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Cost-Benefit Analysis of Green Infrastructure at WMATA Stations

COURSE

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Partnership for
Action Learning
in Sustainability



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ABOUT PALS

The Partnership for Action Learning in Sustainability (PALS) is administered by the National Center for Smart Growth at the University of Maryland, College Park (UMD). It is a campus-wide initiative that harnesses the expertise of UMD faculty and the energy and ingenuity of UMD students to help Maryland communities become more environmentally, economically, and socially sustainable. PALS is designed to provide innovative, low-cost assistance to local governments while creating real-world problem-solving experiences for University of Maryland graduate and undergraduate students.

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1. Executive Summary

WMATA operates across the District of Columbia, Maryland, and Virginia, each of which has its own stormwater rules. Compliance with these rules is required whenever WMATA undertakes major construction projects. The question is therefore not whether WMATA must comply, but which compliance option is most practical and cost-effective at a given station.

This report compares green infrastructure (GI) with two alternatives: gray infrastructure, such as underground stormwater vaults, and off-site compliance, such as purchasing credits in D.C.'s Stormwater Retention Credit (SRC) market. GI includes bioswales, rain gardens, bioretention, and street planters. Unlike gray infrastructure or credit purchase, GI can also provide co-benefits, including reduced localized ponding, modest local cooling, and improved station appearance and rider experience. These benefits are treated qualitatively rather than monetized. The analysis combines a regulatory review, flood-risk screening from the TPB Climate Change Vulnerability Assessment, EPA National Stormwater Calculator modeling, and benchmark cost data.

Five stations were selected for analysis: Benning Road, Archives–Navy Memorial–Penn Quarter, King St–Old Town, Deanwood, and West Hyattsville. They were chosen from a flood-ranked set of WMATA stations using a qualitative filter that also considered reported drainage problems, site suitability for GI, jurisdiction, and equity. They are therefore not simply the five highest-risk stations, but a comparative group suited to testing where GI may be useful.

The findings show that GI improves stormwater performance at all five stations. Increasing GI coverage reduces annual runoff, increases wet-day retention, and raises the amount of rainfall a site can hold before runoff begins. The strongest modeled gains appear at Benning Road, Deanwood, and West Hyattsville, where the largest scenarios reduce annual runoff by roughly 80 percent and raise wet-day retention to about 87 to 88 percent. Archives and King Street also improve, but more modestly because of site constraints and smaller modeled interventions.

GI's value depends on jurisdiction and site conditions. D.C. provides the clearest market benchmark through SRCs. Maryland makes distributed GI the preferred starting point under ESD-to-MEP, though WMATA's project-level use of nutrient

credits should be confirmed case by case. Virginia relies more on numeric phosphorus standards than a credit market.

The report recommends prioritizing GI where on-site retention has legal value, the site is physically suitable, and modeling shows strong performance. Benning Road is the highest priority, followed by Deanwood and West Hyattsville. Archives should be pursued through coordination with area partners, while King St–Old Town is best suited for studying and expanding existing street planters. Overall, GI should be used selectively as a site-specific compliance tool, with additional co-benefits that are not provided by other compliance options.

2. Introduction and Background

2.1 THE POLICY PROBLEM

WMATA operates a large transit system across the District of Columbia, Maryland, and Virginia. Many WMATA properties include extensive paved surfaces and conventional landscaped areas. These areas provide limited stormwater value while still generating ongoing operations and maintenance costs. When WMATA undertakes construction, reconstruction, or other land-disturbing activity, those projects may trigger stormwater requirements imposed by the local jurisdiction. Site design and landscaping choices therefore shape how WMATA satisfies its legal obligations and at what cost.

WMATA's system is highly impervious, rainfall intensity is increasing, and stormwater rules across the region are tied to broader water-quality and runoff-control goals. Converting some areas of existing landscape to green infrastructure could allow WMATA to meet jurisdictional requirements more efficiently. That is only true, however, where site conditions and governing rules make the approach feasible.

Thus, the question that this report seeks to address is: At WMATA stations, which stormwater compliance pathway delivers required regulatory outcomes most cost-effectively, and under what site and jurisdictional conditions? Cost-benefit analysis informs where WMATA should prioritize green infrastructure relative to the principal alternatives — gray infrastructure and the purchase of third-party credits — recognizing that green infrastructure also carries co-benefits that the other compliance options do not.

2.2 WHY GREEN INFRASTRUCTURE IS OFTEN NOT OPTIONAL

Stormwater obligations in WMATA's service area are anchored in the Clean Water Act's NPDES framework, which includes construction stormwater permitting and MS4 requirements. The practical design obligations are imposed through state and local rules. For capital projects, the first trigger is land disturbance. Once that trigger is met, the controlling question becomes what the relevant jurisdiction requires the project to install or achieve. In all three jurisdictions reviewed here, the governing frameworks effectively make distributed site-level stormwater practices a default starting point rather than an optional add-on, and in some

jurisdictions green infrastructure must be implemented to the maximum extent practicable before other compliance pathways may be used. Cost-benefit analysis therefore plays a narrower role than it might otherwise. It does not determine whether WMATA must comply. It informs which compliant pathway delivers the required outcome at the lowest cost or greatest practical value at a given site.

2.3 JURISDICTIONAL FRAMEWORK

WMATA's service area spans three different stormwater-management regimes. These differences matter because they determine both what WMATA must do at a site and how any compliance value from green infrastructure can be measured.

In the District of Columbia, the dominant local driver is the Stormwater Retention Volume requirement for major regulated projects, based on a 1.2-inch rainfall event (District of Columbia Department of the Environment, 2014). The requirement effectively obliges substantial on-site retention, with limited off-site flexibility. D.C. also operates a formal Stormwater Retention Credit program. Credits can be used to satisfy the off-site portion of a project's retention obligation. Each credit represents one gallon of stormwater retention capacity for one year, and prices are privately negotiated rather than fixed. D.C. provides the clearest example in WMATA's service area of a market-based compliance mechanism tied directly to retention obligations.

In Maryland, including Prince George's and Montgomery Counties, the central requirement is Environmental Site Design to the Maximum Extent Practicable (ESD to MEP). Maryland's regulations emphasize maintaining predevelopment runoff characteristics through distributed site design and small-scale practices before resorting to structural BMPs (Maryland Department of the Environment, 2020). Under this framework, distributed green infrastructure is the preferred starting point and must be used to the maximum extent practicable before other compliance pathways are pursued. Nutrient-credit pathways exist in Maryland and are generally preferred at larger scale where on-site infrastructure is not practical. The extent to which WMATA can rely on nutrient trading for project-level compliance, as distinct from MS4-permittee-level flexibility, should be confirmed on a project-specific basis. The Maryland framework is also shaped by county MS4 permits and Chesapeake Bay TMDL obligations for nitrogen, phosphorus, and sediment, with tools such as CAST used to estimate pollutant reductions.

Virginia, particularly Fairfax County, uses a phosphorus-based post-construction standard. For plans submitted on or after July 1, 2025, new development projects must meet a total phosphorus load standard of 0.26 pounds per acre per year, calculated under the Virginia Runoff Reduction Method (Virginia Department of Environmental Quality, 2024). Virginia has fewer specific requirements for green infrastructure as a best management practice than the other two jurisdictions, and compliance is determined through the state's runoff-reduction method and the Virginia Stormwater Management Handbook rather than through a D.C.-style retention-credit market. WMATA stations in Virginia also tend to fall under more specific local jurisdictional requirements; the City of Alexandria, Arlington County, and the City of Fairfax operate on separate MS4 permits. The Virginia portion of this analysis must therefore focus more on comparing BMP strategies that satisfy a numeric water-quality target than on comparing observed credit prices.

Across all three jurisdictions, the Chesapeake Bay TMDL and MS4 permits provide an important regional backdrop. They translate water-quality goals for nitrogen, phosphorus, and sediment into enforceable local obligations.

2.4 ALTERNATIVE COMPLIANCE PATHWAYS

WMATA's decision is rarely green infrastructure or nothing. Three pathways serve as the principal counterfactuals in this report. The first is on-site green infrastructure or distributed ESD practices. The second is gray or structural stormwater infrastructure. The third is off-site or market-based compliance, where the governing jurisdiction allows it.

On-site green infrastructure is embedded in Maryland's ESD-to-MEP framework. It is the primary means of satisfying D.C.'s Stormwater Retention Volume requirement. It also functions as a compliance tool in Fairfax County so long as it meets the required phosphorus outcome under VRRM. Gray or structural infrastructure, including underground vaults, filters, and detention systems, becomes more relevant where space constraints, soil conditions, utility conflicts, or other site limitations make distributed green practices infeasible. For a transit agency that often operates in constrained station environments, gray infrastructure may serve as the next-best compliant alternative when GI cannot practicably achieve the required outcome.

Off-site or market-based compliance is most clearly developed in D.C., where projects may satisfy the allowable off-site portion of their stormwater obligation

through SRC purchase. Maryland presents a more developed nutrient-credit context than Virginia, but one whose direct project-level applicability to WMATA is less clearly established than D.C.'s SRC market. County MS4 permits allow nutrient-credit acquisition in specific contexts, and credits are generally preferred at larger scale where on-site infrastructure is impractical; however, the public record reviewed here does not clearly establish that WMATA can directly rely on nutrient trading for project-level compliance in the same straightforward way as in D.C. In Fairfax County, off-site compliance options exist in some materials but their precise applicability to WMATA projects requires case-specific confirmation. These distinctions shape the cost-benefit comparisons that follow. In D.C., the clearest counterfactual for a constrained site is SRC purchase. In Maryland and Virginia, the dominant comparison is more often between distributed GI and alternative structural BMPs.

3. Flood Risk as a Site-Screening Factor

3.1 WHY FLOOD RISK IS INCLUDED BUT NOT MONETIZED AS THE MAIN GI BENEFIT

Green infrastructure can improve stormwater retention and water quality at WMATA stations, but it is not a flood-mitigation tool in the structural sense. Interview evidence from WMATA staff indicates that bioswales and similar practices do not materially reduce flooding vulnerability at WMATA facilities. Underground stormwater vaults serve that function. Flood risk is therefore used in this analysis as a site-screening and context factor rather than as a benefit stream for the cost-benefit analysis. It helps explain why certain stations are analytically important and how flood exposure affects which compliance pathway is appropriate at a given site.

It is also important to distinguish modeled flood risk from reported operational flooding. The screening data described below model regional inland-flooding exposure under current and future climate scenarios. They do not capture every localized drainage or flooding problem that WMATA experiences in practice. A station can register low modeled flood depth while still presenting real, on-the-ground stormwater issues reported by WMATA staff. Both types of information informed site selection, as described in Section 5.1.

3.2 TPB VULNERABILITY FRAMEWORK

The flood-risk screening draws on station-level data from the National Capital Region Transportation Planning Board's 2023 Climate Change Vulnerability Assessment (Metropolitan Washington Council of Governments, 2023). The assessment scores transportation assets across the region for vulnerability to four climate hazards: extreme heat, FEMA-informed inland flooding (reflecting current conditions), Fathom-informed inland flooding (forward-looking and climate-adjusted), and sea level rise. For each hazard-asset pair, TPB scored exposure and criticality on a scale of 0 to 3 and combined them as $\text{Risk} = (\text{Exposure} \times 0.7) + (\text{Criticality} \times 0.3)$. The resulting scores are classified as High (2.5 to 3.0), Medium (2.0 to 2.49), Low (0.01 to 1.99), or Not Exposed (0). Criticality reflects functional classification and whether an asset is located in one of COG's Equity Emphasis Areas. Equity Emphasis Areas are census tracts with high concentrations of low-income individuals or traditionally disadvantaged racial and ethnic groups.

The Fathom-informed inland flooding layer is the most relevant for this analysis because it is forward-looking. FEMA floodplain maps reflect historical flood probabilities. The Fathom dataset uses Shared Socioeconomic Pathways from CMIP6 to model future flood risk across multiple time horizons and emissions scenarios. This analysis uses the 2020 historical horizon and the 2030 horizon under both the lower-emissions SSP2-4.5 and higher-emissions SSP5-8.5 scenarios. At the 2030 horizon, the two emissions scenarios produce nearly identical results for the stations reviewed. TPB's documentation states the results are preliminary and not for planning use, so this analysis treats them as a screening tool rather than as engineering input.

3.3 STATION-LEVEL FLOOD EXPOSURE

Five stations were selected from the broader ranked group described in Section 5.1: Benning Road, Archives–Navy Memorial, King St–Old Town, Deanwood, and West Hyattsville. The set was drawn from stations ranked by Fathom-informed 2030 flood risk and then narrowed through a qualitative assessment that combined flood relevance with reported drainage problems, site suitability, jurisdiction, and equity. The result is a set that captures variation across these dimensions rather than the five single highest-scoring stations on flood risk alone.

Benning Road is the strongest present-day flood-exposure case. Although it is not in a mapped FEMA flood zone, its Fathom-informed risk score is 2.65 in both 2020 and 2030, placing it in the High band. It is the only High score in the selected set. Modeled flood depths reach approximately 16 feet in the 100-year event and more than 22 feet in the 500-year event, with essentially no change between horizons. Benning Road is also in an Equity Emphasis Area, which raises the criticality side of the framework.

Archives–Navy Memorial is the clearest worsening-near-term case. Its risk score rises from 1.35 to 1.70, remaining in the Low band but moving toward Medium. The shift is driven by the 500-year scenario, where modeled flood depth increases from about 5.9 feet in 2020 to roughly 13 to 14 feet in 2030. The 100-year scenario remains dry.

King St–Old Town functions as a lower-risk comparison station on the modeled data. It falls within the FEMA differential buffer but not within the mapped floodplain proper. Its Fathom-informed risk score is 0.65 in both 2020 and 2030, with zero modeled flood depth at the station point under the reviewed scenarios. As noted

in Section 3.1 and developed in Section 8.2.1, however, WMATA staff report drainage and flooding issues at this station attributable to its extensive impervious surface area. Its low modeled score therefore understates its practical stormwater-management relevance.

Deanwood and West Hyattsville show no modeled Fathom flood depth in either horizon. Each receives a Fathom-informed risk score of 1.25, driven primarily by criticality and EEA status rather than by direct inundation. Their relevance to the analysis comes from criticality, equity weighting, and stormwater-management potential rather than from modeled flood depth.

4. Green Infrastructure Types, Performance, and Cost Logic

4.1 RELEVANT GREEN INFRASTRUCTURE TYPES AT WMATA SITES

Green infrastructure refers to stormwater management practices that mimic natural hydrologic processes. Rather than moving runoff quickly into pipes and discharging it downstream, GI captures, slows, filters, and infiltrates runoff at or near where it falls. It does this through a combination of engineered soil media that absorb and filter runoff, vegetation that slows flow and supports evapotranspiration, infiltration that returns water to the ground rather than the storm sewer, and surface storage that holds runoff during peak flows and releases it gradually.

The GI practices most relevant to WMATA contexts are bioswales, rain gardens, bioretention cells, and street planters. These belong to the same general family of stormwater controls. They capture, retain, infiltrate, filter, and slow runoff before it enters the conventional drainage system.

Bioretention is the broadest category. Bioswales are at-grade practices that capture, slow, filter, and infiltrate runoff through engineered soil media and vegetation before it enters the conventional drainage system. Rain gardens and bioretention cells function similarly to bioswales but use a greater depth of engineered soil to retain a greater volume of water; rain gardens are generally small-scale bioretention systems used in landscaped areas, where runoff can be directed into a shallow planted basin. Street planters are a more constrained urban form of bioretention, typically located in the public right-of-way, that use vertical concrete walls, engineered media, underdrains, and curb cuts to manage runoff in dense settings where open at-grade practices are not feasible.

The most important classification point is that street planters should not be treated as a separate BMP family. In regional literature and in District planning materials, planters are treated as a subtype of bioretention. The critical questions for performance are whether a practice infiltrates or merely filters runoff, whether it is lined or underdrained, what media it uses, and how much runoff volume it can capture. Those design features matter more than the facility label.

4.2 HYDROLOGIC PERFORMANCE

GI practices reduce runoff volume, increase retention, delay the onset of runoff, and in many cases reduce peak flow from smaller storms. They do this through temporary storage, infiltration, filtration, and evapotranspiration. They tend to perform best for frequent small-to-moderate storms rather than for the most extreme flood events. The main operational value of GI is improved performance during repeated rainfall events that would otherwise generate nuisance runoff and unnecessary burden on the site drainage system. It is not the elimination of severe flood risk. A bioretention retrofit may reduce annual runoff substantially and increase the share of wet days retained, but it will not by itself solve deep riverine or large-scale urban flood exposure of the kind identified at Benning Road.

Hydrologic performance is also highly design-sensitive. The same general practice category can perform very differently depending on how much runoff area it treats, how much storage depth it provides, whether infiltration to native soils is feasible, whether an underdrain is present, and whether the system is adequately maintained. Site constraints such as utility conflicts, shallow subsurface conditions, contaminated soils, limited footprint, and heavy surrounding imperviousness can all limit retention or infiltration.

4.3 WATER QUALITY AND NUTRIENT-REMOVAL LOGIC

Bioretention-type practices generally perform well for sediment and other particle-associated pollutants because they slow flow, settle solids, and filter runoff through vegetation and engineered media. They provide on-site removal of sediment, nutrients, metals, and hydrocarbons. Total suspended solids performance is often the strongest and most consistent aspect of bioretention. Nutrient performance is more variable and depends heavily on design, hydrology, and media chemistry.

For planning purposes, the most important distinction is not between a rain garden and a planter. It is between systems that function primarily through infiltration and retention and those that function primarily as filtration systems with liners or underdrains. A facility that captures more runoff depth usually provides stronger credited nutrient and sediment reduction than a similar facility that treats a smaller share of runoff, even if both are called bioretention. Fixed pollutant-removal percentages can therefore be misleading. Planning-level values should be treated as illustrative ranges rather than as precise universal rates.

For phosphorus, the key issue is whether the system can either retain phosphorus-bearing runoff on site or remove dissolved phosphorus through sorption in media with adequate phosphorus-binding capacity. Particulate phosphorus is removed effectively with sediment, but dissolved phosphorus can remain mobile unless media are specifically designed to limit leaching. For nitrogen, the highest-removal pathway is typically denitrification, which requires suitable carbon availability and low-oxygen conditions. Internal water storage, underdrain configuration, and hydraulic residence time often matter more than facility label. Further detail on media chemistry and denitrification design appears in technical sources cited in the references.

The practical implication for WMATA is that street planters should generally be treated as a form of bioretention. Many constrained station-front planters, however, are likely to function as lined or underdrained filtration systems rather than as infiltration systems. Their expected nutrient performance should usually be evaluated more cautiously than that of larger at-grade facilities.

4.4 BROAD COST LOGIC

Open bioretention, rain gardens, and similar at-grade systems are generally cheaper than constrained street planters in both capital cost and ongoing maintenance. Open systems are generally simpler to build. They require excavation, engineered media, planting, grading, and inlet or outlet control, but they do not usually require the structural containment of curbside or boxed planters. Planters, by contrast, are often installed where walls, curb modifications, drainage connections, underdrains, reinforced edges, and careful integration with surrounding pavement are necessary.

The same distinction appears in operations and maintenance. Open bioretention requires inspection, weeding, pruning, debris removal, mulch replacement, and occasional plant replacement. Planters often require more frequent sediment and trash removal and may be less forgiving if maintenance is deferred, because they receive concentrated street runoff in a confined footprint. The cost figures used in this report are planning-level values from guidance documents and literature reviews rather than WMATA bid tabs or maintenance records, so their value is comparative rather than budgetary. The main conclusion is that open bioretention is generally the lower-cost form of GI where it is feasible. Constrained planters are a more expensive but sometimes necessary option for dense urban sites.

The comparison between green and gray infrastructure also depends on scale. WMATA staff indicate that gray infrastructure tends to be more cost-effective at larger scales, where its construction is costly and difficult but its per-unit storage cost falls, while green infrastructure tends to be more cost-effective for smaller drainage areas, on the order of less than one acre. This is operational guidance from WMATA staff rather than an independently established engineering threshold, but it is consistent with the broader cost logic: distributed at-grade GI is well suited to smaller, dispersed drainage areas, while large required storage volumes tend to favor structural solutions. The implications of this scale relationship for the choice between GI, gray infrastructure, and credit purchase are developed further in Section 6.

5. Site Selection and Quantitative Scenario Analysis

5.1 SITE SELECTION METHODOLOGY

WMATA stations were screened using the TPB Climate Change Vulnerability Assessment and related flood-screening information, with all stations ranked according to their Fathom-informed 2030 inland-flooding risk score. From that ranked set, five stations were selected through a qualitative assessment that weighed flood risk alongside several other considerations: reported drainage problems, site suitability for green infrastructure, jurisdictional variation, and equity. Flood-risk ranking alone does not determine whether GI is a realistic compliance or runoff-management option at a given station, so the ranking served as a starting point rather than the sole selection criterion.

Reported drainage problems were drawn from information provided by WMATA, including interviews with WMATA staff, and helped distinguish stations with practical, on-the-ground stormwater issues from those whose relevance rested only on modeled risk. Stations identified through the flood ranking and this operational information were then visually examined using satellite imagery, street view, and in some cases site visits. Considerations included jurisdiction, land cover, available open space, surrounding impermeable surfaces, adjacent buildings, drainage context, soil conditions inferable from FEMA and related tools, and the presence of existing features such as trees, green roofs, or other green infrastructure.

This screening process excluded several flood-relevant stations that were poorly suited to GI implementation. Federal Center, Smithsonian, Capitol South, Shaw–Howard U, and Metro Center all presented major practical constraints. These included highly urbanized surroundings, limited landscape area, existing streetscape features, heavy pedestrian traffic, and the likelihood that new GI would be difficult both to construct and to maintain. In some locations, existing features already occupy the limited available space, and substantial coordination with jurisdictional or federal partners would be required.

The five-station set is therefore best understood as a flood-ranked set narrowed by a qualitative suitability and equity filter. The goal was to identify stations that

together capture variation in flood exposure, jurisdiction, baseline site conditions, and modeled GI performance, while still representing places where GI could plausibly be analyzed as a realistic compliance or runoff-management pathway.

5.2 EPA SCENARIO MODELING AND QUANTITATIVE COMPARISON

The station analysis relies on scenario modeling derived from the EPA National Stormwater Calculator (EPA NSC; U.S. Environmental Protection Agency, n.d.). For each station, the modeling compares approximated baseline conditions with a set of GI intervention scenarios. The purpose is comparative rather than exact. Site area was estimated to create a reasonable modeled footprint, and land cover was visually approximated rather than derived from parcel-level engineering plans. The modeling shows the potential improvement in stormwater management that could result from increasing the share of impervious surface treated by GI. It does not produce a final design acreage or precise as-built calculation.

The modeled scenarios report the same core hydrologic measures for each station: average annual runoff, days per year with runoff, percent of wet days retained, and maximum rainfall retained before runoff begins. Planning-level capital and annual maintenance cost ranges are also reported for the intervention cases. These figures are not site-specific construction bids. Their value is in supporting comparative reasoning across stations and scenarios.

5.3 STATION SCENARIO STRUCTURES

The interventions modeled vary by station. Benning Road, Deanwood, and West Hyattsville each include both rain garden and street planter scenarios at 25, 51, and 100 percent coverage. Archives is modeled only with street planters at 10, 20, 30, 40, 50, and 60 percent. King Street models increases from its existing 20 percent street planter baseline to 30, 40, and 50 percent. This variation avoids imposing a single design on all sites and allows comparison of how different types and scales of GI perform under different conditions.

Treatment sizing for a 1.2-inch storm in the EPA NSC is based on a ratio of GI area to impervious area treated. The scenarios used here standardized that relationship using the tool's recommendations: approximately 5 percent GI area relative to treated impervious area for street planters and 8 percent for rain gardens. The resulting percentages should be understood as modeled treatment

levels built from a common planning assumption rather than as final design prescriptions.

5.4 BASELINE CONDITIONS

All five stations begin with high imperviousness and weak hydrologic performance. The table below summarizes baseline metrics. Station context (jurisdiction, EEA status, flood-risk profile) is described in Section 3.3. The following table shows baseline conditions of the five stations studied using the EPA National Stormwater Calculator. King Street's baseline reflects its existing condition, which already includes approximately 20 percent street planter coverage

Average annual runoff at the modeled stations ranges from 28.01 inches at King Street to 37.39 inches at West Hyattsville. Wet-day retention ranges from 15.59 percent at Archives to 21.27 percent at King Street. Maximum rainfall retained before runoff begins ranges from 0.46 inches at Archives to 0.81 inches at Benning Road. These conditions confirm that existing landscapes at these stations are not functioning as effective stormwater controls.

5.5 MODELED PERFORMANCE RESULTS

Across all five stations, modeled GI reduces average annual runoff relative to baseline. The strongest absolute reductions appear at the largest and most impervious sites. The strongest percentage reductions appear under the most aggressive scenarios at Benning Road, Deanwood, and West Hyattsville. At maximum modeled coverage, these three stations show annual runoff reductions on the order of 80 percent. Table 1 summarizes the headline result for each station, comparing baseline conditions with the scenario that produced the lowest modeled runoff.

Table 1. Headline Modeled Performance Results by Station

Station	Best Modeled Scenario	Baseline Runoff (in.)	Final Runoff (in.)	Runoff Reduction	Baseline Wet Days Retained	Final Wet Days Retained	Baseline Max Rainfall Retained (in.)	Final Max Rainfall Retained (in.)
Benning Road	100% street planters	28.78	5.03	82.5%	19.51%	87.70%	0.81	1.80
Deanwood	100% street planters	31.82	5.59	82.4%	16.74%	87.70%	0.51	1.61
West Hyattsville	100% street planters	37.39	7.01	81.3%	16.79%	87.31%	0.59	1.79
Archives–Navy Memorial	60% street planters	33.55	16.94	49.5%	15.59%	41.20%	0.46	1.01
King St–Old Town	50% street planters	28.01	19.31	28.9%	21.27%	32.89%	0.61	0.80

Note: "Best modeled scenario" refers to the scenario producing the lowest average annual runoff in the modeled outputs.

At West Hyattsville, runoff falls from 37.39 inches at baseline to 7.15 inches under rain gardens at 100 percent and 7.01 inches under street planters at 100 percent. At Deanwood, runoff falls from 31.82 inches to 5.68 and 5.59 inches respectively. At Benning Road, runoff falls from 28.78 inches to 5.12 and 5.03 inches. Archives shows steady improvement as planter coverage increases, from 33.55 inches at

baseline to 30.78 (10 percent), 28.01 (20 percent), 25.25 (30 percent), 22.48 (40 percent), 19.71 (50 percent), and 16.94 (60 percent). King Street improves from its existing baseline of 28.01 inches to 25.08, 22.24, and 19.31 inches at 30, 40, and 50 percent.

The percent of wet days retained matters because it captures runoff frequency rather than just total volume. Operational and compliance gains from GI are likely to come primarily from improving performance during repeated smaller storms rather than from capturing rare catastrophic events. At Benning Road, Deanwood, and West Hyattsville, wet-day retention rises from the 17 to 20 percent range at baseline to approximately 87 to 88 percent under the largest interventions. Archives rises from 15.59 percent to 41.20 percent at 60 percent street planters. King Street rises from 21.27 percent at its existing baseline to 32.89 percent at 50 percent planters.

Maximum rainfall retained measures how much rainfall a site can absorb before runoff begins. At Benning Road, it rises from 0.81 inches at baseline to 1.74 inches (rain gardens) and 1.80 inches (planters) at 100 percent. At Deanwood, it rises from 0.51 to 1.55 to 1.61 inches. At West Hyattsville, it rises from 0.59 to 1.64 to 1.79 inches. At Archives, it rises from 0.46 to 1.01 inches at 60 percent planters. At King Street, it rises from 0.61 to 0.80 inches at 50 percent planters. Across the strongest scenarios, the maximum rainfall retained roughly triples relative to baseline, and Benning Road, Deanwood, and West Hyattsville approach or exceed the first inch to inch-and-a-half of rainfall relevant to several jurisdictional standards.

Taken together, the results show consistent improvement at all five stations, with the largest gains concentrated at Benning Road, Deanwood, and West Hyattsville. Archives and King Street show steady but more modest gains, reflecting their more constrained site conditions and the smaller intervention scales modeled there. The pattern is consistent with the operational logic that GI gains come primarily from improved performance during frequent small storms; green infrastructure remains limited in its ability to capture the largest storm volumes. Full per-scenario results for all stations are reported in Tables 2 and 3.

Table 2. Detailed Modeled Results for Stations with Rain Garden and Street Planter Scenarios

Station	Scenario	Avg. Annual Runoff (in.)	Runoff Reduction	Days/yr with Runoff	Wet Days Retained	Max Rainfall Retained (in.)
Benning Road	Baseline	28.78	—	55.87	19.51%	0.81
Benning Road	RG 25%	22.55	21.6%	50.29	28.04%	0.97
Benning Road	RG 51%	16.50	42.7%	41.69	40.34%	1.24
Benning Road	RG 100%	5.12	82.2%	8.70	87.55%	1.74
Benning Road	SP 25%	22.52	21.8%	50.29	28.04%	0.98
Benning Road	SP 51%	16.46	42.8%	41.89	40.06%	1.26
Benning Road	SP 100%	5.03	82.5%	8.60	87.70%	1.80
Deanwood	Baseline	31.82	—	58.18	16.74%	0.51
Deanwood	RG 25%	25.29	20.5%	52.69	24.61%	0.69
Deanwood	RG 51%	18.49	41.9%	44.59	36.19%	0.98
Deanwood	RG 100%	5.68	82.1%	8.90	87.27%	1.55

Station	Scenario	Avg. Annual Runoff (in.)	Runoff Reduction	Days/yr with Runoff	Wet Days Retained	Max Rainfall Retained (in.)
Deanwood	SP 25%	25.26	20.6%	52.69	24.61%	0.71
Deanwood	SP 51%	18.44	42.0%	44.59	36.19%	1.01
Deanwood	SP 100%	5.59	82.4%	8.60	87.70%	1.61
West Hyattsville	Baseline	37.39	—	64.88	16.79%	0.59
West Hyattsville	RG 25%	29.83	20.2%	57.98	25.64%	0.85
West Hyattsville	RG 51%	21.97	41.2%	47.39	39.23%	1.12
West Hyattsville	RG 100%	7.15	80.9%	9.80	87.44%	1.64
West Hyattsville	SP 25%	29.80	20.3%	57.98	25.64%	0.89
West Hyattsville	SP 51%	21.90	41.4%	47.39	39.23%	1.20
West Hyattsville	SP 100%	7.01	81.3%	9.90	87.31%	1.79

Table 3. Detailed Modeled Results for Constrained Street-Planter Sites

Station	Scenario	Avg. Annual Runoff (in.)	Runoff Reduction	Days/yr with Runoff	Wet Days Retained	Max Rainfall Retained (in.)
Archives–Navy Memorial	Baseline	33.55	—	58.98	15.59%	0.46
Archives–Navy Memorial	SP 10%	30.78	8.3%	57.28	18.03%	0.54
Archives–Navy Memorial	SP 20%	28.01	16.5%	54.49	22.03%	0.63
Archives–Navy Memorial	SP 30%	25.25	24.7%	52.19	25.32%	0.71
Archives–Navy Memorial	SP 40%	22.48	33.0%	49.59	29.04%	0.80
Archives–Navy Memorial	SP 50%	19.71	41.3%	45.99	34.19%	0.88
Archives–Navy Memorial	SP 60%	16.94	49.5%	41.09	41.20%	1.01

Station	Scenario	Avg. Annual Runoff (in.)	Runoff Reduction	Days/yr with Runoff	Wet Days Retained	Max Rainfall Retained (in.)
King St–Old Town	Existing baseline / 20% SP	28.01	—	54.03	21.27%	0.61
King St–Old Town	SP 30%	25.08	9.3%	51.06	25.04%	0.69
King St–Old Town	SP 40%	22.24	19.1%	48.66	28.38%	0.76
King St–Old Town	SP 50%	19.31	28.9%	45.99	32.89%	0.80

5.6 SCENARIO COST RESULTS

Street planters tend to have lower annual maintenance costs than rain gardens at equivalent coverage levels, particularly visible at Deanwood and West Hyattsville. Capital costs scale roughly linearly with coverage. Maintenance cost ranges are wide, in some cases spanning an order of magnitude. At West Hyattsville, the largest rain garden scenario carries annual maintenance estimates ranging from approximately \$2,800 to nearly \$69,000, a range too wide to support precise cost-benefit conclusions without WMATA-specific data. The planning-level capital and maintenance benchmarks underlying these ranges, including the published per-impervious-acre cost figures and the percentage-based O&M multiplier, are discussed in detail in Section 6.4.

6. Cost-Benefit Analysis

6.1 FRAMEWORK AND ANALYTICAL QUESTION

This analysis does not compare green infrastructure to inaction. WMATA must comply with stormwater requirements when projects trigger jurisdiction-specific review thresholds. The relevant question is which compliant pathway is most appropriate at a given site. The analysis therefore compares GI against the principal lawful alternatives: gray infrastructure and, where permitted and practically available, credit purchase or other off-site compliance mechanisms.

The benefit unit is compliance delivered. GI creates economic value when it reduces the cost WMATA would otherwise incur to achieve the same regulatory outcome through credit purchase, gray infrastructure, or another lawful alternative. The compliance environment differs across the service area. D.C. provides a market-based benchmark through SRCs. Maryland's ESD-to-MEP framework dominates project-level design, with nutrient credits more clearly tied to MS4 permittee flexibility than to direct project use. Fairfax County's comparison is generally between BMP pathways meeting the post-construction phosphorus standard.

Green infrastructure also carries co-benefits that the principal alternatives do not. Gray infrastructure and credit purchase satisfy a regulatory obligation but add no surface amenity; distributed GI can reduce localized ponding, provide modest shading and local cooling that mitigates the urban heat-island effect, and improve station appearance and rider experience. These co-benefits are treated here as qualitative considerations rather than monetized benefits, for the reasons set out in Section 7.3.

6.2 TIME HORIZON

The primary analysis uses a five-year near-term horizon, consistent with WMATA's operational and capital planning timeline. This horizon is conservative with respect to GI. Capital costs are front-loaded, while many benefits, such as credit generation, avoided credit purchase, and annual runoff-management gains, accrue over time. Longer horizons remain relevant as sensitivity analysis but should be treated as such rather than as precise forecasts. The available evidence

base is strongest for planning-level modeled performance and benchmark cost ranges, not for long-run observed station outcomes.

6.3 COUNTERFACTUAL COMPLIANCE PATHWAYS AND BENEFIT BENCHMARKS

6.3.1 D.C. Stormwater Retention Credits as the Clearest Market Benchmark

D.C. provides the clearest monetizable compliance benchmark in WMATA's service area. Each SRC represents one gallon of stormwater retention capacity for one year and may be used to satisfy the allowable off-site portion of a project's retention obligation. SRC prices are therefore the most direct observable counterfactual for sites where WMATA could either reduce required SRC purchases through on-site GI or generate credits through eligible voluntary retention.

D.C. SRCs traded at an average of about \$1.41 per credit in Q4 2024 (Green Finance Institute, n.d.). Public program materials suggest a broader price range of roughly \$0.42 to \$2.03 per credit depending on geography and program conditions. They also report that more than 1.7 million credits have been sold since the program's 2014 launch (The Nature Conservancy, 2024). These figures provide a reasonable benchmark for the cost of off-site compliance in D.C. Where a District station's GI scenario meaningfully increases retained runoff, the avoided cost of SRC purchase can be estimated by multiplying credits forgone by an assumed SRC price.

Among the selected stations, Benning Road, Archives, and Deanwood are the most relevant to this subsection because they fall within the District. The current modeling supports the benchmark price logic but does not yet translate each scenario's modeled retained runoff into a project-specific SRC quantity. Producing a complete station-by-station SRC value calculation will require further work to map modeled retention to project-level off-site obligation.

6.3.2 Maryland and Virginia Nutrient-Credit Benchmarks

Maryland and Virginia present a less direct monetization pathway than D.C.'s SRC market. In Maryland, distributed GI is the preferred starting point under the ESD-

to-MEP framework, and nutrient-credit pathways exist and are generally preferred at larger scale where on-site infrastructure is not practical. Credit purchases occur through negotiated agreements rather than at a posted market price (Maryland Department of the Environment, n.d.). One available benchmark is Maryland's in-lieu fee structure of \$13 per pound of nitrogen and \$260 per pound of phosphorus. These figures are best understood as policy benchmarks rather than as observed market prices (Ballard Spahr LLP, 2018). In Virginia, recent public transaction evidence is sparse, and the Falls Church example (Falls Church Pulse, 2026) reflects a local budgeting decision rather than a stable market series.

Maryland cost analyses indicate that some stormwater BMPs can be very expensive on a cost-per-pound-removed basis relative to the state's in-lieu fee benchmarks (Price et al., 2021). Reported infiltration-practice costs are on the order of several hundred dollars per pound of nitrogen removed and several thousand dollars per pound of phosphorus removed, while reported bioretention costs can be higher still. Where a lawful nutrient-credit pathway is actually available, the unit cost of credit purchase may be much lower than the cost of achieving an equivalent reduction through BMP installation alone.

This distinction is especially important for West Hyattsville, the strongest hydrologic-improvement candidate in the selected set. While nutrient-credit pathways are generally preferred at larger scale in Maryland, the extent to which WMATA can rely on nutrient trading for project-level compliance, as distinct from MS4-permittee-level flexibility, should be confirmed on a project-specific basis. The Maryland benchmarks therefore strengthen the comparative logic, and nutrient-credit value is treated here as a meaningful but project-contingent comparison value rather than as a fully settled monetized benefit stream.

6.3.3 Avoided Gray-Infrastructure Cost as the Second Major Benchmark

Where GI delivers required stormwater compliance, the cost of the next-best compliant alternative can be treated as an avoided cost. Available engineering and EPA-based literature suggests that underground detention or retention vaults typically cost on the order of \$0.75 to \$3.00 per gallon of storage for basic capacity. Pumps, plumbing, burial, and installation can raise total costs to roughly \$1 to \$8 per gallon depending on design and site conditions (RTI International & Geosyntec

Consultants, 2015). Sand filter vaults and hydrodynamic separators carry substantial capital costs as well, typically priced per unit or by design flow rather than by storage volume (U.S. Environmental Protection Agency, 1999).

WMATA staff indicate that gray infrastructure tends to be more cost-effective at larger scales, while green infrastructure tends to be more cost-effective for smaller drainage areas, on the order of less than one acre. This is operational guidance from WMATA staff rather than an independently established engineering threshold, but it is consistent with the per-gallon cost structure above: large required storage volumes tend to favor structural solutions, while distributed at-grade GI is well suited to smaller, dispersed drainage areas.

O&M costs for gray infrastructure are less certain but still relevant. Underground systems generally require periodic inspection, sediment removal, cleaning, and occasional component replacement. The currently available material supports only rough order-of-magnitude treatment of these burdens. The avoided-cost value of GI will vary sharply by site. Urban infill conditions, utility conflicts, excavation depth, and proximity to tracks or other critical infrastructure can materially increase the cost of vaults at constrained transit sites. The avoided-cost value of GI is therefore likely to be highest where a GI conversion allows WMATA to avoid expensive underground infrastructure at a difficult site.

6.3.4 Availability and Legal Constraints on Counterfactuals

Not every possible counterfactual is equally available in practice. In D.C., credit use is constrained by program rules, geography, and minimum on-site retention requirements. In Maryland, nutrient-credit use is more clearly documented at the MS4-permittee level than as a project-level substitute available to WMATA, so its applicability to specific WMATA projects should be confirmed case by case. In Virginia, off-site options may exist in some cases but their applicability to WMATA projects requires confirmation. The counterfactual analysis therefore remains bounded by legal and administrative plausibility rather than by purely theoretical alternatives.

6.4 GI COSTS

6.4.1 GI Capital Costs

GI capital costs rise as intervention coverage increases. This is a consistent pattern across the selected stations and reflects the basic tradeoff that more extensive treatment requires greater installation effort. Open bioretention, rain gardens, and similar at-grade systems are generally the lower-cost form of GI where site conditions allow. Curbside or boxed street planters are usually more expensive because they require walls, curb modifications, drainage connections, confined excavation, and tighter integration with surrounding pavement and utilities. Planters should therefore be understood not as a higher-performing BMP by default, but as a more expensive urban adaptation of bioretention used when open systems are infeasible.

To anchor these relative statements in observed costs, this analysis draws on Price et al. (2021), a University of Maryland Center for Environmental Science (UMCES) cost study prepared for the Maryland Department of the Environment. That study compiled stormwater BMP project data from Maryland MS4 counties and normalized all project costs to 2017 dollars using the Construction Cost Index, reporting implementation costs per impervious acre treated (impervious acre equivalent, or IAE). The 2017-dollar values are adjusted here to 2026 dollars using the Consumer Price Index. The two adjustments rest on different indices — the Construction Cost Index to reach 2017 dollars, and the Consumer Price Index to carry those values forward — so the 2026 figures should be read as approximate planning-level benchmarks rather than precise unit costs.

The UMCES data report wide ranges rather than single representative values, and the sample sizes differ sharply by practice:

- **Rain gardens** (MDE code MRNG; nine projects) ranged from \$3,331 to \$348,738 per impervious acre treated, with a median of \$132,049 (2017 dollars). The lowest-cost project in that sample was built for only \$3,331 per impervious acre — approximately **\$4,568 in 2026 dollars**. This is a noteworthy data point: it demonstrates that a rain garden can be constructed at very low cost where site conditions are favorable. It should not, however, be read as a typical or expected cost. The median rain garden cost is substantially higher, and the wide range reflects how strongly site conditions drive cost.
- **Bioretention** (MDE code FBIO; thirteen projects) ranged from \$8,575 to \$587,397 per impervious acre treated, with a median of \$188,823 (2017 dollars) — roughly **\$11,756 to \$798,000, median \$258,900, in 2026 dollars**.

Bioretention is functionally similar to bioswales and provides a larger sample than the single bioswale project. Its observed minimum (\$8,575 per impervious acre) sits above the rain garden minimum, and its median is the highest of the three categories, reinforcing that the rain garden sample contains the lowest achievable observed cost.

- **Bioswales** (MDE code MSWB) appear in the UMCES dataset as a single project at \$53,660 per impervious acre treated — approximately **\$73,587 in 2026 dollars**. Because there is only one observation, the minimum, median, and maximum are identical, and the figure provides no information about whether a less expensive bioswale could be built. It should be treated as a single illustrative value, not a representative unit cost.

Read together, these figures support the report's qualitative cost logic without overstating precision. The rain garden sample shows that low-cost at-grade GI is achievable, the bioretention sample confirms wide cost variability driven by site conditions, and the single bioswale observation cautions against drawing any firm conclusion about bioswale cost from the available data. The broader pattern visible across stations modeled with multiple intervention levels — progressively larger coverage producing steadily higher capital and maintenance costs — holds at Archives, Benning Road, Deanwood, and West Hyattsville. Higher-performing GI scenarios are more effective but require materially larger capital outlays.

6.4.2 GI O&M Costs

Annual maintenance costs also rise with GI coverage. Constrained planters usually impose a heavier recurring burden than open bioretention because they receive concentrated street runoff, trash, and sediment in a smaller footprint. They therefore require more frequent debris removal, inlet cleanout, and streetscape-level upkeep. Open bioretention requires inspection, weeding, pruning, mulch replacement, and occasional plant replacement. Its maintenance burden is usually lower on a per-area basis.

For a planning-level estimate of annual maintenance as a share of capital cost, the UMCES study (Price et al., 2021) provides a useful benchmark. That study estimated O&M for many urban stormwater practices as a percentage of installation cost, deriving its multipliers from the Prince George's County maintenance approach. For micro-scale practices — the category that includes bioretention, rain gardens, and bioswales — UMCES applied an overall annual O&M multiplier of 11.5 percent of installation cost. This is higher than the 2.5 to 6 percent range used in the Chesapeake Assessment Scenario Tool, and falls within

the 8.2 to 13.4 percent range UMCES reported across the urban practices it evaluated. The higher figure reflects updated, locally derived maintenance assumptions rather than a different category of practice.

One WMATA-specific data point illustrates actual maintenance experience. According to interviews with WMATA staff, the bioswales at Landover are serviced three times per year — in May, July, and September — and the prior year's maintenance totaled \$8,599.61 (May, \$3,079.03; July, \$3,090.37; September, \$2,430.21). This figure is a useful real-world anchor, but it reflects a single site over a single year across three service visits. It should be read as an illustrative actual cost rather than as a representative annual maintenance rate.

The model outputs and benchmarks above are useful for comparing GI options against one another within each station but should not be treated as complete WMATA maintenance budgets. WMATA's maintenance work is moving in-house, which may alter the long-run cost basis. The broad comparative logic still supports one practical conclusion. Where site conditions permit a choice, WMATA should generally expect open bioretention to be cheaper to maintain than constrained planters, even where both provide broadly similar treatment functions.

6.4.3 Net Cost Relative to Conventional Landscaping

The differential between GI and conventional landscaping should be treated as a cost, not as a benefit. Baseline station conditions show high impervious cover and modest runoff retention, which supports the argument that existing landscapes are not functioning as strong stormwater controls. But GI is likely more expensive than conventional landscaping on both capital and maintenance dimensions, even though it produces far better hydrologic performance. GI may still be justified where it avoids more expensive credit purchases or gray installations, and where its co-benefits are valued. It should not be presented as a direct cost-saving substitute for ordinary landscaping alone.

6.5 SUMMARY RESULTS BY STATION

The selected stations do not present the same compliance problem, flood-risk profile, or modeled hydrologic opportunity. The strength of the case for GI varies by station.

Benning Road presents the strongest combined case. It is the strongest present-day flood-exposure station and produces some of the strongest modeled hydrologic gains. Baseline runoff falls from 28.78 inches to roughly 5 inches, and wet-day retention rises from 19.51 percent to nearly 88 percent under the largest scenarios. The flood-risk profile separately indicates the need for gray infrastructure or other structural resilience measures. GI is complementary to structural protection at this site, not a substitute.

Archives is the clearest worsening-near-term case and one of the strongest District compliance cases. It is highly impervious and responds steadily to increasing planter coverage. Runoff falls from 33.55 inches at baseline to 16.94 inches at 60 percent, and wet-day retention rises from 15.59 percent to 41.20 percent. Implementation would likely require coordination with jurisdictional partners.

King St–Old Town is the least dramatic modeled-improvement case in the set. Its baseline already includes 20 percent planters, and additional coverage produces incremental rather than transformative gains. Its value is comparative. It shows that GI can still improve runoff performance at a lower-risk station and that existing GI features can be incorporated into the baseline.

Deanwood presents a strong District runoff-management case despite low direct flood exposure. Baseline runoff of 31.82 inches falls to roughly 5.6 inches under the largest scenarios, with wet-day retention rising to approximately 87 percent. It isolates the runoff-management and compliance value of GI from the flood-exposure question.

West Hyattsville presents the strongest Maryland hydrologic-improvement case. It is the largest site, with baseline runoff of 37.39 inches reduced to roughly 7 inches under the largest interventions and wet-day retention rising to approximately 87 percent. Its policy significance differs from the District stations. The relevant comparison is to Maryland's ESD-to-MEP framework and to alternative engineered pathways rather than to a District SRC benchmark.

6.6 SUMMARY INTERPRETATION

The strongest provisional interpretation is not that GI is universally cost-saving. It is that GI may be cost-justified at particular stations when compared against the right compliance counterfactual. In D.C., the clearest counterfactual is often SRC purchase for the off-site share of compliance. In Maryland and Virginia, the

comparison is more often between GI and alternative engineered systems, with Maryland nutrient-credit valuation meaningful at larger scale but contingent on project-level availability.

GI appears most financially attractive where three conditions coincide. The jurisdiction must give on-site runoff reduction clear compliance value. The site must accommodate lower-cost at-grade bioretention rather than only heavily engineered planters. And the next lawful alternative must itself be expensive, whether SRC purchase, underground gray infrastructure, or another constrained-site pathway. GI appears less compelling where hydrologic gains are modest, legal monetization is uncertain, or only highly engineered treatment forms are feasible. Where the economic case is close, the co-benefits described in Section 6.1 may reasonably tip a decision toward GI, but they are not by themselves a substitute for compliance value.

7. Discussion

7.1 A DECISION RULE FOR STATION-LEVEL GI

The results support a structured decision rule for station-level stormwater investments. The first question is what the jurisdiction requires. The second is whether GI is physically feasible at the site. The third is whether modeling indicates that GI will perform well enough to be effective at the chosen site, and to outperform or outvalue the next lawful alternative. This sequence is more useful than treating GI as either an obvious default or an optional environmental add-on.

Where the conditions identified in Section 6.6 align, GI offers meaningful compliance value tied to improved runoff management, alongside co-benefits that the alternative pathways do not provide. Where they do not, gray infrastructure or, in D.C., credit purchase may be the more rational compliance pathway. The decision should turn on comparative compliance value rather than on a presumption that on-site construction is always preferable. In Maryland and Virginia, where the off-site market pathway is less directly available to WMATA at the project level, the analysis is more dependent on comparison with engineered alternatives than with a market benchmark, even though distributed GI is the preferred starting point under Maryland's ESD-to-MEP framework.

The results also clarify where GI should not be expected to do work it is not designed for. Where the main problem is structural flood exposure, very large water volumes, or a highly constrained setting, GI should not be treated as the primary response. Benning Road is the clearest example. GI could produce substantial runoff-management gains there, but the deep flood exposure indicates that structural resilience measures would still be necessary. GI may be worth pursuing as part of a broader package, but not as a stand-alone solution.

7.2 THE ROLE OF FLOOD RISK IN THE ANALYSIS

Flood risk matters in this report but does not operate as the primary monetized benefit of GI. It served as a screening tool that helped identify which stations were worth closer analysis and provided context for interpreting site results. Benning Road stands out for severe present-day exposure. Archives stands out for a worsening 2030 outlook. King Street, Deanwood, and West Hyattsville show that low modeled flood depth does not preclude analytical importance.

The distinction between modeled flood depth and reported operational flooding is worth making explicit. A station may show little or no modeled inland-flooding depth in the screening data yet still experience localized drainage or flooding problems in practice. King Street is the clearest instance: it registers no modeled Fathom flood depth at the station point, but WMATA staff report drainage issues there attributable to extensive impervious area. The two measures answer different questions — one models regional inundation under future climate scenarios, the other reflects on-the-ground operational experience — and a site can rank low on the first while still presenting a real stormwater-management case on the second.

GI performs best as a site-scale runoff-management strategy. It reduces runoff volume, increases retention, and improves performance during frequent rainfall events. It does not solve deep riverine flooding or major urban inundation. Keeping flood risk and GI value analytically separate prevents overstatement. It avoids treating GI as a universal flood solution while still recognizing that flood context affects site priority and the practical meaning of the results.

7.3 LIMITATIONS

Several limitations should shape how these results are interpreted.

First, the cost evidence is largely planning-level. The GI capital and percentage-based O&M figures are drawn from published sources — chiefly the UMCES Maryland cost study (Price et al., 2021) — rather than from WMATA-specific construction bids or comprehensive maintenance records. The analysis incorporates one WMATA-specific maintenance figure, the reported annual cost of servicing the Landover bioswales, but a single site over a single year does not establish a representative maintenance rate. The report therefore supports comparative reasoning about likely cost relationships, not precise budgeting. This limitation is especially important for O&M costs, which vary widely depending on contractor pricing, in-house labor practices, site conditions, litter burden, and maintenance consistency. The published cost figures also carry sampling limitations: several of the per-acre cost values rest on small project counts, and at least one practice category (bioswales) is represented by a single project, so the observed values should be read as ranges and illustrative points rather than firm unit costs.

Second, the hydrologic results are modeled rather than observed. The station comparisons rely on EPA National Stormwater Calculator scenarios, which

support structured planning analysis but do not substitute for engineering design or measured field performance. Station acreage and land cover were approximated rather than derived from survey-grade measurements.

Third, the intervention scenarios were built from a standardized template rather than custom sizing for each station. This kept comparisons internally consistent but means the scenarios are planning comparisons rather than fully optimized designs.

Fourth, the evidence for monetized compliance alternatives is uneven across jurisdictions. D.C. provides the clearest market benchmark through the SRC program. Maryland's ESD-to-MEP framework makes distributed GI the preferred starting point, and nutrient-credit pathways exist and are generally preferred at larger scale where on-site infrastructure is not practical; however, the extent to which WMATA can rely on nutrient trading for project-level compliance, as opposed to MS4-permittee-level flexibility, remains to be confirmed. In Virginia, off-site options may exist in some cases but their applicability to WMATA projects requires case-specific confirmation. Comparison with off-site compliance is therefore most defensible in D.C. and more tentative elsewhere.

Fifth, the analysis combines cost data adjusted under two different indices. The UMCES source normalized project costs to 2017 dollars using the Construction Cost Index, and those values were carried forward to 2026 dollars using the Consumer Price Index. Using different indices for the two steps is a reasonable practical choice but introduces a methodological seam, so the 2026 cost figures should be read as approximate planning-level benchmarks.

Sixth, the flood-risk information is a screening tool rather than an engineering input. FEMA data are static and not forward-looking. The Fathom-informed results are more useful for near-term comparison but still do not substitute for design-grade flood studies. Relatedly, the two principal modeling tools rest on different temporal assumptions: the TPB Climate Change Vulnerability Assessment identifies flood risk using forward-looking, climate-adjusted predictions, whereas the EPA National Stormwater Calculator uses historic rainfall data. The two are used here for different purposes — forward-looking screening versus comparative hydrologic modeling — but the difference in time basis should be kept in mind when interpreting results side by side.

Finally, the analysis does not fully monetize every category of possible benefit or cost. The co-benefits discussed in Section 6 — reduced localized ponding, modest shading and local cooling that mitigates the urban heat-island effect, and improved station appearance and rider experience — are treated qualitatively because the available record does not support quantifying them with confidence at this stage. The same applies to broader effects such as avoided service disruption, nuisance-flood complaints, maintenance callouts, and reputational or equity-related impacts. These considerations may matter in practice, and they can reasonably inform a decision where the compliance-cost case is close, but they are not quantified benefit streams in this analysis.

8. Conclusions and Recommendations

8.1 MAIN CONCLUSION

The strongest case for green infrastructure at WMATA is not generic environmental benefit. It is site-specific compliance value. GI is most compelling where it represents the most practical and cost-justified lawful pathway for meeting stormwater requirements under the governing jurisdictional framework. Where the compliance-cost case is close, the co-benefits GI provides but the alternative pathways do not — reduced localized ponding, modest local cooling, and improved station appearance and rider experience — may reasonably tip a decision toward GI, though they are not a substitute for compliance value.

Across D.C., Maryland, and Virginia, WMATA does not operate under a single stormwater regime. Each jurisdiction defines obligations, performance measures, and available alternatives differently. GI's value depends on how well it performs at a given site, what the jurisdiction requires, and what the next lawful alternative would cost.

8.2 RECOMMENDATIONS

8.2.1 Where GI Should Be Prioritized

WMATA should prioritize GI at stations where three conditions coincide. The governing jurisdiction must require or otherwise make on-site runoff reduction or retention meaningful. The station must have sufficient physical suitability for GI to be constructed and maintained realistically. And modeling — here, the EPA National Stormwater Calculator — must indicate that GI will be effective at the chosen site, with modeled hydrologic gains large enough that GI appears competitive with the next lawful alternative.

Among the stations examined here:

- **Benning Road — highest priority.** It is located in an Equity Emphasis Area, presents the strongest present-day flood exposure in the selected set, and produces the largest modeled hydrologic gains, while remaining a site that is not so constrained as to preclude GI construction. GI should be treated as complementary to structural flood protection rather than as a substitute for it.
- **Deanwood — higher priority.** It is located in an Equity Emphasis Area, sits on a stream, and is surrounded by high-flood-risk areas. It presents a strong District

runoff-management and compliance case where direct flood exposure at the station point is not the central issue.

- **West Hyattsville — moderate priority.** It is located in an Equity Emphasis Area and is the largest site in the set, with ample area suitable for GI. As a Maryland station it falls under the ESD-to-MEP framework, which makes distributed GI the preferred starting point; the relevant comparison is to that framework and to alternative engineered pathways rather than to a District credit benchmark.
- **Archives–Navy Memorial — coordinate with area partners to consider GI.** It is the clearest worsening-near-term case in the District, but its dense urban setting leaves limited area suitable for GI. Implementation would require coordination with jurisdictional and other area partners.
- **King St–Old Town — consider studying and expanding existing GI.** The station already has street planters in place. Although it shows no modeled flood depth in the screening data, WMATA staff report drainage and flooding issues there attributable to extensive impervious surface area. Additional GI shows modest rather than transformative modeled gains, so the practical recommendation is to study and, where warranted, expand the existing planter interventions rather than to undertake a major new installation.

These five should not be assumed to be the only important stations in the system. Future screening should continue to identify additional stations where flood relevance, regulatory context, and GI feasibility align.

8.2.2 Which GI Types Should Generally Be Preferred

Where site conditions allow, WMATA should generally prefer open bioretention, rain gardens, and similar at-grade practices over heavily constrained street planters. Open bioretention is usually the lower-cost form of GI and often provides comparable or better treatment opportunities where space is available. Open systems are simpler to build and maintain, less structurally complex, and less exposed to the concentrated litter and debris burden that affects curbside planters. The observed cost data are consistent with this: the lowest-cost at-grade practices in the available Maryland dataset were built far more cheaply per impervious acre than constrained or boxed alternatives, even though costs varied widely with site conditions.

Street planters should still be considered where urban constraints make them the only realistic bioretention option. In dense station-front settings, especially in D.C., planters may be the only practical means of adding on-site treatment within a constrained footprint. They should be treated as a costlier form of bioretention rather than as a categorically superior practice. Their performance depends less on the planter label than on whether the system infiltrates or merely filters runoff,

whether it is lined or underdrained, what media it uses, whether it includes internal water storage, and whether it can be maintained consistently.

Bioswales and linear bioretention may be valuable where there is enough open space and a suitable drainage path, but they are not universally feasible. Where space is limited and pedestrian traffic is heavy, the choice may be between planters and no meaningful GI at all.

8.2.3 When Gray Infrastructure or Credits Should Be Used Instead

WMATA should use gray infrastructure where the central stormwater or flood problem exceeds the realistic capability of GI. This includes stations with severe structural flood exposure, sites requiring very large storage volumes, and locations where subsurface, utility, circulation, or operational constraints make meaningful on-site GI infeasible. Benning Road is the clearest example. GI could improve compliance and site-scale runoff there, but structural measures are needed to address the larger flood hazard. WMATA staff indicate that gray infrastructure tends to be more cost-effective at larger scales, while green infrastructure is generally more cost-effective for smaller drainage areas, on the order of less than one acre; this operational guidance points toward gray infrastructure where the drainage area or required storage volume is large.

In D.C., WMATA should treat credit purchase as a rational compliance option where on-site GI is constrained or disproportionately expensive. The SRC market provides the clearest observable benchmark for off-site compliance cost. The recommendation is not to maximize on-site GI at all costs. It is to compare GI honestly against the cost of lawful off-site compliance.

In Maryland, distributed GI is the preferred starting point under the ESD-to-MEP framework, and nutrient-credit pathways exist and are generally preferred at larger scale where on-site infrastructure is not practical. WMATA should nonetheless confirm the extent to which it can rely on nutrient trading for project-level compliance, as distinct from MS4-permittee-level flexibility, before treating credits as a settled project-level option. In Virginia, off-site options may exist but their applicability to WMATA projects requires case-specific confirmation; until that is clearer, GI in Virginia should generally be justified through compliance

performance and avoided engineered cost rather than through confident assumptions about tradable credits.

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