Final
Quality Assurance/Quality Control Report

National Stormwater Calculator: Low Impact Development Stormwater Control Cost Estimation Programming

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SECTION 1. Project Description and Objectives

The U.S. Environmental Protection Agency's (EPA) Performance Work Statement (PWS) for Task Order (TO) 026 (PR-ORD-15-00668), National Stormwater Calculator: Low Impact Development Stormwater Control Cost Estimation Programming, states that the purpose of this TO is to implement cost estimation procedures for Low Impact Development (LID) controls previously developed as part of TO 0019 (PR-ORD-14-00308). This project involves programming of the previously developed cost curves and methodology into the existing National Stormwater Calculator (SWC) desktop application. The integration of cost components of LID controls into the SWC will increase its functionality and is expected to promote greater use of the SWC as a stormwater management and evaluation tool. The current SWC estimates runoff at a site based on soil type, landscape and land use information, existing and potential future climate conditions, and stormwater management controls (i.e., LID controls) that can be implemented on a site. The addition of cost estimation will allow planners and managers to evaluate LID controls based on comparison of project cost estimates and predicted LID control performance. Cost estimation is primarily calculated by applying user-identified size (or auto-sizing based on achieving volume control or treatment of a defined design storm) and LID control infrastructure characteristics to volumetric based cost curves. However, other key project and site-specific variables are also included such as whether the project is being applied as part of a new development or redevelopment project, soil permeability, site slope, and possible pretreatment that can result in additional expenses.

Because of the many mitigating factors that are site-specific and project-specific, the costs detailed within this document and implemented in the updated SWC are not recommended for engineering estimates but are for relative comparison of stormwater controls. For instance, land acquisition costs, which can be a large expense for a stormwater management project, are not included in the cost estimation module.

As part of a project's quality control and quality assurance (QA/QC) practices, the EPA quality system requirements defined in EPA Order CIO 2105.0 (EPA Order; formerly EPA Order 5360.1 A2), *Policy and Program Requirements for the Mandatory Agency-wide Quality System*, must be followed for environmental data produced from models. Environmental data are defined as any measurement or information that describe environmental processes, location, or conditions; ecological or health effects and consequences; or the performance of environmental technology. Environmental results are defined as information collected directly from measurements, produced from models, and compiled from other sources such as databases or literature. This project was conducted in accordance with the EPA Order. In particular, the project must comply with Section §6.a(7) of the EPA Order which states that EPA organizations (and consequently, their contractors) will develop, implement, and maintain a quality system in conformance with American National Standards Institute (ANSI)/American Society for Quality Control (ASQC) E4-1994 and includes "approved Quality Assurance Project Plans (QAPPs)" for all applicable projects and tasks involving environmental data. QAPPs generally must be approved prior to any data gathering work or use. A QAPP was developed for this project. The goal of the QAPP is to assure an increased level of certainty that the software program developed and the associated information generated are comprehensive, appropriate, and of the type, quantity, and quality required. A QAPP was developed and submitted to EPA approved in October 2015. This QA/QC Report documents steps taken to implement the QAPP and achieve quality assurance goals.

SECTION 2. Quality Assurance / Quality Control

2.1 Data validation and verification

As stated in the QAPP, data validation confirms that the data used in the project meet QAPP-defined requirements. The bulk of the data used for this project was previously developed as part of TO 019 (PR-ORD-14-0038). Data validation for the previous project was governed by the QAPP developed for TO 019 (PR-ORD-14-0038). Data that was previously reviewed was not re-evaluated for this TO. However, in keeping with the data validation procedures of the previous project, the team employed similar QA activities and procedures. The Project Managers (Struck and Deerhake) as well as the EPA TOCOR reviewed the draft and final products of this TO. The third party data sources that have been selected for this project are trusted sources such as the U.S. Bureau of Labor Statistics (BLS) and the construction cost information company RS Means (https://www.rsmeans.com/info/contact/about-us.aspx). These organizations document and adhere to their own internal quality procedures. The Project Team also received data from the EPA representing construction costs from actual projects as potential case studies for use in QA procedures. Additionally, the Project Team used best professional judgement in sorting through the data to select suitable sites for use as case studies. The case study data is, therefore, considered to be of sufficient quality for the purposes of this TO. The bulk of the remaining data represents outputs generated from the execution of code under development or code being tested. Outputs of program execution were compared to results from calculations accomplished using other tools such as MS Excel, manual calculations, or outputs of the unmodified version of the SWC. The current SWC application contains built-in data consisting of meteorological, hydrological and other data that have been used by the TO team during testing. The data have been used as-is and have not undergone quality assurance or quality control measures by the TO team. A list of the data sources for this TO is provided as follows:

- Cost curves from TO 019 (PR-ORD-14-0038) developed based on unit cost information from RS Means and other sources such as previously constructed projects
- Data from the BLS for computing regional differences in cost and for adjusting for inflation
- Data for previously constructed projects provided by the EPA TOCOR for use as case studies
- Program outputs from both the current version of the SWC and the updated cost estimation capable version
- Unmodified meteorological and hydrological data used by the current version of the SWC as well as the updated version of the SWC
- Draft and final documents and source code produced as deliverables during the execution of this project.

2.2 Methodology and approach validation

The cost estimation approach implemented in the SWC is based on the use of previously developed cost curves for each of the LID controls supported. The process of creating the cost curves is described in detail in the TO 019 (PR-ORD-14-00308) Final Report and has previously been validated. The cost curve production framework consists of a Microsoft Excel spreadsheets that compute costs for various sizes of LID controls that are based on itemized costs and quantities computed from the user-defined design variables. Microsoft Excel macros were used to automate the process of repeatedly sizing and costing the

various LID controls for the various scenarios. See Appendix A of the TO 019 (PR-ORD-14-00308) Final Report for all 18 curves. Under this TO a cost regionalization strategy was developed and implemented at EPA's request to account for regional differences in costs across the United States and within metropolitan areas adjusting cost estimates based on regional cost differences. The regional approach also will allow for year-to-year inflation corrections. The primary means of validating the cost estimation procedures including the cost regionalization approach has been through the use of case studies. Another benefit from the use of case studies is the informative nature of results produced for software testing. The outcomes of software testing are discussed below.

2.3 Software Testing

This section provides a brief description of the testing practices that were applied to this project to prevent, detect and eliminate bugs. Required categories of tests for QA Category III software development projects specified in EPA's *Quality Management Plan* document include:

a) Individual module tests (Unit Testing)

b) Integration tests

c) System Tests

d) Retesting after changes (Regression Testing)

e) Acceptance testing (if applicable)

f) Beta testing (if applicable)

Four categories of tests were initially planned, including unit and regression testing during development, beta testing by external users, and acceptance testing. Due to the small size of the project, integration and system tests were assumed to be covered by regression and acceptance testing. Due to delays in obtaining cost regionalization data, the Project Team had to develop a custom cost regionalization approach which resulted in a compressed project schedule. Also, efficiencies in the design and architecture of the cost update resulted in a much smaller code base. The small size of the project along with compressed schedule necessitated some changes in the implementation of the original QAPP, including the elimination of code reviews and a shorter beta testing period. The categories of testing that were successfully implemented are discussed next.

2.3.1 Unit Testing

Unit testing is a software testing method by which individual units of source code (typically functions and class methods) are tested to determine whether they perform as designed. To support EPA intentions to eventually deploy the SWC as a Web application ("app"), the decision was made to develop the cost module addition in a way that makes transition to a Web app easier. The Project Team therefore developed a significant portion of the code in JavaScript / HTML5 to aid in this future transition. Modifications to the original C# code were made as needed to collect user inputs from the view and pass the inputs to JavaScript code for computing cost estimates. A separate JavaScript single page application (SPA) was developed and tested and integrated with the C# code to complete the update. Unit tests were written for the JavaScript code but not for the C# code. This is because there were no existing unit tests for the C# code prior to this project; therefore, writing unit test for the C# code was considered outside the scope of this effort. Also, the C# code is written as Windows forms application with a fair amount of coupling between the view layer and the rest of the application logic which makes writing unit tests somewhat more challenging.

Unit tests for the JavaScript SPA were developed for a Karma environment using the Jasmine testing framework. The source code for the unit tests are to be delivered along with the source code for the cost module update itself.

2.3.2 Regression Testing

Regression testing seeks to uncover new bugs after changes have been made. For the purposes of this effort, regression tests have been mainly used to ensure that the existing functionality of the SWC is preserved throughout the update process. The addition of cost estimation capabilities should not introduce bugs or errors into existing hydrologic / hydraulic computations performed by the calculator. To meet this goal, the Project Team periodically installs and runs the existing SWC and compares the output to the updated version under development. A straightforward comparison of the output from the two versions is sufficient to indicate if any regression has occurred.

The other strategy the Project Team used to prevent regression was to periodically compare the outputs of the updated SWC under development to the spreadsheet framework that was created as part of TO 019 (PR-ORD-14-0038). Recall that TO 019 (PR-ORD-14-0038) resulted in the creation of a family of cost curves from which regression equations were extracted and programmed into the SWC to support cost estimation. That spreadsheet contains calculations that replicate most of the computations with the updated SWC and has, therefore, been a good tool for comparing results to detect problems.

2.3.3 Beta Testing

A six-week beta testing period was initially planned for this TO. The idea was to release the beta version of the updated SWC to a small group of external users to use and test under real-world conditions. The Project Team planned to use Atlassian's JIRA bug tracking system to collect and track issues and bug reports from beta testers. Due to delays in obtaining cost regionalization data and the scheduled end date of this TO, it was necessary to compress the project schedule to the point where a six-week beta period was no longer feasible. It was possible to arrange a shorter beta testing period due to the small size of the products. Rather than external users, three EPA employees including the TOCOR constituted the team of beta testers. A simple bug tracking spreadsheet was used to track comments and bug reports from beta testers over the two-week beta testing period. This approach was practical and removed the need to manage a geographically distributed team of beta testers. All bugs identified and EPA-requested feature enhancements were reviewed, categorized, and prioritized with the TOCOR. All bugs were fixed, and the fixes were documented in the bug tracking worksheet. Some of feature requests and additions were implemented, those that could not be addressed under the current TO have been documented as possible items to address in the next update of the SWC. After the first day of beta testing, the Project Team fixed all the critical issues that were identified, addressed some of the lower priority feature requests, and released an updated beta version for further testing. For details on the issues reported and how they were addressed, a copy of the bug tracking worksheet is attached as Appendix A. This will allow the beta testers that identified critical issues to confirm that the bug fixes implemented have sufficiently resolved the issues they found.

2.3.4 Acceptance Testing

Acceptance testing consists of testing conducted to determine if all the stipulations in the requirements specification have been satisfied. Internal acceptance testing conducted by the team is not a substitute for EPA's own acceptance testing. Following successful completion of beta testing, the Project Team addressed all remaining comments and delivered Release Candidate 1 to EPA for acceptance testing. Acceptance testing was conducted by EPA to ensure that the Release Candidate 1 met all the requirements. In the QAPP, the Project Team recommended the use of real-world case studies to ensure that the output of the updated SWC is sensible. The updated User Guide contains a well-documented case study that walks through various computations in the SWC and is also ideal for regression testing since the previous version of the User Guide contains the same case study conducted with the previous version of the SWC. The Final Methodology and Results Report also contains another case study that is well-documented. Either of these case studies or a different case study can be used to further confirm that the

project requirements have been met sufficiently. EPA found one issue related to opening one specific previously created file during the acceptance testing of Release Candidate1. The Project Team confirmed that the issue was an existing bug in the previous version of the SWC and was not caused by the modifications made under this TO. The Project Team advised EPA on how the issue may be resolved in the next update and submitted all outstanding deliverables and software development artifacts to complete work under this TO.

2.4 Test Results

This section summarizes the results of conducting the four categories of tests discussed at the beginning of Section 2.3. Rather that provide a comprehensive dump of test output, our goal here is provide an organized summary of testing outcomes, beginning with unit tests.

2.4.1.1 Unit Testing

Unit tests were executed via command line scripts during development using Karma as the test runner, Jasmine as the testing framework, Grunt as the task runner in a headless Phantom JS environment (Phantom JS is a web browser without a user interface used for browser automation and testing). The abbreviated command line output generated from running the unit tests is shown below in Figure 2-1. The figure indicates that 23 of the 23 automated unit tests that were executed all complete successfully with no errors.

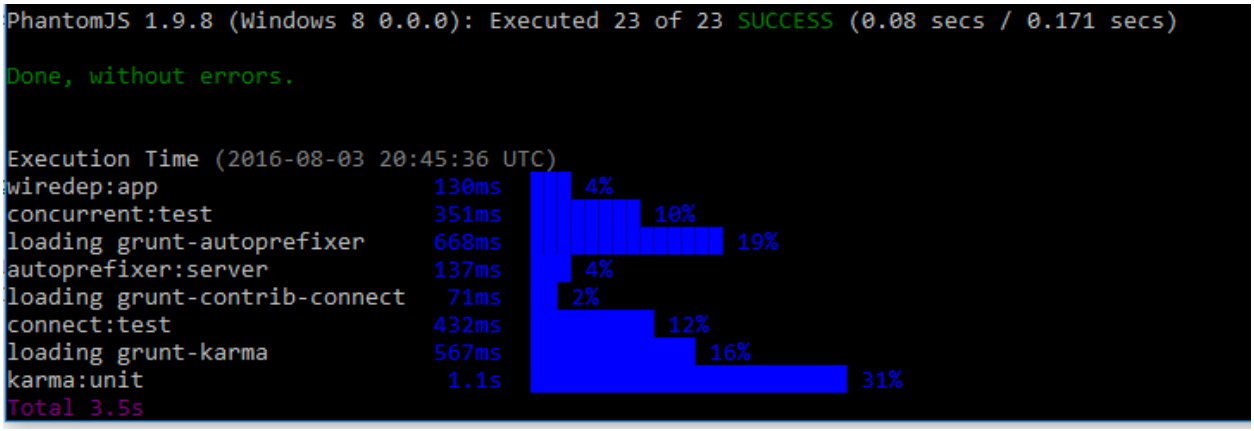

Figure 2-1. Output of running unit tests with Grunt, Karma and Jasmine.

2.4.2 Regression and Internal Acceptance Testing

Regression and acceptance testing was conducted at various stages throughout the project. This section summarizes the results of the final set of tests (to be updated if more testing is conducted before product release). The Project Team conducted two categories of tests:

- *Input Data Manipulation* tests – based on case studies and used to determine if the tool was producing sensible output and output consistent with previous versions;
- *Random Movement and Data Entries to Defeat Tool* tests – based on progressing through the tool in a non-linear fashion in attempt to uncover edge cases that could defeat the tool. Edge cases are conditions and workflows that do not represent the typical use of an application.

Both categories of tests were conducted successfully, and no critical issues were found although the following warning was encountered for some of the inputs. This warning was the same for both the updated SWC and the previous version of the calculator and is, therefore, considered as expected behavior:

LID ERROR: THERE IS NOT ENOUGH PERVIOUS LAND AREA TO HANDLE THE DISCONNECTED IMPERVIOUS AREA OR TO CONSTRUCT RAIN GARDENS OR AN INFILTRATION BASIN. TRY DECREASING THE AMOUNT OF IMPERVIOUS AREA TREATED BY THESE CONTROLS OR THEIR CAPTURE RATIOS.

To demonstrate that appropriate checks for regression were conducted, a series of user interface screen shots are provided in Appendix B using a well-documented case study from the User Guide and showing screenshots from the updated SWC and the previous version side-by-side. The example application computes:

- Pre-development conditions
- Post-development conditions
- Post-development with LID practices
- Climate change impacts.

Under all these conditions, the output from the previous version of the SWC is identical to the output of the current. See Appendix B for side-by-side screen shot comparisons of inputs and outputs of the current and updated versions of the SWC.

2.4.3 Beta Testing

Beta testing is currently still in progress. A summary of the issues that have been reported thus far, along with a description of how each issue was resolved, has been included as Appendix A. Refer to the bug tracking summary table for details of the beta testing.

2.4.4 Acceptance Testing

The results of combined regression and internal acceptance testing conducted by the Project Team are shown in Appendix B. EPA will independently conduct and document their own acceptance tests after the beta period to ensure that all project requirements have been met.

SECTION 3. Change Control and Configuration Management

3.1 Change Control

Change control (CC) is a collection of software engineering practices used to ensure that changes to a product or system are introduced in a controlled and coordinated manner. The goal of CC is to minimize the introductions of faults into the system, minimize impacts to project schedules and budgets from unexpected changes, and to minimize re-work from unexpected changes. The Project Team has been diligent about effectively communicating the adverse impacts of late state changes and has employed the use of mockups to preempt changes. Mockups of the user interface and draft submissions of the design and requirements, were used as tools for pre-empting potential changes by asking for feedback from EPA at the early stages of implementation. This approach worked well, and there have been no major late stage changes.

The updated SWC has been tested successfully on the updated version of the SWMM5 dynamic link library (DLL) and on Windows 10. These are two conditions that were required in the QAPP.

3.2 Configuration Management

Configuration management (CM) is a collection of software engineering practices for establishing and maintaining consistency of a product's performance and functional attributes with its requirements, design, and operational information throughout its life. CM verifies that changes are carried out as prescribed and that documentation of items and systems reflects the true configuration. Since the Project Team is small and the development timeframe has been short, simply ensuring that any and all changes are properly documented and versioned has been adequate with regards to CM; therefore, a formal written CM system consisting of documented CM procedures for CM planning and management, configuration identification, control, status and verification was not produced.

SECTION 4. Audits and Reviews

For large projects, with huge and complex code bases, audits and reviews can uncover faults and defects that may be difficult to detect with tests alone. Various kinds of audits and assessments procedures are available including code reviews, performance evaluation audits, technical systems audits, quality systems audits, and audits of data quality. Due to the limited scope of the current project, an informal code review was initially planned as part of QA/QC procedures. Due to a compressed project schedule stemming from the inability to obtain a subscription to third-party cost regionalization data, it was no longer feasible to do a code review. The Project Team instead focused on testing to demonstrate the updated SWC functioned properly. Since a reduced review process resulted from the small size of the code base, this change is not anticipated to adversely impact the quality of the updated SWC.

SECTION 5. Maintenance and User Support

EPA currently maintains the SWC and provides links on the SWC website for users to contact the SWC team and provide feedback. EPA will retain ownership and responsibility for the updated SWC when this project ends and is expected to provide the same level of support as is currently provided.

The cost-component of the SWC added by this TO has been designed with long-term ease of maintenance in mind. Ease of maintenance is important to the Project Team and was formally added as requirement that had to be satisfied. The Project Team created a spreadsheet tool to facilitate updating the cost data within the tool. The Project Team also opted for a low maintenance alternative for implementing cost regionalization by adding code to dynamically download and process data directly from the BLS. EPA is responsible for the maintenance of the SWC going forward. Maintenance of the cost tool consists of updating the unit costs in the spreadsheet tool and executing the macros in the tool to produce new regression equations for updating the source code of the SWC. EPA developers can obtain a free API key for accessing the BLS API by registering on the BLS website here. The registration key obtained is a string that is added to the source code and used for making requests to the BLS API similar to the manner in which the Bing Maps API key is already being used in the calculator to obtain Bing Maps layers for displaying maps in the calculator.

SECTION 6. System Documentation and Archiving

EPA requires documentation for software projects in all QA categories. EPA QA Category III (Applied Research) is the most suitable category for this project. Required documentation for Category III software development are based on the size of the project, and the discretion of the Project Officer. The documents produced for this project include:

- QA Project Plan – *satisfied by the QAPP (EPA-approved October 2015)*

- Requirements Document – *satisfied by combined Application Features Requirements Document (AFRD) and Software Application Architectural Design Document (SAAD) to be delivered at the end of this TO*
- Design Document – *satisfied by combined AFRD and SAAD*
- Coding Standards or SOPs – *satisfied by combined AFRD and SAAD*
- Source Code with in-line comments – *satisfied by source code constructed under this TO (Final versions of all programing artifacts)*
- User's Manual – *satisfied by the updated User Guide document (delivered as Appendix A of Final Methodology and Results Report)*
- Testing and validation procedures and results summarizing the results of testing the SWC using the two case studies – *satisfied by this document (Final QA/QC Report)*
- Backup Source Code and Build Procedures – *to be delivered electronically to EPA (Final versions of all programing artifacts)*

SECTION 7. Conclusion

This document outlined the steps that were taken to satisfy the QAPP that governs this project. The goal of the TO was to develop and implement a cost estimation procedure for LID controls for inclusion in the SWC. Adding cost estimation capabilities to the SWC is anticipated to further enhance the popularity of the SWC and promote the use of the calculator by new converts. Using data from trusted sources such as the BLS and RS Means, along with LID construction data provided by EPA, facilitated data validation and verification. The use of case studies allowed the cost estimation methodology to be vetted and provided outputs to regression and acceptance testing comparisons. The product's small size and innovative architectural design enabled a reduced beta period without impacting quality. All of the documents produced under this TO have undergone multiple levels of review. The Project Team has developed tools to facilitate updates to the cost data within the tool and welcomes the opportunity to assist EPA through future TOs with maintenance and upgrades.

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Appendix A – Bug Tracking Worksheet

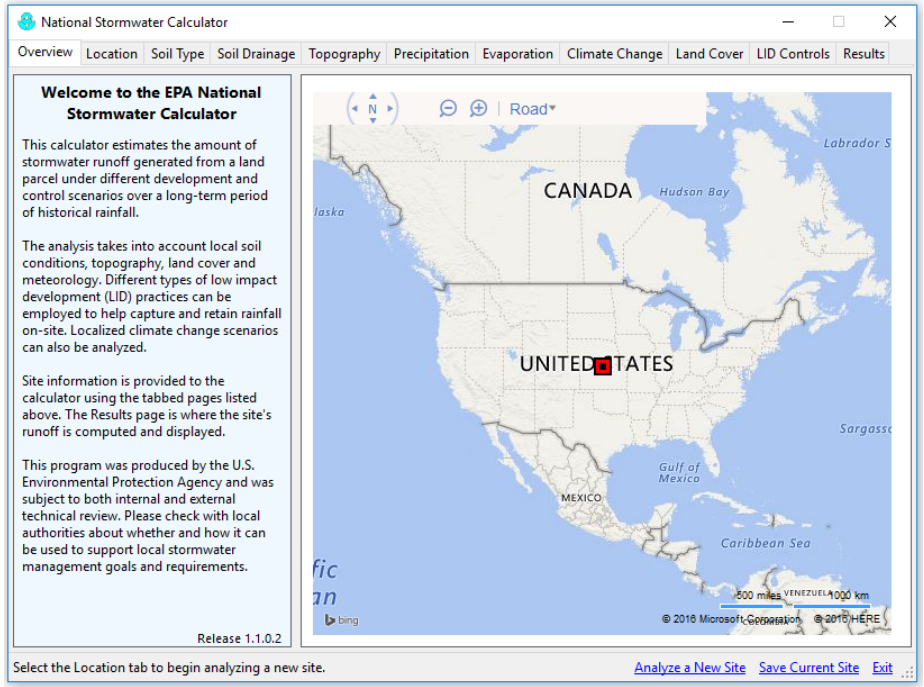
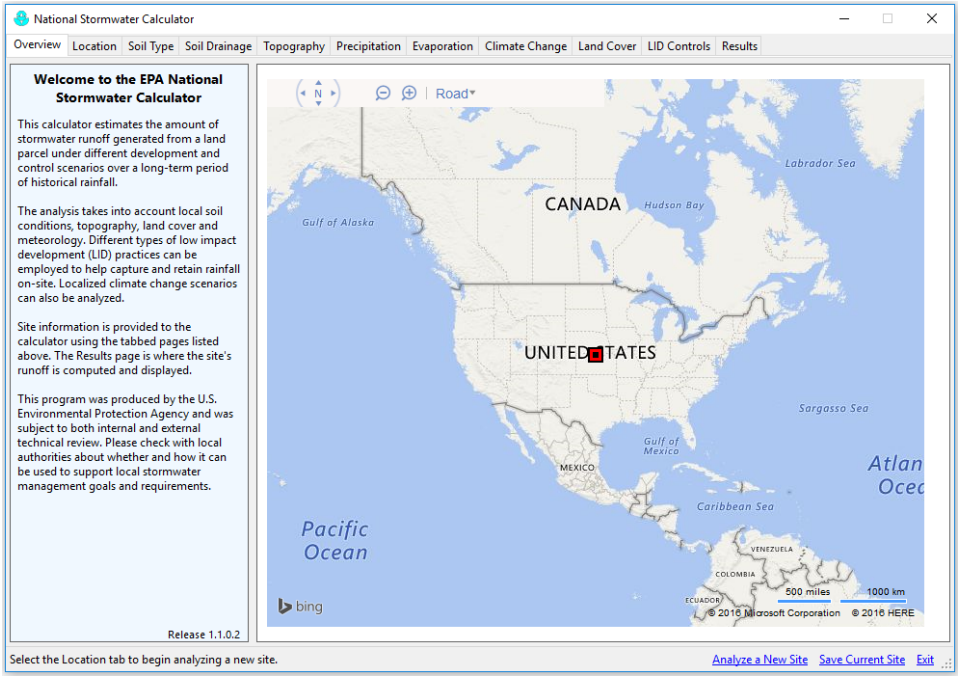
Issue#	App Version	Date Entered	Reported By	Location of Error (Form or View/Screen)	Description / Comments	Issue Type	Status	Date Fixed	Date Fix Confirmed	Fix Description / Comments	Side Effects From Fix
1	MTP 3	8/1/2016	MT	Cost results screen	The cost for Rainwater Harvesting does not appear to be a function of site size or drainage area %. This doesn't seem correct. I checked the other LID's and they are a function of those variables.	Bug / Feature Correction	**Fixed**	8/2/2016	8/15/2016	Updated code to properly compute rainwater harvesting volume	None
2	MTP 3	8/1/2016	JB	Help Dialogs	Under the description tab it may be good to define what a cost curve is. This is the first time the user sees this term in the calculator	Feature addition	**Fixed**	8/2/2016	8/15/2016	To avoid complicating and cluttering the SWC user interface, definitions such as this are included in the User Guide. Users are now being referred to the User Guide for further clarification in all the new help dialogs	None
3	MTP 3	8/1/2016	JB	Site Suitability Help Dialog	The image captions for Site Suitability options, the Poor and Moderate images…the captions are hard to read, should make these clearer.	Bug / Feature Correction	**Fixed**	8/2/2016	8/15/2016	Captions have been replaced with clearer versions	None
4	MTP 3	8/1/2016	JB	Cost Region Help Dialog	Cost Region Pop-Out Window: It may be good to write in some language indicating what it means when a cost multiplier is greater than or less than 1 (National Value). This may not be apparent to every user.	Feature Clarification	**Fixed**	8/5/2016, 8/11/2016	8/15/2016	We have edited the cost region description to include the following text: "Three regions are reported from 20 of the major cities for which BLS data is available. Users can select another region or select "National" to apply a multiplier of 1, representing a national average. If you prefer to apply your own multiplier, select "Other" and enter the multiplier in the Regional Multiplier field (a multiplier >1 would adjust above the National average, while a multiplier <1 would adjust below the National average). The default multiplier for your region is shown in the Regional Multiplier box. The light blue circles in the figure below represent areas within a 100-mile radius of each major city.	None

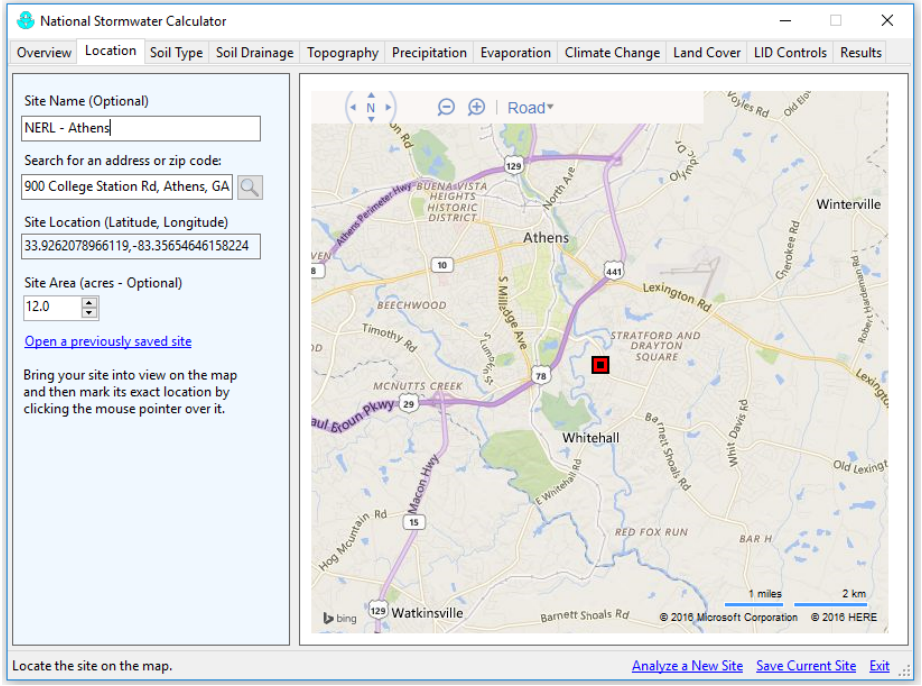
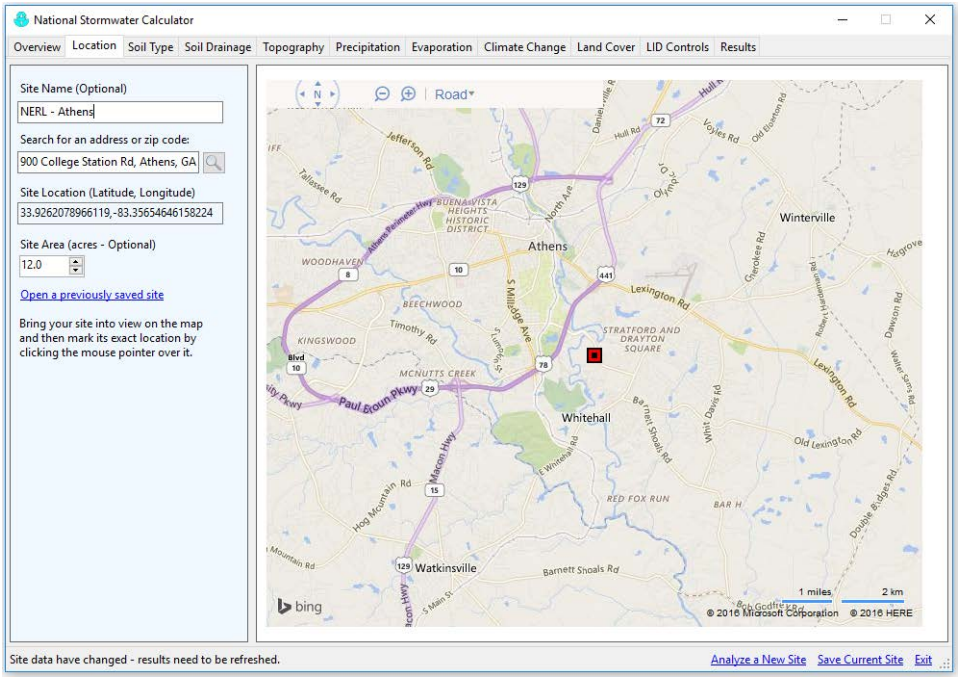
Issue#	App Version	Date Entered	Reported By	Location of Error (Form or View/Screen)	Description / Comments	Issue Type	Status	Date Fixed	Date Fix Confirmed	Fix Description / Comments	Side Effects From Fix
5	MTP 3	8/1/2016	JB	Site Suitability Help Dialog	Site Suitability: For the terms of soil drainage, amount of slope, etc. used for the poor, moderate, and excellent site suitability descriptions we should use the same terminology that is used to define the soil drainage, soil type, and topography. This will help the user understand how choices made with the previous soils tabs affects their decision to choose a "site suitability" option.	Feature Clarification	**Fixed**	8/5/2016, 8/12/2016	8/15/2016	Agreed. Of note, we had previously combined several notions to site suitability which were accounted for elsewhere (e.g., topography and soil infiltration) in our attempt to capture site complexity scoring in the pop up explanations. As these factors are captured in those tabs, we are removing them from user consideration under site suitability. We have instead included language and figures that refer to physical obstacles, haul distance, dewatering, geotechnical hazards, and requirement for more complex media blends. The user choices will not overlap now with the other tabs and provide clearer understanding. This will eliminate the terminology conflict as well.	NA
6	MTP 3	8/1/2016	JB	Cost results screen	For the baseline costs, I thought we discussed letting advanced users change the baseline values (there may be a case where they already know the costs of baseline project costs they'd like to input). Were we still going to add that functionality?	Feature Addition	Added to future improvements list	NA	NA	This feature is beyond what current time and budget would allow. One also must be careful in implying that because costs are known in the baseline scenario that the performance as predicted by the SWC is also known. This feature has been noted as a potential future improvement	NA
7	MTP 3	8/1/2016	JB		We want to let the user know what year the costs are representative of, such as 2015…2017, or the current year on the results tab and the results report print out. How often and when should EPA expect to be able to update the costs for future years?	Bug / Feature Correction	**Fixed**	8/2/2016	8/15/2016	Using BLS data the cost estimates are inflation adjusted to the latest year of BLS data automatically. This is typically 1 year behind the current year. Ideally it be good to revisit the underlying units cost on the order of every 3 to 5 years or when economic conditions change substantially	None

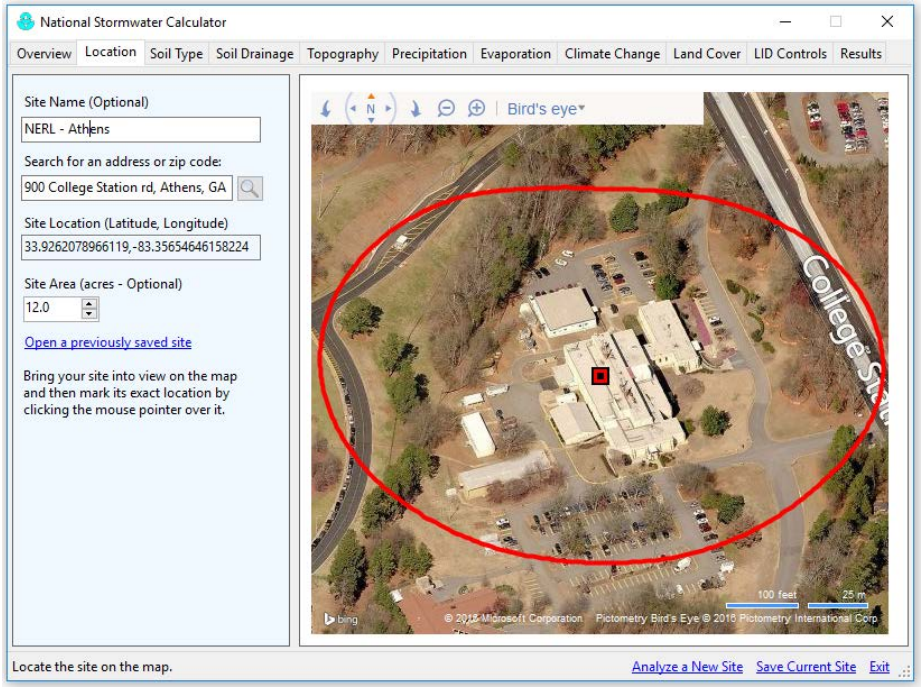
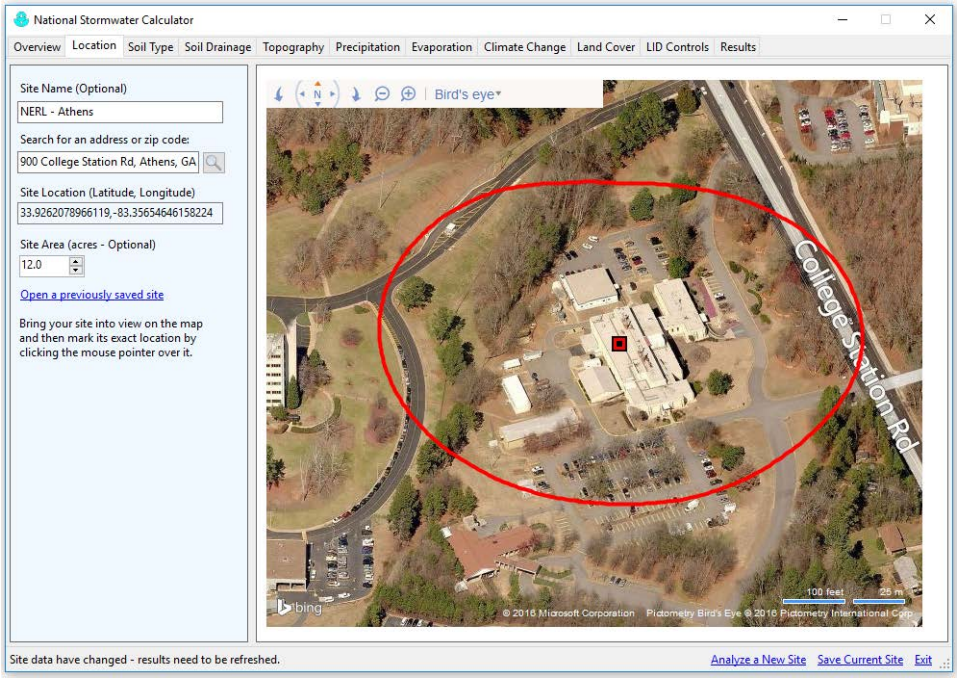
Issue#	App Version	Date Entered	Reported By	Location of Error (Form or View/Screen)	Description / Comments	Issue Type	Status	Date Fixed	Date Fix Confirmed	Fix Description / Comments	Side Effects From Fix
8	MTP 3	8/1/2016	JB	Cost results screen	For the tabular costs summary, it would be good to show a total costs row at the bottom of the table (this would apply for each scenario and for the difference between the scenarios).	Feature Addition	**Added**	8/11/2016	8/15/2016	This feature was not in the final mockups, however, we will add this to the tables.	NA
9	MTP 3	8/1/2016	JB	Cost results screen	Maintenance Costs: it would be good to mention something about these costs being a percentage of the capital costs of the project; and that the maintenance costs are annual for the life of the BMP chosen. It would be good to potentially reference what the estimated lifetime of the BMP is, so someone could estimate the maintenance costs for the projected life of the project BMPs.	Feature Clarification	**Updated User Guide**	8/5/2016	8/15/2016	The maintenance costs are actually computed from unit costs that were derived from literature reviews and represent annual maintenance costs. The life span of the BMP is not a consideration since this is the maintenance you would expect for an average year excluding replacement costs. We will add language in the User Guide describing what is included in the maintenance costs to avoid cluttering the SWC interface	NA
10	MTP 3	8/1/2016	JB	Report PDF	For the Report Print out would it be possible to include a column indicating the difference in costs between the baseline and current scenarios, similar to the summary results page?	Feature Addition	**Added**	8/11/2016	8/15/2016	We will add this feature.	NA
11	MTP3	8/4/2016	JB	Report PDF	For the Report Print out is it possible to include the bar chart graphics from the cost summary results in the calculator? I remember Dan indicating this may be difficult to program. It would be nice to have those graphics included, similar to the runoff graphic charts.	Feature addition	Added to future improvements list	NA	NA	This feature did not make it into the mockups and cannot be feasibly implemented at this stage of the projected. It has been noted as a potential future improvement	NA

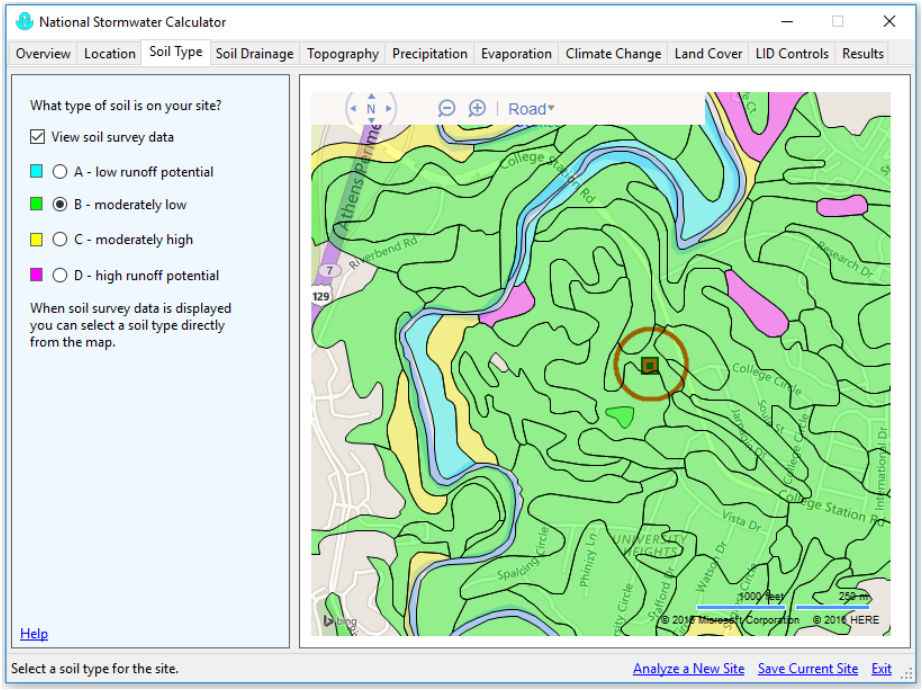
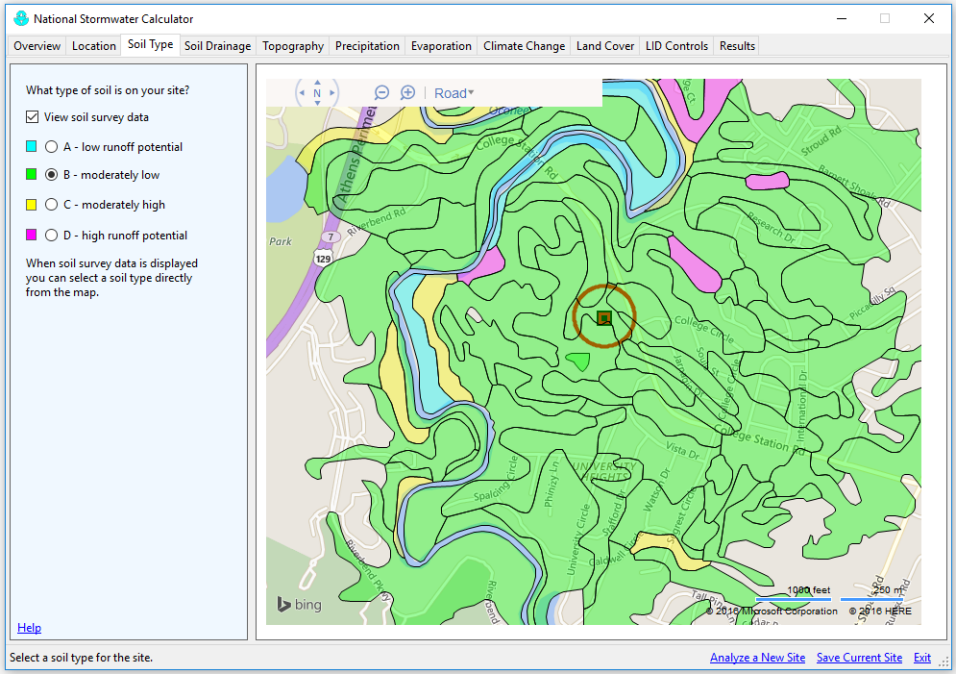
Appendix B – Regression Test Results

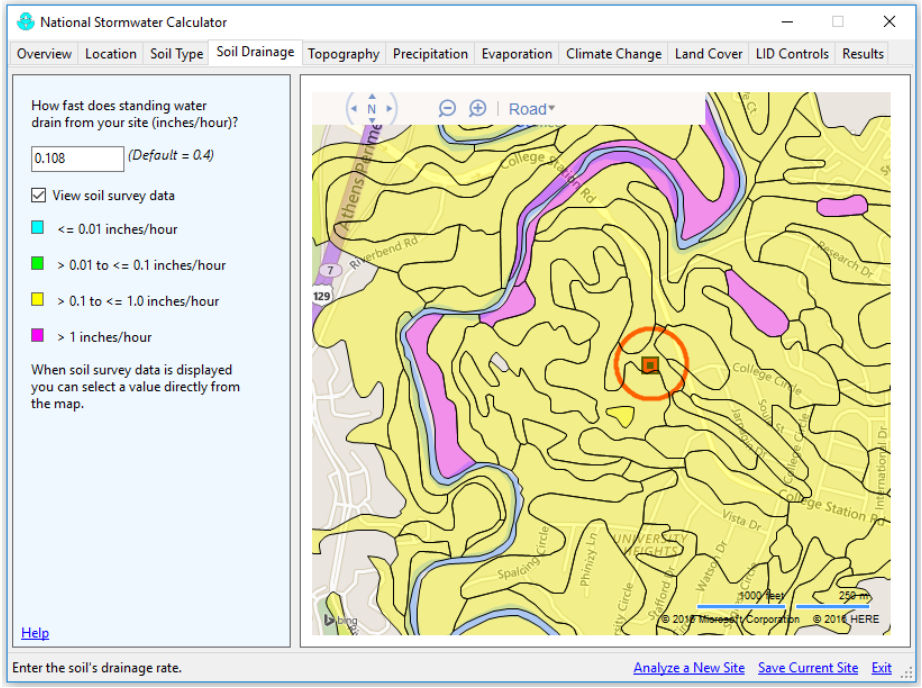
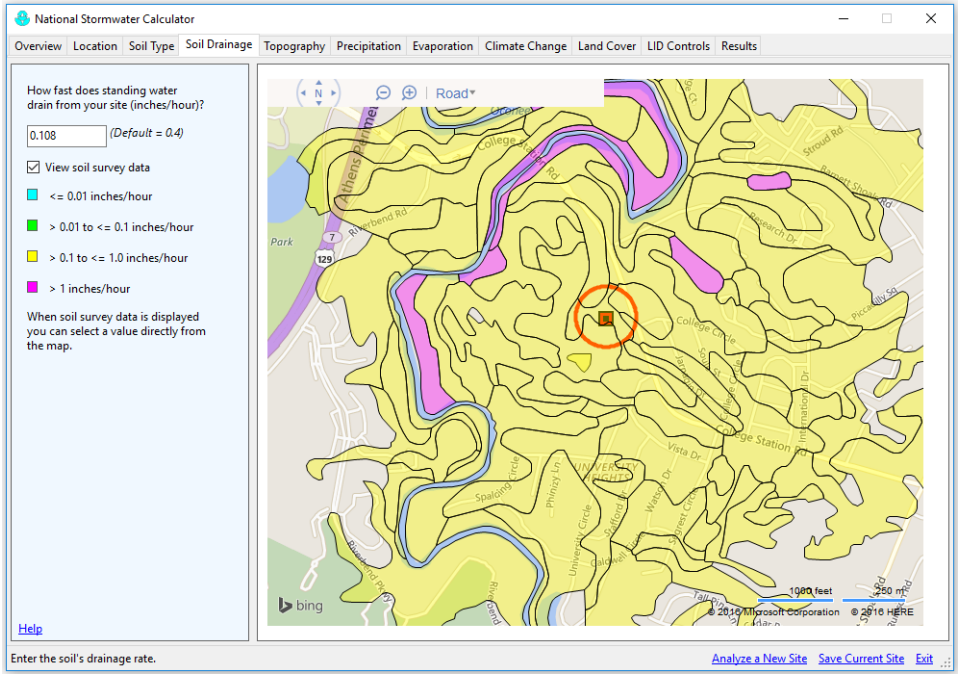
Table B-1. Side-by-side Screenshots Comparing Previous and Current Versions of the SWC (Post-development Condition)

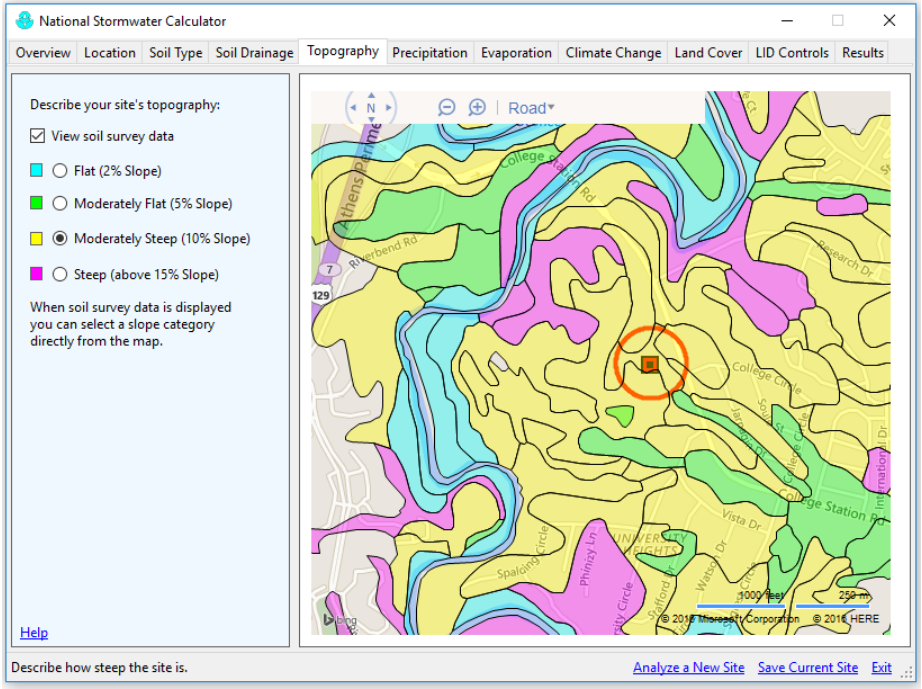
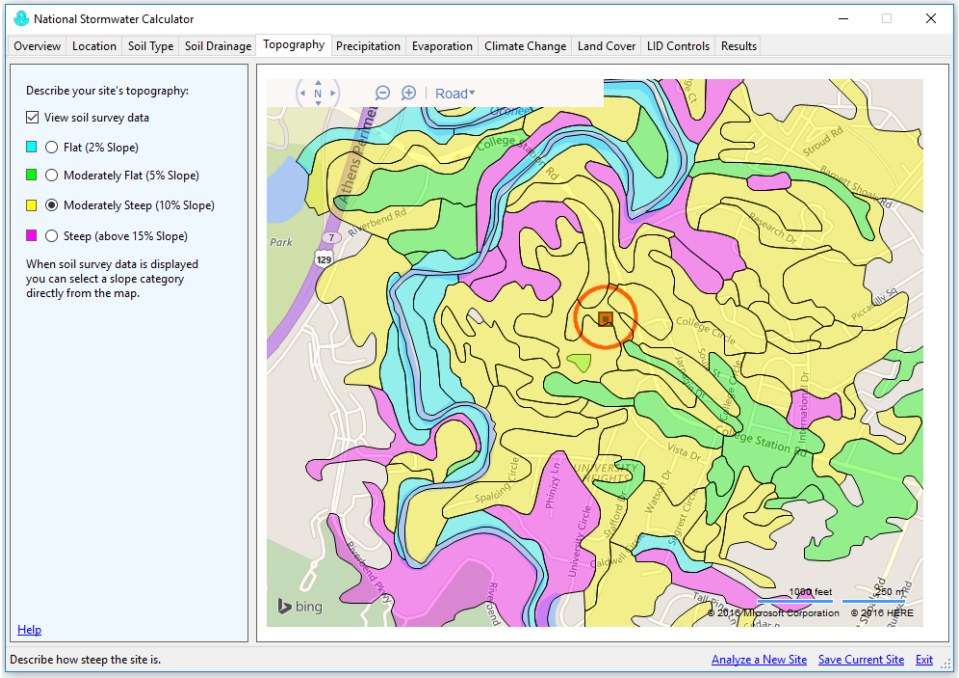
SWC Version 1.1.0.2 **(previous version)** **Current Scenario** - Post-development condition **Baseline Scenario** - NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario** - Post-development condition **Baseline Scenario** - NA
	

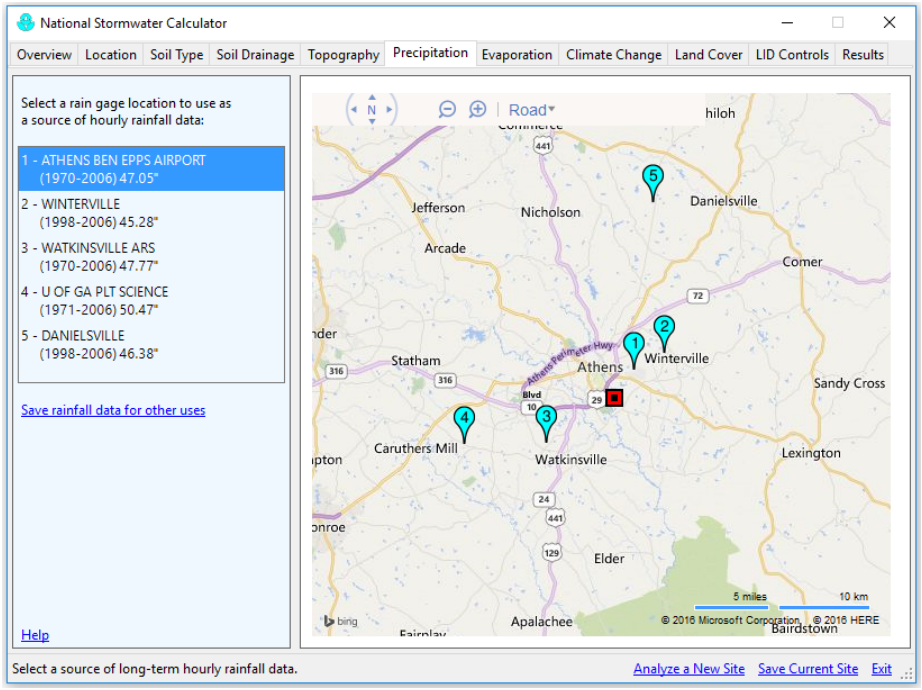
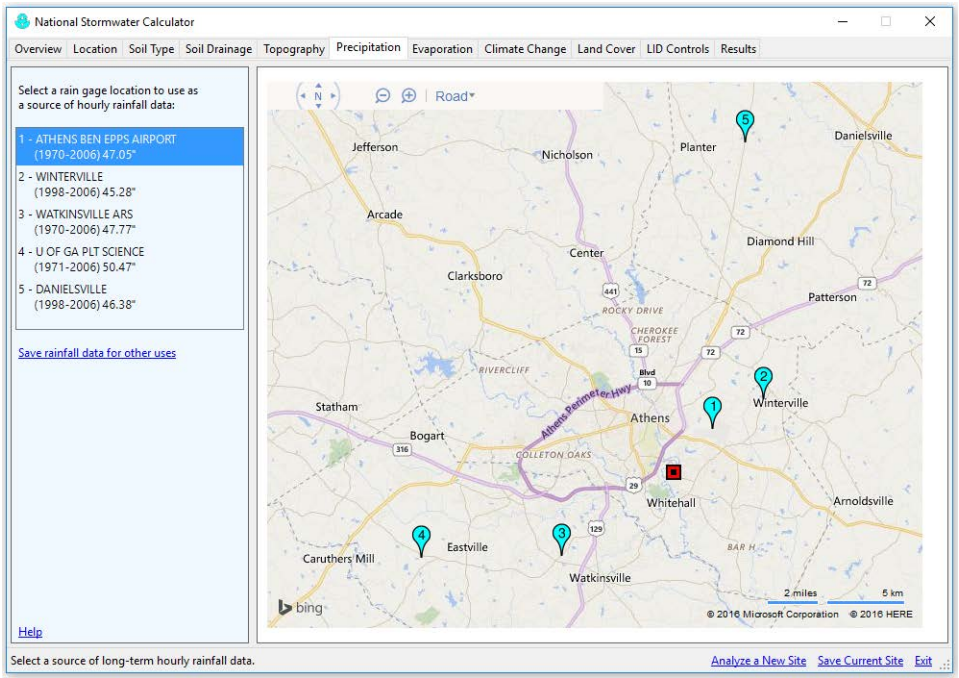
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

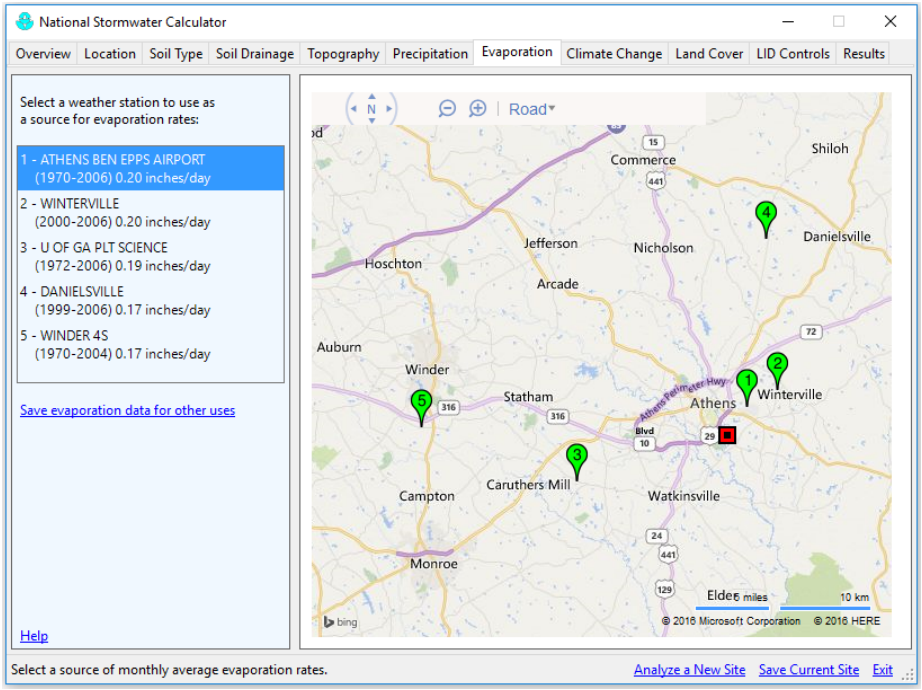
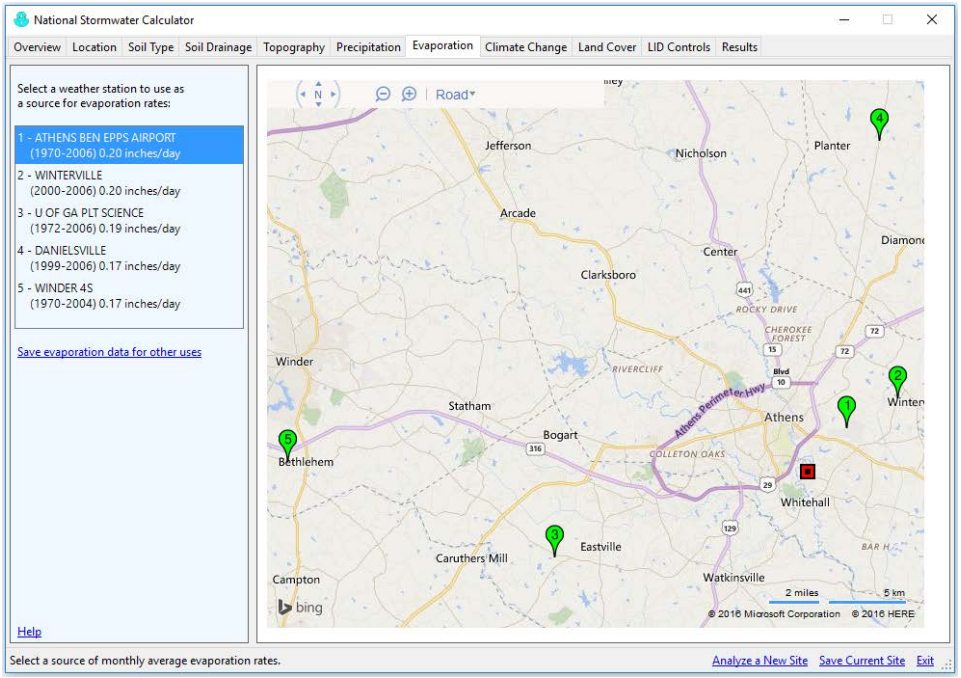
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

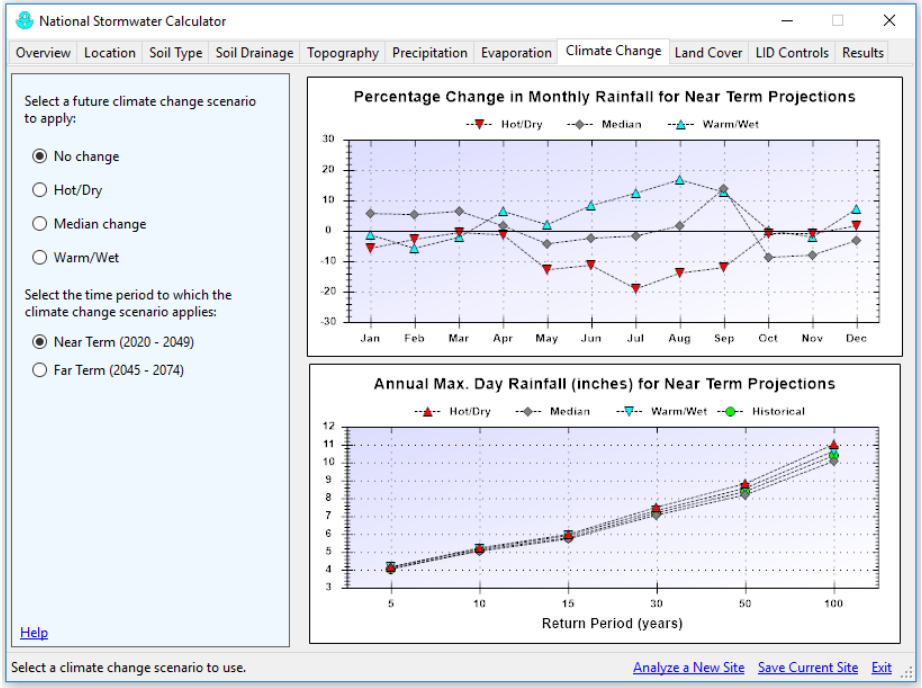
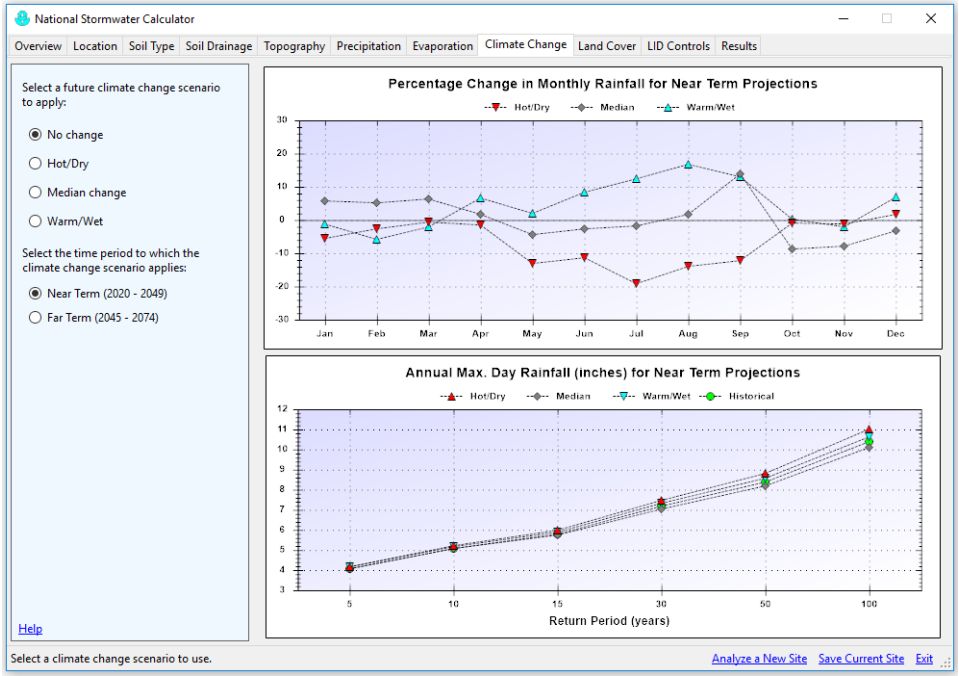
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

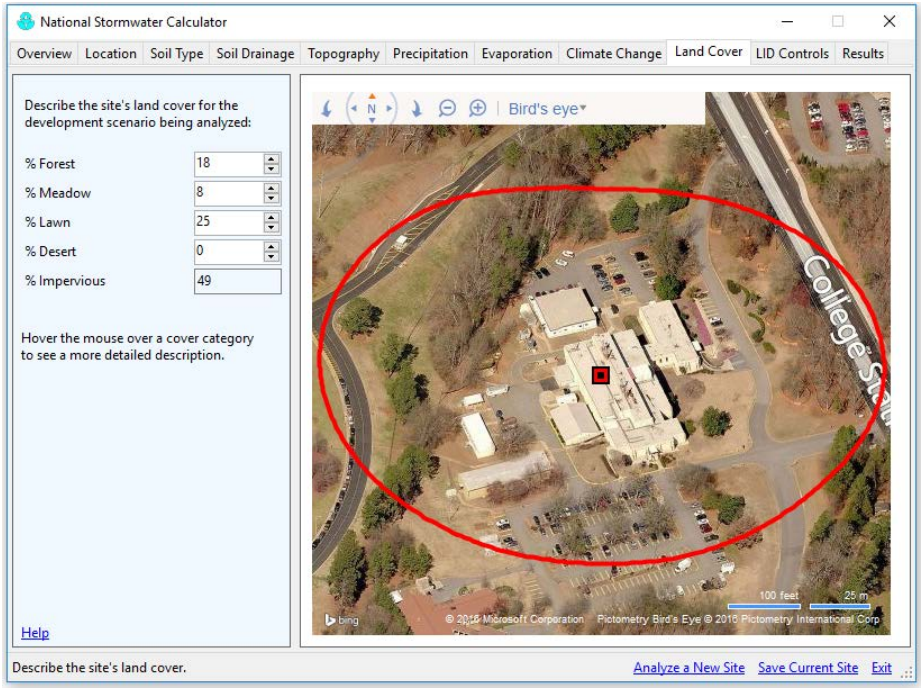
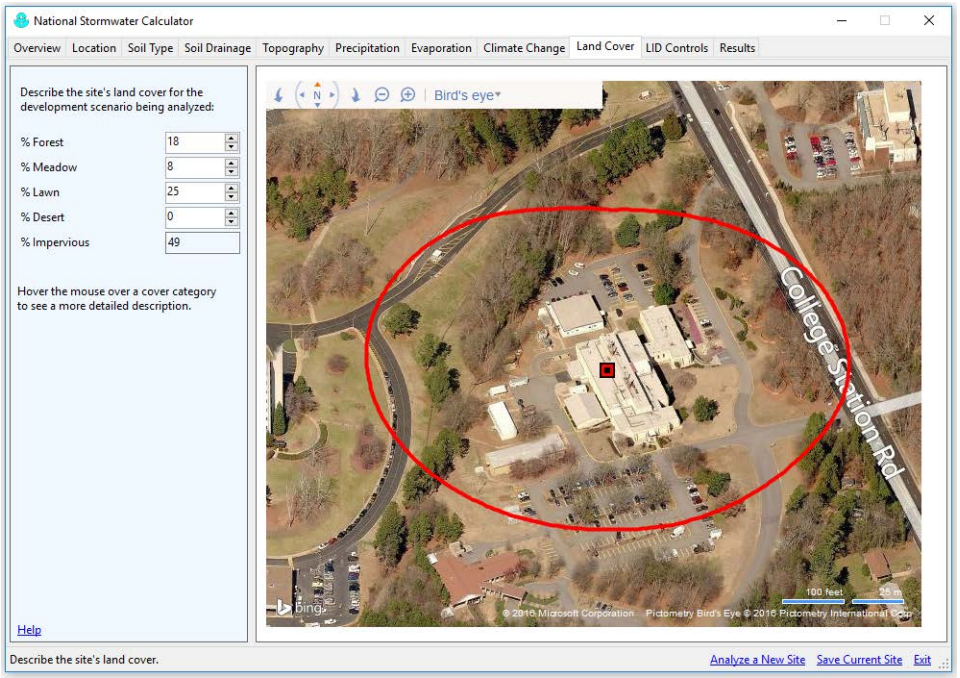
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

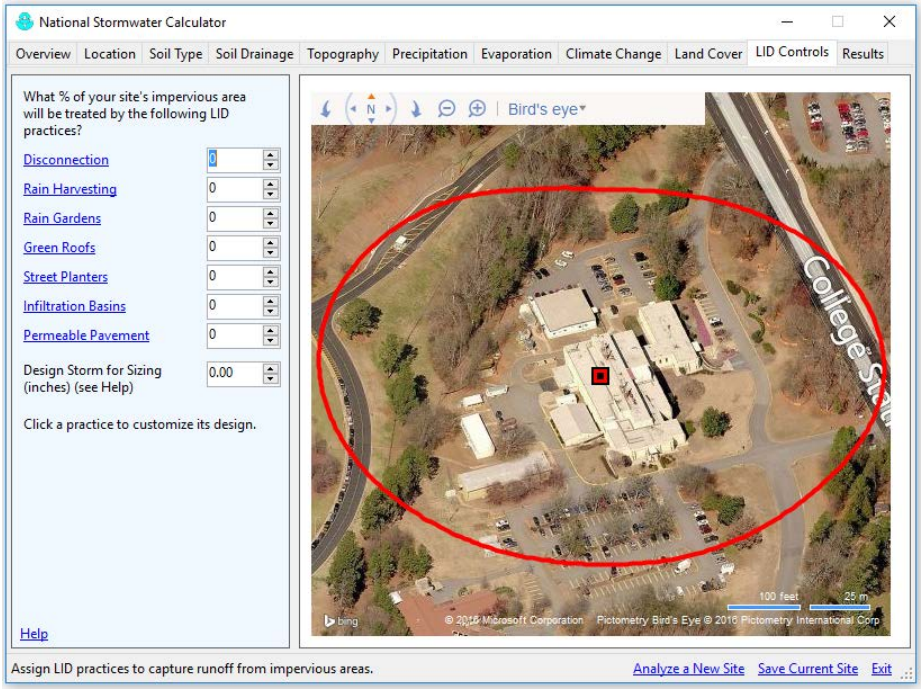
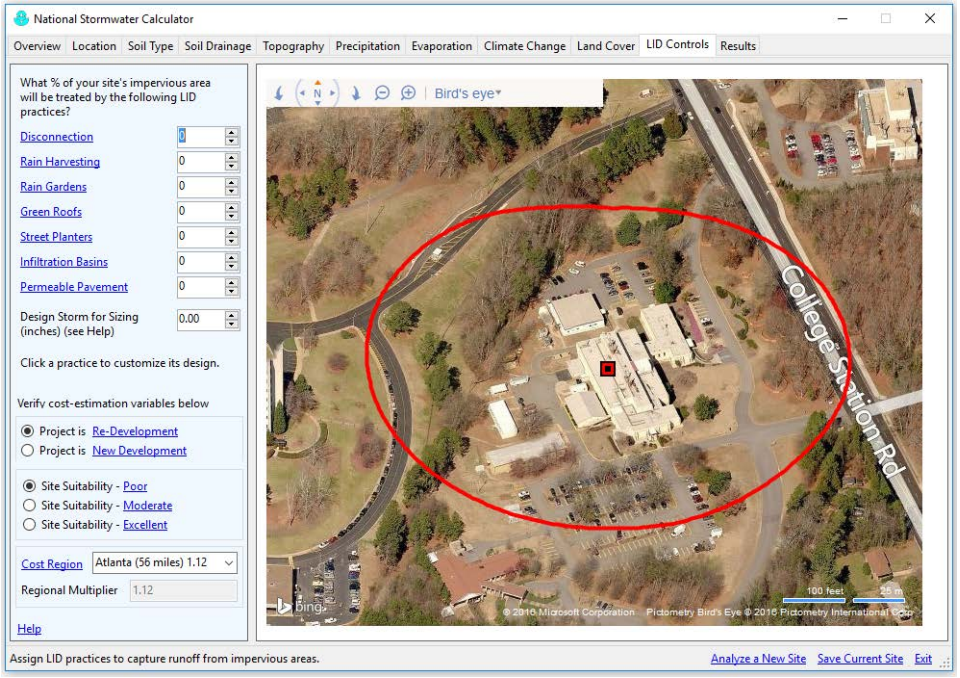
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

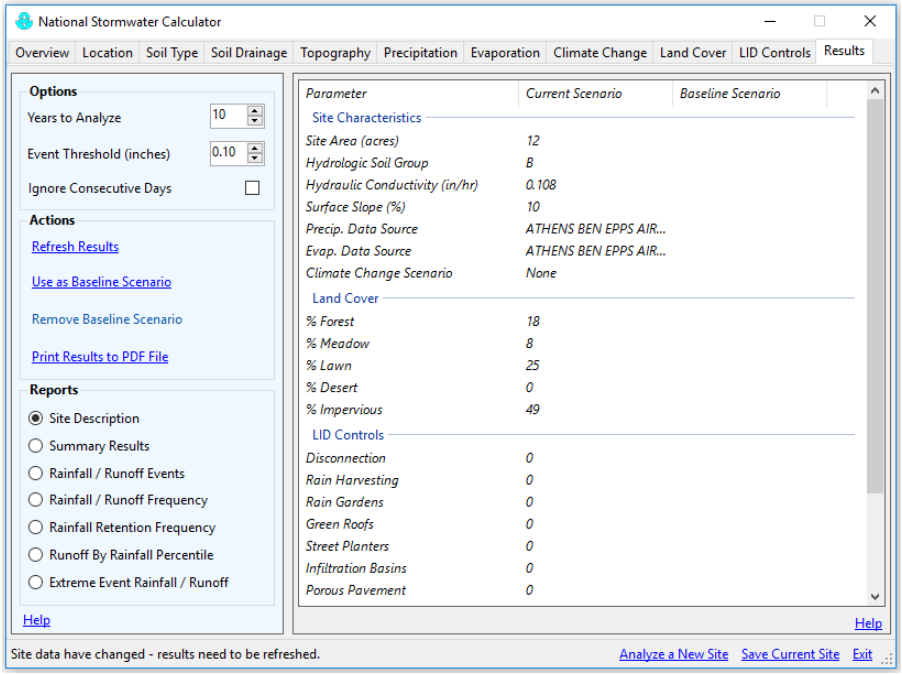
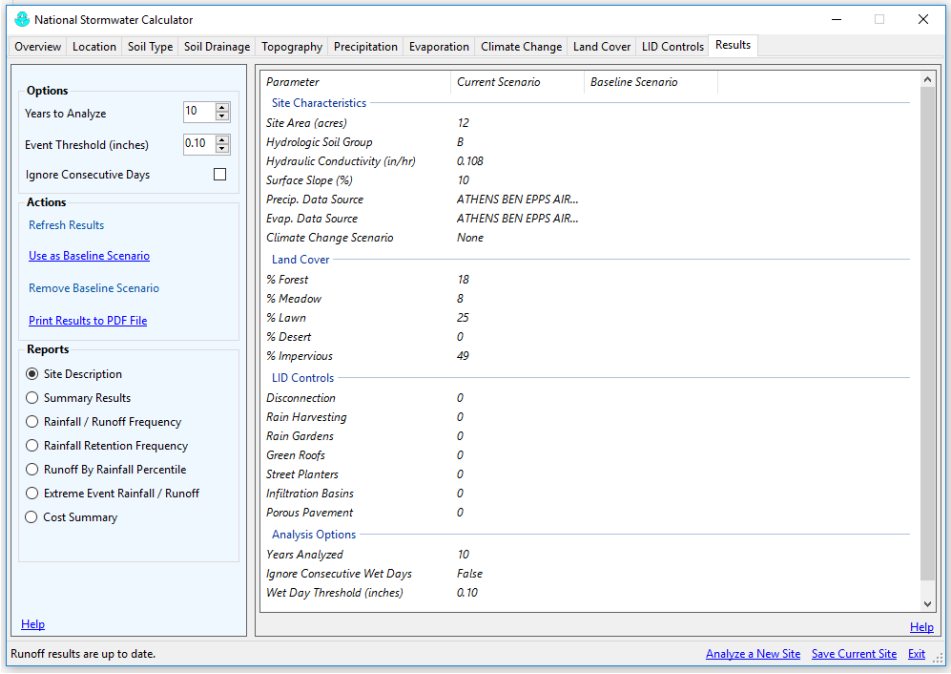
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

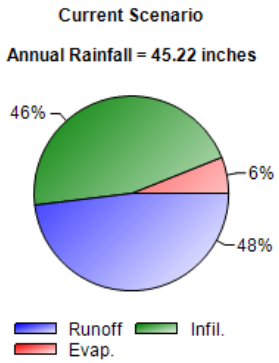
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

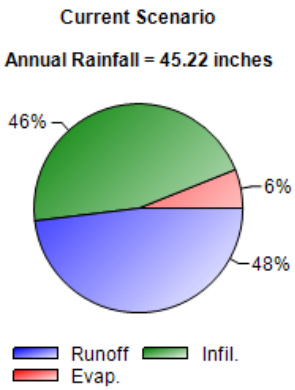
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

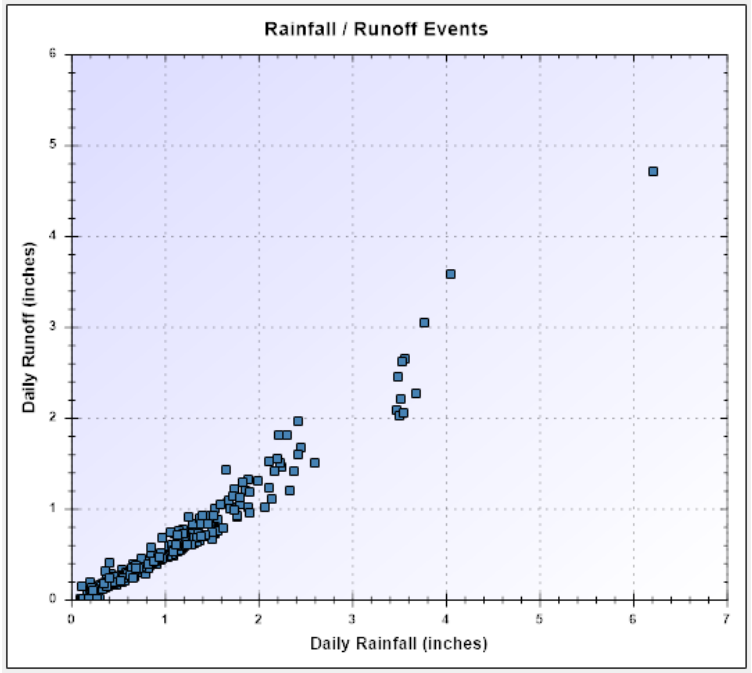
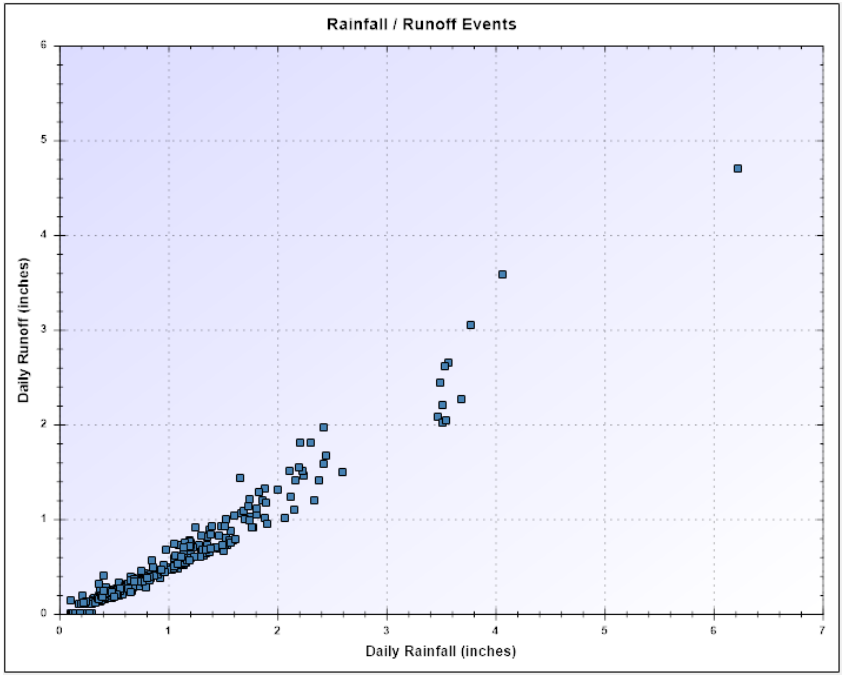
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA

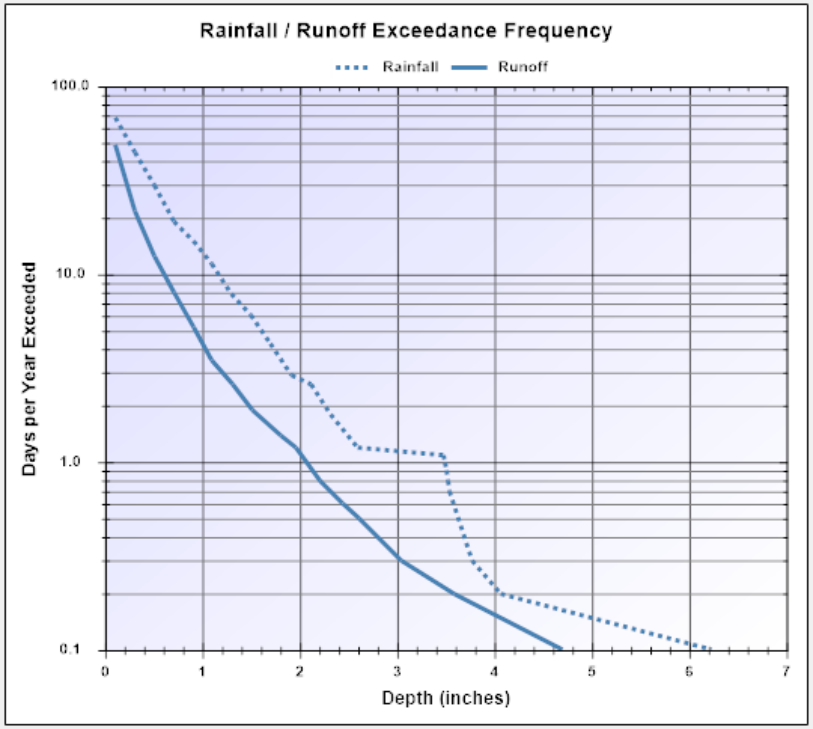
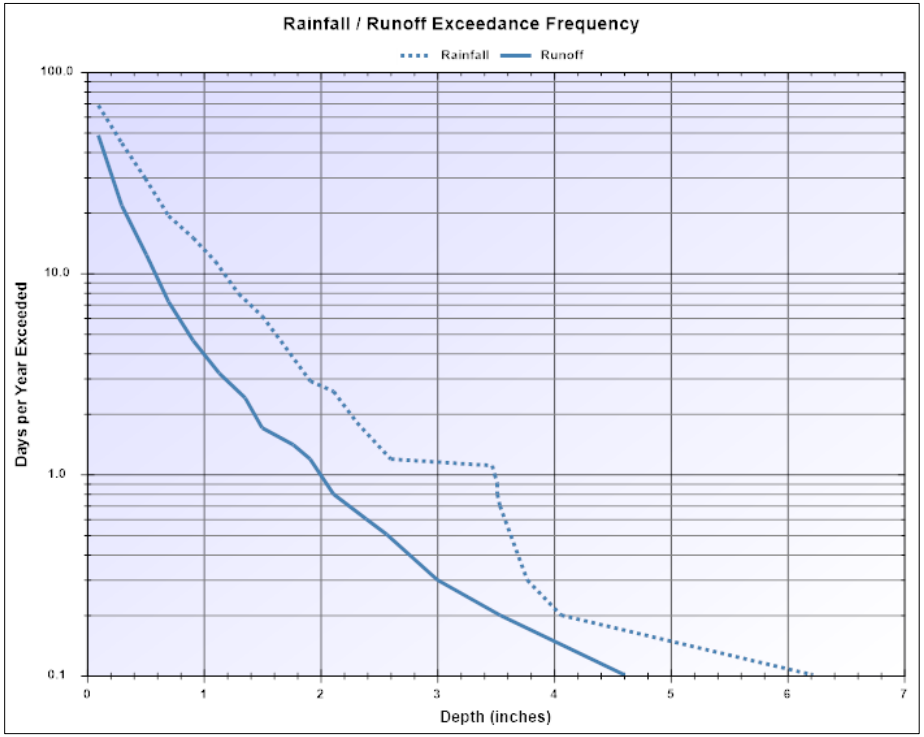


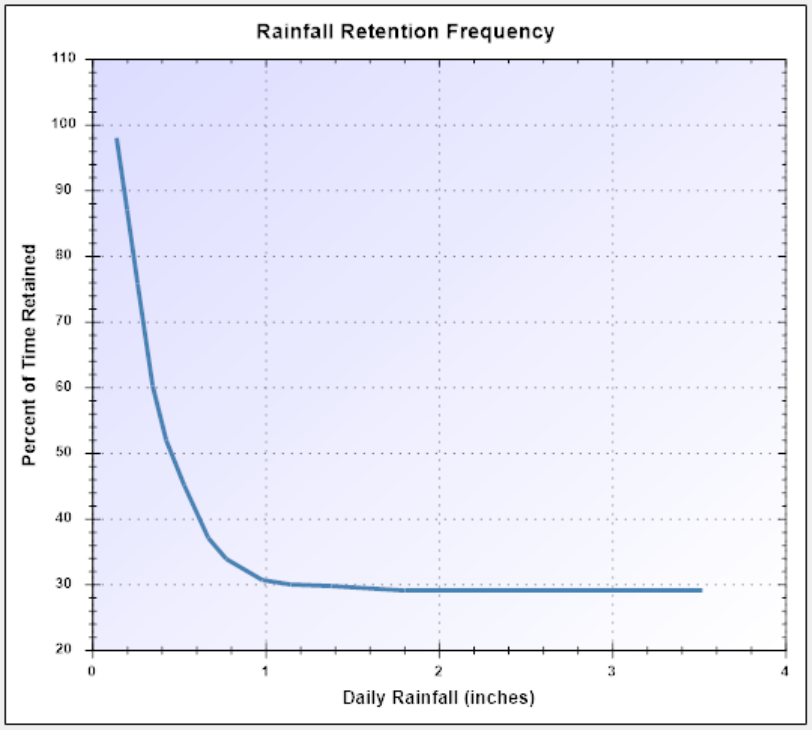
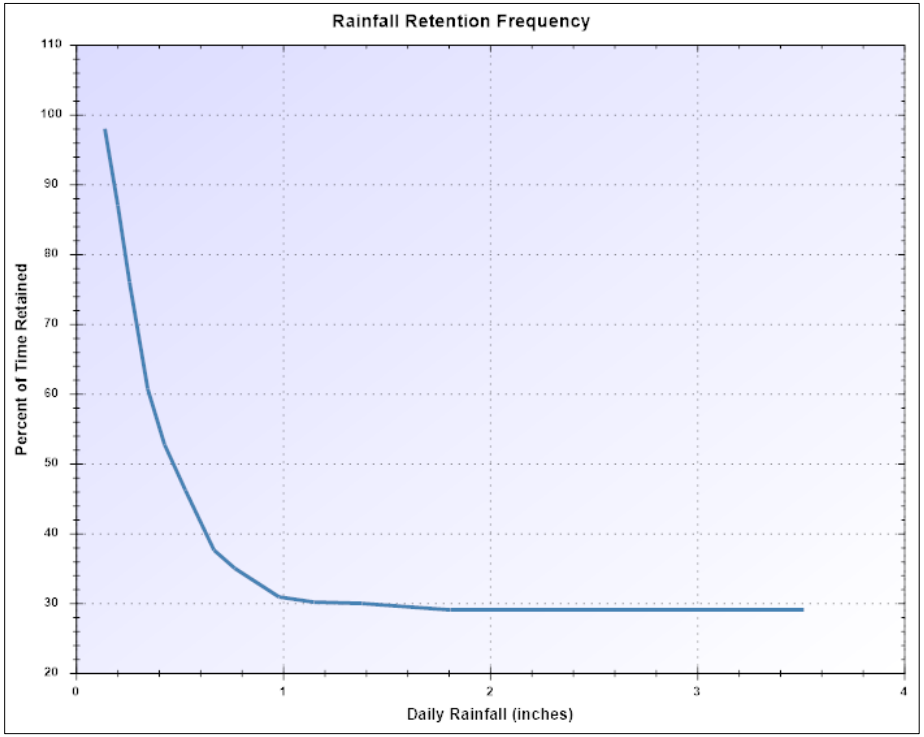
Statistic	*Current Scenario*	*Baseline Scenario*
Average Annual Rainfall (inches)	*45.22*	
Average Annual Runoff (inches)	*22.30*	
Days per Year With Rainfall	*68.46*	
Days per Year with Runoff	*48.57*	
Percent of Wet Days Retained	*29.05*	
Smallest Rainfall w/ Runoff (inches)	*0.11*	
Largest Rainfall w/o Runoff (inches)	*0.30*	
Max. Rainfall Retained (inches)	*1.52*	

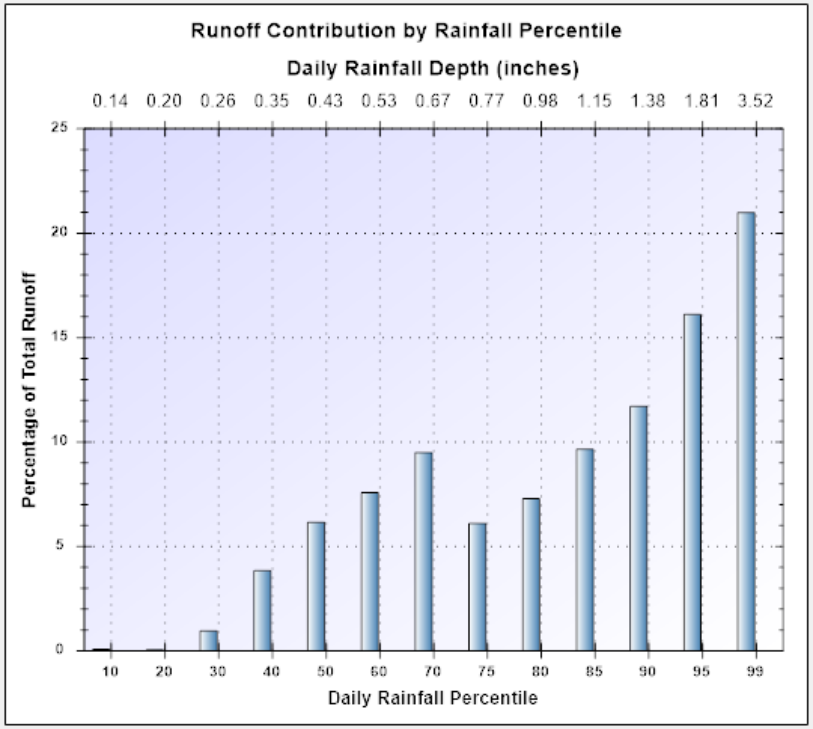
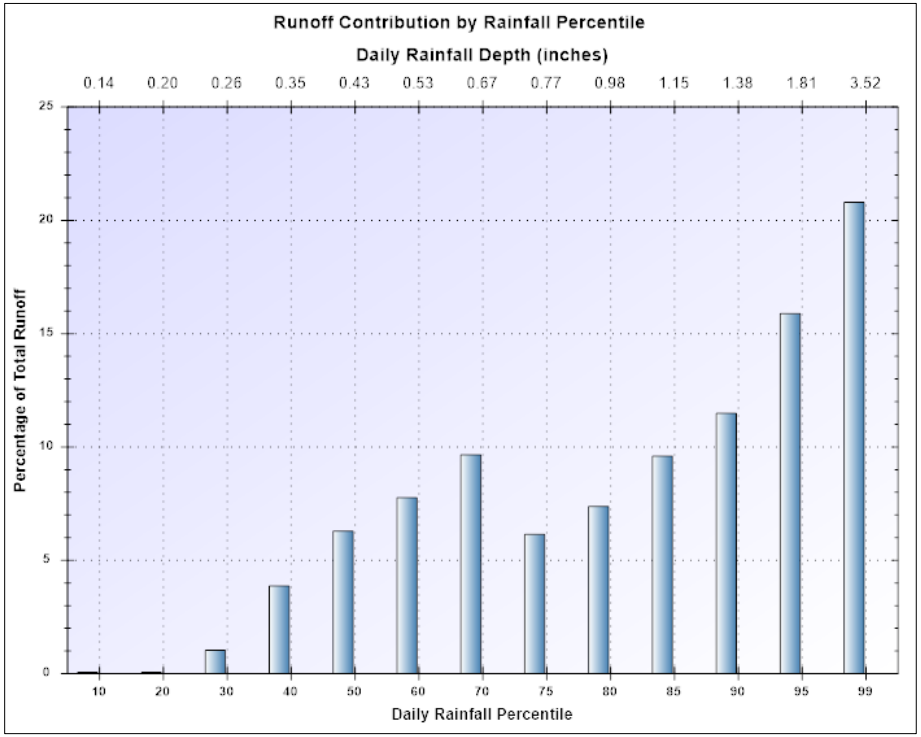


Statistic	*Current Scenario*	*Baseline Scenario*
Average Annual Rainfall (inches)	*45.22*	
Average Annual Runoff (inches)	*22.30*	
Days per Year With Rainfall	*68.46*	
Days per Year with Runoff	*48.57*	
Percent of Wet Days Retained	*29.05*	
Smallest Rainfall w/ Runoff (inches)	*0.11*	
Largest Rainfall w/o Runoff (inches)	*0.30*	
Max. Rainfall Retained (inches)	*1.52*	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

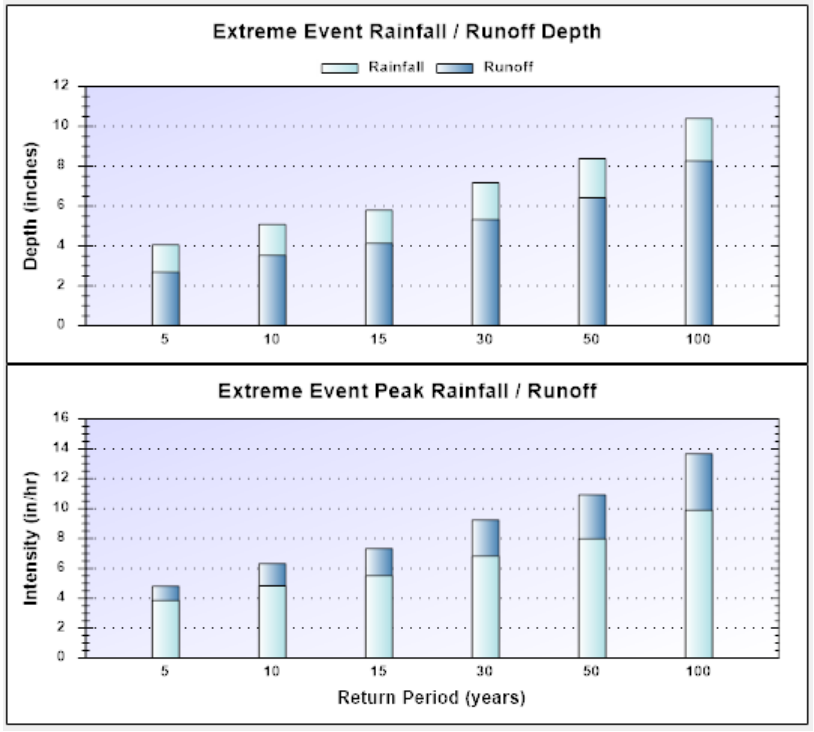
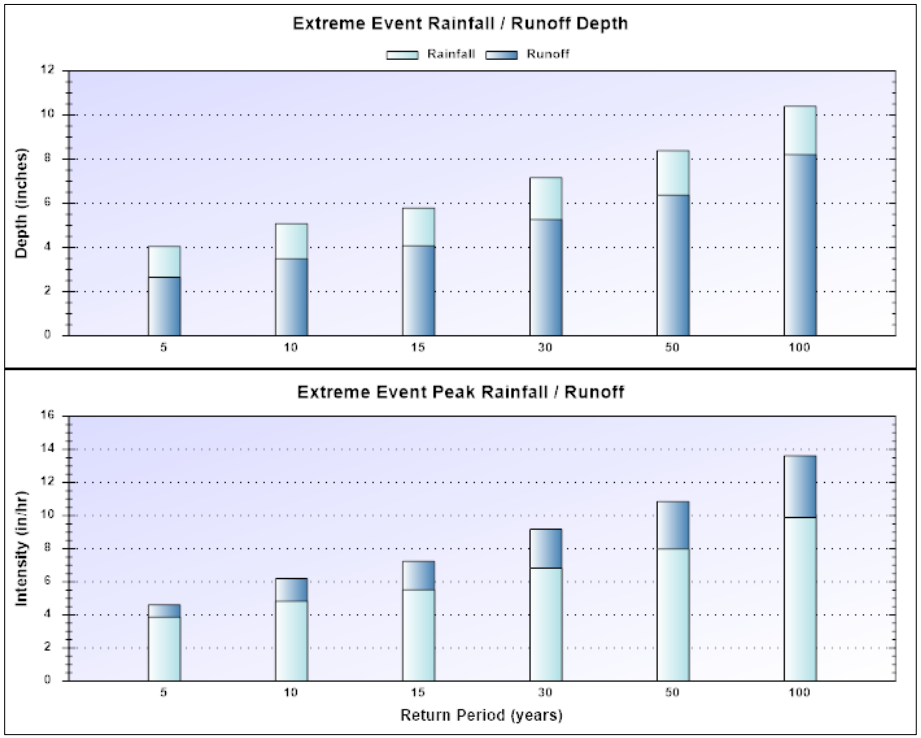
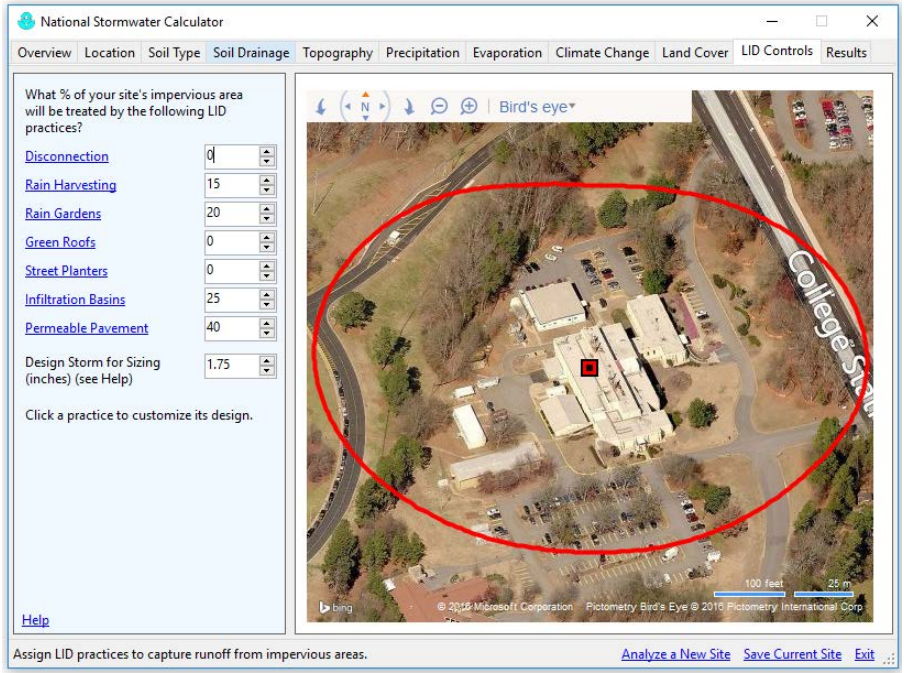
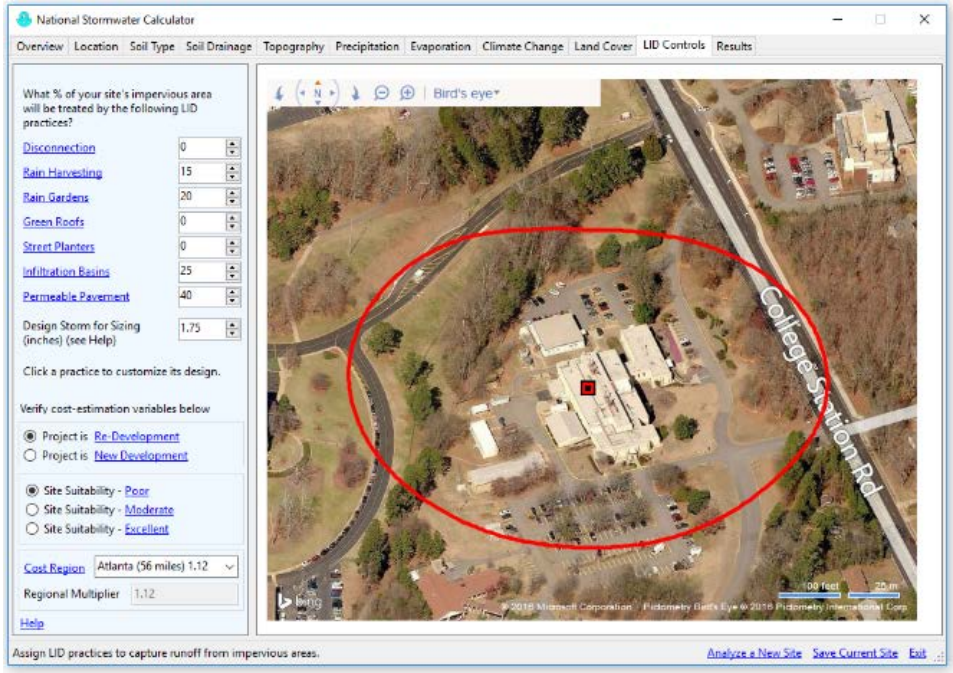
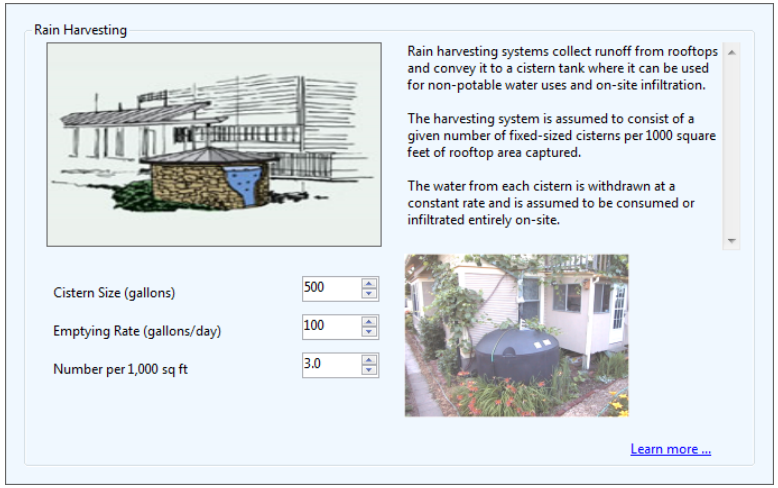
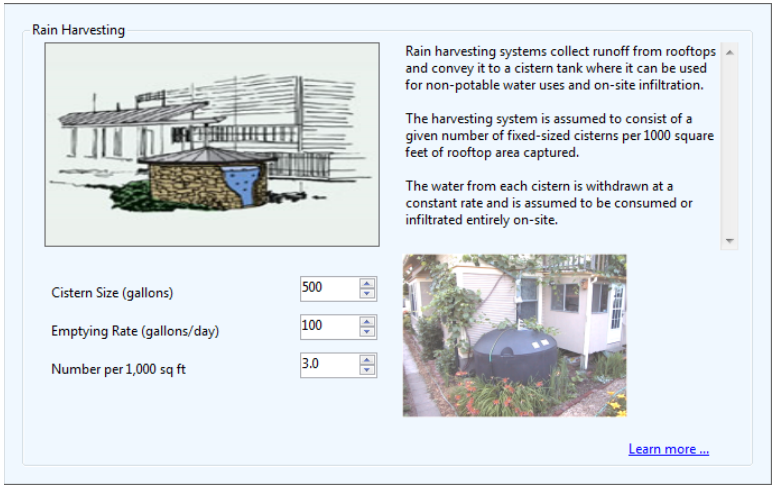
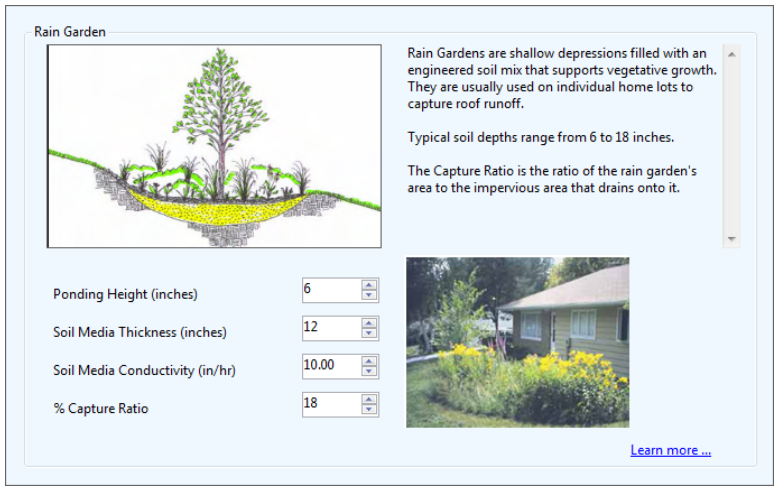
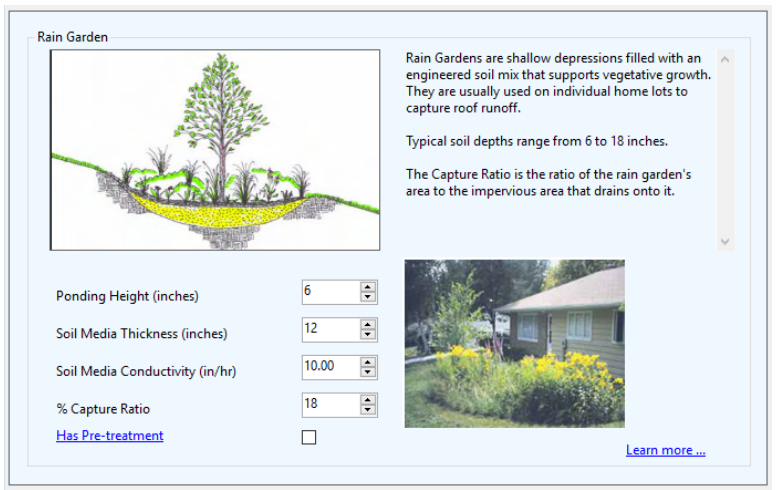
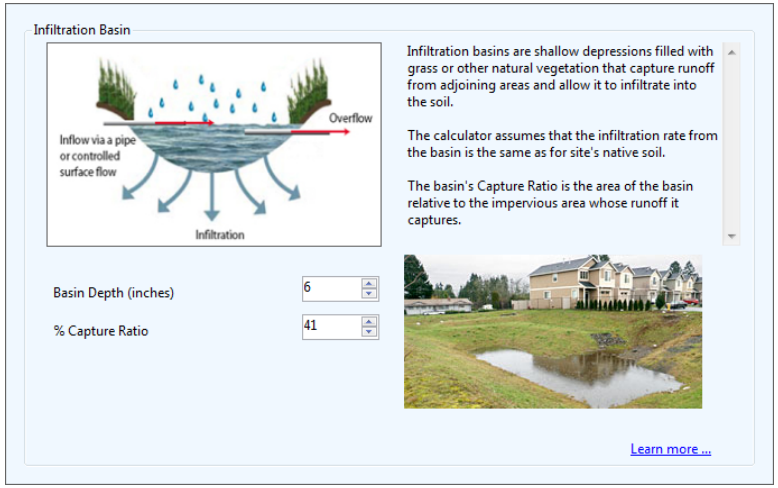
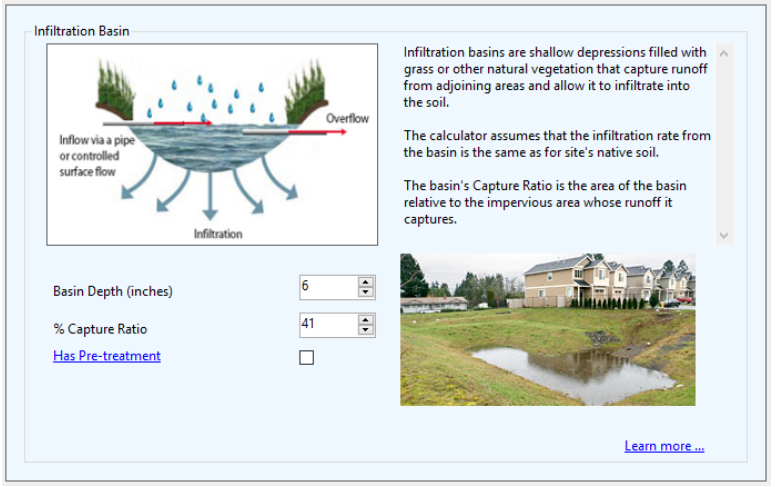
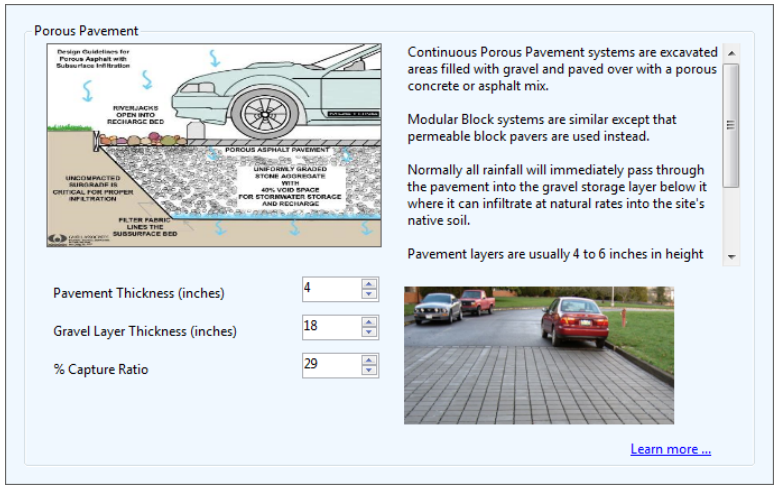
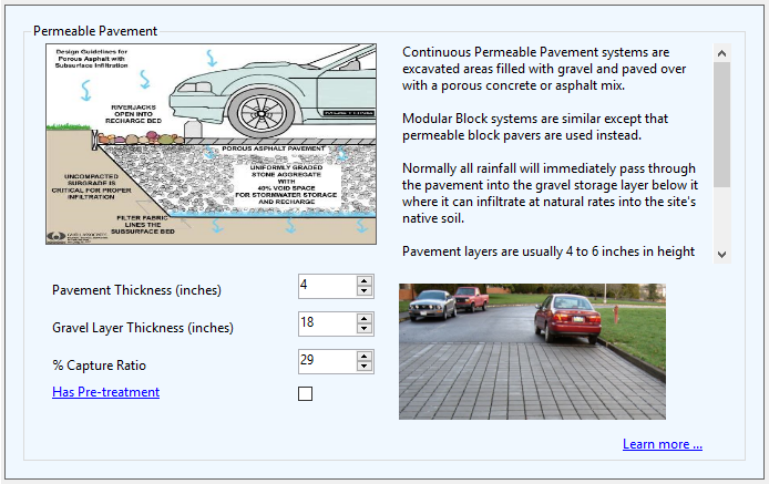
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition **Baseline Scenario -** NA
	

Table B-2: Side-by-side Screenshots Comparing Previous and Current Versions of the SWC (Post-development Condition with LID Controls)

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition
	
	

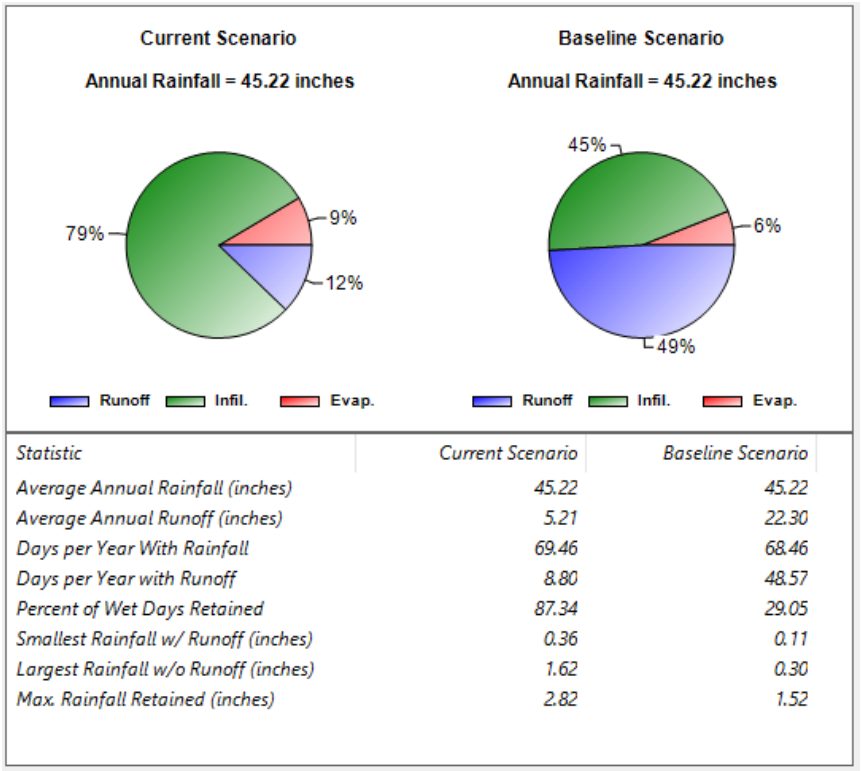
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition
	
	

SWC Version 1.1.0.2

(previous version)

Current Scenario - Post-development condition with LID controls

Baseline Scenario - Post-development condition



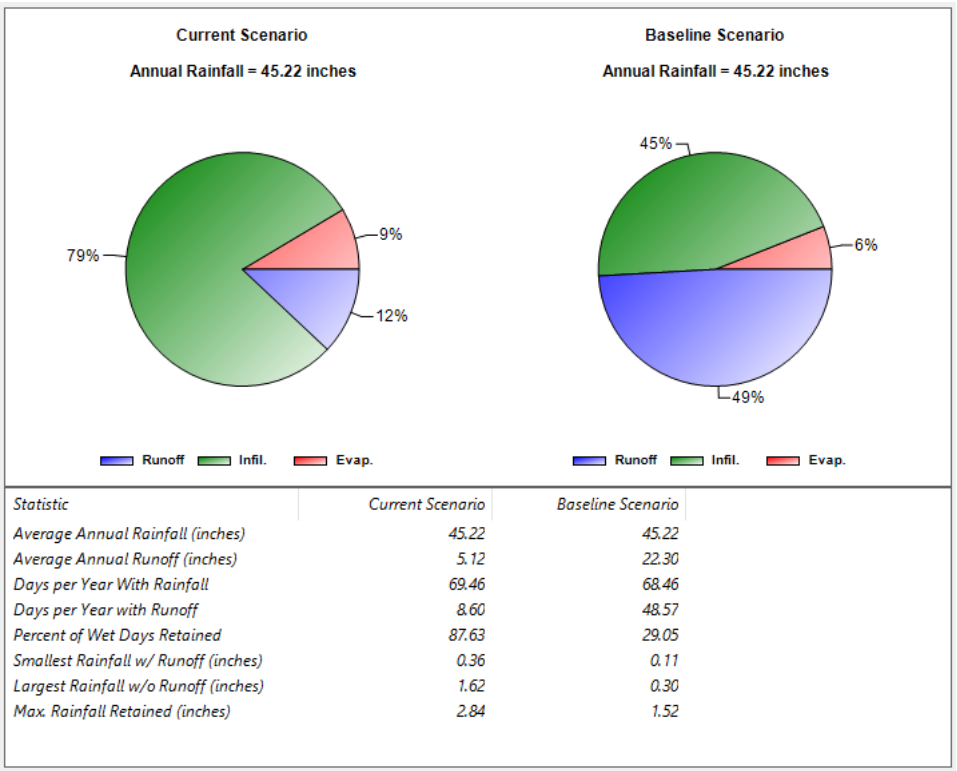
Statistic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	45.22	45.22
Average Annual Runoff (inches)	5.21	22.30
Days per Year With Rainfall	69.46	68.46
Days per Year with Runoff	8.80	48.57
Percent of Wet Days Retained	87.34	29.05
Smallest Rainfall w/ Runoff (inches)	0.36	0.11
Largest Rainfall w/o Runoff (inches)	1.62	0.30
Max. Rainfall Retained (inches)	2.82	1.52

SWC Version 1.2.0.0

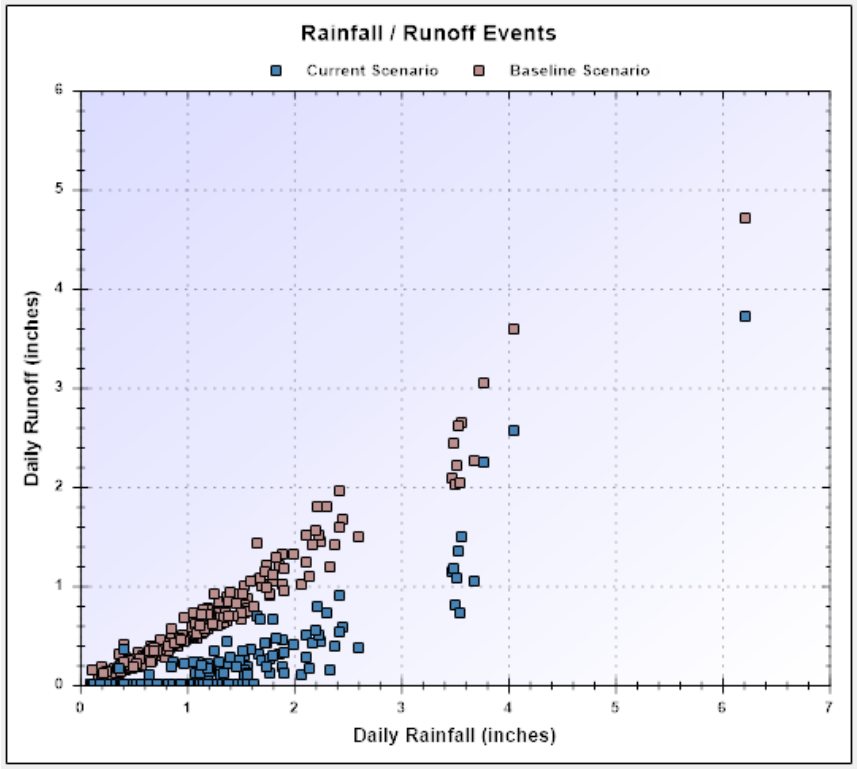
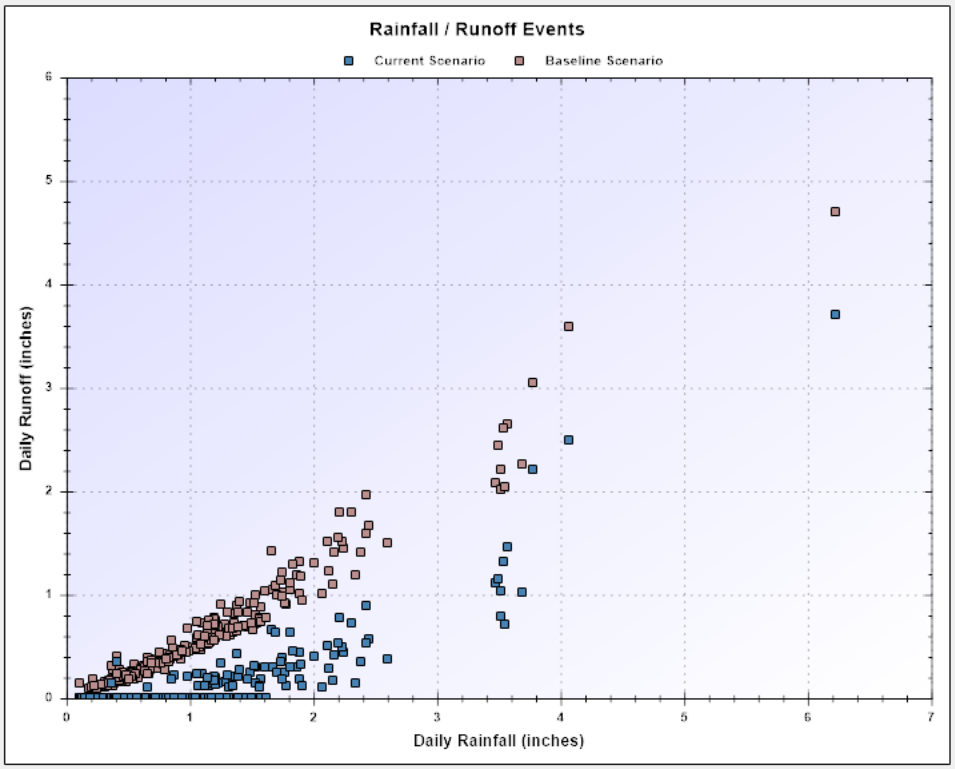
(Updated Cost Capable Version)

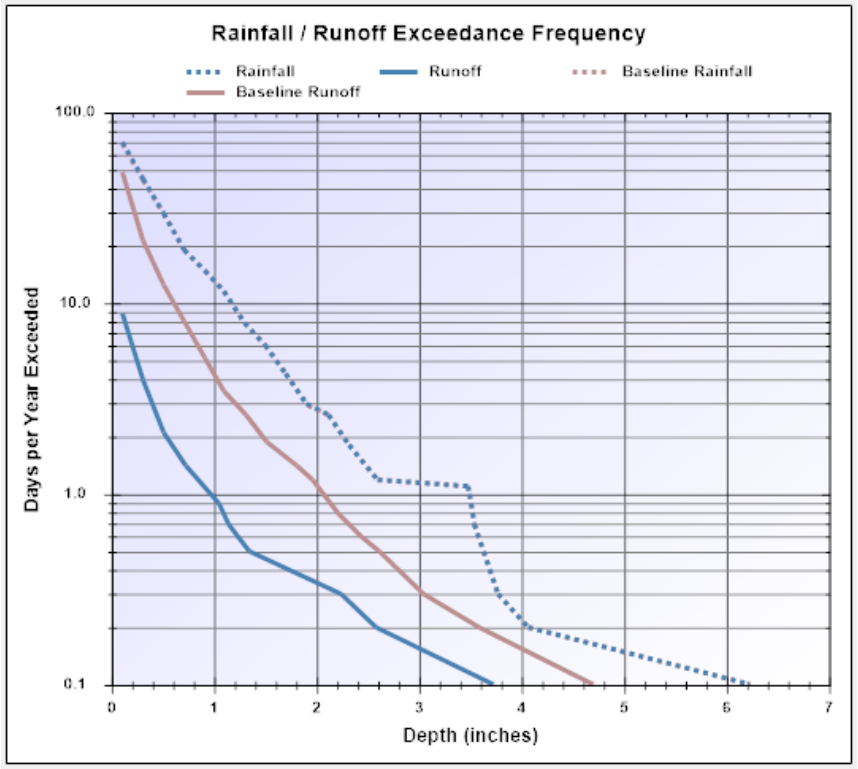
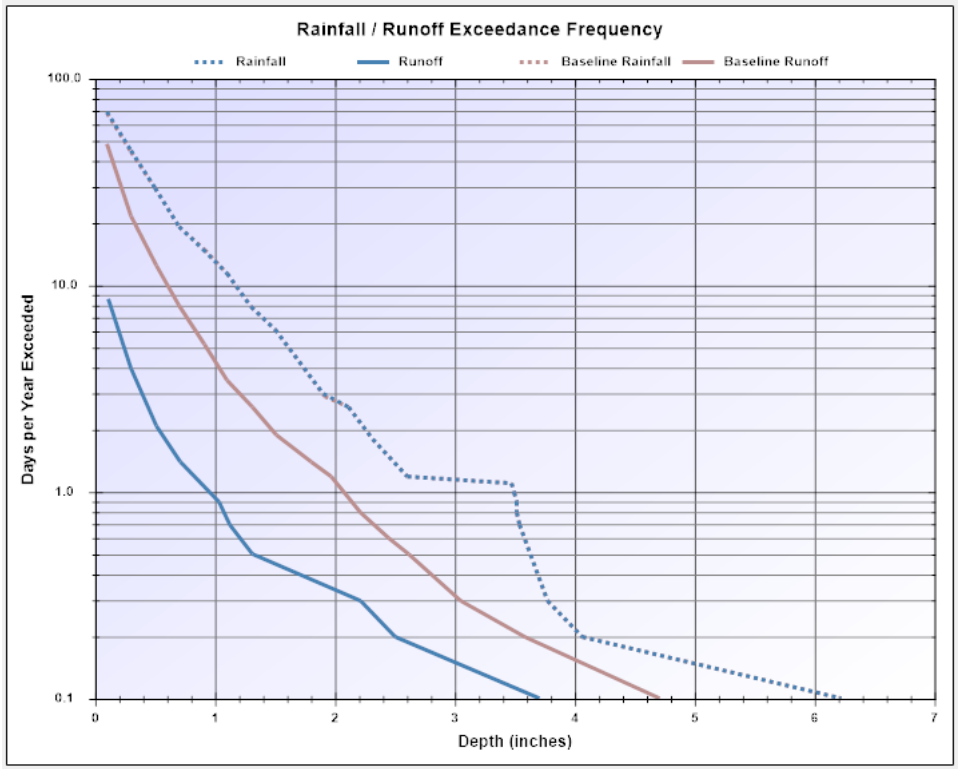
Current Scenario - Post-development condition with LID controls

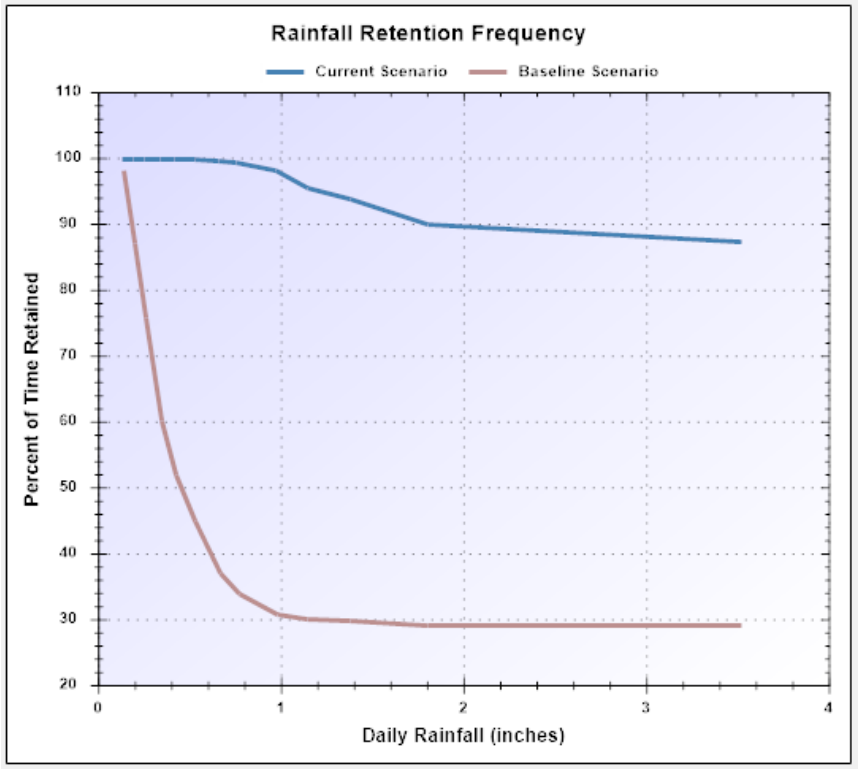
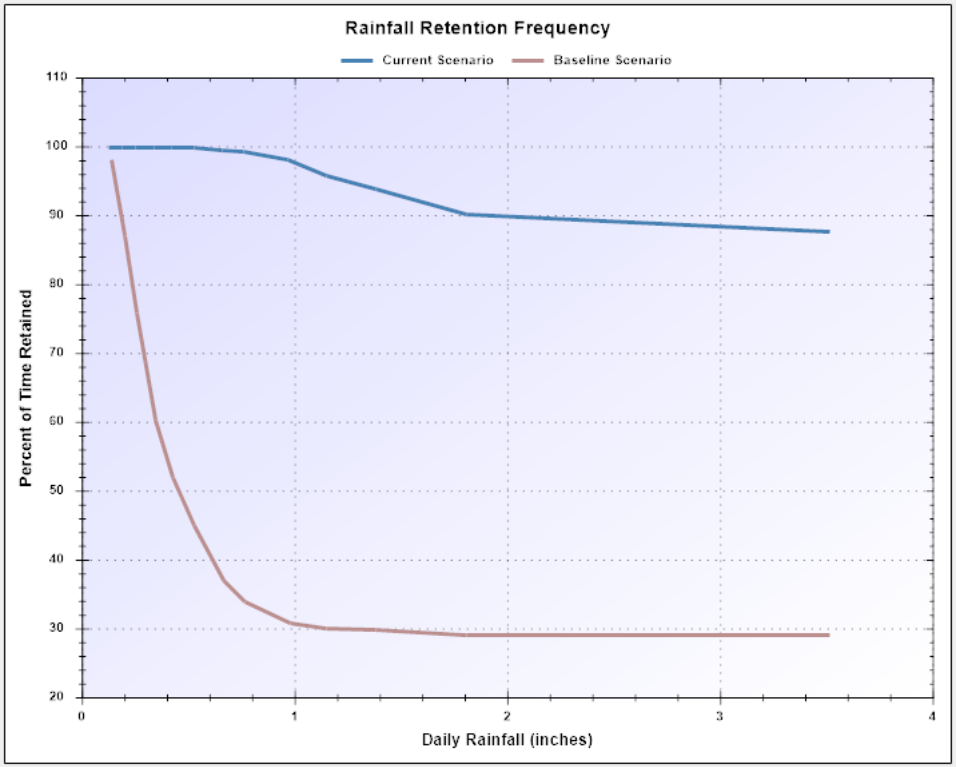
Baseline Scenario - Post-development condition

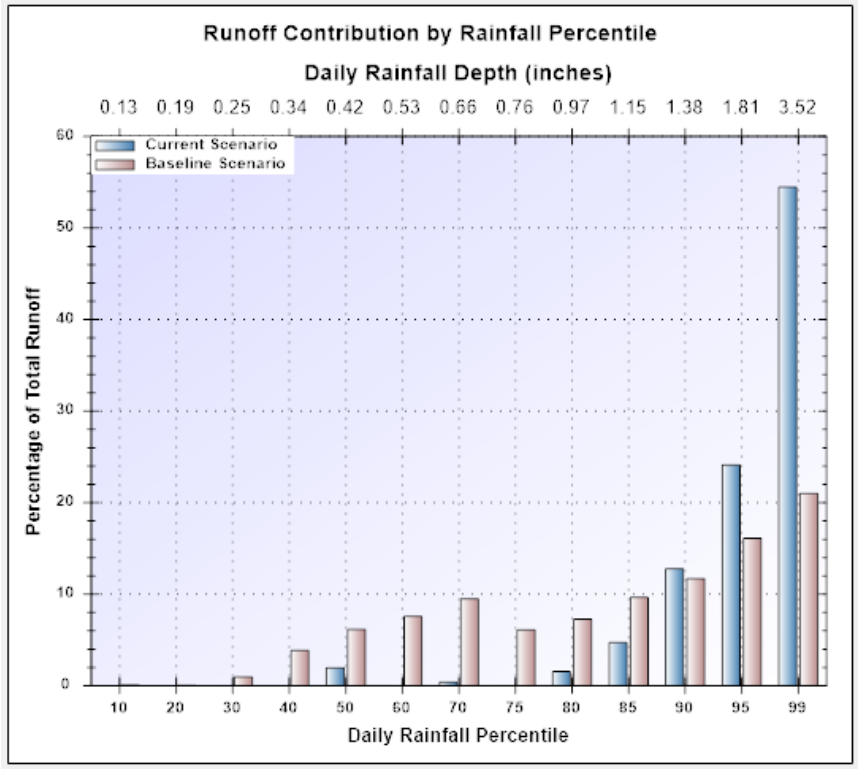
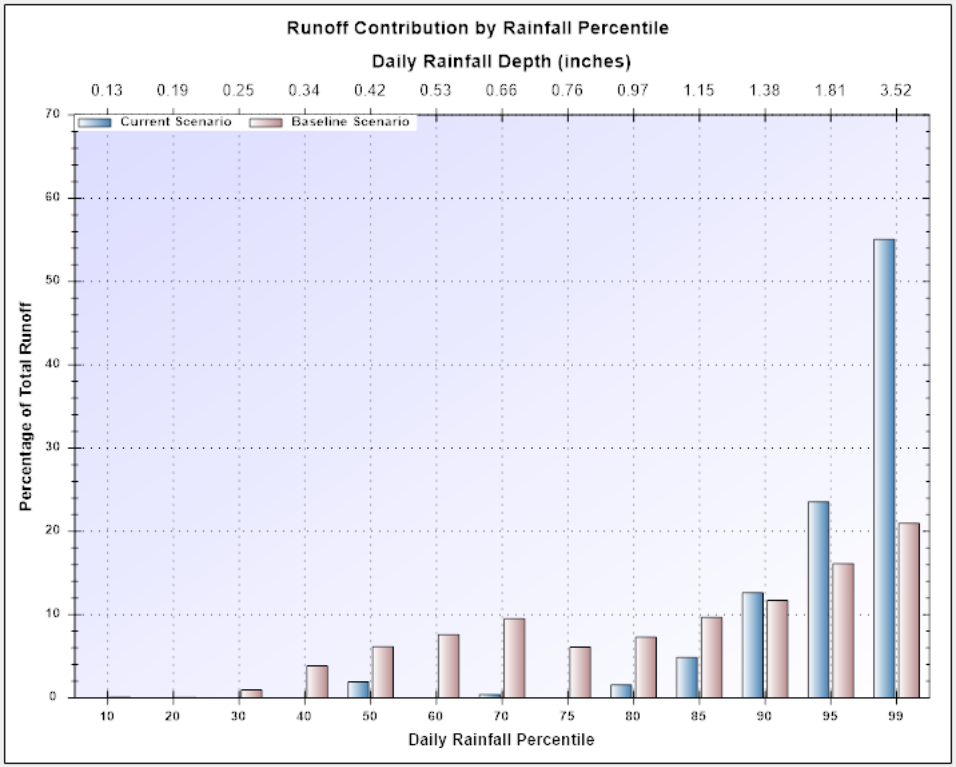


Statistic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	45.22	45.22
Average Annual Runoff (inches)	5.12	22.30
Days per Year With Rainfall	69.46	68.46
Days per Year with Runoff	8.60	48.57
Percent of Wet Days Retained	87.63	29.05
Smallest Rainfall w/ Runoff (inches)	0.36	0.11
Largest Rainfall w/o Runoff (inches)	1.62	0.30
Max. Rainfall Retained (inches)	2.84	1.52

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition
	

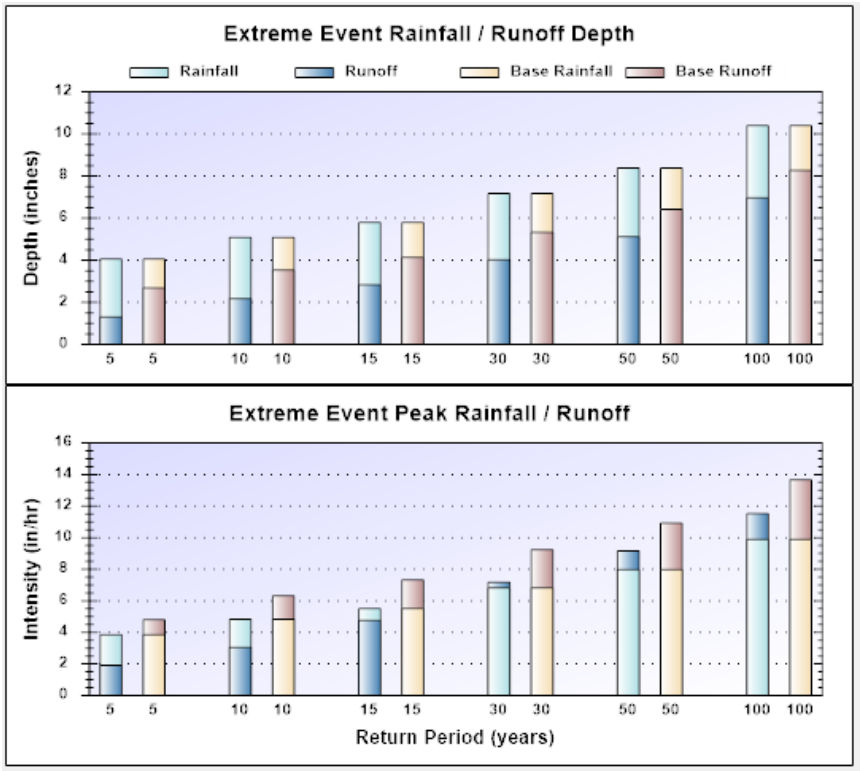
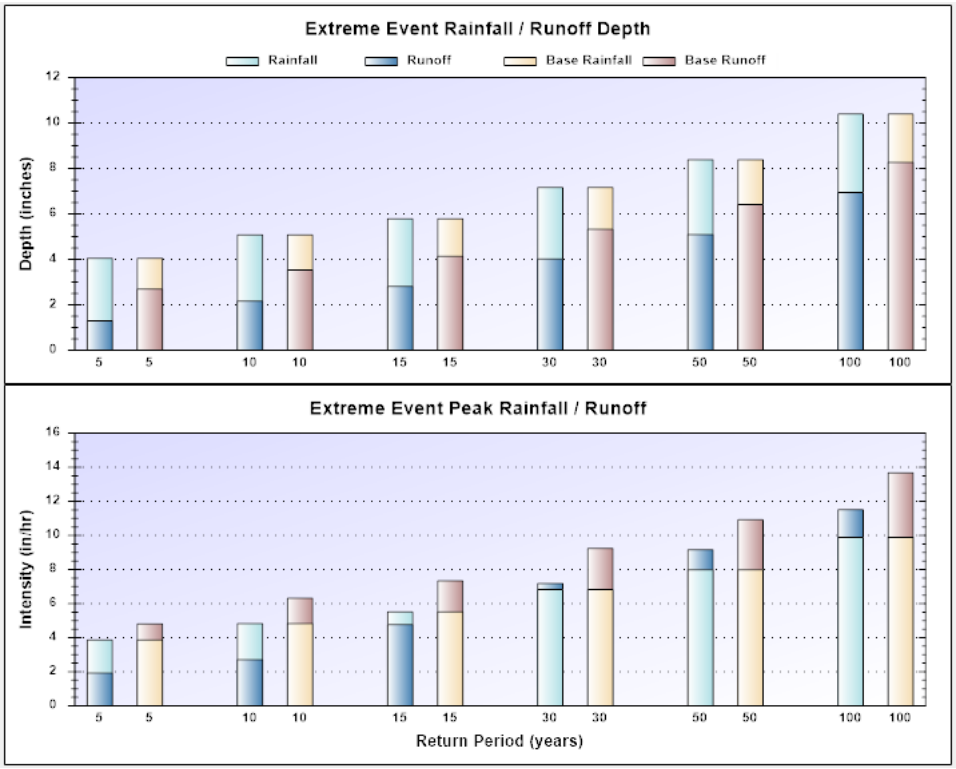
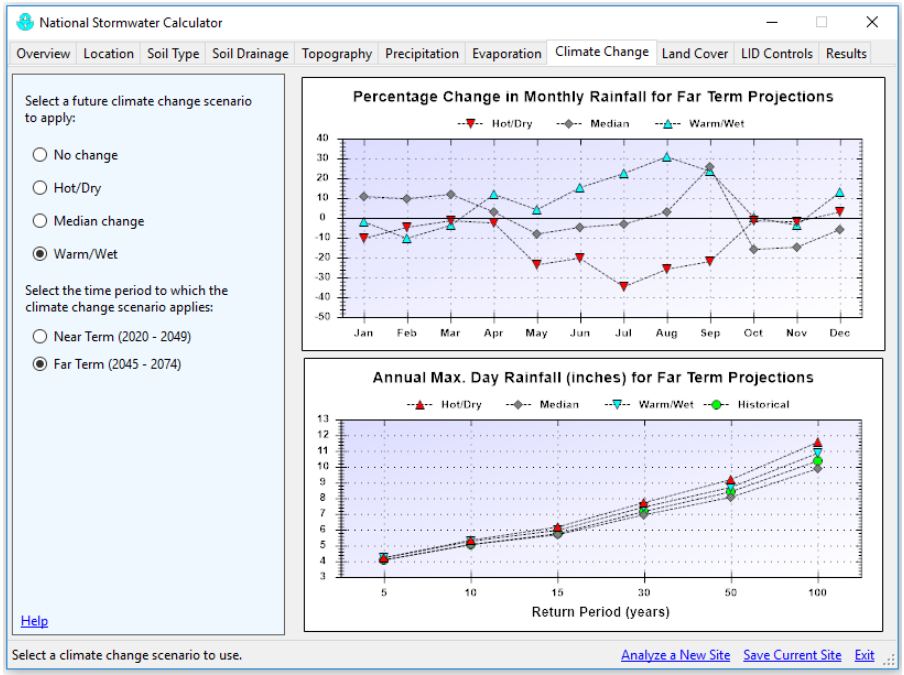
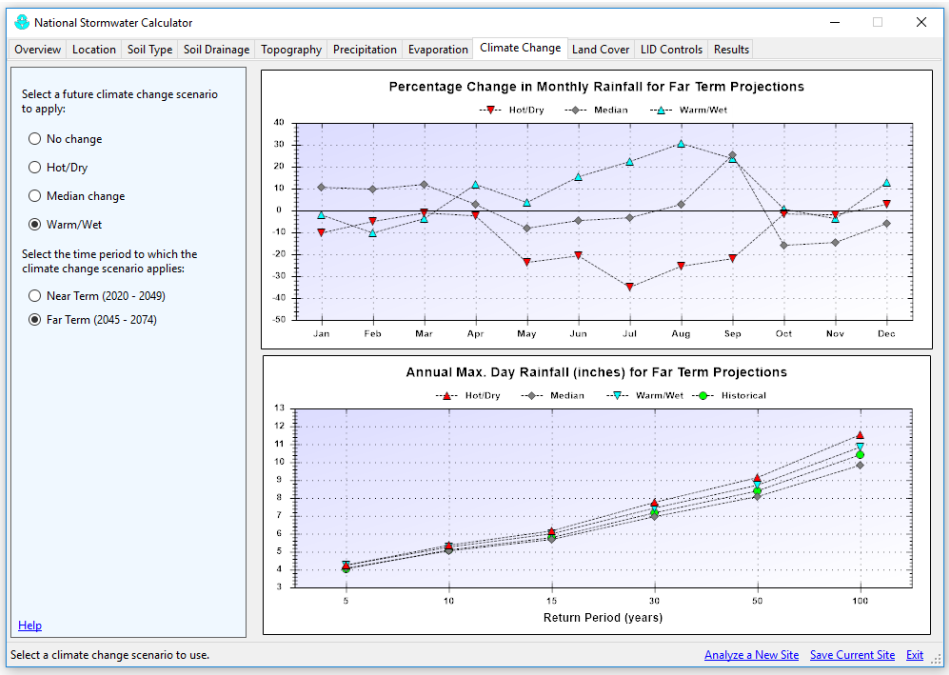
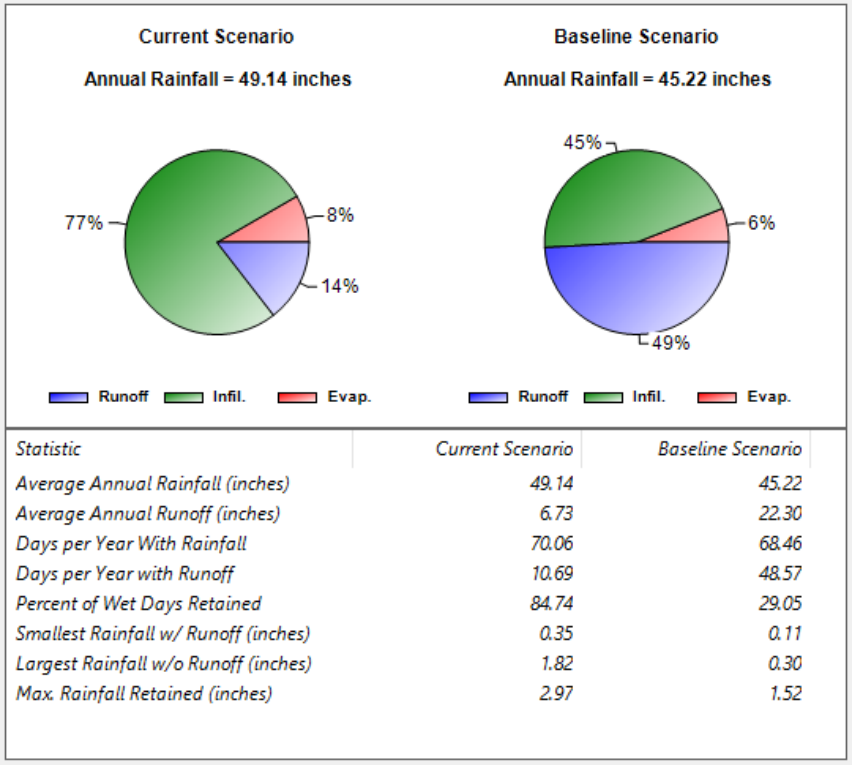
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls **Baseline Scenario -** Post-development condition
	

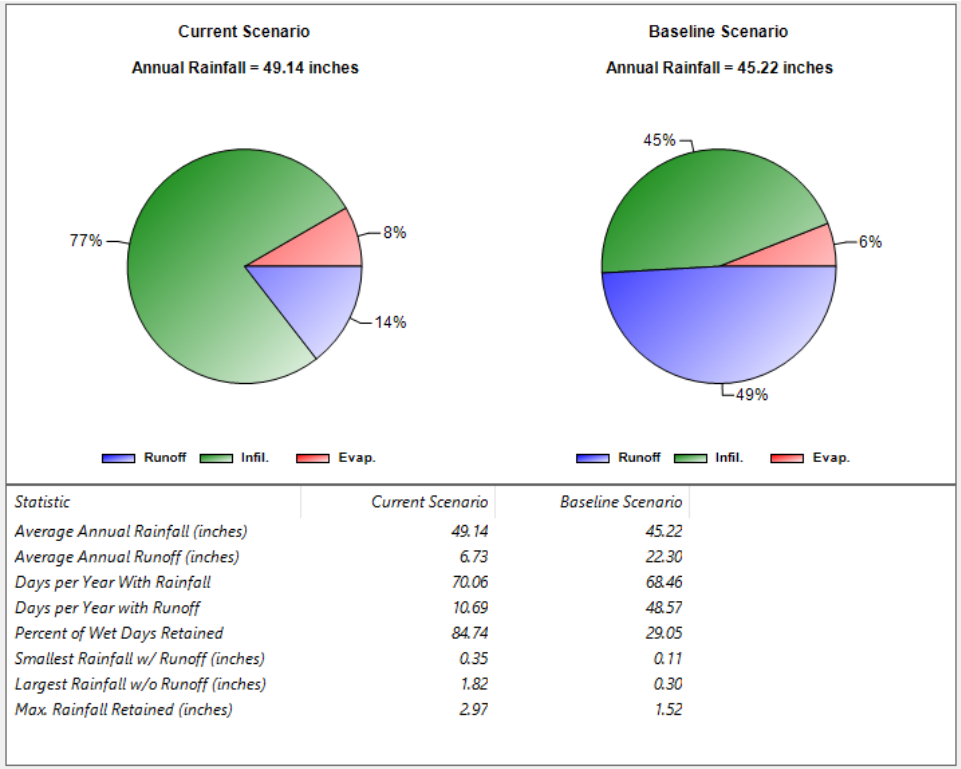
Table B-3: Side-by-side Screenshots Comparing Previous and Current Versions of the SWC (Post-development Condition with LID Controls – Far Term Climate)

SWC Version 1.1.0.2 **(previous version)** **Current Scenario** - Post-development condition with LID controls (Far Term Climate) **Baseline Scenario** - Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario** - Post-development condition with LID controls (Far Term Climate) **Baseline Scenario** - Post-development condition
	

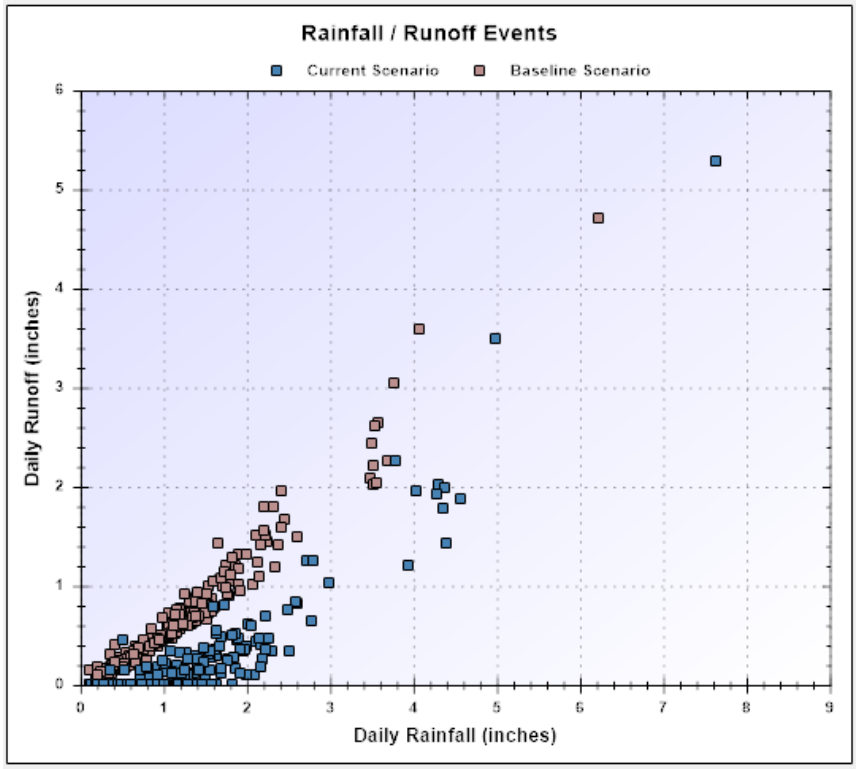
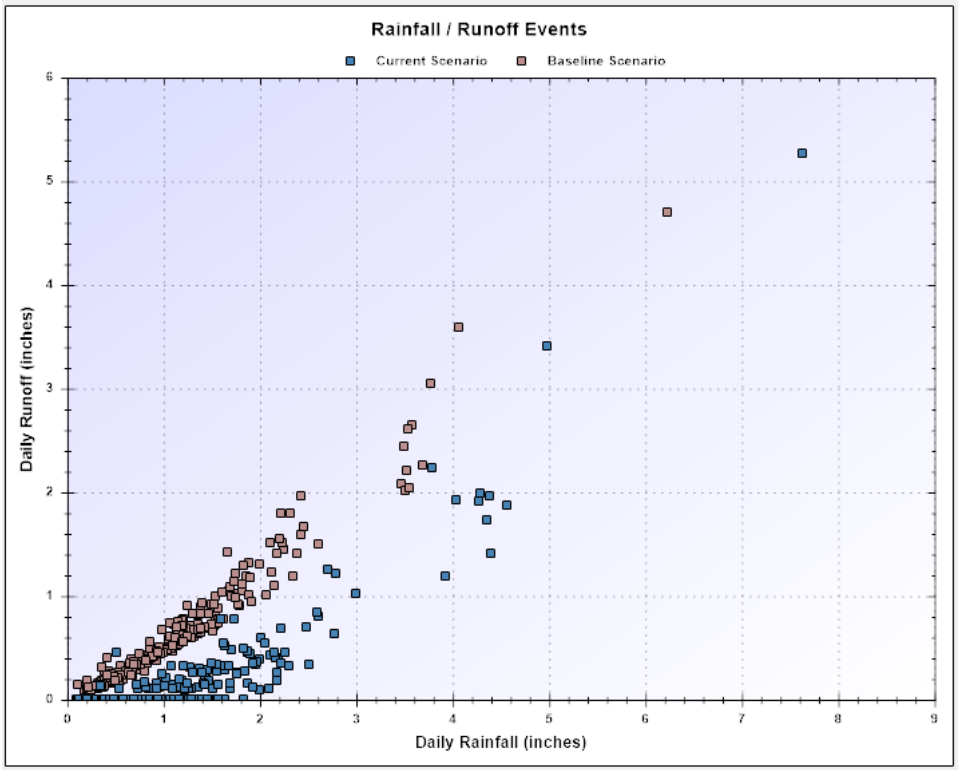
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition

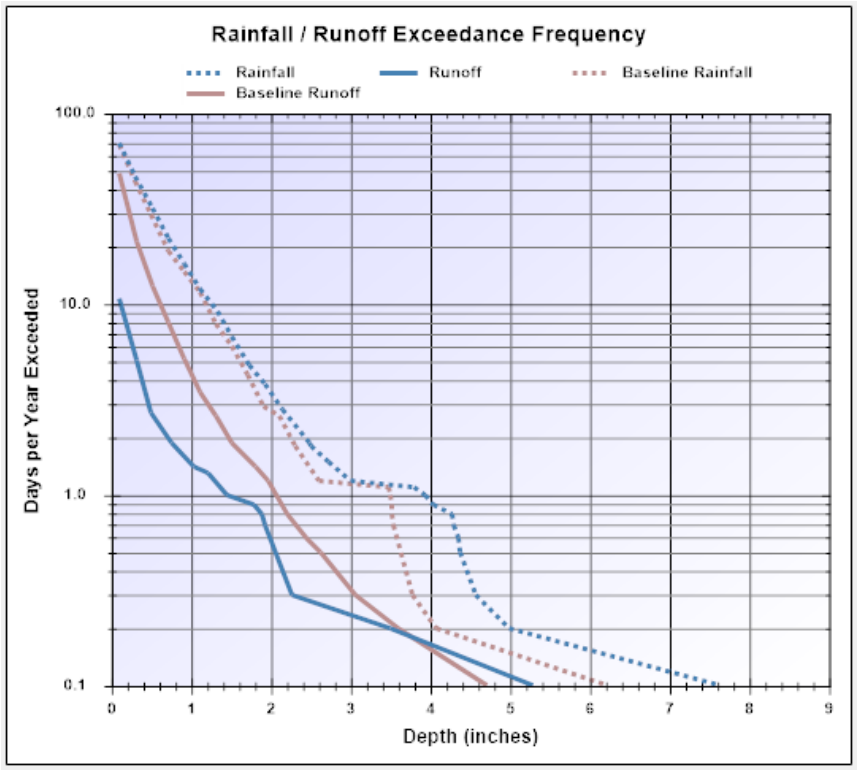
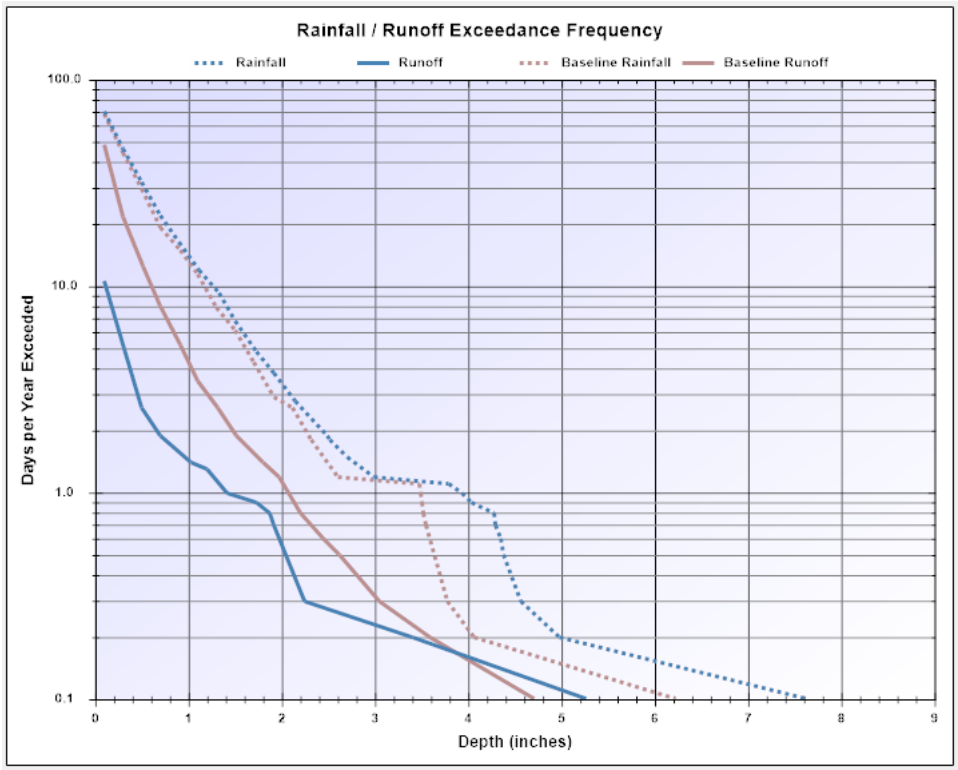


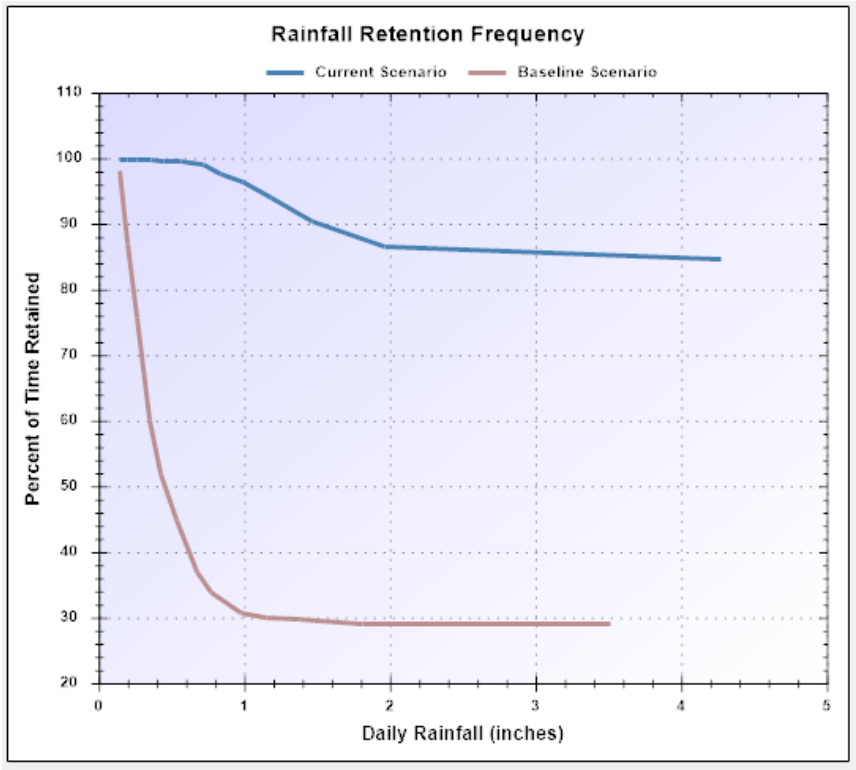
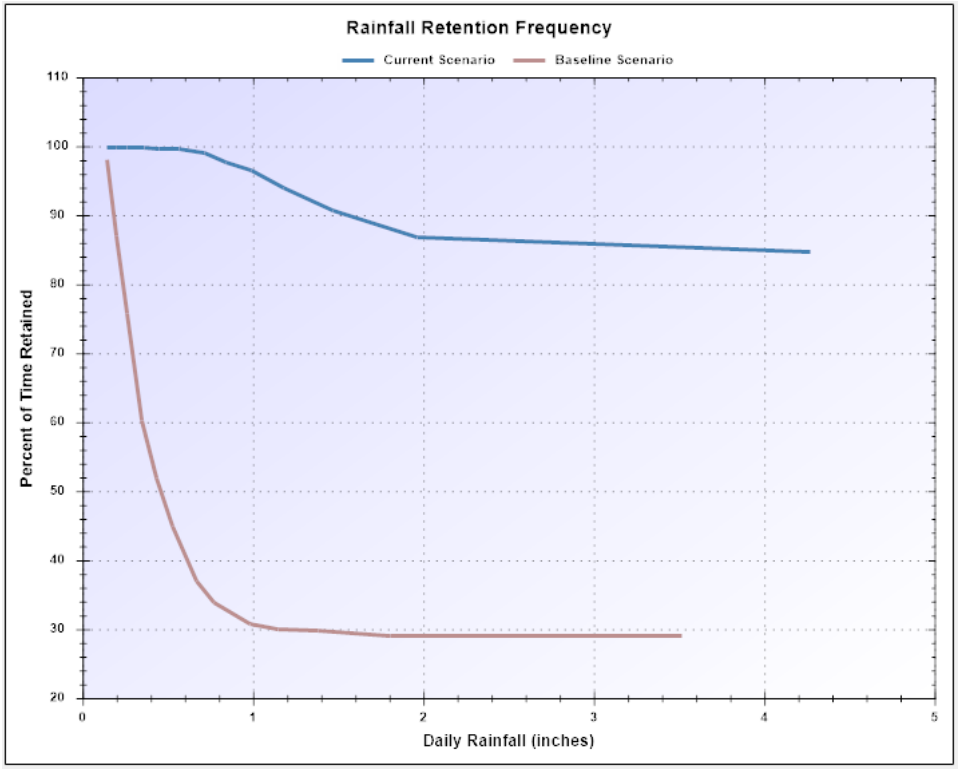
Statistic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	49.14	45.22
Average Annual Runoff (inches)	6.73	22.30
Days per Year With Rainfall	70.06	68.46
Days per Year with Runoff	10.69	48.57
Percent of Wet Days Retained	84.74	29.05
Smallest Rainfall w/ Runoff (inches)	0.35	0.11
Largest Rainfall w/o Runoff (inches)	1.82	0.30
Max. Rainfall Retained (inches)	2.97	1.52

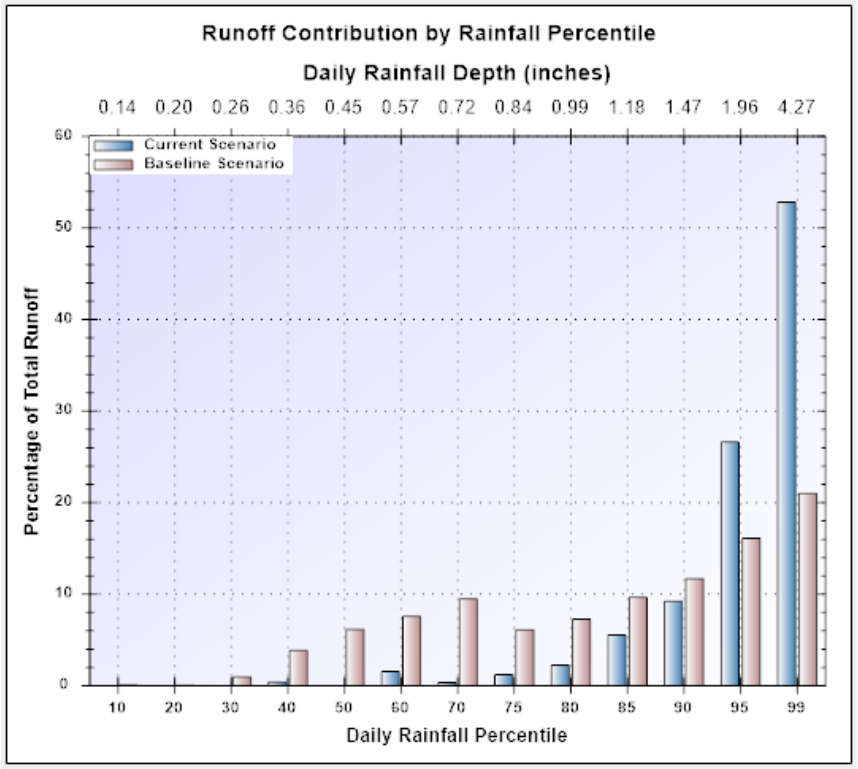
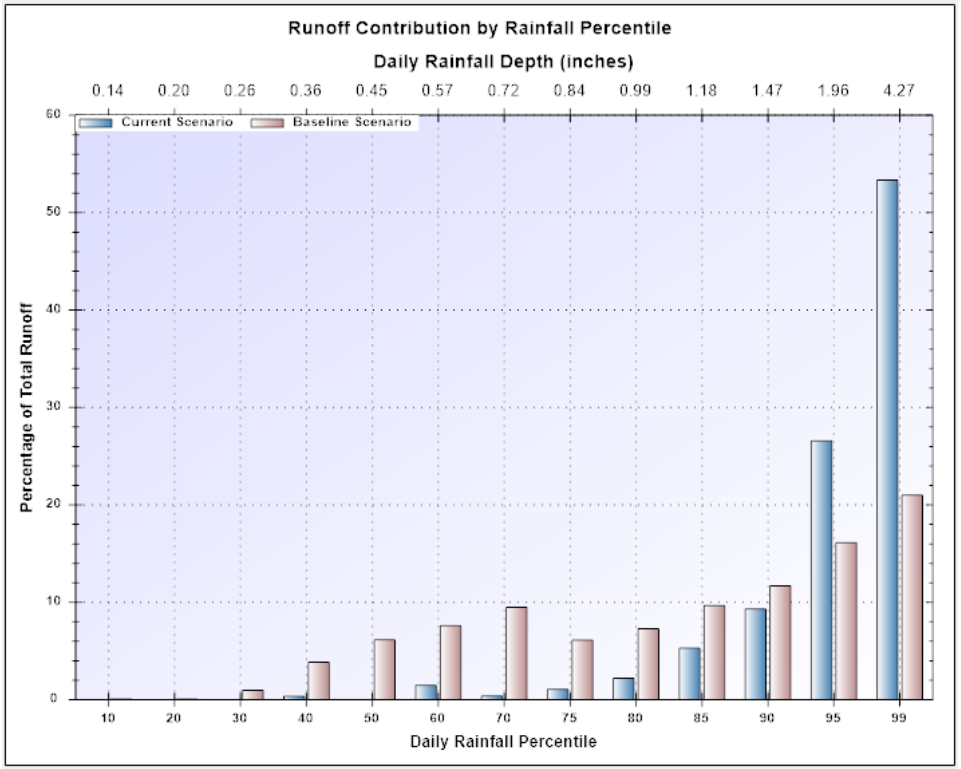


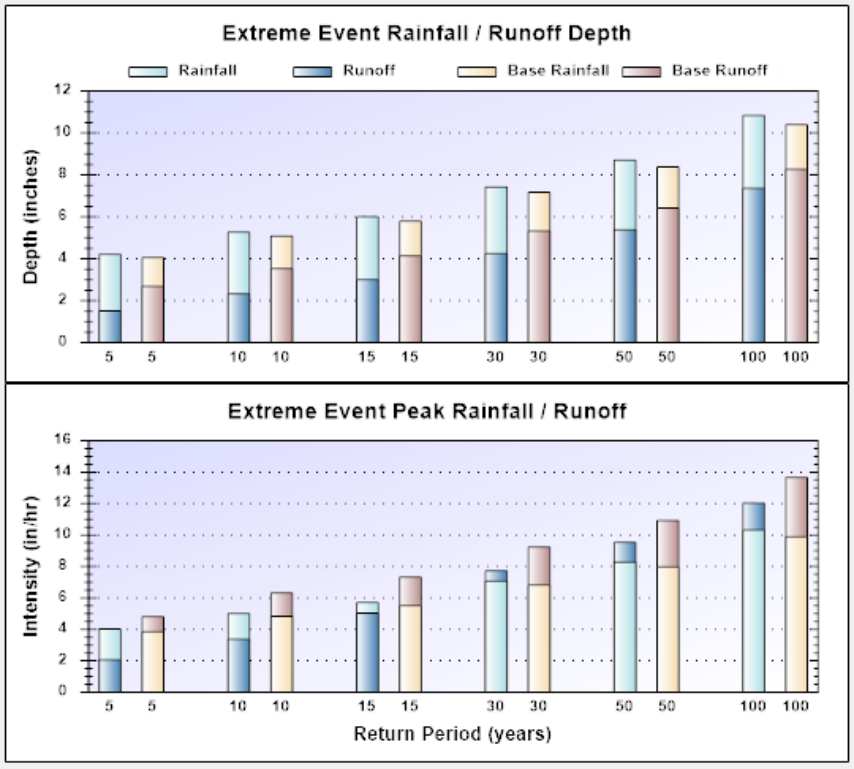
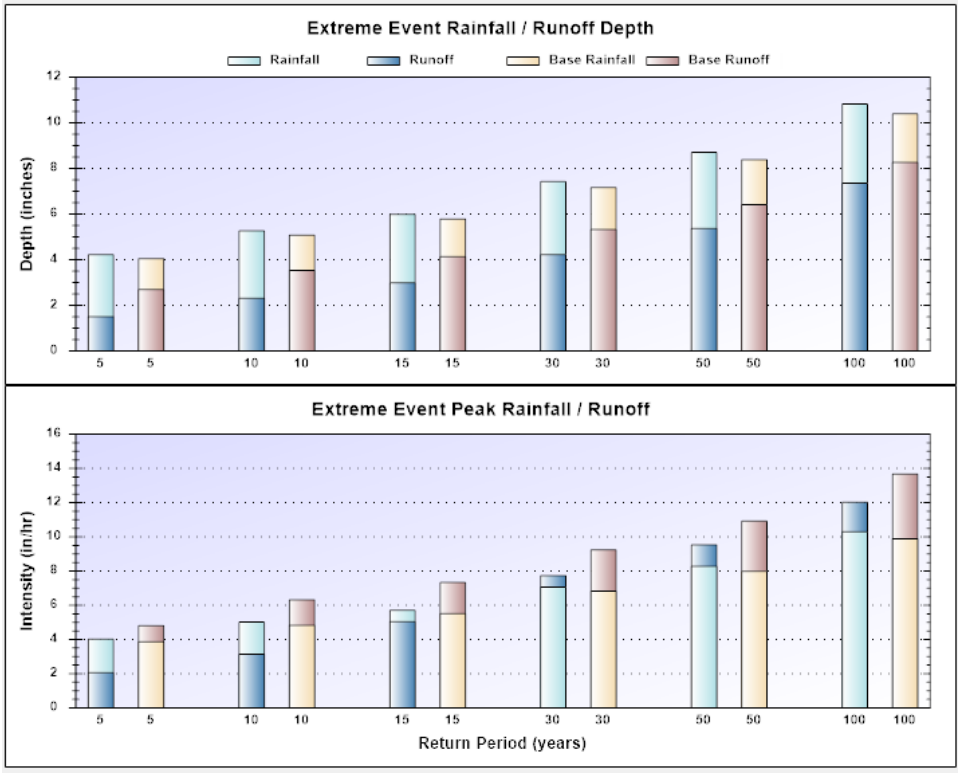
Statistic	Current Scenario	Baseline Scenario
Average Annual Rainfall (inches)	49.14	45.22
Average Annual Runoff (inches)	6.73	22.30
Days per Year With Rainfall	70.06	68.46
Days per Year with Runoff	10.69	48.57
Percent of Wet Days Retained	84.74	29.05
Smallest Rainfall w/ Runoff (inches)	0.35	0.11
Largest Rainfall w/o Runoff (inches)	1.82	0.30
Max. Rainfall Retained (inches)	2.97	1.52

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition
	

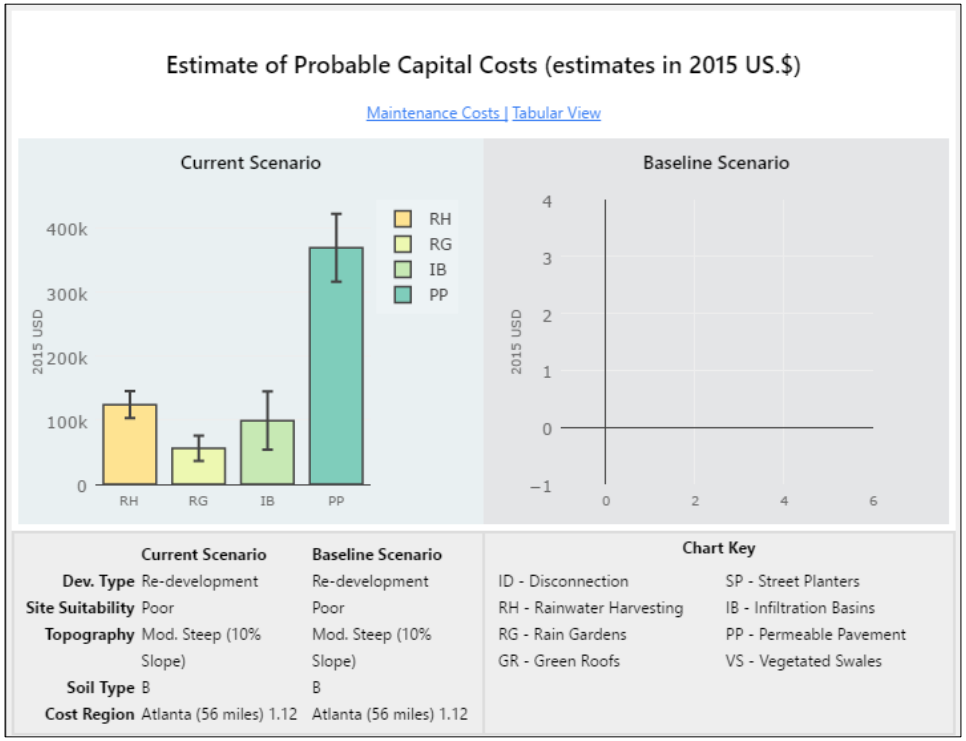
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition
	

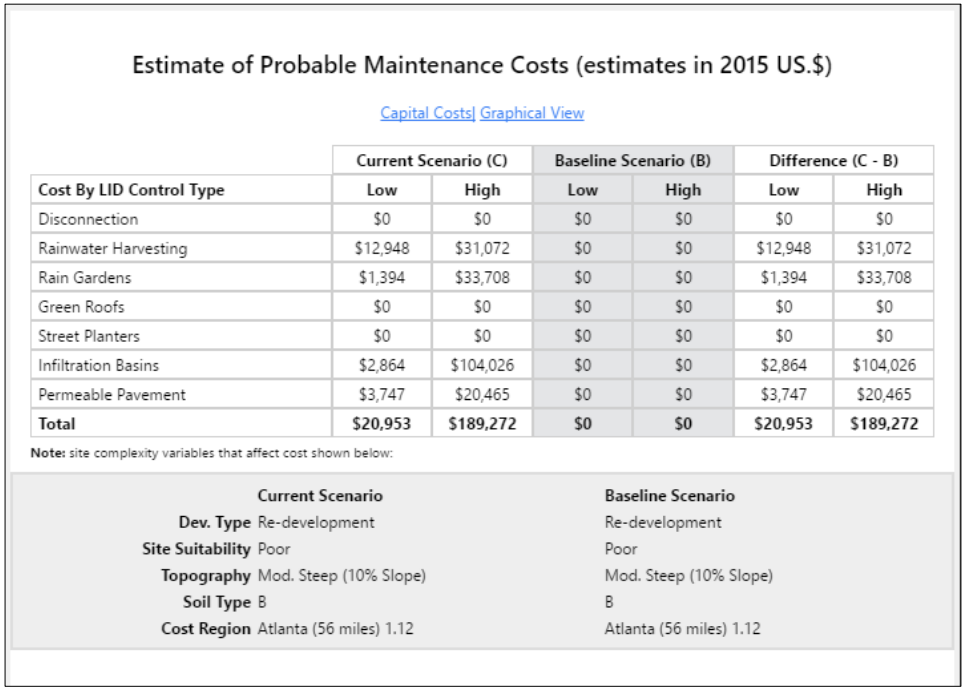
SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition
	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition
	

<table>
<tr><th>SWC Version 1.1.0.2
(previous version)
Current Scenario - Post-development condition with LID controls (Far Term Climate)
Baseline Scenario - Post-development condition</th><th>SWC Version 1.2.0.0
(Updated Cost Capable Version)
Current Scenario - Post-development condition with LID controls (Far Term Climate)
Baseline Scenario - Post-development condition</th></tr>
<tr><td>The previous version of the SWC does not include cost estimation capabilities</td><td>
Estimate of Probable Capital Costs (estimates in 2015 US.$)
Maintenance Costs | Graphical View
<table>
<tr><th></th><th>Drainage Area %</th><th>Has Pre-trt?</th><th colspan="2">Current Scenario (C) Area Treated 12.00 ac</th><th colspan="2">Baseline Scenario (B) Area Treated 12.00 ac</th><th colspan="2">Difference (C - B) Area Treated 0.00 ac</th></tr>
<tr><th>Cost By LID Control Type</th><th>Current / Baseline</th><th>Current / Baseline</th><th>Low</th><th>High</th><th>Low</th><th>High</th><th>Low</th><th>High</th></tr>
<tr><td>Disconnection</td><td>NA / NA</td><td>No / No</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td></tr>
<tr><td>Rainwater Harvesting</td><td>15 / NA</td><td>No / No</td><td>$103,273</td><td>$144,936</td><td>$0</td><td>$0</td><td>$103,273</td><td>$144,936</td></tr>
<tr><td>Rain Gardens</td><td>20 / NA</td><td>No / No</td><td>$36,466</td><td>$75,498</td><td>$0</td><td>$0</td><td>$36,466</td><td>$75,498</td></tr>
<tr><td>Green Roofs</td><td>NA / NA</td><td>No / No</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td></tr>
<tr><td>Street Planters</td><td>NA / NA</td><td>No / No</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td><td>$0</td></tr>
<tr><td>Infiltration Basins</td><td>25 / NA</td><td>No / No</td><td>$54,069</td><td>$144,553</td><td>$0</td><td>$0</td><td>$54,069</td><td>$144,553</td></tr>
<tr><td>Permeable Pavement</td><td>40 / NA</td><td>No / No</td><td>$316,171</td><td>$422,010</td><td>$0</td><td>$0</td><td>$316,171</td><td>$422,010</td></tr>
<tr><td>Total</td><td>100 / NA</td><td>Varies</td><td>$509,979</td><td>$786,998</td><td>$0</td><td>$0</td><td>$509,979</td><td>$786,998</td></tr>
</table>
Note: site complexity variables that affect cost shown below:
<table>
<tr><th></th><th>Current Scenario</th><th>Baseline Scenario</th></tr>
<tr><td>Dev. Type</td><td>Re-development</td><td>Re-development</td></tr>
<tr><td>Site Suitability</td><td>Poor</td><td>Poor</td></tr>
<tr><td>Topography</td><td>Mod. Steep (10% Slope)</td><td>Mod. Steep (10% Slope)</td></tr>
<tr><td>Soil Type</td><td>B</td><td>B</td></tr>
<tr><td>Cost Region</td><td>Atlanta (56 miles) 1.12</td><td>Atlanta (56 miles) 1.12</td></tr>
</table>
</td></tr>
</table>

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition
The previous version of the SWC does not include cost estimation capabilities	

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition
The previous version of the SWC does not include cost estimation capabilities	

Estimate of Probable Maintenance Costs (estimates in 2015 US.$)

Capital Costs| Graphical View

	Current Scenario (C)		Baseline Scenario (B)		Difference (C - B)	
Cost By LID Control Type	**Low**	**High**	**Low**	**High**	**Low**	**High**
Disconnection	$0	$0	$0	$0	$0	$0
Rainwater Harvesting	$12,948	$31,072	$0	$0	$12,948	$31,072
Rain Gardens	$1,394	$33,708	$0	$0	$1,394	$33,708
Green Roofs	$0	$0	$0	$0	$0	$0
Street Planters	$0	$0	$0	$0	$0	$0
Infiltration Basins	$2,864	$104,026	$0	$0	$2,864	$104,026
Permeable Pavement	$3,747	$20,465	$0	$0	$3,747	$20,465
Total	**$20,953**	**$189,272**	**$0**	**$0**	**$20,953**	**$189,272**

Note: site complexity variables that affect cost shown below:

	Current Scenario	Baseline Scenario
Dev. Type	Re-development	Re-development
Site Suitability	Poor	Poor
Topography	Mod. Steep (10% Slope)	Mod. Steep (10% Slope)
Soil Type	B	B
Cost Region	Atlanta (56 miles) 1.12	Atlanta (56 miles) 1.12

SWC Version 1.1.0.2 **(previous version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition	**SWC Version 1.2.0.0** **(Updated Cost Capable Version)** **Current Scenario -** Post-development condition with LID controls (Far Term Climate) **Baseline Scenario -** Post-development condition
The previous version of the SWC does not include cost estimation capabilities