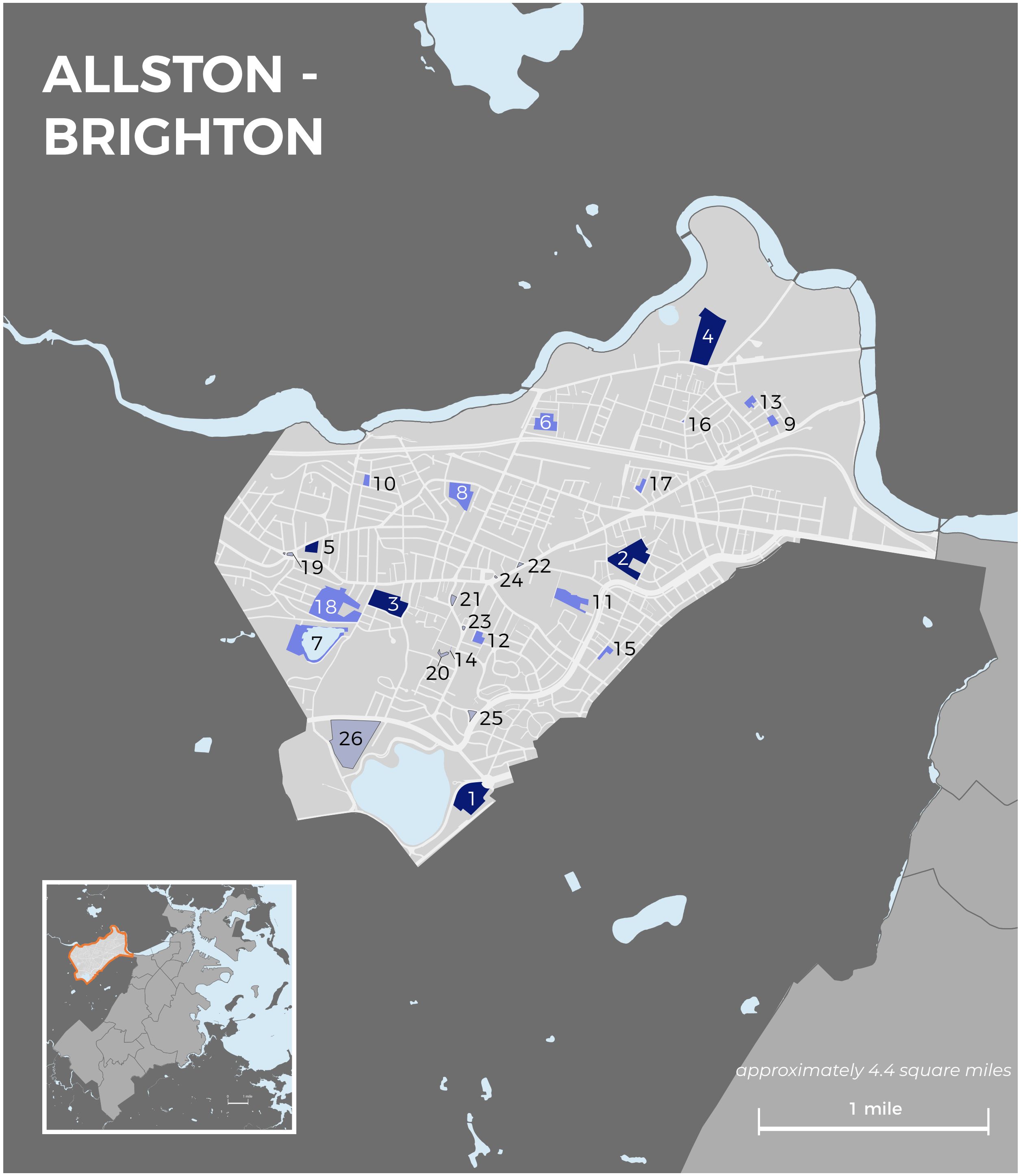
Neighborhood Maps

The following pages include maps for the 16 Boston neighborhoods and are in alphabetical order. The neighborhoods are:

- Allston-Brighton
- Back Bay/Beacon Hill
- Central Boston
- Charlestown
- Dorchester
- East Boston
- Fenway/Kenmore
- Hyde Park
- Jamaica Plain
- Mattapan
- Mission Hill
- Roslindale
- Roxbury
- South Boston
- South End
- West Roxbury

Each neighborhood map shows the parks colored by BPRD GSI suitability categories. BWSC phosphorus reduction categories and vulnerable parks identified by CRB are indicated with circles beside the park names on the same page.





ALLSTON-BRIGHTON

BPRD Priority Ranking

1 Cassidy Playground
2 Ringer Playground
3 Rogers Park
4 Smith Playground
5 Hardiman Playground

6 Portsmouth Street Playground
7 Chandler Pond
8 McKinney Playground
9 Hooker-Sorrento Street Playground
10 Hobart Park
11 Fidelis Way Park
12 Joyce Playground
13 Raymond V. Mellone Park
14 Theresa Hynes Park Access Easement
15 Brian Honan Park
16 Fern Square
17 Penniman Road Play Area
18 The Cenacles

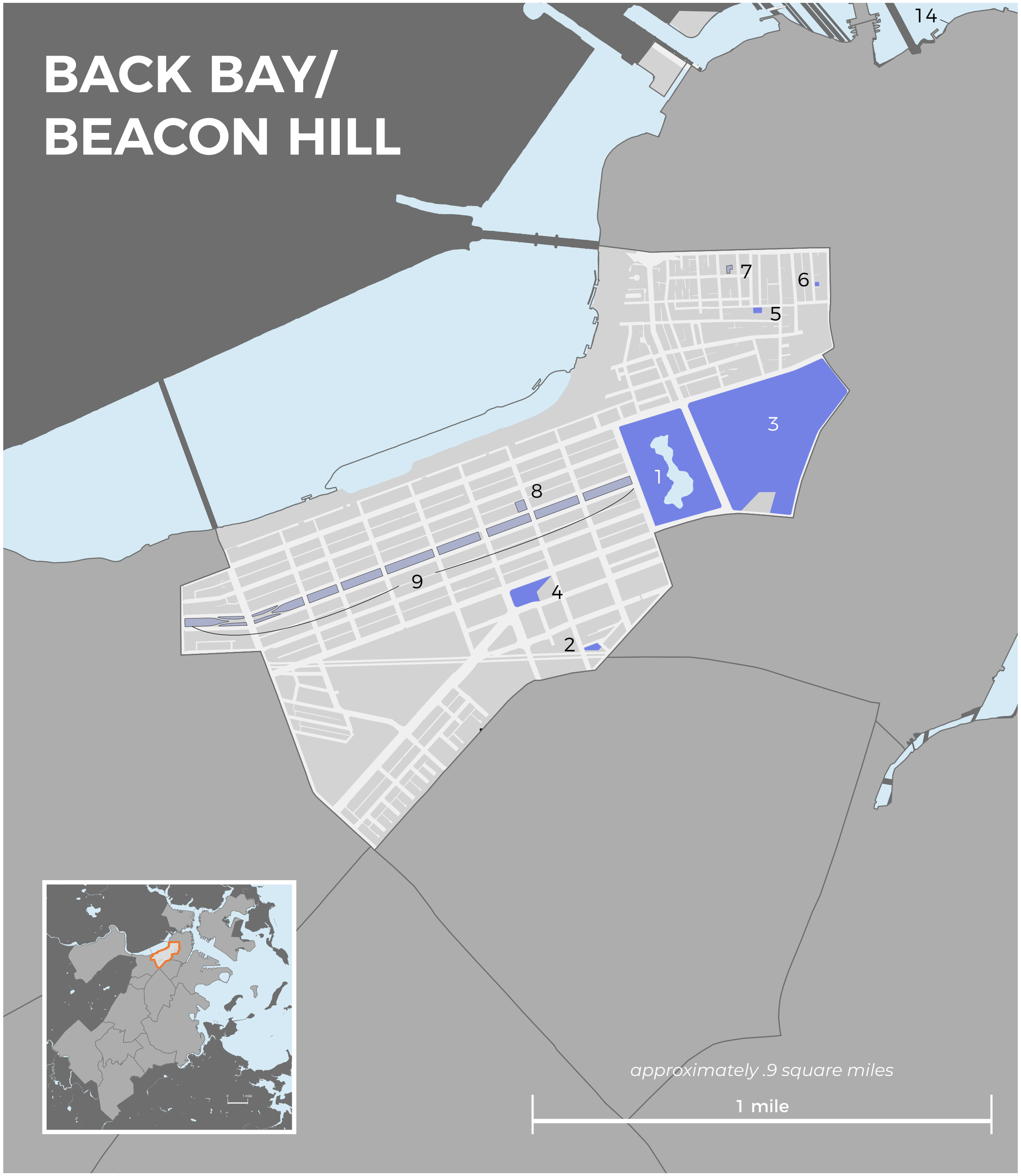
19 Oak Square
20 Theresa Hynes Park
21 Brighton Common
22 Cunningham Park
23 Jackson Square
24 Public Ground
25 Shubow Park
26 Evergreen Cemetery

BPRD Priority Parks

Highly Advantageous
Advantageous
Less Advantageous

Co-Benefits

BWSC ranking for P removal
Low Med High
BWSC priority parks:
CRB vulnerable parks:



BACK BAY/BEACON HILL

BPRD Priority Ranking

1. Public Garden
2. Frieda Garcia Park
3. Boston Common
4. Copley Square Park
5. Myrtle Street Playground
6. Temple Street Park

7. Phillips Street Play Area
8. Clarendon Street Totlot
9. Commonwealth Avenue Mall

BPRD Priority Parks

- Highly Advantageous
- Advantageous
- Less Advantageous

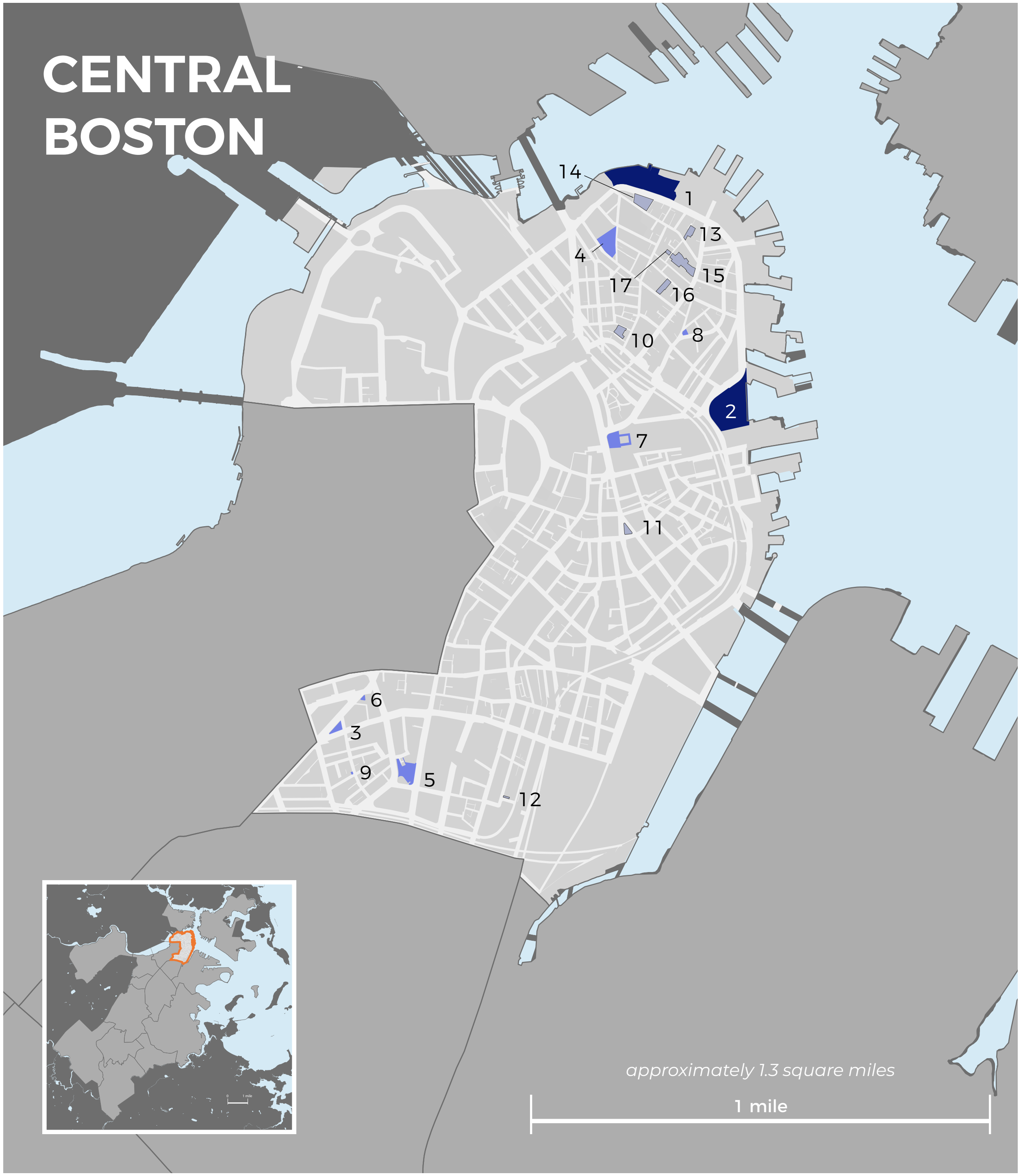
Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:



CENTRAL BOSTON

BPRD Priority Ranking

1 Langone Puopolo
2 Christopher Columbus Park

3 Statler Park
4 DeFilippo Playground
5 Elliot Norton Park
6 Lincoln Square - Central
7 Faneuil Square
8 Rachel Revere Square
9 Bay Village Garden

10 Cutillo Park
11 Angell Memorial Square
12 Tai Tung Park
13 Charter Street Park
14 Copp's Hill Terrace
15 Paul Revere Mall
16 Polcari Park
17 Webster Avenue Playground

BPRD Priority Parks

Highly Advantageous

Advantageous

Less Advantageous

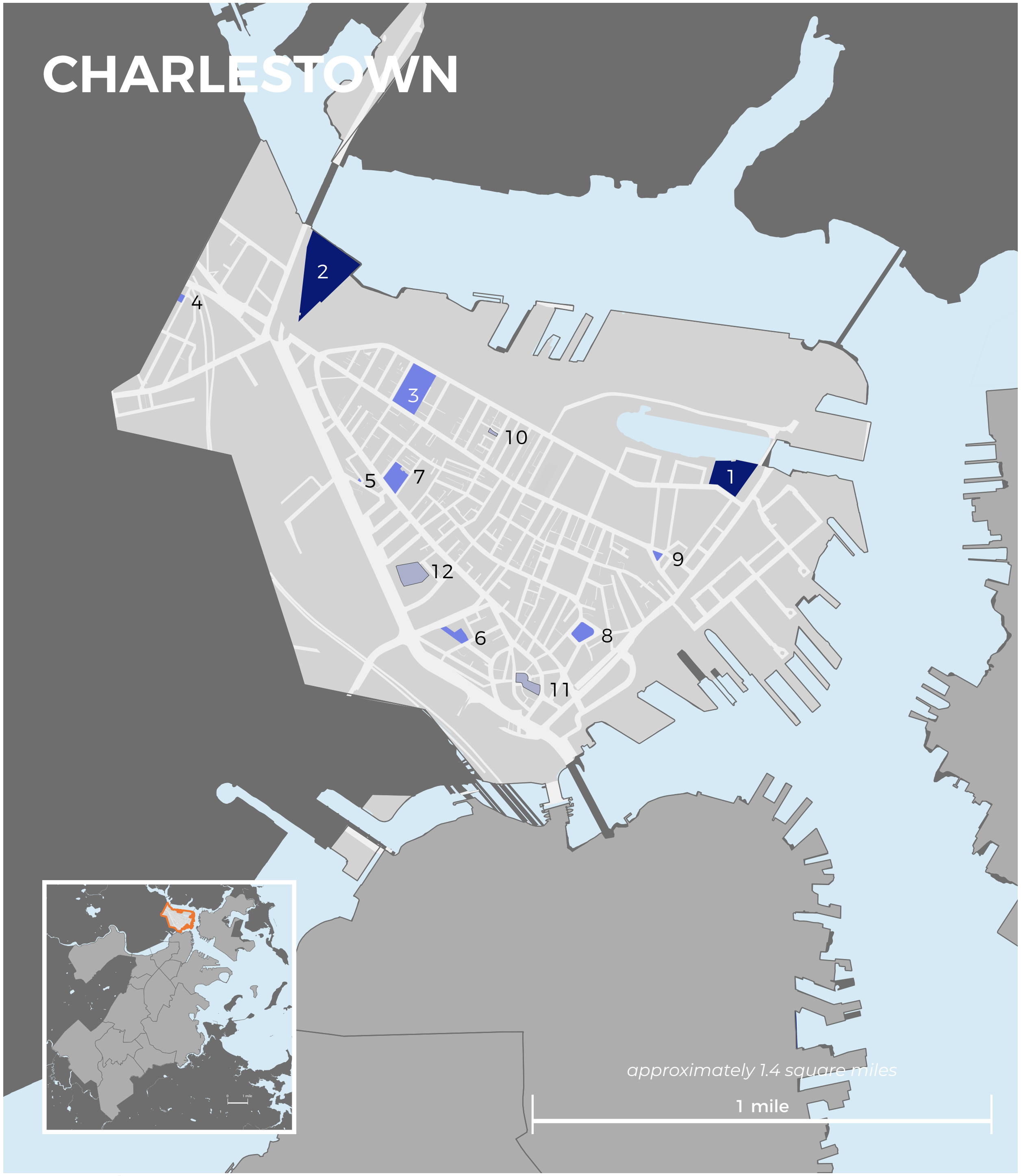
Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:



CHARLESTOWN

BPRD Priority Ranking

1 Barry Playground
2 Ryan Playground

3 Doherty Playground
4 Caldwell Street Play Area
5 Essex Square
6 Peter Looney Park
7 Edwards Playground
8 Winthrop Square
9 Hayes Square

10 Cook Street Play Area
11 Harvard Mall
12 Phipp's Street Burying Ground

BPRD Priority Parks

Highly Advantageous

Advantageous

Less Advantageous

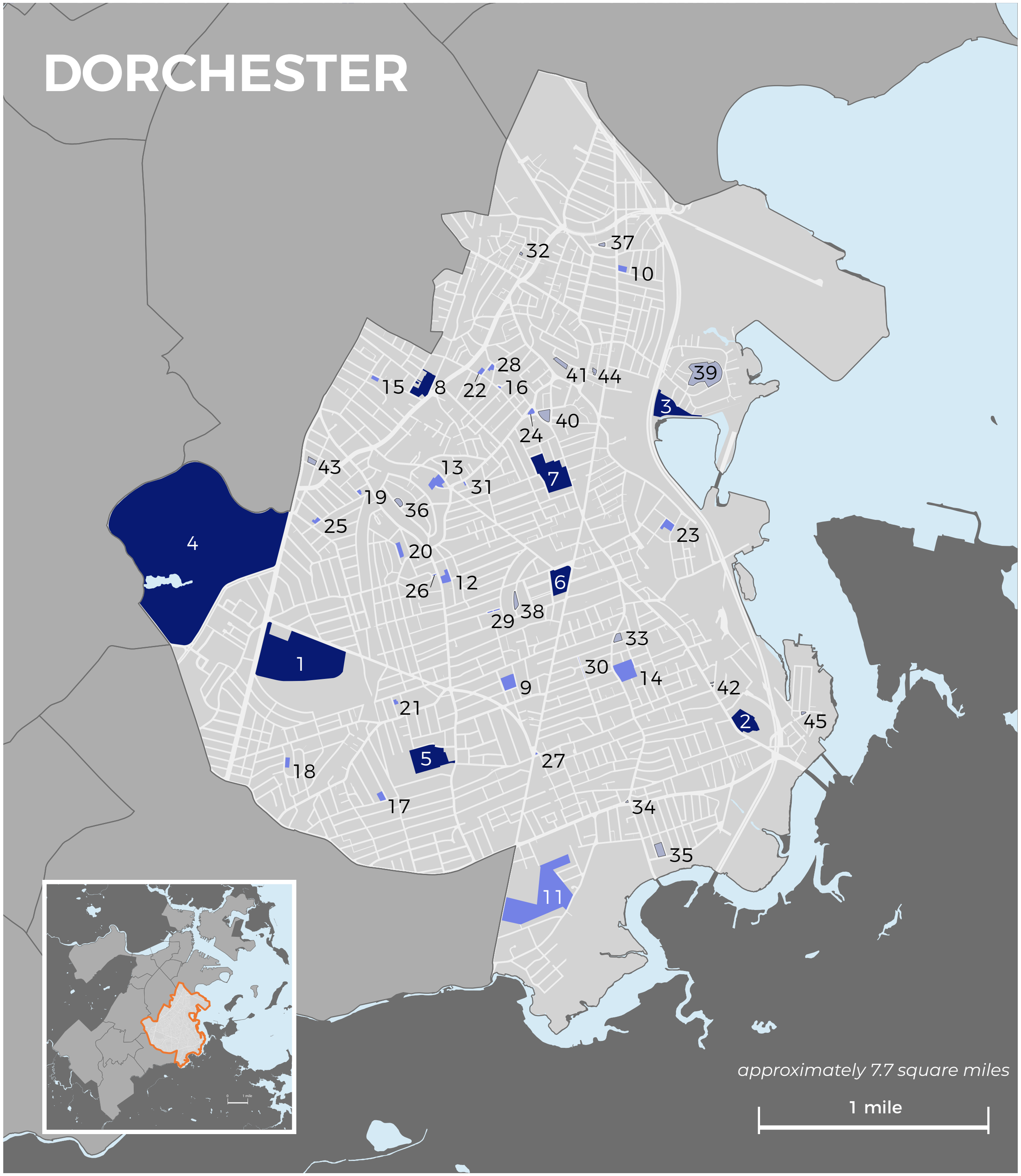
Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:



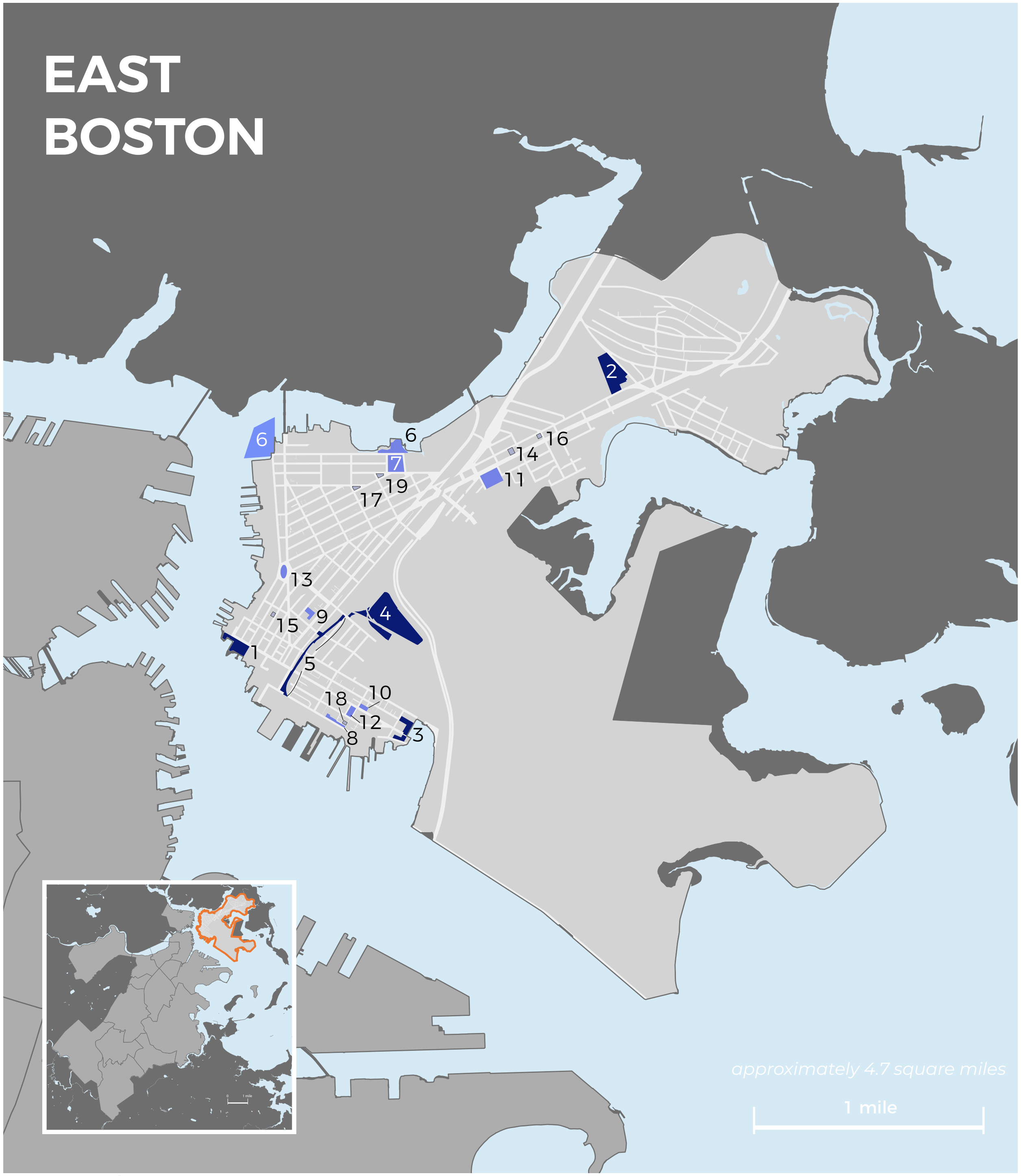
DORCHESTER

BPRD Priority Ranking

1 Harambee Park
2 Garvey Playground
3 McConnell Park
4 Franklin Park
5 Roberts Playground
6 Doherty/Gibson Playground
7 Ronan Park
8 Ceylon Park

9 Rev. Loesch Family Park
10 Ryan Play Area
11 Dorchester Park
12 Mother's Rest at Four Corners
13 Geneva Cliffs
14 Hemenway Playground
15 Children's Park
16 Fernald Rock
17 Thetford Evans Playground
18 Willowwood Rock
19 Fenelon Street Playground
20 Ripley Playground
21 Elmhurst Street Park
22 Quincy/Stanley Play Area
23 Byrne Playground
24 Coppens Square
25 Erie/Ellington Playground
26 Algonquin Square
27 Peabody Square
28 Stanley-Bellevue Park
29 Tremlett Square
30 Florida Street Reservation
31 Tebroc Street Park

32 Nellie Miranda Memorial Park
33 Adams/King Playground
34 Henry Square
35 Martin/Hilltop Playground
36 Mt. Bowdoin Green
37 Mullen Square
38 Wellesley Park
39 Savin Hill Park
40 Allen Park
41 Downer Avenue Playground
42 O'Donnell Square
43 Puddingstone Park
44 Deer Street Park
45 Doucette Square



EAST BOSTON

BPRD Priority Ranking

		Co-Benefits
1	LoPresti Park	CRB vulnerable; BWSC High
2	Noyes Playground	BWSC High
3	Porzio Park	CRB vulnerable; BWSC High
4	East Boston Memorial Park	BWSC Low
5	East Boston Greenway	CRB vulnerable; BWSC High
6	Condor Street Combined	BWSC High
7	American Legion Playground	BWSC High
8	The Rockies	BWSC Med
9	Paris Street Playground	BWSC Low
10	Sumner & Lamson Streets Playground	BWSC Low
11	Bennington Street Cemetery	BWSC High
12	Brophy Park	CRB vulnerable; BWSC Low
13	Central Square	BWSC Low
14	McLean Playground	BWSC High
15	Veterans Park	BWSC Low
16	Cuneo Park	BWSC High
17	Putnam Square	BWSC Low
18	Golden Stairs Terrace Park	BWSC Med
19	Prescott Square	BWSC Low

Parks 1–5: Highly Advantageous; 6–13: Advantageous; 14–19: Less Advantageous.

BPRD Priority Parks

- Highly Advantageous
- Advantageous
- Less Advantageous

Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:

FENWAY/LONGWOOD

BPRD Priority Ranking

1 Back Bay Fens

2 Riverway
3 Edgerly Road Playground
4 Ramler Park
5 Joslin Park
6 Symphony Community Park

7 Commonwealth Avenue Mall

BPRD Priority Parks

- Highly Advantageous
- Advantageous
- Less Advantageous

Co-Benefits

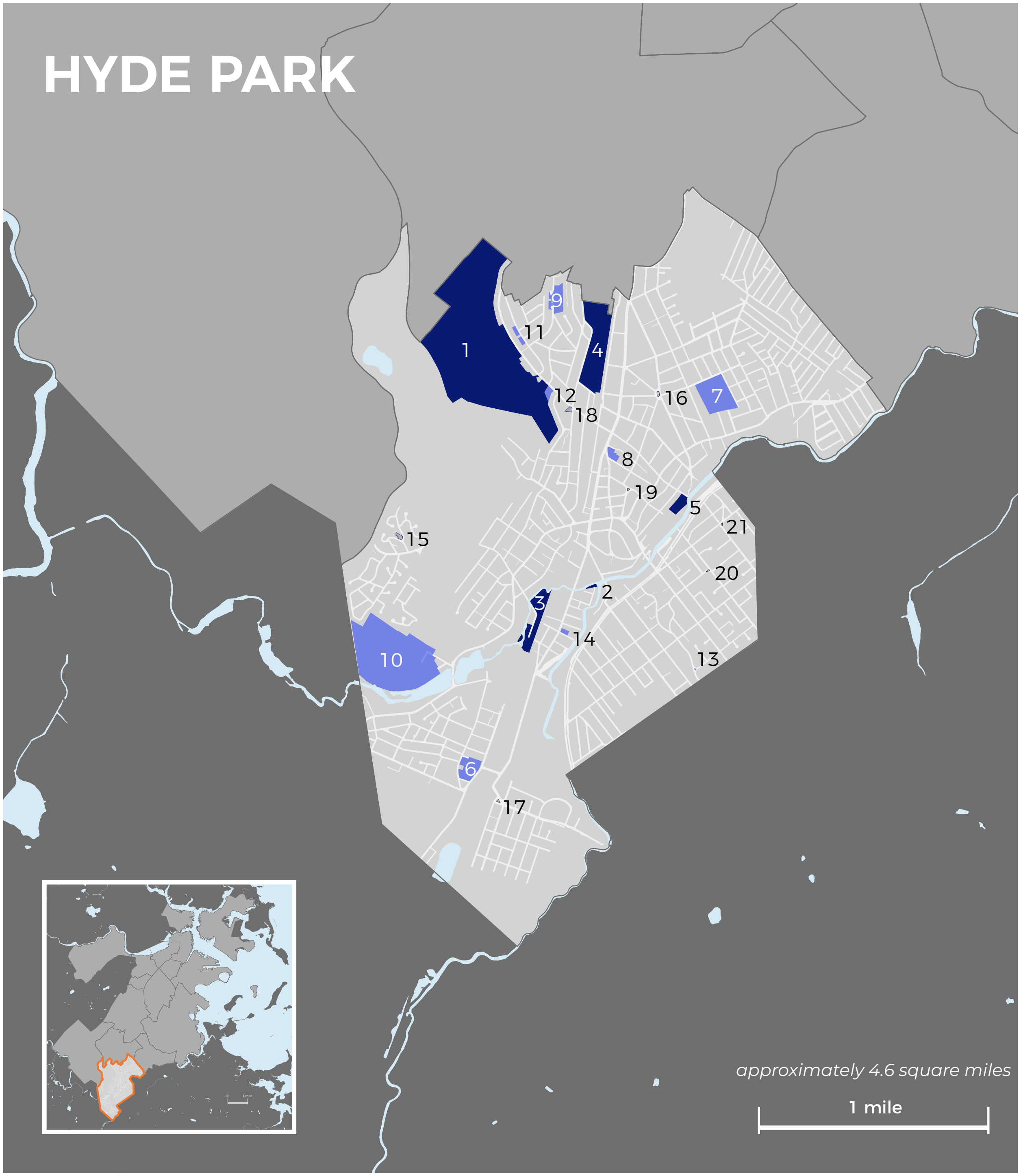
BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:

IMPLEMENTATION



HYDE PARK

BPRD Priority Ranking

1 George Wright Golf Course
2 Blake Estates Urban Wild
3 Reservation Road Park
4 Sherrin Woods
5 West Street Urban Wild

6 Iacono/Readville Playground
7 Ross Playground
8 Dell Rock
9 Monterey Hilltop
10 Fairview Cemetery
11 DeForest Urban Wild
12 McGann Park
13 Williams Square
14 Amatucci Playground

15 Stonehill Park
16 Foley Square
17 Hurley Park
18 West Austin Rock
19 Webster Square
20 Jones Square
21 Woodworth Square

BPRD Priority Parks

Highly Advantageous

Advantageous

Less Advantageous

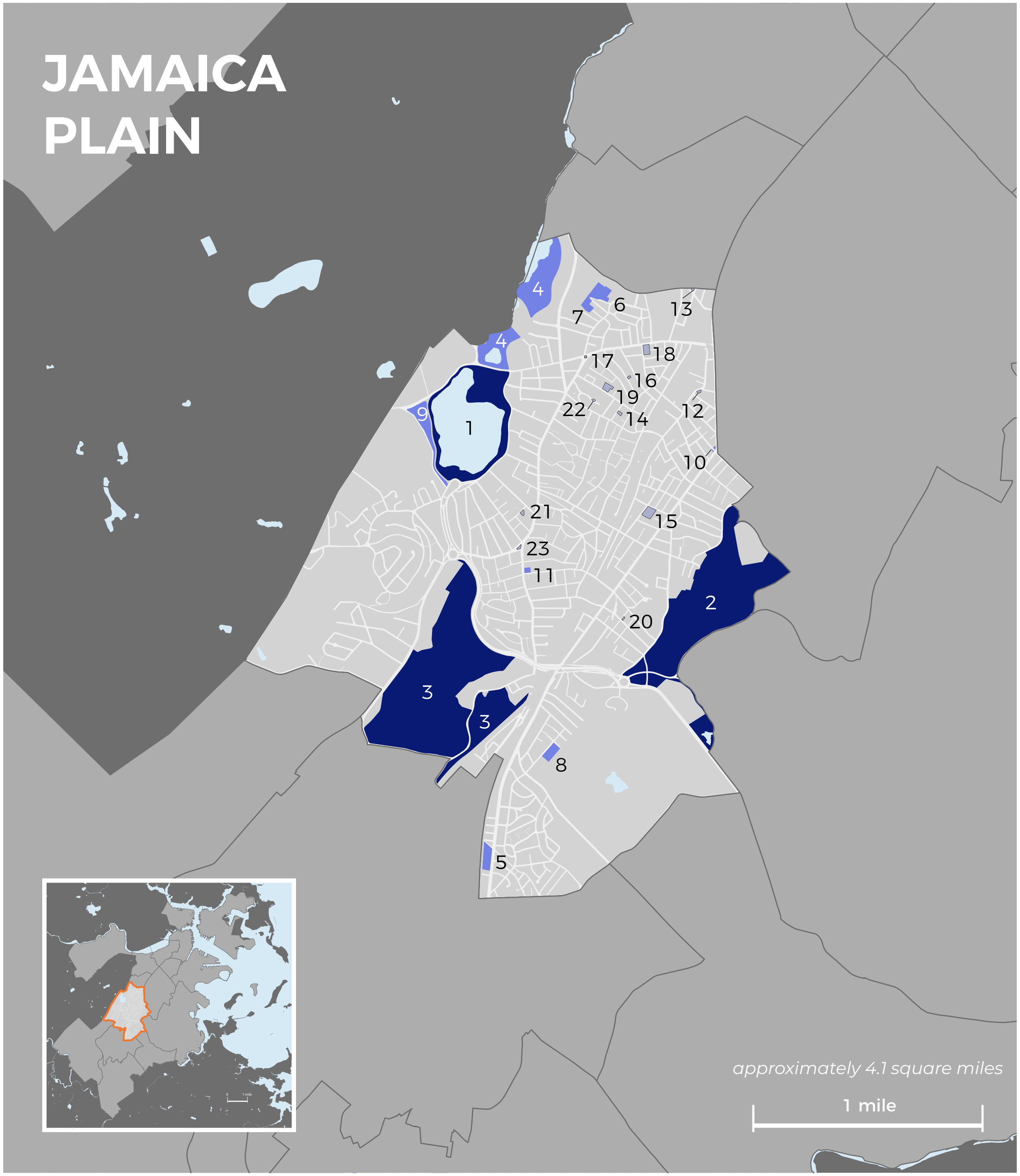
Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:



JAMAICA PLAIN

BPRD Priority Ranking

1	Jamaica Pond Park	High
2	Franklin Park	High (BWSC priority park)
3	Arnold Arboretum: Bussey Brook	High (BWSC priority park)
4	Olmsted Park	High (BWSC priority park)
5	Pagel Playground	Med
6	Jefferson Playground	Med
7	Nira Rock	Med
8	Parkman Playground	Low
9	Parkman Memorial	Med
10	Egleston Square Plaza	High
11	South Street Mall & Courts	Med
12	Dimock and Amory Street Park	BWSC priority park
13	Heath Square	Med
14	Beecher Street Play Area	Low
15	Flaherty Playground	Med
16	Forbes Street Playground	Med
17	Mahoney Square	Med
18	Mozart Street Playground	High
19	Paul Gore Street Park	Low
20	Rossmore/Stedman Park	Low
21	Brewer-Burroughs Tot Lot	Med
22	Oakview Terrace	Low
23	Soldier's Monument	Med

Parks 1–3: Highly Advantageous; 4–11: Advantageous; 12–23: Less Advantageous.

BPRD Priority Parks

- Highly Advantageous
- Advantageous
- Less Advantageous

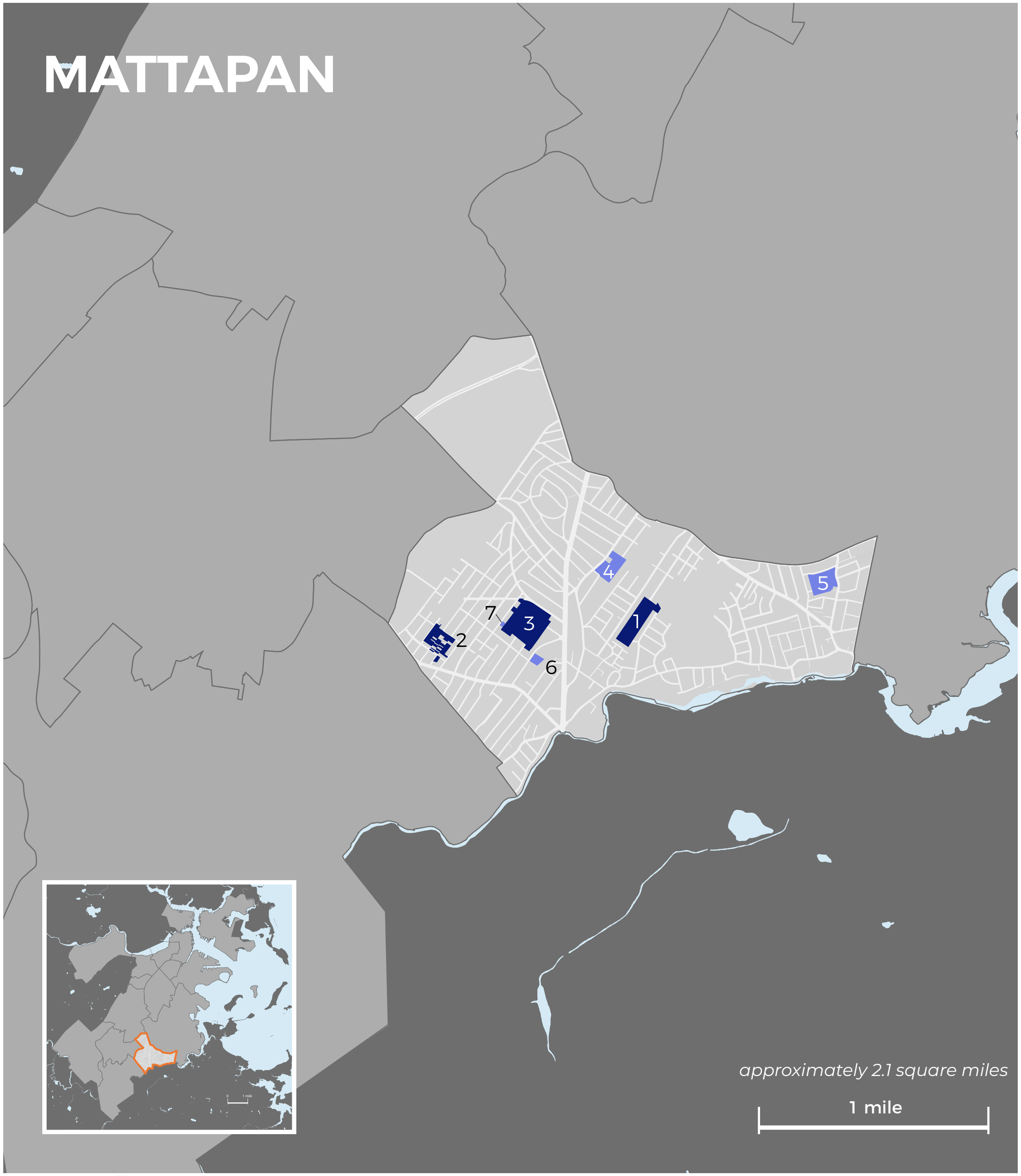
Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:



MATTAPAN

BPRD Priority Ranking

1 Gladeside Urban Wild
2 Mattahunt Woods
3 Almont Park

4 Walker Playground
5 Walsh Playground
6 Woodhaven
7 Ernst Chery Jr. Playground

BPRD Priority Parks

- Highly Advantageous
- Advantageous
- Less Advantageous

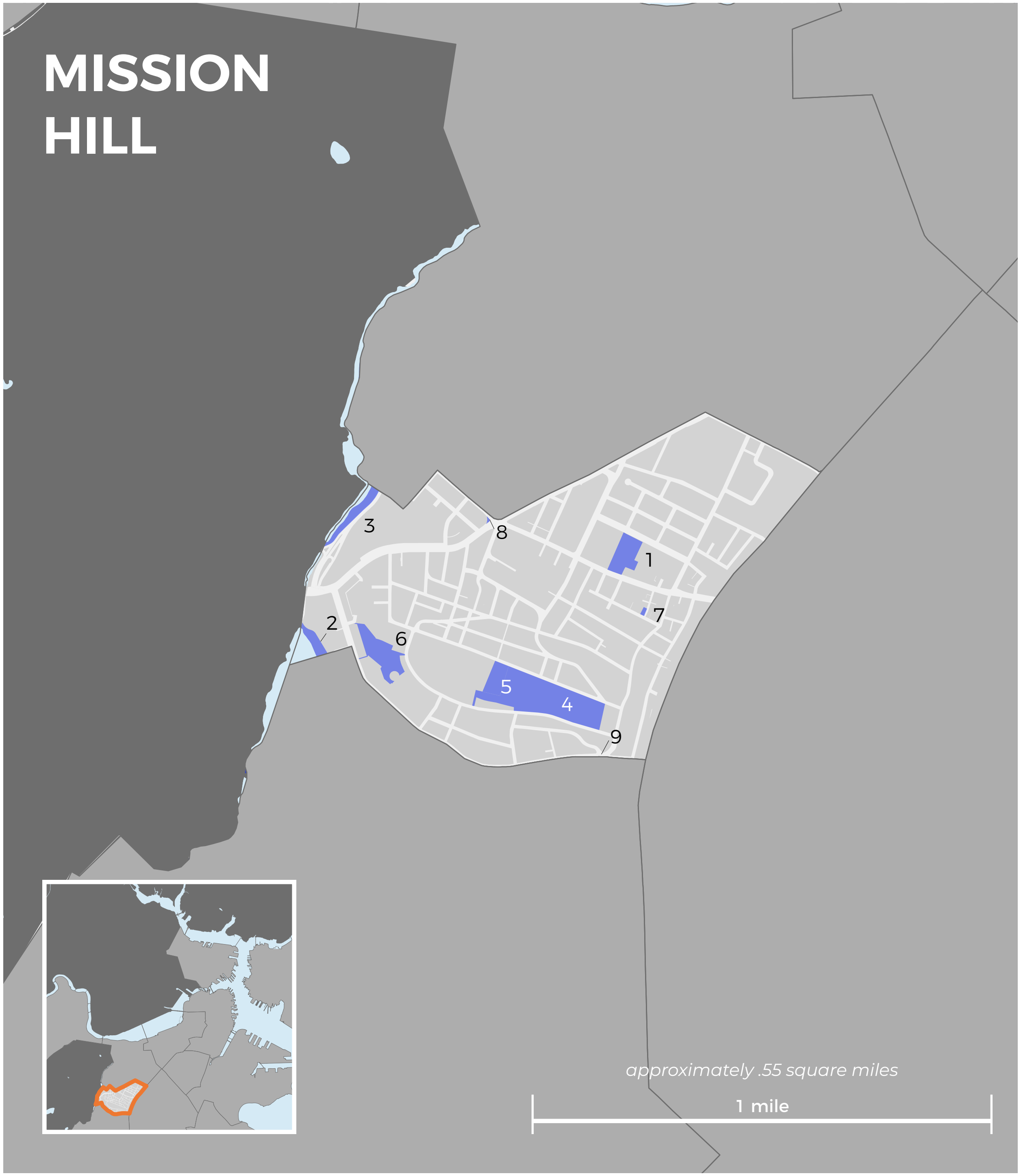
Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:



MISSION HILL

BPRD Priority Ranking

			BWSC ranking for P removal
Advantageous	1	Mission Hill Playground	High
Advantageous	2	Olmsted Park	High
Advantageous	3	Riverway	High
Advantageous	4	McLaughlin Playground	High
Advantageous	5	Parker Hilltop	High
Advantageous	6	Back of the Hill	Low
Advantageous	7	Gibbons Playground	Med
Advantageous	8	Hanlon Square	High
Less Advantageous	9	Heath Square	Med

BPRD Priority Parks

- Highly Advantageous
- Advantageous
- Less Advantageous

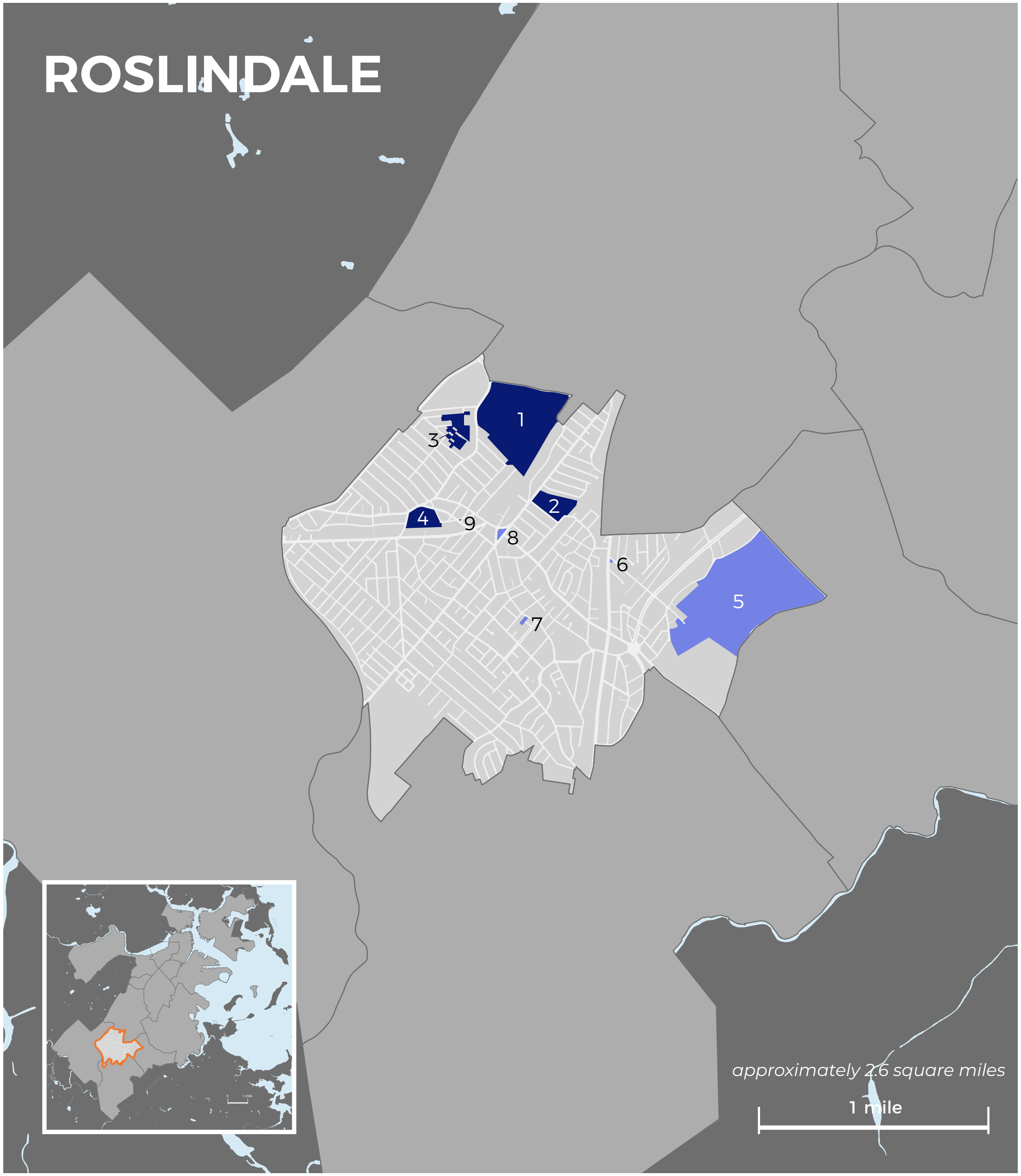
Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:



ROSLINDALE

BPRD Priority Ranking

1 Arnold Arboretum: Bussey Brook
2 Healy Playground
3 Roslindale Wetlands Urban Wild
4 Fallon Field

5 Mt. Hope Cemetery
6 Mount Hope Park
7 Poplar Street Play Area
8 Adams Park

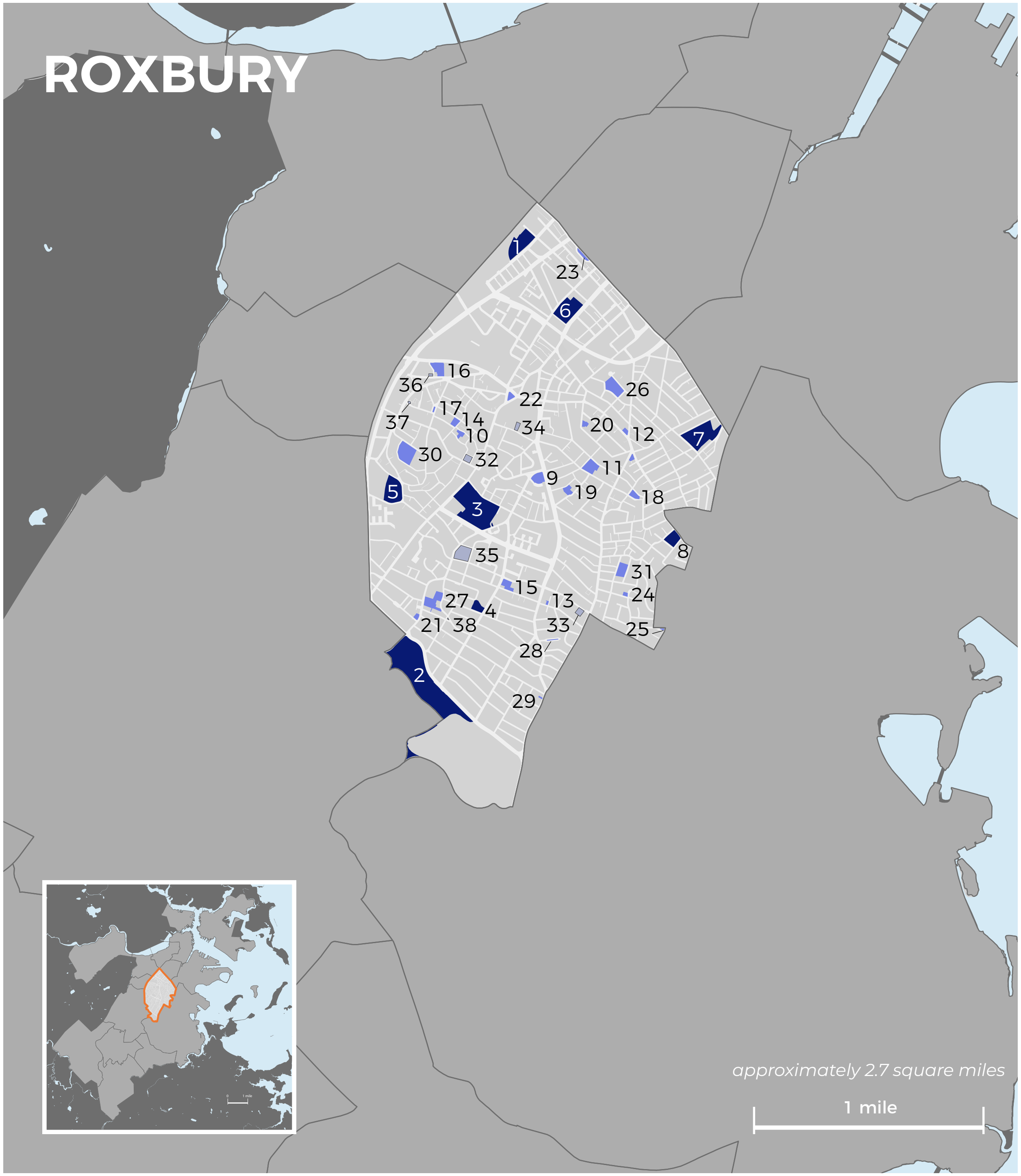
9 Emmel Square

BPRD Priority Parks

Highly Advantageous
Advantageous
Less Advantageous

Co-Benefits

BWSC ranking for P removal
Low Med High
BWSC priority parks:
CRB vulnerable parks:



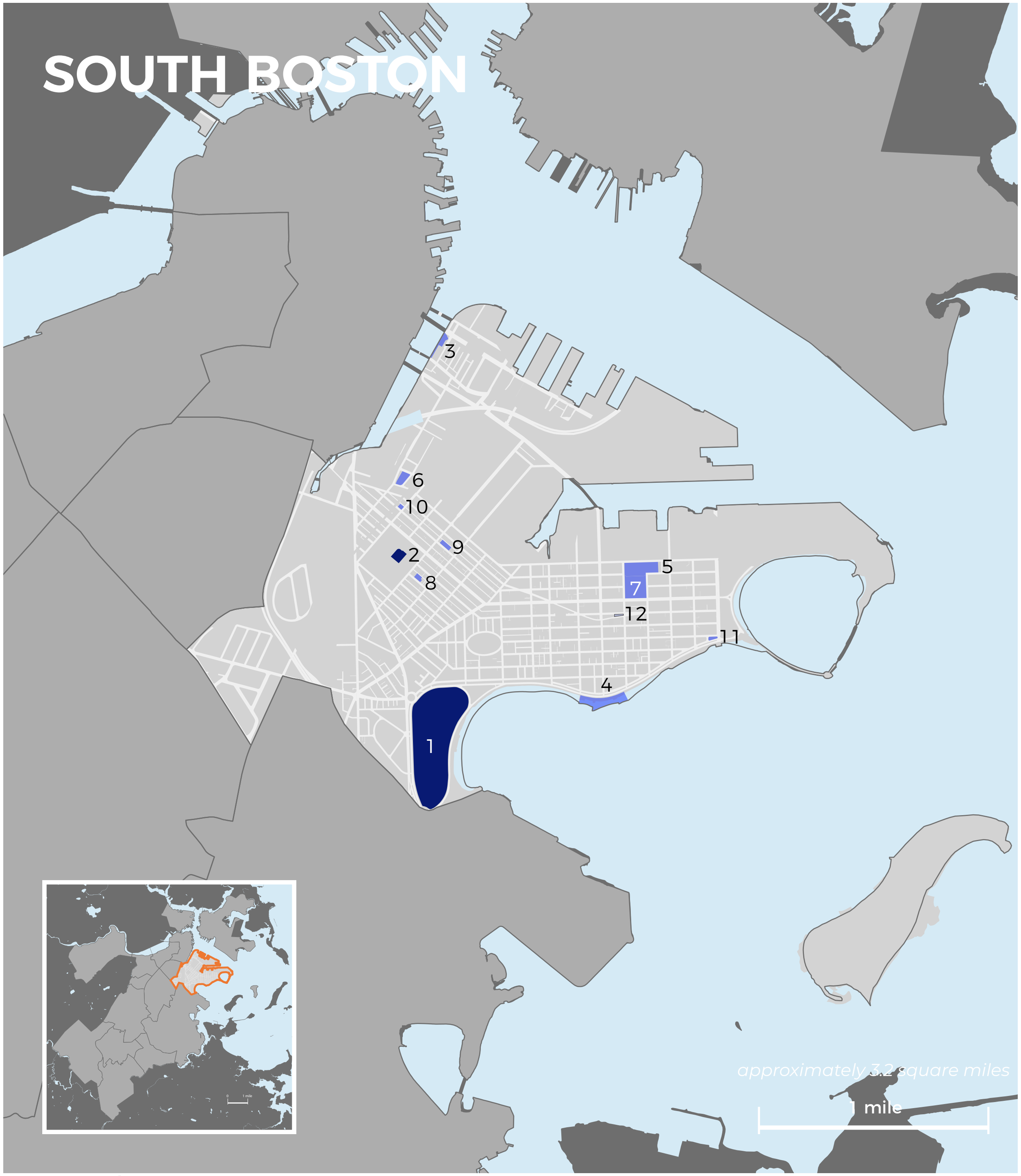
ROXBURY

BPRD Priority Ranking

1 Carter Playground
2 Franklin Park
3 Malcolm X Park
4 Trotter School Playground
5 Marcella Playground
6 Ramsay Park
7 Clifford Playground
8 Hannon Playground

9 Buena Vista
10 Rockledge Street Urban Wild
11 Howes Playground
12 Dudley Town Common
13 Holborn Street Playlot
14 Lambert Avenue Playground
15 Laviscount Park
16 Jeep Jones Park
17 Kittredge Park
18 Dennis Street Park
19 Little Scobie Playground
20 Mt. Pleasant Play Area
21 Msgr. John Roussin Park
22 Gourdin Park
23 Chester Park
24 Beauford Play Area
25 Denton Square
26 Edna V. Bynoe Park
27 Crawford Street Playground
28 Elm Hill Park
29 Grove Hall Plaza
30 Highland Park
31 Winthrop Playground

32 Cedar Square
33 Quincy Street Play Area
34 St James Street Park
35 Horatio Harris Park
36 King Street Play Area
37 Linwood Park
38 Wolf Square



SOUTH BOSTON

BPRD Priority Ranking

1 Moakley Park
2 Orton Field

3 Martin's Park (Children's Wharf)
4 L Street Beach
5 Christopher Lee Playground
6 A Street Park
7 Medal of Honor Park
8 Sweeney Playground
9 Buckley Playground
10 Flaherty Park
11 Columbia Park

12 Lincoln Square - South

BPRD Priority Parks

Highly Advantageous

Advantageous

Less Advantageous

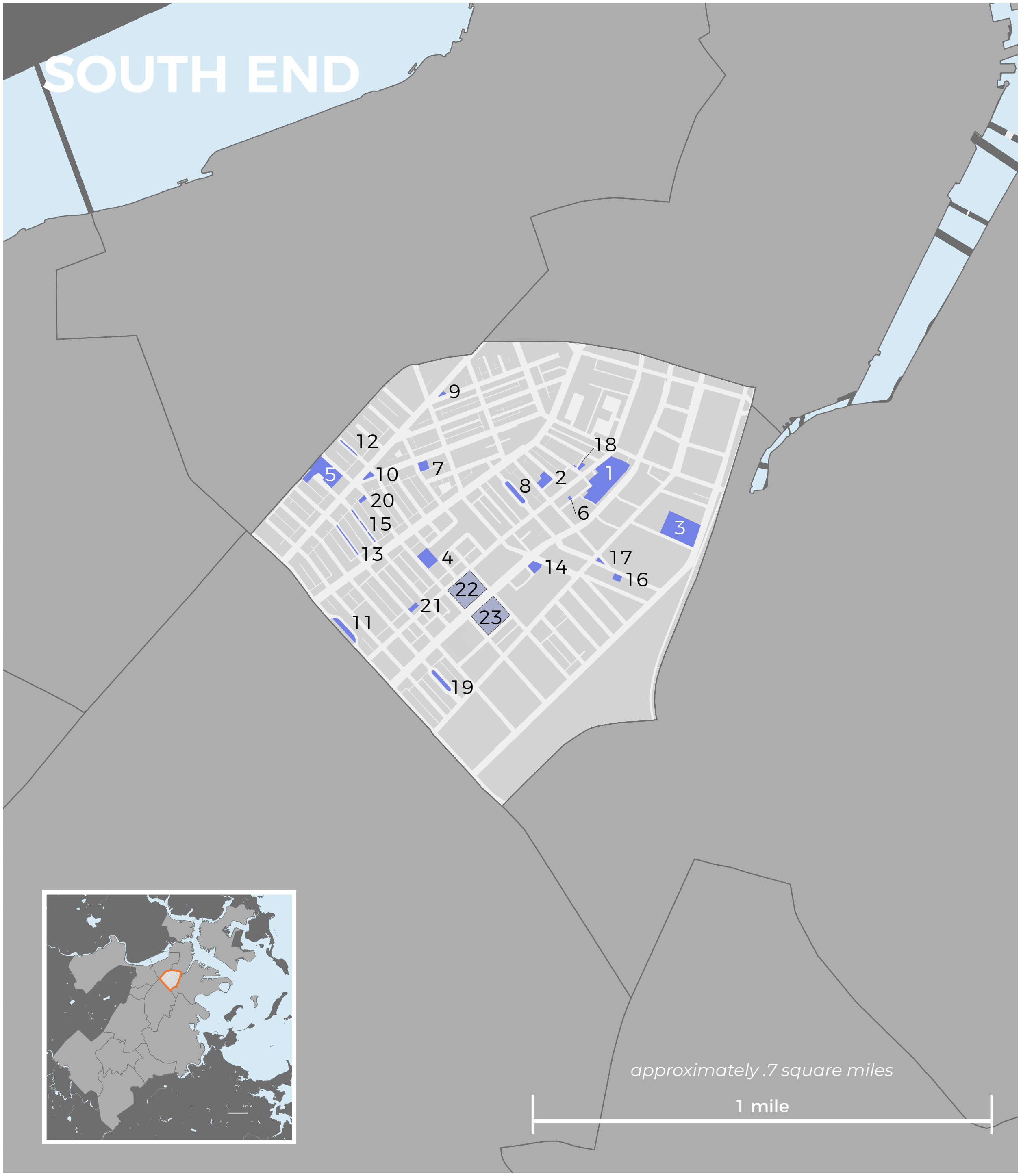
Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:



SOUTH END

BPRD Priority Ranking

1 Peters Park
2 Ringgold Park
3 Rotch Playground
4 O'Day Playground
5 Titus Sparrow Park
6 Bradford Street Play Area
7 Hayes Park
8 Union Park
9 Childe Hassam Park
10 Harriet Tubman Square
11 Chester Park
12 Braddock Park
13 Concord Square
14 Msgr. Reynolds Playground
15 Rutland Square
16 St Helena's Park
17 Waltham Square
18 Watson Park
19 Worcester Square
20 Hiscock Park
21 Newland Street Park

22 Blackstone Square
23 Franklin Square

BPRD Priority Parks

Highly Advantageous

Advantageous

Less Advantageous

Co-Benefits

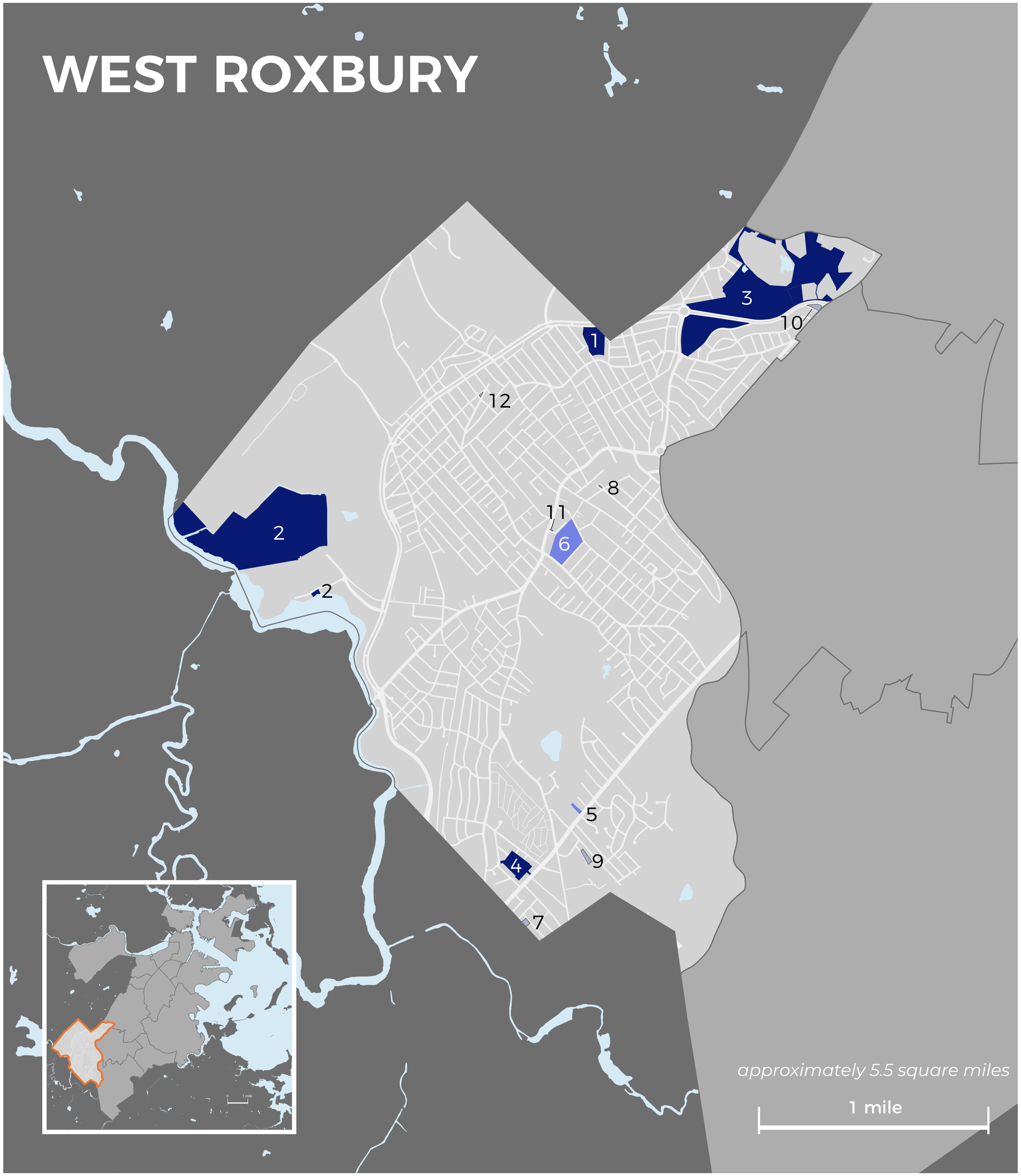
BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:

IMPLEMENTATION



WEST ROXBURY

BPRD Priority Ranking

1 Hynes Playground
2 Millennium Park
3 Allandale Combined
4 Draper Playground

5 Beethoven School Play Area
6 Billings Field

7 Carroll Pond Playground
8 Duffie Square
9 Dunbarton Woods
10 VFW Parkway
11 Zero Quinn Way
12 Piemonte Park

BPRD Priority Parks

- Highly Advantageous
- Advantageous
- Less Advantageous

Co-Benefits

BWSC ranking for P removal

Low Med High

BWSC priority parks:

CRB vulnerable parks:

(Credit: HWG)

Appendices

A. Plants
B. Sample Maintenance Plan
C. Precedent Study

Appendix A: Plants

Appendix A: Plants

SEED MIXES

For every project, choose mixes that meet the project GSI Objectives, fit the Park Context and will thrive in the site conditions. The following considerations are meant to provide design guidance based on seeding strategies and species used in existing GSI practices.

Considerations

- Use native seeds that are used to growing in the climactic conditions of Boston and that provide benefits to local ecosystems.
- Use Wet, Dry or Wet and Dry tolerant seed mixes depending on the practice (see plant matrix). Mixes that are meant for wet conditions are typically not suitable for GSI that is permanently flooded.
- Plan for whether the practice will be online or offline during plant establishment. Conditions such as water levels may vary from the design plans during construction and establishment.
- Use plugs or #1 gallon containers for plants in areas that may get washed out during establishment or in GSI areas with permanent standing water.
- If there is irrigation, a greater diversity of species may be used.
- Use a diversity of species in order to ensure some of the plants will survive and thrive and to increase ecosystem benefits.
- Use clover in lawn/turf mixes as a ground cover that provides erosion control, food for pollinators and other animals, and to add nutrients into the soil.
- If project GSI Objectives and the budget allows, consider using custom mixes.
- For droughty lawn/turf conditions, use more fescues over Kentucky Bluegrass unless there is irrigation or if specifying turf-type mixes for sports facilities.
- For grass, use low or no-mow mixes to minimize maintenance required.
- Use wildflowers to provide diversity and attract pollinators.
- Use plugs of plants that will self-seed to increase the seed bank and establish particular species faster.
- Specify cover crops to provide quick-germinating plants for stabilization until the other species have established (i.e., spring oats or grain rye).
    - Choose species appropriate for the seeding season.
    - Consider the aesthetics when choosing cover crops and how they might differ from the final design.
    - Consider whether the cover crop is annual, perennial or if it will self-seed.
- Ensure maintenance expectations and requirements are understood during and after seed establishment.
- References for seed selections include:
    - Ernst Conservation Seeds: https://www.ernstseed.com/
    - New England Wetland Plants: https://newp.com

PLANTS

The following pages list various plants that have proven to be successful in existing GSI and are tolerant of the varying conditions and water levels as well as urban environments.

The plants are divided into three categories: Wet and Dry, Dry, and Wet Tolerant. The GSI with these conditions is shown in the matrix at the end of this appendix. Plants that are also known to have salt tolerance are indicated with an (S) next to their name.

Many of the plants listed have cultivars that are smaller than the straight species. For sites with limited space or sight line concerns, choose compact cultivars to maintain a maximum size to the plantings.

To limit destruction from waterfowl, multiple design and construction techniques should be used. Woody plants and taller, thicker vegetation can be a deterrent. Plants that can help to deter waterfowl are indicated with a (DW) next to their name.

The plant list should not be considered comprehensive. It includes plants that have proven to be highly resilient, low maintenance and successfully used in various GSI applications. Other plants may be suitable depending on the GSI Objectives, Park Context and Site Analysis for the specific project (see the Guide).

Plant selection should always be performed by a trained professional (Landscape Architect/ Designer, Horticulturist, etc.) or someone trained in plant design with a strong working knowledge of GSI.

WET AND DRY

Trees:

- *Gleditsia triacanthos*, Honeylocust (S)
  (some cultivars are seedless)
- *Quercus bicolor*, Swamp White Oak (S, DW)
- *Ulmus americana*, American Elm (S)
  (use disease resistant cultivars)
- *Ulmus hybrids*, Elm (S)
  (use disease resistant cultivars)

Shrubs:

- *Cornus sp. (alba, amomum, racemosa sericea)*, Shrub Dogwoods (DW)
  (some cultivars of C. alba and C. sericea are compact)
- *Clethra alnifolia*, Summersweet (S)
  (some cultivars are *compact*)
- *Morella pensylvanica*, Bayberry (S)
  (some cultivars are *compact*)
- *Viburnum dentatum*, Arrowwood (S)
  (some cultivars are *compact*)

Perennials and Grasses:

- *Amsonia hubrichtii*, Bluestar
- *Aster sp.*, Aster (S)
- *Carex pensylvanica*, Pennsylvania Sedge
- *Eupatorium fistulosum*, Joe-Pye Weed
- *Juncus effusus and tenuis*, Soft Rush *and* Poverty Rush (S)
- *Rudbeckia sp.*, Black-eyed Susan
- *Panicum virgatum*, Switchgrass (S, DW)

Gleditsia triacanthos

Viburnum dentatum

Rudbeckia species

DRY

Trees:

- *Cercis canadensis*, Redbud
- *Celtis occidentalis*, Common Hackberry (S)
- *Juniperus virginiana*, Eastern Red Cedar (S, DW)

Shrubs:

- *Hypericum sp.*, St John's-wort
- *Morella pensylvanica*, Bayberry (S)
  (at least one compact cultivar)
- *Rhus aromatica*, Fragrant Sumac (S)
  (at least one compact cultivar)

Perennials and Grasses:

- *Asclepias tuberosa*, Butterfly Weed (S)
- *Chasmanthium latifolium*, Northern Sea-Oats (S)
- *Echinacea purpurea*, Coneflower (S)
- *Liatris spicata*, Blazing Star (S)
- *Oenothera fruiticosa*, Sundrops (S)
- *Penstemon digitalis*, Beardtongue (S)
- *Pycanthemum muticum*, Short-toothed Mountain Mint
- *Schizachyrium scoparium*, Little Bluestem
- *Solidago sp.*, Goldenrod (S)
- *Sporobolus heterolepis*, Prairie Dropseed (S)

Cercis canadensis

Morella pensylvanica

Liatris spicata and Schizachyrium scoparium

WET

Trees:

- *Acer rubrum*, Red Maple
- *Amelanchier canadensis*, Serviceberry (DW)
- *Liquidambar styraciflua*, Sweetgum (DW)
  (some cultivars are seedless)
- *Nyssa sylvatica*, Tupelo (S)

Shrubs:

- *Aronia sp.* , Chokeberry (S)
  (some cultivars are *compact*)
- *Cephalanthus occidentalis*, Buttonbush (S, DW)
  (at least one compact cultivar)
- *Cornus sp. (alba, amomum, racemosa)*, Dogwood (DW)
  (some cultivars of C. alba and C. sericea are compact)
- *Ilex glabra*, Inkberry (S)
  (some cultivars are *compact*)
- *Ilex verticillata*, Winterberry (DW)
  (some cultivars are *compact*)
- *Vaccinium angustifolium and corymbosum*, Lowbush and Highbush Blueberry (S)

Perennials and Grasses:

- *Carex vulpinoidea*, Fox Sedge (S)
- *Chelone glabra*, Turtlehead
- *Iris versicolor*, Blueflag Iris (S)
- *Lobelia cardinalis*, Cardinal Flower
- *Scirpus cyperinus*, Woolgrass

Acer rubrum

Ilex verticillata

Iris versicolor

Plant List Matrix

	Water-front (natural)	Water-front (urban)	Wood-land	Meadow	Open Lawn	Sports Fields	Play-ground	Dog Park	Garden	Hard-scape	Parking Lot	ROW	Structure
Stores													
Detention Basin				[green]	[green]						[green]	[green]	
Cistern					[gray]	[gray]	[gray]		[gray]	[gray]	[gray]		[gray]
Storage Chambers				[gray]	[gray]	[gray]		[gray]		[gray]	[gray]	[gray]	[gray]
Infiltrates													
Infiltration Basin				[green]	[green]					[green] T	[green] T	[green] T	[green] T
Infiltration Chambers					[gray]	[gray]		[gray]		[gray]	[gray]	[gray]	[gray]
Porous/Permeable		[gray]					[gray]			[gray]	[gray]	[gray]	
Trench/Dry Well							[gray]			[gray]	[gray]	[gray]	[gray]
Filters Wet/Dry													
Rain Garden	[green] T			[green]			[green] T	[green] T	[green] T	[green] T			[green] T
Bio Soft	[green] T			[green]			[green] T	[green] T	[green] T	[green] T	[green] T	[green] T	[green] T
Bio Hard		[green] T					[green] T		[green] T	[green] T	[green] T	[green] T	[green] T
Swale soft	[orange]		[orange]	[orange]	[orange]	[orange]	[orange]	[orange]	[orange]	[orange]	[orange]	[orange]	[orange]
Swale hard		[orange]					[orange]		[orange]	[orange]	[orange]	[orange]	[orange]
Sand Filter	[orange] T			[orange]	[orange]		[orange] T	[orange] T		[orange] T	[orange] T	[orange] T	[orange] T
Tree Pit							[green] T	[green] T	[green] T	[green] T	[green] T	[green] T	
Tree Trench							[orange] T	[orange] T	[orange] T	[orange] T	[orange] T	[orange] T	[orange] T
Wet Swale	[blue]		[blue]	[blue]		[blue]			[blue]		[blue]	[blue]	
Constructed Wetland	[blue] T	[blue] T									[blue] T	[blue] T	
Shallow Marsh	[blue] T		[blue] T	[blue]									
Restores													
Shoreline Resto-ration	[green] T	[green] T											
Slope Stabilization	[orange] T	[orange] T	[orange] T	[orange]	[orange]			[orange] T	[orange] T			[orange] T	
Pavement Reduction	[green] T	[green] T					[green] T	[green] T	[green] T	[green] T	[green] T	[green] T	

[gray] No Plants
[green] Wet and Dry Tolerant
[orange] Dry Tolerant
[blue] Wet Tolerant
T = Possible Tree Planting

Appendix B:
Sample Maintenance Plan

Maintenance Plan
Green Stormwater Infrastructure
Playground

TABLE OF CONTENTS

FIGURES

APPENDICES

Maintenance Plan
Green Stormwater Infrastructure
Playground

1.0 INTRODUCTION

This Guide provides a general description of the function and maintenance requirements for the Green Infrastructure Stormwater Management Improvements at the Playground. Proper maintenance is vital to their long-term success.

The maintenance provider is required to familiarize themselves with this Guide and inspect and maintain the following practices (**Figure 1**) as outlined in this maintenance guide throughout the year.

INFILTRATES

Permeable Surface

- Porous pavement is designed to allow the infiltration of stormwater through voids provided in the surface and subsurface gravel bed.

FILTERS AND INFILTRATES

Vegetated Sand Filter

- Runoff is collected in the existing catch basin and directed to a diversion manhole structure, which is designed to divert runoff to the sand filter bed beneath the lawn surface. A weir wall is set a specific elevation to divert runoff from small storms and allow larger storms to overflow into the existing drainage system. The diverted water is discharged to a perforated pipe embedded in gravel above the sand. The stormwater infiltrates or filters through the sand and subsoils to remove phosphorus and reduce stormwater runoff prior to discharge to the storm drain system.

Figure 1 – GSI Locations

2.0 RESPONSIBILITY FOR MAINTENANCE

Owner: Boston Parks and Recreation Department (BPRD)
1 City Hall Square, Suite 500
Boston, MA 02201

Contact: TBD
Name:
Email:
Ph:

BPRD is responsible for the continuous operation and maintenance of the GSI and associated drainage areas.

3.0 FUNCTION & MAINTENANCE

How Does Green Infrastructure Work?

Green Stormwater Infrastructure (GSI) is nature-based approach to stormwater treatment and management. These stormwater practices or “treatment areas” are designed to mimic nature and use the natural filtration properties of soil and plants to remove pollutants from stormwater runoff prior to discharging to the City owned municipal drainage system. GSI relies on the following four basic steps to function properly. These four steps will be referenced throughout this Guide.

If one of these steps does not function properly, the entire system can be compromised and the GSI practice itself could be contributing to maintenance problems. This can lead to a landscape nuisances, more frequent maintenance and costly repairs/improvement.

What is required for Maintenance?

As these are nature-based systems that often rely on plant upkeep, the maintenance for GSI typically falls under landscape and general site maintenance services. The regularly scheduled maintenance as outlined in this guide is critical to ensure proper function, maintain infiltration rates and storage capacity and preserve the pollutant removal capabilities as well as the visual integrity. Regularly scheduled maintenance can prevent deficiencies in the effectiveness of the systems, due to sediment build-up, damage, or deterioration.

1. **Collect (Inlets)**
2. **Capture Sediment (Pretreatment)**
3. **Move Water (Pipes)**
4. **Treat and Manage (Filters and Infiltrates)**
5. **Overflows (Structure)**

General maintenance includes the following:

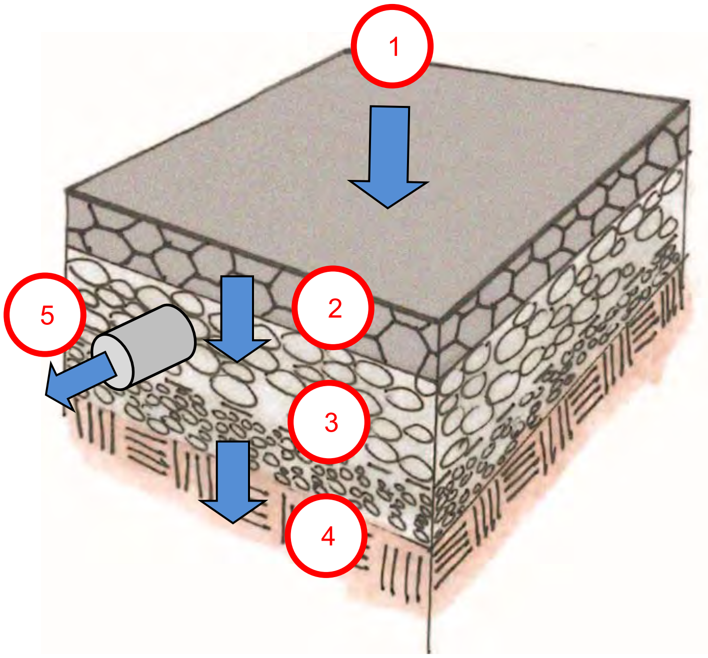
1. Sediment removal from pretreatment.
2. Maintaining the drainage function and pollutant removal capacity of the systems.
3. Maintaining healthy native, tress, plants and vegetative cover as well as the removal of unwanted weeds.

This section describes the function and maintenance for each practice. Included in the appendices is a specific maintenance checklist for each area along with a plan showing the location of the items to be inspected and maintained.

It is recommended that all practices be maintained regularly as part of the routine park maintenance or at a minimum 3 times per year and after major rain events.

- **Early Spring**: during spring cleanup
- **Summer:** During lawn mowing and other routine park maintenance
- **Late Fall:** after the leaves have fallen during leaf removal
- **After major storm events**: 2” of rain or greater

3.1 Permeable Surface



<Photos to be updated upon completion of construction)

FUNCTION:

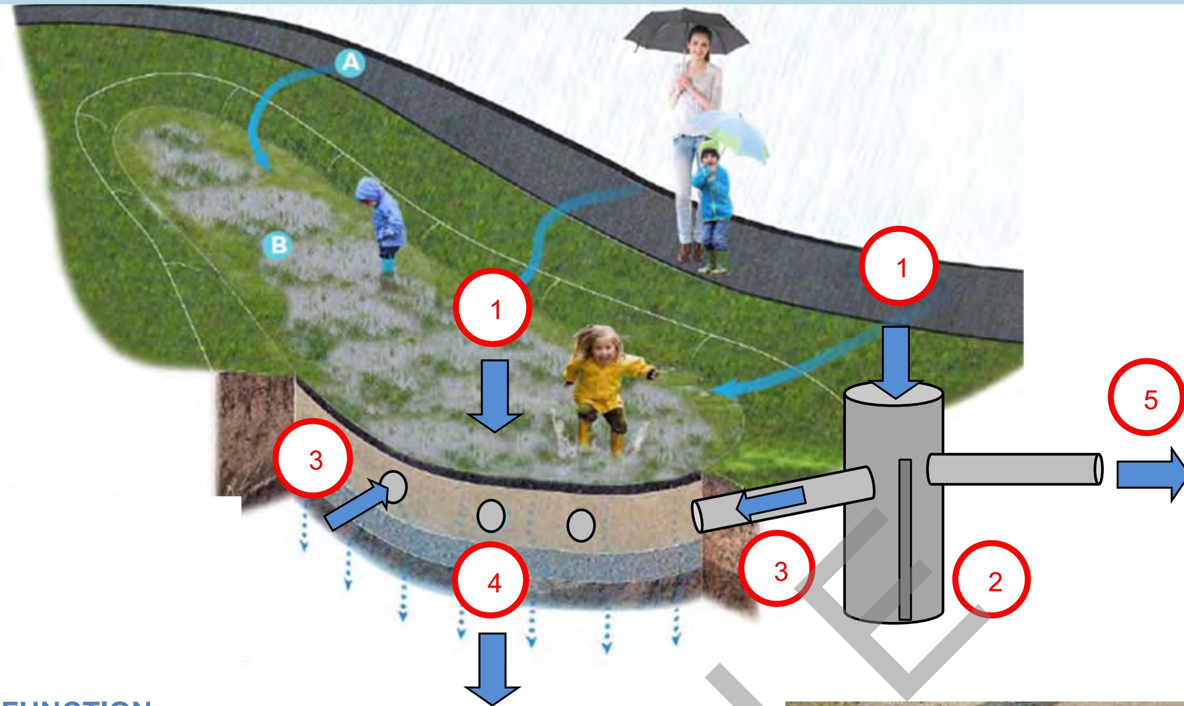
1. COLLECT – Permeable Surface
   Stormwater runoff is collected at the surface.
2. MOVE – Permeable Surface Voids
   Stormwater drains through the void spaces provided in the coarse porous pavement.
3. CAPTURE–Gravel Storage Bed
   Stormwater runoff is captured in the gravel storage bed beneath the pavement. Sediment is not captured prior to infiltrating through the porous pavement and sub surface; therefore, WINTER SANDING IS NOT ALLOWED.
4. TREAT AND INFILTRATE – Gravel and Subsoil
   Runoff is infiltrated into the gravel storage bed and sub soils.
5. OVERFLOW –
   When the capacity of the porous pavement is exceeded runoff enters the underdrain connected to the existing drainage network.

SURROUNDING AREA – Playground and Plaza

Problems such as unstabilized soils, erosion, and sanding during the winter can contribute to long-term maintenance problems. See Section 4.0

See Appendix A for Maintenance Checklist

3.2 Vegetated Sand Filter



FUNCTION:

1. COLLECT – Catch Basin
   Stormwater runoff is collected from the path surface via overland flow through the catch basin/diversion structure.
2. CAPTURE–Catch Basin and Diversion Manhole.
   The catch basin/diversion structure capture sediment and debris in the 4' sump prior to discharge.
3. MOVE- Pipe and Manifold
   Stormwater is diverted to an 8" pipe (manifold) and discharges to the sand filter through 4" perforated laterals.
4. TREAT AND MANAGE – Sand and Subsoil
   Runoff if is filtered through the sand and infiltrated into the sub soils .
5. OVERFLOW – Pipes
   When the capacity of the sand filter is exceeded the diversion, manhole directs runoff to the existing drainage system.

SURROUNDING AREA –Playground and Access Drive
Problems such as unstabilized soils, erosion, and over sanding during the winter can contribute to long-term maintenance problems. See Section 4.0
See Appendix A for Maintenance Checklist

3.3 Landscape Maintenance

By design, plants in the bioretention area trees in the enhanced tree trench are meant to help filter the stormwater as it passes through and flourish throughout the growing season. The plants do not require fertilizers, watering and/or mowing. Remove and replace vegetation as necessary, using the appropriate species as shown on the Planting Plans, see **Appendix B**.

Plants			
Task	**Frequency**	**Requirement**	**Time of Year**
Plant Cutting & Pruning	Annually	• Leave dry standing stalks during the dormant months and remove in the spring. • Cut back grasses, sedges, and rushes in the spring. • Prune trees to remove deadwood and low hanging branches.	• Early Spring
Plant Thinning	Once every 3 years	• Separation of herbaceous vegetation rootstock should occur when over-crowding is observed	• Early Spring or Late Fall
Plant Replacement	As required	• Replace/replant diseases, unhealthy or dead plans to maintain a healthy plant community	• Early Spring or Fall
Watering	First three months after planting or drought	• During establishment or drought conditions, plants should be watered a minimum of once every seven to ten days.	• June-Sept.
Mowing	NOT REQUIRED	• NONE	• NA
Fertilizing	NOT REQUIRED	• NONE	• NA
Mulch	NOT REQUIRED	• NONE	• NA

To reduce the level of effort, regular weeding should occur quarterly from April thru October.

Weeds			
Task	**Frequency**	**Requirement**	**Time of Year**
Weeding	Quarterly	• Weeding should be limited to invasive and exotic species, which can overwhelm the desired plant community. • Non-chemical methods including hand pulling and hoeing are recommended • Chemical herbicides should be avoided.	• Early Spring • Late Spring • Late Summer • Late Fall

3.5 Weed Guide

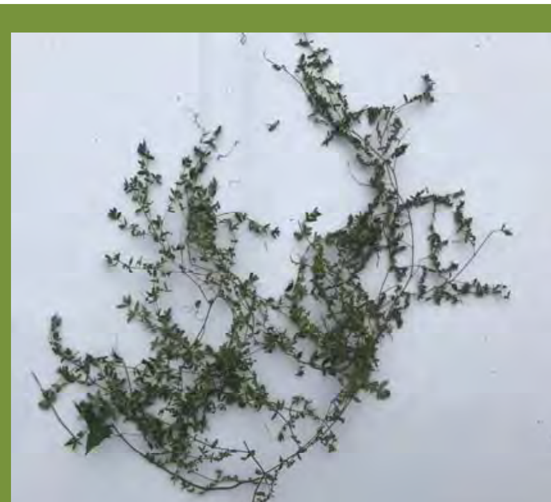
Yellow Toadflax *(Linaris vulgaris)*

Redroot Pigweed- *(Amaranthus retroflexus)*

Smartweed *(Polygonum lapathifolium)*

Dandelion *(Taraxacum officinale)*

Fireweed *(Erechtites hieracifolia)*



Spotted Spurge (Euphorbia maculata)


Catalpa Tree Seedling (Catalpa speciosa)


Crabgrass *(Digitaria ischaemum)*


Green Foxtail (Setaria viridis)


Norway Maple Tree Seedling (Acer platanoides)


Ragweed (*Ambrosia artemisiifolia*)


Japanese Knotweed (Polygonum cuspidatum)

4.0 ROUTINE MAINTENANCE

Other routine maintenance should include the following:

- Removal of trash and litter from paved and perimeter areas.
- Check for erosions problems and sediment source(s) if excessive, frequent sediment accumulation occurs
- Sweeping:
  - Minimum of once per year after the spring thaw.
- Contributing drainage pipes:
  - Inspected annually for proper operation.

5.0 SNOW REMOVAL

Snow removal from the practice is not necessary. Plowed or shoveled snow piles should not block the catch basin structure.

- De-Icing
  - Excessive salting of roads should be avoided. Use of large amounts of sand should also be avoided to avoid obstructing/clogging the conveyance system.

6.0 LONG-TERM POLLUTION PREVENTION PLAN

Long-term pollution prevention measures implemented at each project site will further reduce pollutants in stormwater discharges after construction.

4.1 Lawn/Landscaping Maintenance

Lawn and landscaping maintenance will be conducted with minimal use of fertilizers and pesticides to protect the nearby wetland and water resources. The practices discharge to a phosphorus impaired water body and phosphate-based fertilizers are not to be used.

4.5 Illicit Discharges

No illicit discharge connections will be made to the drainage network.

4.6 Personnel Training

All staff/ personnel responsible for maintaining the practices will be given a copy of this Plan and will receive training in the applicable practices and implementation described in the Plan.

7.0 ESTIMATED OPERATION AND MAINTENANCE BUDGET

<Provide an estimated average annual operating and maintenance budget for the proposed system >

Catch Basin/Diversion Structure	**$ 250**
Permeable Surface:	**$ 500**
Vegetated Sand Filter (subsurface):	**$ 250**
Other Routine Maintenance:	**$ 1,000**

- Removal of trash and litter
- Annual sweeping
- Seeding

It should be noted that the maintenance costs provided are estimates only and some of the maintenance will be completed during the routine park maintenance program and may be incorporated into the existing park maintenance budget.

APPENDIX A

Maintenance Checklist

Vegetated Sand Filter - Maintenance Checklist
Green Stormwater Infrastructure
Playground

Date:

Time:

Inspector:

Maintenance Item	Description	Maintenance Req'd (Y/N)
1. Collect **Includes:** Catch basin/Diversion Structure **Frequency:** Inspect three times per years during regular park maintenance and after major storm events (2" of rain or greater) **When:** Spring, Summer, Late Fall		
Inlet Grate	Remove all trash, leaf litter and inlet clogging. Remove sediment regularly or when accumulation impedes proper inflow and/or outflow.	
Actions to be taken:		
2. Capture **Includes:** Deep Sump **Frequency:** Inspect bi-annually and after major storm events the first year; then annually and after major storm events (2" of rain or greater) **When:** Spring and Fall		
Deep Sump	Remove trash, sediment and debris from the structures and debris from the surface.	
Pipes	Check for clogged pipes and clean as necessary	
Weir	Check that weir is not clogged and clean as necessary	
Actions to be taken:		
3. Move **Includes:** Manifold and laterals **Frequency:** Inspect annually or if drainage problems are observed **When:** Spring		
Pipes and Manifold	Check for clogging and clean if necessary	
Laterals	Open cleanouts and check for standing water. If standing water observed or surface ponding	
Action to be Taken:		

Maintenance Item	Description	Maintenance Req'd (Y/N)
4. Sand Filter **Includes:** Mowed lawn area **Frequency:** Inspect three times per years during regular park maintenance and after major storm events (2" of rain or greater) **When:** Spring, Summer, Late Fall		
Debris Cleanout	Remove any trash and debris from the surface.	
Side Slopes	Signs of erosion gullies, animal burrowing, overtopping or slumping are observed. Repair as necessary.	
Sediment/Organic Debris Removal	Remove sediment accumulation and properly dispose when accumulation is greater than or equal to 3 inches or you cannot see stones.*	
Vegetation Maintenance Replacement	Area mowed regularly with routine park maintenance. Over seed bare or thin grass growth areas.	
Water Draining properly	If standing water is observed for more than 48 hours after a storm event, check cleanout of underdrain clogging. If necessary, rototill or aerate the bottom 6 inches to breakup any hard-packed sediment, and re-seed	
Actions to be taken:		
5. Overflow Structure **Includes:** Outlet structures **Frequency:** Inspect annually and after major storm events (2" of rain or greater) **When:** Spring		
Overflow Structure	Check for sediment accumulation that impacts inflow. If sediment accumulation. Schedule cleaning. Check for clogging in the catch basin/diversion structure.	
Actions to be taken:		
Other Routine Grounds Maintenance **Includes:** Surrounding landscape beyond the practice. **Frequency:** Inspect three times per year during regular park maintenance and after major storm events **When:** Spring, Summer, Late Fall		
Debris Removal	Remove trash from perimeter areas.	
Pavement Sweeping	Sweep contributing paved surfaces minimum once a year after spring thaw.	
Surrounding Drainage Network	Ensure proper operation.	
Contributing drainage area	Check to ensure the surrounding area is stabilized. Look for erosion and other sediment sources	
Actions to be taken:		

*Sediment shall be disposed of offsite in a pre-approved location.

Permeable Pavers - Maintenance Checklist
Green Stormwater Infrastructure
Playground

Date:

Time:

Inspector:

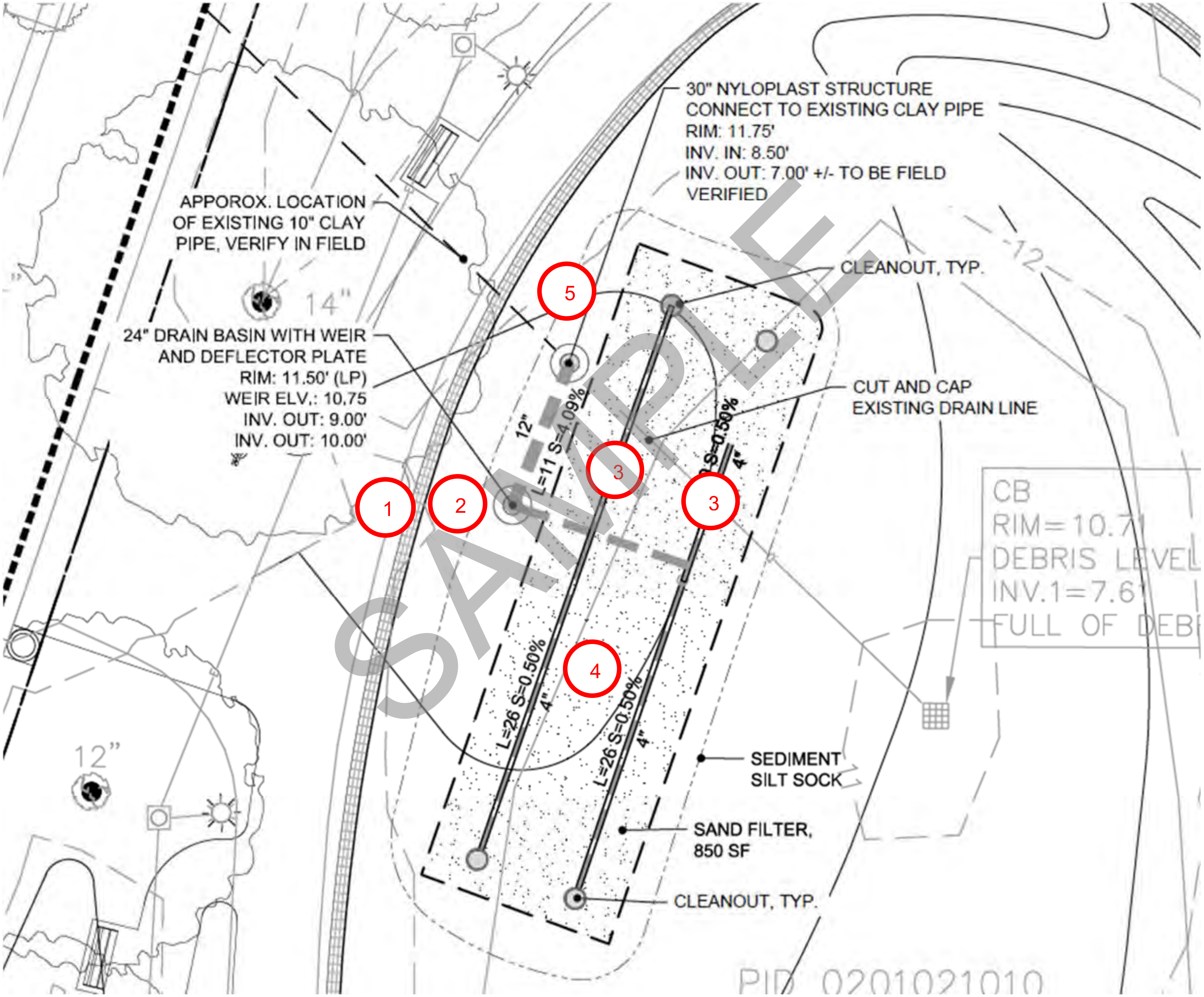
Maintenance Item	Description	Maintenance Req'd (Y/N)
1. Collect **Includes:** Permeable Surface **Frequency:** Inspect bi-annually for sediment, sand and debris accumulation **When:** Early Spring, Late Fall		
Debris removal	Remove all trash and leaf litter.	
Actions to be taken:		
2. Move **Includes:** Permeable surface void spaces **Frequency:** Inspect bi-annually for sediment, sand and debris accumulation **When:** Early Spring, Late Fall		
Permeable Pavers/Pavement	Maintain porosity of void spaces between pavers Annually vacuum pavement. DO NOT SWEEP POROUS SURFACE.	
Water Draining properly	If ponding water is observed at the surface for more than 48 hours after a storm event, check cleanouts for underdrain clogging and standing water in underdrain. If underdrains are dry, the clogging is at the surface and try pressure washing to clean clogged voids. If underdrains are filled with water-see Overflow below.	
Actions to be taken:		
3. Capture **Includes:** Gravel Storage Bed **Frequency:** Inspect annually or if drainage problems are observed **When:** Spring		
Laterals	Open cleanouts and check for standing water. If standing water observed see overflow requirements below.	
Action to be Taken:		

Maintenance Item	Description	Maintenance Req'd (Y/N)
4. Treat and Manage (Filters and Infiltrates) **Includes:** Subsoil **Frequency:** NA **When:** NA		
None required	None required	
5. Overflow **Includes:** Underdrain **Frequency:** Inspect annually and after major storm events (2" of rain or greater) **When:** Spring		
Water Draining properly	If standing water is observed at the surface for more than 48 hours after a storm event, check cleanouts for underdrain clogging and standing water in underdrain. If water is observed in the underdrains, flush underdrains and cleanout structure.	
Actions to be taken:		
Other Routine Maintenance **Includes:** Surrounding landscape beyond the practice. **Frequency:** Inspect three times per year during regular park maintenance and after major storm events **When:** Spring, Summer, Late Fall		
Debris Removal	Remove trash from perimeter areas.	
Pavement Sweeping	Sweep contributing paved surfaces minimum once a year after spring thaw.	
Surrounding Drainage Network	Ensure proper operation.	
Contributing drainage area	Check to ensure the surrounding area is stabilized. Look for erosion and other sediment sources	
Actions to be taken:		

*Sediment shall be disposed of offsite in a pre-approved location.

APPENDIX B

Maintenance Plans


30" NYLOPLAST STRUCTURE
CONNECT TO EXISTING CLAY PIPE
RIM: 11.75'
INV. IN: 8.50'
INV. OUT: 7.00' +/- TO BE FIELD
VERIFIED
APPOROX. LOCATION
OF EXISTING 10" CLAY
PIPE, VERIFY IN FIELD
14"
24" DRAIN BASIN WITH WEIR
AND DEFLECTOR PLATE
RIM: 11.50' (LP)
WEIR ELV,: 10.75
INV. OUT: 9.00'
INV. OUT: 10.00'
CLEANOUT, TYP.
CUT AND CAP
EXISTING DRAIN LINE
12" L=11 S=4.09%
S=0.50% 4"
CB
RIM=10.71
DEBRIS LEVEL
INV.1=7.61
FULL OF DEB
L=26 S=0.50% 4"
L=26 S=0.50% 4"
SEDIMENT
SILT SOCK
SAND FILTER,
850 SF
CLEANOUT, TYP.
12"
PID 0201021010
1
2
3
3
4
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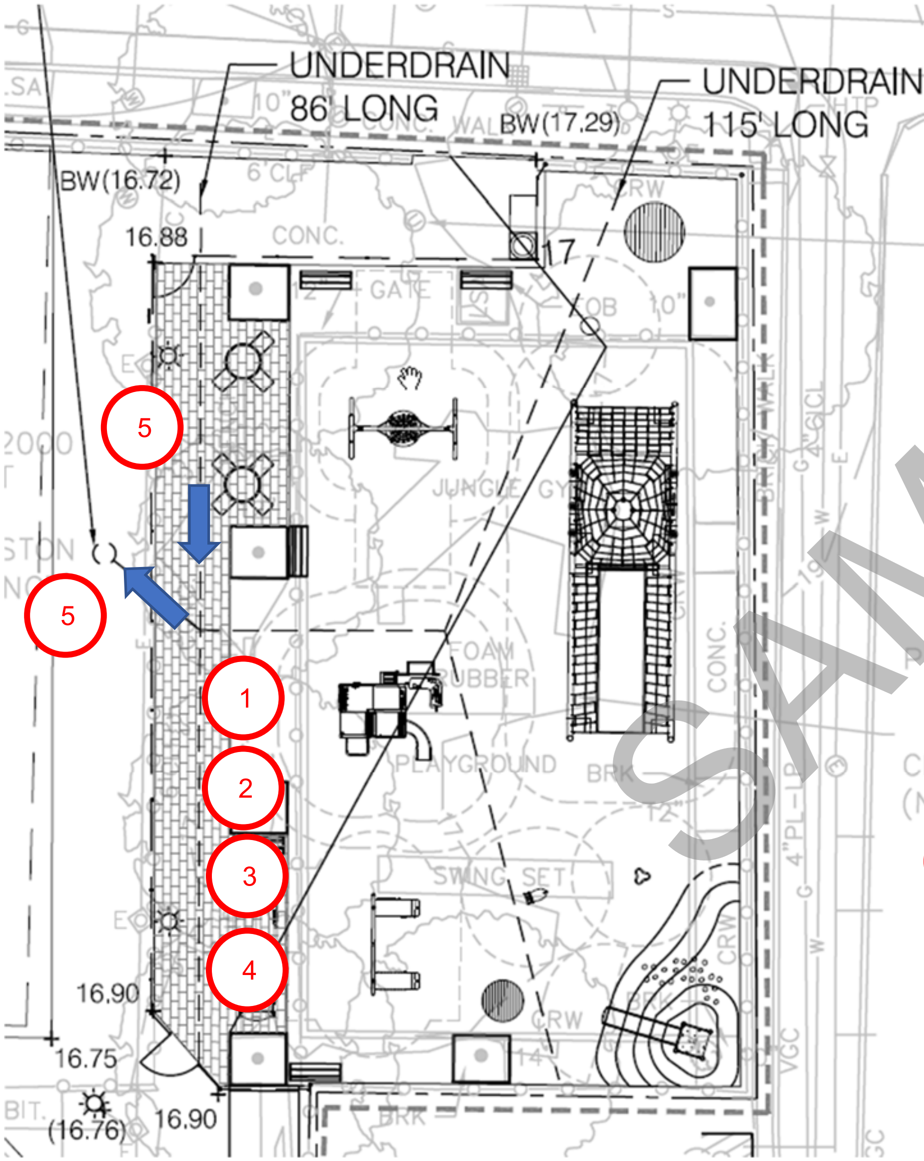
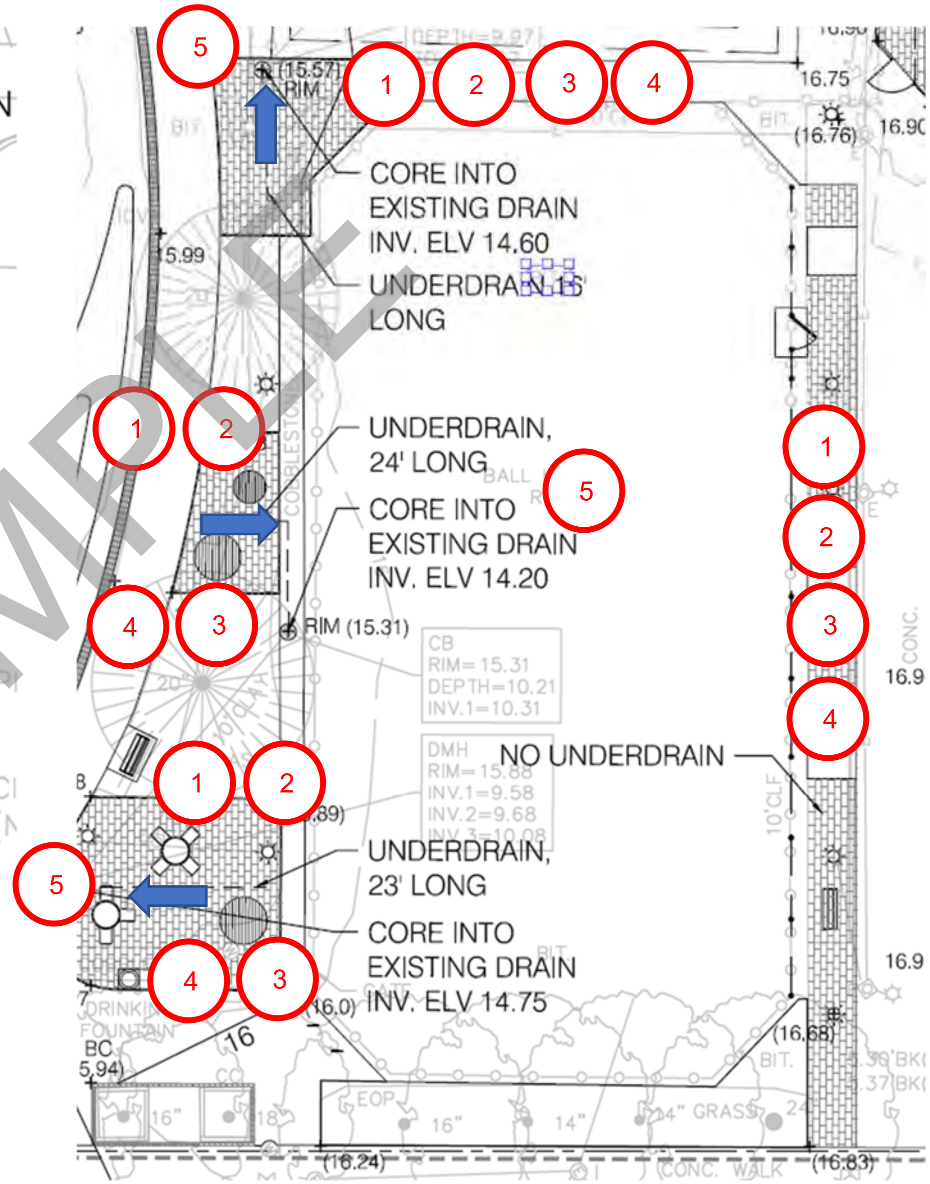
SAMPLE

PERMEABLE PAVERS





Appendix C:
Precedent Study

Boston Parks and Recreation Department
Green Infrastructure Guiding Principles

Precedent Study - Relevant Literature and Case Studies

Green Infrastructure at Shoelace Park, Bronx River Greenway, NYC

Prepared for: Boston Parks & Recreation

Prepared by: Horsley Witten Group

Table of Contents

1. Introduction

Implementing green infrastructure (GI) in parks to maximize environmental, economic, social and aesthetic benefits is not a new concept. While many municipalities like Philadelphia and New York City (NYC) maintain citywide GI partnerships, not all GI programs are organized formally, with GI implemented on more of an ad-hoc or opportunistic basis. The U.S. Environmental Protection Agency (EPA) outlines important components of successful GI programs in parks including: fostering interagency and community relationships and partnerships, leveraging funding opportunities, thoughtful site selection for GI practices, agreement on a GI maintenance plan, and the importance of high visibility pilot projects (EPA, 2017). While these are not all necessary components of a GI program for parks, they are important to consider in the evaluation of GI planning in parks. This memorandum examines GI implementation in five U.S. cities – NYC, Philadelphia, Seattle, Portland, and Chicago – with particular analysis on lessons learned from GI implementation in city parks. In the text that follows:

- GI is defined for the purposes of this memorandum;
- GI responsibilities for the City of Boston Parks and Recreation Department (BPRD) are documented as cited by other City department reports;
- Case study information is presented in a narrative form as well as a reference matrix; and
- Best practices and lessons learned from case study research are discussed.

GI Defined for this project

Why GI in Parks

As many cities grapple with aging municipal infrastructure, fiscal resource constraints, and a changing climate, cities like Boston are increasingly looking to develop strategies to maximize co-benefits on municipal investments. Studies have shown that incorporating stormwater GI in parks provides multiple benefits from investments including improved water quality, reduced flooding, economic development, increased public education, additional green space, improved recreation value through improved drainage and thus increased use, and enhanced social and environmental equity (EPA, 2017). For the purposes of this project, GI will be discussed broadly and as it relates generally to two categories of benefits – improved stormwater management and additional co-benefits, which include urban heat capture from increased tree canopy and social and environmental equity. Moreover, adding GI to parks provides opportunities for improvements in existing parks and the addition of green space within the urban environment in places where green space may be less abundant.

Stormwater and Resilience Co-benefits

Runoff from rain and melting snow carries sediment and pollutants from impervious surfaces into waterways, which can cause water quality impairments, particularly in areas with combined sewer overflows (CSOs). Because of the significant amount of paved surfaces across the City of Boston, as well as the historic development and associated age of infrastructure, those pollutants move into Boston's surface waters with even greater ease. The incorporation of GI practices within the City can provide greater opportunities to improve stormwater management by capturing and treating runoff, reducing impervious cover, reducing stormwater volumes through infiltration and reuse, improving overall drainage, and ultimately improving downstream water quality. These practices not only help with stormwater management, but also can improve park aesthetics and the users' overall experience, provide habitat, conserve potable water, improve air quality, provide public education, and strengthen interdepartmental relationships by working with other departments to achieve City-wide goals and initiatives (e.g., Imagine Boston 2030 and Climate Ready Boston) through the implementation of GI.

It is important to recognize that while improving Boston's water quality and flood management are important actions for the City of Boston as a whole, BPRD's goals are not solely related to water management in parks – they are much more robust. While there are connections between BPRD's goals and benefits from GI, the specific mission of BPRD is to improve access, equity, and excellence in public open spaces citywide. That said, many of the non-stormwater management related co-benefits of GI listed above are closely tied to BPRD's mission. For example, increased urban tree canopy in Boston can provide improved aesthetics of public open spaces while also capturing/absorbing urban heat and reducing runoff. The expansion of GI in Boston's parks also increases access and equity to public greenspace, potentially in areas that were previously lacking, improves public rights-of-way (ROW), and can also provide a reduction in energy costs through shading (i.e., from trees). These co-benefits and others help achieve BPRD's mission and also provide increased resilience to climate change impacts and potential long-term cost savings for the City of Boston as a whole.

A more complete description of the functions and benefits of specific GI practices will be presented as part of the Design Guide for BPRD.

2. Interconnections – GI in Boston Parks

During the course of this analysis, HW reviewed relevant City of Boston reports to better understand how municipal and agency partners reference BPRD's GI responsibilities and suggest priorities as they relate to GI in parks and other city-maintained areas (e.g., ROWs). Currently GI in BPRD parks is implemented on an ad-hoc basis. GI practices *in parks* only accept runoff from the park, rather than accepting stormwater from offsite areas. In addition, any non-mowing maintenance (e.g., landscaping other than grass cutting and basic pruning) is contracted out by BPRD.

HW developed a matrix (Attachment A) that lists the reports reviewed to date, references to BPRD and their GI responsibilities and opportunities, and page numbers for each citation. In general, the documents reviewed indicate that GI is important to the City of Boston and should be a priority across the various departments and agencies; in particular, as GI relates to increasing the City's resilience to climate change and extreme weather. Throughout the reports, BPRD is identified as a key partner in efforts to increase the City's resilience. Table 1 summarizes the reports reviewed and topics covered, specifically related to GI planning, implementation, and maintenance. For more detailed information, see Attachment A.

Table 1. Reviewed reports that reference GI in Boston

Report	GI Topic
Greenovate Boston – 2014 Climate Action Plan Update	Discussion of GI as it relates to climate preparedness, flood protection, improved water quality.
City of Boston Climate Resilience Initiatives	GI's role in managing stormwater, mitigating urban heat. BPRD's role in using GI to improve aesthetics and stormwater management in the public right of way and on public lands.
City of Boston Climate Vulnerability Assessment	Discussion of Boston's most significant vulnerabilities/hazards: extreme heat, stormwater flooding, and coastal/riverine flooding.

Enhancing Resilience in Boston A Guide for Large Buildings and Institutions - Feb 2015	GI and other resilience fact sheets; case studies included.
Boston Green Links Map	GIS data relevant for current, planned, and future greenspace projects.
Boston Complete Streets Report	Significant discussion of BPRD role in GI responsibilities, planning, maintenance.
Boston Open Space and Recreation Plan	Boston parks goals and objectives related to GI in parks, improvements, and interconnections with other City-department led projects.
CRWA Green Street Guidelines for Allston Brighton	Park accessibility and equity; references to BPRD street tree requirements.

3. Case Studies

Listed below are brief descriptions of GI implementation in five U.S. cities – New York City, Philadelphia, Seattle, Portland, and Chicago – with a particular discussion of the following for each city:

- Lessons learned on partnerships,
- Management of GI in the public ROW,
- Funding structures,
- Maintenance, and
- Public outreach.

To better compare each of the cities and understand the role of each parks department in implementing GI, the table below summarizes a few defining features related to parks and GI planning and management.

Table 2. Case Study Summary Information

City	# of Parks and Recreation Facilities[1]	Acres of Parks	CSO Reduction Consent Decree: Y or N	Parks Dept manages offsite stormwater runoff: Y or N	Parks Dept. manages street trees: Y or N
Boston	399	2,346	Y	N	Y
NYC	1,700	29,000	Y	Y	Y
Philadelphia	1,999	10,200	Y	Y	Y
Seattle	532	6,414	Y	Y	N
Portland	1091	11,712	N (ended in 2011)	Y	N
Chicago	840	8,100	Y	N	N

In addition to the above summary information, a more complete matrix, staff contacts, and links to relevant reports and websites can be found in Attachment B.

New York City

Background

[1] Reported numbers vary from city to city with most reporting parks and programming sites (e.g., ice hockey rinks, tennis courts). Click on the numbers to visit each site for more details.

NYC's Green Infrastructure Program is a multiagency effort led by the Department of Environmental Protection (DEP). NYC is currently under a consent decree with the New York State Department of Environmental Conservation to reduce Combined Sewer Overflow (CSO) discharges into New York City's waterbodies. The City's GI program supports the implementation of green stormwater management practices in order to reduce the amount of stormwater runoff entering the sewer system.

DEP and agency partners[2] design, construct, and maintain a variety of GI practices such as green and blue roofs, rain gardens/bioretention facilities, tree pits, and ROW bioswales ("green streets") on City-owned property such as parks, streets, sidewalks, schools, and public housing. At the outset of the partnership, DEP and NYC's Department of Parks and Recreation (DPR) signed a memorandum of understanding (MOU) laying out responsibilities for day-to-day operations of GI permitting, planning, design, construction, maintenance, and monitoring. That MOU is updated annually. While the MOU details the official channels of communication and agency responsibilities, oversight is required by DEP staff and their consultants to ensure that DPR and other agency partners are involved in the agreed-upon components of the GI implementation process.

To further meet the goal of reducing CSOs, DEP purposefully designs and constructs Green Streets projects in DEP-designated priority sewersheds where the CSO impact is most significant. In 2015, DEP committed $36 million to the Community Parks Initiative (CPI), a targeted capital investment program to reconstruct parks in underserved communities. The $36 million is devoted to Phase I of GI construction, which covers construction costs at 28 CPI sites within combined sewer areas (NYC DEP, 2015). In 2016, DEP and DPR investigated and designed GI retrofits on more than 90 park sites. DEP works with the DPR Capital Unit and the DPR Green Infrastructure/Forestry Unit to identify, design, and implement these projects, some of which are incorporated into ongoing capital projects (NYC, 2017). In 2017, DPR expects to complete construction on 22 of the 28 sites and will begin construction at the additional six sites in CPI Phase 1 (NYC, 2017). DEP funds full-time staff at partnering agencies including DPR (5 staff) and DOT (3 staff), who provide design review primarily for the ROW projects (NYC DEP, 2017).

Public Rights-of-Way Management

NYC's Green Streets Program initially began solely as a community beautification project to improve aesthetics in the public ROW. As water quality and CSO impacts rose to the forefront, NYC looked to Seattle and Portland for examples of public ROW improvements that also provided multiple benefits including increased capture and treatment of stormwater runoff.

In NYC, typical street trees in the public ROW are maintained by DPR. However, this does not include the trees in the more advanced green street stormwater management practices; those are permitted by DPR but installed and maintained by DEP. This process complicates ROW landscape management for DPR because DPR receives complaints about green street issues, such as the presence of debris and sediment, but ultimately DEP is responsible for performing the maintenance of these more advanced stormwater management practices in the ROW garden.

Maintenance and Monitoring in Parks

DPR maintains all GI in parks with their staff horticulture crews in each of the 5 NYC Boroughs. DPR employs 150 gardeners across NYC's five Boroughs. The horticulture crews maintain all types of

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[2] Agency partners include: NYC Department of Parks and Recreation (DPR), NYC Department of Transportation (DOT), NYC Economic Development Corporation (EDC), NYC Department of Design and Construction (DDC), NYC Housing Authority (NYCHA), and the NYC Department of Education (DOE).

gardens, including green infrastructure practices in parks. In addition, DPR employs seasonal staff who join the crews during the busiest seasons of the year, usually from March to October. In addition, each Borough has a horticulture manager who oversees all horticulture operations in the Borough including maintenance.

DPR crews perform standard maintenance including the removal of sediment and trash, pruning/trimming of plants, etc. These crews are responsible and have the capacity (i.e., budget, equipment, training, etc.) to maintain GI on park property, but they do not maintain GI on DEP property/DEP maintained practices (e.g., GI in the ROW).

Image 1. Multiagency GI project: Gowanus Canal Stormwater Management, Brooklyn Photo Credit: Inhabit.com

In terms of construction of GI in NYC parks, DPR considers the important design parameters which include the type of soil, practice sizing, plant selection, and space required. Their approach is to look at these parameters to identify GI opportunities throughout the park system, while at the same time, acknowledging that each practice must be customized to address site-specific issues in each park. In addition, DPR monitors the efficiency and effectiveness of many GI practices in NYC parks. Their approach is to monitor as much and as often as possible, and DPR often relies on grant funding to implement monitoring for GI practices. Grant funding agencies for GI monitoring include: EPA, New York State, and the National Science Foundation (NSF).[3]

NYC DPR has partnered with a few regional universities to monitor GI sites. As partners, they pursue grant funding together and try to link the funding to the installation of new GI sites, so monitoring devices can be installed during construction. Through these monitoring efforts, DPR assesses the sites' performance in capturing the design volume of runoff. In almost all cases, the monitoring has shown the actual volumes captured by the GI practices are greater than the design volumes.

DPR is also accessing specific design techniques and how they are performing. Information collected is used to adapt current practices, modify future practices, or eliminate certain techniques if they are underperforming or not functioning properly. In addition, DPR is looking at plant selection and what species or varieties work best, evapotranspiration (ET) rates and the corresponding optimal design. DPR also has control sites in natural areas which provide a reference point for the highest level of stormwater capture and to set design goals.

DPR recently began a study looking at the difference in stormwater capture rates between street trees with no tree guards and those with tree guards with an inlet from the roadway. DPR staff indicated that their research has shown that tree guards allow a tree pit to retain a lot more water by keeping the soil from being compacted.

[3]Personal correspondence with Bram Gunther, NYC DPR, June 23, 2017.

Looking to the Future
Currently, DPR uses GI to manage only stormwater from park surfaces (i.e., onsite runoff). However, on certain DEP-managed properties and special projects, runoff can be managed from offsite surfaces surrounding a park. For example, DEP partnered with the Trust for Public Land, the School Construction Authority and the Department of Education on a playground at P.S. 261, using GI to manage nearly half a million gallons of stormwater annually in the Gowanus Watershed. City-wide discussions are ongoing to increasingly use parks to manage stormwater from other areas, including private property.

While DPR has not used high visibility GI project sites to leverage stewardship and funding, they have relied on neighborhood and park-specific conservancies to promote and maintain GI at the local level. As one example, the Gowanus Conservancy applies for funding using its non-profit status and also recruits volunteers for maintenance of bioswales and the urban forest in Gowanus Park.[4] DPR and DEP often work with friends groups or conservancies, environmental education programs, and implement "green jobs" training programs in coordination with GI plantings and maintenance. This has proven to be an effective strategy for New York City. As described below, Philadelphia uses a similar approach.

Philadelphia

Background
The City of Philadelphia is under a consent decree with the State of Pennsylvania to reduce CSOs. Similar to NYC, Philadelphia uses GI to reduce stormwater runoff volumes entering the sewer system as part of a CSO-reduction strategy. Their GI program - Green City, Clean Waters - was created as a public-private partnership devoted to CSO reduction and stormwater management improvements. Philadelphia Water Department is the lead public agency for Green City, Clean Waters. Private partners include private developers, businesses and industrial property owners. Philadelphia Water Department's Parcel Based Billing Initiative ties a property's impervious cover to its stormwater fee. Green City, Clean Waters saw this as an incentive for private property owners to reduce impervious cover and implement GI to receive a credit in the stormwater portion of their bill if properties are retrofitted with green stormwater management infrastructure (Philadelphia Water Dept., 2011).

A subset of this program, "Green Parks," is led by Philadelphia Parks and Recreation (PPR). Green City, Clean Waters estimates that existing Philadelphia-owned public parks can manage 21% of the City's stormwater runoff. As of March 2017, the "Green Parks" program included green stormwater management infrastructure on 184 streets, 51 open spaces, 8 schools, 3 vacant lands, and 1 parking lot (NPRA, 2017). For a complete listing of city-wide GI, see the Green City, Clean Waters Map.

Image 2. Tiered Bioretention at Cliveden Park, Philadelphia

[4]https://www.nytimes.com/2015/12/16/nyregion/sponge-park-in-brooklyn-to-treatpolluted-waters-of-gowanus-canal.html

Public Rights-of-Way Management
PPR manages typical street trees (as well as park trees) in Philadelphia, including planting, pruning, and removal. Most of this work is done by contracted arborists overseen by PPR. However, city-wide Green Streets (GI within the public ROW) are managed and maintained by the interagency Green City, Clean Waters, led by Philadelphia Water Department.

Maintenance and Monitoring in Parks

> ***"Vital to fully understand and consider where and how people picnic, play sports, and generally use a space before siting and constructing GI" (TPL, 2016).***

Recognizing that city departments and agencies have different goals, Philadelphia implements a Stormwater Plan Review Team that brings together water department and parks department staff to evaluate GI projects for potential conflicts with park uses (TPL, 2016).

Even with the best procedure in place, reconciling competing agency interests is difficult. In the example of a tiered bioretention area in Philadelphia's Cliveden Park, partners tried to work together to specify roles for each agency. The top two basins were built by the water department, the wetland at the bottom was designed by the Pennsylvania Horticultural Society, and the lower portion was mowed and cleaned by PPR. However, there was a misunderstanding about how much assistance PPR required for ongoing maintenance. Initially maintenance was conducted by the local "friends of the park" group, which is comprised of mostly elderly neighbors. The steep slope and various plant types made the job more challenging than originally anticipated (TPL, 2016).

Looking to the Future
Green City, Clean Water estimates that city-wide GI updates required to meet their CSO goals will cost $1.67 billion. As of March 2017, approximately $800 million has been spent on GI (NPRA, 2017). While implementation of GI in Philadelphia parks appears to be moving forward with public support[5], managers occasionally struggle in balancing water quality goals with the local uses of the park. Citing issues with GI implementation in Columbus Square Park, the GI Program Manager at Philadelphia Water Department indicated that it is vital to fully understand and consider where and how people picnic, play sports, and generally use a space before siting and constructing GI (TPL, 2016). This comment was reiterated by natural resource managers in Portland and Chicago.

Seattle

Background
Seattle's Stormwater Code requirements, NPDES Permit, CSO-Consent Decree, and the Western Washington Stormwater Manual drove the initial push of GI implementation in Seattle. Over time, the City has gone beyond these early requirements and included implementing voluntary water quality

Image 3. Ballard Street Green Street Planters, Seattle, WA

[5] https://philly.curbed.com/2016/4/1/11346548/important-green-stormwater-infrastructure-projects

improvements, volume reductions, and flow control in re-designed urban creeks as opportunities arise. In 2013, Seattle's City Council Resolution 31459 established GI as a critical aspect of a sustainable drainage system and challenged Seattle to rely on GI to manage stormwater runoff whenever possible. In addition to the City's NPDES reporting requirements, an annual update is submitted to the City's Office of Sustainability and Environment on any new GI practices installed as well as the infiltration rates, as Seattle is attempting to reduce stormwater runoff by 700 million gallons by 2025.[6] Locations of GI practices are mapped and publically available on the 700 million gallons website. Seattle Public Utilities (SPU), King County Wastewater Treatment Division (WTD), Seattle Department of Transportation (DOT), and Seattle Parks and Recreation (SPR) all partner to manage and maintain GI across the city. In Seattle, any development that triggers the stormwater code must meet stormwater management requirements and include a GI approach as part of the project design. All City of Seattle capital improvement projects must also integrate GI into projects per stormwater code requirements. There is not a separate, dedicated funding source for GI projects in Seattle. Rather, capital improvement projects and operation and maintenance (O&M) is funded through operational budgets.

Public Rights-of-Way Management

The City of Seattle manages their ROWs with a well defined shared multi-agency approach: SPU and King County WTD maintain GI in the ROW. Seattle DOT maintains street trees, and SPR maintains GI in parks.

Maintenance and Monitoring in Parks

SPR employees, as part of their landscape, stormwater, and wastewater maintenance roles, maintain GI in parks. Operations include GI plant establishment and maintenance, including replacement, weeding, sediment removal, and mulching. SPR employees are also responsible for permeable pavement cleaning, sweeping, pressure washing, and testing for functionality.

SPU and SPR collaborate often and look for partnership opportunities that satisfy overlapping agency goals. State grant funding opportunities are available and used to supplement operational budgets. While partnering on GI projects in parks leverages combined resources and partners' expertise, responsibilities should be discussed upfront. Seattle agency staff indicated that responsibilities during a GI construction phase are typically straightforward, but plans for maintenance are often not as clearly defined and should be addressed early on to ensure adequate funding as well as a strong understanding of the requirements.[7]

Partnering on GI projects in parks leverages combined resources and partners' expertise, but responsibilities should be discussed upfront.

SPR staff noted that there is a learning curve associated with the implementation of GI plantings and stormwater management practices. For example, establishing plantings in bioretention areas need more attention than typical park landscape plantings. In some cases, bioretention plantings may establish quickly, causing potential sightline issues and requiring maintenance that may not be needed for grass and low shrub plantings. In general, SPR has found that these plantings need maintenance more similar to a landscape shrub bed than grasses and flowers. SPR conducts annual inspections to examine general operation of GI practices, landscape health and litter removal, and to ensure that drains are not clogged. However, permeable pavement and the required maintenance have not yet been fully embraced.

[6] Map of Seattle GI Practices.

[7], [8]Email correspondence with Cheryl Eastberg, SPR, June 21, 2017.

In general, SPR does not monitor for stormwater treatment, capture, or infiltration metrics in park GI practices. However, SPR staff indicated that GI has clearly added more "green" to places like streets where previous areas were impervious and/or unsightly. As part of the agency's current policy, SPR does not manage offsite stormwater with new GI practices on park land due to the increased pollutant load, especially from roadways. However, SPR staff indicated that the department authorized the management of offsite runoff via a few existing Seattle park GI practices, and that the potential exists to do more of this at some point in the future. [8]

Looking to the Future
Seattle's Green Stormwater Infrastructure Implementation Strategy 2015-2020 indicates that in order to keep additional stormwater runoff (gallons) out of the sewer system, GI may be required to be integrated into future and existing park development and land-banked site development beyond what is required by stormwater code. This might include managing adjacent ROW runoff along the Park/ROW boundary or front of a park property.

Portland

Background
Almost entirely implemented, maintained, and managed through the Portland Bureau of Environmental Services (BES), the City of Portland's GI program is the most extensive of the 5 analyzed cities. Portland's stormwater management program began in the early 1990s as part of the City's response to meeting requirements set forth in their National Pollutant Discharge Elimination System (NPDES) MS4 Permit issued by the state to address water pollution from stormwater and combined sewer overflow (CSO) discharges. Work on Portland's major CSO control projects ended in 2011, and the city is no longer under a CSO consent decree. Initial work focused on more traditional or "grey" wastewater and stormwater infrastructure improvements to mitigate CSOs. GI implementation began around 1994 with a push from political leadership at the time. Portland has a ratepayer funded sewer system, and a stormwater utility fee is collected as part of that ratepayer fee. Through that fee mechanism, funding is allocated to both green and grey infrastructure projects. This funding can be used for park projects with partnerships, such as the Holman Park Project, which is described in more detail below.

Image 4. Ankeny Green Street, Portland

Public Rights-of-Way Management
BES maintains all "Green Street" practices (e.g., tree pits/bioretention/bioswales) and associated plantings 4 times per year. Currently four full time BES maintenance staff coordinate with private landscape companies to perform quarterly maintenance. BES is in the process of executing new maintenance contracts, and has awarded 5 the contracts to five companies to provide us ample maintenances services, as needed. BES staff estimates that given the current and constantly growing inventory of GI practices, they will utilize up to three 4-person crews year-round.

Watering is generally done during the first 1-2 years, but not beyond, unless there are site-specific issues. Green streets have been extremely successful in Portland. As part of an effort to improve maintenance in green street practices, Portland's Green Street Steward Program enrolls volunteers to maintain Green Street plantings. BES provides Green Steward's with maintenance guidance on: trimming the vegetation and removing weeds when necessary, removing and disposing of sediment, picking up trash and debris, clearing curb openings, and watering plants during the establishment period (first two years). BES also offers a quick, one-on-one training at the GI site to approved Green Stewards, in addition to providing volunteers with a Green Stewards Maintenance Guide.

The Portland Parks and Recreation Department (PPRD) only maintains GI practices within the parks, and the City's Urban Forestry Department is responsible for tree maintenance in the city ROW and on city-owned property. Four full-time staff at BES are responsible for maintenance, but the Bureau also hires contractors to help install and maintain GI practices. If a tree is installed in one of BES' stormwater facilities, BES maintains that tree along with the rest of the vegetation. If the City installs a stormwater facility on private property, the property owner maintains it. The BES maintenance department is divided into a "horticulture" section which maintains aboveground plantings, pruning, and sediment cleanout, and a "pipe" section which maintains traditional stormwater infrastructure including pipes, detention basins, as well as parts of more advanced GI practices (e.g., underground storage). Green streets are maintained primarily by the horticulture group.

When neighbors and community members understand the benefits of GI, a sense of ownership and willingness to maintain GI features is often more likely.

Maintenance and Monitoring in Parks
PPRD owns more than 11,000 acres of land. Most of their responsibilities fall into the categories of turf maintenance and land stewardship. PPRD constructs and maintains GI within the parks when required by the City's Stormwater Code. PPRD typically only manages onsite park runoff unless the GI practice is part of a larger partnership project to better manage stormwater in the surrounding neighborhood. BES and PPRD have partnered in the past to implement GI and achieve multiple benefits. For example, in Portland's Holman Park, both agencies along with the Portland Department of Transportation (PDOT) worked together on park improvements to reduce area crime, slow traffic, and create a neighborhood community gathering space, as well as improve stormwater management. The end result is a neighborhood bikeway with Green Streets and stormwater retrofits in the adjacent public park. Through the use of an infiltration planter, infiltration basin, landscape filter strip, green street components, green roof, and street trees, runoff is managed from approximately 16,100 ft^2 of concrete and asphalt. Most of the runoff captured infiltrates, thereby providing treatment for water quality before being discharged to the drainage network. The park re-design also reduced the overall impervious cover within the contributing drainage area. The cost of design and construction was $368,813 with $62,953 contributed through EPA grant funding. PPRD currently maintains the GI in Holman Park, and BES maintains the

adjacent Green Streets. Due to the success of this project, BES has a desire to replicate this partnership, but nothing has been formally discussed.[9]

In addition, BES has conducted extensive monitoring of its GI practices throughout the city. Monitoring activities include infiltration testing, flow metering, flow testing, water quality sampling, and sediment/soil sampling. In BES's 2013 Monitoring report, the department discusses monitoring results for individual GI practices and facilities. The report documents differences in design, site conditions, and data quality that must be considered before any difference can be considered significant.

Looking to the Future

Similar to other cities, BES staff indicated that partnerships to implement GI are important, but it is often difficult to manage competing agency interests and potential funding issues for non-traditional park measures such as GI practices. BES staff also noted that outreach is key to public acceptance and understanding of GI. When neighbors and community members understand the benefits of GI, a sense of ownership and willingness to maintain GI features is often more likely.

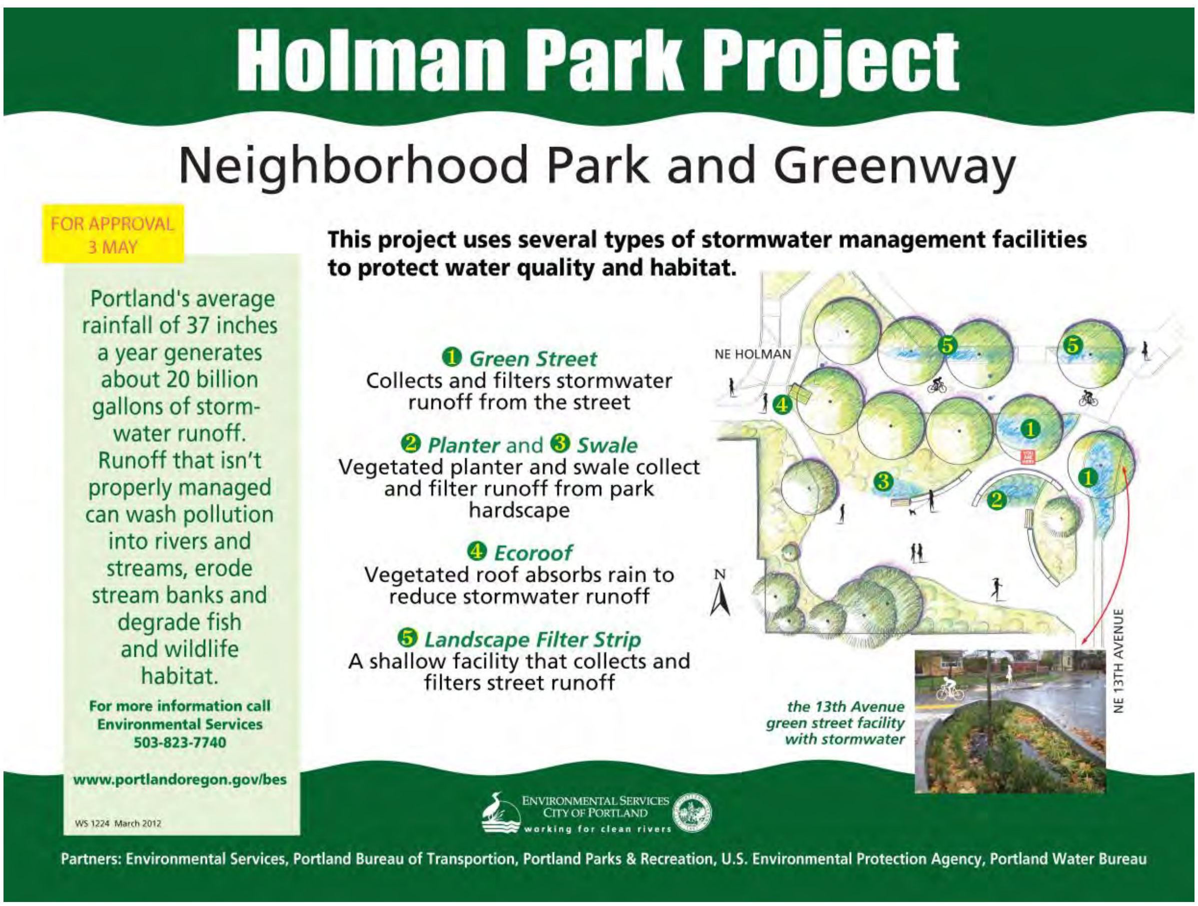

Image 5. Holman Park Example Signage, Received from Portland BES, August 2017.

[9] Personal correspondence with Kate Hibschman Portland BES, June 9, 2017.

Chicago

Background

While Chicago implements its own green infrastructure strategy, the City itself does not have a federal consent decree mandating investments to reduce CSOs. That obligation is held by the Metropolitan Water Reclamation District of Greater Chicago (MWRD). MWRD partners with City departments and the Chicago Park District to implement green infrastructure projects in addition to other CSO-reduction strategies.[10] Representatives from MWRD, the Chicago Park District, and other city and regional agencies are encouraged to partner on green initiatives across departments and agencies. That said, the Chicago Park District differs from BPRD in a few key ways. First, the Chicago Park District technically operates outside of the City of Chicago government with its own Taxing Authority and Board of Commissioners. As such, the Chicago Park District does not compete with other city agencies for funding. The Chicago Park District is responsible for more than 600 parks, 8,800 acres, and 240 recreation centers, but is not responsible for managing or maintaining cemeteries or street trees. The Chicago Park District's operating budget is approximately $470 million annually. 70 percent is derived from property taxes, 30 percent from events and activities at Parks-owned properties (e.g., concerts at Soldier Field, which the Chicago Park District manages). Chicago Park District capital projects are generally funded using a "thirds" structure – one-third from the Park District budget, one-third from local or state representatives/grant funding, and one-third from private funders, citizen group fundraising efforts.

Image 6. Nave Pier Bioinfiltration Sign, Chicago, Illinois

Public Rights-of-Way Management

Chicago Park District is not responsible for street trees (or cemetery maintenance) or other trees in the public ROW, outside of park land. Chicago Park District is only responsible for GI practices on park lands. Chicago's Bureau of Forestry is responsible for maintenance of street trees. Chicago Department of Transportation (DOT) is responsible for GI in the public ROW.[11] MWRD partners with Chicago's Department of Water Management and Chicago DOT and other agencies on pilot projects to manage stormwater through GI in the public ROW.

Maintenance and Monitoring in Parks

In general in Chicago, most GI projects are funded through EPA grants and water and sewer agency funding. GI specifically in parks is implemented on more of an ad-hoc basis, since no formal plan exists for GI in Parks. As such, Chicago Park District does not implement a specific GI maintenance plan for parks. If GI practices exist in parks, maintenance considerations are incorporated into larger park maintenance operations. Chicago Park District staff indicated that planning for maintenance up front is important, as costs are generally more than expected, for example, if plants don't thrive based on environmental conditions or are vandalized. For the first one or two years the Chicago Park District

[10] List of MWRD GI Projects
[11] For more information: Green Alley's Program

contracts out the maintenance of GI in parks. Staff indicated that it is important to purchase a 1-2 year warranty on plants/GI practices to ensure that plantings and equipment function properly. After 1-2 years of contracted maintenance, in-house staff are responsible for maintenance of GI practices. The Chicago Park District employs a full staff of masons, landscape architects, and horticulturists to accommodate diverse maintenance needs. Green roofs are currently maintained by the Chicago Park District landscape architect department. Chicago Park District staff indicated that cisterns and underground storage may have a larger upfront cost, but are less costly to maintain over time for the Chicago Park District. Rain gardens and bioswales require more consistent maintenance and labor on the part of parks' staff.

Partnerships

Partnerships in implementing GI are promoted at the City-level. The mayor's office appoints a sustainability officer within each city department as well as the "sister agencies" like Chicago Park District. That person is responsible for coordinating and leveraging partnership among their agency-derived projects. As one example, Chicago Park District partnered with the Chicago Water Department to install a 100,000-gallon underground stormwater retention facility underneath a Chicago Park District-owned parking lot. Chicago Park District paid for the permeable pavement resurfacing, and Chicago Water Department paid for the retention system. In general GI in Chicago parks is implemented through partnerships with Chicago's City Water Department and/or MWRD. Costs for improved drainage are generally higher than parks maintenance costs, and it is important to bring partners together to leverage funds and meet shared goals.

Reference: Personal correspondence with Brendan Daley, Chicago Park District, June 7, 2017.

The Chicago Park District does not currently conduct any monitoring operations of GI efficiency in parks. However, Chicago Park District has partnered with local universities and MWRD to monitor select GI practices in parks for water quality and drainage improvements. All of the Chicago Park District's "Natural Areas" have a volunteer natural steward that helps to maintain park grounds. The Chicago Park District also relies on schools and other volunteer groups for plantings and maintenance of GI and park landscaping in general.

Looking to the future

Chicago Park District staff reiterated a theme that was common throughout the analysis of GI in each of the 5 cities – Park and Recreation Department staff should think about the neighbors and people who live and work in the direct vicinity of GI practices. It is important to educate the community on the importance and benefits of GI. To that end, the Chicago Park District has used signage about the types of plantings and their purposes in the GI practice (e.g., grasses vs. flowering plants) so that people understand the benefits and reasoning for choosing specific plantings.

With sustainability officers working in each department, Chicago tries to push for more sustainable and "green practices" across all city-run operations. It was suggested that if one such program does not already exist, it would be beneficial for BPRD to consider forming a cross-agency committee that considers the implementation of state-of-the-art sustainable practices for municipal projects.

Case Study Matrix

As part of data collection efforts, relevant literature, reports, and facts sheets were reviewed. HW staff also conducted first person interviews to obtain additional information. More complete information as it relates to funding mechanisms, working with partners, maintenance and monitoring, and high visibility GI projects is listed in Attachment B. Contact information for interviewees at each of the five cities is also included.[12]

4. Summary of Guiding Principles for GI in Parks – Case Study Best Practices

Similarities

A few common themes resonated throughout the conversations with the city parks departments and other city department staff, as well as throughout the reviewed reports.

- **Agency goals and missions vary amongst the different agencies.** The goals of city parks' departments, for example, are not the same as the local water and sewer agencies. While parks provide opportunities for green infrastructure in the way of green space in cities that are already built out, costs for construction and especially maintenance can be significant. It is important to work with partners on GI projects in parks and discuss funding and specific roles for permitting, design, construction, and maintenance upfront.
- **Understanding how community members and neighbors use park space is a critical consideration when siting a GI project.** Parks staff must understand how the space is used in order to effectively design a stormwater GI practice in a park to ensure continued appropriate use of the space.
- **Funding structures for GI are often complicated but grant funding should be leveraged when possible.** Many cities rely on grant funding from agencies like EPA in order to supplement funding for GI projects. As mentioned, NYC in particular has experience success in leveraging grant funding for GI projects when they are tied to monitoring for improvements (e.g., better water quality, improved drainage).
- **Public outreach about the benefits of GI can increase public support and acceptance.** Implementing GI in parks and along the public ROW is a departure from what many people traditionally view as stormwater management. Traditional/grey infrastructure practices have historically been "out of sight" or underground. Using GI to manage stormwater brings that resource management closer to the public view and that departure from the normal warrants explanation. City staff from Portland and Chicago indicated that public acceptance and even a sense of ownership of GI projects is attributable to public education and outreach before construction of the GI practice even begins. Through the public meeting processes and descriptive signage about the benefits of GI to the community, stormwater management and other co-benefits such as increased access to greenspace, potential reduction of urban heat, and increased tree canopy can be communicated to the public. In turn, the public is more likely to support funding for future projects and also be interested in maintaining the GI practice.

Differences

The most obvious differences across all five case studies relate to how GI is managed and maintained in the public ROW. While park departments in Philadelphia and NYC are technically responsible for street trees, another agency is responsible for the more intensive maintenance (e.g., sediment cleanout). Of all

[12] An interview was not conducted with a Philadelphia representative. Reports on Philadelphia's PPP, Green City, Clean Waters were reviewed to compile information on the city's GI program.

five cities surveyed, no city parks departments are responsible for maintaining GI in the public ROW. Table 3 describes the ROW responsibilities across the five cities.

Funding for GI projects in parks also differs across each of the five cities. This is mainly due to the fact that GI in parks is funded through different mechanisms and organizational structures. For example, in NYC and Philadelphia GI funding is often channeled from the partnership to parks projects like Philadelphia's Green Parks program and NYC's Community Parks Initiative. Grant funding can also be leveraged and volunteers from the community can help with maintenance of GI in parks, as demonstrated by the Green Stewards' Program in Portland.

Table 3. ROW GI Responsibilities

New York City	Philadelphia	Seattle	Portland	Chicago
Street trees in the public ROW are maintained by DPR. More advanced stormwater management practices, such as tree pits, are permitted by DPR, but installed and maintained by DEP. DEP is responsible for performing maintenance of more advanced street tree stormwater management practices as well as other GI in the ROW (e.g., bioretention, rain garden).	PPR manages all street trees and is responsible for planting, pruning and removing street trees. Most of this work is done by contracted arborists overseen by PPR. City-wide Green Streets including GI within the public ROW is managed and maintained by interagency Green City, Clean Waters, led by Philadelphia Water Department.	SPU and the King County Wastewater Treatment Division maintain GI in the ROW. Seattle DOT maintains street trees. SPRD maintains GI in parks.	BES maintains all Green Street practices (e.g., bioretention/bioswales in the ROW) and plantings. The Parks Department maintains GI practices within parks, and Portland's Urban Forestry Department is responsible for tree maintenance in the city right of way and city owned property.	Chicago Park District is not responsible for street trees (or cemetery maintenance) or other trees in the public ROW, outside of park land. Chicago Park District is only responsible for GI practices on park lands. Chicago's Bureau of Forestry is responsible for maintenance of street trees. Chicago DOT is responsible for GI in the public ROW. MWRD partners with Chicago's Department of Water Management and Chicago DOT and other agencies on pilot projects to manage stormwater through GI in the public ROW.

Where does Boston go from here

Per the Boston Complete Streets Design Guidelines and based upon our discussion with BPRD staff, BPRD is currently responsible for maintaining green stormwater infrastructure in the public ROW and street trees (Boston, 2013). GI in BPRD parks is implemented on more of an ad-hoc basis and GI practices in parks do not accept stormwater from offsite areas. In regards to maintenance, any non-mowing maintenance (e.g., landscaping other than grass cutting and basic pruning) is contracted out by BPRD. Some challenges to GI implementation that Boston exist and warrant further discussion with other city department partners. These challenges include implementing GI in the context of historical sites and landscapes, as well as the implementation of GI in some of Boston's narrow streets with high density development, especially in the City's urban core.

Following discussions with technical experts and our review of reports and literature, we recommend that BPRD further discuss this responsibility with local agency partners (e.g., Boston Water and Sewer

Commission). In addition, BPRD can reach out to contacts in NYC about the New York GI partnership and MOU between NYC Parks and NYC DEP. MOUs, especially at the outset of interagency partnerships, can help ensure that roles and financial responsibilities are clear.

While benefits of stormwater management through the incorporation of GI in city-owned parks are clear, financial obligations and maintenance responsibilities must be agreed upon before any project begins. This is especially true if GI practices in parks manage both onsite and offsite stormwater. Similar to Boston, Chicago was the only city out of all 5 cities that does not have GI practices within their parks that treat offsite stormwater runoff. Both NYC and Seattle allow offsite stormwater runoff to be treated thru GI practices within the parks, but only under certain conditions. These are typically part of larger improvements projects that are often linked to multi-agency partnerships with joint funding for construction and implementation.

Based upon our research, GI practices in parks are often installed, but the finer details regarding who will maintain them, what type of equipment is needed, how much and how often maintenance should occur is not always clearly defined. None of the five cities surveyed operate using a park-specific guide for GI design, construction and maintenance. The Design Guide that will be developed as part of this study will help to address and prevent some of the more complicated issues encountered in other cities. These items along with specific funding, design, maintenance and monitoring recommendations for GI practices in Boston parks will be discussed in the GI Design Guidelines, completed as part of this study.

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