San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

TECHNICAL MEMORANDUM: GREEN STORMWATER INFRASTRUCTURE MAINTENANCE COST MODEL

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1. PURPOSE

This analysis has been conducted as part of the Triple Bottom Line analysis for the Sewer System Improvement Program of the San Francisco Public Utility Commission (SFPUC) to assist the SFPUC's Urban Watershed Management Program (UWMP) in strategic planning and budgeting for the maintenance of green stormwater infrastructure (GSI) implemented through the Sewer System Improvement Program (SSIP).

In recent years, GSI has become a more common tool for stormwater management in San Francisco, especially with the mandates of the Stormwater Management Ordinance.[1] As more GSI moves from proposal and planning stages into construction and operation at SFPUC, UWMP will lead the planning, assist with managing, and implement the ongoing operations and maintenance (O&M) of these GSI installations. In addition to GSI developed through the SSIP, SFPUC will also be responsible for some of the maintenance obligations associated with GSI in the right-of-way in redevelopment areas. To prepare for this new maintenance obligation, UWMP is developing cost estimates for GSI.

This analysis supports these efforts by enabling UWMP staff to quantify, at the planning level, the scope and scale of projected GSI O&M in San Francisco over the next 20 years. To estimate the scale of annual budget and staffing commitment, the analysis estimates maintenance costs per GSI project type, including dollar costs and labor requirements. The output of this study is a spreadsheet-based planning tool that takes as inputs GSI physical plan installation estimates (by project type, size, and date), and yields as output a projection of planning-level maintenance costs and staffing obligations for UWMP.

This analysis recognizes the approximate nature of these numbers as high-level planning estimates, rather than precise or exact values. The maintenance cost model is intended to be used as a tool to help inform the SFPUC regarding the scale of existing, planned, proposed, and future GSI maintenance burdens, and to help plan and budget for future maintenance obligations in terms of both labor and dollar costs. As the SFPUC installs more GSI over time, the maintenance cost model can be updated with ground-truthed cost figures, and expanded to include new types of GSI projects.

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[1] The Stormwater Management Ordinance – Article 4.2 of the San Francisco Public Works Code, Sections 147-147.6 – mandates that any development project that disturbs more than 5,000 square feet must install GSI to manage the quantity and quality of stormwater runoff. In areas with separated sewer systems (MS4), a development is required to capture and treat rainfall from a 0.75" storm, using acceptable GSI installations, and to complete a Stormwater Control Plan (SCP), demonstrating how the GSI installations will operate. In areas with combined sewer systems (CSS), a development is required to reduce the flow rate and volume of stormwater entering the CSS to LEED Sustainable Sites Credit 6.1 levels, and to complete a SCP to demonstrate compliance.

Introduction to Green Infrastructure

Traditional stormwater management infrastructure – so-called grey infrastructure – typically comprises sewers, detention vaults, and pumps that collect stormwater during a rain event and transport it to a treatment facility. Low Impact Development (LID), also known as Green Stormwater Infrastructure or GSI, is an alternative to traditional grey infrastructure for managing stormwater. Instead of funneling water directly to pipelines that convey it to treatment facilities and/or outfalls, GSI aims to slow or divert the flow of water into the sewer system. Using GSI practices, stormwater is detained, retained, or infiltrated. For example, a typical GSI installation would be a landscaped area called a bioretention planter. In a rain garden, stormwater absorbs into the soil and can slowly infiltrate the ground, thereby alleviating a portion of the burden on grey infrastructure. Another type of GSI installation would be a rainwater harvesting system that captures and contains a volume of rainwater, alleviating the immediate burden on the sewer system during the peak of the storm, and then allowing the stored rainwater to be reused for non-potable activities (e.g. toilet flushing or irrigation). GSI can have co-benefits, such as creating open space, reducing combined sewer discharges, and mitigating the ecological disturbance and channel erosion caused by some grey infrastructure. It also has the potential to increase the overall capacity of a stormwater management infrastructure system.

More and more, GSI is being adopted as a stormwater management tool, in addition to conventional grey infrastructure. Under the Stormwater Management Ordinance, any development project in San Francisco with a ground surface disturbance of over 5,000 square feet must install GSI to manage the quality and quantity of stormwater runoff from the site. In addition, the SFPUC's Sewer System Improvement Program (SSIP), a 20-year, multi-billion dollar capital investment program to upgrade aging sewer infrastructure, includes the development of numerous GSI investments.

Like grey infrastructure, GSI must be maintained in order to preserve its function and performance. GSI maintenance typically includes landscaping activities (such as re-planting to replace dead or diseased plants, adding mulch, aerating and tilling soil, or pruning), cleaning activities (such as debris removal, de-sedimentation, or sweeping and vacuuming), and/or hardware replacement activities (such as replacing broken or malfunctioning valves, riprap, piping, etc.).

Acronyms

GSI	Green Stormwater Infrastructure
LID	Low Impact Development
SCP	Stormwater Control Plan
SFPUC	San Francisco Public Utilities Commission
SSIP	Sewer System Improvement Program
UWA	Urban Watershed Assessment
UWMP	Urban Watershed Management Program

Memo Structure

The following sections of this memorandum describe the development process for the GSI model, including a summary of case study findings; and the mechanics of the GSI model, including inputs and outputs.

2. MODEL DEVELOPMENT

AECOM's approach to developing the SFPUC GSI maintenance model is described below.

- **Case Study Analysis**: Case study interviews were conducted with staff in four cities currently operating green infrastructure maintenance programs for the development of applicable lessons to San Francisco's program.
- **GSI Project Definition**: GSI was defined in terms of GSI project types, scope, and scale of typical installations.
- **Cost Estimates**: Estimates of maintenance costs per GSI project type were developed, including both labor and materials components.
- **Other Inputs**: Other user-defined inputs required for the maintenance cost model were identified, such as the proportion of GSI installations for which SFPUC is responsible, and year in which maintenance starts.
- **Model Production**: The maintenance model was designed and produced.
- **Model Validation & Finalization**: The maintenance model was validated and finalized with UWMP.

The remainder of this section will address each of the first four steps – case study analysis, GSI project definition, estimation of costs, and identification of other required inputs – in the maintenance cost model development process.

Case Study Analysis

AECOM interviewed representatives from the GSI maintenance programs in four cities: Philadelphia, Syracuse, Portland, and Seattle.

Philadelphia's GSI program began in 2009 with a handful of pilot projects, and has grown to include 197 installations in 57 sites. Portland's GSI program has been operational since the first green street was constructed in 2003; currently, Portland maintains GSI installations on more than 1,300 green streets. Seattle's GSI maintenance program involves oversight of 666 bioretention facilities, 48 biofiltration projects, and 117 pervious paving projects in the right-of-way. The GSI program in Syracuse has grown exponentially since 2010 – from several initial pilot projects in 2010 to sixty installations in 2011 to more than 120 installations in 2013 – as the result of a concerted programmatic push called Project 50.

TABLE 1: CASE STUDY PROGRAM ORIGINS & SIZE

Case Study	Program Origin & Number of Installations	
Philadelphia	2009.	197 installations over 57 sites
Portland	2003.	Installations on more than 1,300 green streets
Seattle	dna.	666 bioretention facilities, 48 biofiltration projects, 117 pervious paving projects
Syracuse	2010.	More than 120 installations

Source: Interviews (Fall 2013), secondary research. dna = data not available.

The intent of the interviews was to develop insights applicable to San Francisco's GSI program from cities already managing GSI maintenance programs. The GSI programs studied are relatively new, with programs less than five years old in three of the four cities. This is particularly useful for San Francisco, as the experience and insights relating to starting and growing a GSI maintenance program will inform SFPUC's management decisions during the early stages of its own program.

The following section outlines the major findings of the case study interviews.

Case Study Findings

Table 2 below outlines the six key findings of the interviews and related research with GSI program management staff in Philadelphia, Portland, Seattle, and Syracuse. Full-text interview transcriptions are included in Appendix A.

TABLE 2. KEY FINDINGS FROM CASE STUDIES

Finding #1:	**Builder is responsible for maintenance duties for an initial establishment / warranty period for new GI installations.**
Philadelphia	Builder is responsible for 2 months of maintenance post-construction, and provides a one-year warranty on plants and components.
Portland	*DNA*
Seattle	Builder is responsible for all maintenance for the first year post-construction
Syracuse	Builder is responsible for all maintenance for the first year post-construction.
Finding #2:	**Maintenance work is primarily contracted to outside forces.**
Philadelphia	Maintenance work is contracted via RFP for a one-year period, which can be extended annually up to four times. A private contractor (AKRF) won the initial maintenance contract and extended to the maximum four years. Upon RFP re-issue, AKRF won the bid for a second time.
Portland	The majority of GSI maintenance work is performed by contractors. The City's GSI maintenance program's two staff members may perform some limited GSI maintenance as needed.
Seattle	The majority of GSI maintenance work is contracted to a job skills training program within Seattle's Parks Department, the Seattle Conservation Corps.
Syracuse	The majority of GSI maintenance work is contracted to a green jobs workforce development agency, Onandaga Earth Corps.
Finding #3:	**In-house staffing levels are minimal. Staff are primarily charged with coordinating GSI programs among agencies, administering and supervising contracts, and performing inspections.**
Philadelphia	In-house staff comprise 4.25 full-time equivalent employees who manage the maintenance contract with AKRF, coordinate maintenance work, and perform inspections.
Portland	In-house staff comprise 2 full-time equivalent employees who manage the maintenance contractors, inspect sites, and perform day-to-day administrative program work, such as scheduling contractors, issuing work orders, and entering information into Portland's database system.
Seattle	In-house staff comprises only 1 full-time person, who oversees tasks and tracks maintenance activities that are performed by contractors and other City departments.
Syracuse	In-house staff comprises only 1 dedicated, full-time person. Many other municipal staff are peripherally involved in the program and 1 staff-person spends part of his time on program management.

Finding #4:	Database systems help facilitate maintenance schedules.
Philadelphia	Philadelphia is in the process of integrating their GSI maintenance work into their citywide asset management database (Cityworks).
Portland	Portland is in the process of switching from a database maintained by the GSI program to a central database for sewer and stormwater maintenance work. Integrating GSI work into the central sewer and stormwater maintenance database is an attempt to streamline processes and keep up with workload.
Seattle	All GSI assets will eventually be incorporated into Seattle's asset management system (MAXIMO), which can generate work orders when maintenance is required and track maintenance work and inspections.
Syracuse	All GSI assets are catalogued in Syracuse's citywide database system (MAXIMO). The maintenance requirements for each asset are built into the database, which then generates work orders for all scheduled maintenance, as per the maintenance requirement (e.g. quarterly inlet cleaning).
Finding #5:	**GSI maintenance is primarily funded by the agency's general operating budget (i.e. water, sewer, and stormwater fee revenues).**
Philadelphia	The GSI program is funded by the general operating budget.
Portland	The GSI program is funded by the general operating budget.
Seattle	*DNA*
Syracuse	The GSI program is funded by general sewer use fees, which are assessed on annual property tax bills.
Finding #6:	**Understanding GSI maintenance costs on a per-unit basis appears to be a work in progress among various agencies.**
Philadelphia	The city has detailed costs in their maintenance contract, but had reservations about sharing details with other consultants. Costs vary by size and program; average costs per typical GSI site appear to be approximately $4,100.
Portland	The city estimates costs for GSI facility maintenance along green streets to be $1.55 per square foot per year. The GSI program is currently validating this estimate, based on actual costs.
Seattle	Seattle budgets $2.21 per SF for years 1-3, and drops cost by 25% to $1.66 per SF in years 4 and beyond, for total average cost of $500-$570 per year for bioretention facilities. The city plans to update cost estimates with actual data over time.
Syracuse	Cost estimates are a work in progress; the city offered to share data on but has not responded to additional requests for information.

Source: Interviews (Fall 2013), secondary research

Although climates and labor costs vary between these four cities and San Francisco, the findings are focused on program management, broadly applicable, and relevant to the San Francisco context. The prevalence of contracting GSI maintenance work to private contractors, rather than developing in-house maintenance crews, is a particularly important finding for consideration.

Defining GSI for San Francisco

Defining GSI for San Francisco includes (1) identifying a finite list of GSI project types, and (2) determining the scope and scale of planned GSI.

Defining GSI Project Types

A finite, defined list of GSI project types allows standard assumptions, such as costs and units of measurement, to be made about projects during the planning and budgeting stage. This allows GSI program staff to plan for ongoing operational and staffing needs beyond the initial capital development cost of each GSI installation.

AECOM's previous work with SFPUC has involved classifying SSIP-related projects into project types and sub-types.[2] For this project, AECOM worked with SSIP staff and UWMP to compile a list of GSI project types and sub-types from the previous analysis. Major GSI categories are classified into project types, while variations within categories are classified into sub-types and in some cases, further delineated by sub-sub-types. Table 3 lists the ten project types with associated sub-categories.

TABLE 3. CATEGORIZATION OF GSI PROJECT TYPES

Project Type	Project Sub-Type	Project Sub-sub-type
Bioretention: *Stormwater facilities that rely on vegetation and engineered soils to capture, infiltrate, transpire, and remove pollutants from runoff.*	Soft Edge (a.k.a. Rain Garden)	Infiltrative
		Underdrained
	Hard Edge (a.k.a. Planter)	Infiltrative
		Underdrained
Bioswale: *A broad, shallow channel comprised of a soil medium and dense vegetation covering the bottom and side slopes.*	Soft Edge	*none*
	Hard Edge	*none*
Infiltration Gallery: *An underground stormwater storage structure that receives inflow through sub-surface piping.*	*none*	*none*
Pervious Paving: *Any porous load-bearing surface that temporarily stores rainwater prior to infiltration or drainage to a controlled outlet.*	Infiltrative	Local Road[3]
		Collector Road[3]
		Arterial Road[3]
	Underdrained	Local Road
		Collector Road
		Arterial Road
Infiltration Basin: *An unvegetated, rock-filled trench that receives surface stormwater runoff and allows it to infiltrate.*	*none*	*none*
Constructed Wetland: *Man-made wetlands designed to collect and purify stormwater through microbial transformation, plant uptake, settling, and adsorption.*	Surface	*none*
	Sub-surface	*none*
Vegetated Roof: *Roofs that are entirely or mostly covered with vegetation and soils.*	Extensive	*none*
	Intensive	*none*

[2] As part of the Triple Bottom Line (TBL) model for SFPUC, AECOM developed an economic model (Lifecycle Analysis, or LCA, model). Work for the LCA model included defining the universe of GSI project types, sub-types, and sub-sub-types for potential GSI in San Francisco. The terms for project types, sub-types, and sub-sub-types are in use by SFPUC and defined through common usage.

[3] Definitions based on [Federal Highway Administration Highway Functional Classification]

Project Type	Project Sub-Type	Project Sub-sub-type
Blue Roof: *A roof design that is explicitly intended to store water, typically rainfall.*	Extensive Pans or Check Dams	*none*
Rainwater Harvesting: *The practice of collecting and using rainwater from various surfaces, such as roofs and patios.*	Indoor - no dual plumbing	*none*
	Indoor - dual plumbing	*none*
	Outdoor Irrigation	*none*
Creek Daylighting: *The redirection of a stream into an above-ground channel.*	Public Land	Large City parcel
	Public Land	ROW + City parcels
	Private Land	ROW + private parcels

Source: AECOM, UWMP, based on the SFPUC Triple Bottom Line Lifecycle Analysis Module (AECOM 2013).

Determining GSI Scope and Scale

Publicly-owned GSI is being developed throughout San Francisco, through SFPUC's SSIP and compliance with the San Francisco Stormwater Design Guidelines in redevelopment areas. Determining the scope and scale of planned SFPUC GSI involves understanding the suite of GSI projects being proposed, planned, engineered, and funded for San Francisco as part of these two efforts.[4]

To understand the scope and scale of SSIP GSI, AECOM met with representatives of the Urban Watershed Assessment (UWA) team, the team that is developing the project planning for SSIP. The Bayside portion of the UWA is complete and the UWA team is now beginning the process of determining the count and type of GSI projects for the Westside area of the city (pending certain challenges, including the heterogeneity of land uses and densities across the city, and stormwater performance requirements). When this work has been finalized, the UWA team will be able to provide the count and type of GSI projects proposed for San Francisco. With these estimates, UWMP will then populate the maintenance model by project type, as GSI projects are designed and built over the next twenty years. The inputs for each installation will include project name, project location, project type (including any sub- categorizations), and project size.

To understand the scope and scale of GSI in redevelopment areas, AECOM contacted representatives from the engineering companies responsible for redevelopment project engineering. At this stage, with many redevelopment area projects in preliminary phases or planning hiatus, reliable estimates of the amount and type of GSI in redevelopment areas were not available.[5]

[4] GSI is being developed and funded in other realms by other agencies, but SFPUC's GSI maintenance obligations will be confined to GSI associated with the SSIP and compliance with the San Francisco Stormwater Design Guidelines in redevelopment projects.

[5] For the Candlestick and Hunters Point Shipyard Phase 2 sites, project engineers estimate 193,250 square feet of bioretention will be constructed (as per email from Todd Adair, Principal/Vice President with BKF Engineers, received on 18 October 2013).

Estimating Maintenance Costs

AECOM procured maintenance cost rates, per project type, from Sustainable Watershed Designs (SWD).[6],[7] AECOM confirmed with UWMP staff that the rates developed by SWD are appropriate estimates. The maintenance cost rates include an estimate of labor hours for each project type, as shown in Appendix B. Maintenance cost rates are expressed as equivalent annualized costs, predicated on an estimated life span (also included in Appendix B).

To determine per-unit costs, SWD identified prototypical GSI installations for each project type and outlined the necessary maintenance tasks, including material requirements and labor hours to perform each task, given the prototypical GSI installation. A generic hourly rate of $66 was assumed for labor.[8] SWD's detailed maintenance cost estimates are included in Appendix C.

To allow for more flexibility in the planning of GSI maintenance, five different levels of service were created for each BMP type. The SFPUC currently uses Quarterly maintenance as the default for planning purposes. For more information on the level of service for GSI maintenance in other municipalities, please refer to the case studies in Appendix A. Table 4 provides definitions for each level of service, and the number of associated regular maintenance visits and rehabilitation visits. The BMP unit costs for each level of service are also provided in Appendix B.

TABLE 4. BMP LEVELS OF SERVICE

Service Level	Frequency of Visits	# of Regular Maintenance Visit per Year	# of Rehabilitation Visits per Year
A	Visit every month – Monthly	11	1
B	Visit every three months – Quarterly	3	1
C	Visit every six months – Semiannual	1	1
D	Visit every twelve months - Annual	0	1
E	Visit every five years - Quinquennial	0	1/5

Identifying Other Model Inputs

Along with project types, scope and scale of planned GSI installations, and maintenance cost estimates, other inputs are required to model O&M budget and staff requirements over time. One required user-defined input is the proportion of planned GSI installations for which the SFPUC has maintenance responsibility. For some GSI, other entities, either public agencies (e.g. DPW) or private agencies (e.g. homeowners' associations), will be responsible for portions of the maintenance work. To accurately model the SFPUC's budget and staff requirements, this division of maintenance responsibility must be accounted for in the maintenance cost model. Another user-defined input is

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[6] Estimates received from Rob Dusenbury, PE, of Sustainable Watershed Designs via email on January 8, 2014. The independent development of cost rates is outside the scope of AECOM's work on this project.

[7] Sustainable Watershed Designs was renamed and is now doing business as Lotus Water.

[8] According to SFPUC staff Mike Adamow, the average fully loaded hourly rate for a SFPUC crew of two gardeners and one supervisor would be approximately $66 per hour per crew member (per email correspondence dated 2/19/2014). For information on customizing this rate to fit another municipality, refer to the maintenance model User Guide.

the construction period for planned GSI installations. For each project, a start year for maintenance work must be entered. From these inputs, the maintenance model calculates the first year for which O&M is required for a particular GSI installation.

Another user-defined input is an optional cost adjustment factor that can be applied for unique maintenance scenarios. For instance, higher than normal maintenance costs may be incurred for projects with high visibility or heavy sediment loads. Under these circumstances, the user can apply a cost adjustment factor to either increase or decrease maintenance costs.

Because the maintenance cost model constructs an estimate of budget requirements *over time*, the model must also contain standardized financing assumptions. Within the maintenance cost model, a start year for analysis is assumed (i.e. the present value year, or 'Year 0'), as well as an escalation rate for maintenance costs, and a discount rate for O&M. Default values are built into the maintenance model, and can be modified at the user's discretion.

3. MAINTENANCE MODEL

Model Inputs

The maintenance cost model requires the following inputs from a user:

General project inputs:

- Project Name – a unique name that will be used to identify a particular project
- Watershed – the watershed within which the project falls
- Number of BMP Types – the number of BMPs in a project, up to 20

Inputs for each of the BMPs[9]:

- BMP Type – the broadest category of BMP grouping
- BMP Sub-type – refinement of the BMP grouping
- BMP Sub-sub-type – further (and finest) refinement of the BMP grouping
- Spatial Distribution of BMP[10] – an indication of the BMP layout as either concentrated (concentrated in one location), dispersed (linear or spread across a long stretch of right-of-way), or typical (the average or usual layout)
- BMP Size – the linear feet, square feet, or cubic feet of BMP
- Proportion of BMP cost for which SFPUC has O&M Responsibility – a percentage of the total cost
- Cost Adjustment Factor – a percentage increase or decrease of the O&M cost if the BMP is more expensive or less expensive to maintain than the typical BMP of its type
- Comments – about the BMP, the project, or the Cost Adjustment Factor
- SFPUC Maintenance Start Date – the first year in which SFPUC is/will be responsible for maintenance of the BMP

[9] Please refer to the User Guide for recommendations on customizing these parameters.
[10] For definitions of Spatial Distribution of each BMP, please refer to the Project Input tab of the model.

- SFPUC Maintenance End Date – the year in which SFPUC will end its maintenance responsibility for a BMP (i.e. if the BMP is scheduled to be decommissioned in a certain year or the BMP is only in operation for a certain construction phase)

Additional parameters are contained within the maintenance cost model and auto-populate based on built-in model assumptions. These parameters can be modified by the user as data becomes available.[11] They include:

- Start year of analysis (i.e. the present value year, or 'Year 0', currently set to 2014)
- Annual escalation rate for O&M costs (a default rate of 3% is included)
- Annual discount rate for O&M costs (a default rate of 1.32% is included)
- Unit cost for O&M corresponding to each BMP type
- O&M labor hours per unit corresponding to each BMP type

Model Outputs

Once populated, the maintenance model will output the following information:

- Annual budget requirements, forecast for twenty years
- Net present value of the twenty-year annual budget forecast
- Annual staffing requirements, forecast for twenty years, in terms of both labor hours and full-time staff equivalents (FTE)

The maintenance model calculates the annual budget requirements based on per-unit material and labor costs for maintenance work performed by a maintenance crew. The labor costs are based on estimated person-hours necessary to perform required maintenance activities for a typical GSI installation, divided by the size of a typical GSI installation. This bottom-up approach does not account for additional management costs that might arise, such as the cost for program management staff. For example, the budget would not account for the cost of hiring a full-time staff person if a fractional FTE is required (i.e., 0.25 FTE or 0.5 FTE) for the work. In reality, for organizational reasons, SFPUC may hire a full-time crew person to perform work rather than a part-time person, which would result in higher costs than the maintenance model would present. The maintenance model also does not include costs for contract administration and/or inspection, should SFPUC contract GSI maintenance work out to another agency or to a private contractor.

The outputs will be contained in three dashboards – one to view the budget and labor forecasts for particular BMPs or groups of BMPS; one to view the budget and labor forecasts for particular projects or groups of projects; and one to view the budget and labor forecasts for a particular watershed. Each dashboard will contain the same information as outlined above for a different subset of the input data.

Initial Findings

- **Bioretention and creek daylighting require more labor-intensive maintenance than other project types.** Creek daylighting, in particular, has a very high per-unit labor cost of almost $30 (per linear foot). The material component of the maintenance cost for bioretention is $3.55 per square foot.

[11] Please refer to the User Guide for recommendations on customizing these parameters.

- **Rainwater harvesting requires more material maintenance than other project types.** The material component of the maintenance cost for rainwater harvesting is over $8 per square foot, whereas most other project types have per-unit material maintenance costs below $1.50.
- **Permeable paving, vegetated roofs, and blue roofs are the cheapest to maintain.** Annualized unit maintenance costs for pervious paving are under $0.20 per square foot, the lowest of any project type.
- **Other cities contract out their GSI maintenance work.** Instead of developing and managing GSI maintenance crews in-house, all four cities interviewed for this study contract GSI maintenance work to outside groups (private contractors and/or non-profits). Instead, cities retain a small team within the public agency to undertake contract management, data collection, and inspections for their GSI investments.

Final Model

The maintenance cost model was developed in Spring 2014 and updated in December 2014, November 2016, and September 2018. The excel-based maintenance cost model that accompanies this memorandum is dated September 2018. Next steps in the development of the maintenance cost model include ground-truthing the labor hour assumptions in the model using actual maintenance labor hours. Please consider reaching out to Michael Adamow, SFPUC GI Planning Specialist at madamow@sfwater.org, or Sarah Minick, Utility Planning Division Manager at sminick@sfwater.org if your municipality is willing to share any available data on green infrastructure maintenance labor hours so that we may continue to refine this model.

APPENDIX A

Transcriptions of Case Study Interviews

Below are the transcriptions of the case study interviews with Philadelphia, Portland, Seattle, and Syracuse.

City of Philadelphia Case Study

Interview with representatives Lance Butler and Gerald Bright regarding Philadelphia's GSI maintenance program
Date: October 25, 2013 (11AM conference call)

A. Confirm name/title/role of interviewee(s)

Lance Butler, Manager of Environmental Restoration O&M (EROM) Program (since 2010). Responsible for programmatic management, in-house staff management, contract management, integration of GSI maintenance work into Cityworks

Gerald Bright, Supervisor of GSI Maintenance (since 2012). Helps manage staff, equipment, materials, storage, contract administration, design reviews, and some overflow inspection work. Responsible for inter-agency and inter-departmental coordination (with streets, parks, sewer maintenance group, etc.). Responsible for integrating GSI maintenance into Cityworks.

B. History and Structure

1. What is your role in the GI program/how long have you been involved in GI

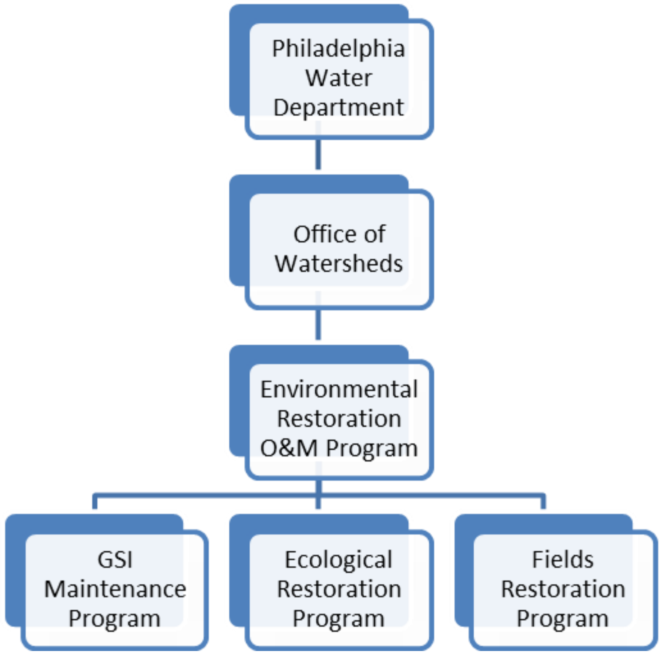
   See above.

2. How long has your city had a GI maintenance program (MP)? How has it evolved over time? What does it entail?

   The City has had maintenance work requirements since pilot GSI projects in 2009. These maintenance requirements have grown over time, as the amount of GSI has grown.

3. Where within the City organization does the GI MP fall? (I.e. what department?) Is this different from other types of sewer system or stormwater infrastructure maintenance programs?

   See graphic below. GSI maintenance is a separate entity from sewer or other grey infrastructure maintenance.

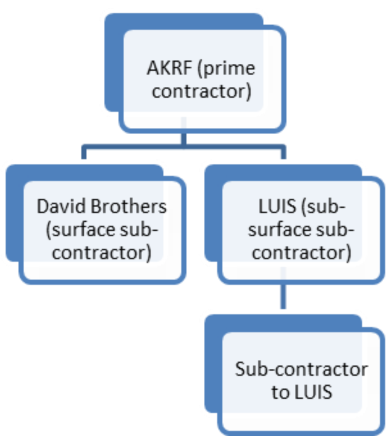


C. Labor/Staff

4. How many staff (clarify FTE)/ FTE does your GI MP have? What is the budget for the program? Are any of the staff shared between agencies/departments?

   The in-house GSI Maintenance Program staff is 4.25 people: Gerald, a Surface Maintenance representative, a Sub-Surface representative, a Field Inspections Leader, and Lance (one quarter of his time).

   The GSI Maintenance Program contracts a significant amount of the maintenance work to a prime contractor (AKRF) with about 14 staff, who spend varying amounts of time doing GSI maintenance. AKRF has 4 core staff dedicated to the GI contract with Philadelphia. AKRF has two sub-contractors, who have teams of 3-5 who work on this contract. See graphic below.



5. What tasks do staff perform?
   In-house staff do investigations and site inspections. When a maintenance need arises, we call the contractor. We do post-work inspections of contractor maintenance. We also review contractor maintenance reports and annual reports. Our in-house surface maintenance staff-person coordinates and schedules inspections, researches vegetation species to refine species selection and to determine best plants to use (he will even go to the nursery and hand-pick the plants he wants). He is a civil engineer and certified arborist. The sub-surface maintenance staff-person coordinates and schedules inspections of drainage pipes and clean-out pipes, develops efficient work flows (geographical efficiencies, for example), reviews camera footage of pipe inspections, and does design review. She is an environmental engineer and has NASCO training.

   A significant amount of the maintenance work is contracted out. In terms of that contract, 75% of the contractor's time is spent doing routine, regularly scheduled maintenance work; 25% of the contractor's time is spent on reactive or emergency work, and on supporting the GSI Maintenance group's efforts to prepare the maintenance manual and manage their database.

6. Is there a BMP inspections program? Is this undertaken by the same crew? Do maintenance crews collect data for maintenance planning or QA/QC purposes?
   The contractor's sub-surface crews have an inspection crew, a maintenance crew, and then post-maintenance inspection crew. For surface maintenance, they don't do a pre-maintenance inspection. (Note: underdrains and other overflow safety mechanisms are very important to incorporate into GSI installations. Urban soils are a nightmare: must be prepared for dramatic changes in soil medium.)

7. Is there a level of service framework and target for GI maintenance? (A-F rating of GI conditions in Seattle)
   For sub-surface systems, we ensure annual flushing. In terms of surface systems, we inspect once per month during the growing season. The primary goal of our maintenance work is to preserve functionality and safety. We want to ensure that surface treatments are not overgrown, that site lines are maintained, that basin slopes are stable, that no excessive erosion has occurred. At a finer scale, we want to maintain a particular aesthetics (formal at the street level; some tolerance for 'native volunteers' in other areas, like park settings or industrial corridors).

8. What types of training do staff receive?

9. Are any GI maintenance tasks contracted out?
   a. If yes, who do you contract out to (other city department? Private contractor? HOAs? Neighborhood groups? Non-profits? Etc.) A significant amount of the maintenance work is contracted out to a private contracting firm.

   b. If yes, how do you select contractors and how is the relationship managed? We follow a standard RFP process. We sign a 1-year contract with a contractor, which can be extended up to 4 years. Our contract with AKRF was first established in 2009, and extended each year for another year, to the maximum 4 years. In 2013, we re-issued the RFP, and AKRF won the bid again. Note that working with a contractor has some initial growing pains, but now, for us, it is working very smoothly. We have 1 person hot-seated with us in our office a few days per week.

D. Materials

10. What types of equipment and resources does the GI MP have?
    Between the GSI Maintenance group and other EROM groups, we have cameras, vacuums, equipment that can cut roots, an assortment of hand tools, dump trucks, bobcats, etc.

11. Is equipment shared with other programs/departments?
    Some, yes.

12. Are renewal and replacement (R&R) efforts included in the GI maintenance work?
    As far as GSI is concerned, these systems are built for a 25-year lifetime. We have not reached that point yet. We require the constructing entity to provide 2 months of maintenance, like watering, weeding, pruning, mulching, etc. We also require a 1-year warranty. After the first year, we take on maintenance. Replacement is considered part of the maintenance responsibility, if, for example, a tree dies.

13. How are R&R decisions made/what is the process for determining long term maintenance plan/program?

14. Who maintains more specialized components like curbs, underdrains, pumps, etc.?
    It depends on the location, the component, and so on.

E. Budget

15. What is your annual GI MP budget? Can you break it down into labor vs. materials?
    We have 4.25 people on staff. The maintenance contract value is $1.4M. Lance estimates another $600,000 in staff wages, including fringe, overhead, etc., for a total budget of approximately $2M.

16. Where do budget funds come from? What is budget process? (Stormwater fee revenue? General fund sources? Other?)
    Budget funds come from general operating budget (water, sewer, and stormwater fee revenues).

    Has your department done any work to quantify or benchmark the annual costs per GI item? (would anyone else know the answer)
    We would like to do detailed statistics, but our analyses have not reached that level of granularity yet. To date, calculations have been done on a per-site basis. Each site was estimated to cost approximately $4,600. Actual costs seem to show per-site costs of about $4,100. We have 57 sites with 197 Stormwater Management Practices (SMPs). By January 2014, we will have 105 sites with 303 SMPs. We have classified 11 types of SMPs. Over time, as we acquire more data and experience, we can refine our numbers and statistics.

17. Do you have any methods to estimate costs for future maintenance?
    Most of our work is trying to determine the number of SMPs we expect to install. Each one is different, in terms of size, amount of piping, etc. Most of our work is centered around planning and design, and knowing how many projects we have. We base the contract value

on a static estimate of contractor time to do maintenance. Our estimate was $4,600 per site, including surface and sub-surface maintenance.

18. Do you accept donations to put towards GI maintenance (i.e. Adopt-A-Green-Street program)

City of Portland Case Study

Written response from representatives Gary Irwin and Michele Juon to AECOM questions regarding Portland's GSI maintenance program
Date: January 1, 2014 (received email with written responses)

A. Confirm name/title/role of interviewee(s)

   Gary Irwin, Wastewater Collection System Manager and Michele Juon, Watershed Revegetation Program (WRP) Manager

B. History and Structure

   1. What is your role in the GI program/how long have you been involved in GI

      Gary Irwin, Wastewater Collection System Manager and Michele Juon, Watershed Revegetation Program (WRP) Manager in the City of Portland Bureau of Environmental Services (BES) are responsible for the Stormwater Operations and Maintenance portion of the City's green street (swales and planters in the right-of-way) and parcel-based (regional stormwater facilities). Gary has been involved with the program for 3 years and Michele has been involved for over two years.

   2. How long has your city had a GI maintenance program (MP)? How has it evolved over time? What does it entail?

      BES has been maintaining parcel-based facilities since 2003 and green streets since they were first constructed in 2003. The City now maintains over 1,300 green streets. The green street maintenance program expanded rapidly and has forced the City to reevaluate our current maintenance practices and develop strategies to keep up with the workload, such as switching from a database maintained by the WRP to the Corporate Maintenance/Asset Management System for the Sewer and Stormwater Collection System. There are currently two full-time equivalent staff in the WRP that manage our three maintenance contractors and oversee the administration of the green street maintenance program

   3. Where within the City organization does the GI MP fall? (I.e. what department?) Is this different from other types of sewer system or stormwater infrastructure maintenance programs?

      The Wastewater Division, which is responsible for the operation and maintenance of the sewer and stormwater collection systems. The Wastewater Group secures the funding and the WRP is the maintenance service provider responsible for the green street and parcel-based facility maintenance.

C. Labor/Staff

   4. How many staff (clarify FTE)/ FTE does your GI MP have? What is the budget for the program? Are any of the staff shared between agencies/departments?

      As stated above there are two full-time equivalent staff in the WRP that manage outside maintenance contractors and perform day-to-day administration of the maintenance program for the green streets. The budget for the past two years for green streets and parcel based facility maintenance has been $757K.

5. What tasks do staff perform?
   The staff performs some maintenance on green streets, but, they mostly manage/schedule our three maintenance contractors, issue work orders, and enters information into our database and other administrative tasks.

6. Is there a BMP inspections program? Is this undertaken by the same crew? Do maintenance crews collect data for maintenance planning or QA/QC purposes?
   As part of the Bureau's asset management and maintenance management programs, the Wastewater Group has initiated an inspection and condition assessment program that is being incorporated into the CMMS for the collection system. The WRP recently started conducting these quarterly inspections of all the green street facilities. The inspections drive the work orders for the maintenance contractors and also help to assess if the facilities are meeting the budgeted/designated Level of Service (LOS).

7. Is there a level of service framework and target for GI maintenance? (A-F rating of GI conditions in Seattle)
   BES has developed LOS for green streets - A, B, C with each varying the amounts and types of maintenance, frequencies, and acceptable amount of plant cover, etc. We identified a LOS B, which we are currently budgeted at, which includes 4 site inspections by staff a year with 3-4 maintenance treatments, as necessary.

8. What types of training do staff receive?
   The WRP staff consists of biologists/ecologists but did not receive any special green infrastructure maintenance training as this has been learned on the job.

9. Are any GI maintenance tasks contracted out?
   The green street maintenance is contracted out.

   a. If yes, who do you contract out to (other city department? Private contractor? HOAs? Neighborhood groups? Non-profits? Etc.) The City has 3 long-term maintenance contractors. The contractors are landscape companies from the private sector that bid on the green street maintenance work.
   b. If yes, how do you select contractors and how is the relationship managed? The contractors are managed by the two WRP staff and one contract employee. They issue work orders and check in with the contractors to assure they are completing their work. The staff spot check the facilities that have been maintained to assure QA/QC.

D. Materials

10. What types of equipment and resources does the GI MP have?
    The two full-time staff has trucks and tools for green street maintenance.

11. Is equipment shared with other programs/departments?
    No.

12. Are renewal and replacement (R&R) efforts included in the GI maintenance work?
    Repair functions are part of the GI maintenance work and could include repairs to structural facility elements or major replanting. If the green street requires a complete replanting and

replacement of soil this would be considered a capital renewal project and fall outside the maintenance program.

13. How are R&R decisions made/what is the process for determining long term maintenance plan/program?
    Repair of green streets is defined by the Bureau's service level. For example if a greater than 25% of the planted area has missing or dead vegetation, a replanting would occur to bring the facility up to service level requirements. Additionally, the inspections/condition assessments will identify other repair needs such as structural repairs or repairs necessary because of vandalism. The inspection/condition assessment program will be the primary basis for determining when repairs are warranted. Additionally, repairs and/or maintenance may be required in specific response to safety concerns.

14. Who maintains more specialized components like curbs, underdrains, pumps, etc.?
    Curbs are the responsibility of the Bureau of Transportation and are not part of the collection system responsibility. Damage to structural elements within the green streets such as concrete check dams, overflow drains and piping are handled by collection system maintenance staff.

E. Budget

15. What is your annual GI MP budget? Can you break it down into labor vs. materials?
    Our annual budget for the past two years has been $757K. An example of the breakdown for green street maintenance for Fiscal Year 12/13 (from July 1, 2012 - June 30, 2013) includes the following:

    - WRP staff conducting site inspections, maintenance and administrative tasks - $108K
    - Maintenance - Contractor crews performing maintenance activities, plus materials - $319K
    - Note: The remaining $757K budget is for green street maintenance is does not include the breakdown for the parcel-based facility maintenance.

16. Where do budget funds come from? What is budget process? (Stormwater fee revenue? General fund sources? Other?)
    Funding for the GI maintenance comes from the City's operating budget funded by revenue received from the City's sewer/water bills.

17. Has your department done any work to quantify or benchmark the annual costs per GI item?
    The City estimated a square footage cost of $1.55 for the green street facility maintenance. The maintenance program is currently validating this estimate based on actual costs.

18. Do you have any methods to estimate costs for future maintenance?
    We will continue to use our $1.55 square foot until we have information that would warrant an adjustment.

19. Do you accept donations to put towards GI maintenance (i.e. Adopt-A-Green-Street program)
    No. The Bureau does have a Green Street Stewards Program where people/businesses can adopt a green street however this is voluntary.

City of Seattle Case Study

Written response from representative Tracy Trackett to AECOM questions regarding Seattle's GSI maintenance program
Date: November 4, 2013 (received email with written responses)

A. Confirm name/title/role of interviewee(s)
   See below.

B. History and Structure
   1. What is your role in the GI program/how long have you been involved in GI
      Tracy Trackett, PE, Green Stormwater Infrastructure Program Manager.

   2. How long has your city had a GI maintenance program (MP)? How has it evolved over time? What does it entail?
      The program currently oversees 666 bioretention facilities, 48 biofiltration projects, and 117 pervious pavement projects in the right-of-way, of all sizes. The majority of the projects are out of the warranty period.

   3. Where within the City organization does the GI MP fall? (I.e. what department?) Is this different from other types of sewer system or stormwater infrastructure maintenance programs?

C. Labor/Staff
   4. How many staff (clarify FTE)/ FTE does your GI MP have? What is the budget for the program? Are any of the staff shared between agencies/departments?
      Program has 1 administrative staff-person, who oversees tasks and tracks activities. Maintenance crews are provided by the Seattle Conservation Corps.

   5. What tasks do staff perform?

   6. Is there a BMP inspections program? Is this undertaken by the same crew? Do maintenance crews collect data for maintenance planning or QA/QC purposes?

   7. Is there a level of service framework and target for GI maintenance? (A-F rating of GI conditions in Seattle)

   8. What types of training do staff receive?

   9. Are any GI maintenance tasks contracted out?

      a. If yes, who do you contract out to (other city department? Private contractor? HOAs? Neighborhood groups? Non-profits? Etc.)
         SPU requires the constructing contractor to be responsible for maintenance on a GI project for one year post-construction. After the warranty expires, SPU contracts maintenance to Seattle Conservation Corps, a job skills training program within Seattle's Parks Department. Seattle's Department of Transportation is responsible for permeable pavement installed within the right-of-way.

SPU is investigating uniting DOT, SPU, and the Parks Department's GI maintenance efforts, as well as other maintenance program models.

b. If yes, how do you select contractors and how is the relationship managed?
The Seattle Conservation Corps is contracted through the Parks Department. All GI projects will be incorporated into Seattle's asset management system (MAXIMO), which generates work orders when maintenance is required and tracks maintenance work and inspections.

D. Materials

10. What types of equipment and resources does the GI MP have?

11. Is equipment shared with other programs/departments?

12. Are renewal and replacement (R&R) efforts included in the GI maintenance work?

13. How are R&R decisions made/what is the process for determining long term maintenance plan/program?

14. Who maintains more specialized components like curbs, underdrains, pumps, etc.?

E. Budget

15. What is your annual GI MP budget? Can you break it down into labor vs. materials?
The annual program cost is $350,000-$400,000, which will increase to $1.5M in 2020.

16. Where do budget funds come from? What is budget process? (Stormwater fee revenue? General fund sources? Other?)

17. Has your department done any work to quantify or benchmark the annual costs per GI item?
We generally budget $2.21/SF of landscaped bioretention areas for the first three years of maintenance. For the fourth year and beyond, we drop the cost by 25 percent (to $1.66/SF). These numbers are likely conservative, but they represent our initial costs. Until we have data to update these numbers, we will continue to use these estimates. By site, our costs are $500-$570/year for bioretention facilities.

18. Do you have any methods to estimate costs for future maintenance?

19. Do you accept donations to put towards GI maintenance (i.e. Adopt-A-Green-Street program)

City of Syracuse Case Study

Interview with representative Madison Quinn regarding Syracuse's GSI maintenance program
Date: October 29, 2013 (9AM conference call)

A. Confirm name/title/role of interviewee(s)
Madison Quinn, Public Information Specialist and Program Coordinator for Save the Rain.

B. History and Structure

1. What is your role in the GI program/how long have you been involved in GI?
   Let me start with some background on the Save the Rain program. Onandaga County is under mandate to mitigate CSOs. The previous plan for mitigating CSOs was to build more sewage treatment facilities. This plan faced community resistance as well as environmental justice challenges. When Joanie Mahoney started as County Executive, she developed the Save the Rain program, with green infrastructure solutions to mitigate CSOs. The first projects in 2010 were pilot projects (e.g. GI in parking lots). In 2011, we revved up with the Project 50 plan (5o projects in one year), and exceeded our goals building about 60 projects. With the momentum from Project 50, we completed another 48 in 2012. Today (late 2013), we have over 120 installed GI projects (122 exactly). I came onboard in July 2011. (I was with the County Executive prior to this role.)

2. How long has your city had a GI maintenance program (MP)? How has it evolved over time? What does it entail?
   With all Save the Rain installations, we write a one-year maintenance responsibility term into the contract – i.e. the builder must undertake all maintenance responsibilities for the GI installation for the first year post-construction. After the initial year, the maintenance obligation transitions to one of several tracks:

   - We have tried, where possible, to incorporate some of the GI maintenance work into the routine, existing maintenance work carried out by other departments (e.g. landscape maintenance teams in parks might be able to incorporate the landscape maintenance of a rain garden in that park).
   - We contracted with Onandaga Earth Corp (OEC) to do some of the maintenance work.
   - In addition, Save the Rain has one full time staff person who primarily conducts inspections but may occasionally do light maintenance work.
   - Save the Rain also has several other term contracts for specific maintenance tasks (vacuuming permeable paving, green roof maintenance).
   - Private property owners undertake the maintenance for installations on private property.
   - Finally, we are planning to centralize the management of all the GI projects by hiring a maintenance manager soon (by spring 2013) who will coordinate and oversee maintenance contracts/actions for all GI installations.

3. Where within the City organization does the GI MP fall? (I.e. what department?) Is this different from other types of sewer system or stormwater infrastructure maintenance programs?
   The Save the Rain program is an initiative of the County Executive Office. Operationally, Save the Rain is a program under the Department of Water and Environmental Protection.

C. Labor/Staff

4. How many staff (clarify FTE)/ FTE does your GI MP have? What is the budget for the program? Are any of the staff shared between agencies/departments?

   We have one full-time maintenance staff person who performs field inspections. I spend part of my time on management of the maintenance work, and many other people touch the program, but we really only have one dedicated in-house maintenance staff person. Save the Rain holds trainings for the maintenance staff of other departments who might be doing GI maintenance work, such as the parks department, DPW, City Water, and so on. We have held workshops for the best management practices for GI, to help train departmental staff (and also private property owners, who will be responsible for GI maintenance).

   Every GI asset is catalogued in our database program, MAXIMO. The maintenance requirements for each asset are built into the database, which then generates work orders for all scheduled maintenance, as per the maintenance requirements (e.g. quarterly inlet cleaning). Maintenance schedules are determined by GI feature type (i.e. permeable paving requires vacuuming x times per year; rain gardens require pruning x times per month, etc.).

   We have a grant program for large-scale GI installations on private property (the minimum capture requirement is 60,000 gallons per year). Participating property owners sign a 10-year maintenance agreement as part of the conditions of the grant award.

   After the expiration of the initial one-year contractor's maintenance obligation on Project 50 GI installations, Save the Rain quickly had multiple GI maintenance duties coming online. To get this work done, Save the Rain signed a one-time maintenance contract with OEC for about $20,000, which has subsequently been extended. EOC is a green jobs workforce development agency. They hire local youths between ages 15 – 25. Working with the Department of Labor, we negotiated a prevailing livable wage with EOC of $11.33/hr.

   Save the Rain is currently trying to issue an RFP to hire a Maintenance Manager, who would coordinate maintenance activities and contractors for all GI projects. We want to avoid putting out RFPs for a maintenance/landscape contractors, who would be selected based on lowest bid. We value the job opportunities and green job workforce development provided by organizations like OEC, and want to incorporate these additional benefits into our maintenance program. In order to coordinate that successfully, we need the professional services of a maintenance manager (which could be an individual or a dedicated staff person with a larger firm).

5. What tasks do staff perform?

6. Is there a BMP inspections program? Is this undertaken by the same crew? Do maintenance crews collect data for maintenance planning or QA/QC purposes?

   Our in-house maintenance staff person does inspections, but I am not sure if he is on a particular program or schedule. He does keep maintenance logs with photos, etc. and uploads these to MAXIMO.

7. Is there a level of service framework and target for GI maintenance? (A-F rating of GI conditions in Seattle)

In medians, for example, we have to have low-growing vegetation to preserve sight lines. In parks, we try to blend into the surrounding aesthetic. We also conduct community engagement and outreach to get buy-off from the public on project design.

8. What types of training do staff receive?

9. Are any GI maintenance tasks contracted out?
    a. If yes, who do you contract out to (other city department? Private contractor? HOAs? Neighborhood groups? Non-profits? Etc.) We contract general maintenance to OEC (see above). We also have term contracts for vacuuming permeable paving, and for green roof maintenance.
    b. If yes, how do you select contractors and how is the relationship managed? Our inspector communicates with OEC, and we have a contract with them to do general maintenance work. We keep a spreadsheet that outlines which GI installations are maintained by the construction contractors (as per their initial establishment maintenance agreement), by private property owners, by other government departments, by OEC, and/or by any others. The new Maintenance Manager will be responsible for coordinating between groups who do maintenance work, especially as we involve more groups like OEC in the maintenance work.

D. Materials

10. What types of equipment and resources does the GI MP have?
    We rent a vacuum truck to vacuum porous pavement, although we are considering purchasing one ourselves or in conjunction with another department. Our inspector uses a County vehicle.

11. Is equipment shared with other programs/departments?

12. Are renewal and replacement (R&R) efforts included in the GI maintenance work?

13. How are R&R decisions made/what is the process for determining long term maintenance plan/program?

14. Who maintains more specialized components like curbs, underdrains, pumps, etc.?

E. Budget

15. What is your annual GI MP budget? Can you break it down into labor vs. materials?
    We have term contracts for vacuuming permeable pavement, for green roof maintenance, and for general landscaping –exact contract amounts can be provided. We also have the salary costs of our one maintenance employee. The staff cost plus the contract values constitutes the majority of our maintenance budget.

16. Where do budget funds come from? What is budget process? (Stormwater fee revenue? General fund sources? Other?)
    Funds for the Save the Rain program, including maintenance, come from the sewer use fee which is assessed on annual property tax bills. We do not have a stormwater fee, so entities like parking lots do not contribute (because they typically don’t have sewer hookups), even though they add runoff to the stormwater system. The rate structure for the sewer use fee is

very simple, so most parcels pay a similar amount. All budget funds come from the sewer use fee. Capital funds are derived from GO bonds.

17. Has your department done any work to quantify or benchmark the annual costs per GI item? (would anyone else know the answer)
    We have some maintenance cost estimates that I can send to you.

18. Do you have any methods to estimate costs for future maintenance?
    We have some annual breakdown of estimates that informs our term contracts.

19. Do you accept donations to put towards GI maintenance (i.e. Adopt-A-Green-Street program)
    We are discussing an ‘Adopt-a-Green’ scheme. This has not yet launched on the website, but we have been talking about it with interested parties (CH2M Hill, a gardening club, etc.).

APPENDIX B

GSI Maintenance Cost Estimates Per Project Type (2014 Dollars)

Below are the BMP-specific maintenance cost estimates for each level of service. The Annualized Unit Maintenance Cost (AUMC) is based on an assumed hourly rate of $66 per hour per crew member. For detailed maintenance cost estimates for each BMP, refer to Appendix C.

Project Type	Project Sub-type	Project Sub-sub-type	Cost Units	Estimated Life Span (years)	Service Level	Annualized Unit Maintenance Cost (AUMC) (2014 dollars)	O&M Labor Hours Per Unit (hours)
Bioretention	Soft Edge (a.k.a. Rain Garden)	Infiltrative	$/ft2	30	A	$6.44	0.078
					B	$3.24	0.030
					C	$2.44	0.018
					D	$2.05	0.012
					E	$1.42	0.002
		Underdrained	$/ft2	30	A	$6.90	0.085
					B	$3.49	0.034
					C	$2.64	0.021
					D	$2.22	0.015
					E	$1.45	0.003
	Hard Edge (a.k.a. Planter)	Infiltrative	$/ft2	30	A	$7.04	0.088
					B	$3.47	0.034
					C	$2.58	0.020
					D	$2.14	0.013
					E	$1.44	0.003
		Underdrained	$/ft2	30	A	$7.50	0.095
					B	$3.73	0.037
					C	$2.78	0.023
					D	$2.31	0.016
					E	$1.47	0.003
Bioswale	Soft Edge	none	$/ft2	30	A	$6.44	0.078
					B	$3.24	0.030
					C	$2.44	0.018
					D	$2.05	0.012
					E	$1.42	0.002
	Hard Edge	none	$/ft2	30	A	$7.04	0.088
					B	$3.47	0.034
					C	$2.58	0.020
					D	$2.14	0.013
					E	$1.44	0.003
Infiltration Gallery	none	none	$/ft2	20	A	$3.89	0.046
					B	$2.01	0.018
					C	$1.55	0.011
					D	$1.31	0.007
					E	$0.93	0.001

Project Type	Project Sub-type	Project Sub-sub-type	Cost Units	Estimated Life Span (years)	Service Level	Annualized Unit Maintenance Cost (AUMC) (2014 dollars)	O&M Labor Hours Per Unit (hours)
Pervious Paving	Infiltrative	Local Road	$/ft2	15	A	$0.25	0.002
					B	$0.20	0.001
					C	$0.18	0.001
					D	$0.18	0.001
					E	$0.12	0.000
		Collector Road	$/ft2	15	A	$0.28	0.003
					B	$0.22	0.002
					C	$0.20	0.001
					D	$0.19	0.001
					E	$0.13	0.000
		Arterial Road	$/ft2	20	A	$0.30	0.003
					B	$0.24	0.002
					C	$0.22	0.002
					D	$0.21	0.001
					E	$0.14	0.000
	Underdrained	Local Road	$/ft2	15	A	$0.28	0.003
					B	$0.21	0.002
					C	$0.19	0.001
					D	$0.18	0.001
					E	$0.12	0.000
		Collector Road	$/ft2	15	A	$0.31	0.003
					B	$0.23	0.002
					C	$0.21	0.001
					D	$0.20	0.001
					E	$0.13	0.000
		Arterial Road	$/ft2	20	A	$0.34	0.003
					B	$0.25	0.002
					C	$0.23	0.002
					D	$0.22	0.001
					E	$0.14	0.000
Infiltration Basin	none	none	$/ft2	50	A	$3.89	0.046
					B	$2.01	0.018
					C	$1.55	0.011
					D	$1.31	0.007
					E	$0.93	0.001

Project Type	Project Sub-type	Project Sub-sub-type	Cost Units	Estimated Life Span (years)	Service Level	Annualized Unit Maintenance Cost (AUMC) (2014 dollars)	O&M Labor Hours Per Unit (hours)
Constructed Wetland	Surface	none	$/ft2	30	A	$3.71	0.048
					B	$1.71	0.018
					C	$1.21	0.010
					D	$0.96	0.007
					E	$0.61	0.001
	Subsurface	none	$/ft2	30	A	$3.83	0.048
					B	$1.82	0.018
					C	$1.32	0.010
					D	$1.07	0.007
					E	$0.72	0.001
Vegetated Roof	Extensive	none	$/ft2	30	A	$0.33	0.004
					B	$0.33	0.004
					C	$0.33	0.004
					D	$0.33	0.004
					E	$0.33	0.004
	Intensive	none	$/ft2	20	A	$0.33	0.004
					B	$0.33	0.004
					C	$0.33	0.004
					D	$0.33	0.004
					E	$0.33	0.004
Blue Roof	Extensive Pans or Check Dams	none	$/ft3	50	A	$0.13	0.002
					B	$0.13	0.002
					C	$0.13	0.002
					D	$0.13	0.002
					E	$0.13	0.002
Rainwater Harvesting	Indoor - no dual plumbing	none	$/ft3	50	A	$1.11	0.006
					B	$0.89	0.003
					C	$0.84	0.002
					D	$0.81	0.001
					E	$0.74	0.0003
	Indoor - dual plumbing	none	$/ft3	50	A	$1.11	0.006
					B	$0.89	0.003
					C	$0.84	0.002
					D	$0.81	0.001
					E	$0.74	0.000

Project Type	Project Sub-type	Project Sub-sub-type	Cost Units	Estimated Life Span (years)	Service Level	Annualized Unit Maintenance Cost (AUMC) (2014 dollars)	O&M Labor Hours Per Unit (hours)
	Outdoor Irrigation	none	$/ft3	50	A	$0.39	0.001
					B	$0.39	0.001
					C	$0.39	0.001
					D	$0.39	0.001
					E	$0.34	0.000
Creek Daylighting	Public Land	Large City parcel	$/ft	30	A	$7.77	0.094
					B	$3.86	0.035
					C	$2.88	0.020
					D	$2.39	0.013
					E	$1.72	0.003
		ROW + City parcels	$/ft	30	A	$8.03	0.098
					B	$4.12	0.039
					C	$3.15	0.024
					D	$2.66	0.017
					E	$1.77	0.003
	Private Land	ROW + private parcels	$/ft	25	A	$8.03	0.098
					B	$4.12	0.039
					C	$3.15	0.024
					D	$2.66	0.017
					E	$1.77	0.003

Source: Rob Dusenbury, PE, of Sustainable Watershed Design, January 2014; AECOM, 2014. Refer to **Error! Not a valid bookmark self-reference.** (Detailed Maintenance Cost Estimates from Sustainable Watershed Designs).
Note: The sum of the labor component and the material component of the AUMC is equal to the AUMC. The AUMC is based on an assumed hourly rate of $66 per hour per crew member.

APPENDIX C

Detailed Maintenance Cost Estimates from Sustainable Watershed Designs

Below are the detailed maintenance cost estimates developed for this effort by Rob Dusenbury at Sustainable Watershed Designs

BIORETENTION FACILITIES (HARD EDGE)

BMP Component[1,2]	Regular Maintenance (per monthly visit) Task	(hrs/1,000 ft²)	Rehabilitation (per annual visit) Task	(hrs/1,000 ft²)	Definition / Notes
Mobilization/Demobilization[3,4,5]	Preparation, Travel, and Setup Time	1.75	Preparation, Travel, and Setup Time	3.50	
Inlet & Outlet Low-flow Channel	Clean debris & sediment from flow path. Reset/replace armoring rock as needed.	0.60	Clean debris & sediment from flow path. Reset/replace armoring rock as needed.	0.60	Low-flow channel in swales and some other bioretention armored with gravel/cobbles to prevent soil erosion.
Splash Pad / Forebay (stone or concrete)	Clean out debris & sediment. Replace missing or eroded rip rap.	0.80	Clean out debris & sediment. Re-level concrete pad.	1.60	Prevents erosion at the point where water enters the facility, directly adjacent to the inlet.
Planting	Trim/prune.	0.80	Replace diseased and dead plants.	1.20	It is assumed that all facilities will have irrigation systems.
Mulch (wooden or stone)	Remove sedimentation with flat-head shovel. Spot mulch.	0.40	Add new layer of mulch (wooden). Even out and fill bare patches (stone).	1.20	Rock and cobble mulch equipment and labor requirements vary from wood mulch.
Weeds and Trash	Remove.	0.80	Remove.	0.80	Would be ideal to co-opt the services of a neighborhood group to do this weekly.
Soil Media	Regrade and stabilize any eroded areas.	0.40	Aeration and tilling.	1.60	
Aggregate Subgrade Layer					May be located under the soil media to augment storage and/or drainage.
Structural Elements (e.g., curbs, curb walls, check dams)			Repair chips & cracks in concrete. Regrade/reset stone elements.	1.00	Structural perimeter that frames the facility. Structural maintenance, repair and replacement to be determined by policy discussions with DPW.
Irrigation System	Adjust and test head patterns.	0.80	Replace broken or malfunctioning heads, valves, valve boxes and piping.	1.00	DPW responsibility.
Reporting	Complete standard maintenance form.	0.40	Complete standard maintenance form.	0.80	Assume a standard form will be developed to record condition of each item addressed on this sheet.
TOTAL UNIT LABOR - TYPICAL BIORETENTION:		6.75		13.30	
Underdrain and Cleanouts	Clear obstructing debris.	0.40	Snake or jet pipe.	1.60	Clean outs provide access to undrain for maintenance.
Impermeable Liner (membrane)			Repair tears, cracks or holes.	1.00	For use when infiltration is prohibited (Maher Zone, soil contamination, liquefaction concerns, high GW or bedrock, insufficient offset from structures).
TOTAL UNIT LABOR - UNDERDRAINED BIORETENTION:		7.15		15.90	
Trench Drain	Clear obstructing debris.	0.40	Repair or replace broken grates.	0.50	Can be cast-in-place, pre-cast concrete.
Monitoring Wells	Replace damaged or missing caps.	0.40	Replace broken pipe housing.	0.50	
Driveway / HP Ramp Extensions			Repair chips & cracks, repair or replace truncated dome panels.	0.50	Driveway apron extensions through planters.
	SUBTOTAL:	0.80	SUBTOTAL:	1.50	
MAXIMUM TOTAL UNIT LABOR - BIORETENTION:		7.95		17.40	

Average Labor Rate =	$70.00	per hour

Fixed Costs		MATERIALS ($$/1,000 ft²)
Materials	Monthly	$60
	Annual	$600

		($/ft²/year)	Labor component
ANNUAL TOTALS:	TYPICAL:	$7.39	$6.13
	UNDERDRAINED:	$7.88	$6.62

Notes

1) The average site is assumed to manage one acre of impervious area and contain 3,000 ft² of bioretention area.
2) An average rain garden is assumed to have a footprint of 250 ft².
3) A field crew of three is assumed for maintenance and rehab activities.
4) Preparation is assumed to take 30 minutes in the morning, traveling to the site is assumed to take 30 minutes,15 minutes to set up, and traveling home at the end of the day 30 minutes.
5) It is assumed that a crew can handle one site in one full working day for the eleven monthly visits, and one site in two full days for the annual visit.

BIORETENTION FACILITIES (SOFT EDGE)

BMP Component[1,2]	Regular Maintenance (per monthly visit) Task	(hrs/1,000 ft²)	Rehabilitation (per annual visit) Task	(hrs/1,000 ft²)	Definition / Notes
Mobilization/Demobilization[3,4,5]	Preparation, Travel, and Setup Time	1.75	Preparation, Travel, and Setup Time	3.50	
Inlet & Outlet Low-flow Channel	Clean debris & sediment from flow path. Reset/replace armoring rock as needed.	0.50	Clean debris & sediment from flow path. Reset/replace armoring rock as needed.	0.50	Low-flow channel in swales and some other bioretention armored with gravel/cobbles to prevent soil erosion.
Splash Pad / Forebay (stone or concrete)	Clean out debris & sediment. Replace missing or eroded rip rap.	0.50	Clean out debris & sediment. Re-level concrete pad.	1.60	Prevents erosion at the point where water enters the facility, directly adjacent to the inlet.
Planting	Trim/prune.	0.80	Replace diseased and dead plants.	1.20	It is assumed that all facilities will have irrigation systems.
Mulch (wooden or stone)	Remove sedimentation with flat-head shovel. Spot mulch.	0.40	Add new layer of mulch (wooden). Even out and fill bare patches (stone).	1.20	Rock and cobble mulch equipment and labor requirements vary from wood mulch.
Weeds and Trash	Remove.	0.50	Remove.	0.50	Would be ideal to co-opt the services of a neighborhood group to do this weekly.
Soil Media	Regrade and stabilize any eroded areas.	0.40	Aeration and tilling.	1.60	
Aggregate Subgrade Layer					May be located under the soil media to augment storage and/or drainage.
Structural Elements (e.g., curbs, curb walls, check dams)			Repair chips & cracks in concrete. Regrade/reset stone elements.		Structural perimeter that frames the facility. Structural maintenance, repair and replacement to be determined by policy discussions with DPW.
Irrigation System	Adjust and test head patterns.	0.80	Replace broken or malfunctioning heads, valves, valve boxes and piping.	1.00	DPW responsibility.
Reporting	Complete standard maintenance form.	0.40	Complete standard maintenance form.	0.80	Assume a standard form will be developed to record condition of each item addressed on this sheet.
TOTAL UNIT LABOR - TYPICAL BIORETENTION:		6.05		11.90	
Underdrain and Cleanouts	Clear obstructing debris.	0.40	Snake or jet pipe.	1.60	Clean outs provide access to undrain for maintenance.
Impermeable Liner (membrane)			Repair tears, cracks or holes.	1.00	For use when infiltration is prohibited (Maher Zone, soil contamination, liquefaction concerns, high GW or bedrock, insufficient offset from structures).
TOTAL UNIT LABOR - UNDERDRAINED BIORETENTION:		6.45		14.50	
Trench Drain	Clear obstructing debris.		Repair or replace broken grates.		Can be cast-in-place, pre-cast concrete.
Monitoring Wells	Replace damaged or missing caps.	0.40	Replace broken pipe housing.	0.50	
Driveway / HP Ramp Extensions			Repair chips & cracks, repair or replace truncated dome panels.		Driveway apron extensions through planters.
	SUBTOTAL:	0.40	SUBTOTAL:	0.50	
MAXIMUM TOTAL UNIT LABOR - BIORETENTION:		6.85		15.00	

Average Labor Rate =	$70.00	per hour

Fixed Costs		MATERIALS ($$/1,000 ft²)
Materials	Monthly	$60
	Annual	$600

		($/ft²/year)	Labor component
ANNUAL TOTALS:	TYPICAL:	$6.75	$5.49
	UNDERDRAINED:	$7.24	$5.98

Notes

1) The average site is assumed to manage one acre of impervious area and contain 3,000 ft² of bioretention area.
2) An average rain garden is assumed to have a footprint of 250 ft².
3) A field crew of three is assumed for maintenance and rehab activities.
4) Preparation is assumed to take 30 minutes in the morning, traveling to the site is assumed to take 30 minutes,15 minutes to set up, and traveling home at the end of the day 30 minutes.
5) It is assumed that a crew can handle one site in one full working day for the eleven monthly visits, and one site in two full days for the annual visit.

INFILTRATION TRENCHES

BMP Component[1]	Regular Maintenance (per monthly visit) Task	(hrs/1,000 ft^2)	Rehabilitation (per annual visit) Task	(hrs/1,000 ft^2)	Definition / Notes
Mobilization/Demobilization[2,3,4]	Preparation, Travel, and Setup Time	1.25	Preparation, Travel, and Setup Time	1.75	
Inlet & Outlet	Remove debris and any other blockages. Reset/replace rip-rap as needed.	0.40	Remove debris and any other blockages. Reset/replace rock as needed.	0.40	
Splash Pad / Forebay (stone or concrete)	Clean out debris & sediment. Replace missing or eroded rip rap.	0.80	Clean out debris & sediment. Re-level concrete pad.	1.60	Prevents erosion at the point where water enters the facility, directly adjacent to the inlet.
Weeds and Trash	Remove.	0.40	Remove.	0.80	Would be ideal to co-opt the services of a neighborhood group to do this weekly.
Stone Media	Regrade and stabilize any eroded areas.	0.40	Add rock to restore surface to original grade.	1.00	
Structural Elements (e.g., curbs, curb walls, check dams)			Repair chips & cracks in concrete. Regrade/reset stone elements.	1.00	Structural perimeter that frames the facility. Structural maintenance, repair and replacement to be determined by policy discussions with DPW.
Reporting	Complete standard maintenance form.	0.30	Complete standard maintenance form.	0.60	Assume a standard form will be developed to record condition of each item addressed on this sheet.
TOTAL UNIT LABOR - TYPICAL BIORETENTION:		3.55		7.15	
Trench Drain	Clear obstructing debris.	0.40	Repair or replace broken grates.	0.50	Can be cast-in-place, pre-cast concrete.
Monitoring Wells	Replace damaged or missing caps.	0.40	Replace broken pipe housing.	0.50	
	SUBTOTAL:	0.80	SUBTOTAL:	1.00	
MAXIMUM TOTAL UNIT LABOR - INFILTRATION		4.35		8.15	
Average Labor Rate =	$70.00	per hour			

Task		MATERIALS ($$/1,000 ft^2)
Materials	Monthly	$40
	Annual	$400

		($/$ft^2$/year)	Labor component
ANNUAL TOTALS:	TYPICAL	$4.07	$3.23

Notes

1) The average site is assumed to manage one acre of impervious area and contain 3,000 ft^2 of infiltration area.
2) A field crew of three is assumed for maintenance and rehab activities.
3) Preparation is assumed to take 30 minutes in the morning, traveling to each site is assumed to take 30 minutes plus 15 minutes to set up, and traveling home at the end of the day 30 minutes.
4) It is assumed that a crew can handle two sites in one full working day for the eleven monthly visits, and one site in one full day for the annual visit.

PERMEABLE PAVING SYSTEMS

BMP Component[1]	Regular Maintenance (per quarterly visit) Task	(hrs/1,000 ft²)	Rehabilitation (per annual visit) Task	(hrs/1,000 ft²)	Definition / Notes
Mobilization/Demobilization[2,3,4,5]	Preparation, Travel, and Setup Time.	0.07	Preparation, Travel, and Setup Time	0.15	
Permeable Wearing Course	Sweep and vacuum.[6]	0.02	Pressure washing.[4]	0.48	The ~6" surface layer of pervious concrete, asphalt, or unit pavers..
			Repair damaged surface.[7]	0.48	
Aggregate Subgrade Layer					Usually 12-18" of gravel beneath the wearing course that is generally inaccessible.
Structural Containment Walls					Structural perimeter that frames the facility. Structural maintenance, repair and replacement to be determined by policy discussions with DPW.
Reporting	Complete standard maintenance form.	0.02	Complete standard maintenance form.	0.04	Assume a standard form will be developed to record condition of each item addressed on this sheet.
TOTAL UNIT LABOR - TYPICAL BIORETENTION:		0.11		1.15	
Underdrain, Cleanouts, and Outlet	Clear obstructing debris.	0.03	Snake or jet pipe.	0.06	Can be cast-in-place, pre-cast concrete.
Impermeable Liner (membrane)					
	SUBTOTAL:	0.03	SUBTOTAL:	0.06	
MAXIMUM TOTAL UNIT LABOR - PERMEABLE PAVEMENT		0.14		1.21	

Average Labor Rate =	$70.00	per hour

Task		MATERIALS ($$/1,000 ft²)
Materials	Quarterly	$0
	Annual[7]	$100

ANNUAL TOTALS:		($/ft²/year)	Labor Component
	TYPICAL:	$0.20	$0.10
	UNDERDRAINED:	$0.21	$0.11

Notes

1) The average site is assumed to manage approximately two acres (~4 blocks) of impervious area and therefore contain 25,000 ft² of permeable pavement.
2) A field crew of two is assumed for sweeping/vacuuming, and a crew of three for pressure washing.
3) Preparation is assumed to take 30 minutes in the morning, traveling to each site is assumed to take 30 minutes, no set-up time necessary when using vacuum truck or 15-minutes when pressure washing, and traveling home at the end of the day 30 minutes.
4) It is assumed that a crew can sweep/vacuum six sites with a truck in one full working day for the three quarterly visits, and pressure wash by hand two sites in one full day for the annual visit.
5) The vacuum truck is assumed to make a one-hour roundtrip back to base to empty its hopper after the morning shift.
6) Assuming an 8' wide strip of permeable pavement, an average 25,000 ft² site would be 3,125' long. It is assumed the truck can cover that in 30 minutes.
7) It is assumed that 1% of the total permeable pavement area needs repair on an annual basis; $10/ft² in materials plus a 3-man crew for two full days per 1,000/ft².
8) Replacement costs are based on unit construction costs.

WETLANDS

BMP Component[1]	Regular Maintenance (per quarterly visit) Task	(hrs/1,000 ft²)	Rehabilitation (per annual visit) Task	(hrs/1,000 ft²)	Definition / Notes
Mobilization / Demobilization[2,3,4]	Preparation and Travel Time	1.20	Preparation, Travel, and Setup Time	1.80	
Inlet & Outlet Low-flow Channel	Clean debris & sediment from flow path. Reset/replace armoring rock as needed.	0.40	Clean debris & sediment from flow path. Reset/replace armoring rock as needed. Snake or jet inlet/outlet pipe.	0.80	Low-flow channel in swales and some other bioretention armored with gravel/cobbles to prevent soil erosion.
Splash Pad / Forebay (stone or concrete)	Clean out debris & sediment. Replace missing or eroded rip rap.	0.40	Clean out debris & sediment. Replace missing or eroded rip rap. Re-level concrete pad.	0.80	Prevents erosion at the point where water enters the facility, directly adjacent to the inlet.
Planting	Trim/prune.	0.60	Replace diseased and dead plants. Remove excess biomass.	1.60	It is assumed that all facilities will have irrigation systems.
Weeds and Trash	Remove.	0.40	Remove.	0.40	Would be ideal to co-opt the services of a neighborhood group to do this at least monthly.
Soil Media	Regrade and stabilize any eroded areas.	0.40	Regrade and stabilize any eroded areas.	0.40	
Reporting	Complete standard maintenance form.	0.40	Complete standard maintenance form.	0.80	Assume a standard form will be developed to record condition of each item addressed on this sheet.
TOTAL UNIT LABOR - TYPICAL BIORETENTION:		3.80		6.60	
Impermeable Liner (membrane)			Repair tears, cracks or holes.	1.60	For use when infiltration is prohibited (Maher Zone, soil contamination, liquefaction concerns, high GW or bedrock, insufficient offset from structures).
	TOTAL UNIT LABOR - LINED WETLAND:	3.80		8.20	
Monitoring Wells	Replace damaged or missing caps. Remove overgrowth around well.	0.20	Replace damaged or missing caps. Remove overgrowth around well. Replace broken pipe housing.	0.40	
	SUBTOTAL:	0.20	SUBTOTAL:	0.40	
	MAXIMUM TOTAL UNIT LABOR - WETLANDS	4.00		8.60	
Average Labor Rate =	$70.00	per hour			

Task		MATERIALS ($$/1,000 ft²)
Materials	Quarterly	$40
	Annual	$400

		($/ft²/year)	Labor Component
ANNUAL TOTALS:	SURFACE / SUBSURFACE:	$1.78	$1.26
	LINED:	$1.89	$1.37

Notes
1) The average site is assumed to manage one acre of impervious area and contain 2,500 ft² of wetland.
2) A field crew of three is assumed for maintenance and rehab activities.
3) Preparation is assumed to take 30 minutes in the morning, traveling to each site is assumed to take 30 minutes, and traveling home at the end of the day 30 minutes.
4) It is assumed that a crew can handle two sites in one full working day for the three quarterly visits, and one site in one full day for the annual visit.

GREEN ROOFS

BMP Component[1]	Maintenance / Rehabilitation (per semi-annual visit) Task	(hrs/1,000 ft²)	Definition / Notes
Mobilization/Demobilization[2,3,4]	Preparation and Travel Time	0.40	
Drain / Outlet	Clean debris.	0.05	
Planting	Trim & prune. Replace diseased and dead plants.	0.40	It is assumed that all green roofs will have irrigation systems.
Mulch (wooden or stone)	Even out and add mulch where showing thin.	0.10	
Weeds and Trash	Remove.	0.30	
Soil Media			
Irrigation System	Adjust and test head patterns. Replace broken or malfunctioning heads, valves, valve boxes and piping.	0.40	
Reporting	Complete standard maintenance form.	0.10	Assume a standard form will be developed to record condition of each item addressed on this sheet.
TOTAL UNIT LABOR - TYPICAL GREEN ROOF:		1.75	
Average Labor Rate =	$70.00	per hour	

Task		MATERIALS ($$/1,000 ft²)
Materials	Semi-annual	$50

ANNUAL TOTALS:		($/ft²/year)	Labor Component
	TYPICAL:	$0.35	$0.25

Notes
1) The average site is assumed to be a 5,000 ft² rooftop.
2) A field crew of two is assumed for maintenance and rehab activities.
3) Preparation is assumed to take 30 minutes in the morning, traveling to the site is assumed to take 30 minutes, and traveling home at the end of the day 30 minutes.
4) It is assumed that a crew can handle two sites in one full working day.

BLUE ROOFS

BMP Component[1]	Maintenance / Rehabilitation (per semi-annual visit) Task	(hrs/1,000 ft²)	Definition / Notes
Mobilization/Demobilization[2,3,4]	Preparation and Travel Time	0.20	
Drain / Outlet	Remove debris.	0.10	
Check Dams / Pans	Adjust pans as they may have been blown around. Rehabilitate the check dams	0.30	
Reporting	Complete standard maintenance form.	0.20	Assume a standard form will be developed to record condition of each item addressed on this sheet.
	TOTAL UNIT LABOR - TYPICAL GREEN ROOF:	0.80	
Average Labor Rate =	$70.00	per hour	

Task		MATERIALS ($$/1,000 ft²)
Materials	Semi-annual	$10

		($/ft²/year)	Labor Component
ANNUAL TOTALS:	TYPICAL:	$0.13	$0.11

Notes
1) The average site is assumed to be a 10,000 ft² rooftop.
2) A field crew of two is assumed for maintenance and rehab activities.
3) Preparation is assumed to take 30 minutes in the morning, traveling to the site is assumed to take 30 minutes, and traveling home at the end of the day 30 minutes.
4) It is assumed that a crew can handle two sites in one full working day.

RAINWATER HARVESTING

BMP Component[1]	Monthly Maintenance (per monthly visit) Task	(hrs/1,000 gal)	Semi-annual Maintenance (per semi-annual visit) Task	(hrs/1,000 gal)	Replacement[5] (per 10 years) Task	($$/1,000 gal)	Definition / Notes
Mobilization/Demobilization[2,3,4]			Preparation, Travel, and Setup Time	0.27			
First Flush Diverter			Clean out debris & sediment from reservoir and outlet	0.05	Replace automatic self-draining valve.	$250	
Gutter Screens			Clean out debris	0.15			
Filters			Replace (once per year)	0.10			
Storage Tanks			Dewater & vacuum/clean out (once per year)	0.30	Should not need replacement if in protected environment.		
Pump					Replace	$2,000	
Reporting			Inspect system to confirm proper operation. Complete standard maintenance form.	0.10			
TOTAL UNIT LABOR - OUTDOOR REUSE:		0.00		0.97		$2,250	
Mobilization/Demobilization[2,3,4]	Preparation and Travel Time	0.27	Travel time to lab	0.13			
WQ sampling	Take WQ samples & read flow meters	0.05	Take WQ samples & read flow meters	0.05			
UV Irradiator	Inspect & service as-needed	0.05	Replace light and clean sleeve (once per year)	0.10	Replace	$2,000	
More Powerful Pump					Replace	$2,000	This is the incremental cost of replacing a larger pump which would be expected to maintain water pressure for indoor application in a large building.
Reporting	Complete standard maintenance form	0.05					
TOTAL UNIT LABOR - INDOOR REUSE:		0.42		1.25		$6,250	

Average Labor Rate = $70.00 per hour

Task		MATERIALS ($$/1,000 gal)
Materials	Monthly[6,7]	$6
	Annual[8]	$37

ANNUAL TOTALS:		($/gal/year)	Labor Component
	IRRIGATION:	$0.50	$0.14
	TOILET FLUSHING:	$1.26	$0.50

Notes

1) The average site is assumed to manage a 10,000 ft² rooftop and have a 7,500 gallon cistern.
2) A field crew of two is assumed for maintenance and replacement activities.
3) Preparation is assumed to take 30 minutes in the morning, traveling to each site is assumed to take 30 minutes, 30 minutes to the lab, and traveling home at the end of the day 30 minutes.
4) It is assumed that a crew can handle four sites with two trips to the lab in one full working day for the eleven monthly visits, and two sites in one full day for the two semi-annual visits.
5) It is assumed that some individual components will need to be replaced every 10 years.
6) Not required for irrigation systems.
7) Based on $30 per e.Coli test and $10 per turbidity test at the SFPUC lab, plus $5 for sample containers.
8) Includes monthly items plus new filters, UV bulb & sleeve, and backflow preventer inspection.

CREEK DAYLIGHTING

BMP Component [1]	Regular Maintenance (per weekly visit)		Rehabilitation (per annual visit)		Replacement[5] (per 30 year life span)		Definition / Notes
	Task	(hrs/1,000 gal)	Task	(hrs/1,000 gal)	Task	($$/1,000 gal)	
Mobilization /Demobilization[2,3,4]	Preparation, Travel, and Setup Time	1.50	Preparation, Travel, and Setup Time	3.00			
Inlet Splash Pad / Forebay (stone or concrete)	Clean out debris & sediment. Replace missing or eroded rip rap.	1.50	Clean out debris & sediment. Replace missing or eroded rip rap. Re-level concrete pad.	4.00	Excavate & rebuild.		Prevents erosion at the point where water enters the facility, directly adjacent to the inlet.
Planting	Trim/prune.	1.00	Replace diseased and dead plants.	2.00	Full replanting.		It is assumed that all facilities will have irrigation systems.
Weeds and Trash	Remove.	2.00	Remove.	2.00			Would be ideal to co-opt the services of a neighborhood group to do this weekly.
Side Slopes	Regrade and stabilize any eroded areas.	1.00	Regrade and stabilize any eroded areas.	1.00	Excavate and replace media.		
Reporting	Complete standard maintenance form.	0.40	Complete standard maintenance form.	0.80			Assume a standard form will be developed to record condition of each item addressed on this sheet.
TOTAL UNIT LABOR – TYPICAL CREEK:		7.40		12.80			
Structural Elements (e.g., curbs, curb walls, check dams)			Repair chips & cracks in concrete. Regrade/reset stone elements.	2.00	May not be necessary.		Structural perimeter that frames the facility. Structural maintenance, repair and replacement to be determined by policy discussions with DPW.
Irrigation System			Adjust and test head patterns. Replace broken or malfunctioning heads, valves, valve boxes and piping.	2.00	May not be necessary.		DPW responsibility.
TOTAL UNIT LABOR – UNDERDRAINED CREEK:		7.40		16.80			
Trench Drain	Clear obstructing debris.	0.50	Repair or replace broken grates.	0.50	Excavate & replace entire drain system.		Can be cast-in-place, pre-cast concrete.
Impermeable Liner (membrane)			Repair tears, cracks or holes.	1.00	Excavate & replace liner.		For use when infiltration is prohibited (Maher Zone, soil contamination, liquefaction concerns, high GW or bedrock, insufficient offset from structures).
SUBTOTAL:		0.50	SUBTOTAL:	1.50	SUBTOTAL:	$0	
Average Labor Rate =	$70.00	per hour					

Task		MATERIALS ($$/1,000 gal)
Materials	Monthly[6,7]	$50
Materials	Annual[8]	$1,000

		($/gal/year)	Labor Component
ANNUAL TOTALS:	TYPICAL:	$30.86	$27.31
	HARD EDGES:	$31.14	$27.59

Notes
1) The average site is assumed to contain 2,000 LF of creek channel with an average of 8 ft width.
2) A field crew of two is assumed for rehab activities.
3) Preparation is assumed to take 30 minutes in the morning, traveling to each site is assumed to take 30 minutes, 30 minutes to the lab, and traveling home at the end of the day 30 minutes.
4) It is assumed that a crew can handle one 2,000 LF site in one full working day for the eleven monthly visits, and one site in two full days for the annual visit.
5) Replacement costs are based on unit construction costs.