CLASIC

CASE STUDY

Community Life-Cycle Analysis for Stormwater Infrastructure Costs

Philadelphia

Pennsylvania

CLASIC Case Studies showcase the variety of ways that the online tool can assist communities with stormwater project planning and decision-making.

CASE STUDY HIGHLIGHTS

- Demonstration of using the CLASIC and GSI TBL Tool together for benefits and costs
- Benefit information for tradeoff analysis, planning, and decision support for increased green space

Background and Project Purpose

The Philadelphia Water Department (PWD)[1] developed the Green City, Clean Waters (GCCW) program to meet the City of Philadelphia's Clean Water Act obligations to reduce combined sewer overflows. The program will reduce the volume of stormwater entering local waterways by about 8 billion gallons per year by 2036. The GCCW program implements green stormwater infrastructure (GSI) to manage stormwater runoff from about 35% of the impervious surfaces in the combined sewer system (approximately 10,000 acres). PWD has developed a detailed process to identify opportunities are analyzed throughout the combined sewer area in public right-of-ways, city-owned property, and non-city property where there is an interest in stormwater management. Figure 1 shows the city divided by "districts" within the combined sewer area (CSO area) where the runoff reduction is most critical.

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[1] The case study highlights using the CLASIC and GSI TBL Tool to observe benefit and cost information of simulated scenarios and to see the benefit value of increasing the vegetation in a stormwater practice. While the case study area is within Philadelphia, the results are hypothetical to the Philadelphia Water Department due to the need to adjust stormwater management practice design and costs to fit their data.

BENEFITS

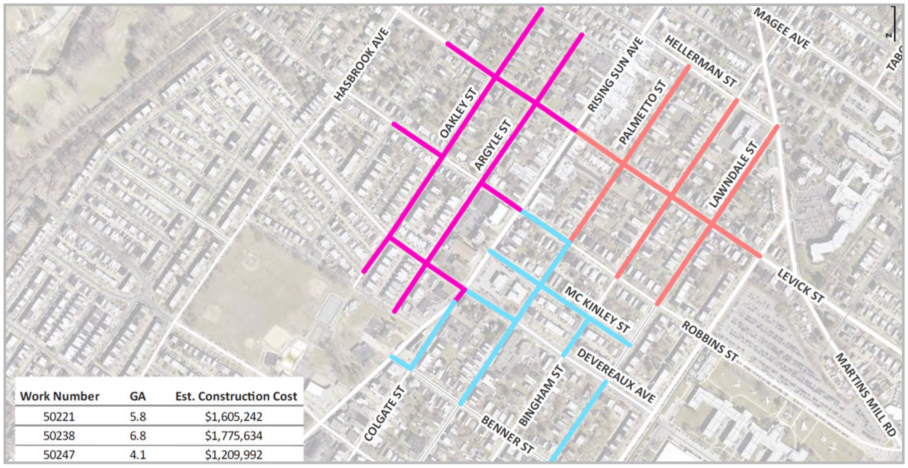
Evaluating a greening spectrum

The Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC) and the Green Stormwater Infrastructure Triple Bottom Line (GSI TBL) tools offer a way to observe the impact of increased greening options as reflected in benefits[2] of the particular stormwater practices. The output from CLASIC displays benefits of different GSI that can be used to communicate with partners interested in similar projects and help with project tradeoffs and prioritization. The output from the GSI TBL tool can help understand the cost and benefit of implementing “greener” vs “grayer” approaches. Many cities ask how to qualify and quantify the returns on investment in using successively green practices. How can CLASIC help support using, or not using, the greener practices when runoff reduction is the primary goal of the GSI?

Figure 1. There are four PWD Planning Districts that align with Philadelphia City Planning Commission (PCPC) Districts. These areas are assigned to specific planners and allow strategic alignment with the planning commission to maximize area and stormwater runoff reduction.

Figure 2 shows the study area for this case study. This area was selected to observe the differences in benefits for 30 infiltration, detention, and slow release practices. The stormwater infrastructure typically used in Philadelphia is reduce runoff.

Lawncrest Green Projects



Work Number	GA	Est. Construction Cost
50221	5.8	$1,605,242
50238	6.8	$1,775,634
50247	4.1	$1,209,992

Figure 2 Study area in Philadelphia were projects are planned to reduce runoff.

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[2] Humans experience benefits that flow from services provided by nature. These benefits are termed “co-benefits” when there is a specific targeted benefit that can be considered the “primary” benefit. For stormwater projects the primary benefit can be attributed to the improved water quality from installing projects that treat runoff or pollution. All other benefits would be co-benefits. For simplicity, the term co-benefit is not used here in but all are reported as benefits.vegetation in a stormwater practice. While the case study area is within Philadelphia, the results are hypothetical to the Philadelphia Water Department due to the need to adjust stormwater management practice design and costs to fit their data.

KEY INPUTS

The study area was delineated in the CLASIC tool using the polygon feature. The case study used default values from national databases from the NLCD (2016), SSURGO, climate data, precipitation and evaporation, from EPA BASINS model. CLASIC includes default values for water quality based on land use. Other defaults for are described in the guidance document. The area in Figure 2 is 97 acres with 63% impervious surface. The study area was broken into census blocks to enable selecting blocks for different GSI options (see Figure 3).

GSI SCENARIOS

The stormwater management alternatives for the study area are based on the types of practices used in Philadelphia. The types of practices include tree trenches and infiltration/storage trenches and bioretention. CLASIC technologies such as infiltration trenches and raingardens have design characteristics that closely resemble designs used in Philadelphia. The CLASIC scenarios model runoff capture between 91,300 and 92,000 cubic feet per year. Typical stormwater designs in Philadelphia capture a 1.5-inch storm (on average) and the CLASIC scenarios "depth to capture" was also set to 1.5 inches.

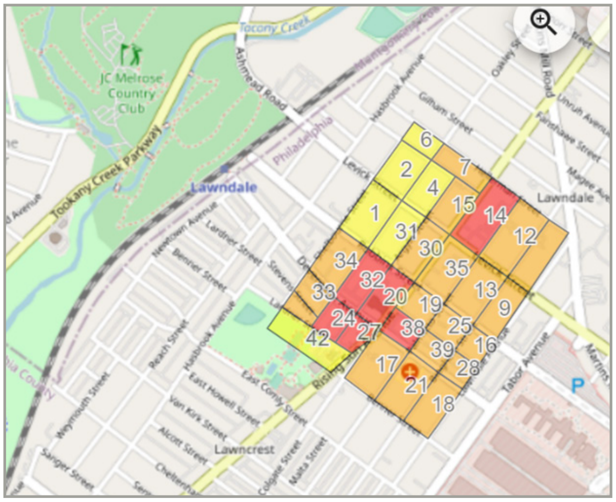


Figure 3 Study area in CLASIC with census blocks delineated.

- The **Baseline Scenario** does not include any technologies and is the case were runoff is not treated. The Baseline is the scenario to which the subsequent scenarios are compared.

- **Scenario 1** - Includes large, deep infiltration trenches (23) that capture approximately 92,000 cubic feet per year. No vegetation is added to the infiltration trenches and this is considered the "gray" scenario.

- **Scenario 2** - A mix of large, deep infiltration trenches (8) and medium raingardens (22). The raingarden vegetation selected is grass – representing a minimally "greener" approach. This scenario captures 91,400 cubic feet of runoff per year.

- **Scenario 3** – A "greener" mix of large, deep infiltration trenches (9), raingardens (10) and bioretention (6). The vegetation is for the raingardens and bioretention is "diverse" with flowering species and two trees. This scenario captures 91,300 cubic feet of runoff per year and is the "greenest" scenario which should provide the greatest co-benefits.

PERFORMANCE

Hydrology and Water Quality

CLASIC hydrologic performance summaries are below for the three scenarios. The percent change in runoff compared to baseline is approximately 6% for Scenario 1, 12% for Scenario 2 and 13% for Scenario 3. The increase in infiltration for the Scenarios is 9.5%, 17.5% and 19.2% (respectively). The hydrologic performance is greater in Scenarios 2 and 3 due to the mix of infiltration trenches and raingardens in Scenario 2 and raingardens and bioretention in 3 as well as the increased number of practices needed to manage the target cubic foot of volume captured (92,000 cubic feet).

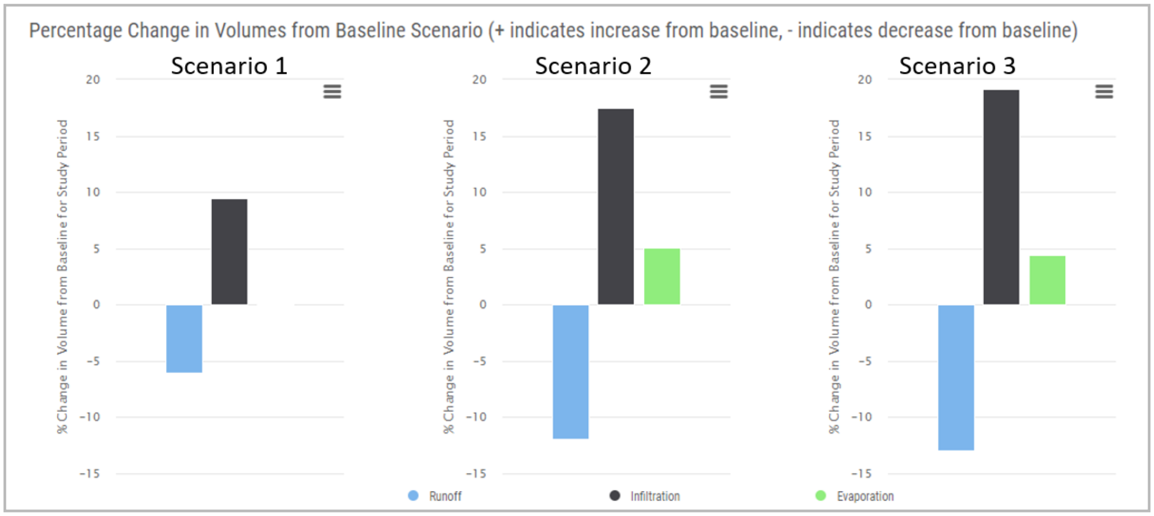


Figure 4 Runoff, infiltration, and evaporation changes from baseline for Scenarios 1, 2, and 3.

CLASIC output below shows modeled water quality changes in total suspended solids (TSS) from baseline are approximated at 12.8%, 15.7% and 15.6% for TSS. TN, TP and FIB (not shown) also decrease with Scenarios 2 and 3 reducing the most of these pollutants.

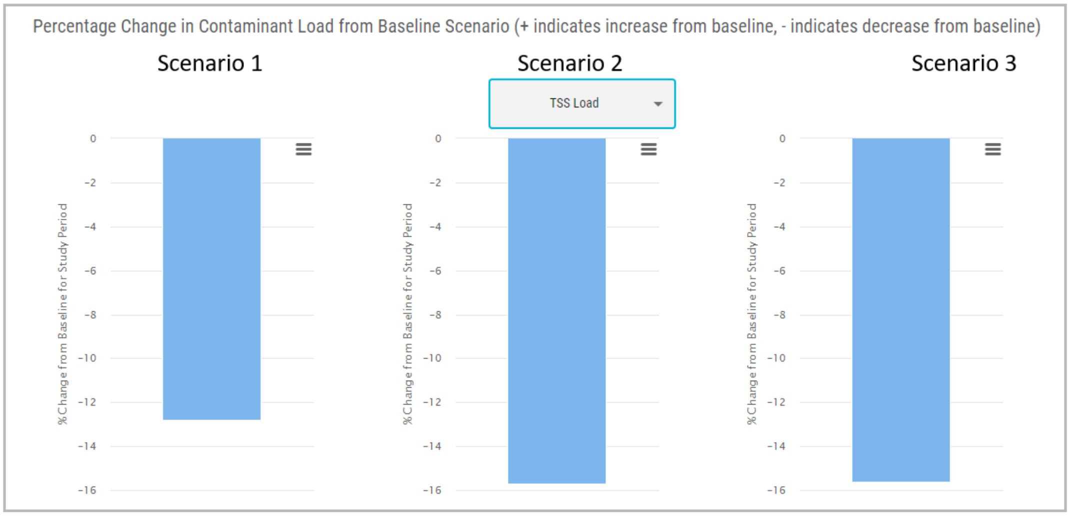


Figure 5 Total suspended solid load changes (%) from baseline for Scenarios 1, 2 and 3.

COSTS

CLASIC generates a cost for construction, maintenance, and major rehabilitation based on the study period. The study period of 35 years accounts for at least one rehabilitation period for each stormwater practice. The scenarios did not include a sensitivity analysis for discount rates. However, CLASIC does allow user-selected rates from 0% to 5%. Because CLASIC costs do not consider cost flux that occurs with labor or other potential escalation, a 0% discount rate assumes discount rate is the same as the rate of increase in different construction and maintenance costs.

Table 1 shows the construction, annual maintenance, and rehabilitation costs for each alternative. Figure 6 provides a snapshot of costs depicted in CLASIC Summary Tab. The average annual costs are the total costs (undiscounted) divided by the study period (35 years). The dollars per gallon shown is the total cost divided by number of gallons treated – for Scenario 1, 92,000 cubic feet (or 688,207 gallons); Scenario 2, 91,400 cubic feet (or 683,719 gallons) and Scenario 3, 91,300 cubic feet (or 682,971 gallons).

Table 1 Scenario 1, 2, and 3 cost categories and present value calculations

	Scenarios Present Value in $		
Cost category	**1**	**2**	**3**
Construction	$899,185	$1,680,932	$1,991,157
Maintenance	$954,822	$1,076,644	$1,603,270
Rehabilitation	$887,869	$709,312	$1,139,893
Total (35 yr, 0% discount)	$2,741,876	$3,466,888	$4,734,320
Annual Average	$78,339	$99,054	$135,266
Dollars per gallon (total cost divided by gallons of runoff captured)	$3.98	$5.07	$6.93

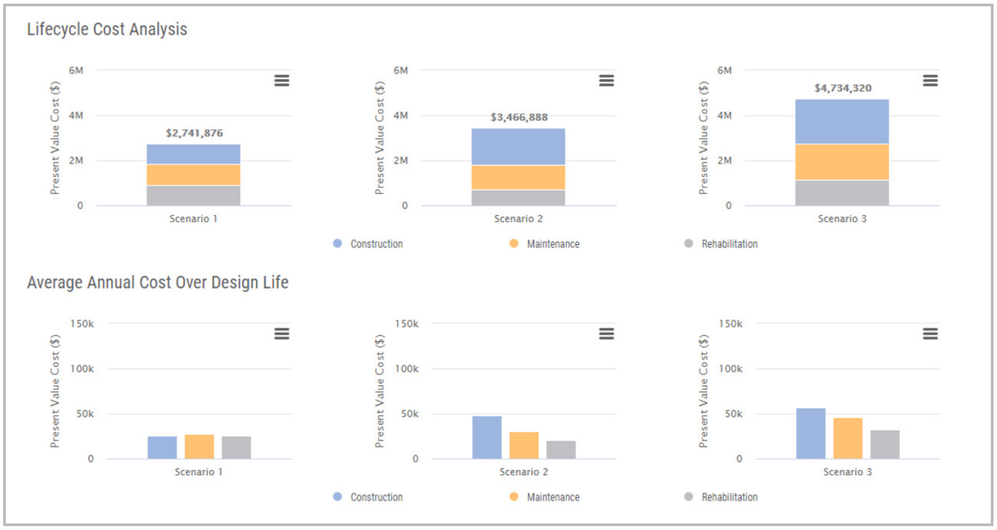


Figure 6 CLASIC Lifecycle cost output in present value (35 years, 0% discount rate) for construction, maintenance, and rehabilitation for Scenarios 1, 2, and 3.

BENEFITS

Benefit Indicator Importance

CLASIC provides a relative benefit scenario analysis where the user sets levels of importance for economic, social, and environmental categories associated with stormwater practice benefits for a community. The user selects levels of importance:

1 = Not Important

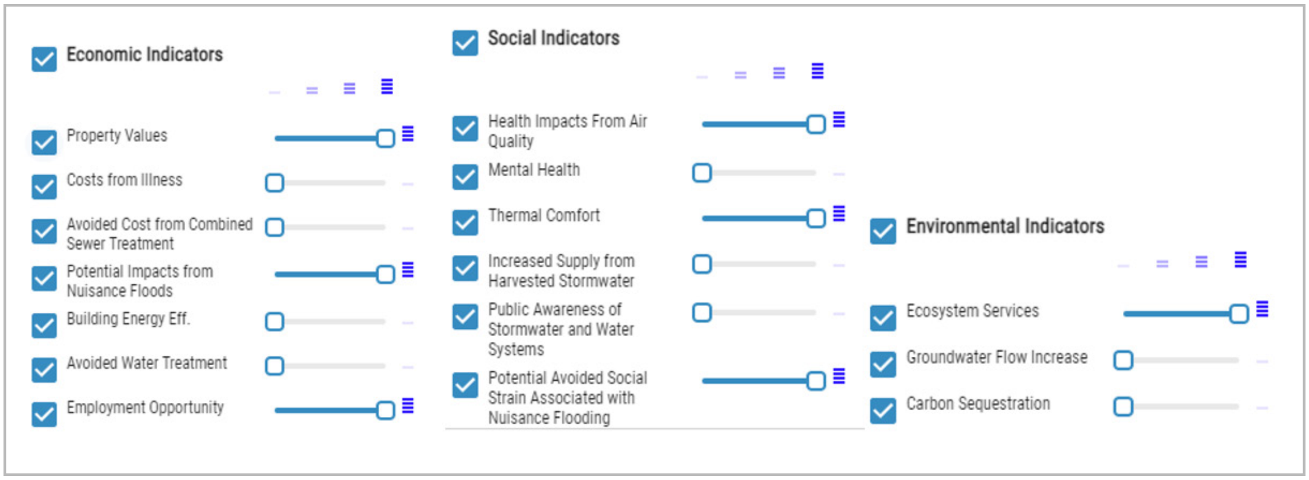
2 = Somewhat Important

3 = Medium Importance

4 = Very Important

The benefit scores connect with performance output (runoff reduced, pollution reduced), area of greenspace added, and are scaled with the user's importance level. The importance levels for the economic indicators (shown below) are to compare the benefits of the scenarios to property values, potential impacts from pluvial (nuisance) flooding, and employment opportunity. The social indicators selected are for health impacts for air quality, thermal comfort, and avoided social strain with pluvial (nuisance) flooding[3] . Environmental indicator benefits selected for importance were ecosystem services. The ecosystem services score is dependent on the green space size and adding diversity of vegetation (flowering vegetation) and trees.[4] These are benefits within the GSI TBL Tool, described below in the next section.

Benefits increase if the technology placement is within impervious areas. For Scenarios 1, 2, and 3 the technology placement is within pervious areas due to land use cover constraints in the study area.



☑ Economic Indicators
- ☑ Property Values
- ☑ Costs from Illness
- ☑ Avoided Cost from Combined Sewer Treatment
- ☑ Potential Impacts from Nuisance Floods
- ☑ Building Energy Eff.
- ☑ Avoided Water Treatment
- ☑ Employment Opportunity

☑ Social Indicators
- ☑ Health Impacts From Air Quality
- ☑ Mental Health
- ☑ Thermal Comfort
- ☑ Increased Supply from Harvested Stormwater
- ☑ Public Awareness of Stormwater and Water Systems
- ☑ Potential Avoided Social Strain Associated with Nuisance Flooding

☑ Environmental Indicators
- ☑ Ecosystem Services
- ☑ Groundwater Flow Increase
- ☑ Carbon Sequestration

Figure 7 CLASIC benefit indicator importance selection for Scenarios 1, 2, and 3.

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[3] Monetary values were not calculated therefore, double-counting was not considered.

[4] Literature support and methods for relative benefit scoring is within the CLASIC guidance document.

The CLASIC output below displays the dial and column graph to observe scores for the economic, social and, environmental scores for the three scenarios. Scenario 1 has the lowest benefit score, Scenario 2 has a moderate score, and Scenario 3 has the highest score. The type and greener nature of the stormwater practices throughout the study area accounts for the benefit score being higher for Scenarios 2 and 3.

Scenario 1 Benefit Summary

The infiltration trenches do not offer green space, therefore the benefits are lower than the other two scenarios. There are no environmental benefits for Scenario 1 as measured by increased green space that provides habitat (biodiversity) and pollination services. The potential to reduce nuisance (pluvial) floods is the primary social benefit and the score of 0.77 reflects avoided social strain that may be reduced by runoff reduction. The economic score (1.56) includes reduced costs associated with nuisance (pluvial) flood reduction and improved job creation, which is linked with estimated maintenance hours. The "total" co-benefits score for Scenario 1 is shown in the bar graph (2.33).

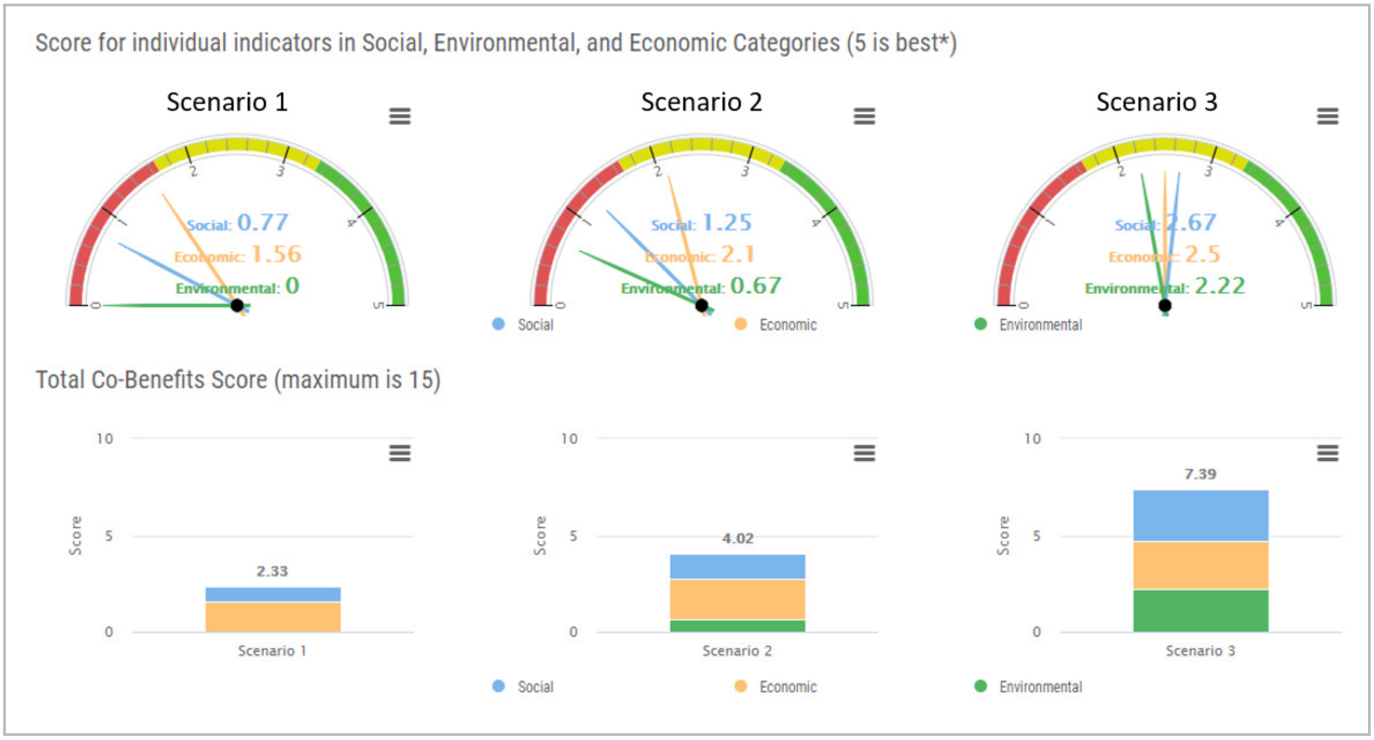


Figure 8 Output display for benefits for Scenarios 1, 2, and 3.

Scenario 2 Benefit Summary

The benefits of a mixture of infiltration trenches and raingardens with grass provide higher scores for all three categories social, economic, and environmental. With the addition of grassed raingardens, (largely a vegetated depression that filters runoff through 36" of media) the environmental category score for ecosystem services is 0.67. This reflects the vegetated space of the raingardens providing potential habitat compared to the baseline. The social and economic categories account for the reduction of nuisance (pluvial) flooding and increased job creation. The total score is 4.02 for Scenario 2.

Scenario 3 Benefit Summary

Scenario 3 has the highest score compared to Scenario 1 and 2. This Scenario reflects more diverse and flowering vegetation and trees in each raingardens and bioretention. The score of 2.2 for environmental category reflects that the flowering vegetation and trees support pollinators and biodiversity. The economic category score is 2.5 which reflects increased job creation with increased hours estimated for maintaining the trenches, bioretention, and raingardens. Stormwater practices with trees and diverse vegetation require more hours of labor than the other two scenarios. The highest score is for the social benefit (2.67) and includes air quality benefits of the trees. The two other scenarios do not have air quality benefits. The total score of 7.39 is the highest score compared to Scenario 1 and 2.

CLASIC output also provides the individual scores for benefits generated as shown below. Figure 9 shows the social categories selected for scoring. The avoided social strain for nuisance flooding is observed as an individual benefit for all three Scenarios. Scenario 3 is the only scenario with the added benefits the health benefit from improved air quality. Thermal comfort is selected but there are no anticipated benefits from the Scenarios because impervious cover removal for green space would result in the thermal comfort co-benefit.

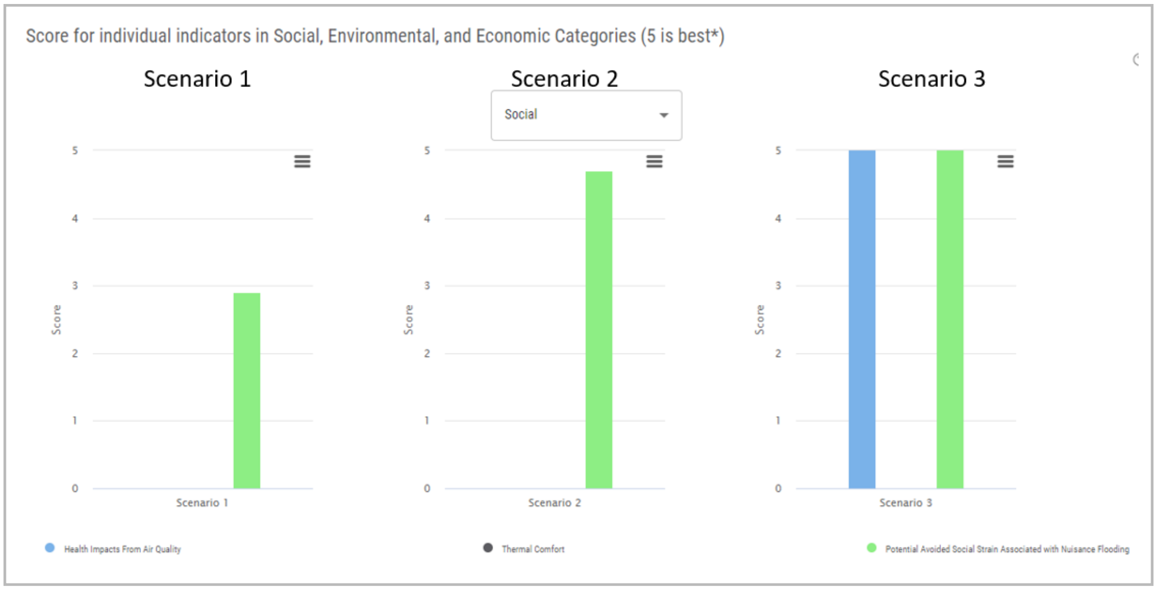


Figure 9 Social category scores for individual benefits selected.

CLASIC also displays individual categories for economic and environmental benefits. The economic benefits are shown in Figure 10 below. Scenario 2 and Scenario 3 are similar in individual score for reductions of pluvial (nuisance) flooding benefits. The inclusion of the reduced nuisance (pluvial) flooding for social and economic benefits relates to research showing that flooding has economic (direct) damage costs as well as human costs (social strain, emotional strain). The employment opportunities are highest for Scenario 3 compared to Scenarios 1 and 2. Although property values were selected as a benefit – similar to thermal impacts – the benefits of property value increase accrue when impervious cover is removed and replaced with green space.

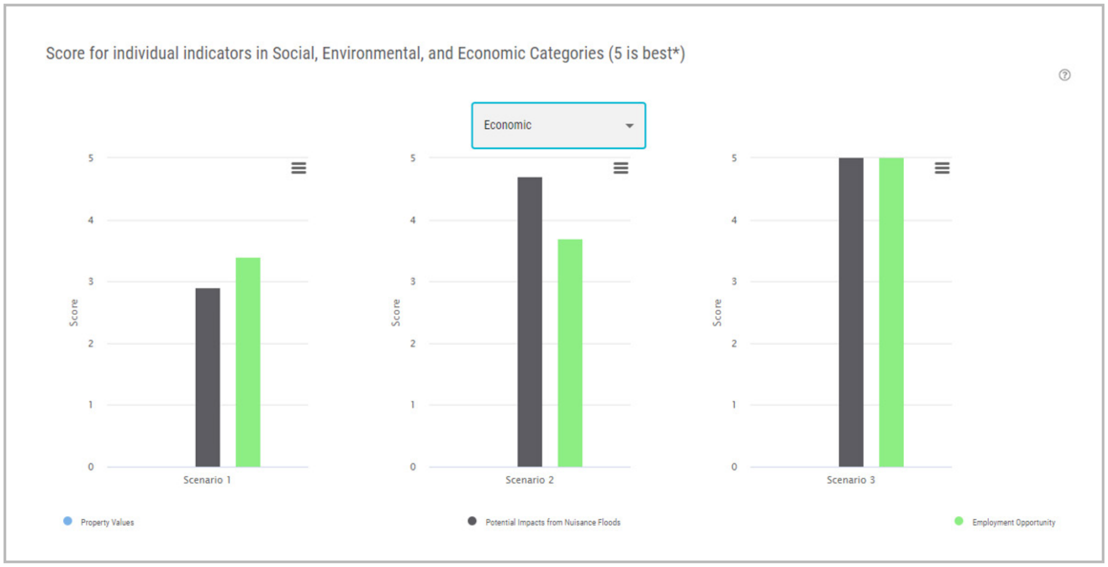


Figure 10 Economic category scores for individual benefits selected.

Finally, the environmental individual benefit as related to ecosystem services is highest for Scenario 3. Figure 11 shows that Scenario 2 has minor ecosystem service score and Scenario 1 does not have any benefit score because the ecosystem service score is related to diversity of vegetation and trees within the raingardens and bioswales.

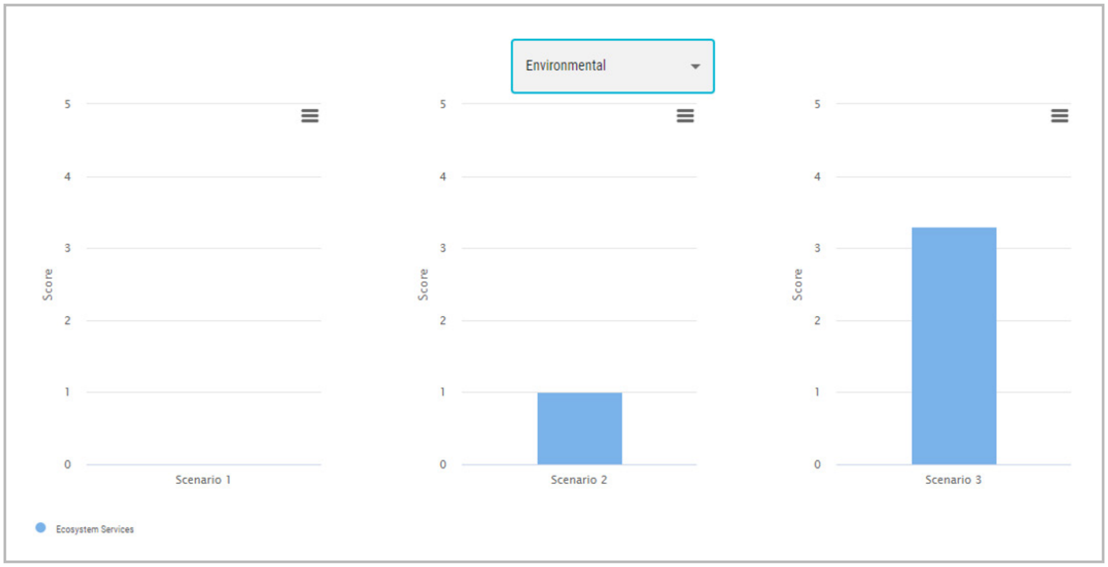
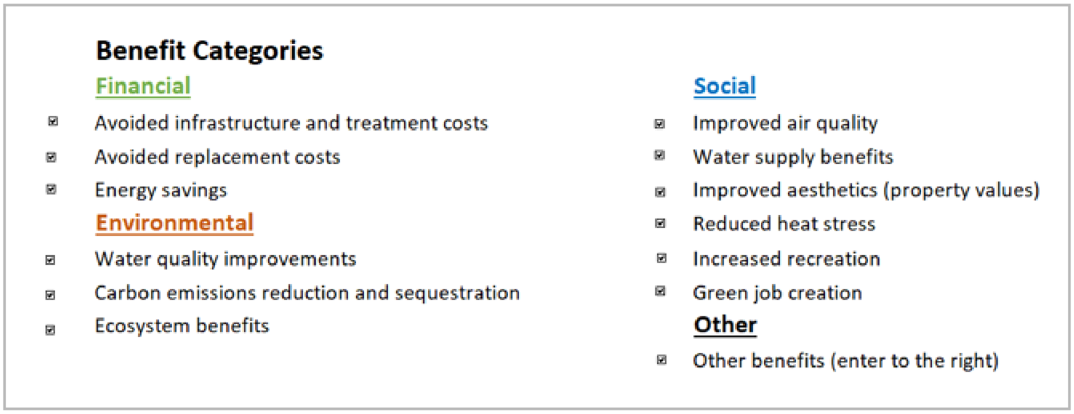


Figure 11 Environmental category scores for individual benefits selected.

FRAMEWORK AND TOOL FOR QUANTIFYING THE TRIPLE BOTTOM LINE BENEFITS OF GREEN STORMWATER INFRASTRUCTURE (GSI TBL TOOL)

Using the GSI TBL Tool helps understand the monetary values associated with selected benefits for each scenario. The two tools were developed to help the user obtain information on tradeoffs for evaluating multiple options and outcomes that green stormwater infrastructure may provide to a community.

The suite of benefit categories that can be assessed using the GSI TBL Tool are:



Benefit Categories

Financial

☑ Avoided infrastructure and treatment costs
☑ Avoided replacement costs
☑ Energy savings

Environmental

☑ Water quality improvements
☑ Carbon emissions reduction and sequestration
☑ Ecosystem benefits

Social

☑ Improved air quality
☑ Water supply benefits
☑ Improved aesthetics (property values)
☑ Reduced heat stress
☑ Increased recreation
☑ Green job creation

Other

☑ Other benefits (enter to the right)

To supplement the outcomes for the scenarios described in this case study, the GSI TBL Tool is used to obtain monetary value for a subset of benefits and estimated benefit-cost ratios for components of the scenarios. For this the case study, different discount rates are not used.[5]

The way the GSI TBL tool is employed for this part of the case study was to demonstrate “marginal” or incremental tradeoffs of using different three green scenarios similar to the CLASIC scenarios: no vegetation, some vegetation, and more vegetation. Then a fourth scenario is run to determine returns to scale by observing estimates for benefit cost ratios. The assumptions for Scenario 4 are described in a section GSI TBL Scenario 4 – Economies of scale and increasing benefits.

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[5] Discounting. Costs and benefits are sensitive to discounting when: 1) the timing of the effects vary (costs and benefits occur at different time periods); and 2) the value of costs or benefits change overtime. With stormwater infrastructure investments the costs may be incurred at intervals over time, may vary, or increase. In this case study, the costs of construction are substantial and occur in the early years, while the benefits increase as time goes on (i.e. trees provide more value overtime). The sensitivity to discounting (increasing the rate) in this case of substantial upfront costs that decrease overtime and benefits that increase over time will decrease benefits and increase costs in the present value. (US EPA. (2010). Guidelines for Preparing Economic Analyses. Discounting Future Benefits and Costs. (Accessed at https://www.epa.gov/sites/production/files/2017-09/documents/ee-0568-06.pdf)

For the first three scenarios, the inputs used in the GSI TBL tool constrained the benefit and cost estimates for one street in one block the study area – or an estimated 10 single family homes, with a management area of 24 acres, a management population of 200 and a median home value of $177,300 (Census Bureau).[678] The simulation for Scenario 1 included one infiltration trench, Scenario 2 included one raingarden and one infiltration trench, Scenario 3 one raingarden, one infiltration trench, and bioretention and two trees. The design dimensions inputs were similar to those in CLASIC. The default costs in the GSI TBL Tool were used for capital and operations. The GSI TBL Tool does not estimate retrofit costs, therefore CLASIC retrofit costs were used.[9] These simulations help understand marginal (incremental) changes of using successively greener infrastructure by extracting benefits and costs of the scenario combinations. Figure 12 summarizes the present values of the three benefit categories for the three Scenarios.

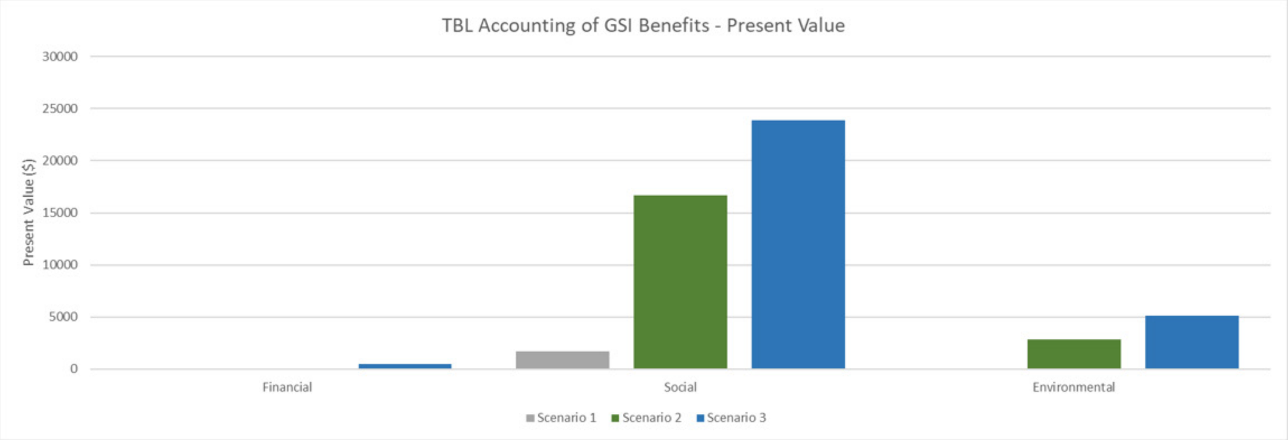

Figure 12 Summary of the benefit categories for GSI TBL Scenario 1, 2, and 3.

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[6] The management area of 24 acres was selected as the area where the stormwater infrastructure scenarios would be observed by the community block. From the GSI TBL Tool Guidance "It does not need to consist only of the GSI drainage area; for example, it may consist of a watershed or neighborhood where multiple GSI installations will manage some portion of impervious area."

[7] The management area population estimation of 200 is very conservative using the GSI TBL Tool Guidance which suggests using a population density of the area. Using population density for 24 acres estimates 455 people per square mile (11,379 people per square mile from https://censusreporter.org/profiles/86000US19111-19111/)

[8] Data obtained from census Reporter for zip code 19111 accessed at https://censusreporter.org/profiles/86000US19111-19111/

[9] PWD has cost data for the practices, however, these costs were not input into CLASIC but can be in the future to provide better accuracy of benefit and cost analyses.

Financial Benefit Category Summary

Financial benefits relate to the actual cost savings or avoided costs associated with the green practice. The financial benefits estimated in the GSI TBL tool for this case study only included the energy savings benefit. In this case study, avoided infrastructure, treatment costs and replacement costs did not apply. (For more information on how these benefits are estimated please see the GSI TBL Guide). For the characteristics of this case study, the benefits were estimated for trees added. The energy savings benefit only accrues if trees are added. Therefore, only Scenario 3 shows financial benefits. For Scenario 3 it is anticipated that the green space associated with trees and green infrastructure would have energy savings overtime, and that those benefits increase overtime as the trees mature.

Social Benefit Category Summary

The social benefits estimated for this case study include improved air quality, heat stress, property values, and increased job creation.[10] The social benefits did not include water supply and recreation. The recreation and water supply may be included if the placement of the practices are more closely tied to recreation or water supply impacts. For example, placement of pocket parks, stormwater parks or substantial increase in vegetation and canopy provide recreational use values that can be estimated in the GSI TBL tool. Water supply benefit estimation in the tool is estimated if there are harvesting systems that reduce potable water demand or practices that increase infiltration. Water supply impact by infiltration requires data on the quantity of recharge expected based on location of practices in areas that are hydrologically connected to aquifers or water supply. Therefore this case study can be thought to provide a lower bound of potential benefit values.

Air quality is improved by green infrastructure through reduced greenhouse gas emissions due to energy reduction (cooling) or direct pollutant removal from the air. Heat stress is estimated based on days where temperatures cause an increase in hospital visits. The more acres, and greener the practice, equate to higher associated health benefits.

Property values are estimated from a percentage of increased residential property values from green space added. For this case study, only single family residential properties were valued to reflect the study area. To value the commercial benefits, more detailed information is needed and commercial properties are not within the small study area.

Job benefits are estimated using the total value of construction jobs and the annual value of maintenance jobs using representative wage approach. The assumptions included market wages between $17 - $20 and employment of 20-30% of underemployed or unemployed workers.

Environmental Benefit Category Summary

Environmental benefit estimation includes carbon, water quality, and ecosystem benefit through habitat creation. For this case study only the carbon and ecosystem were estimated. Water quality benefits, as estimated by the tool, would necessitate additional data to estimate appropriate assumptions regarding willingness to pay, expected water quality improvement and number of residents impacted. Carbon sequestration and value of avoided greenhouse gas emissions from reduced energy use are estimated based on number and size of trees and area of vegetation added to the study area. Terrestrial ecosystem and biodiversity benefits are associated with habitat area added and monetary estimates of willingness to pay for certain ecosystem services. The estimates

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[10] Reservation Wage Approach was used as opposed to the avoided social cost approach. Avoided social cost has a lower benefit value. For information on how these benefits are calculated please see the GSI TBL Tool guide.

for biodiversity is a growing field and specific estimates are unavailable for a national scale tool. For this tool, literature values and a relative qualitative ranking of benefits provide an estimated value of biodiversity and ecosystem benefits.

Summary of Individual GSI TBL Scenarios 1 -3 Benefits

GSI TBL Scenarios 1 -3 demonstrate successively greener stormwater technologies and the benefits associated with using greener approaches. The simulation for GSI TBL Scenario 1 included one infiltration trench, GSI TBL Scenario 2 included one raingarden and one infiltration trench, GSI TBL Scenario 3 one raingarden, one infiltration trench, and one tree. Table 2 shows the benefits and costs and how the estimated totals of benefits and costs provide a benefit-cost ratio.[11] The study period is 35 year and the discount rate is set to zero.

Table 2 Summary of the benefit categories, estimated costs and benefit-cost ratio for GSI TBL Scenarios 1, 2, and 3.

	GSI TBL Scenario 1	GSI TBL Scenario 2	GSI TBL Scenario 3
Financial	-	-	$492
Social	$1,707	$16,680	$23,890
Environmental	-	$2,861	$5,108
Total Estimated cost	$119,823	$196,563	$99,679
Benefit-cost ratio	0.01	0.1	0.15

GSI TBL Scenario 1

The financial and environmental values are zero because one infiltration trench is not anticipated to impact benefit categories other than jobs creation in the social benefit category.

GSI TBL Scenario 2 (Figure 13)

The addition of a rain garden to an infiltration trench adds to job benefits. With a raingarden, ecosystem benefits in the environmental benefits category and property value increase as well as air quality benefits are added in the social benefits category.

GSI TBL Scenario 3 (Figure 14)

With the addition of a tree to the raingarden and infiltration trench increased benefits include a financial benefit for energy savings. The social benefit category has higher values for property values and air quality, as well as the added benefit of carbon to ecosystem benefits in the environmental benefit category.

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[11] Benefit cost ratios are used in planning and project selection. The benefits should, in general, outweigh the costs of a project (i.e. the ratio should be at least 1.0). The simulations for this case study include very conservative assumptions and more data is necessary to provide adequate assumptions and estimates for all benefits.

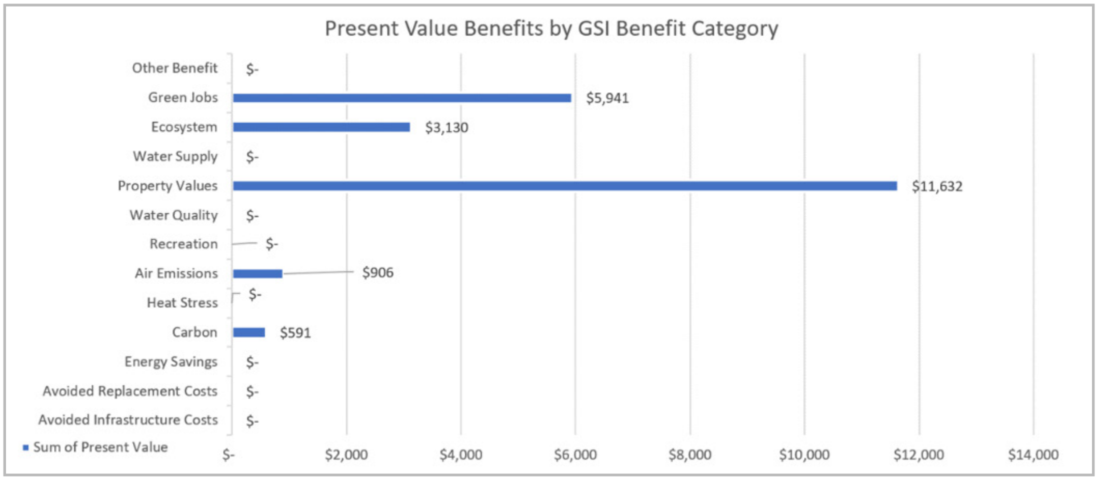

Figure 13 GSI TBL Scenario 2 present value of benefits for one infiltration trench and one raingarden.

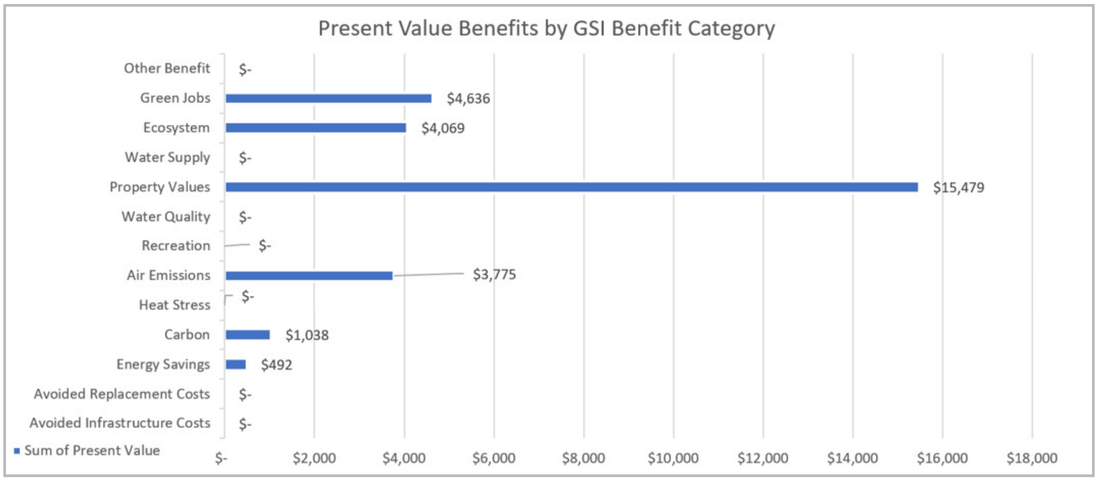

Figure 14 GSI TBL Scenario 3 present value of benefits for one infiltration trench, one raingarden and one tree.

GSI TBL Scenario 4 – Economies of scale and increasing benefits

GSI TBL Scenarios 1, 2, and 3 estimated the incremental monetary benefits of increasing green-space. While the results are modest and do not support (via benefit-cost) the installation of single practices, in reality, practices installed in Philadelphia involve multiple stormwater practices in planning areas (e.g. 30 in the case study area). GSI TBL Scenario 4 includes six raingardens, 18 infiltration trenches and 15 trees. This scenario is similar to Scenario 3 for the CLASIC tool and captures approximately 92,300 cubic feet of water. This scenario, when compared with the other GSI TBL tool outputs demonstrate the economy and return to scale of benefits for increasing green-space and stormwater infrastructure. That is, using a few green practices may not necessarily be cost effective or have benefits that exceed costs. But using many practices together increases aggregate benefits which over time may exceed costs.

Figure 15 shows the total present value of the 24 practices and 15 trees. Property value increase is the largest benefit, however there is no heat stress benefit. Heat stress will be further discussed below. Other benefits such as water supply, water quality, recreation, and avoided replacement and infrastructure costs were not anticipated to accrue due to the placement of the stormwater practices in areas that would not impact these benefits. Figure 16 shows the present value of undiscounted benefits overtime. Property values plateau and green jobs decrease overtime when the construction is complete and only maintenance jobs are available. Air emission benefit continues to grow during the sturdy period (35 years) as the trees mature. Carbon, energy savings and ecosystem are too small to be shown in the figure.

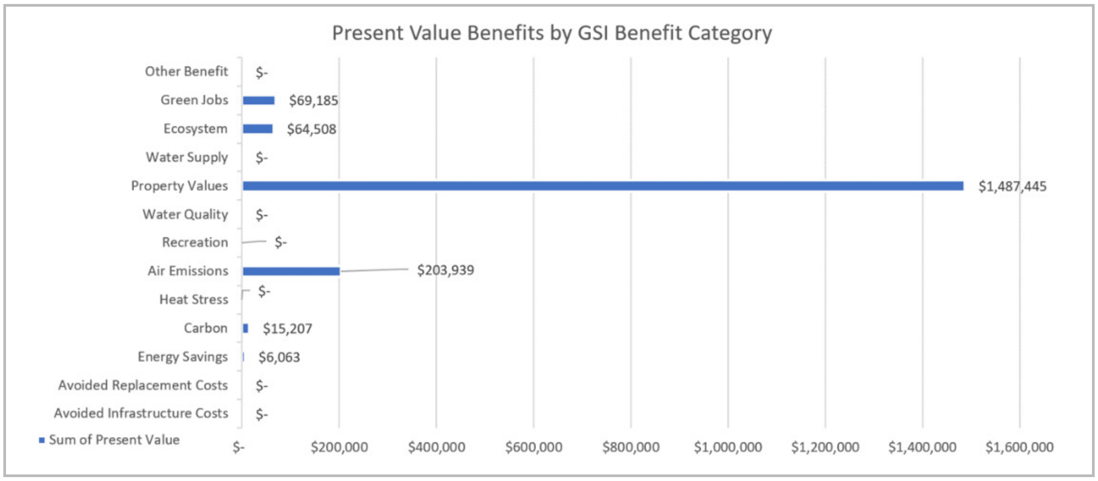

Figure 15 GSI TBL Scenario 4 with estimated co-benefits for 24 stormwater technologies and 15 trees.

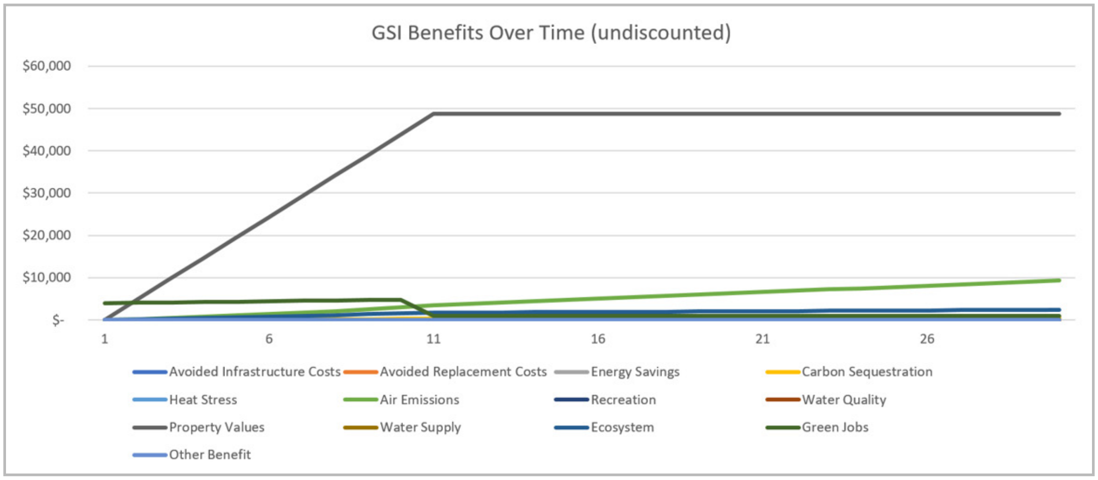

Figure 16 GSI TBL Scenario 4 Benefits (35 years) show how individual benefits change overtime.

Table 3 shows the total benefit and cost and benefit-cost ratios of GSI TBL Scenario 4. As shown, the benefit cost-ratio is below 1. However, the benefit calculations are very sensitive to assumptions. For example, property values change drastically with each assumption in how many houses are impacted and how to value the impact. GSI TBL Scenario 4 only includes a fraction of the estimated homes experiencing value increases. For example, the average annual aggregate increase for approximately 1200 homes is $48,468, which again only uses values estimated to increase with full implementation of GSI TBL Scenario 4 for a fraction of those homes.

Table 3 GSI TBL Scenario 4 benefit cost and benefit-cost ratio

TBL Accounting - Benefits	Present Value
Financial	$6,063
Social	$1,720,969
Environmental	$79,715
Total estimated cost	$4,090,676
Benefit-cost Ratio	0.45

How to use this information for integrated planning

Using benefit information helps the City of Philadelphia extend and integrate planning and implementation of stormwater practices across city departments and non-profit organizations that have similar interests in certain benefits. As an example, GSI TBL Scenario 4.1 estimated the number of trees needed in GSI TBL Scenario 4 to achieve a benefit-cost ratio above 1 while also focusing on achieving heat stress benefits. A successive number of trees were added to GST TBL Scenario 4. The property value assumptions were adjusted to include a larger fraction of homes. This is under the assumption that with more trees, more properties would experience an increase in value than GSI TBL Scenario 4. At 105 trees, heat stress benefit was still zero but the benefit cost ratio was above 1.0 due to property value and air quality benefit increase. Heat stress benefits were observed with the addition of 140 trees and an increase in canopy of 5%. Figures 17, 18 and Table 4 show the present values and costs overtime and the benefit-cost-ratio for the GSI TBL Scenario 4.1 with 5% increase in canopy.

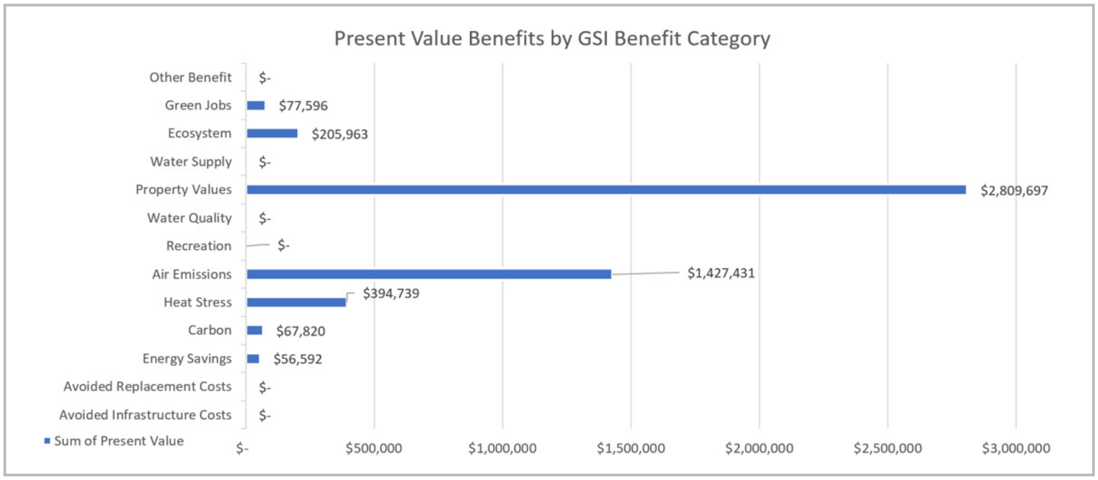

Figure 17 GSI TBL Scenario 4.1 Heat stress, air quality, and property value change (as well as other benefits) with the addition of 140 trees which is an estimated 5% increase in canopy. Current canopy estimate is 18% for this area.

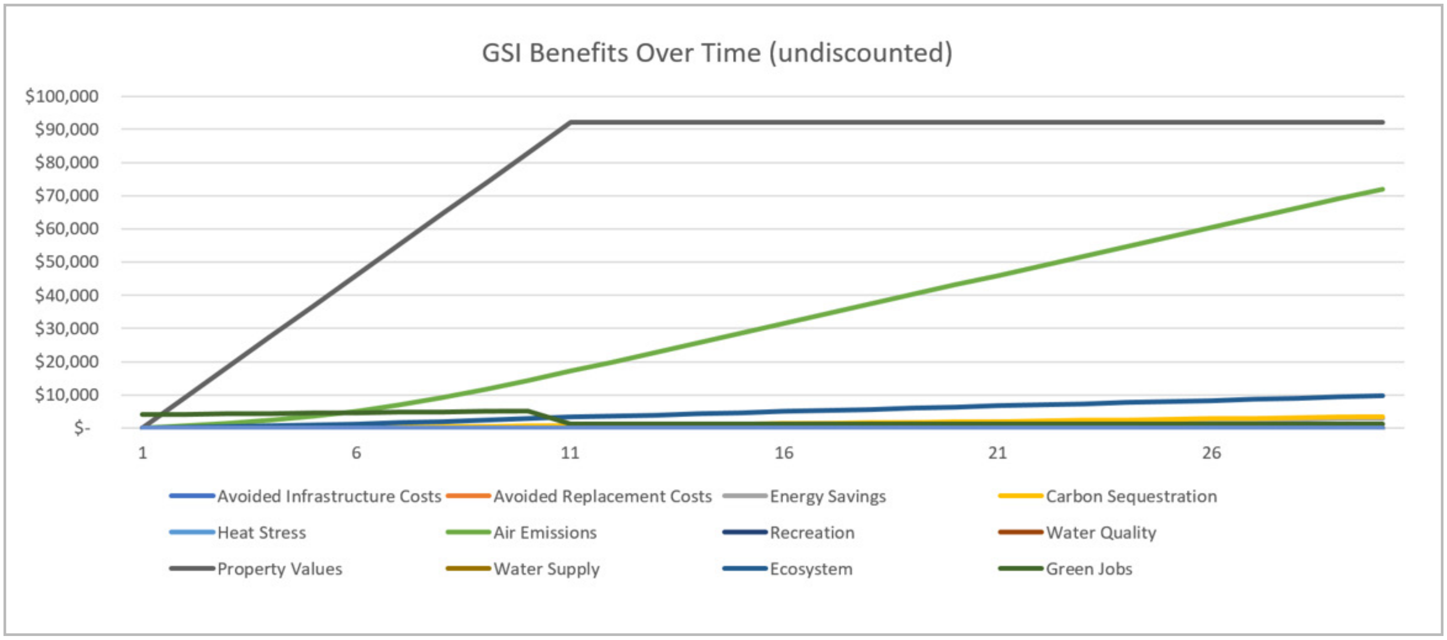

Figure 18 GSI TBL Scenario 4.1 Benefits overtime (35 years) for GSI TBL Scenario 4.1.

Table 4 GST TBL Scenario 4.1 Benefit, cost and benefit-cost ratio.

TBL Accounting - Benefits	Present Value
Financial	$56,592
Social	$4,709,463
Environmental	$273,783
Total estimated cost	$4,162,017
Benefit-cost Ratio	1.21

Calculating monetary values for benefits provides as way to quantify outcomes from city-wide programs that focus on green space such as the Urban Forest Strategic Plan (in progress). It also provides a way to communicate health benefits to other groups (such as organizations working to improve health outcomes) in a metric that may help increase interest in other funders for green space. While addition of 140 trees may not be possible in this particular study area, areas with vacant land or lots that can be converted to urban forests where the benefits estimated can support the implementation of increasing canopy in concert with stormwater practices to secure substantial benefits overtime.

SUMMARY

The CLASIC and GSI TBL tools were used to assess a case study in Philadelphia, Pennsylvania to observe the benefits of increasing green infrastructure. The study area is an actual planning area in Philadelphia and stormwater technologies reflect the best CLASIC selections for stormwater management practices used in Philadelphia. Three scenarios in CLASIC provided comparison of increasingly green stormwater technologies:

- The Baseline Scenario does not include any technologies and is the case were runoff is not treated. The Baseline is the scenario to which the subsequent scenarios are compared.
- Scenario 1 - Includes large, deep infiltration trenches (23) that capture approximately 92,000 cubic feet per year. No vegetation is added to the infiltration trenches and this is considered the "gray" scenario.
- Scenario 2 - A mix of large, deep infiltration trenches (8) and medium raingardens (22). The raingarden vegetation selected is grass – representing a minimally "greener" approach. This scenario captures 91,400 cubic feet of runoff per year.
- Scenario 3 – A "greener" mix of large, deep infiltration trenches (9), raingardens (10) and bioretention (6). The vegetation is for the raingardens and bioretention is "diverse" with flowering species and two trees in each garden. This scenario captures 91,300 cubic feet of runoff per year and is the "greenest" scenario which should provide the greatest co-benefits.

Cost per gallon is shown below as well as benefit summary scores. CLASIC shows qualitative support for increasing benefits of successively green infrastructure with Scenario 3 having the greatest benefit scores. This information is useful to communicate which benefits accrue due to different stormwater characteristics such as flowering vegetation and trees.

Table 5 Summary table from CLASIC – Cost per gallon and benefit scores

	Scenario 1	Scenario 2	Scenario 3
Dollars per gallon (total cost divided by gallons of runoff captured)	$3.98	$5.07	$6.93
Benefit Scores	2.33	4.02	7.39

The answer to the question if the benefits outweigh the costs is demonstrated by the GSI TBL tool. The GSI TBL Tool shows specific benefits estimated with easily accessible data (e.g. Census data). The benefits are considered conservative because all benefit categories were not estimated due to necessity of additional data to support assumptions. Benefits estimated for simplistic GSI TBL Scenarios 1, 2, and 3 show incremental cost and benefit of successively green characteristics.

- Scenario 1 included one infiltration trench;
- Scenario 2 included one raingarden and one infiltration trench; and,
- Scenario 3 one raingarden, one infiltration trench, and one tree.

GSI TBL Scenario 3 demonstrated the greatest monetary benefit values. Trees and provide many benefits that are captured within the tool including the financial benefit for energy savings. The social benefit category increased as trees add to property values as well as air quality. With the addition of trees, the carbon and ecosystem benefits also increased in the environmental category.

GSI TBL Scenario 4 and 4.1 shows the economies of scale through changes in the benefit-cost of a simulation of 24 green practices similar to what is implemented in Philadelphia. GSI TBL Scenario 4.0 added 15 trees to the study area, and 4.1 added 140 trees which would increase the canopy by approximately 5%. The trees increase benefits significantly and the benefit cost ratio over 1 is observed when the canopy is increased by 5%. This area is highly impervious and addition of 140 trees may be unlikely, however GSI TBL Scenario 4.1 demonstrates how important coordination across various city initiatives, such as the Urban Forest Strategic Plan, can provide the benefit quantities additive to stormwater projects to increasingly leverage the natural resource benefits to the communities in Philadelphia.