

GREEN INFRASTRUCTURE MAINTENANCE

IN THE CHESAPEAKE BAY WATERSHED



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Section 1. Objectives, Audience, Methods

The objectives of this white paper about green stormwater infrastructure (GSI) maintenance in the Chesapeake Bay watershed are to:

1. Investigate the current status of GSI maintenance through document review, interviews, surveys, and other means.
2. Identify key themes about GSI maintenance, both programmatic and practice-specific, that are of importance to local governments, maintenance contractors, engaged nonprofit organizations (NGOs), and others in the field.
3. Provide constructive and useful guidance tailored to specific needs to assist the above audiences with these challenges. In this way, the guidance is focused rather than comprehensive.

Intended audiences include local government stormwater staff, contractors that perform GSI work on public and private properties, NGOs that intersect with GSI as a partner with other entities, and other practitioners that have a role in GSI maintenance (e.g., HOA or commercial property managers).

To inform development of this white paper, the project team:

- Reviewed available GSI maintenance literature and resources;
- Surveyed 67 Chesapeake Bay region GSI practitioners via email and at the Chesapeake Conservation Landscaping Council (CCLC)'s Turning a New Leaf conference (41 responses received);
- Conducted a series of focus group interviews with various Bay region stakeholder groups and individuals (25 participants). In total, six groups were convened along with several one-on-one interviews, and detailed notes taken. In some cases, interviewees or survey participants were asked to supply additional documents and data.

Participants included:

- Local government stormwater staff that manage hundreds to thousands of stormwater practices.
- Local government stormwater staff managing dozens to roughly 100 stormwater practices.

Various size contractors that do GSI maintenance work as part of their services

- Non-profit and regional groups that work with local governments and other parties to secure grants and/or assist with both programmatic and field work for GSI.

Chesapeake Bay Landscape Professional (CBLP) Level 1 and Level 2 instructors who teach

- about GSI function and performance and who also have their own private businesses designing/building GSI.

A special interview was conducted with the GSI lead for Seattle Public Utilities due to that

- group's national leadership on a range of GSI topics, including Level of Service.

Information from the survey and focus groups was compiled into themes, which led directly

- to the outline for this white paper.

A prevailing theme among GSI practitioners is that time and resources are limited, leading to a feeling of not being able to accomplish all that is needed or even required. Maintenance often takes a back seat to more pressing matters. In short, there is a need to prioritize and focus; balance functional, ecological, and aesthetic considerations; recruit, train, and maintain a workforce that can do the work; and prevail on decision-makers and funders about the critical role of maintenance. This white paper addresses these various topics.

The project team is indebted to the many practitioners who responded to the survey and participated in the focus groups (see list below). Many also shared valuable resources from their programs.

Focus Group Participants:

We are indebted to the focus groups participants who lent us their time and wisdom in highlighting the many challenges and opportunities with GSI maintenance.

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For participants affiliated with public agencies or organizations, titles and affiliations are listed for identification purposes only. Participation in interviews and drafting is in an individual capacity and reflects the participants' own professional perspectives and opinions. It should not be interpreted as representing the views, policies, or official position of their respective public agency, organization, the participants' employers, or any associated public body. Input provided is intended solely for the context of this white paper, does not constitute formal professional or legal advice, and should not be relied upon by any third party outside the scope of this project. Information is provided "as-is" based on data available at the time of compilation. Correspondence, notes, and interview materials may be subject to applicable public information laws, including FOIA/COIA disclosure requirements.

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Hirschman Water & Environment, LLC is a small environmental consulting firm located in Charlottesville, Virginia.

The Chesapeake Conservation Landscaping Council is a nonprofit organization, based in Maryland, that educates and support professionals to implement sustainable landscapes and green infrastructure practices for a healthy and resilient Chesapeake Bay watershed.

The Alliance for the Chesapeake Bay is a nonprofit organization, based in Annapolis, Maryland, that restores the lands and waters of the Chesapeake Bay watershed.

Section 2. Level of Service – An Overarching Planning, Budgeting, and Field Operations Strategy

Level of Service (LoS) is a common asset management strategy among public utilities but is less common for stormwater than for water and wastewater. LoS is a framework that allows the owner of assets to define specific and actionable objectives related to performance, customer expectations, safety, cost-effectiveness, environmental stewardship, and other operation and maintenance (O&M) considerations. At its core, LoS is also a means to prioritize, allocate resources, and track and report on alignment with goals.

Think of a stock portfolio. Some investments are meant to take a risk in exchange for higher gains. Others aim for a more conservative, steady approach, and there will be some losers in the bunch. However, you wouldn't want ALL of your investments to be in just one of those categories (especially the losers!).

Using the portfolio analogy, a community's GSI practices may also fall into various categories. For example:

- A select few, high profile practices. These may be adjacent to the front door of the public library, elementary school, or town hall, and may require a higher level of design and more frequent and skilled maintenance.
- Then there may be a larger group of "typical" practices—shopping center parking lots, HOA common areas, the less-visible corners of public property. These can be the ones that present the most challenging maintenance situations as owners struggle with the resources to get it done.
- Another category may be those that are truly out-of-site, out-of-mind behind a manufacturing facility or fenced off in a far corner of the shopping mall parking lot.
- Finally, there are those long-neglected practices that fail to meet either performance or aesthetic metrics, and which may require total rehabilitation to restore these assets.

The point is that different GSI practices operate in different contexts, and the needs for and outcomes of maintenance also vary. If "failure" is something to be avoided, how do we define failure given the context: performance, aesthetics, community perception of the practice, and other considerations? This is where a LoS framework may be helpful.

Creating such a framework requires an investment of time and financial resources, but can pay off in the long run in terms of more targeted and cost-effective O&M. It can also serve as a valuable communication tool between local governments, HOAs, GSI owners and hired contractors, and the communities where GSI practices are located.

Table 1 provides an example developed for this white paper of a LoS framework that is adapted to GSI. The table includes three LoS categories: Standard, Enhanced, and Premier.

There is no one-size-fits-all with LoS, so this example is for illustrative purposes, and can be modified, simplified, or tailored to specific organizational needs.

For instance, it is fine to have just two LoS categories instead of the three represented in the table (e.g., Standard and Enhanced – see the case study at the end of this section).

Standard Enhanced Premier



Description & LoS Objectives	<ul style="list-style-type: none"> Meets regulatory standards & permit conditions Limited public visibility (e.g., behind buildings, not near sidewalks, travel ways) Function more important than aesthetics 	<ul style="list-style-type: none"> Meets regulatory standards & permit conditions Some public visibility and interaction with the practice Function & aesthetics are equally important 	<ul style="list-style-type: none"> Meets regulatory standards & permit conditions Highly visible to the public and intended for demonstration, education, engagement Aesthetics must meet higher thresholds while maintaining function
Target % of GSI Portfolio	60%	38%	2%
Current Condition of Practice	<p>Poor: neglected, both vegetation and structural elements need attention. May need total rehabilitation or at least heavy intervention to restore function</p> <p>Fair: Vegetation and some structural elements need attention. Requires several maintenance visits longer than typical to restore function and/or public acceptance</p> <p>Good: Maintenance requires limited and achievable with several routine maintenance visits. Vegetation needs routine work, such as weeding, invasive control, tree pruning, replanting bare areas, etc.</p> <p>Exceptional: Practice has been well-maintained and can achieve functional and aesthetic goals with ongoing routine maintenance</p>		
Planting Design	Simple: 2-4 species and mostly grasses that can be cut annually. Trees and shrubs can be incorporated and/or may be required by standards. Have some level of ecological and pollinator value.	Middle Level Complexity: 4-8 species. Preference for design influenced by natural plant communities and ecological value. Cues to care incorporated (see Section 3).	High Level Complexity: Model practice for native plant communities and ecological value. May include amenities for public viewing and/or interaction. Most important category for cues to care.
Inspection Frequency	Annual or every other year	At least 2X per year; preference for seasonal	Seasonal, with increased frequency during growing season. Variable depending on plant management needs. Generally 4-6 hours per visit.
Maintenance Visit Frequency & Anticipated Time per Visit	As-needed based on inspections. Preference for annual. 2-3 hours per visit.	Seasonal (4X per year). 3-5 hours per visit.	Seasonal, with increased frequency during growing season. Variable depending on plant management needs. Generally 4-6 hours per visit.
Maintenance Workforce	Public landscape crew or private contractor	Public landscape crew or private contractor, with at least supervisor trained in GSI, plant ID, and native plant communities. Preference for certifications. Some role for volunteers under supervision.	Public landscape crew or private contractor, with supervisor and some crew members trained in GSI, plant ID, and native plant communities, with certifications. Role for trained volunteers if available and supervised.
Equipment Needed for Maintenance	Standard maintenance tools for pruning, weeding, removing sediment, seasonal cutting back of herbaceous vegetation. Occasional use of mini-excavator, skid steer, dump truck, or similar to remove sediment or make repairs. Use of battery-powered equipment preferred.		
Community Engagement & Involvement	None	Could be included in tours, educational presentations, crew training events, etc. Some communication with surrounding community.	Somewhat frequent engagement and communication with community through website, newsletters, emails, etc.
Annual O&M Budget Per Practice	Less than \$5K	\$5 -- \$10K	\$10 -- \$25K
Rehab Costs If Needed	\$50 -- \$75K	\$75 -- \$100K	\$100K -- \$250K

*Numbers here are illustrative only

The information below provides guidance on the LoS concepts presented in

Table 1.

- **Description & LoS Objectives:** This is where a program or contractor can be explicit about the overall context of a GSI practice, or portfolio of practices. It can also describe the site context that leads to categorizing practices into one of several LoS categories.
- **Target % of GSI Portfolio:** This may be helpful for a program or contractor to set targets for each LoS category, as this aids in tying O&M to available staff and budget resources. In most cases, there should be more “standard” practices than either “enhanced” or “premier.” And, truthfully, for most communities, a very small percentage should be in the premier zone.
- **Current Condition of Practice:** An assessment of current conditions—an asset inventory—is very helpful to understand the gap between current conditions and the LoS objectives. For instance, if a “premier” practice is overgrown and creating downstream erosion, there would be higher price to pay to bring it up to the LoS designation compared to if it was in the “standard” category.
- **Planting Design:** This topic is one of the most common challenges noted by both GSI owners and maintenance contractors, and many focus group participants expressed a desire for stronger communication early in the design process so that practices are “more maintainable” in line with available resources. These LoS descriptions can serve as the basis for this type of communication, **provided the LoS category is identified during the design phase.**
- **Inspection Frequency:** Here is another staff and resource allocation issue. The LoS designations can set the types of SMART goals (see below).
- **Maintenance Visit Frequency:** This is very similar in intent to the Inspection category above in terms of allocating the actual crew time and budget resources.
- **Maintenance Workforce:** This pertains to not only the number of crew members needed, but also their skill sets, training, and certifications that aid crews in achieving successful maintenance outcomes.
- **Equipment Needed:** Similar tools and equipment are needed for routine GSI maintenance across all practice types.
- **Community Engagement & Involvement:** Our research revealed several innovative ways to engage volunteers and community members in envisioning practices, learning about their value and function, and even participating in some aspects of maintenance. But, this should not be the expectation for ALL the practices in the portfolio, and this is another way that LoS can help prioritize.

- Annual O&M Budget: This can be tricky to quantify conclusively at the planning stage, but at least allows a matching of LoS goals with available budgets or the scopes of contracted services. The numbers in the table are “per practice,” and are for illustrative purposes only, as each program must line up maintenance visit costs (per visit or annual) with program budgets. See **Section 4** for guidance on maintenance costs.
- Rehab Costs If Needed: Some of the research demonstrated the stark contrast between practices that receive ongoing maintenance versus those that have been “lost in the weeds” for some time and need a complete redo—the classic “pay me now or pay me later” scenario. This can be valuable for making a stronger argument for adequate funding for routine maintenance and/or prioritizing the practices that need a full rehab intervention.

Again, it is important to stress that this discussion is illustrative, and categories and entire frameworks can be customized to needs. And it is worth noting that industry recommendations for LoS frameworks suggest using SMART (**S**pecific, **M**easurable, **A**chievable, **R**elevant, and **T**ime-bound) goals.

One final notion that may be entertained in an LoS framework: can some currently failing practices be decommissioned rather than undergoing an expensive rehabilitation?

This can be a fraught question in the world of total maximum daily limits (TMDL), numerical and reportable pollution reduction goals, and legal and permit requirements. That said, the Chesapeake Bay Landscape Professional program has assessed approximately a thousand practices through the Level 1 field practicums conducted since 2016. On occasion, some BMPs are under-performing in all regards but these practices also treat a very small drainage area and result in very nominal reductions. In the stock portfolio analogy, these may be ones to “sell off” before you end up throwing good money after bad, especially if the reductions can be compensated for elsewhere in the portfolio.

This illustrates that delving into LoS may lead to some unanticipated ideas.

Level of Service Case Study: Fairfax County, VA

Fairfax County has oversight responsibility for over 2,500 public and private stormwater practices. A Level of Service designation – either Standard or Enhanced – is used for the public practices the County is responsible for maintaining to help budget for contracted maintenance, using a spreadsheet containing typical tasks along with unit costs per square foot of practice area.

The Standard (Level 1) and Enhanced (Level 2) categories are linked to service level and routine maintenance descriptions in RFPs and maintenance contracts, noting that Level 2 practices require a higher level of attention for vegetation management and aesthetics.

Importantly, this entire framework was based on a comprehensive field assessment of existing conditions, providing a strong foundation for assigning the different levels.

The following are examples of the LoS descriptions for the Green Infrastructure category. These descriptions then refer to a more detailed “Post Construction Maintenance Guide.”

Services *The objectives encompass the maintenance of facility conditions in alignment with specified mandates concerning functionality, environmental adherence, and site-specific design nuances. These mandates and nuances may entail, but are not confined to, the upkeep of approved vegetative coverage, appropriate infiltration, grading, pre-treatments, inflows, outfalls, safety protocols, structural elements, and aesthetic standards. Maintenance activities shall be overseen by individuals duly trained and certified in accordance with the National Green Infrastructure Certified Program, supplemented by an Arborist holding certification recognized in the State of Virginia.*

Routine maintenance, also known as preventative maintenance, refers to regular, scheduled tasks performed to reduce the risk and likelihood of asset failure to ensure the proper functioning, cleanliness, and upkeep of assets. These activities are conducted to prevent costlier repairs, extend the lifespan of assets, and maintain operational efficiency. Routine maintenance typically includes cleaning, minor repairs, and adjustments. The specific tasks vary depending on the type of facility or asset. Routine maintenance is proactive, with the overarching goal of addressing potential issues before they become major problems, ensuring the continuous and optimal operation of the assets.

Routine maintenance is mandated to be provided at a **Standard Level of Service** and frequency to ensure that, except in cases of reasonably unforeseen non-routine maintenance needs, the requirements for function and regulatory compliance are consistently met. Additionally, an **Enhanced Level of Service** may be engaged at specific facilities to fulfill aesthetic expectations or other site-specific design considerations.

Detailed routine maintenance instructions can be found in the county's Post Construction Maintenance Guide. Contractors are expected to complete the tasks outlined for each scheduled event in accordance with this guide.

Some Key Lessons Learned

- The Level 1 (Standard Level of Service) involves only weeding aggressive non-native species, but no mulching. This can lead to a grass-dominant facility. Level 2 (Enhanced Level of Service) includes weeding (invasive and sometimes aggressive natives) and mulching for a diverse ecosystem with a preferred community aesthetic (see photos below).
- It is important for the RFP process to establish the value of qualifications early in the process, especially in low-bid situations. As the process advances toward an award, the facility manager has less and less control over the contractor selection.
- With a qualified contractor, the facility manager can help move a facility from establishment of design planting plan into an adaptively-managed maturity (see adaptive management in Section 3). In some instances, this may mean a loss of diversity, or even the pruning back of aggressive natives.

Figure 1.



Left: Level 1 Standard Level of Service facility over time becomes dominated by grasses.. Right: Level 2 Enhanced Level of Service is managed for more diversity.

Photo Credit: Fairfax County, VA

Level of Service Resource: Seattle Public Utilities Department (SPU) GSI Operation & Maintenance Materials

The Seattle Public Utilities Department (SPU) has an active and long-standing GSI program, largely involving construction of bioswales and stormwater planters along public roadways. The information below is excerpted from several documents that outline SPU's protocols for assigning "Acceptable" and "Unacceptable" designations based on the condition of the practices and developing condition assessment report cards.

While Seattle has a very large and sophisticated GSI program, these examples are distilled to provide examples of how visual assessments of practice conditions can be used to prioritize resources and drive corrective actions.

Acceptable & Unacceptable Designations Using Visual Indicators

SPU was an early leader in utilizing the Level of Service concept for its GSI roadside projects. At first, the concept used letter grades of A, B, C, and D to designate varying levels of service. More recently, the concept was simplified to use "Acceptable" and "Unacceptable" criteria. This is related to the condition report cards noted above, as it is a means to evaluate field conditions compared to established performance standards for:

- Establishment period
- Routine maintenance
- Major corrective action

The evolving SPU Green Stormwater Infrastructure Operation & Maintenance Manual provides visual indicators for various GSI components. A few examples are presented below (in Figure 2), with side-by-side comparisons of acceptable and unacceptable conditions. Note that these are only selected examples, as the manual contains many more categories.

Figure 2.
Facility Footprint
(After Major Storm Event)

Source: (*Green Stormwater Infrastructure Manual for Capital Improvement Projects, 2020*).



Figure 3.

Vegetation (Top: Blocking Inlets and Outlet Structures; Bottom: Visibility & Site Lines)



Source: (Green Stormwater Infrastructure Manual for Capital Improvement Projects, 2020).

Condition Assessment Report Cards

This report card assigns a letter grade for the condition of individual GSI practices (as noted, mostly roadside swales). The purpose of these reports is to help SPU and the public understand the condition of individual GSI projects, how the project design affects the condition, and to make recommendations for improving the function, plant performance, and maintenance of these projects as well as to inform future design decisions.

How Are Number Grades Determined?

Grades are determined using a checklist that rates the condition of twenty project components (plant health, for example). Each component receives a rating from 0 to 5. A rating of 5 fully meets the target (mostly healthy plants in this example). A rating of 0 is well below target (many dead, stressed, or missing plants) and requires significant effort to correct and bring it closer to target. Project components are grouped into three categories:

- Safety
- Function
- Plant Performance

A few examples in each category are provided in Table 2 below, with scores in the right-hand column assigned for one particular practice. Note that the full checklist is quite lengthy, so it is not included in its entirety here.

Table 2. GSI Report Card Score Examples

Safety			
Sight Lines	1	Sight lines meet SDOT requirements. No plants taller than 24" within 30' of intersections. No plants taller than 24" within 10' of driveways. Any fire hydrants are clearly visible and accessible.	3.3
Vertical Drop	2	Vertical drop into facility is continuously visible. Vertical drop from pedestrian areas is < 18" if no low rail is present. Vertical drop is < 30" if low rail is present. Vertical drop is > 30" has a barrier rail.	4.8
Function			
Flow Blockage	6	Water can flow freely without plant growth, sediment, or debris blockage at curb cuts, weirs, trench drains, pipe outfalls, inlets, trash racks, and/or catchbasin grates	4.8
Sediment Build-up	7	Ponding depth and freeboard are at minimum of 80% of design depth	5.0
Soil Erosion & Washouts	8	Little or no erosion, channelization, or scouring on facility sides and bottom. Little or no erosion, settling, or undercutting at drain curb cuts and grates.	5.0
Plant Performance			
Plant Health	11	Vegetation appears healthy. Plants do not show signs of significant stress, wilting, spotting or holes in leaves, broken leaders or branches, or branch die-off. Trees do not lean.	4.8
Plant Coverage	12	Bottom zone plant coverage is greater than 80%.	5.0
Plant Density	13	Plants are sufficiently dense to shade out and outcompete weeds.	4.0

Source: Seattle Public Utilities, GSI Project Softscape Conditions Report Card, Carkeek Cascade

Section 3. Planning & Design Issues That Impact Maintenance

The often-tenuous link between those who design GSI and those charged with its maintenance was one of the challenges noted frequently by the survey respondents and focus groups. There are many discussions to be had on this topic. This section is not intended to be an exhaustive analysis of how to better link design and maintenance, but an opportunity to highlight some innovative thoughts and concepts expressed by focus group participants. The topics in this section include:

- Vegetation – from design to maintenance
- Other GSI Elements – drainage area, inlets, pre-treatment, side slopes, etc.
- Rainfall Depth Capture – accounting for changing climate patterns
- Cues to Care – incorporating maintenance cues into design
- Adaptive Management – making the concept apparent at the design stage
- Recommended Approach – a few thoughts on better integration between design and maintenance
- Maintenance Paper Trail – guidance on the documents that help transition a project from planning/design to construction and maintenance

Vegetation

Vegetation was mentioned frequently during the focus groups as well as in the survey, with plant identification, establishment, management, and invasive species being some of the top challenges.

Planting plans should reflect the capabilities of the responsible maintenance party. This concept ties into the Level of Service discussion in Section 2 above.

Some factors to consider include:

- Permitting – This varies between jurisdictions, but some consider vegetation (particularly woody plants) to be part of the permitted facility. This means that if vegetation fails, replacement is required under the permit. Some inspectors may insist on replanting the exact same species that previously failed. From a horticultural standpoint, it is best to plant a different species. Without better guidance in the design plan, this could become a stumbling block. An adaptive management section in the plan may help designers, GSI owners, and regulatory personnel develop a common understanding of adaptive management. **Table 5 in the Adaptive Management section below** provides an example of how this can be done.
- Replacement Costs – This can be a significant cost and technical expertise factor for responsible parties. If the original plan includes larger container plants and/or ball and

burlap trees, replacement costs may be quite high. Some of our focus groups recommended heavy reliance on plugs and smaller plant stock.

- Minimum Acceptable Condition – This is another factor related to Level of Service, and something that will be of interest to inspectors and regulatory personnel. Often, checklists include a simple percent survival rate, but other elements are also important: safety, site lines, and public acceptance being a few of them. The **Case Study from Seattle in Section 2** includes a framework that incorporates safety, function, and plant performance, with photo references for acceptable and unacceptable conditions. The **Fairfax County Case Study** also includes standards for acceptable maintenance.

Other GSI Elements

Vegetation is arguably the most important component of a GSI practice in terms of what the public sees and the responsible party maintains. However, other components of a practice are instrumental in its performance and function. The inspection checklist used in CBLP Level 1 certification training includes some of these components:

- Drainage Area
- Inlets
- Pre-Treatment Areas
- Side Slopes
- Overflow/Spillway Structures

As noted above, focus groups identified a need to have visual benchmarks for acceptable and unacceptable site conditions. **Table 3** provides some examples for this type of protocol, borrowing the “acceptable/unacceptable” framework used by Seattle Public Utilities, except adapted to the items commonly used on BMP inspection checklists in the Bay region. Importantly, the table highlights decisions made at the design stage that can lead to acceptable or unacceptable conditions.

Table 3. Acceptable and Unacceptable Site Conditions

Acceptable

Unacceptable

Drainage Area



Acceptable: Parking lot drainage area relatively clean of sediment, oil stains, stored materials

Design Factors: This is an O&M and communication issue with GSI owners. See note to right about signage and training.



Unacceptable: Material storage in parking lot drainage area contributing sediment and debris to vegetated filter strip

Design Factors: Signage and training can help prevent this type of activity

Inlets



Acceptable: Free-flowing, formed curb to ensure inflow

Design Factors:

- Formed inlet at low point
- Enough drop to ensure inflow
- Rocks at bottom to reduce energy (although posing another maintenance challenge)



Unacceptable: Clogged with debris & vegetation, diverting water so loss of function

Design Factors: At grade inlet design; water must make 90-degree turn, so just a little blockage will divert water past the inlet

Pre-Treatment



Acceptable: Clear flow path into practice, little sediment accumulation

Design Factors:

- Ease of maintenance with concrete base
- Any trash or debris easy to spot and remove with simple tools



Unacceptable: River cobble clogged with sediment

Design Factors:

- River cobble inherently difficult to keep clear of sediment
- No defined maintenance regime identified in the plan

Acceptable

Unacceptable

Side Slopes



Acceptable: Side slopes stable, well-vegetated

Design Factors:

- Slope not overly steep; easier to stabilize
- Clear mowed edge provides “cues to care”



Unacceptable: Side slopes unstable, eroding, not enough vegetation

Design Factors:

- Doesn't account for runoff characteristics from parking lot, especially as designed for sheet flow
- Too steep for sheet flow condition
- No pre-treatment; inadequate vegetative cover
- Requires better plan for conveyance into practice

Spillway / Over flow



Acceptable: Atrium grate clear for outflow

Design Factors:

- Atrium grate (half-dome shaped) better for not collecting mulch and debris (but not fail-proof)
- Use of closely-spaced plantings to serve as “green mulch”



Unacceptable: Overflow clogged with mulch & debris, blocking outflow

Design Factors:

- Flat drop inlet structure prone to clogging
- Reliance on mulch for ground cover instead of using a “green mulch” concept

Vegetation



Acceptable: Good coverage

Design Factors:

- Layered vegetation types
- Somewhat “shaggy” look at edge of parking lot as transition zone to riparian buffer (appropriate site context)
- Fence serves as a cue to care



Unacceptable: Overgrown, blocks to site lines to front of school building

Design Factors:

- Trees, shrubs, herbaceous closely-spaced in original planting plan
- No adaptive management concept for how to maintain through time
- Difficult to maintain for site context – highly visible at front of school

Rainfall Depth Capture

Some focus group participants mentioned the challenge of managing stormwater under changing climate conditions. These challenges are multi-fold but include maintenance. The [NOAA Mid-Atlantic Regional Integrated Science & Assessments \(MARISA\)](#) project notes that there could be as much as a 30% increase in average annual days with two or more inches of precipitation by mid-century, and 60% by the end of the century (Mid-Atlantic Regional Integrated Science and Assessments, 2025). Other precipitation factors, such as rainfall intensity, are also expected to change, as well as the duration of droughts and increase in desiccating winds.

Table 4 provides guidance on how GSI design and maintenance can be adapted to climate conditions. These ideas are representative of some GSI components, but not comprehensive, as much thought and work is going towards modeling future climate scenarios as well as forecasting watershed responses. More information on stormwater and watershed adaptations to climate change can be found in the Chesapeake Stormwater Network (CSN) and Rand’s [Advancing Climate-Resilient Stormwater Management](#) – a series of tools and a vulnerability assessment for stormwater managers (Miro & Romita Grocholski, 2026). CSN also produced [four memos](#) on the subject, with memo 4 addressing some conceptual BMP design issues (4 CSN Climate Reports, 2026).

Table 4. Adapting GSI for Climate Conditions

BMP Component	Climate-Related Challenges	Possible Solutions
Inlets	Increased rainfall amounts and intensities can overwhelm inlets, causing runoff to bypass GSI practices. Debris build-up due to lack of maintenance would have consequences for proper function and performance.	<ul style="list-style-type: none"> • Add a safety factor to inlet sizing • Ensure adequate drops and conveyance into the practice • Include testing of inlets at installation to simulate partially clogged conditions to ensure water still enters the practice
GSI Surface	Higher flows can create erosion, cutting channels, preferential flow paths, and sinkholes.	<ul style="list-style-type: none"> • Incorporate pre-treatment forebays that not only settle out heavier sediments but help to slow down the water entering the practice. This may require increasing forebay size and storage. • Strive to have dense plant coverage within the first few growing seasons to act as natural erosion resistance.
Vegetation	Both the wet and dry ends of the climate spectrum can stress vegetation. If intended vegetation dies or becomes unhealthy, invasives that are more climate-tolerant may rush in to fill the voids.	<ul style="list-style-type: none"> • Plant palettes incorporate resilient native plants that tolerate both wet and dry conditions. • Watering during the first few growing seasons will become even more important during dry conditions. • Consider the role of ultimate tree canopy in the design and in adaptive management plans.
Overflows	Overflows and spillways may be activated with more frequency and sooner during a storm, meaning that practices have reduced storage and pollutant removal performance. Also, overflow structures may become more prone to clogging, which can lead to structural damage in the practice.	<ul style="list-style-type: none"> • Consider adding storage through sizing and storage features within the soil media or underdrain layer (arch culverts, deeper stone layers, etc.). • Add redundant design features for overflow, so that if the main overflow structure becomes clogged, there are weirs or other means to ensure safe overland flow without breaching berms or causing downstream flooding.

Cues to Care

Joan Nassauer, Landscape Architecture Professor at the University of Michigan, piloted the concept of “Cues to Care” (Li & Nassauer, 2020). Based on cultural preferences for neatness and orderliness in landscapes, the concept suggests using neat frames or edges in an otherwise “messy” landscape. These elements convey human intention and promote public acceptance. Various techniques to incorporate cues to care include mowed edges, fences, other frames or edges, bird feeders and houses, commonly known (and native) flowering plants and trees, architectural details, art, and other strategies.

These elements, when used in native and sustainable landscape designs, can also function as “cues to maintenance.” This applies to both residential landscapes as well as GSI practices in public settings. The main thing to note is that cues to care can and should be part of the design process.

The following photos show just a few examples of cues to care. There are many other online resources, such as (Elmiger, 2011).

Figure 3. Cues to Care Examples



A mowed strip along sidewalk and art demonstrate that the area is cared for, and acts as a transition from the hard infrastructure to the wooded area



The fence and sign indicate that the native landscaping has a purpose. Note also the stone edging in the center of the photo.



This signage not only indicates that the landscape is intentional but also provides instructions for maintenance crews to maintain the mowed edge (such a sign could also direct crews to cast the grass clippings AWAY from the GSI practice).



Pathways and signage in the public-facing wetland/natural area.



Pathways and signage in the public-facing wetland/natural area.



Split-rail fence creating a boundary between the parking lot and a rain garden/riparian buffer.

Photo credits: Chesapeake Conservation Landscaping Council, Hirschman Water & Environment, LLC

Adaptive Management

Focus groups also discussed the need for better information on how adaptive management plays a role in the lifecycle of a GSI practice. It can be difficult at the design stage to envision all the possible adaptive management scenarios, but just including a section in the design plan that can be used as a communication tool would provide a huge benefit.

Table 5 provides an example of how this could be done. It is a model that should be adapted to different project design objectives and site conditions.

Table 5. Adaptive Management Plan Example




	Installation – First 3 years	3 to 7 years	8+ years
			
Description	<ul style="list-style-type: none"> • Young plants maturing. • Open spaces between plants subject to invasives threat. • Survival rates vary between plant species. 	<ul style="list-style-type: none"> • Some plants out-competing others; may become tree or shrub dominated. • Some of the herbaceous species that prefer full sun may be dying out. • Filter bed may develop preferential flow paths, sinkholes, or capacity diminished due to decomposing mulch and plant material. 	<ul style="list-style-type: none"> • As trees and shrubs mature, practice surface becomes shaded. • May become a two-layer system: canopy and ground cover.
Inspection & Maintenance Key Objectives	<ul style="list-style-type: none"> • Observe water flow patterns during storms. Make adjustments to inlets, flow along surface and behind check dams, overflow structures, etc. • Seasonal invasive management. • Remove dead & diseased plants and replant with different species and/or existing species that appear to be thriving. 	<ul style="list-style-type: none"> • Ensure inlets are clear and water is entering the practice. • Prune trees and shrubs in appropriate season. Limb up to maintain or create site lines. • Replant more shade-tolerant ground covers as needed. • Continue to monitor and control invasives as needed. • Adjust filter bed to promote more level ponding surface without damaging vegetation that is doing well. 	<ul style="list-style-type: none"> • Pruning to allow site lines through practice (especially if in a well-trafficked area). • Promote higher level of ground cover on surface by planting more shade-tolerant species. • Continue to check inlets, overflow, and filter bed.

Photo credit: Hirschman Water & Environment, LLC

Recommended Approaches for Better Linking Design and Maintenance

Even though the concept of a designer working and communicating with maintenance teams makes complete sense, this process is not formalized. And, very often, the designer may not know who will be commonly conducting the maintenance (e.g., a contractor hired by a government agency or private entity). Nevertheless, some aspects of this conversation can and must be part of the design process.

To summarize, the following are some key points to “design with maintenance in mind.”

1. Conduct early consultations between designers, owners, responsible maintenance entities, and inspectors to inform a Level of Service discussion that can be communicated to all parties. Avoid “installing what cannot be maintained.” See the list below of possible topics to include in these discussions.
2. Incorporate adaptive management narratives and graphics in the plan and communicate these features to inspectors and regulators.
3. Incorporate “cues to care” in the design wherever possible.
4. Create a GSI maintenance paper trail at the design stage that formalizes roles, responsibilities, and communication channels.

As for #1 above, these consultations can be aided by some form of a questionnaire that the designer works through with the property owner, provided that that entity is known at the time of plan development. Here is a list, as a starting point, of questions that could be in the questionnaire.

Design Phase Questionnaire

- Do you have a maintenance crew (or contractor) that maintains landscape features on a regular basis? Are GSI practices part of this work?
- How many practices are the crew responsible for maintaining?
- What’s the anticipated frequency of maintenance visits: quarterly, semi-annual, annual, every 3 years, as needed, other?
- How much time does the crew typically have for each site: 30 minutes, 1 hour, up to 3 hours, other?
- What tools and equipment do the crew have available for maintenance: hand tools for pruning, cutting, digging, weeding; small mowers capable of cutting high – approximately 6-8 inches; weed whackers, etc.?
- Are there concerns or restrictions about use of chemical herbicides (e.g., glyphosate)? What degree of chemical use is authorized and/or appropriate for the site?
- Has the crew had any training and/or experience identifying and working with native plants?
- Has the crew had any training and/or experience identifying and controlling invasive plant species?
- Has the crew been trained to understand how GSI practices function?

The answers to these and similar questions would provide the design professional with a realistic sense of how much maintenance will be performed, by whom, and its degree of sophistication. This information can be then translated into appropriate design features, such as the planting plan.

GSI Maintenance Plans & Paper Trail

Upon completion of the design phase, the breadcrumbs that are left behind to inform future maintenance are the O&M plan and paper trail of documents. These tend to be context-specific, whether the practice is a required part of an MS4's BMP portfolio, and local and state regulations and guidance. In general, many practices will have an O&M plan and perhaps a maintenance agreement that is part of the property deed. Even small-scale and voluntary GSI practices will leave behind some kind of paper trail. This section provides some guidance on these documents.

The Operation & Maintenance (O&M) Plan

These tend to be generic based on the type of practice, but in their best incarnations are more site-specific and prescriptive. The following elements may be helpful.

1. Show graphically the components of the specific BMP: Don't assume that maintenance crew members will understand what is meant by terms such as inlet, outlet, overflow, inlet protection, energy dissipator, filter bed, gravel diaphragm, spillway, etc. The plan should show graphically each component and explain its purpose. Maintenance crews like to know not just WHAT to do but also WHY they are doing it to improve the function of the BMP and protect the environment. It is useful to explain to them how the BMP is intended to work (see **Figure 4** for an example).
2. Maintenance Tasks: The main part of the plan is the task list – weeding, pruning, thinning, replanting, repairing erosion on side slopes or in the filter bed, ensuring inlets are still functional, and other tasks.
3. Task Frequency, Seasonality, or in response to Visual Site Inspection Triggers: Maintenance crews must use their time efficiently, so this is an important consideration. Site inspection condition assessments are a great option (if inspections are taking place). The triggers would include items such as percent cover by invasive or unwanted plants, accumulation of sediment in forebays and on the filter bed, debris accumulation at inlet points, and other visual cues. Several very helpful resources tie maintenance response to visual triggers on a scale of severity (the issue is minor, moderate, or severe). One such tool is CSN's Bioretention Illustrated (Scott et al., 2013). It is also helpful to approximate the time demands for specific tasks, as this translates to the maintenance budget and staffing. **Table 6** shows an excerpt from an O&M plan that specifies tasks, frequencies, and how O&M changes through time.
4. Routine vs. Non-Routine Maintenance: Most of what is articulated above involves routine maintenance. In other words, maintenance that can reasonably be anticipated ahead of

time. However, the unexpected will inevitably occur during the life of the BMP. A lot of this is tied to extreme weather on both the wet and dry side. Specific non-routine maintenance needs cannot be predicted, but the O&M plan can at least note those that are typical with various BMPs. The importance of this is that the O&M plan is tied (in the ideal world) to a maintenance budget, and non-routine responses are the most challenging to include in such a budget.

5. Tools, Equipment & Training/Certification: The plan is not complete without this category. For instance, if the plan calls for mowing or bush-hogging the BMP to eight inches once per year in the late winter, then the crew must have the equipment to cut at that height. Other considerations are tools/equipment that will minimize soil compaction, allow for the efficient use of time, respect the site owner's desires about the use of herbicides, and of course use of sustainable practices, such as battery-powered equipment. Finally, as detailed elsewhere in this document, training and certification can be required for crew leaders and members.

Figure 4. Example of BMP Components from O&M Plan

These graphics – intended to be part of an O&M plan – show the actual as-built practice and explains the purpose of each component to help maintenance crews understand how the practice is intended to function.

Drainage Area & Uphill Catch Basins



Purpose: The two uphill catch basins collect runoff from the travelway in front of the building and surrounding grass slopes and diverts the runoff into the bioretention practice.

Inlet & Forebay



Purpose: The 12-inch corrugated metal pipe brings drainage area runoff into the bioretention. There is a small catchment area at the pipe outlet called a forebay, intended to catch sediment, debris, and trash for easier clean-out. The purpose of the rocks is to break up the energy of the incoming water and prevent erosion on the filter bed.

Figure 4. Example of BMP Components from O&M Plan continued

Side Slopes



Purpose: The side slopes encircle the BMP and are the first line of defense against overland erosion coming from uphill.

Filter Bed & Vegetation



Purpose: The filter bed consists of a 3-foot deep layer of sandy soil media that is designed to filter pollutants out of stormwater. The soil in combination with the vegetation work to process and filter pollutants. The filter bed was covered with mulch at the time of planting, but annual re-mulching should not be required after the first two growing seasons if dense vegetation cover is established.

Underdrain



Purpose: The underdrain consists of clean-outs in the filter bed (left) and an outlet in the woods below the spillway (right). The purpose of the underdrain is to ensure that water does not stand in the filter bed for any longer than 3 days.

Overflow Weir & Spillway



Purpose: The stone weir sets the ponding depth and allows higher flows to exit the BMP and flow into the woods. Where the water exits the BMP, the middle part of the weir should be several inches lower than the edges, forcing water down the middle of the stone channel.

Source: (Friends of the Rappahannock 10-Year Operation & Maintenance Plan for George Washington Carver Agricultural Research Center, 2024)

Table 6. Example of O&M Plan Tasks/Timing

This is just one example of demonstrating maintenance tasks based on seasonality, planned frequency of maintenance, and adapting through time. This example is for the filter bed, but the O&M includes similar charts for all the components in **Figure 4**.

Element 4: Filter Bed (see vegetation on p.15)			
	1 - 3 years: 2025 – 2027	4 - 7 years: 2028 – 2031	8 - 10 years +: 2032 – 2034 +
Growing Season: March - Sept.	AFTER Storm: check for: <ul style="list-style-type: none"> A. mulch washing away B. erosion C. sediment accumulation from side slopes or drainage area D. sinkholes E. standing water F. Trash SEE FILTER BED RESPONSE CHART ON NEXT PAGE. As plants mature, it will be harder to see the surface of the filter bed, so these tasks can be done in the Fall or Winter (see below). M	<ul style="list-style-type: none"> After several years as plants and mulch decompose, the filter bed may raise above the initial elevation, reducing storage capacity. In this case, it may be necessary to raise the rock spillway elevation an equal amount. Q	<ul style="list-style-type: none"> Same as to the left. AN
Plant Maturity: Oct. - Nov.	<ul style="list-style-type: none"> Same as above Remove at least some of the leaves that accumulate in the filter bed. M	<ul style="list-style-type: none"> Same as above Q	<ul style="list-style-type: none"> Same AN
Dormancy: Dec. - Feb..	<ul style="list-style-type: none"> Same as above. This is probably the best time to do the filter bed inspection. If necessary, re-mulch ONLY if bare areas appear. Re-mulching whole filter bed should not be necessary. M	<ul style="list-style-type: none"> If capacity is lost, this is the best season to remove some material from the filter bed; will have to work around vegetation. DO NOT add any additional mulch. AN	<ul style="list-style-type: none"> Same AN
Frequency Key: M = Monthly Q = Quarterly AN = As Needed S = Seasonal			

Source: (Friends of the Rappahannock 10-Year Operation & Maintenance Plan for George Washington Carver Agricultural Research Center, 2024)

The Maintenance Paper Trail

Upon completion of the design phase, the breadcrumbs that are left behind to inform future maintenance are the O&M plan and paper trail of documents. These tend to be context-specific, whether the practice is a required part of an MS4’s BMP portfolio, and local and state regulations and guidance. In general, many practices will have an O&M plan and perhaps a maintenance agreement that is part of the property deed. Even small-scale and voluntary GSI practices will leave behind some kind of paper trail. This section provides some guidance on these documents.

Some of the components of the paper trail can include:

1. Maintenance agreements recorded in the property deed are often required for regulated practices.
2. A memorandum of understanding (say, between a grant recipient organization and responsible maintenance entity) outlining expectations, general approach, such as using sustainable practices, and funding for maintenance.
3. Some organizations use RFPs or other procurement tools to obtain maintenance services. These documents can be accompanied by a statement of intent noting maintenance expectations, signed prior to construction by the property owner or manager. This statement can in fact be page 1 of the written maintenance plan and specifications. See the end of this section for sample language.
4. The maintenance plan should also include inspection and completed work task forms as part of the communication chain between maintenance contractors (or in-house staff) and property managers. This helps ensure that maintenance is taking place in response to inspection findings and the plan's specifications. Sample instructions for these forms are also provided below.

Sample Language for RFPs and Inspection and Work Completed Forms

Sample "Statement of Intent" for use in RFPs and/or as Page 1 of the Maintenance Plan:

"It is the desire of the owners to manage the stormwater BMP's in an environmentally conscious and sustainable manner. The specifications outlined below reflect our intent to maintain the BMP's so that they provide the maximum stormwater treatment and ecosystem services while minimizing air, water, and soil pollution. Please read all specifications carefully and prepare your bid to accurately reflect the scope of services listed."

Sample language about ongoing documentation of inspections and completed work:

"The contractor shall email documentation of work performed within 7 days of completion. This notification shall include the date and scope of work performed, before and after photos, and a completed inspection report."

Section 4. Costs of GSI Maintenance

The nature of GSI practices brings a unique set of maintenance challenges that differ from those of traditional green spaces and designed landscapes. Contractors or municipal staff may not be familiar with structural elements such as inlets, underdrains, overflow devices, and outfalls, native plants may not be recognized by crews that maintain traditional landscapes composed of non-native plants. Meeting the challenges of budget and capacity like these will require working with stakeholders at all points along the design, installation, and maintenance process.

GSI practices that are designed beyond the capacity of the field teams to maintain them, errors made during construction, or a lack of training in how to properly maintain GSI can increase mistakes and costs. GSI management teams may overcome these challenges by:

- Developing unit costs for additional work repairs within the maintenance contract. This helps manage costs and avoids surprise invoices.
- Engaging contractors that understand GSI maintenance. This prevents costly errors and helps crews solve problems and decide how to use their time on site.
- Avoiding the 'low bid' process that often results in contracting with unqualified contractors who are unable to perform work that meets the maintenance standards.
- Providing training for crews based on the needs identified in the field.
- Conducting regular inspections during and post-construction to ensure functionality, and proactive plant replacements during the establishment and warranty period.

Tracking Maintenance Costs and Crew Hours

It is imperative that organizations develop a process to track costs and labor hours for GSI maintenance, along with equipment and material costs for each practice that they maintain. Relating those costs to the square footage of the practice will yield a \$ / sq. ft. maintenance cost that can provide some general guidance when developing annual maintenance costs and budgets. Costs for GSI practices will vary depending upon the level of service, type of practice, and efficiency of the maintenance teams.

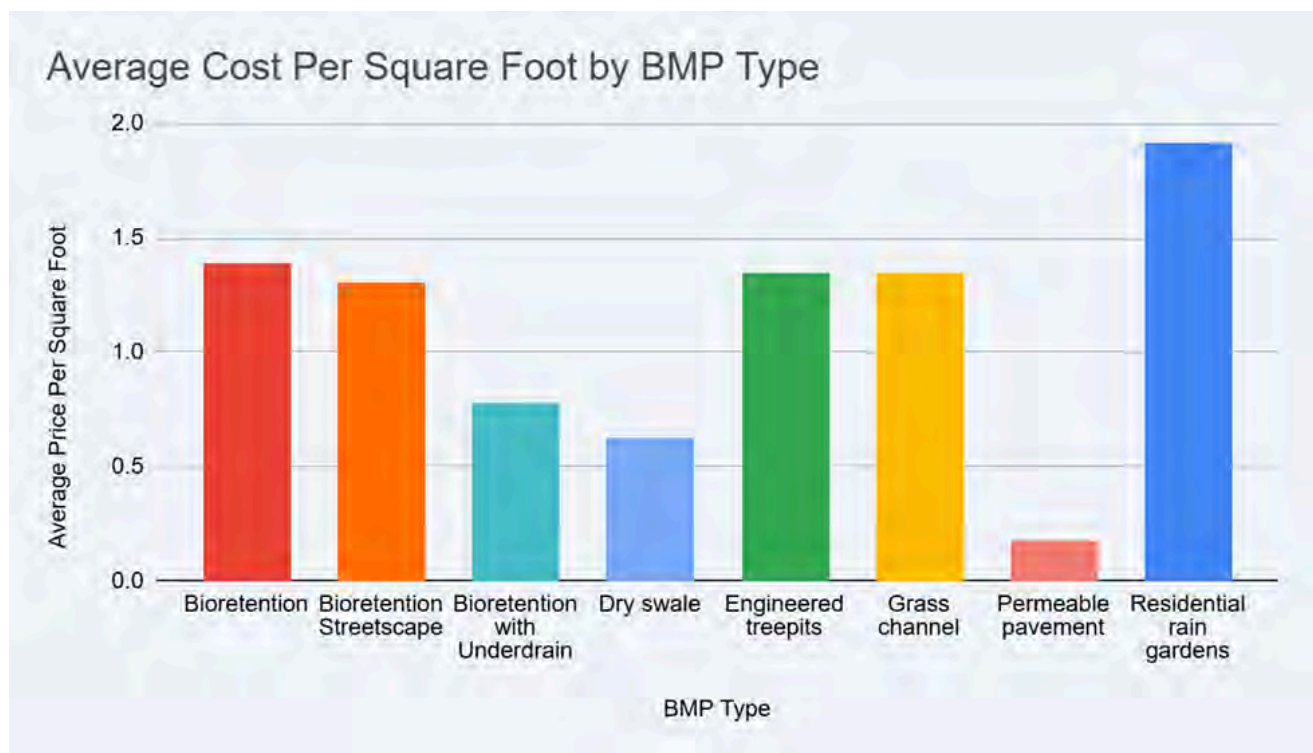
Surveyed participants provided some weighted cost averages for 43 green roof maintenance visits and 187 bioretention maintenance visits based on contractor invoices for GSI maintenance in Washington, DC. Analyzing the invoices provides some insight into sq. ft. maintenance costs:

- Green roof maintenance average routine maintenance cost per visit - \$3.21 per square foot
- Bioretention maintenance average routine maintenance cost per visit - \$2.78 per square foot.

The Alliance for the Chesapeake Bay analyzed over 2000 GSI routine maintenance invoices for different practices. **Figure 5** illustrates the labor costs per square foot for a routine maintenance visit.

Debris disposal costs and material costs such as mulch, stone, and plants were not included in the average cost calculations.

Figure 5.. Average Routine Maintenance Visit Cost Per Square Foot



In addition to tracking maintenance costs, it can also be useful to track the labor hours used in performing GSI maintenance. Tracking labor hours for each maintenance visit can be very helpful when estimating the number of hours required for future maintenance visits. Knowing the average maintenance hours per visit is also important for efficiency and success in the field. Communicating expectations to crews regarding estimated labor helps with daily scheduling, jobsite decision making, and work efficiency, all of which affect the overall cost of maintenance in a positive or negative manner.

While it may not be practical to perform this type of tracking for every practice in a large portfolio, tracking maintenance activities in several key practices can be a good start and will provide key data that can be applied to budgeting for other GSI practices.

Data Drives the Budget

Routine, preventative maintenance of GSI is key to managing costs, but if the maintenance budget is not sufficient, the condition of practices may suffer. A useful maintenance budget must rely on data. That is why it is important to develop a consistent method for tracking data in the field and reporting to management. Interview participants report using specialized software platforms such as [Brightly Asset Management](#) (Asset Management for Infrastructure, 2024), or standardized reporting through platforms like [Jotform](#) (Free Online Form Builder & Form Creator, 2026) to collect maintenance visit data. These platforms can be accessed through phone apps so that data and photos are recorded on site as work is completed.

Larger municipalities with many stormwater practices will already have cost data and records to help in the budget process, but data is often inconsistent or missing, so implementing a standardized practice for collecting data will make the budget more accurate and help when deciding how to best allocate limited resources.

Smaller municipalities, or contractors just starting to maintain GSI may not have access to historical data. Those organizations should establish maintenance cost tracking processes as soon as possible and may want to consider utilizing industry standard unit costs like those listed above or hire an experienced GSI consultant to help estimate maintenance labor, equipment, and material costs.

Proactive Maintenance Equals Cost Savings Over Time

Utilizing a consultant, hiring an inspector, and training staff to inspect GSI practices will help identify maintenance needs. If inspections are infrequent, more serious issues can develop. Routine maintenance will prevent larger, more costly non-routine maintenance later.

Figure 6.



Photos Credit: City of Annapolis, MD

The example shown in Figure 6 makes the economic case for routine maintenance. The photo at left shows the failed bioretention practice, clogged with sediment and standing water at the time of county inspection. No routine maintenance had been performed for 3 years. The cost of soil media replacement and replanting for this neglected practice was \$42,890. The photo at

the right illustrated the same practice after renovation. The routine maintenance costs (including regular sediment removal) following renovation for 3 visits per year were \$885 / visit or \$2655 annually, or \$7,965 for 3 years of maintenance.

This represents net savings over 3 years of \$35,015.

Estimating Maintenance Costs

The reality of most GSI maintenance programs is that there is usually a gap between what resources are needed for maintenance, and what resources are available. When managers accurately track maintenance costs and labor hours and develop production factors for estimating, they can better estimate costs and compare those estimated costs with actual budget numbers. This process will help to make the case for increased funding in the future and can inform how to best utilize limited resources in the present.

This may be carried a step further by tracking labor hours and costs for specific maintenance tasks. Understanding the total number of hours spent maintaining a practice on an annual basis is important, but no two GSI practices are the same. So, while understanding the total number of hours and costs associated with a GSI practice is very helpful, being able to accurately estimate and forecast maintenance costs and labor hours based on maintenance tasks specific to elements in a GSI practice can be useful when developing budget costs. **Table 8** lists several common bioretention routine maintenance tasks and production factors associated with maintaining them. These factors can serve as a baseline for estimating labor hours, and labor hours can be calculated into costs based on the prevailing wage. Material costs such as mulch and plant replacements, along with any specialized equipment costs can all be added to the estimated labor costs to develop an overall maintenance budget specific to a GSI practice – even when that practice only exists on a plan before it is built and becomes part of the GSI maintenance budget.

Always consider the surrounding conditions such as traffic and proximity of the truck to the work area. Consider how challenges such as accessibility, fencing, and side slopes might impact how materials get into the bioretention area, or how debris will be removed from the bioretention area. Adjust estimated hours accordingly, + 10% to 50%, to allow for these constraints. Managing invasive plants will require more frequent visits and time on site for removal and management.

When developing a maintenance estimate, if you are unsure about specific site conditions such as weed density or trash and sediment loads, averaging the different rates for each maintenance task can be a good strategy. These production factors were developed through a combination of field experience trial and error, and research and are intended to be a starting point for maintenance estimates. Actual hours performing these maintenance tasks should be monitored so that adjustments to production factors can be made to match how the maintenance team performs in the field.

Table 8. Routine Bioretention Maintenance Task Production Factors

Routine Bioretention Maintenance Task	Production factor
Hand weeding and removal, high weed density, overgrown	100 sq. ft. / hour
Hand weeding and removal, medium weed density	200 sq. ft. / hour
Hand weeding and removal, low weed density	500 sq. ft. / hour
Install mulch	1.5 hours / cu. yd.
Pruning and cleanup, woody shrubs small (1 - 2 ft.)	12 plants / hour
Pruning and cleanup, woody shrubs medium (2 - 4 ft.)	5 plants / hour
Pruning and cleanup, woody shrubs large	2 plants / hour
Pruning and cleanup, woody shrub large, rejuvenation	1 plant / hour
Heavy sediment removal from stone rip-rap - remove stones and sediment by hand, re-install cleaned stone	5 sq. ft. / hour
Medium sediment removal from stone rip-rap - remove stones and sediment by hand, re-install cleaned stone	7 sq. ft. / hour
Light sediment removal from stone rip-rap - remove stones and sediment by hand, re-install cleaned stone	12 sq. ft. / hour
Perennial maintenance, cut back foliage by hand and remove	150 sq. ft. / hour
Perennial maintenance, cut back foliage with mechanical trimmers and remove	400 sq. ft. / hour
Perennial maintenance, cut back grasses, small	50 plants / hour
Perennial maintenance, cut back grasses, medium	25 plants / hour
Perennial maintenance, cut back grasses, large	9 plants / hour
Light sediment removal from ponding surface (<.50")	225 sq.ft. / hour
Medium sediment removal from ponding surface (.50" – 1.0")	125 sq.ft. / hour
Heavy sediment removal from ponding surface (1.0" - 2.0")	50 sq.ft. / hour
Light sediment removal from a smooth surfaced sediment forebay (<.50")	350 sq. ft. / hour
Medium sediment removal from a smooth surfaced sediment forebay (.50" – 1.0")	300 sq. ft / hour
Heavy sediment removal from a smooth surfaced sediment forebay (1.0" - 2.0")	250 sq. ft. / hour
Remove trash from bioretention area, low trash density, rural area	8500 sq. ft. / hour
Remove trash from bioretention area, medium trash density, more urban areas	4250 sq. ft. / hour
Remove trash from bioretention area, high trash density, city areas, commercial zones	2125 sq. ft. / hour

Always consider the surrounding conditions such as traffic and proximity of the truck to the work area. Consider how challenges such as accessibility, fencing, and side slopes might impact how materials get into the bioretention area, or how debris will be removed from the bioretention area. Adjust estimated hours accordingly, + 10% to 50%, to allow for these constraints. Managing invasive plants will require more frequent visits and time on site for removal and management.

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Section 5. GSI Workforce, Training, Recruitment, Retention

The challenges of hiring, retaining, and training a GSI workforce were highlighted in the survey and focus group interviews. Related to this, many contractor participants noted additional challenges with client expectations of costs and outcomes, and reluctance to pay for routine and ongoing maintenance – with much higher costs accrued later on to rehabilitate failing practices.

An achievable business model for those who install and maintain practices is a must if GSI is to be a successful enterprise for government agencies, contractors, and communities.

Table 9 lists some challenges noted in the survey and focus groups, as well as ideas and workarounds used by some. This is not an exhaustive treatment of the whole GSI workforce issue, as it is a complex, market-driven issue with many public and private components. This table at least provides ideas to consider for some of the most common challenges. Below the table, we provide some case studies about organizations that have had success with volunteers and non-profit partners engaged on the O&M responsibilities.

Table 9. Common Workforce-Related Challenges in GSI Maintenance

Challenge	Ideas
Low bid procurement can result in unqualified contractors	<ul style="list-style-type: none"> • Pre-qualifying or qualifications-based procurement (as authorized by procurement rules). Can be more expensive, but better results. • Partnering with qualified non-profits for some of the more skilled tasks; use contractors for “heavy lifting,” mowing, etc. • Diversify contractors, e.g., big vs. small, specialized vs. general.
Willingness to pay for routine maintenance; preventative vs. reactive maintenance (pay now or pay more later)	<ul style="list-style-type: none"> • Data and case studies to demonstrate deferred maintenance costs more in the long run. • Demonstrate efficiency in terms of time and cost of seasonal maintenance visits compared to annual or less frequent.
Being able to offer competitive wages for more complex type of landscaping	Provide consistent (year-round) work schedules, more stability.
High turnover	<ul style="list-style-type: none"> • Provide career advancement opportunities (applies to contractors and government agencies with in-house crews). • Retention bonuses. • Seasonal training and information on why the GSI practices are important and how they work can motivate workers.

Table 9. Common Workforce-Related Challenges in GSI Maintenance Continued

<p>Shortage of qualified decision-makers in the field – someone who can ID maintenance priorities for the crew</p>	<ul style="list-style-type: none"> • Development of standard operating procedures (SOPs) for different tasks. • Prioritize functional maintenance; aesthetic as possible (relates to Level of Service in Section 2). • Advancement from within the crew. • Trainings, such as those offered by the Chesapeake Bay Landscape Professional (CBLP) program • Provide QR Codes posted at site with link to design and maintenance plans.
<p>Lack of public understanding and support for more expensive GSI maintenance and value of GSI</p>	<ul style="list-style-type: none"> • Partner with NGOs that can be trusted voice in the community. • Take decision-makers on field trips
<p>Recruitment</p>	<ul style="list-style-type: none"> • Recruit from workforce programs and allied non-profits (see Howard EcoWorks case study below). • Recruit people who are already in the field (e.g., traditional landscape firms). • Be honest about nature of work; find people who want to be outside, working with plants. • Some contractors find that recruitment from high school level more successful than college grads.
<p>Qualified workforce</p>	<ul style="list-style-type: none"> • Training such as those provided through the CBLP program. • Trainings in multiple languages. • Seasonal training at the actual sites where the crews are working. Focus on season-specific tasks. • Gather team members from all levels of an organization (e.g. designers, engineers, maintenance teams) for training, as sharing of perspectives and experiences can lead to better solutions.
<p>Designs that are more maintainable (see also Section 3)</p>	<ul style="list-style-type: none"> • Involve multiple departments (e.g., local gov't) at design stage to weigh in on “maintainability,” even assigning maintainability score. • Communication between responsible parties and contractors to make practices more maintainable through adaptive management.

CASE STUDIES - Using Volunteers to Assist with GSI Maintenance

Our focus groups turned up several programs that have made productive use of volunteers. Two of these are profiled in this case study.

Capital Trees, Richmond, VA

Capital Trees is a non-profit that is “dedicated to transforming Richmond, Virginia, through the power of public greenspaces.” The organization is involved with tree planting and maintenance of green infrastructure practices on public land, including the highly visible “Low Line,” a large, landscaped area along the Kanawha Canal and Virginia Capital Trail (The Low Line - Capital Trees, 2025). This work is a collaboration between Capital Trees, the City of Richmond, and CSX, the entity that owns the railroad trestle above the Low Line.

After the initial, very ambitious planting, the area quickly became overgrown due to lack of maintenance. That’s when Capital Trees stepped in. Much of the work to rehab and continue to maintain the area is done by 10-15 volunteers who participate in the weekly Wednesday work days. This effort is supplemented by special community volunteer events, some coordinated by the local community foundation, the combined efforts totaling 800 to 1,100 volunteer hours on an annual basis. All of this has paid off in terms of the function and aesthetics of the landscape.

According to Mary Petres, who manages the program, and who has a contracting and landscape design background, some of the key elements of the program include:

- The regularity of the weekly volunteer sessions with a corps of “regulars” that have come to enjoy each other’s company, adding a social element to the experience.
- Coordinating the pruning, planting, and weeding work of the volunteers with the heavier tasks that require outside contractors. Mary notes that most of these contractors don’t have the skills to perform detailed plant care, so are involved with more of the “heavy lifting,” under Mary’s careful supervision.
- All volunteers are provided with hands-on training at the actual sites. Over time, a corps of leaders has emerged from the group.
- Adhering to Mary’s admonition: Don’t install what can’t be maintained, and an understanding that regular maintenance is more cost-effective in the long run.
- Careful record-keeping on work hours, costs, tree survival rates, and other factors, inform their approach for tasks such as tree planting and maintenance.

The steady, organized, data-driven approach and making the experience rewarding for the volunteers are elements that have contributed to the success of this program.

M-NCPPC Department of Parks & Recreation, Prince George's County, MD -- M&T Bank

Another example of creative and effective volunteer engagement is observed within the Maryland-National Capital Park and Planning Commission, Department of Parks and Recreation in Prince George's County (M-NCPPC). As described by M-NCPPC's Environmental Sustainability Coordinator Lauren Belle, the agency established a partnership with M&T Bank to support the maintenance of Best Management Practices (BMPs) across multiple M-NCPPC-owned sites throughout the county.

By aligning the bank's employee volunteer program with agency maintenance needs, this collaboration leverages private-sector volunteer hours to address operational priorities. Within this framework, M-NCPPC provides structured, site-based training to volunteers, enabling them to perform routine maintenance activities such as invasive plant management, litter removal, planting, and mulching. This approach supports maintenance at sites that may otherwise receive limited attention due to resource constraints.

Although such partnerships require coordination and administrative oversight, they have proven to be an effective mechanism for extending maintenance capacity. As noted by Belle, the collaboration has yielded measurable benefits by augmenting departmental resources while fostering private-sector engagement in environmental stewardship. Also, the M&T Bank employees enjoy working outside and learning about how these practices protect the local waterways and Chesapeake Bay.

CASE STUDIES - Non-Profits Playing a Role in GSI Maintenance

Among the organizations that responded to the GSI maintenance survey and participated in the focus groups, there were a handful of non-profits that took a very active role in both calling attention to the importance of maintenance AND doing some of the actual labor to maintain local practices. Many of these programs include a workforce development element, which serves as an important co-benefit while offering critical support for maintenance. These types of partnerships between local government (or other types of BMP owners) and local non-profits are not widespread, but calling attention to this model seems important as another creative avenue for ensuring effective GSI maintenance. Two programs are profiled below, followed by some key lessons learned.

Alliance for the Chesapeake Bay, Washington, DC

The Alliance for the Chesapeake Bay launched a project in 2021 called "Maintaining Stormwater Practices in the Anacostia Watershed," Intended to remedy deficiencies in maintenance for many of the BMPs funded through local government cost-share programs, such as RiverSmart Homes (D.C.), RainScapes (Montgomery County, MD), and Rain Check Rebate (Prince George's County, MD).

The hallmarks of the project are to bring awareness to the importance of maintenance, offer technical and financial assistance for homeowners and contractors to conduct needed maintenance, and create a network of support to conduct these tasks.

The Maintaining Stormwater Practices in the Anacostia Watershed program promoted long term maintenance through four strategies:

- Stormwater Maintenance Resource Center: a virtual maintenance resource site that offers BMP installation and maintenance resources, photos and videos, and virtual assistance through a help desk feature for residential property owners.
- Free BMP Inspections: a certified CBLP pro conducts a site assessment and provides a written report of maintenance recommendations.
- Cost-share Maintenance Service: property owners are paired with a contractor to learn proper maintenance techniques with 75% of maintenance cost (up to \$1,000). Homeowners participate in maintenance alongside the contractor.
- Green Ambassador Program: a neighborhood volunteer program that provides peer-to-peer support through maintenance days, information sharing, and hands-on learning experiences.

The outreach was multi-faceted, with project staff working closely with the local governments to coordinate maintenance and outreach. One key element was using certified Chesapeake Bay Landscape Professionals inspectors to work directly with BMP owners, explain the intended purpose and function of the BMPs, and provide guidance on needed maintenance tasks. CBLP also assisted property owners and small local contractors through educational hands-on maintenance work on participating program BMPs.

The Alliance for the Chesapeake Bay also led a 2022-2025 project in which they directed GSI maintenance for the DC Department of Energy and Environment (DOEE), serving as a liaison between the agency and four contractors who were hired to perform inspections and routine maintenance for over 400 GSI practices on public land. The Chesapeake Conservation Landscaping Council provided custom, seasonal training at sites managed by these contractors. All contractor staff completed CBLP-Crews BMP maintenance training, as well as training on maintenance topics such as decision-making, plant identification, pruning techniques, and inlet maintenance. CBLP offered workforce development opportunities by training crew members on maintenance techniques specific to the BMP sites under their responsibility.

Figure 7.



Photo credit: Chesapeake Conservation Landscaping Council.



Photo credit: Jordan Gochenaur, Alliance for the Chesapeake Bay.

The photo at left shows contractors participating in field training led by CBLP professionals. At right, crews prepare for maintenance at DC GSI practices.

Howard EcoWorks

Howard EcoWorks is a multi-faceted non-profit that designs, installs, and maintains many types of GSI practices in central Maryland (Howard EcoWorks, 2024). These activities are paired with a strong workforce development program, partnering with a wide range of workforce agencies, HOAs, governments agencies, and private property owners. Some typical tasks include installing and maintaining rain gardens and conservation landscapes, conducting invasive management for forest restoration and tree planting projects, and exploring innovative approaches, such as use of biochar in the practices. Since 2021, EcoWorks has provided direct service to Howard County under a grant agreement to maintain some larger stream restoration projects (e.g., pruning, invasives management, tree shelter maintenance). Workforce elements drive the organization. Their offerings include:

- UPLIFT – A 10-month work development program, focusing on unemployed or underemployed individuals with an interest in entering the green industry. Participants get hands-on experience working with sustainable landscapes and receive a variety of industry trainings and certifications (e.g., CBLP-Associate, First Aid/CPR, OSHA). The program has a strong track record of placing participants in permanent jobs through ongoing relationships with landscape contractors and local governments.
- READY – A 2-month summer green career exploration program geared to young adults. Participants also receive some of the trainings and certificates noted above.
- EcoAmbassadors – A 2-month paid summer internship geared to high school students that supports leadership development and community action projects.

EcoWorks has expanded over the years to include services contracted by local governments and community colleges, fee-for-service options for HOAs and other organizations, and grants to help with outreach to properties managed by faith communities, HOAs and other organizations.

Figure 8.

Howard EcoWorks participants plant a rain garden.
Photo Credit: Howard EcoWorks



Some Key Lessons Learned from Non-Profit Partnerships

A few key take-homes from these programs include:

- Local governments partnering with non-profits can be a very constructive model. In many ways, the non-profit can do things more efficiently (e.g., procurement, training) and are seen as more approachable by citizens and neighborhood associations.
- Training of contractor crews that takes place at the actual sites where they work is extremely impactful, providing a hands-on learning approach, and the lessons-learned seemed to stick, as evidenced by the improved conditions of the BMPs. At first, maintenance tasks at many sites were overwhelming because they had been largely untouched since installation. Once the contractors got them under control, maintenance work was more routine.
- For groups with relatively small crews, maintaining rain gardens and conservation landscaping is one thing, but it is a much broader challenge to maintain larger-acreage restoration projects. More specific guidance from the partnering local government would be helpful to allow these crews to effectively prioritize work activities at any given site.
- On the topic of guidance, the non-profits involved in GSI installation and maintenance noted the importance of standard operating procedures for specific tasks. This helps crews prioritize tasks and know what the benchmarks of success would be.
- It can be a challenge to recruit people to do this type of work (a common theme among contractors). The most successful workers are those who enjoy being outside, getting their hands dirty, are mission-driven for environmental work, and are interested in using the experience to move to higher-level positions.
- Creating an effective training-to-employment pipeline is a critical element of these programs and requires much more than technical training. That's where partnering with local workforce agencies to provide specialized wrap-around services (e.g., transportation, childcare, health care, counseling) is important.
- While not all regions may have a local non-profit that can play this role, there are ways – big and small – to cultivate the government/non-profit relationship, perhaps beginning with outreach to citizens and evolving to more hands-on activities.

Chesapeake Bay Landscape Professional (CBLP) Certification & Training Program

CBLP was developed by a consortium of partners including CCLC, University of Maryland Sea Grant, Penn State Extension, Wetlands Watch, and the Virginia Department of Wildlife Resources to provide high-quality, consistent training on green infrastructure and conservation landscaping across the Bay watershed. CBLP provides a two-level professional credential as

well as certificate courses on BMP maintenance, riparian buffers, and living shorelines. The CBLP program also offers an entry-level certificate for young adults and early career workers called CBLP-Associate, and custom and advanced training workshops. CBLP classes are held throughout the year at various locations, with the ultimate goal of raising the standard of practice across the region. <https://cblpro.org/>

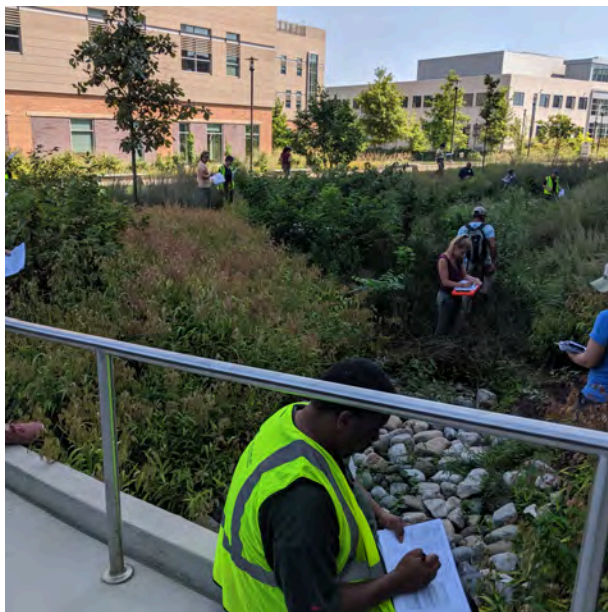


Figure 9.
CBLP Level 1 classes visit and inspect GSI practices
Photo credit: Chesapeake Conservation Landscaping Council

Section 6. Looking Ahead -- The Future of GSI Maintenance

Compared to other sectors, GSI remains a hands-on, largely low-tech industry with high reliance on people with specialized skills in horticulture, design, and engineering. In fact, many people likely seek refuge in this industry for precisely these reasons.

As with all things, changes are inevitable – some thrust upon us by a changing climate, regulations, and budget realities. Others will allow more efficiency due to technology advances. We cannot see today what has yet to be imagined, but the list below represents continuations of existing trends.

- **Rising Challenges of Resiliency** - Changing climate patterns with more extremes on both the dry and wet side will continue to challenge GSI and vegetated practices in general. With more extreme and intense rainfall, more attention will need to be focused on redundant systems in BMP designs, whereby if one component fails, others can take up the slack. Systems need to be designed, more so than currently practiced, to have defined and safe overflow routes when practices become clogged and/or overflow more frequently. These components will require more monitoring and inspection (remotely or in-person) as well as maintenance to sustain function and performance.
- **Salty Practices** – Snow accumulation may diminish with the changing climate, but winter sleet and ice will persist, leading to continued use of road salts. Vegetated practice designs will need to adapt to higher salinity levels in runoff, and a more important reckoning about the impacts of salt on water bodies.
- **“SMART” BMPs Continue to Evolve** -- Continuous Monitoring and Adaptive Control (CMAC) systems use real-time weather forecast data to directly monitor and make automated and predictive control decisions to manage stormwater storage and flows within a BMP. This can be applied to pond outlets, underdrain flow, or other types of outlets, with the goal of maximizing storage compared to passive structures (e.g., outlet orifice sized based on engineering calculations). This type of system will undoubtedly continue to evolve and become accessible for a wider range of practices. Maintenance protocols will have to include the sensors and electronic and mechanical components involved.
- **Modular Systems & Technologies** – Today’s stormwater market is already characterized by many modular systems. As long as there is regulatory pressure to implement GSI, there will continue to be an evolution of materials and systems in a competitive marketplace. Management will be influenced by sensors (e.g., soil moisture, flow, temperature, etc.), drones and remote sensing to monitor things like plant coverage and health, invasives, and other items related to BMP performance. No doubt, AI models will come into play. Apps will be developed to better track time and budgets related to maintenance.
- **Workforce of the Future** – Much has been made of the need for an enhanced workforce specializing in GSI. As employment markets continue to shift and change, it is likely that GSI alone will not be a large enough sector to substantiate a large workforce but could be combined with other infrastructure design and maintenance fields to create a cadre of “urban technicians.” The current trends of workforce training will diversify, and it is hoped to continue the programs geared towards providing opportunities to a full range of employment-seekers.

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