RainWays Version 1.0 Users Guide

August, 2012

Prepared for

3 Rivers Wet Weather

3901 Penn Ave. Bldg #3
Pittsburgh, PA 15224

Prepared by
Tetra Tech, Inc.
Fairfax, VA 22030

Revision History

Table i-1: Change Record

Version Number	Description of Change	Change Effective Date	Change Entered By
1	Version1.0 Final	August 2012	Vladi Royzman Brandon Wood

Contents

1 Introduction

Green infrastructure (GI) within the Pittsburgh region can provide a number of benefits. In combined sewer areas, it can result in reduced overflows, lead to downsized overflow control facilities and reduce the volume of flow that reaches the treatment plant. In the local system it can improve system performance, including reduced risk of basement backup, minimized nuisance flooding and a reduction in the need for additional sewer capacity to convey flows. In addition to the volumetric benefit, green infrastructure reduces pollutants and improves water quality.

In response 3Rivers Wet Weather developed RainWays a tool that includes;

1. GI Homeowners Tool
2. GI Engineering/Planning Tool
3. GI Regional Map showing projects in the region and in RainWays.
4. Information on GI options

To support the tools 3 analysis were conducted to identify priority areas and feasible sites/ locations for GI projects, a GI Placement GIS layer and performance curves to allow users to place GIs in the tool and view the impact of the GI on the environment. The system is integrated into the 3Rivers Wet Weather Drupal CMS.

The high level planning tool helps to evaluate the question of “Where is green infrastructure cost effective”, and the Citizen focused public site is developed for homeowners for educational purpose. In this project, SUSTAIN was used to pre-process data from client and a triple bottom analysis was conducted to identify priority GI locations. Then the Drupal system stores SUSTAIN’s output. The GI project data for existing and future projects is managed within the Drupal database tables along with the performance curve data, vendor list and GI criteria type list.

1.1 References

USEPA (U.S. Environmental Protection Agency). (2004a). *Stormwater Best Management Practice Design Guide*. EPA/600/R-04/121. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

USEPA (U.S. Environmental Protection Agency). (2004b). *The Use of Best Management Practices (GIs) in Urban Watersheds*. EPA/600/R-04/184. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

Shoemaker, L., J. Riverson, K. Alvi, J. X. Zhen, S. Paul, and T. Rafi. 2009. SUSTAIN—A Framework for Placement of Best Management Practices in Urban Watersheds to Protect Water Quality. EPA/600/R-09/095. U.S. Environmental Protection Agency, Water Supply and Water Resources Division, National Risk Management Research Laboratory, Cincinnati, OH.

1.2 User Roles

The following user roles will be implemented in the system and access through the single sign-on and include the following

User	Add New GIs through Citizen Tool	Edit GIs through Citizen Tool	Publish Projects through Citizen Tool	Add New GIs through Planning Tool	Edit GIs through Planning Tool	Collaborate Project through Planning Tool	Publish Project through Planning Tool
Administrator	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Planner Owner	Yes after Log-in	Only theirs	Only theirs	Yes only theirs	Yes only theirs	Yes – set-up collaboration team on their project	Yes only theirs
Planner Collaborator	Yes after Log-in	Only theirs	Only theirs	NO	NO	Yes	NO
Citizen	Yes after Log-in	Only theirs	Only theirs	NO	NO	NO	NO

2 Home and Menu Bar

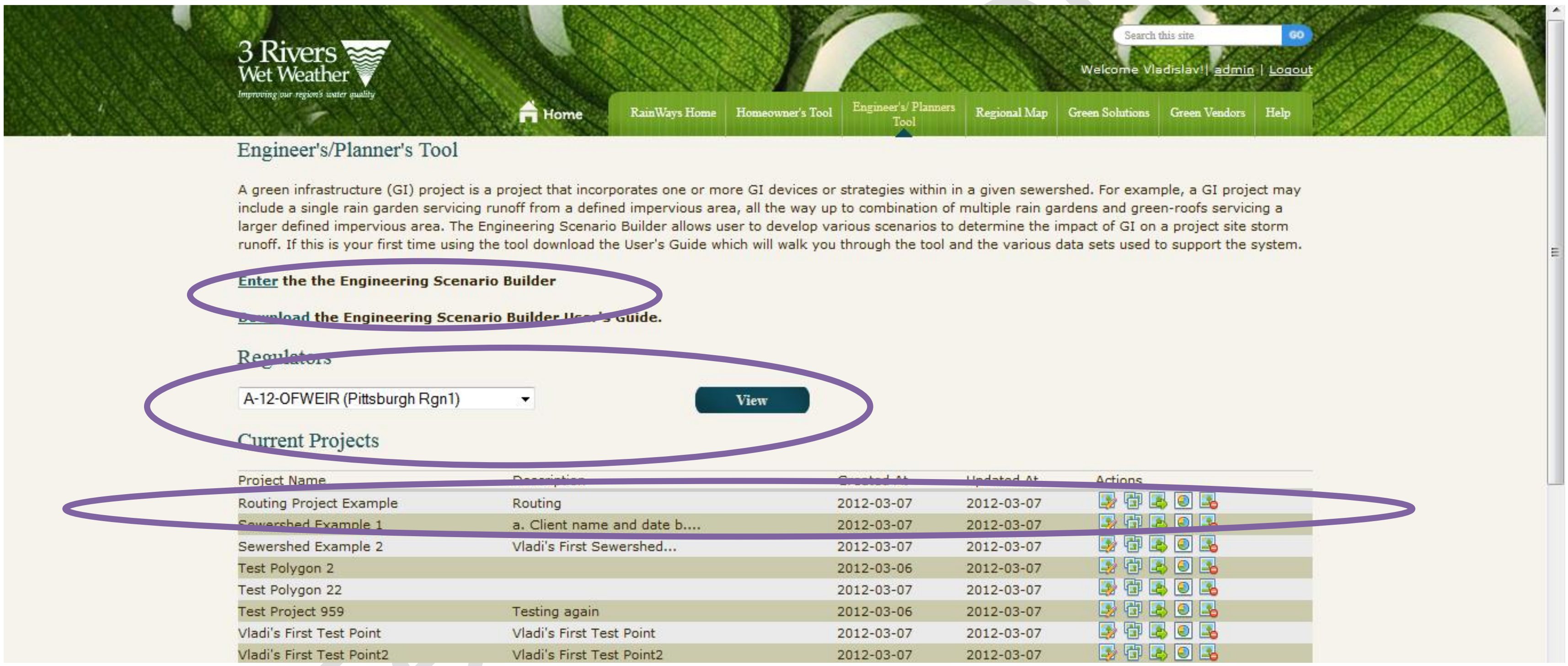
The RainWay tool has several sections to allow homeowners, propery owners and engineers/planners to select GI. The tool consists of the following areas;

1. Homeowners tool that allows property owners to easily select and plan GI projects
2. Engineer's/Planners Tool that allows engineers and planners to use the tool to run various scenarios on selection of GI projects.
3. Regional Map that shows all of the published GI projects
4. Green Solutions an information page on GI projects that can be implemented in the a Pittsburgh area.
5. Green Vendors is a listing of green vendors in the area
6. Help links to the users guide.

3 Engineering Planning Tool

A GI project is a project that incorporates one or more GI devices or strategies within in a given sewershed. For example, a GI project may include a single rain garden servicing runoff from a defined impervious area, all the way up to combination of multiple rain gardens and green-roofs servicing a larger defined impervious area. The online public interfaces using the web-based map tools will allow user to add a new project and view/edit an existing project, layout local watershed maps.

3.1 Home Page



The home page of the tool allows registered users to create project scenarios. A user can either;

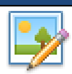
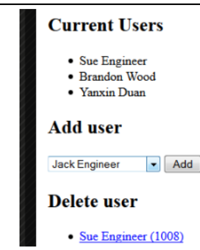
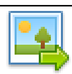
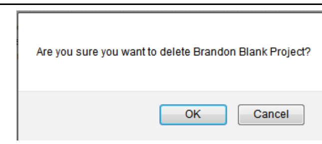
1. Enter the Scenario Builder (see Section 3.2)
2. Download the Users Guide

3. Create and View a Regulator Report (see Section 3.4)
4. Edit, Share, Provide Info, Generate Report or Delete an Existing Project.

3.1.1 Current Projects

The current project tables lists all of the projects that are in the system entered in the system and has a user as either an owner or collaborator. A user can either;

Project Name	Description	Created At	Updated At	Actions
Routing Project Example	Routing	2012-03-07	2012-03-07	
Sewershed Example 1	a. Client name and date b....	2012-03-07	2012-03-07	
Sewershed Example 2	Vladi's First Sewershed...	2012-03-07	2012-03-07	
Test Polygon 2		2012-03-06	2012-03-07	
Test Polygon 22		2012-03-07	2012-03-07	

Icon	Description
	Edit – this will open the Scenario Builder window and allow the user to edit an existing project.
	Share – Which allows a user to add a new user or delete existing users. Only the owner of a project can add new users or access share. (See Figure on the left). Use the drop down and Add button and the user will appear in the Current Users List. If user need to delete a user click on the users name below the Delete user list. This will remove the user from the project only not the system. 
	Info links to the Information Forms (see Section 5). This information should be filled out only after a project is active and no longer planned. The form allows users to publish projects to the Green Infrastructure map and add additional information about the project.
	Report links to the report. (see Section 3.3)
	Delete existing projects will remove the project permanently from the system. Only administrators can delete projects. Prior to delete the following pop-up will open and  project owners and verify that indeed user want to delete the project.

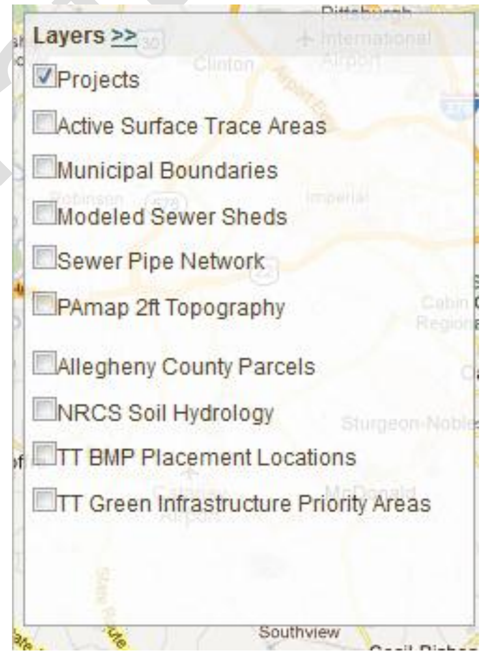
3.2 Scenario Builder

You must be a registered use to enter the Scenario Builder. You can enter the Scenario Builder to either create a new project or edit existing. Once user enter the Scenario Builder interface user will see 2 main windows one is the GI tool frame and the second is the map layers frame. These two panels are the main controls. In addition, the tool has basic Google map controls such as Zoom, Pan, Map/Satellite View and Street View.

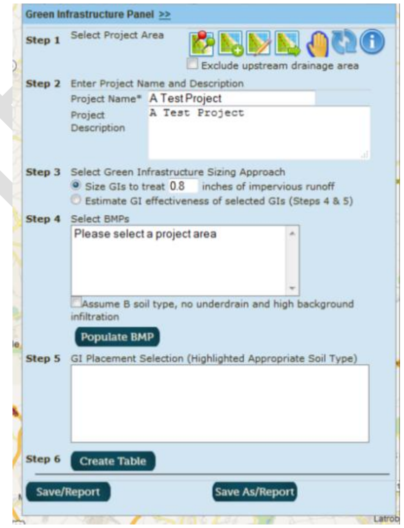
3.2.1 Layers Panel

The following GIS data layers are included in the GI Scenario Builder. To view a layer check on the checkbox to the left of each layer name.

Layer	Description
Projects	Listing of all of the projects in the system. You can click on the rain drop icon to view details.
Municipal Boundary	Municipal Boundary to show all of the municipal boundary
Modeled Sewer Sheds	Modeled Sewer Sheds include the approximate 2000 SWMM model sewersheds published by CDM
Sewer Pipe Network	Sewer Pipe Network displays the county sewer network. This layer contains the latest available data for the ALCOSAN waste water system. This layer is a product of a coordinated effort between 3RWW, ALCOSAN, the Regional Basin Planners and the 83 Municipalities within the ALCOSAN service area. This layer is updated every 6 to 9 months.
PAmap 2ft Topography	2 foot topography layer to help users determine site information.
Alleghany County Parcels	Layer to show all of the parcels in the cound
NRCS Soil Hydrology	Soil types for the entire Pittsburgh Area. B, C,D and the quarry/water. The color legend is included to the righ 
TT GI Composite Layer	The GI Placement data layer to demonstrate the various GIs that are recommended in a project area. (See Section 6.2)
Green Infrastructure Priority Areas (GIPA)	The Green Infrastructure Priority Areas (GIPA) layer shows the priority areas for GI. (See Section 6.1)



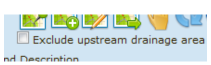
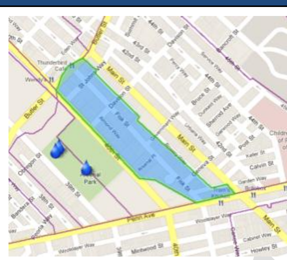
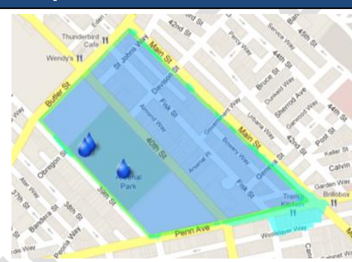
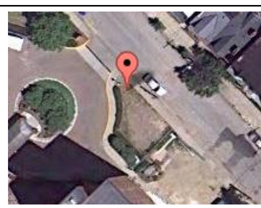
3.2.2 Green Infrastructure Panel

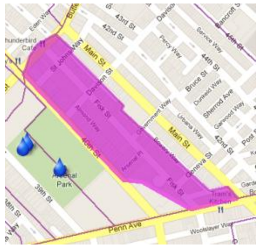
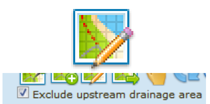
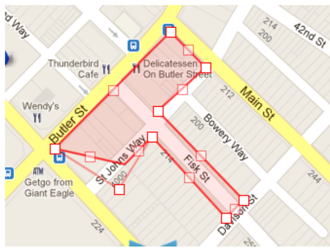
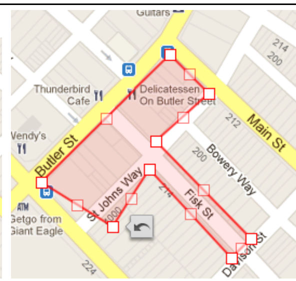
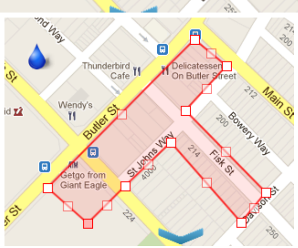
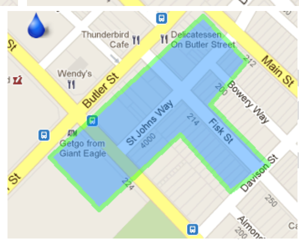
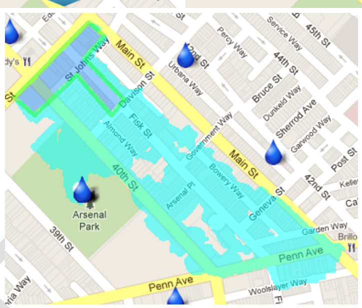


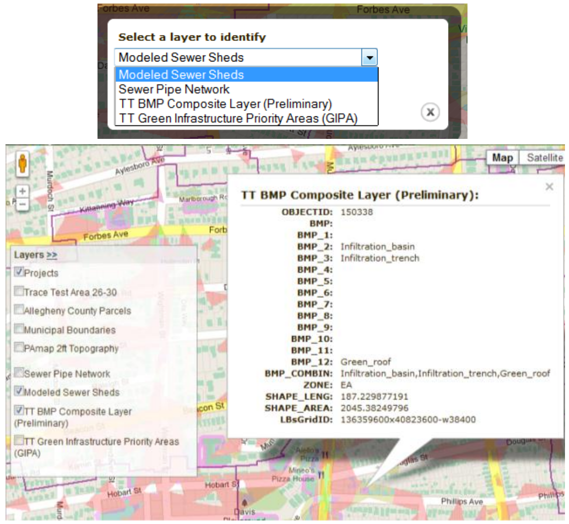
The GI Panel is used to select project area and populate the GI information based on the GI Composite Layer.

1. Step 1. Select your project area by drawing a polygon, selecting a point or selecting a sewershed and determine if you want to exclude upstream drainage.
2. Step 2. Enter Project Name and Description.
3. Step 3. Select whether user would like to treat a specific storm event (1-3 inches) or allow the system to determine the storm event control based on the GI sizes
4. Step 4. Is the list of GIs that returned based on the selected project area.
5. Step 5. Is the specific location and number of GI groupings in a project area.
6. Step 6. The user creates the table to populate the information for drainage quantity to a particular GI.

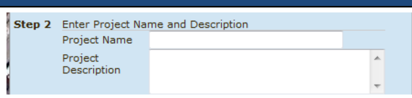
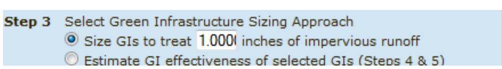
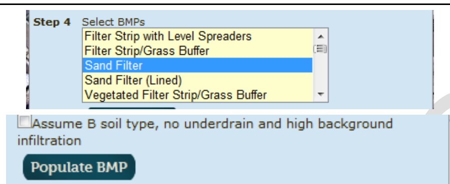
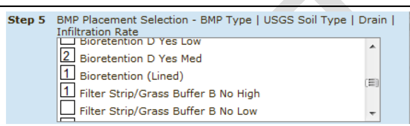
3.2.2.1 Step 1. The first step is to select your project area.

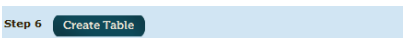
Icon	Example	Description
	 	**First step is to determine if user would like to include drainage just inside your project or include both inside and contributing upstream drainage.** This option only applies to when a user draws the project area based on a polygon. The first example inside only the second includes contributing. This step determines the amount of area that drains to various GIs. If user select inside only the drainage from inside the project area will count towards the flow to a GI. If user do not select both the tool will also take into account contributing flow to the project site based on the hydrologic delineated area.
	 	The first is **delineated based on a small polygon created by the system**. Regardless if the user selects Inside only the system will always return contributing. This option is primarily used to determine flow amounts to a specific GI. The first step is to click the icon and then place on a specific location on the map. Next click dealinate to dealinate the area that drains to that specific spot.

	 	The next to **select a modeled sewershed**. Regardless if the user selects Inside only the system will always return inside only because each sewershed is treated as a unique hydrology and therefore do not include contributing. This option is good for planners that want to determine the GI scenarios to control flow within a sewershed. First the user clicks on the icon and then select the sewershed that user would like to work with. Next click delineate to delineate the area.
	    	**Draw a project polygon** allows the user to draw a polygon around their project area. Note that the inside check only works for this option. First the user clicks on the icon then clicks on the map to draw the polygon nodes. They will be automatically connected as user draw. The user may click on a vertices and move it if it was not placed correctly. Once the user is finished they click the dealinate to dealinate the area. The example on the left shows both inside and contributing calculated.
	**See Examples Above**	**Once a user selects a project area they click dealinate.** This queries the spatial database and returns the hydrologic response unit distribution and recommended GIs.

		**The identify button** helps the user view specific data in various layers in the scenario builder. These layers can help in making decision on GI placement or view specific information on the map. Click on the icon, select a layer and click on the map. To switch layers click on the icon again and select a different layer.

3.2.2.2 Green Infrastructure Panel Steps 2-7.

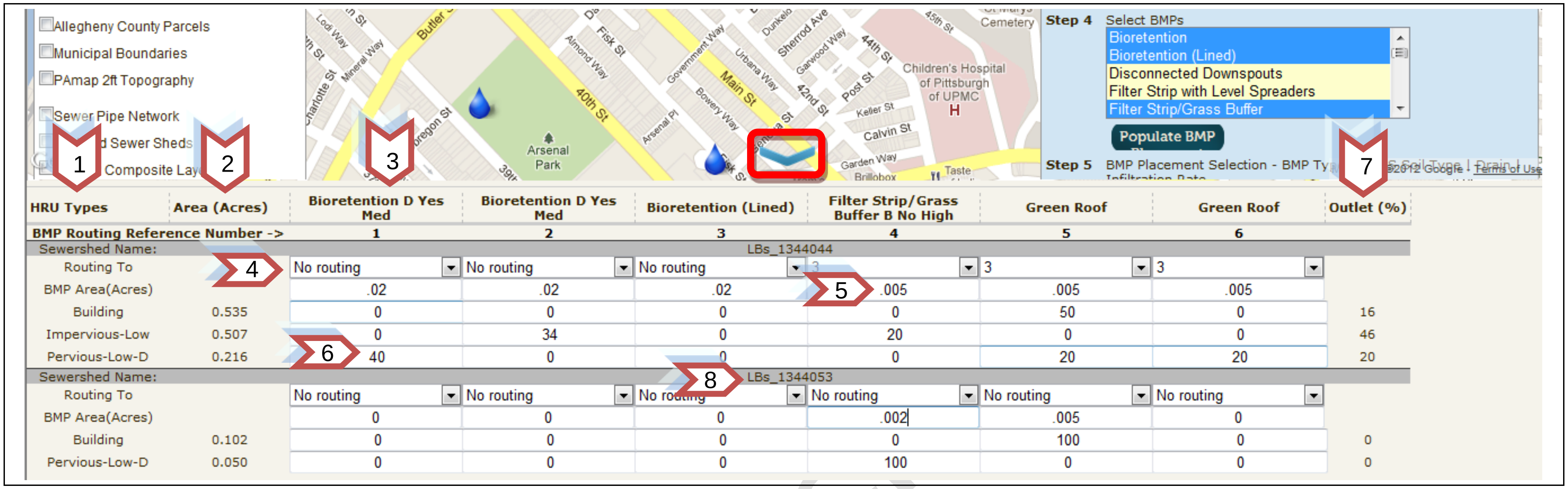
Example	Description
	**Step 2** a user enters in a unique project name, project description and notes. The description should include information about the project and basic information such as; Client Name and Date, Engineering Company Name, Political Subdivision and Assumptions Used/Notes.
	**Step 3** a user can either select a Treatment Depth for a particular storm event or allow the system based on GI sizing to determine the controlled storm event. Following Step 6 when the user creates the table if they choose to determine the GI effectiveness based on size the user will be presented with the chance to enter GI sizes for each GI selected.
	**Step 4** includes the list of GIs to select from. Once user dealinate the project area the listing of GIs will appear. The first highlighted set of GIs are those recommended based on the GI Placement Layer. The rest a user can still select but were not included in the recommendation. Once user select your GIs click Populate GI to fill in the table for Step 5. Finally if a user wishes to use engineering standards only they can select the checkbox underneath the drop down to filter values for B Soil Type, No Underdrain and High Background Infiltration.
	**Step 5** includes the GIs selected based on USGS Soil Type, Drain and Infiltration Rate. Some GIs such as Bioretention Lined, Green Roofs only have a single GI listing. These GIs correspond to the performance curves described Section 6.3. The system filters the list based on the predominant soil type in the selected area. These are listed first and highlighted in green.

	For each GI the user selected in the previous step the user can enter the number of each type of GI the user would like to include in their project area. Since the tool allows for routing (see Step 7) we recommend that user only include multiple numbers of a specific type if user wishes to route. The tool uses an aggregate approach for GI determination therefore to make scenario building easier the user should aggregate the GIs to make it simpler to route specific volume percentage to those GIs.
	**Step 6** is the final step prior to filling out the drainage table. Click create table once user have selected your GIs and entered the number. Note that each time user create the table it will clear out your previous table entries.

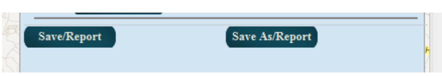
Step 7 Drainage Table

Step 7 is the drainage table and where the user routes flow to each GI. The system allows a user to show hide the table by clicking on the arrow highlighted in red below.

1. The table allows a user to specify for each Hydrologic Response Unit (see Section 6.2 for listing) a specific volume percentage. Each HRU is associated with a specific volume which allows the tool to calculate the flow from each HRU.
2. Shows the area in acres for each HRU per a specific sewershed. In the example below the project area spans 2 sewersheds.
3. The columns after the sewershed correspond to the GI Types, Soil, Drain and Infiltration Rate selected in Step 5. The corresponding GI reference numbers helps count the GIs and is used in the routing information.
4. Next the user can route GI flow from one GI to another. This step is more critical when selection the second option under Step 3 since in this step the system always users to size the GI according to the flow it needs to capture. With the first option the GI will always be sized to capture the entire flow going to the GI.
5. Next the user can size GIs, this option is only available if the users selects the second option under Step 3. This allows a user to enter the acres of GI used on the project to determine the size of control.
6. The final step is to route a specific volume percentage per HRU to each GI.
7. As a user is entering the volume percentage in the step above the system shows the remaining overflow percentage existing the project area.
8. Finally each project is divided among the modeled sewersheds. The name of the sewershed is included here.



3.2.2.3 Saving Projects

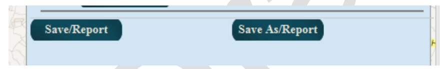
Example	Description
	Once the user has completed the scenario the user has 2 options; either saves the scenario or a save as which will allow the user to save the scenario as a new record to compare the scenario to other scenarios. The system will require the user to rename the project scenario to a unique name. Once the user has clicked the user will open the report and can view/print. See Section 3.3 for report details.

3.3 Project Report

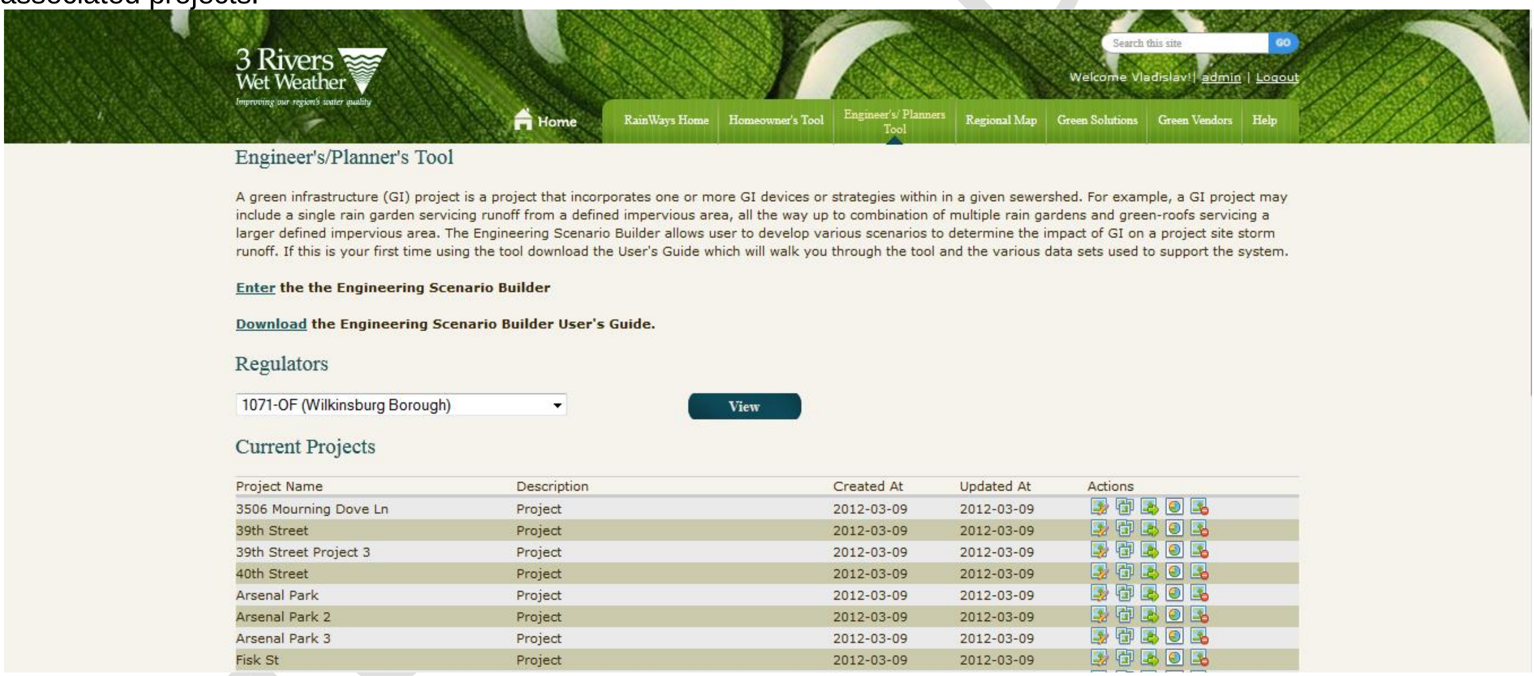
The project report summarizes project information, site characteristics, GI performance and configuration, and cost information. GI performance is calculated based on EPA SUSTAIN derived performance curves for the City of Pittsburgh.

3.3.1 Accessing the Report

There are 2 ways to access the report.

1. Clicking the saves/report or save as/report button on the GI Panel 

2. Through the Engineering/Planning Tool home page. Users that collaborate with a project owner can see the report for their associated projects.



3.3.2 Report Content

Introduction and Project Description

Description and Calculations

The project name will appear at the top of the project report. This name should be descriptive enough to differentiate it from other projects. The user is allowed to define a project description while creating his or her project. Some recommended project descriptions items include:

a. Client name and date
b. Engineering company name
c. Political subdivision
d. Assumptions used
e. Note

Description and Calculations

Print this page

Sewershed Example 1

Introduction

The project report summarizes project information, site characteristics, BMP performance and configuration, and cost information. BMP performance is calculated based on EPA SUSTAIN derived performance curves for the City of Pittsburgh.

Description

a. Client name and date b. Engineering company name c. Political subdivision d. Assumptions used e. Notes

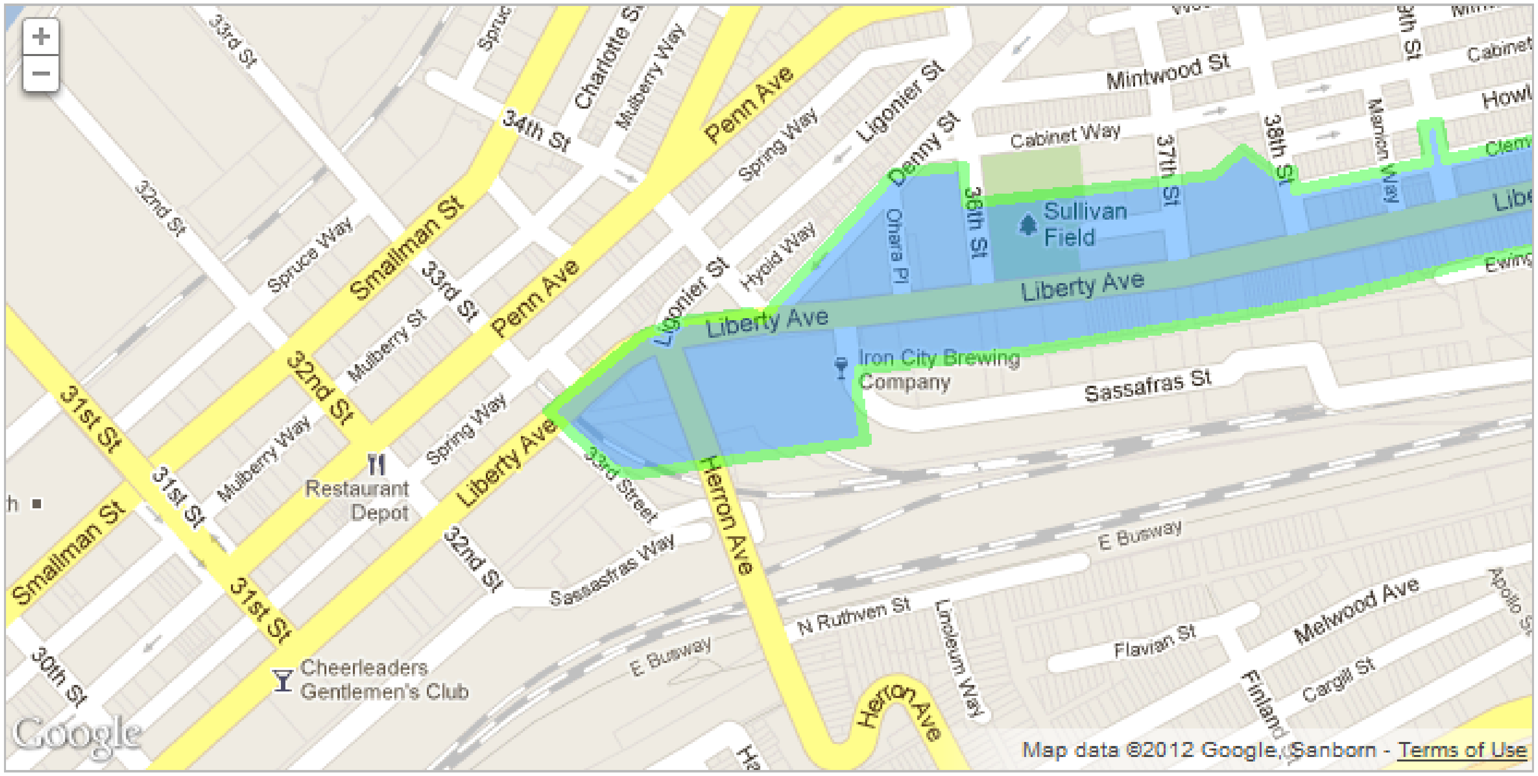
Project Setting

Description and Calculations

A project map showing the project area and/or drainage area is displayed below the description.

Screen Shot

Project Setting



Site Characteristics

Description and Calculations

Site characteristics relate to the selected project area in the engineering tool. These are general cost and spatial facts about the project, including:

a. Project size (area within the sewershed or delineated polygon or point)
b. Total project cost (includes construction and O&M costs for all GIs in present dollars)
c. Priority area ranking (GIPA) **(See Section 6.1 for details)**
d. Treatment depth or equivalent treatment depth

e. Total impervious area within the project area
f. Point of connections (POCs) and regulators that are part of the project area or drainage area
g. Municipalities that are part of the project area or drainage area

The **treatment depth** is the surface runoff depth over the contributing impervious drainage area to the GI. It could be the design depth of first flush that needs to be captured by the green infrastructures. The GI performance curves were developed considering all three factors; impervious drainage area, treatment depth, and GI capacity. The GI capacity is calculated based on the provided impervious drainage area and the treatment depth. If the GI capacity is given then based on the provided drainage area the treatment depth is calculated. All these three factors are dependent to each other.

POCs are shown as their codes with the associated sewershed code in parentheses (e.g. “A-23-00 (LBs_1344156)”). The sewershed code can be found via the identify tool on the scenario builder tool.

Screen Shot

Site Characteristics

Project size: 26.424 acres

Total project cost: $5,400,000

Priority area ranking: Medium-High (5.73/10)

Equivalent design depth: 54.24 inches

Total impervious area: 10.482 acres

POC(s)/Regulator(s): A-23-00 (LBs_1344156)

Municipalitie(s): Pittsburgh Rgn1

Sewershed GI Performance

Description and Calculations

The sewershed GI performance table shows all GIs per sewershed that were selected by the user in the engineering tool. The HRU flow distribution is shown for each HRU and GI in each sewershed and summarized graphically at the end of each line as a small pie chart.

The colors in the pie chart correspond to the GIs and effluent colors shown in the next section’s pie chart legend. The screenshot below shows 25% flow allocation to two GIs (blue and yellow) and 50% which is not routed to GIs (green).

Impervious-Mod	0.117	0.3	25% flow	25% flow	

Additionally, GI effectiveness and reduction are shown. Effectiveness is calculated to be the percent reduction of the total flow in the sewershed relative to the volume reduction of the GI, regardless of the flow distribution to the GI. For example, if there were a bioretention basin that received 50% of the sewershed’s flow and reduced this flow by 50%, the GI effectiveness for that bioretention basin would be 25%.

Screen Shot

Sewershed BMP Performance

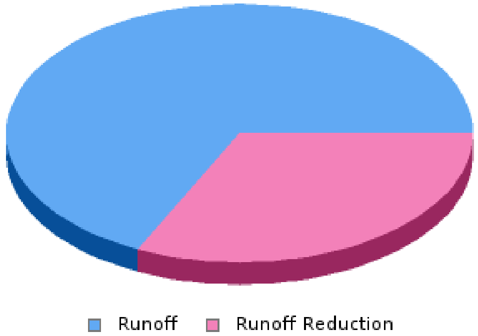
Sewershed	HRU	Acres	Annual flow from HRU (acre-ft)	Bioretention C Yes Med (1)	Bioretention D Yes High (2)
CDM_1348459	BMP Capacity			53765 gallons	53765 gallons
	Impervious-High	0.076	0.2	25% flow	25% flow
	Impervious-Mod	0.117	0.3	25% flow	25% flow
	Impervious-Low	0.115	0.29	25% flow	25% flow
	Pervious-High-D	0.03	0.01	25% flow	50% flow
	Pervious-Mod-D	0.096	0.03	50% flow	25% flow
	Pervious-Low-D	0.115	0.03	10% flow	78% flow
	Percent BMP Effectiveness			25.34%	26.97%
	BMP Runoff Reduction			0.22 acre-ft	0.23 acre-ft
	BMP Capacity			5377 gallons	5377 gallons
	Impervious-Mod	0.11	0.28	0% flow	4% flow
	Pervious-High-D	0.132	0.04	5% flow	6% flow

Project GI Performance

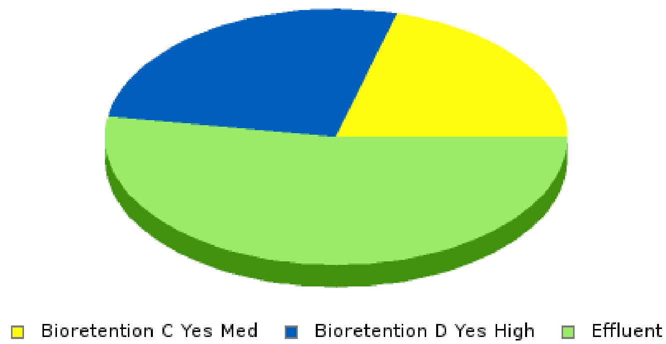
Description and Calculations

Project GI performance summarizes the overall reduction of the project across all selected sewersheds and GIs. If GI flow is being routed between GIs, only GIs routing to no other GI are considered in this overall reduction calculation.

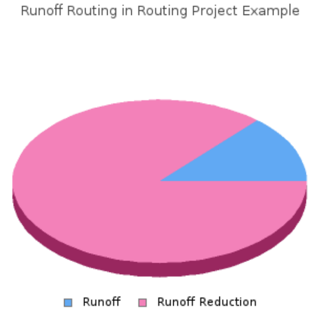
The first chart will always show the volume of runoff that is reduced by the selected GIs and the subsequent net runoff or effluent.

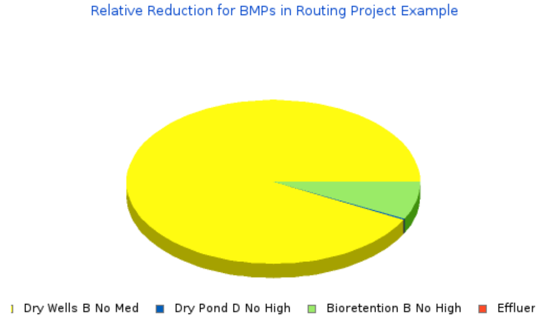


The second chart shows the distribution of reduction across the GIs in addition to flow that routed through the GIs that is untreated by the GIs (effluent). These colors correspond to the HRU flow distribution pie charts in the Sewershed GI Performance table discussed in the previous section.



Screen Shot





Total Runoff pre-BMP	87.92 acre-ft
Total Reduction	86.6 %
Total Runoff Captured	76.14 acre-ft
Total Outlets	11.78 acre-ft

Project GI Routing

Description and Calculations

The scenario builder allows for the user to route flow between GIs. When flow is routed from one GI to another, 100% of the effluent of the upstream GI is routed to the downstream GI, in addition to any HRU flow contribution to the downstream GI. It is the responsibility of the user that flow is routed in only one direction. This routing is displayed graphically with effluent values routed between GIs in the Project GI routing section. It is important to note that flow is shown in the order of most downstream to most upstream.

Screen Shot

Project Cost

Description and Calculations

Project GI costs are broken down into two categories: construction and operations and maintenance (O&M). Construction costs are based on data from San Diego, California and adjusted by Engineering News-Record (ENR) construction cost index ratios between San Diego and Pittsburgh (this ratio is defined to be 1.14). O&M costs are calculated at present value based on a 3% interest rate and the given GIs design lifespan (typically 20 years).

All costs are based on a unit cost per area and calculated based on GI size. The present value is calculated using the following equation:

$$P = A\frac{(1+i)^N}{\left(i+(1+i)^N\right)}$$

Where *P* is the present value, *A* is the annual O&M cost in present value, *i* is the interest rate or inflation rate and *N* is the number of years or design lifespan of a given GI.

For drainage areas to a GI exceeding 1 acre, a power function is used to account for economy of scale. The coefficients and exponents of this power function are given in the cost Appendix of this manual.

Screen Shot

Project BMP Cost

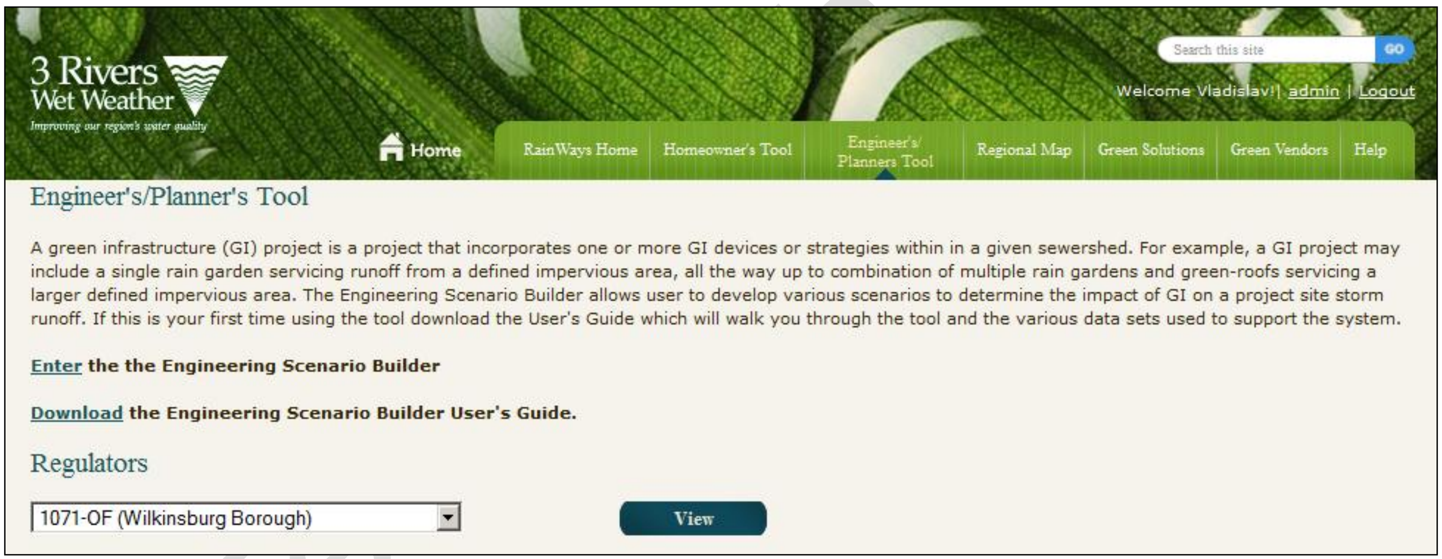
Sewershed	Green Infrastructure BMP	Construction Cost	O&M Costs (total, present value)	Lifespan (years)	Total Cost
LBs_1344371	Dry Wells B No Med	$1,300,000	$60,000	20	$1,400,000
	Dry Wells B No Med	$1,300	$60	20	$1,400
	Dry Pond D No High	$190	$4	20	$190
	Dry Pond D No High	$190	$4	20	$190
	Bioretention B No High	$1,000	$72	20	$1,100
	Bioretention B No High	$1,000	$72	20	$1,100

3.4 Regulator Report

In order to aggregate all published projects in the RainWays tool, the regulator report calculates the total reduction of published green infrastructure projects into a high level view on stormwater reduction as it relates to combined sewer overflow (CSO) prevention.

3.4.1 Accessing the Regulator Report

The regulator report can be accessed in the Engineer's/Planner's tool home screen. This lists all regulators that currently have projects associated within them. Additionally, the associated municipality with each regulator is shown in the list. To view a regulator report, simply select a regulator from the drop down and press **View** to bring up the regulator report.



3.4.2 Report Content

Project Setting

Description and Calculations

The name of the regulator appears at the top of the report with a brief description that explains the purpose of the report.

Screen Shot

Regulator A-26-OFWEIR

Introduction

This report summarizes all projects that are published and are part of the above stated regulator. Additional information can be found in the report Appendices.

Site Characteristics

Description and Calculations

The characteristics section provides a high level view of the regulator, including the number of projects within the regulator, the sum cost of those projects (including O&M costs over the project lifespan), total area as well as the total impervious area of the area.

Screen Shot

Characteristics

Number of Projects: 3
Total Cost: $11,000,000
Total Area: 137.7 acres
Total Impervious Area: 35.4 acres

System Assessment

Description and Calculations

For each regulator, system assessment curves have been developed that estimate the number of CSOs in a given year with various levels of volume reduction. These curves are presented in the system assessment table.

Overflows are shown as a function of depth reduction in inches. This curve is then linearly interpolated to estimate the number of CSOs reduced given the green infrastructure project configuration for that regulator.

Screen Shot

System Assessment

POC	Reg. ID	0.00"		0.02"		0.05"		0.10"		0.30"		0.80"	
		Overflows	Volume	Overflows	Volume	Overflows	Volume	Overflows	Volume	Overflows	Volume	Overflows	Volume
A-26-00	A-26-OFWEIR	52	10.00000	51	10.00000	51	10.00000	45	9.47660	36	7.34629	32	4.71887

GI Performance

Description and Calculations

The Green Infrastructure Performance section provides a high level view of each project in a regulator area, including project name, size, total flow, the number of GIs and their overall performance.

This information is then summarized into a total reduction for areas draining to the given regulator. This reduction is then used to estimate the CSO reduction based on the system assessment curve presented in the previous section. Additionally, volume reduction estimates are provided to show the load to the storm sewer network draining to that regulator.

Screen Shot

Green Infrastructure Performance

Project	Area (acres)	Total Flow (acre-ft)	Number of GIs	GI Reduction (%)	GI Volume Reduction (acre-ft)
Arsenal Park	6.2	2.3	3	78.4	2
Arsenal Park 2	6.2	2.3	3	78.4	2
Arsenal Park 3	6.2	2.3	3	78.4	2
Penn Ave	6.2	2.3	3	78.4	2
40th Street	6.2	2.3	3	78.4	2
Geneva St	6.2	2.3	3	78.4	2
Fisk St	6.2	2.3	3	78.4	2
39th Street	6.2	2.3	3	78.4	2
39th Street Project 3	6.2	2.3	3	78.4	2
Ater Way 2	6.2	2.3	3	78.4	2
My House Project 2	6.2	2.3	3	78.4	2
3506 Mourning Dove Ln	6.2	2.3	3	78.4	2
Total runoff pre-green infrastructure	38 acre-feet				
Total Reduction	98.7 %				
Total Runoff Captured	37.72 acre-ft				
Total Outlets	0.49 acre-ft				
Number of CSOs prevented	52 (100 %)				

Project GI Cost

Description and Calculations

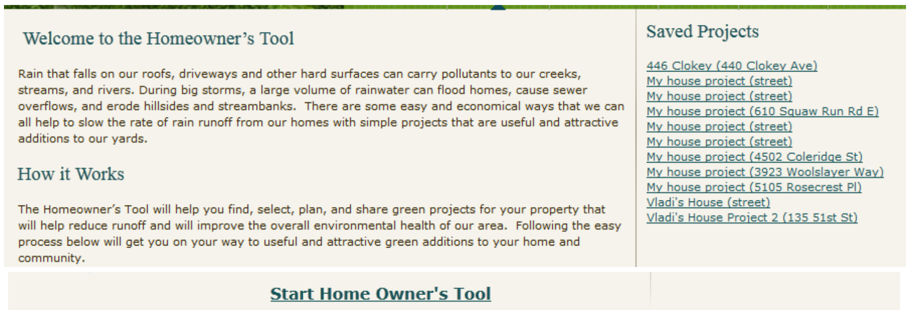
While costs are summarized for all projects in a given area in the regulator characteristics section of the report, specific costs for each project are also presented. These costs are calculated using per unit area costs for each GI in each project, as well as present value O&M costs over the lifespan of the projects.

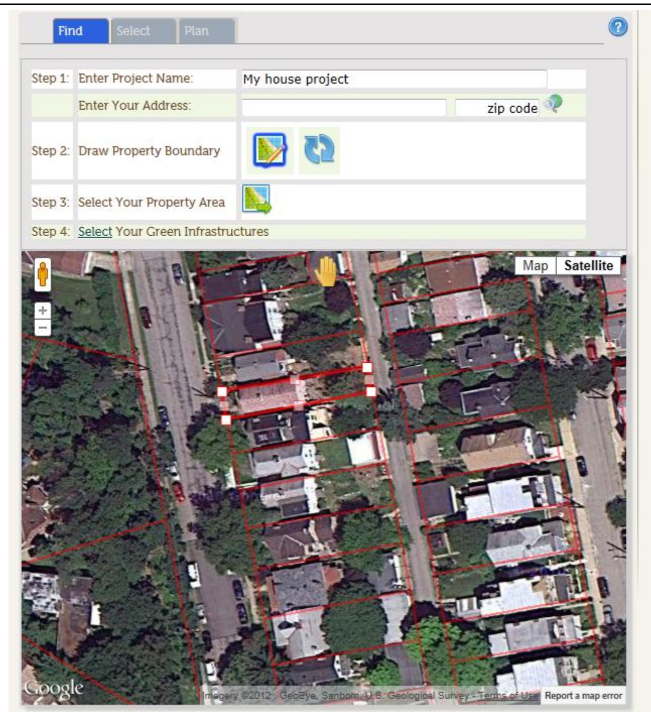
Screen Shot

Project Costs

Project	Construction Cost	O&M Costs (total, present value)	Total Cost
Arsenal Park	$46,000	$3,200	$49,000
Arsenal Park 2	$46,000	$3,200	$49,000
Arsenal Park 3	$46,000	$3,200	$49,000
Penn Ave	$46,000	$3,200	$49,000
40th Street	$46,000	$3,200	$49,000
Geneva St	$46,000	$3,200	$49,000
Fisk St	$46,000	$3,200	$49,000
39th Street	$46,000	$3,200	$49,000
39th Street Project 3	$46,000	$3,200	$49,000
Ater Way 2	$46,000	$3,200	$49,000
My House Project 2	$46,000	$3,200	$49,000
3506 Mourning Dove Ln	$46,000	$3,200	$49,000

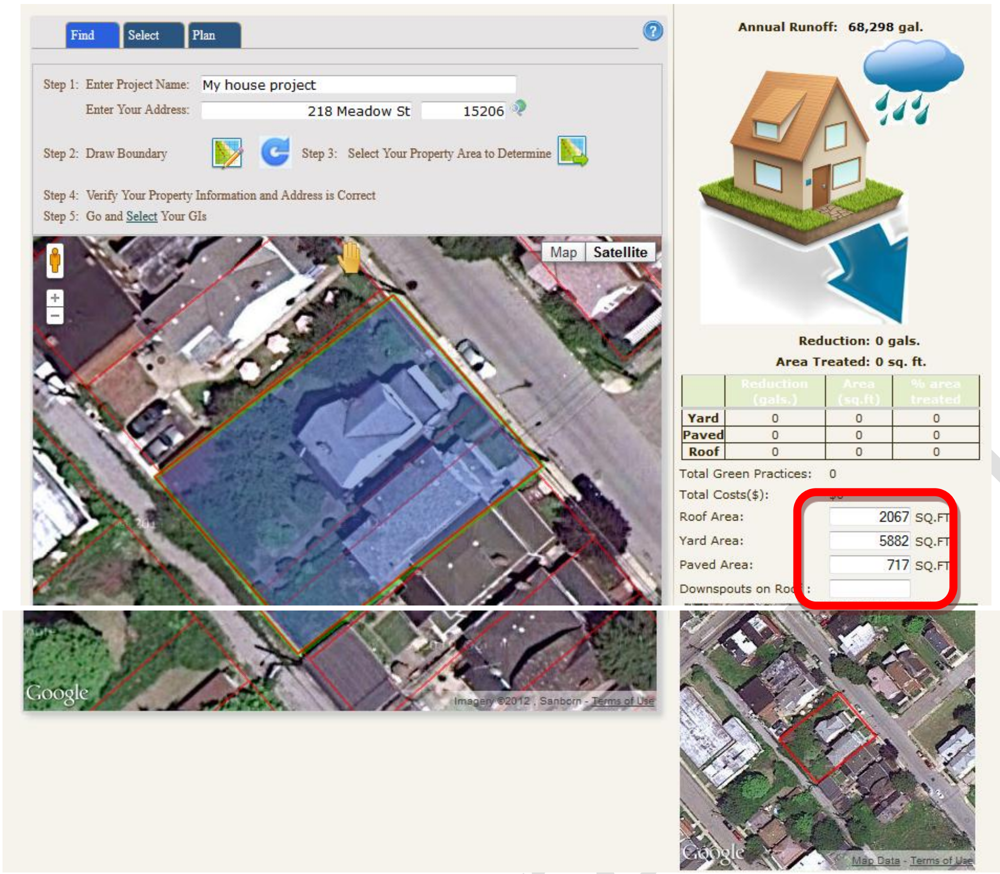
4 Homeowner Owner Tools

<table>
<tr><th>Screen Example</th><th>Description</th></tr>
<tr><td>


</td><td>The homeowner's tool allow property owners or planners to select their property and plan GI projects. The home page allows a logged in user to view saved projects or to start a new project by click Start Home Owners Tool</td></tr>
<tr><td>


</td><td>If the user is starting a new project they will be directed to the Find Tab that allows them to find a project using either the map or by entering in an address. If the user uses the map to locate the project the system will reverse geocode and provide the address for the center of the property. There is no limit to the size of property a user can select so theoretically a plan can select a block of homes to determine basic GI plans.

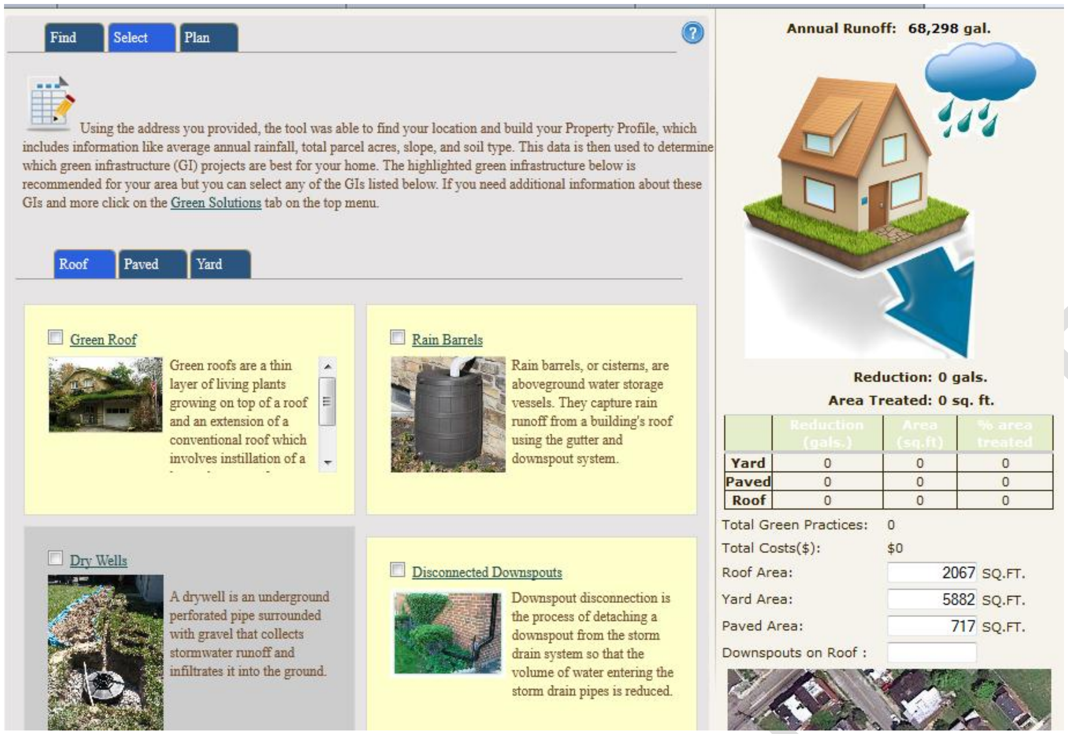
Once the user has drawn their property they go to Step 3 and select the property to delineate the area selected. After the area is selected they review their property information and move on to select the GIs for their site.</td></tr>
</table>



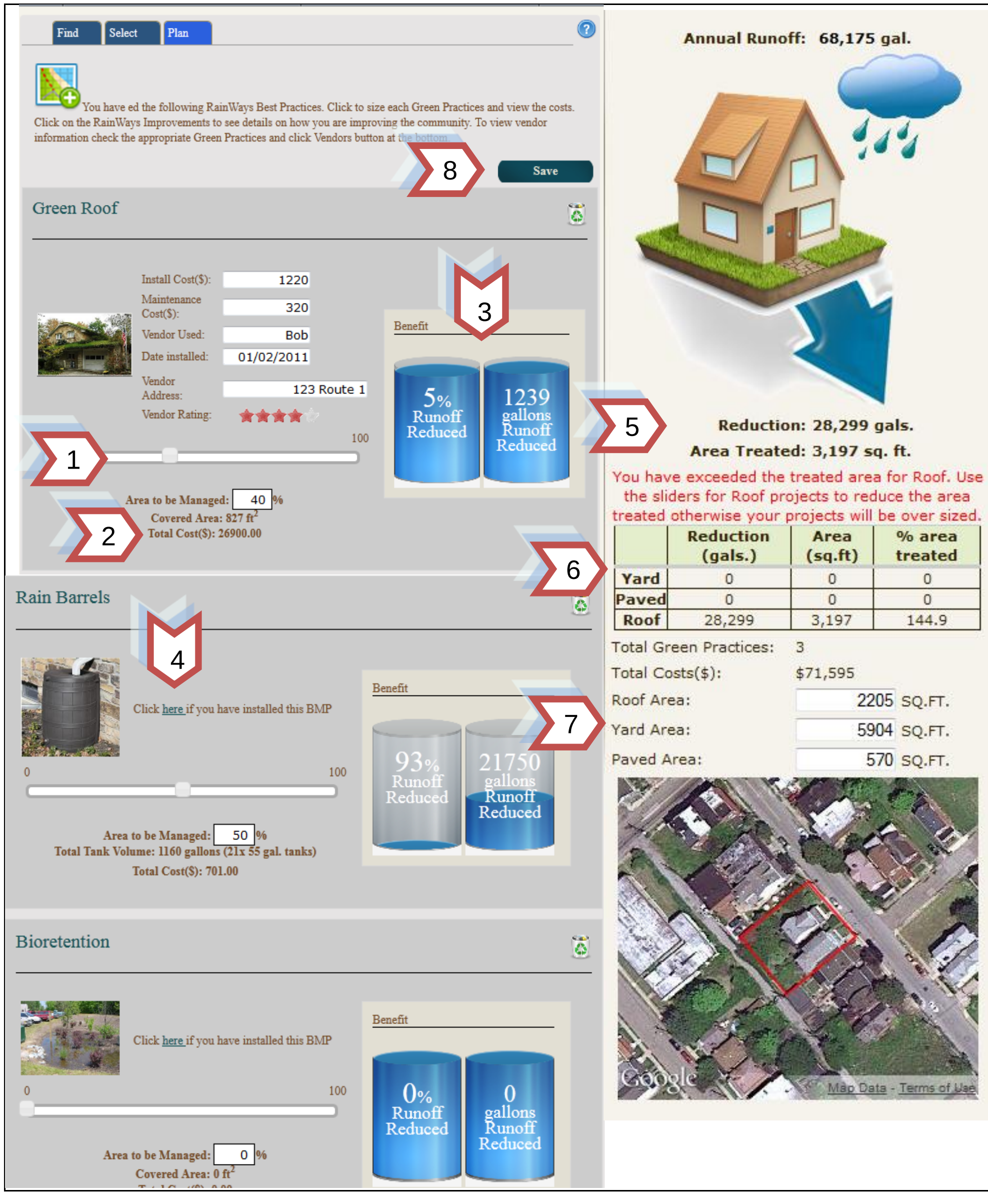
Once the user has highlighted the property they click the delineate button to select the property and pull the property information. Note that the property information for Yard, Roof and Paved and annual runoff for each is dynamically calculated based on HRU and does not use the county parcel information.

Once the user has selected the property the Select and Plan Tab are enabled along the user to move on to Select GIs.

Prior to moving forward a user should review that the total area for Roof, Yard and Paved is appropriate and if it is not change according.



The select tab highlights the appropriate Yard, Paved or Roof GI that is recommended for installation. The user has the option to choose additional GIs they feel are suited for their property.



The last step in the tool is the Plan Tab. The user can toggle between this and the Select tab to add additional GI projects.

The following are the key functional features of the page.

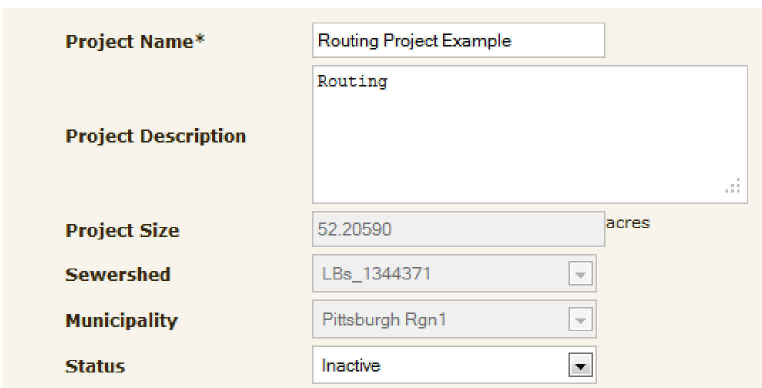
1. The slider allows a user to size the GI. Each GI is increased by 5% intervals as they move the slider.
2. Based on the slider the area managed shows how much of the total area is managed as you increase the size. The covered are is the actually size of the GI with the exception of Rain Barrels and Downspout Disconnects which are measured in volume captured.
3. As you move the slider the benefits rain barrels empty and fill the first value in the rain barrel shows the overall percent reduction for this entire property roof, yard or paved area. The second number shows the volume reduction as it relates to the entire property.
4. Once a user is ready to install the GI they click the link to show the cost, date and vendor installation information. This should only be completed if the GI was installed.
5. As the user adjusts the values the amount captured and the total area treated increases. The total area treated can extend past the property size but the user is provided that information in the table below.
6. The table is a breakout of the reduction, area treated and then the overall % area treated for roof, yard and paved. If the value is above 100% a message will alert the user they have over treated the property.
7. The tool allows the user to set the total square feet for the roof, yard and paved area if the calculations by the tool they do not feel are accurate. Based on these changes the GI sizing, flow and reduction to and from the property are adjusted.
8. Once the user is completed they can either close the window or click save. If at this point if they have not logged in they will be prompted to login to the tool. Once they are logged in they will be

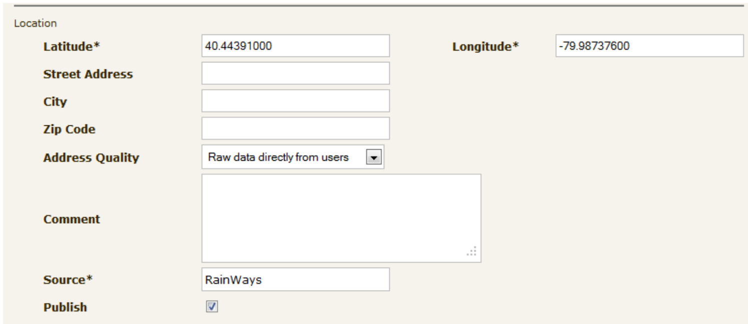
	asked whether they want to publish the project and after they respond the project is saved.

5 Green Infrastructure Metadata Forms

The GI metadata forms allow users to enter additional information about implemented projects that were entered through the homeowners or engineering/planning tool. Users can enter information about either a project or a GI located on the project. Any information collected in the homeowners or engineer tool will be prepopulated in these forms. In addition, administrators can add new projects through the forms that have not been entered in the homeowners or engineering/planning tool.

5.1.1 Project Forms

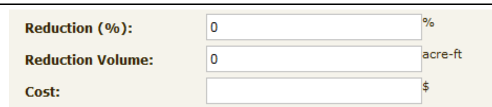
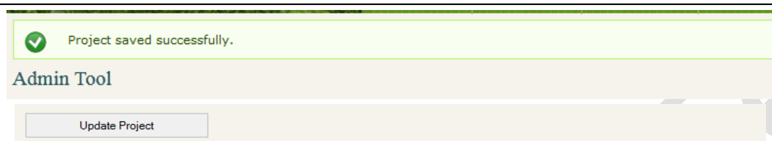
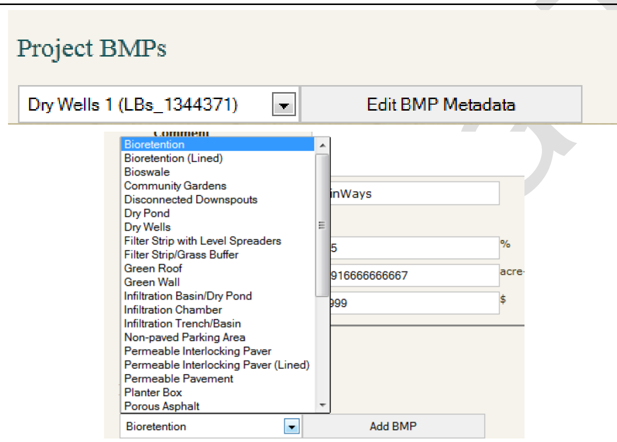
Screen Shot	Description
	The first section is the project general information. The project name is required. For those projects that were entered through the engineering and homeowners tool the data for project name, project size, sewershed and municipality will already be entered. For these projects the user can only change the project name, project description and status. All other data elements will need to be changed through the engineering or homeowner tool. For new projects both the sewershed and municipality is required. Project name is also required.
	The second section is the contact information for the project.

<table>
<tr>
<td>
</td>
<td>The third section is the locational information and source. The latitude and longitude will be prepopulated for those projects entered through the engineer and homeowners tool. These fields are required.

Address quality refers to how the location of the project was determined. For engineer and homeowners it is always set to Raw data directly from users

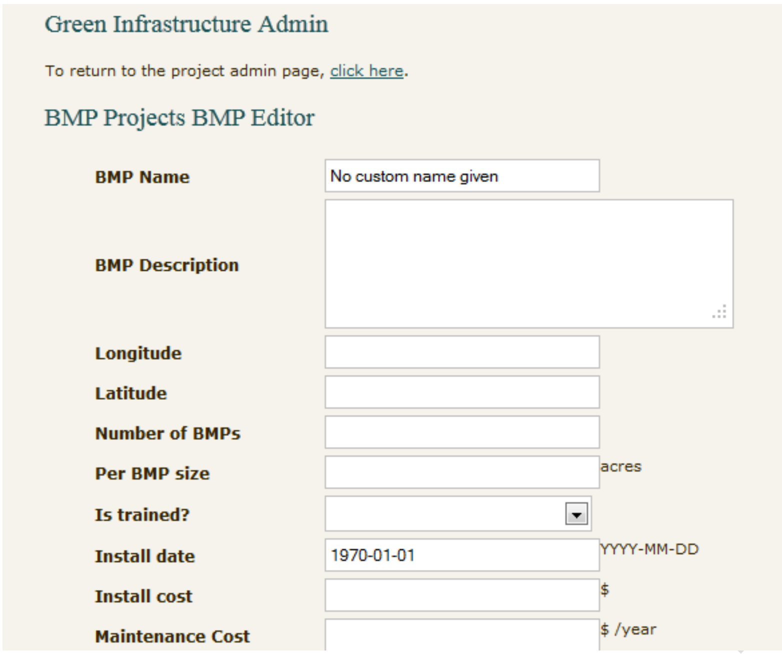
Comments is a place to enter all of your notes and any additional information

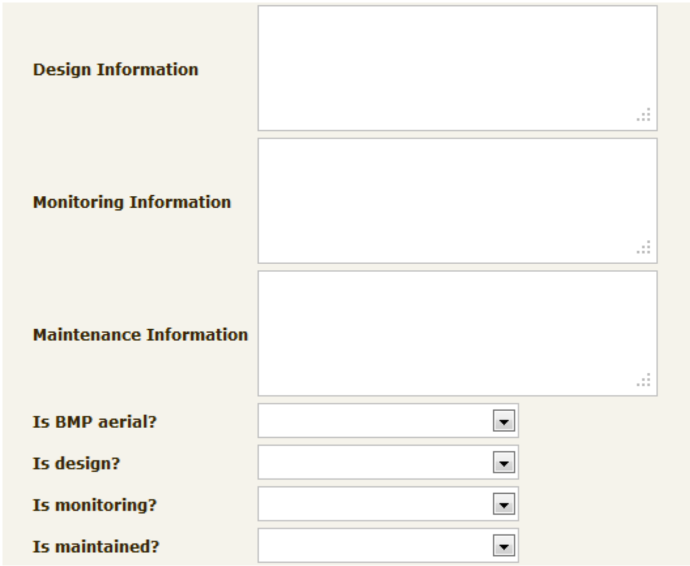
Source is the source of the project. For engineers and homeowners it gets set to RainWays but the user can change the default here. This field is required.

The last field is whether the user would like to publish the project on the GI Map.</td>
</tr>
<tr>
<td>
</td>
<td>For those projects entered only through these forms and not through the homeowners and engineering tool the user has the option to enter the reduction percent, reduction volume and a total cost.</td>
</tr>
<tr>
<td>
</td>
<td>Once user are complete they can save the project. If all required fields are entered into the database and in the correct format user will received a successfully add message. Otherwise the user will receive a message about the errors on the page.</td>
</tr>
<tr>
<td>
</td>
<td>Once user have added a project if the project was initially created in the engineering or homeowner's tool user will see the GI projects and the ability to edit metadata. Those projects added through the engineering and homeowner's tool cannot have new GIs added but must added metadata to existing GIs in the project. To add a new GI the user must go back to the engineering or homeowner's tool to enter the information.

If users are entering projects directly into this form and not through the other tool, once the user click add project the user will see the list of GI to add to the project. Select the GI and add to the project. Once user add it click Edit GI Metadata to enter information about the GI.</td>
</tr>
</table>

5.1.2 Green Infrastructure Forms

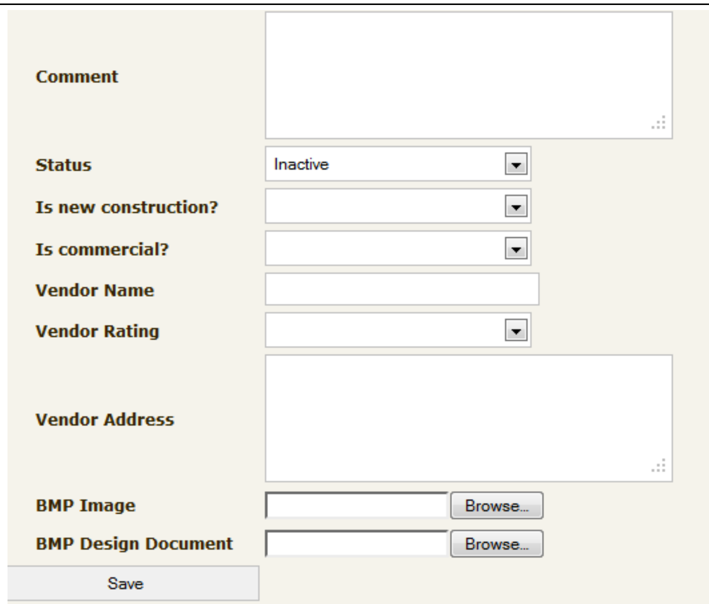
Screen Shot	Description
 Green Infrastructure Admin To return to the project admin page, click here. BMP Projects BMP Editor BMP Name: No custom name given BMP Description Longitude Latitude Number of BMPs Per BMP size: acres Is trained? Install date: 1970-01-01 YYYY-MM-DD Install cost: $ Maintenance Cost: $ /year	Once a user has added a project they are ready to add GIs to the project. The system only requires the GI Name to be added the rest of the data is optional. The longitude and latitude information for a GI is the location of GI on the project site. This is only applicable if multiple GIs exist on a project site. Is Trained is an indicator if the GI is linked together in a treatment train. Installation and maintenance cost should be entered in present value terms.



The following is information about the design, maintenance and monitoring for the GI project. The system also allows users to upload design documentation if required.

User can also simply indicate whether;

- The GI was visible by aerial photography
- The GI is designed based on specifications
- The GI is currently being monitored for performance
- The GI is being maintained based on recommended maintenance programs.



The last set of details allow users to enter comment information, the current status of the GI project.

Next the user enters whether this is new construction or retro fit and if it is a commercial or residential GI.

Finally the vendor information is entered.

In addition, to text the system allows a user to upload an image of the GI and any design documentation.

Once the user is done they click Save and then will see a Successfully Submitted message or an error message if something was not properly entered.

6 Engineering Approach Supporting Design

6.1 Green Infrastructure Priority Areas

The current project is driven by an interest in implementation of green infrastructure to support control of CSO discharges. Therefore, a question to be addressed is: "In which locations will green infrastructure provide the most potential to reduce CSO discharges?" CSO discharges are most likely to be reduced in locations where other CSO controls can be avoided completely, or where a significant reduction in sizing of facilities is possible with green infrastructure. This ability to support CSO control must therefore be considered in conjunction with other anticipated controls that will be used in the control of the CSO discharges. These issues are addressed in an evaluation of the existing collection system and understand of potential future controls.

Additional questions relate to factors that are associated with technical feasibility. This category of evaluation is intended to identify potential areas based on the ability to support green infrastructure. This technical category considers the physical opportunities such as land area, space, slope, soils, and parcel configuration. Identification of these locations through a prioritization process can lead to areas that would benefit the collections system from pilot project opportunities.

However, it is difficult to separate the potential to reduce CSO discharges and technical siting factors with other factors that make application of green infrastructure feasible and beneficial. If social or political factors make placement of green infrastructure currently infeasible or difficult, there is not a specific benefit in the identification of these locations as priority areas. Thus, this must be taken into consideration as a key aspect in the identification process. The overlapping potential of each of the following broad categories will influence the success of green infrastructure controls. Tier II factors should be considered globally, but are best applied to those areas that have been identified in Tier I.

Table 1 identifies characteristics identified with high and low potential for identification of successful green infrastructure opportunities and demonstrations. The table identifies two categories. The first tier is based on the ability to meet the project objective of CSO reduction and the technical feasibility of implementing green infrastructure. The second tier considers social and political factors that, if met, may improve the chances of successful implementation.

Table 1: Area Selection Criteria

Category	Characteristics of High Potential	Characteristics of Low Potential
Tier I – Technical Considerations		
Collection System Configuration and Potential Future CSO Controls (Benefit for CSO Control)	• Small tributary area to individual CSO • Municipal CSO area upstream of ALCOSAN regulator • Area previously identified as basin planner as having higher feasibility for green infrastructure benefit • CSO area not directly adjacent to other combined areas. • Identified storm sewer area within combined sewer area.	• Immediately adjacent to proposed tunnel or major facility locations. • Interceptor capacity limited.

Category	Characteristics of High Potential	Characteristics of Low Potential
	• Size of precipitation event to be controlled in order to reach target	
Physical Characteristics that Promote Potential for Green Infrastructure Demonstration and Effectiveness	• Significant number of public parcels (size, location) • Large impervious areas with potential to control (e.g. parking lot directed to island GI, roof runoff diverted to pervious area or GI) • Slope (0%-8%) for majority of area • Existing permeable area available to support adjacent properties • Larger (public) rights of way • Problem drainage with small storm events	• Predominately private parcels • Small parcels with little or no impervious area • Steeply sloped areas • Narrow rights of way
Tier II – Planning, Political, Social Considerations		
Support for Green Infrastructure or Practices (institutional feasibility)	• Municipality highly supportive of green infrastructure • ALCOSAN (or other agency) focused pilot area for green infrastructure • Downspout disconnection program target areas • Street Trees • Redeveloping area/ area in transition • Political/ Council District with focused emphasis • Active stewardship community (community gardens or other citizen lead stewardship)	• Municipality not supportive of green infrastructure • Minimal redevelopment or blighted area not yet in transition • Identify underground utility

6.1.1 Approach

This project will address each criterion which has readily available data to support or can be evaluated with reasonable limited analysis. Some of the criteria identified may currently be undefined or unsupported by data. In such cases, these decision variables remain included in the listing in order to provide a comprehensive picture and suggest areas of future information development.

Area evaluation: tier I: Technical Considerations

Collection System Configuration and Potential Future CSO Controls
(Benefit for CSO Control)

1) Small tributary area to individual ALCOSAN CSO
    a) Currently available data: Sewersheds tributary to ALCOSAN regulators (GIS layer)
    b) Future data source: Updated sewersheds
    c) Proposed analysis:
        i) Note: existing data is sufficient for this analysis.

ii) Identify distribution of combined area per ALCOSAN point of connection (POC). Rank small to large. Group into thirds with smallest group being highest potential, middle group being moderate potential and large areas being smallest potential. Actual acreage associated with groupings may be modified by best professional judgment.

2) Municipal CSO area upstream of ALCOSAN regulator
   a) Currently available data: locations of existing municipal CSOs (spatial data) and tributary areas.
   b) Future data source: no change anticipated other than minor corrections to tributary areas.
   c) Proposed analysis: identify areas tributary to municipal CSO locations.
3) Area previously identified by basin planner as having higher feasibility for green infrastructure benefit
   a) Currently available data: Spatial layer from ALCOSAN showing basin planner identified areas for implementation of green practices.
   b) Future data source: Updated layer from ALCOSAN based on ongoing alternatives analysis (may or may not change)
   c) Proposed analysis: Identify areas per layer provided. Review Saw Mill Run documents as no areas were identified in the spatial layer.
4) CSO area not directly adjacent to other combined areas.
   a) Currently available data: Map of combined areas by ALCOSAN POC
   b) Future data source: No change anticipated
   c) Proposed analysis: Select areas based on extent to which they are remote from other locations. Best professional judgment. Identify by POC.
5) Not adjacent/ tributary to proposed large CSO facilities
   a) Currently available data: ALCOSAN regional planning scenarios 1 – 7
   b) Future data source: ALCOSAN updated regional planning scenarios and basin planner updated scenarios
   c) Proposed analysis: Using currently available data and best professional judgment/ inspection, eliminate areas from “high priority” that do not have municipal overflows and are immediately tributary to major CSO control facilities identified as high priority locations. The product of this will be a list of remaining POCs that may not be addressed in large/ priority facilities.
6) Identified storm sewer area within combined sewer area.
   a) Currently available data: One overall map identifying municipal sewers by type/ layer for combined sewer areas.
   b) Future data source: information on location of stream removal projects (pending from ALCOSAN).
   c) Proposed analysis: Highlight identified storm sewers within the municipal combined sewer areas. Define approximate area served and point of connection/ if municipal overflows exist in the proximity. Limit to larger areas. To be selected based on best professional judgment. Exclude stream flow removal areas as these are already being addressed.
7) Size of precipitation event to be controlled in order to reach target.
   a) Currently available data: ALCOSAN H/H models (preferred baseline conditions with stream flow removal and early action projects identified).
   b) Future data source: revised ALCOSAN H/H models
   c) Proposed analysis: For locations identified in items 1 – 6 above perform the following:

i) Define available regulator capacity: base on ALCOSAN report documenting regulator capacity. However if physical regulator capacity is > 3x DWF, limit to 3x DWF.
ii) Run H/H models identified for the typical year and develop time series data upstream of regulator to compare with regulator capacity.
iii) Define storm event thresholds that correspond with various overflow frequencies.

Physical Characteristics that Promote Potential for Green Infrastructure Demonstration and Effectiveness

1) Public parcels: assess number, size and density. Generally greater than 1 acre to allow for GI placement area.
2) Large impervious areas with potential to control within parcel boundaries. Consider size of parking area or building footprint relative to total parcel size. May be limited based on slope / soils. parking lot directed to island GI, roof runoff diverted to pervious area or GI)
3) Slope: Preferred 0%-8% for majority of area
4) Existing permeable area available to support adjacent properties: Can be evaluated based on impervious area, parks, and other parcel data
5) Larger (public) rights of way. Opportunities are improved when ROW greater than 42 feet. A street ROW layer would be beneficial if this is to be included as a criterion. Known data includes parcel data and street centerline/ street edge of pavement data, but unclear if ROWs have been defined.
6) Problem drainage with small storm events. No known data exists to summarize this in GIS format. This would be a potential future enhancement.
7) Street Trees. Existing street trees provide a current function for tree canopy (interception), as well as evapotranspiration for infiltrated stormwater. Generally, new GIs would not be considered that would require removal of established street trees.
8) Ownership type by taxing body for vacant lots

Area evaluation: tier 2: Planning, Political, Social Considerations

1) Redeveloping area/ area in transition
   a) Currently available data: *unknown: to be determined based on Allegheny County planning information*
   b) Future data source: *to be determined*
2) Municipality highly supportive of green infrastructure
   a) Currently available data: *selected municipalities/ agencies publically supportive of green infrastructure implementation, based on input from 3 Rivers, steering committee (to be requested)*
   b) Future data source to be developed: survey or assessment of support for green practices as determined by municipal resolution and review of development ordinances.
3) Downspout disconnection program
   a) Currently available data: *input from 3 Rivers regarding pilot locations for downspout disconnection practices. Also any criteria that has been developed for selection of downspout disconnection areas. Requested from 3R on 5/10/11, Beth Dutton gathering information.*
   b) Future data source to be developed: locations where downspouts are connected/ disconnected.
4) Political/ Council District with focused emphasis
   a) Currently available data: *Similar to item 2, any specific areas within a community that have been identified by that community as a focus area for green infrastructure based on local municipal priorities. To be requested from/ identified by 3 Rivers.*

b) Future data source to be developed: TBD.
5) ALCOSAN (or other agency) focused pilot area for green
a) Currently available data: *ALCOSAN provided map and GIS layer highlighting priority areas (received)*
b) Future data source to be developed: NA.
6) Active stewardship community (community gardens or other citizen lead stewardship)
a) Currently available data: *specific focal areas by other organizations (initial list to be prepared by Collective Efforts/ 3 Rivers) – to be requested*
b) Future data source to be developed: more formalized identification of various groups who are promoting such practices.

Data required for the above analysis includes GIS data sets and hydraulic model data. Tetra Tech is currently coordinating with the 3 Rivers program manager consultant for assessing models previously provided by ALCOSAN. Models preferred for this analysis should reflect baseline conditions (essentially existing conditions + stream flow and near term projects). A listing of desirable GIS data layers is identified in Table 2. This listing is based on known existing and/ or desired data sources that would support the project. Data importance is noted with various ranking (required (R), high (H), moderate (M) or low (L).)

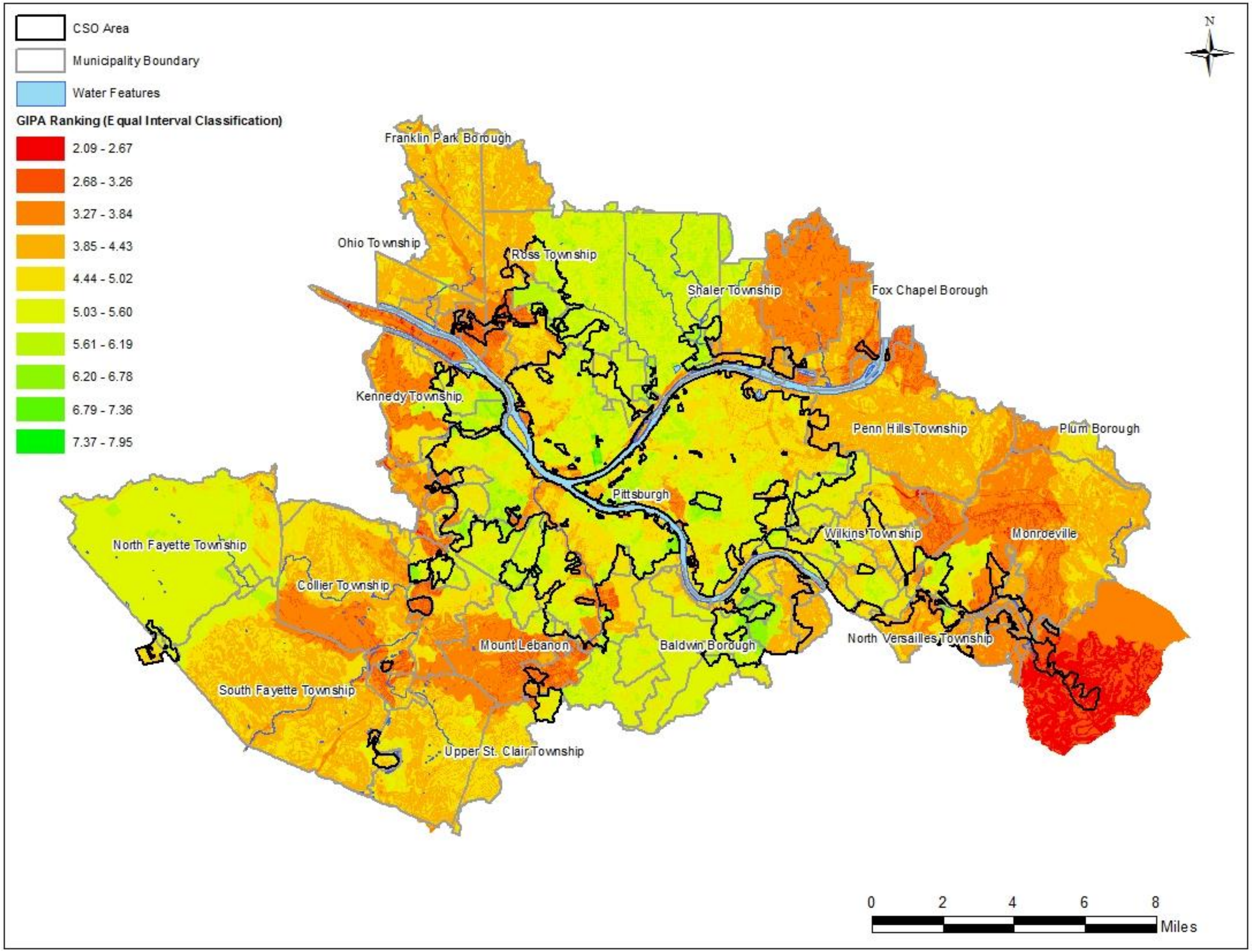
Table 2: GIS Data Layers Value: R = required; H= high, M = moderate, L = low

Item	Value	GIS Data	Known Potential Data Source if not available from 3 Rivers	Year
1	M	Abandoned Mine Land Inventory Areas, Sites and Point - has subsidence areas	PASDA	2011
2	R	Aerial Photos (Google Maps more current)	PASDA	2006-2007
3	M	Allegheny Land Trust Greenprint	ALCOSAN	2009
4		ALCOSAN identified green infrastructure potential locations	ALCOSAN	2010
5		ALCOSAN identified stream removal project areas	ALCOSAN	pending
6	L	AMD Treatment/Land Recycling Projects	PASDA	2011
7	M	Brownfields	PASDA	2009
8	H	Building Footprints	Allegheny County Website/PASDA	2008
9	M	Cemeteries	Allegheny County Website/PASDA	2002
10	L	Contours	ALCOSAN (2', 4' 10' 20' & 100')	2008
11	H		PASDA (5')	2004
12	M	Development Areas	*Unknown*	??
13	H	Downspout Disconnection Program Pilot Areas	*Unknown*	
14		Downspout Disconnection Assessment (e.g. status of downspout disconnection)		
15	L	Floodplain - 100 Yr	Allegheny County Website/PASDA	2000
16		Green Infrastructure Practices (existing)	*To be started from available information as part of this project*	
17	H	Greenways	Allegheny County Website/PASDA	2010

Item	Value	GIS Data	Known Potential Data Source if not available from 3 Rivers	Year
18	M	Hydrology Areas (water bodies)	Allegheny County Website/PASDA	2006
19	M	Hydrology Lines (streams, drainages, large river boundaries)	Allegheny County Website/PASDA	2006
20	R	Impervious (closed polygons)	ALCOSAN	2010
21	R	Land Use/Land Type** (land use/types including utilities, residential, commercial, agricultural, business	Southwestern Pennsylvania Commission (via ALCOSAN)	2006
22	R		Allegheny County Website/PASDA	2004
23	H	Landslide prone areas	nothing available, but retaining wall .shp from All. Co/PASDA	
24	R	Municipal boundaries (will not match sewershed boundaries exactly)	Allegheny County Website/PASDA	2011
25	R	Municipal sewer system -manholes	One overall map	2011
26	R	Municipal sewer system -sewers	One overall map	2011
27	M	Municipal zoning	unknown	2002
28	M	National Wetlands Inventory	Allegheny County Website/PASDA	2000
29	R	Parcels	Allegheny County Website/PASDA	2011
30	H	Parking	Allegheny County Website/PASDA	2000
31	H	Parks	Allegheny County Website/PASDA	2000
32	M	Problem drainage locations	*Unknown/ unmapped*	
33	H	Public Buildings	Allegheny County Website/PASDA	2002
34	L	Railroad Lines	Allegheny County Website/PASDA	2006
35	R	Sewershed boundaries	ALCOSAN	2011
36	R	Slopes	PASDA	2010
37	R	Soils (also http://www.pa.nrcs.usda.gov/Soils/soilsinfo.html)	Allegheny County Website/PASDA	2000
38	H	Street Centerlines	Allegheny County Website/PASDA	2006
39	H	Street Edge of Pavement	Allegheny County Website/PASDA	2006
40	H	Street Right of Way	*unknown*	
41	M	Stormwater Management Watersheds	PASDA	2002
42	M	Trees – Street	*unknown*	
43	M	Watersheds	Allegheny County Website/PASDA	2000
44	M	Wooded Areas	PASDA	2011
		Planning Documents/Offices	**Source**	
		Allegheny County Comprehensive Plan	http://www.alleghenyplaces.com/	
		City of Pittsburgh Urban Redevelopment Authority	http://www.ura.org/	

Item	Value	GIS Data	Known Potential Data Source if not available from 3 Rivers	Year
		City of Pittsburgh City Planning	http://www.city.pittsburgh.pa.us/cp/	
		*PASDA - Pennsylvania Spatial Data Access *Allegheny County GIS Website - this website links to PASDA	http://www.alleghenycounty.us/dcs/gis/available.aspx	

6.1.2 Final GIPA Scoring and Map


CSO Area
Municipality Boundary
Water Features
GIPA Ranking (Equal Interval Classification)
2.09 - 2.67
2.68 - 3.26
3.27 - 3.84
3.85 - 4.43
4.44 - 5.02
5.03 - 5.60
5.61 - 6.19
6.20 - 6.78
6.79 - 7.36
7.37 - 7.95
N
Franklin Park Borough
Ohio Township
Ross Township
Shaler Township
Fox Chapel Borough
Kennedy Township
Penn Hills Township
Plum Borough
Pittsburgh
North Fayette Township
Wilkins Township
Monroeville
Collier Township
Mount Lebanon
Baldwin Borough
North Versailles Township
South Fayette Township
Upper St. Clair Township
0
2
4
6
8
Miles

The Green Infrastructure Priority Areas (GIPA) layer highlights the locations where green infrastructure will provide the most potential to reduce CSO discharges. In order to create the GIPA layer, sixteen input datasets were identified, analyzed, ranked, weighed, and finally intersected to create the final output. All of the analysis and geospatial work was done using ESRI's ArcGIS geoprocessing tools in the ModelBuilder processing environment.

The sixteen input layers are broken down into two main categories, Technical Considerations and Planning, Political, and Social Considerations. The Technical Considerations category is furthermore divided into two groups, Collection System Configuration, and Physical Characteristics.

The following section summarizes how each of the input layers was processed and ranked.

Collection System Configuration Inputs:

1. Small tributary areas to individual ALCOSAN CSO
   a. Area summarized by POC (Point of Connection)
   b. Grouped by area into thirds, smallest 1/3 received ranking of 10, middle 1/3 received a ranking of 5, and largest 1/3 received ranking of 1.
2. Municipal CSO area upstream of ALCOSAN regulator
   a. Areas tributary to municipal CSO area received ranking of 10, all other areas received ranking of 1.
3. Basin Planner identified areas of high feasibility of green infrastructure
   a. Basin Planner identified green infrastructure areas received ranking of 10, all other areas received ranking of 1.
4. Storm sewer areas within CSO area
   a. Areas of storm sewer within CSO areas received ranking of 10, all other areas received ranking of 1.
5. Frequency of precipitation event
   a. Non-CSO areas received ranking of 1, other areas received ranking value between 2 and 10 based on frequency compared to initial abstraction.
6. Volume of precipitation event
   a. Non-CSO areas received ranking of 1, other areas received ranking value between 2 and 10 based on volume compared to initial abstraction.

Physical Characteristic Inputs:

7. Public Parcels
   a. Public parcels with an area greater than 1 acre received a ranking value of 10, public parcels with an area less than 1 acre received a ranking value of 5, and all non-public parcels received a ranking value of 1.
8. Parcels with a high percentage of impervious area
   a. Parcels with greater than 25% impervious area received a ranking value of 10, all other parcels received a value of 1.
9. Slope
   a. Slope percent was created using 10 meter elevation dataset.

b. Slope less than 4% received ranking value of 10, slope between 4% and 8% received a ranking value of 5, all other slope values received a ranking value of 1.

10. Existing Permeable Area
    a. Permeable areas received a ranking value of 10, all other areas received a ranking value of 1.
11. Public Right-of-Ways (ROW)
    a. Public Right-of-Ways received a ranking value of 10, all other areas received a ranking value of 1.

Planning, Political, and Social Consideration Inputs:

12. ALCOSAN focused pilot area for green infrastructure
    a. ALCOSAN green infrastructure areas received a value of 10, all other areas received a ranking value of 1.

Once each of the sixteen input layers was analyzed, processed and ranked, each of the inputs was assigned a weight based on its level of significance. The weights were assigned as follows:

Input Layer	Weight
1. Small tributary areas to individual ALCOSAN CSO	0.05
2. Municipal CSO area upstream of ALCOSAN regulator	0.1
3. Basin Planner identified areas of high feasibility of green infrastructure	0.08
4. Storm sewer areas within CSO area	0.05
5. Frequency of precipitation event	0.07
6. Volume of precipitation event	0.07
7. Public Parcels	0.05
8. Parcels with a high percentage of impervious area	0.1
9. Slope	0.05
10. Existing Permeable Area	0.05
11. Public Right-of-Ways (ROW)	0.05
12. Problem drainage areas	0.05
13. Redeveloping and transition areas	0.04
14. Municipality or council district supportive of green infrastructure	0.05
15. Downspout disconnection program areas	0.04
16. ALCOSAN focused pilot area for green infrastructure	0.05
17. Active stewardship community	0.05
TOTALS	1

The final step in the process was to combine all sixteen inputs through an overlay process and to remove any water features (rivers, lakes, ponds, etc.) from the layer. Once this was completed the layer was then classified into 10 groups based on the Natural Breaks (Jenks) classification method.

6.2 GI Placement

The siting tool developed by Tetra Tech for EPA *SUSTAIN* model was used to identify suitable sites for placement of GIs on the basis of suitability criteria including elevation, slope, soil type, urban land use, roads, stream location, and drainage area. The siting tool was developed to assist users in selecting suitable locations for different types of low impact development (LID) techniques or conventional GIs. The following tables list the GIS data, the data format, and the default site suitability criteria for the siting tool taken from EPA published report (Shoemaker et al. 2009; http://www.epa.gov/nrmrl/wswrd/wq/models/sustain) to identifying potential site locations. A suitable location map for potential GI types was created and is available for the user through the web-based interfaces as guidance.

GIS Data Requirement for GI Suitability Analysis

GIS Layer	Format	Description
DEM	Raster file	The DEM is used to calculate the drainage slope and drainage areas that are used to identify the suitable locations for GIs.
NLCD Land Use	Raster file	The USGS Multi-Resolution Land Characteristics Consortium NLCD land use grid is used to eliminate the unsuitable areas for GIs.
Percent Imperviousness	Raster file	The impervious grid is used to identify the suitable locations for GIs for the given suitability criteria.
Soil	Shape file	The soil data contain the soil properties such as hydrological soil group, which are used to identify suitable locations for GIs.
Urban Land Use	Shape file	The urban land use data contain the boundaries for the buildings and the impervious areas needed to identify suitable locations for LIDs.
Road	Shape file	The road layer is used to identify suitable locations for some GIs that must be placed within a specific road buffer area.
Stream	Shape file	The stream layer is used to define a buffer so that certain GI types can be placed outside the buffer to minimize the impact on streams.
Groundwater Table Depth	Shape file	The groundwater table depth layer is used to identify suitable locations for the infiltration GIs; derived from monitoring data.

GIS Data Format Requirement for GI Suitability Analysis

GIS Layer	Data Type	Field Name	Field Type	Field Value / Description

GIS Layer	Data Type	Field Name	Field Type	Field Value / Description
DEM	Raster file	VALUE	Floating	ESRI grid
NLCD Land Use	Raster file	VALUE	Integer	ESRI grid
Land Use Lookup	Table	LUCODE	Integer	should be same as in the VALUE field in NLCD Land Use layer
		LUNAME	String	Description about the land use type
		SUITABLE	Short	1 or 0 (1 = suitable; 0 = unsuitable)
Percent Imperviousness	Raster file	VALUE	Integer	0 – 100
Soil	Shape file	MUKEY	String	Hydrological soil classification (STATSGO or SSURGO or local dataset)
Soil Lookup	Table	MUKEY	String	should be same as in the MUKEY field
		HYDGRP	String	A or B or C or D
Urban Land Use	Shape file	LU_DESC	String	Buildings or Roadways or Parking Lots
Road	Shape file	N/A	N/A	N/A
Stream	Shape file	N/A	N/A	N/A
Groundwater Table Depth	Shape file	GWDEP_FT	Double	Depth to groundwater table

GI Criteria for Suitable Locations Used in the Siting Tool

GI Type	Drainage Area (acre)	Drainage Slope (%)	Impervious (%)	Hydrological Soil Group	Water Table Depth (ft)	Road Buffer (ft)	Stream Buffer (ft)	Building Buffer (ft)
Bioretention	< 2	< 5%	> 0%	A–D	> 2	< 100	> 100	-
Constructed Wetland	> 25	< 15%	> 0%	A–D	> 4	--	> 100	--
Dry Pond	> 10	< 15%	> 0%	A–D	> 4	--	> 100	--
Grassed Swale / Bioswale	< 5	< 4%	> 0%	A–D	> 2	< 100	--	--
Green Roof	--	--	--	--	--	--	--	--

GI Type	Drainage Area (acre)	Drainage Slope (%)	Impervious (%)	Hydrological Soil Group	Water Table Depth (ft)	Road Buffer (ft)	Stream Buffer (ft)	Building Buffer (ft)
Infiltration Basin	< 10	< 15%	> 0%	A–B	> 4	--	> 100	--
Infiltration Trench	< 5	< 15%	> 0%	A–B	> 4	--	> 100	--
Porous Pavement (Concrete/ Asphalt) / Permeable Interlocking Paver	< 3	< 1%	> 0%	A–B	> 2	--	--	--
Rain Barrel	--	-	--	--	--	--	--	< 30
Sand Filter (non-surface)	< 2	< 10%	> 0%	A–D	> 2	--	> 100	--
Sand Filter (surface)	< 10	< 10%	> 0%	A–D	> 2	--	> 100	--
Vegetated Filter Strip / Grass Buffer	--	< 10%	> 0%	A–D	> 2	< 100	--	--
Wet Pond	> 25	< 15%	> 0%	A–D	> 4	--	> 100	--

6.3 GI Performance and Cost

The GI performance curves represent a computationally efficient and technically defensible way of predicting a GI response, while eliminating the need for on-the-fly, computationally intensive modeling through the web. The step-by-step approach used to developing the GI performance curves is outlined below:

- Developed unique Hydrologic Response Units (HRUs) by overlaying landuse (pervious, rooftops, and impervious areas), soil (hydrologic soil group B, C, and D), and slope (low, moderate, and high) GIS layers for the study area. The HRU layer provides 13 unique combinations of slope, soil and landuse that potentially have a different rainfall-runoff response.

- NEXRAD precipitation data for the ALCOSAN service area for the 2003 Typical Year was used in this study.
- Modeled the rainfall-runoff response from each HRU on unit area basis (one acre) for the selected rainfall data. An existing ALCOSAN sewershed model (calibrated for the study area) was used to develop the HRU timeseries as a boundary condition to the *SUSTAIN* GI modeling effort.
- A set of 131 unique *SUSTAIN* modeling scenarios were developed for a unique combination of 16 GI types, 3 GI footprint soil type with low, medium, and high infiltration rates, and with an option of underdrain for poorly drained soil types.
- The EPA *SUSTAIN* model was run for a range of treatment depth (i.e. runoff depth to be captured) versus treatment capacity (i.e. GI size) for each scenario to develop 131 performance curves. Each performance curve provides the runoff volume captured and the GI cost for the given treatment depth or treatment capacity.

6.3.1 Hydrologic Response Unit Types

HRU Type	Description
HRU1	Building
HRU2	Impervious, high slope
HRU3	Impervious, moderate slope
HRU4	Impervious, low slope
HRU5	Pervious, high slope, soil D
HRU6	Pervious, high slope, soil C
HRU7	Pervious, high slope, soil B
HRU8	Pervious, moderate slope, soil D
HRU9	Pervious, moderate slope, soil C
HRU10	Pervious, moderate slope, soil B
HRU11	Pervious, low slope, soil D
HRU12	Pervious, low slope, soil C
HRU13	Pervious, low slope, soil B

6.3.2 Data Used

- Elevation data (DEM) to generate slope.
- Land use (pervious and impervious).
- Soil (Hydrologic Soil Group).
- NEXRAD precipitation data for the 2003 Typical Year.
- An existing ALCOSAN sewershed model (baseline scenario).

- GI cost information.

6.3.3 Model Input and Specifications

The following variables went into calculating the performance and cost of the GIs. The height, width and length of GIs defined the surface storage capacity. This also serves as the key for Appendix A, Appendix B, and Appendix C which are the criteria values used in the model.

GI Size Key – the following table shows the GI size specification used in the model.

BMPSITE	GI dimension group identifier
WIDTH	Basin bottom width (ft)
LENGTH	Basin bottom length (ft) / diameter (ft) for rain barrel
OHEIGHT	Orifice Height (ft)
DIAM	Orifice Diameter (in)
EXTP	Discharge Coefficient (0-0.99 or 1=1.0, 2=0.61, 3=0.61, 4=0.5)
RELTP	Release Type (1-Cistern, 2-Rain barrel, 3-others)
DDAYS	Number of dry days (Rain Barrel Option)
WEIRTP	Weir Type (1-Rectangular,2-Triangular)
WEIRH	Weir Height (ft)
WEIRW	(weir type 1) Weir width (ft)
THETA	(weir type 2) Weir angle (degrees)

GI Substrate Key – the following table shows the GI soil media specification.

BMPSITE	GI dimension group identifier
INFILTM	Infiltration Method (0-Holtan, 1-Green Ampt)
POLROTM	Pollutant Routing Method (1-Completely mixed, >1-number of CSTRs in series)
POLREMM	Pollutant Removal Method (0-1st order decay, 1-kadlec and knight method)
SDEPTH	Soil Depth (ft)
POROSITY	Soil Porosity (0-1)
FCAPACITY	Soil Field Capacity (ft/ft)
WPOINT	Soil Wilting Point (ft/ft)
AVEG	Vegitative Parameter A (0.1-1.0) (Empirical), only required for Holtan infiltration method
FINFILT	Soil layer infiltration rate (in/hr)

UNDSWITCH	Consider underdrain (1), Do not consider underdrain (0)
UNDDEPTH	Depth of storage media below underdrain (ft)
UNDVOID	Fraction of underdrain storage depth that is void space (0-1)
UNDINFILT	Background infiltration rate, below underdrain (in/hr)
SUCTION	Average value of soil capillary suction along the wetting front, value must be greater than zero (in)
HYDCON	Soil saturated hydraulic conductivity, value must be greater than zero (in/hr)
IMDMAX	Difference between soil porosity and initial moisture content, value must be greater than or equal to zero (a fraction)

Note: Pollution Reduction and Pollution Removal was not used as these apply only to Water Quality based calculations.

6.3.4 GI Performance Curves

Below are the GI Effectiveness calculations for each of the GI-HRU combinations. These calculations are used in the Engineering and Homeowner Tool for GI Size/Performance.

For each GI, the user defines the percentage of each HRU's runoff that routes to that GI. This is calculated in the following way:

$$V_{Runon} = \sum_{i=1}^{n} A_{HRU,i} D_{HRU,i} + \sum_{j=1}^{m} V_{BMP,j}$$

Where V is the volume (acre-inches) of runoff routed to the GI, $A_{HRU,i}$ is the area (acre) of an HRU, $D_{HRU,i}$ is the annual runoff depth (inches) per unit area for that HRU, n is the number of HRUs in the sewershed, $V_{BMP,j}$ is the effluent volume for an upstream GI, and m is the number of upstream GIs.

This volume is then converted to an equivalent impervious drainage area using the following equation:

$$A_{impervious} = \frac{V_{Runon}}{D_{impervious}}$$

Where $A_{impervious}$ is the equivalent impervious drainage area (acres), V_{runon} is the volume of water routed to the GI, and $D_{impervious}$ is the annual runoff depth from one acre of impervious area, which happens to be 31.24 inches for the typical year 2003.

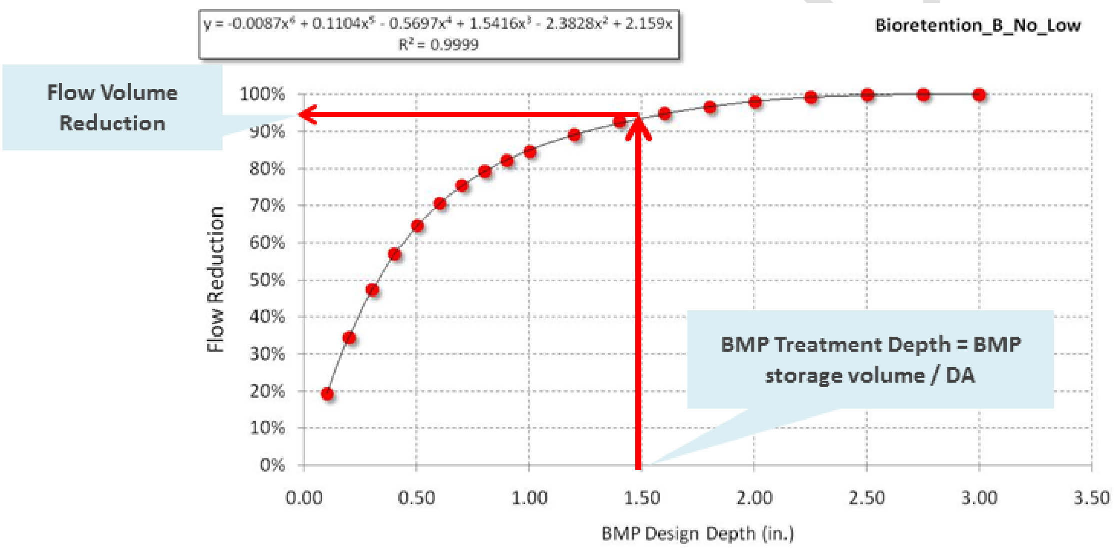
This area is then used to calculate the impervious runoff treatment depth based on the user specified GI size and the given GI per unit area capacity.

$$D_{treatment} = \frac{V_{GI-Capacity}}{A_{impervious}}$$

Where $D_{treatment}$ is the treatment depth (inches), $V_{GI\text{-}Capacity}$ is the GI capacity volume calculated from per unit area capacity and the GI size (surface area), and $A_{impervious}$ is the equivalent impervious drainage area.

Once this treatment depth has been calculated, the performance curve can be used to find an equivalent flow volume reduction, shown below.

Example Performance Curve used to Generate Reduction.



If the user specifies the runoff treatment depth in the engineering tool interface, then the reduction is simply directly looked up using the performance curve and the size of the GI is calculated based on the given runoff treatment depth and the equivalent impervious drainage area.

Appendix A: GI Sizing Data

BMPType	SoilType	Underdrain	Infiltration	WIDTH	LENGTH	OHEIGHT	DIAM	EXITYPE	RELEASETYPE	WEIRTYPE	WEIRH	WEIRW
GreenRoof	B/C/D	Yes	0 (lined)	1	819.4	0	0	2	3	1	0.2	41.0
PanterBox	B/C/D	Yes	0 (lined)	1	230.5	0	0	2	3	1	0.5	11.5
Wetland/Wetpond	B/C/D	Yes	0 (lined)	1	144.6	1	6	2	3	1	2.5	7.2
Bioretention-lined	B/C/D	Yes	0 (lined)	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter-lined	B/C/D	Yes	0 (lined)	1	230.5	0	0	2	3	1	0.5	11.5
VegetatedSwale-lined	B/C/D	Yes	0 (lined)	1	465.4	0	0	2	3	1	0.3	23.3
PermeablePaver-lined	B/C/D	Yes	0 (lined)	1	1125.6	0	0	2	3	1	0.01	56.3
PorousConcrete/Asphalt-lined	B/C/D	Yes	0 (lined)	1	1423.5	0	0	2	3	1	0.01	71.2
Bioretention	B	No	Low	1	250.3	0	0	2	3	1	0.75	12.5
SandFilter	B	No	Low	1	264.0	0	0	2	3	1	0.5	13.2
VegetatedSwale	B	No	Low	1	625.9	0	6	2	3	1	0.3	31.3
Bioswale	B	No	Low	1	354.1	0	0	2	3	1	0.5	17.7
InfiltrationTrench	B	No	Low	1	196.2	0	0	2	3	1	0.5	9.8
PermeablePaver	B	No	Low	1	355.0	0	0	2	3	1	0.01	17.8
InfiltrationBasin	B	No	Low	1	302.5	0	0	2	3	1	0.5	15.1
DryPond	B	No	Low	1	114.3	0	0	2	3	1	3	5.7
PorousConcrete/Asphalt	B	No	Low	1	380.1	0	0	2	3	1	0.01	19.0
DownspoutDisconnection	B	No	Low	1	2420.0	0	0	2	3	1	0.05	121.0
FilterStrip	B	No	Low	1	2792.3	0	0	2	3	1	0.03	139.6
Bioretention	B	No	Med	1	250.3	0	0	2	3	1	0.75	12.5
SandFilter	B	No	Med	1	264.0	0	0	2	3	1	0.5	13.2
VegetatedSwale	B	No	Med	1	625.9	0	0	2	3	1	0.3	31.3
Bioswale	B	No	Med	1	354.1	0	0	2	3	1	0.5	17.7
InfiltrationTrench	B	No	Med	1	196.2	0	0	2	3	1	0.5	9.8
PermeablePaver	B	No	Med	1	355.0	0	0	2	3	1	0.01	17.8
InfiltrationBasin	B	No	Med	1	302.5	0	0	2	3	1	0.5	15.1
DryPond	B	No	Med	1	114.3	0	0	2	3	1	3	5.7
PorousConcrete/Asphalt	B	No	Med	1	380.1	0	0	2	3	1	0.01	19.0
DownspoutDisconnection	B	No	Med	1	2420.0	0	0	2	3	1	0.05	121.0
FilterStrip	B	No	Med	1	2792.3	0	0	2	3	1	0.03	139.6
Bioretention	B	No	High	1	250.3	0	0	2	3	1	0.75	12.5
SandFilter	B	No	High	1	264.0	0	0	2	3	1	0.5	13.2
VegetatedSwale	B	No	High	1	625.9	0	0	2	3	1	0.3	31.3
Bioswale	B	No	High	1	354.1	0	0	2	3	1	0.5	17.7
InfiltrationTrench	B	No	High	1	196.2	0	0	2	3	1	0.5	9.8
PermeablePaver	B	No	High	1	355.0	0	0	2	3	1	0.01	17.8
InfiltrationBasin	B	No	High	1	302.5	0	0	2	3	1	0.5	15.1
DryPond	B	No	High	1	114.3	0	0	2	3	1	3	5.7
PorousConcrete/Asphalt	B	No	High	1	380.1	0	0	2	3	1	0.01	19.0
DownspoutDisconnection	B	No	High	1	2420.0	0	0	2	3	1	0.05	121.0
FilterStrip	B	No	High	1	2792.3	0	0	2	3	1	0.03	139.6
Bioretention	B	Yes	Low	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter	B	Yes	Low	1	230.5	0	0	2	3	1	0.5	11.5

BMPType	SoilType	Underdrain	Infiltration	WIDTH	LENGTH	OHEIGHT	DIAM	EXITYPE	RELEASETYPE	WEIRTYPE	WEIRH	WEIRW
VegetatedSwale	B	Yes	Low	1	465.4	0	0	2	3	1	0.3	23.3
Bioswale	B	Yes	Low	1	296.3	0	0	2	3	1	0.5	14.8
PermeablePaver	B	Yes	Low	1	393.5	0	0	2	3	1	0.01	19.7
PorousConcrete/Asphalt	B	Yes	Low	1	424.6	0	0	2	3	1	0.01	21.2
Bioretention	B	Yes	Med	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter	B	Yes	Med	1	230.5	0	0	2	3	1	0.5	11.5
VegetatedSwale	B	Yes	Med	1	465.4	0	0	2	3	1	0.3	23.3
Bioswale	B	Yes	Med	1	296.3	0	0	2	3	1	0.5	14.8
PermeablePavement	B	Yes	Med	1	257.0	0	0	2	3	1	0.5	12.8
PorousConcrete/Asphalt	B	Yes	Med	1	424.6	0	0	2	3	1	0.01	21.2
Bioretention	B	Yes	High	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter	B	Yes	High	1	230.5	0	0	2	3	1	0.5	11.5
VegetatedSwale	B	Yes	High	1	465.4	0	0	2	3	1	0.3	23.3
Bioswale	B	Yes	High	1	296.3	0	0	2	3	1	0.5	14.8
PermeablePaver	B	Yes	High	1	393.5	0	0	2	3	1	0.01	19.7
PorousConcrete/Asphalt	B	Yes	High	1	424.6	0	0	2	3	1	0.01	21.2
VegetatedSwale	C	No	Low	1	625.9	0	0	2	3	1	0.3	31.3
Bioswale	C	No	Low	1	354.1	0	0	2	3	1	0.5	17.7
DryPond	C	No	Low	1	114.3	0	0	2	3	1	3	5.7
DownspoutDisconnection	C	No	Low	1	2420.0	0	0	2	3	1	0.05	121.0
FilterStrip	C	No	Low	1	2792.3	0	0	2	3	1	0.03	139.6
VegetatedSwale	C	No	Med	1	625.9	0	0	2	3	1	0.3	31.3
Bioswale	C	No	Med	1	354.1	0	0	2	3	1	0.5	17.7
DryPond	C	No	Med	1	114.3	0	0	2	3	1	3	5.7
DownspoutDisconnection	C	No	Med	1	2420.0	0	0	2	3	1	0.05	121.0
FilterStrip	C	No	Med	1	2792.3	0	0	2	3	1	0.03	139.6
VegetatedSwale	C	No	High	1	625.9	0	0	2	3	1	0.3	31.3
Bioswale	C	No	High	1	354.1	0	0	2	3	1	0.5	17.7
DryPond	C	No	High	1	114.3	0	0	2	3	1	3	5.7
DownspoutDisconnection	C	No	High	1	2420.0	0	0	2	3	1	0.05	121.0
FilterStrip	C	No	High	1	2792.3	0	0	2	3	1	0.03	139.6
Bioretention	C	Yes	Low	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter	C	Yes	Low	1	230.5	0	0	2	3	1	0.5	11.5
VegetatedSwale	C	Yes	Low	1	465.4	0	0	2	3	1	0.3	23.3
Bioswale	C	Yes	Low	1	296.3	0	0	2	3	1	0.5	14.8
PermeablePaver	C	Yes	Low	1	393.5	0	0	2	3	1	0.01	19.7
PorousConcrete/Asphalt	C	Yes	Low	1	424.6	0	0	2	3	1	0.01	21.2
InfiltrationTrench	C	Yes	Low	1	177.1	0	0	2	3	1	0.5	8.9
InfiltrationBasin	C	Yes	Low	1	259.3	0	0	2	3	1	0.5	13.0
Bioretention	C	Yes	Med	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter	C	Yes	Med	1	230.5	0	0	2	3	1	0.5	11.5
VegetatedSwale	C	Yes	Med	1	465.4	0	0	2	3	1	0.3	23.3
Bioswale	C	Yes	Med	1	296.3	0	0	2	3	1	0.5	14.8
PermeablePavement	C	Yes	Med	1	257.0	0	0	2	3	1	0.5	12.8
PorousConcrete/Asphalt	C	Yes	Med	1	424.6	0	0	2	3	1	0.01	21.2
InfiltrationTrench	C	Yes	Med	1	177.1	0	0	2	3	1	0.5	8.9

BMPType	SoilType	Underdrain	Infiltration	WIDTH	LENGTH	OHEIGHT	DIAM	EXITYPE	RELEASETYPE	WEIRTYPE	WEIRH	WEIRW
InfiltrationBasin	C	Yes	Med	1	259.3	0	0	2	3	1	0.5	13.0
Bioretention	C	Yes	High	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter	C	Yes	High	1	230.5	0	0	2	3	1	0.5	11.5
VegetatedSwale	C	Yes	High	1	465.4	0	0	2	3	1	0.3	23.3
Bioswale	C	Yes	High	1	296.3	0	0	2	3	1	0.5	14.8
PermeablePaver	C	Yes	High	1	393.5	0	0	2	3	1	0.01	19.7
PorousConcrete/Asphalt	C	Yes	High	1	424.6	0	0	2	3	1	0.01	21.2
InfiltrationTrench	C	Yes	High	1	177.1	0	0	2	3	1	0.5	8.9
InfiltrationBasin	C	Yes	High	1	259.3	0	0	2	3	1	0.5	13.0
VegetatedSwale	D	No	Low	1	625.9	0	0	2	3	1	0.3	31.3
Bioswale	D	No	Low	1	354.1	0	0	2	3	1	0.5	17.7
DryPond	D	No	Low	1	114.3	0	0	2	3	1	3	5.7
DownspoutDisconnection	D	No	Low	1	2420.0	0	0	2	3	1	0.05	121.0
FilterStrip	D	No	Low	1	2792.3	0	0	2	3	1	0.03	139.6
VegetatedSwale	D	No	Med	1	625.9	0	0	2	3	1	0.3	31.3
Bioswale	D	No	Med	1	354.1	0	0	2	3	1	0.5	17.7
DryPond	D	No	Med	1	114.3	0	0	2	3	1	3	5.7
DownspoutDisconnection	D	No	Med	1	2420.0	0	0	2	3	1	0.05	121.0
FilterStrip	D	No	Med	1	2792.3	0	0	2	3	1	0.03	139.6
VegetatedSwale	D	No	High	1	625.9	0	0	2	3	1	0.3	31.3
Bioswale	D	No	High	1	354.1	0	0	2	3	1	0.5	17.7
DryPond	D	No	High	1	114.3	0	0	2	3	1	3	5.7
DownspoutDisconnection	D	No	High	1	2420.0	0	0	2	3	1	0.05	121.0
FilterStrip	D	No	High	1	2792.3	0	0	2	3	1	0.03	139.6
Bioretention	D	Yes	Low	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter	D	Yes	Low	1	230.5	0	0	2	3	1	0.5	11.5
VegetatedSwale	D	Yes	Low	1	465.4	0	0	2	3	1	0.3	23.3
Bioswale	D	Yes	Low	1	296.3	0	0	2	3	1	0.5	14.8
PermeablePaver	D	Yes	Low	1	393.5	0	0	2	3	1	0.01	19.7
PorousConcrete/Asphalt	D	Yes	Low	1	424.6	0	0	2	3	1	0.01	21.2
Bioretention	D	Yes	Med	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter	D	Yes	Med	1	230.5	0	0	2	3	1	0.5	11.5
VegetatedSwale	D	Yes	Med	1	465.4	0	0	2	3	1	0.3	23.3
Bioswale	D	Yes	Med	1	296.3	0	0	2	3	1	0.5	14.8
PermeablePavement	D	Yes	Med	1	257.0	0	0	2	3	1	0.5	12.8
PorousConcrete/Asphalt	D	Yes	Med	1	424.6	0	0	2	3	1	0.01	21.2
Bioretention	D	Yes	High	1	220.0	0	0	2	3	1	0.75	11.0
SandFilter	D	Yes	High	1	230.5	0	0	2	3	1	0.5	11.5
VegetatedSwale	D	Yes	High	1	465.4	0	0	2	3	1	0.3	23.3
Bioswale	D	Yes	High	1	296.3	0	0	2	3	1	0.5	14.8
PermeablePaver	D	Yes	High	1	393.5	0	0	2	3	1	0.01	19.7
PorousConcrete/Asphalt	D	Yes	High	1	424.6	0	0	2	3	1	0.01	21.2

Appendix B: GI Substrate Data

BMPType	SoilType	Underdrain	Infiltration	INFILTM	SDEPTH	POROSITY	FCAPACITY	WPOINT	AVEG	FINFILT	UNDSWITCH	UNDDEPTH	UNDVOID	UNDINFILT
GreenRoof	B/C/D	Yes	0 (lined)	2	0.5	0.35	0.25	0.1	0.6	2	1	0.17	0.4	0
PanterBox	B/C/D	Yes	0 (lined)	2	2.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0
Wetland/Wetpond	B/C/D	Yes	0 (lined)	2	0.1	0.1	0.1	0.1	0.6	0.1	0	0	0	0
Bioretention-lined	B/C/D	Yes	0 (lined)	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0
SandFilter-lined	B/C/D	Yes	0 (lined)	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	0
VegetatedSwale-lined	B/C/D	Yes	0 (lined)	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0
PermeablePaver-lined	B/C/D	Yes	0 (lined)	2	0.25	0.45	0.06	0.02	1	2	1	0.5	0.4	0
PorousConcrete/Asphalt-lined	B/C/D	Yes	0 (lined)	2	0.1	0.45	0.06	0.02	1	2	1	0.5	0.4	0
Bioretention	B	No	Low	2	2	0.35	0.25	0.1	0.6	0.3	0	0	0	0.3
SandFilter	B	No	Low	2	2.5	0.35	0.06	0.02	1	0.3	0	0	0	0.3
VegetatedSwale	B	No	Low	2	0.8	0.35	0.25	0.1	0.6	0.3	0	0	0	0.3
Bioswale	B	No	Low	2	1.5	0.35	0.25	0.1	0.6	0.3	0	0	0	0.3
InfiltrationTrench	B	No	Low	2	3	0.45	0.06	0.02	1	0.3	0	0	0	0.3
PermeablePaver	B	No	Low	2	2.25	0.45	0.06	0.02	1	0.3	0	0	0	0.3
InfiltrationBasin	B	No	Low	2	2	0.35	0.06	0.02	0.4	0.3	0	0	0	0.3
DryPond	B	No	Low	2	0.5	0.35	0.25	0.1	0.3	0.3	0	0	0	0.3
PorousConcrete/Asphalt	B	No	Low	2	2.1	0.45	0.06	0.02	1	0.3	0	0	0	0.3
DownspoutDisconnection	B	No	Low	2	0.5	0.2	0.15	0.08	0.3	0.3	0	0	0	0.3
FilterStrip	B	No	Low	2	0.5	0.2	0.15	0.08	0.4	0.3	0	0	0	0.3
Bioretention	B	No	Med	2	2	0.35	0.25	0.1	0.6	0.8	0	0	0	0.8
SandFilter	B	No	Med	2	2.5	0.35	0.06	0.02	1	0.8	0	0	0	0.8
VegetatedSwale	B	No	Med	2	0.8	0.35	0.25	0.1	0.6	0.8	0	0	0	0.8
Bioswale	B	No	Med	2	1.5	0.35	0.25	0.1	0.6	0.8	0	0	0	0.8
InfiltrationTrench	B	No	Med	2	3	0.45	0.06	0.02	1	0.8	0	0	0	0.8
PermeablePaver	B	No	Med	2	2.25	0.45	0.06	0.02	1	0.8	0	0	0	0.8
InfiltrationBasin	B	No	Med	2	2	0.35	0.06	0.02	0.4	0.8	0	0	0	0.8
DryPond	B	No	Med	2	0.5	0.35	0.25	0.1	0.3	0.8	0	0	0	0.8
PorousConcrete/Asphalt	B	No	Med	2	2.1	0.45	0.06	0.02	1	0.8	0	0	0	0.8
DownspoutDisconnection	B	No	Med	2	0.5	0.2	0.15	0.08	0.3	0.8	0	0	0	0.8
FilterStrip	B	No	Med	2	0.5	0.2	0.15	0.08	0.4	0.8	0	0	0	0.8
Bioretention	B	No	High	2	2	0.35	0.25	0.1	0.6	1	0	0	0	1
SandFilter	B	No	High	2	2.5	0.35	0.06	0.02	1	1	0	0	0	1
VegetatedSwale	B	No	High	2	0.8	0.35	0.25	0.1	0.6	1	0	0	0	1
Bioswale	B	No	High	2	1.5	0.35	0.25	0.1	0.6	1	0	0	0	1
InfiltrationTrench	B	No	High	2	3	0.45	0.06	0.02	1	1	0	0	0	1
PermeablePaver	B	No	High	2	2.25	0.45	0.06	0.02	1	1	0	0	0	1

BMPType	SoilType	Underdrain	Infiltration	INFILTM	SDEPTH	POROSITY	FCAPACITY	WPOINT	AVEG	FINFILT	UNDSWITCH	UNDDEPTH	UNDVOID	UNDINFILT
InfiltrationBasin	B	No	High	2	2	0.35	0.06	0.02	0.4	1	0	0	0	1
DryPond	B	No	High	2	0.5	0.35	0.25	0.1	0.3	1	0	0	0	1
PorousConcrete/Asphalt	B	No	High	2	2.1	0.45	0.06	0.02	1	1	0	0	0	1
DownspoutDisconnection	B	No	High	2	0.5	0.2	0.15	0.08	0.3	1	0	0	0	1
FilterStrip	B	No	High	2	0.5	0.2	0.15	0.08	0.4	1	0	0	0	1
Bioretention	B	Yes	Low	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.3
SandFilter	B	Yes	Low	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	0.3
VegetatedSwale	B	Yes	Low	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.3
Bioswale	B	Yes	Low	2	1.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.3
PermeablePaver	B	Yes	Low	2	0.25	0.45	0.06	0.02	1	2	1	2	0.4	0.3
PorousConcrete/Asphalt	B	Yes	Low	2	0.1	0.45	0.06	0.02	1	2	1	2	0.4	0.3
Bioretention	B	Yes	Med	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.8
SandFilter	B	Yes	Med	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	0.8
VegetatedSwale	B	Yes	Med	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.8
Bioswale	B	Yes	Med	2	1.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.8
PermeablePavement	B	Yes	Med	2	0.25	0.45	0.06	0.02	1	2	1	2	0.4	0.8
PorousConcrete/Asphalt	B	Yes	Med	2	0.1	0.45	0.06	0.02	1	2	1	2	0.4	0.8
Bioretention	B	Yes	High	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	1
SandFilter	B	Yes	High	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	1
VegetatedSwale	B	Yes	High	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	1
Bioswale	B	Yes	High	2	1.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	1
PermeablePaver	B	Yes	High	2	0.25	0.45	0.06	0.02	1	2	1	2	0.4	1
PorousConcrete/Asphalt	B	Yes	High	2	0.1	0.45	0.06	0.02	1	2	1	2	0.4	1
VegetatedSwale	C	No	Low	2	0.8	0.35	0.25	0.1	0.6	0.1	0	0	0	0.1
Bioswale	C	No	Low	2	1.5	0.35	0.25	0.1	0.6	0.1	0	0	0	0.1
DryPond	C	No	Low	2	0.5	0.35	0.25	0.1	0.3	0.1	0	0	0	0.1
DownspoutDisconnection	C	No	Low	2	0.5	0.2	0.15	0.08	0.3	0.1	0	0	0	0.1
FilterStrip	C	No	Low	2	0.5	0.2	0.15	0.08	0.4	0.1	0	0	0	0.1
VegetatedSwale	C	No	Med	2	0.8	0.35	0.25	0.1	0.6	0.2	0	0	0	0.2
Bioswale	C	No	Med	2	1.5	0.35	0.25	0.1	0.6	0.2	0	0	0	0.2
DryPond	C	No	Med	2	0.5	0.35	0.25	0.1	0.3	0.2	0	0	0	0.2
DownspoutDisconnection	C	No	Med	2	0.5	0.2	0.15	0.08	0.3	0.2	0	0	0	0.2
FilterStrip	C	No	Med	2	0.5	0.2	0.15	0.08	0.4	0.2	0	0	0	0.2
VegetatedSwale	C	No	High	2	0.8	0.35	0.25	0.1	0.6	0.25	0	0	0	0.25
Bioswale	C	No	High	2	1.5	0.35	0.25	0.1	0.6	0.25	0	0	0	0.25
DryPond	C	No	High	2	0.5	0.35	0.25	0.1	0.3	0.25	0	0	0	0.25
DownspoutDisconnection	C	No	High	2	0.5	0.2	0.15	0.08	0.3	0.25	0	0	0	0.25
FilterStrip	C	No	High	2	0.5	0.2	0.15	0.08	0.4	0.25	0	0	0	0.25
Bioretention	C	Yes	Low	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.1

BMPType	SoilType	Underdrain	Infiltration	INFILTM	SDEPTH	POROSITY	FCAPACITY	WPOINT	AVEG	FINFILT	UNDSWITCH	UNDDEPTH	UNDVOID	UNDINFILT
SandFilter	C	Yes	Low	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	0.1
VegetatedSwale	C	Yes	Low	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.1
Bioswale	C	Yes	Low	2	1.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.1
PermeablePaver	C	Yes	Low	2	0.25	0.45	0.06	0.02	1	2	1	2	0.4	0.1
PorousConcrete/Asphalt	C	Yes	Low	2	0.1	0.45	0.06	0.02	1	2	1	2	0.4	0.1
InfiltrationTrench	C	Yes	Low	2	3	0.45	0.06	0.02	1	2	1	0.5	0.4	0.1
InfiltrationBasin	C	Yes	Low	2	2	0.35	0.06	0.02	0.4	2	1	0.5	0.4	0.1
Bioretention	C	Yes	Med	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.2
SandFilter	C	Yes	Med	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	0.2
VegetatedSwale	C	Yes	Med	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.2
Bioswale	C	Yes	Med	2	1.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.2
PermeablePavement	C	Yes	Med	2	0.25	0.45	0.06	0.02	1	2	1	2	0.4	0.2
PorousConcrete/Asphalt	C	Yes	Med	2	0.1	0.45	0.06	0.02	1	2	1	2	0.4	0.2
InfiltrationTrench	C	Yes	Med	2	3	0.45	0.06	0.02	1	2	1	0.5	0.4	0.2
InfiltrationBasin	C	Yes	Med	2	2	0.35	0.06	0.02	0.4	2	1	0.5	0.4	0.2
Bioretention	C	Yes	High	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.25
SandFilter	C	Yes	High	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	0.25
VegetatedSwale	C	Yes	High	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.25
Bioswale	C	Yes	High	2	1.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.25
PermeablePaver	C	Yes	High	2	0.25	0.45	0.06	0.02	1	2	1	2	0.4	0.25
PorousConcrete/Asphalt	C	Yes	High	2	0.1	0.45	0.06	0.02	1	2	1	2	0.4	0.25
InfiltrationTrench	C	Yes	High	2	3	0.45	0.06	0.02	1	2	1	0.5	0.4	0.25
InfiltrationBasin	C	Yes	High	2	2	0.35	0.06	0.02	0.4	2	1	0.5	0.4	0.25
VegetatedSwale	D	No	Low	2	0.8	0.35	0.25	0.1	0.6	0.02	0	0	0	0.02
Bioswale	D	No	Low	2	1.5	0.35	0.25	0.1	0.6	0.02	0	0	0	0.02
DryPond	D	No	Low	2	0.5	0.35	0.25	0.1	0.3	0.02	0	0	0	0.02
DownspoutDisconnection	D	No	Low	2	0.5	0.2	0.15	0.08	0.3	0.02	0	0	0	0.02
FilterStrip	D	No	Low	2	0.5	0.2	0.15	0.08	0.4	0.02	0	0	0	0.02
VegetatedSwale	D	No	Med	2	0.8	0.35	0.25	0.1	0.6	0.06	0	0	0	0.06
Bioswale	D	No	Med	2	1.5	0.35	0.25	0.1	0.6	0.06	0	0	0	0.06
DryPond	D	No	Med	2	0.5	0.35	0.25	0.1	0.3	0.06	0	0	0	0.06
DownspoutDisconnection	D	No	Med	2	0.5	0.2	0.15	0.08	0.3	0.06	0	0	0	0.06
FilterStrip	D	No	Med	2	0.5	0.2	0.15	0.08	0.4	0.06	0	0	0	0.06
VegetatedSwale	D	No	High	2	0.8	0.35	0.25	0.1	0.6	0.1	0	0	0	0.1
Bioswale	D	No	High	2	1.5	0.35	0.25	0.1	0.6	0.1	0	0	0	0.1
DryPond	D	No	High	2	0.5	0.35	0.25	0.1	0.3	0.1	0	0	0	0.1
DownspoutDisconnection	D	No	High	2	0.5	0.2	0.15	0.08	0.3	0.1	0	0	0	0.1
FilterStrip	D	No	High	2	0.5	0.2	0.15	0.08	0.4	0.1	0	0	0	0.1
Bioretention	D	Yes	Low	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.02

BMPType	SoilType	Underdrain	Infiltration	INFILTM	SDEPTH	POROSITY	FCAPACITY	WPOINT	AVEG	FINFILT	UNDSWITCH	UNDDEPTH	UNDVOID	UNDINFILT
SandFilter	D	Yes	Low	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	0.02
VegetatedSwale	D	Yes	Low	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.02
Bioswale	D	Yes	Low	2	1.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.02
PermeablePaver	D	Yes	Low	2	0.25	0.45	0.06	0.02	1	2	1	2	0.4	0.02
PorousConcrete/Asphalt	D	Yes	Low	2	0.1	0.45	0.06	0.02	1	2	1	2	0.4	0.02
Bioretention	D	Yes	Med	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.06
SandFilter	D	Yes	Med	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	0.06
VegetatedSwale	D	Yes	Med	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.06
Bioswale	D	Yes	Med	2	1.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.06
PermeablePavement	D	Yes	Med	2	0.25	0.45	0.06	0.02	1	2	1	2	0.4	0.06
PorousConcrete/Asphalt	D	Yes	Med	2	0.1	0.45	0.06	0.02	1	2	1	2	0.4	0.06
Bioretention	D	Yes	High	2	2	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.1
SandFilter	D	Yes	High	2	2.5	0.35	0.06	0.02	1	2	1	0.5	0.4	0.1
VegetatedSwale	D	Yes	High	2	0.8	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.1
Bioswale	D	Yes	High	2	1.5	0.35	0.25	0.1	0.6	2	1	0.5	0.4	0.1
PermeablePaver	D	Yes	High	2	0.25	0.45	0.06	0.02	1	2	1	2	0.4	0.1
PorousConcrete/Asphalt	D	Yes	High	2	0.1	0.45	0.06	0.02	1	2	1	2	0.4	0.1

Appendix C: GI Cost Data

Description	Drainage Area Cost ($/sq ft)	Annual O&M ($/sq ft)	New Construction ($/sq ft)	New Construction (underdrain) ($/sq ft)	Lifespan (years)
Bioretention		1.6	20.5	26.2	20
Bioretention (Lined)		1.6	43.75	43.75	20
Bioswale		1.59	20.5	26.2	20
Dry Pond		0.08	3.8		20
Filter Strip/Grass Buffer		1	0.75		20
Vegetated Filter Strip/Grass Buffer		1	0.75		20
Green Roof		0.44	28.1	28.1	20
Infiltration Basin/Dry Pond		0.64	20.5	26.2	20
Infiltration Trench/Basin		0.64	16	21.7	20
Permeable Pavement		0.41	8.8	12.95	20
Permeable Interlocking Paver		0.41	8.8		20
Permeable Interlocking Paver (Lined)		0.41	14.5	14.5	20
Planter Box		1.6	42.6	42.6	20
Porous Asphalt		0.41	6.8	10.95	20
Porous Asphalt (Lined)		0.41		12.5	20
Porous Concrete		0.41	9.25	0.41	20
Porous Concrete (Lined)		0.41		16.5	20

Description	Drainage Area Cost ($/sq ft)	Annual O&M ($/sq ft)	New Constructio n ($/sq ft)	New Construction (underdrain) ($/sq ft)	Lifespa n (years)
Rain Barrels	0.3				20
Sand Filter		0.64	12.8	18.5	20
Sand Filter (Lined)		0.64		34.9	20
Vegetated Swale		1	2.41	8.11	20
Vegetated Swale (Lined)		1		9.66	20
Wetlands		0.09	2.3		20
Wet Pond		0.26	6.6		20
Filter Strip with Level Spreaders	4.7	1			20
Dry Wells		1.34	26.1		20
Disconnected Downspouts	0.3				20