USER MANUAL

SLAT

Stormwater Load Analysis Tool

Version 1.0

Developed by

City of Austin Watershed Protection Department

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City of Austin
WATERSHED
PROTECTION

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I. INTRODUCTION

The City of Austin Stormwater Load Analysis Tool (SLAT) was developed in conjunction with 2014 updates to the Environmental Criteria Manual (ECM) Section 1.6, specifically 1.6.7 and 1.6.9. The goal of the tool is to calculate whether a site's proposed stormwater control measures: (1) comply with the load-based non-degradation requirements within the Barton Springs Zone, or (2) achieve load-based equivalency with a properly sized sedimentation/filtration control outside of the Barton Springs Zone. The tool is not meant to replace engineering analyses that may be needed, including but not limited to control measure design, stormwater conveyance design, and continuous simulation modeling for sites with routing or controls that do not fit the assumptions of the tool.

SLAT is not intended to replace or contradict any part of the ECM. Users must still comply with all ECM requirements, even if they are not explicitly evaluated or used in SLAT.

SLAT has the following key advantages and limitations:

A. Advantages

1. SLAT accommodates alternative stormwater control measures (SCMs) by allowing the user to manually input pollutant effluent concentrations.

2. SLAT streamlines design calculations by automatically calculating site runoff volume and optionally calculating SCM runoff capture efficiency and infiltration field size.

3. SLAT generates output tables and plots that can help demonstrate compliance to City review staff.

B. Limitations

1. SLAT does not accommodate sites with more than four drainage areas (see Section III).

2. SLAT makes many limiting assumptions about a site's stormwater routing and conveyance network (see Section III).

II. SYSTEM REQUIREMENTS

SLAT is an Excel-based tool. The user needs to have Microsoft Excel 2007 (or a more recent version) and be able to run Excel Macro (.xlsm) files.

The tool has protected sheets; public users are not intended to edit the internal calculation formulas. If you suspect that there is an error with the formulas, please report it to the developers by contacting Michelle Adlong at michelle.adlong@austintexas.gov.

III. CALCULATION ASSUMPTIONS

This simplified analysis tool is not meant for complex scenarios that would be more appropriate for a continuous simulation model. Figure 1 shows a typical stormwater control measure (SCM) layout that would work well with SLAT.

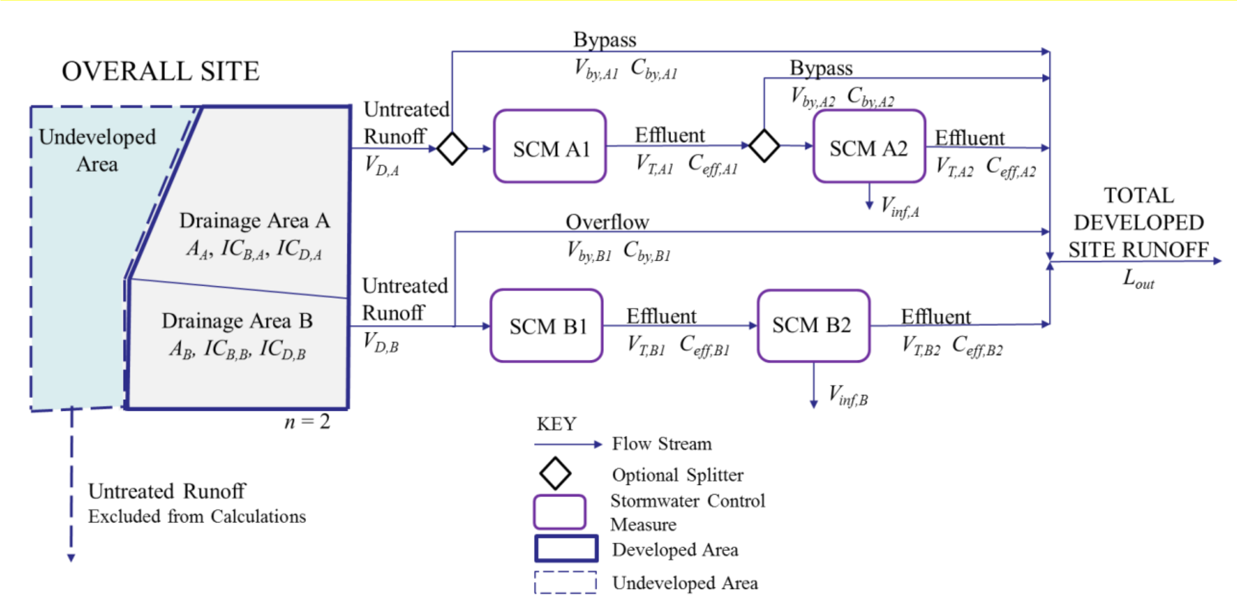


Figure 1: Typical site and stormwater control measure configuration that would function with SLAT.

The following is a list of some initial assumptions and definitions that the user should know in order to evaluate whether SLAT is appropriate for their proposed site.

A. Drainage Areas

A drainage area is the physical area of land that contributes to one SCM or a series of SCMs. Depending on the site's developed conditions, a drainage area can be a natural subwatershed or an engineered drainage area that includes conveyance infrastructure. Each drainage area is assigned its own impervious cover percentage. When comparing existing and proposed developed conditions, the physical boundary and size of the drainage areas stays the same, and is defined by the developed site condition.

B. Maximum Number of Drainage Areas

SLAT can evaluate up to four distinct drainage areas for one site. If the user wants to analyze five or more drainage areas with SLAT, they can open multiple SLAT spreadsheets and add the resulting loads together. Note that when the user has more than one drainage area, the discharge location(s) must still comply with ECM requirements.

C. Stormwater Control Measures

Also known as BMPs, stormwater control measure (SCM or control) is an engineered system designed to capture and/or treat stormwater. Refer to the ECM for a list of SCMs allowed inside and outside the Barton Springs Zone.

D. SCMs in Parallel

SLAT will not calculate controls in parallel from a single drainage area. If the user wants to use controls in parallel, they should model it with separate drainage areas, or use a continuous simulation model.

E. SCMs in Series

SLAT can calculate effluent loads for a series of up to two SCMs from a single drainage area. For the second SCM in series, such as when modeling a retention/irrigation system, only flow routed through the first SCM is considered influent to the second SCM. Overflow from the first SCM is assumed to flow directly offsite. If this is not the case, the user should use a continuous simulation model.

F. Base Impervious Cover

While the existing condition of most sites is undeveloped (0% impervious cover), the tool does not assume such and the user must input the base impervious cover percentage. No matter how small, any impervious cover from the existing site shall be accounted for when the user inputs the baseline impervious cover.

G. Sites outside the Barton Springs Zone

SLAT's primary intended purpose is to calculate load compliance for sites within the Barton Springs Zone. However, SLAT has the capability to alternately compare load equivalency to sedimentation/filtration systems, for sites outside the Barton Springs Zone. The assumed parameters for the comparable system are based on the water quality capture volume requirements of ECM 1.6.2 and sedimentation/filtration design guidelines in ECM 1.6.5, specifically: water quality volume is a function of the impervious cover ("half-inch-plus" rule), control is off-line (contains splitter), drawdown time is 48 hours with no lag time before beginning of discharge, and no treatment train (no second control in series). The calculation uses the current ECM sedimentation/filtration effluent concentrations (rather than the outdated efficiency ratios formerly listed in ECM 1.6.5) in calculating the effluent load. The end result is a Load Equivalence Factor, similar to that for within the Barton Springs Zone, but comparing the proposed system to a standard sedimentation/filtration system rather than the "existing" conditions of the site.

H. Pollutants

SLAT calculates pollutant concentrations for eight pollutants. The following list summarizes the pollutant abbreviations and concentration units used in SLAT. SLAT's conversion factors are consistent with the listed concentrations. If the user chooses to provide effluent concentration data, it is important that that the input values are consistent with the correct units, especially the metals (which are often found in µg/L in other sources).

COD Chemical Oxygen Demand, mg/L

E. coli Escherichia coli, CFU/100 mL

Pb Total lead, mg/L

TN Total nitrogen, mg/L

TOC Total organic carbon, mg/L

TP Total phosphorus, mg/L

TSS Total suspended solids, mg/L

Zn Total zinc, mg/

I. Bypass Concentrations

SLAT determines pollutant concentration in the bypass flows using regressions based on City of Austin stormwater monitoring data. Typically, concentrations of contaminants in stormwater vary throughout the storm. The concentrations tend to be higher in the first portion of stormwater runoff, in a phenomenon known as "first flush" (California Department of Transportation 2005). While a constant event mean concentration (EMC) is assumed for raw runoff that receives no treatment, SLAT assigns a bypass concentration (C_{by}) to runoff that bypasses a control. The bypass concentrations are based on runoff data that has been collected and analyzed by COA staff (WPD 2014). The use of bypass concentration accounts for the fact that pollutant concentrations in runoff are time-varying and generally decrease as a storm progresses.

Figure 2 is an example of the variation of the concentration of zinc over the course of a storm. As the storm progresses and cumulative runoff increases, the measured pollutant concentration decreases exponentially. In other words, when an SCM captures the first flush, it also captures the dirtiest water. The remaining volume of runoff that bypasses is cleaner, having a lower pollutant concentration.

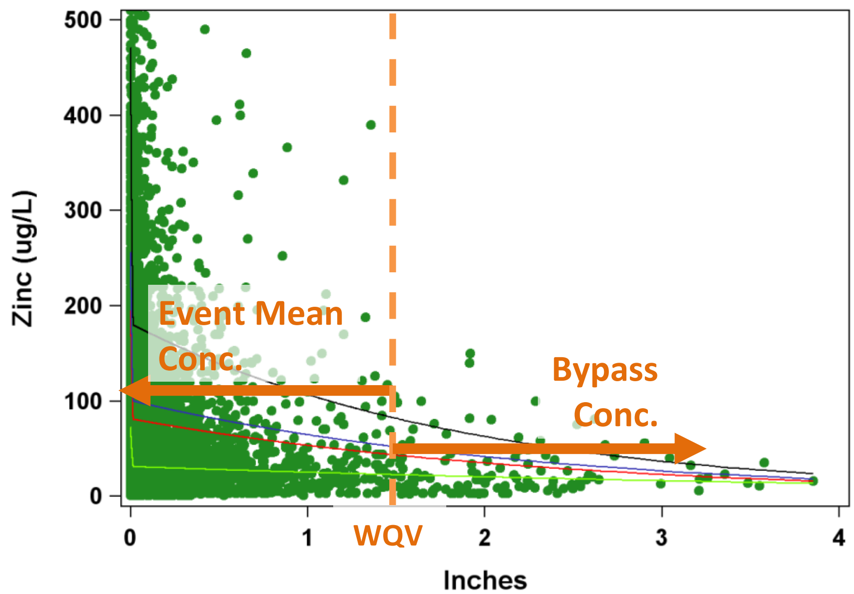


Figure 2: Example of variation of zinc concentration throughout a storm and effect on effluent concentration of an SCM with a 1.5 inch capture volume.

SLAT calculates the bypass concentration as an exponential function of water quality volume. For each pollutant, there are two different functions. The first applies to controls that are "off-line" (contain splitters) and thus isolate the first flush within the water quality volume. The second function applies to controls that are "on-line" (do not contain splitters) and thus may have mixing throughout the storm.

The bypass concentration expression is conservative in multiple ways. First, rather than being a "partial event mean concentration," the bypass concentration is calculated at the point that runoff volume equals water quality volume, and this concentration is assumed for the remainder of the bypassing flow. Second, the expressions are developed from the 80th and 90th percentiles of data points for controls with splitters and without splitters, respectively. Even so, the method gives credit for the water quality benefits of capturing the most polluted first flush and, compared to the use of a constant event mean concentration (EMC) throughout the storm, results in smaller required capture volumes to achieve load compliance.

For some pollutants at low water quality volumes, particularly for on-line controls, the exponential bypass concentration regressions are highly conservative and exceed the runoff event mean concentrations. In these cases, according to ECM Table 1-12, the bypass concentration should simply be equal to the event mean concentration, i.e. C_D from ECM Table

1-10. Therefore, the calculator takes the minimum value between C_D and the bypass concentration regression when it calculates the actual concentration in the flows that bypass SCM 1, $C_{by,1}$.

Concentrations for flows that bypass SCM 2 are assumed to be equal to the effluent concentration of SCM 1, per Table 1-12. This is due to the assumption discussed in Section III.E.

IV. CALCULATION PROCEDURE OVERVIEW

SLAT follows the procedures outlined in ECM Section 1.6.9, and therefore any user should be able to manually replicate the results of the SLAT using only the updated equations and tables in Section 1.6.9, and these equations are not repeated here. However, the tool does appear more complex, as it anticipates and can calculate a range of design scenarios at once, such as multiple drainage areas, different types of SCMs, and other user input options. Therefore the tool's internal functions have an additional built-in layer of logic. Figure 3 provides a flowchart overviewing the load compliance calculations detailed in ECM 1.6.9.

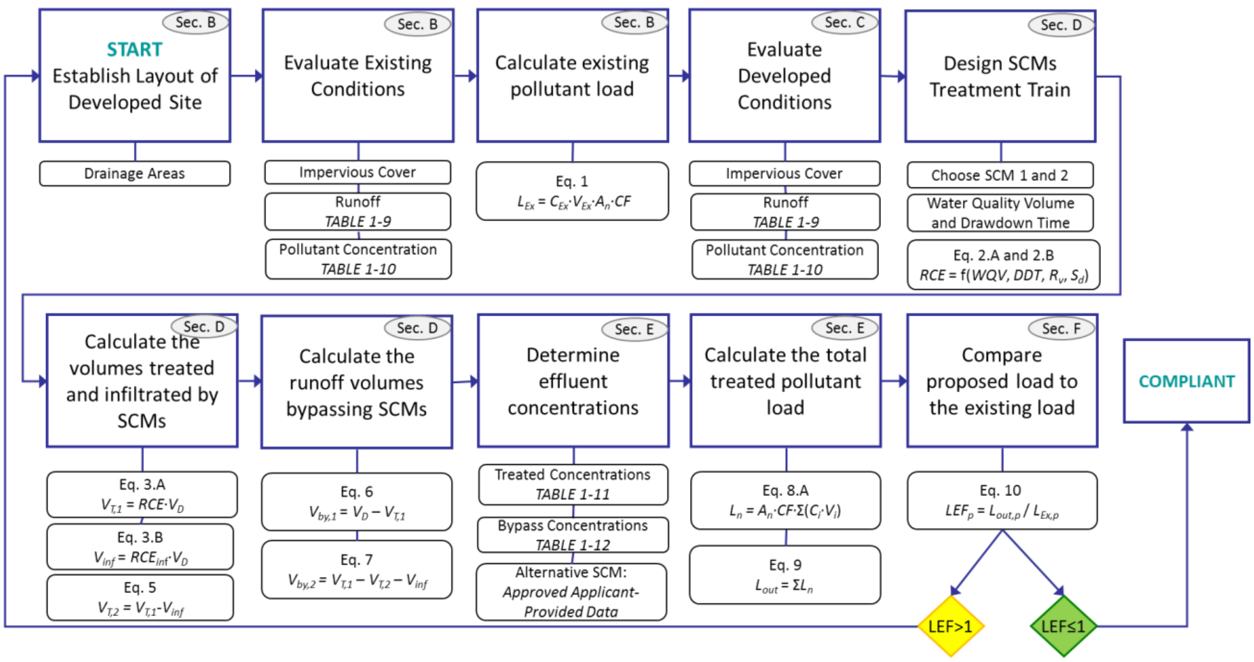


Figure 3: Flowchart with calculation overview

In SLAT, the two worksheets intended for the user viewing are "1. ENTER DATA" and "2. RESULTS." However, worksheets three through five are also visible so the user can view the contents of the internal calculations.

A. Runoff Capture Efficiency Calculation

SLAT uses a probabilistic methodology which uses rainfall statistics to calculate runoff capture efficiency. The probabilistic methodology is considered to be an alternative to continuous simulation modeling for conducting planning level analyses, but still requires a firm understanding of meteorological conditions and urban drainage design and practice. The procedure is based off of a method derived in the book *Urban Runoff Management Planning with Analytical Probabilistic Models* (Adams and Papa, 2000).

The following excerpt from the preface describes the methodology:

> It is an approach based on analytical models formulated with derived probability distribution theory. Rather than running time series of numerical meteorological data through simulation programs, the meteorology is described by the probability distribution of its characteristics: rainfall volume, duration, average intensity, and interevent time. These input probability distributions are then mathematically transformed by hydrologic and hydraulic models to create probability distributions of system outputs. These analytical models are often closed-form mathematical equations that describe the complete probability distributions of system performance parameters. Because of their analytical form, these models are extremely compact, computationally efficient, and easy to use.

The following rainfall statistics provide basic input into the model and remain constant for all analyses. The statistics were produced by WPD staff, which used SWMM to analyze 45 years of hourly rainfall data (1948-1993) from the Mueller airport. (Note: This data is subject to COA updates with more recent rainfall data, which may result in changes to the calculated runoff capture efficiency.)

v = mean annual rainfall event volume = 0.40 inches

t = mean annual rainfall event duration = 5.77 hours

b = interevent time = 103.63 hours

The following variables are derived from runoff monitoring data and are functions of the drainage area's proposed impervious cover percentage:

R_v = Runoff-rainfall ratio (unitless) (See ECM 1.6.9, Table 1.9)

S_d = depression storage (inches) (See ECM 1.6.9, Table 1.9)

The following variables are chosen by the designer and relate to the proposed stormwater control measure (SCM):

WQV = water quality volume of the control (inches)

DDT = drawdown time of the control (hours)

t_L = lag time between end of storm event and beginning to drain control (hours)

t_D = drain time, or total time for full control to empty (hours)

For pumped systems: $t_D = DDT + t_L$

For gravity-drained systems: $t_D = DDT$

The probability of a spill of any size occurring, $G_p(0)$, is defined by the following expression, which is taken from Equation 8.4a in the book (Adams and Papa, 2000). This expression makes the conservative assumption that the SCM is full at the end of the last rain event.

$$G_P(0) = \frac{\frac{\lambda}{\Omega}}{\frac{\lambda}{\Omega} + \frac{\zeta}{\phi}} * \frac{(\frac{\psi}{\Omega}) + (\frac{\zeta}{\phi}) e^{-(\frac{\psi}{\Omega} + \frac{\zeta}{\phi}) S_A}}{\frac{\psi}{\Omega} + \frac{\zeta}{\phi}} e^{-\zeta \cdot S_d}$$

Where:

λ (lambda) = $1/t$ (hrs^{-1})
Ω (omega) = treatment rate of the BMP = WQV/t_D (ft^3/hr)
ζ (zeta) = $1/v$ (in^{-1})
ψ (psi) = $1/b$ where b is the interevent time period (hrs^{-1})
φ (phi) = R_v = Runoff-Rainfall coefficient (unitless)
S_A = WQV = Water quality volume (inches)
S_d = depression storage (inches)

Runoff capture efficiency (*RCE*) is the fraction of the average annual runoff volume that is captured, i.e. not spilled, by the SCM. An *RCE* of zero represents no capture of the yearly average runoff volume (complete spillage), and an *RCE* of one represents complete capture of the yearly average runoff volume.

$$1 = RCE + G_P(0)$$

Combining the above two equations and substituting for the defined statistics and variables yields the following expression for runoff capture efficiency:

$$RCE = 1 - \frac{t_D}{t_D + \frac{t \cdot WQV}{v \cdot R_v}} * \frac{(\frac{t_D}{b \cdot WQV}) + (\frac{1}{v \cdot R_v}) \exp\left[-\left(\frac{t_D}{b \cdot WQV} + \frac{1}{v \cdot R_v}\right) WQV\right]}{\frac{t_D}{b \cdot WQV} + \frac{1}{v \cdot R_v}} \exp\left(\frac{-S_d}{v}\right)$$

Equation 1

B. Infiltrated Water Quality Volume and Infiltration Field Size

The infiltrated or irrigated water quality volume is typically chosen by the designer. Since the load calculations are based on surface runoff only, all volume that is infiltrated, irrigated, beneficially reused, or otherwise removed from surface flow is also removed from the load calculations. Therefore, increasing infiltrated volume helps match baseline loads.

For an infiltration or irrigation field with no ponding water, the infiltrated volume is correlated to the soil infiltration rate, the application time, and the size of the field. Knowing infiltrated volume can dictate field size, and vice versa, based on the following simplified expression for sizing retention/irrigation fields.

For gravity-draining systems, the application rate is assumed to be an average of WQV_{inf} / DDT. For irrigated systems, the application rate is assumed to be a constant irrigation rate of WQV_{inf} / DDT.

$$A_{field} = \frac{WQV_{\inf} \cdot n_z}{DDT \cdot I} A_n$$

Equation 2

Where:

A_{field} = irrigation field size (Acres)

WQV_{inf} = Infiltrated water quality volume (inches)

n_z = number of zones where irrigation is alternated (usually 2 for typical retention/irrigation)

DDT = Drawdown time, or time for first control to empty its full water quality volume, starting at the beginning of drawdown, assumed equal to the application or irrigation time (hours)

I = infiltration rate (in/hr)

A_n = Drainage area size (acres)

C. Annual Infiltrated Volume

To convert from a known infiltrated water quality volume to a yearly average infiltrated volume V_{inf}, SLAT uses the runoff capture efficiency expression listed in Equation 1, but replaces the *WQV* of SCM 1 with WQV_{inf}. It is necessary to recalculate runoff capture efficiency because simply multiplying WQV_{inf} by the average annual number of rainfall events would result in an artificially high V_{inf} (some runoff events are less than the infiltrated water quality volume).

$$RCE_{inf} = 1 - \frac{t_D}{t_D + \frac{t \cdot WQV_{\text{inf}}}{v \cdot R_v}} * \frac{(\frac{t_D}{b \cdot WQV_{\text{inf}}}) + (\frac{1}{v \cdot R_v}) \exp\left[-\left(\frac{t_D}{b \cdot WQV} + \frac{1}{v \cdot R_v}\right) WQV_{\text{inf}}\right]}{\frac{t_D}{b \cdot WQV_{\text{inf}}} + \frac{1}{v \cdot R_v}} \exp\left(\frac{-S_d}{v}\right)$$

As with SCM 1, the result is then multiplied by the total runoff volume to determine the average annual volume infiltrated (inches per year):

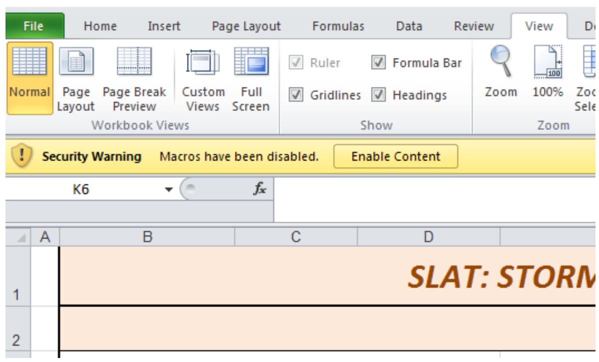
$$V_{inf} = RCE_{inf} \cdot V_D$$

V. STEP-BY-STEP INSTRUCTIONS

Note that the following screenshots apply to Microsoft Office 2010. Other versions may appear slightly different.

A. Before Starting a New Project

1. Open the Excel file
2. Enable macros in the spreadsheet. If "Security Warning" pops up, click "Enable Content."
    a. Note: If macros are not enabled, spreadsheet can still function. However, the shortcut buttons, including "Restore Defaults," will not work.



3. Open the "1. ENTER DATA" worksheet, if it is not already open.
4. Click "Restore Defaults" Button in the upper right corner. This will reset cells that have values from previous analyses, inputting default values for a few key cells. The default values are listed in Appendix A.

When inputting data for a new project, the user should fill out the yellow highlighted cells. The following list describes all cell types that the user may encounter when performing an analysis.

Required User Input	Cell contains required user input. User should replace default values with site-specific information.
Key User Input	Cell contains user input that is a key variable for SCM sizing. User may choose to iterate with this variable during SCM design.
Internal Calculation	Cell is calculated based on user input. User does not change this cell.
Error	Warning that user input is inconsistent with other inputs, which may result in inaccurate calculations.
Calculator Output	Cell displays a key calculation result.
Does Not Apply	Cell does not need to be altered, based on previous user inputs.

There are two worksheets that the user alternates between.

1. ENTER DATA – this is the primary worksheet where the user will input data
2. RESULTS – this worksheet summarizes the results of the calculations, and provides plots to visualize load compliance.

The user can use the orange buttons to toggle between worksheets or may select the worksheet tab at the bottom of the window. Plan reviewers may ask for both worksheets to be printed as proof that the analysis was performed.

B. Inputting Data for a New Project

The following instructions move through the user input cells from top to bottom. For all cell inputs, the user shall remain compliant with requirements of ECM 1.6.9 and all other relevant sections of the ECM and LDC, even if not specifically mentioned in this user manual or in SLAT. All inputs are subject to approval by the plan reviewer.

Row 12: Basic Info

Input name to identify site (such as address or development), name of person who is performing analysis, and date of analysis. This information is for tracking purposes only.

Row 14: Is your site within the Barton Springs Zone?

Yes - Site development is subject to Section 25-8-514 of the Land Development Code (LDC), and tool is being used to demonstrate that proposed loads are less than or equal to existing conditions loads.

No – Site development is not subject to the above-referenced standards. Selecting “No” allows the user to demonstrate equivalence (full or partial) with sedimentation/filtration performance outside of the Barton Springs Zone.

Row 15: How many drainage areas does your site have?

Input a number from 1 to 4. In SLAT, each drainage area is assumed to be treated by a separate control treatment train, with no intermixing of runoff between drainage areas. See ECM Section 1.6.9 for definition of drainage area.

If the user activates more than one drainage area, additional columns become highlighted for additional user inputs. Each drainage area is distinct, and the below instructions apply to each drainage area that is activated.

If the user wishes to use more than four drainage areas, they can still use SLAT. However, they would need to create additional drainage areas in a second SLAT spreadsheet. To prove load compliance, the user would need to manually add the Developed Load and Existing Loads from both “2. RESULTS” worksheets, ensuring that all drainage areas are included. They would then need to calculate an overall load equivalency factor (LEF) to demonstrate compliance.

Row 17: Drainage area to the control

Input the area, in acres, that drains to the SCM. See Section III for more information about drainage areas.

Row 18: Base impervious cover of the drainage area, IC_B (%)

Input the percentage of impervious cover in the drainage area for the existing condition. Definitions must comply with the Land Development Code Section 1.9.2 and should be agreed upon by the plan reviewer. For a completely undeveloped site, the input is 0. Note that the percentage applies only to the drainage area, not the net site.

Row 19: Developed impervious cover of the drainage area, IC_D (%)

Input the percentage of impervious cover in the drainage area for the proposed developed condition. Note that landscaped areas are considered pervious but developed, meaning that while they do not add to the impervious cover percentage, they must still be included in a drainage area.

Row 20: Annual average runoff for the existing site (in/yr)

Displays the calculated total yearly runoff, per unit acre, for the existing site.

Row 21: Annual average runoff for the developed site (in/yr)

Displays the calculated total yearly runoff, per unit acre, for the proposed developed site, prior to capture by any control.

Row 26: SCM Type

From the drop-down list, select the proposed stormwater control measure that is first in series. If “Alternative” is selected, rows 62 through 68 will become activated and the user will need to input the effluent concentration later.

Row 27: Is SCM 1 off-line?

Select whether the SCM is off-line or on-line. An off-line control isolates the water quality volume when the control is full, and typically a splitter box is used.

Row 28: What is the water quality volume?

Input the proposed water quality capture volume, in watershed-inches.

For example, a control with water quality volume of 2.0 inches would capture 100% of runoff from all storms that produce two inches or less runoff, but would have bypass for storms that produce greater than two inches of runoff. The larger the water quality volume, the higher the runoff capture efficiency.

Water quality volume is independent of drainage area size. To scale actual volume units (i.e. Acre-inches or cubic feet), the water quality volume must be multiplied by the drainage area and converted to desired units.

Row 29: Minimum water quality volume

Displays, for user reference, the minimum water quality volume allowed for each drainage area. Within the Barton Springs Zone, the minimum water quality volume follows the “Half-Inch Plus” rule for sizing water quality ponds per ECM Section 1.6.2. Outside the Barton Springs Zone, the minimum water quality volume is set to 0, as in these cases SLAT is likely being used to determine partial (or full) equivalence to a standard sedimentation/filtration system.

Row 30: SCM 1 Actual Volume (ft^3)

Displays, for user reference, the actual volume of the control when accounting for the size of the drainage area. Note that this is for water quality purposes only, and does not include extra volume required, such as for freeboard.

Row 31: Drawdown Time (hours)

Input the design drawdown time, in hours, for the control to drain from full to empty. This excludes the "lag time" when the control is full but cannot release the water. For example, a typical retention/irrigation system with a 12-hour lag time and a 72 hour total time (from end of storm event to emptying) would have a 60-hour drawdown time.

The minimum drawdown time is 48 hours. There is no maximum drawdown time, however, longer drawdown times cause decreased runoff capture efficiency. The user may want to iterate with drawdown time and water quality volume in order to find the best fit for their proposed site.

Row 32: Do you already know the runoff capture efficiency?

Input Yes or No. If the user wishes to use the built-in calculator for runoff capture efficiency, they should leave the default value of No. If the user wishes to perform their own independent engineering analysis, such as through continuous simulation, they can input Yes.

Row 33: User Entered Runoff Capture Efficiency

Activates if the user input Yes in row 31. The input is expressed as a percentage, from 0 to 100 (not a fraction from 0 to 1).

Row 34: Runoff Capture Efficiency, RCE (%)

Displays, for user reference, the runoff capture efficiency (*RCE*) used in subsequent calculations. This will either be the *RCE* calculated internally by SLAT using a probabilistic methodology (see Section III), or the *RCE* input by the user, depending on the input for row 31.

Row 35: Annual average volume treated by SCM 1, $V_{T,1}$ (in/yr)

Displays, for user reference, the average annual volume treated by SCM 1 per unit acre. This volume is the product of the runoff capture efficiency (row 34) and the developed runoff (row 21).

Row 36: Annual average bypass volume, $V_{by,1}$ (in/yr)

Displays, for user reference, the average annual volume that bypasses SCM 1 (or overflows, if using an on-line control). The sum of the bypass volume and the treated volume (row 35) equal the developed runoff (row 21).

Row 38: How is effluent from SCM 1 discharged?

Input Pumped or Gravity Drained. Note that gravity drained can only be used for systems that use sedimentation/filtration as the first control, and where site topography allows. This input is for tracking purposes, and is not used for any calculations.

Row 39: Delay after end of rainfall before discharging SCM 1 (hours)

Input the lag time from 0 to 12 hours. For a typical system, 12 is used. If SCM 1 is a sedimentation/filtration and is discharged by gravity (no pumps), the user has the option to eliminate the time delay and input 0.

Row 42: SCM Type

From the drop-down list, select the proposed stormwater control measure that is second in series. If "Alternative" is selected, rows 71 through 77 will activate and the user will need to input the effluent concentration later. Note that "Infiltration Field" also includes irrigation fields.

Row 43: Percent of SCM 1's water quality volume routed to SCM 2

Input the percent of the water quality volume that is routed to the second control as a number from 0 to 100. In other words, input the water quality volume of SCM 2, expressed as a percent of the water quality volume of SCM 1.

For a typical retention/irrigation system without a splitter, the input would be 100, as 100% of the capture volume would be routed to an irrigation field. However, hypothetically the designer might not want to route the entire water quality volume to the infiltration field if the effluent concentration from SCM 1 is clean enough. For example, if SCM 1 water quality volume is 2.0 inches and the user inputs 90 into row 43, the "water quality volume" of the second control would be 2.0" x 0.90 = 1.80".

Row 44: Water quality volume routed to SCM 2 (inches)

Displays, for user reference, the water quality volume of SCM 2. For most systems which use an infiltration field as SCM 2, this "water quality volume" is simply the volume of water irrigated during the drawdown time over the field area. For a hypothetical system using an alternative control as SCM 2, there may be a volume storage component.

Row 45: Annual average volume routed to SCM 2, $V_{T,2} + V_{inf}$ (in/yr)

Displays, for user reference, the annual average volume that is routed to SCM 2. Similar to row 35 for SCM 1, this volume is calculated from the runoff capture efficiency, using the same drawdown time as SCM 1.

Row 46: Does SCM 2 reduce volume, such as by infiltration?

If the SCM contains an infiltration field, irrigation field, beneficial reuse, or any other volume reduction technique, the answer should be "Yes." If using an alternative SCM, it may or may not have an infiltration field. Note that with typical existing technology, it is extremely difficult, if not impossible, to achieve load compliance without the volume reduction associated with infiltration or irrigation.

Row 47: Do you already know the infiltrated volume?

The user has two options: “Yes,” and “No; infiltrate all routed water.” For a typical analysis, the user would input “No; infiltrate all routed water.”

An example of a case where the user chooses “Yes” may be a rainwater harvesting system where some, but not all, of the volume is consumed by beneficial reuse. The user could model beneficial reuse like infiltration, since both are volume reduction measures, but the user would need to know the expected usage rate for row 48.

Row 48: User-entered infiltrated water quality volume, WQV_{inf} (inches)

This volume is the maximum amount of water that can be infiltrated over the drawdown period of SCM 1, expressed in inches. Though there is no storage component for infiltration, it is analogous to the “water quality volume” infiltrated.

Typically, the designer selects the infiltrated water quality volume; for infiltration fields with no spillage, it should be equal to the water quality volume routed in row 44. Infiltrated volume, together with soil infiltration rates, dictates the required infiltration field size. See Section III for more information.

Row 49: Annual Infiltrated Volume, V_{inf} (in/yr)

Displays, for user reference, the annual average volume of water that is removed from surface runoff through infiltration (or irrigation). This volume is the product of the modified runoff capture efficiency using WQV_{inf} (row 48) and the annual average volume routed to SCM 2 (row 44). See Section III for more information.

Row 50: Annual non-infiltrated volume treated by SCM 2, $V_{T,2}$ (in/yr)

Displays, for user reference, the annual average volume of water that is routed to SCM 2 but is not infiltrated or otherwise removed from the surface flow. This value may be non-zero for alter alternative SCMs with a user-input effluent concentration.

Row 51: How is water applied to the infiltration field?

Input Irrigation or Level Spread. Note that level spread can only be used for gravity-drained sedimentation/filtrations as the first control, and where site topography allows level spreading. However, the converse is not true, for example a gravity-drained system may feed to a drip irrigation system. This input is for tracking purposes, and is not used for any calculations.

Row 52: Number of application zones

Input the number of zones that the infiltration field is divided into for rotating irrigation. Typically this is two zones, per the requirements in ECM 1.6.7, with each zone being irrigated for half of the total application time.

Row 53: Soil infiltration rate (inches per hour)

Input the soil infiltration rate. While the default is 0.2 in/hr, the actual user input is often less than 0.2 in/hr. The infiltration rate should reflect the site-specific soil permeability and is subject to approval by the plan reviewer.

SLAT assumes that the irrigation rate is equal to the soil infiltration rate. If the irrigation rate is actually less than the soil infiltration rate, then the user should input the lesser irrigation rate instead. The irrigation rate should never be greater than the soil infiltration rate.

Row 54: Total application time, t_{app} (hours)

Displays, for user reference, the amount of time that water is applied to the infiltration field. SLAT assumes that t_{app} is equal to the drawdown time of SCM 1. The total application can be divided by the number of zones to determine the application time per zone.

Row 55: Do you know the infiltration field area?

Input “No; calculate area” if the user wishes the SLAT tool to calculate the size of infiltration field necessary to absorb all infiltrated water from row 49. If the user already has performed their own sizing calculations for the infiltration field, they should select “Yes.”

Row 56: User-Entered Infiltration Field Area (Acres)

Activates if the user input “Yes” for row 55. Input the calculated field size here. This input is for tracking purposes, and is not used for the load calculations.

Note that there are no minimum or maximum limits to the cell, and the user-entered field size does not change the amount of volume infiltrated (the user must change the volume manually). The user may choose to use rows 57 and 58 for guidance when sizing the infiltration field.

Row 57: Calculated field area for given volume (Acres)

Displays, for user reference, the field size that is being proposed. If the user inputs “No; calculate area” for row 55, it displays the SLAT-calculated area. If the user inputs “Yes” for row 55, it displays the user-input area.

Row 58: Minimum field area for load compliance (Acres)

Displays, for user reference, the field size that SLAT predicts is necessary to meet load compliance *within that drainage area only.* This is intended to provide a reference to the user as they size their system and is not used for load calculations.

When multiple drainage areas are used, the user could hypothetically provide a field smaller than the recommended size if they "over-treat" the runoff in another drainage area.

Rows 64 through 71: Input effluent data for alternative SCM 1 (mg/L and CFU/100 mL)

Activates if the user input "Alternative" for row 26. The user should input the effluent concentration for each of the eight pollutants, and the concentrations should be supported by approved published data per in ECM 1.6.9.3.G.

While concentrations for the metals lead (Pb) and zinc (Zn) are typically expressed in *µg/L* in the literature, the concentrations should be input in *mg/L* for the tool.

Rows 74 through 81: Input effluent data for alternative SCM 2 (mg/L and CFU/100 mL)

Activates if the user input "Alternative" for row 42. The user should input the effluent concentration for each of the eight pollutants, and the concentrations should be supported by approved published data per in ECM 1.6.9.3.G.

While concentrations for the metals lead (Pb) and zinc (Zn) are typically expressed in *µg/L* in the literature, the concentrations should be input in *mg/L* for the tool.

VI. EXAMPLE PROJECTS

A. Two Drainage Areas

A developer is planning a subdivision for a commercial site within the Barton Springs Zone with a net site area of 20 acres and a net impervious cover of 20%. The existing site is undeveloped and is subject to the SOS Ordinance. The developer wishes to incorporate rainwater harvesting and reuse for a large building in the development. They wish to treat the rest of the drainage area with a variant of retention/irrigation, but with sedimentation/filtration as a first control. The developer needs to size their stormwater control measures (SCMs) such that the pollutant loads in the runoff from the developed areas are no greater than baseline loads. The proposed site layout is shown below in Figure 4.

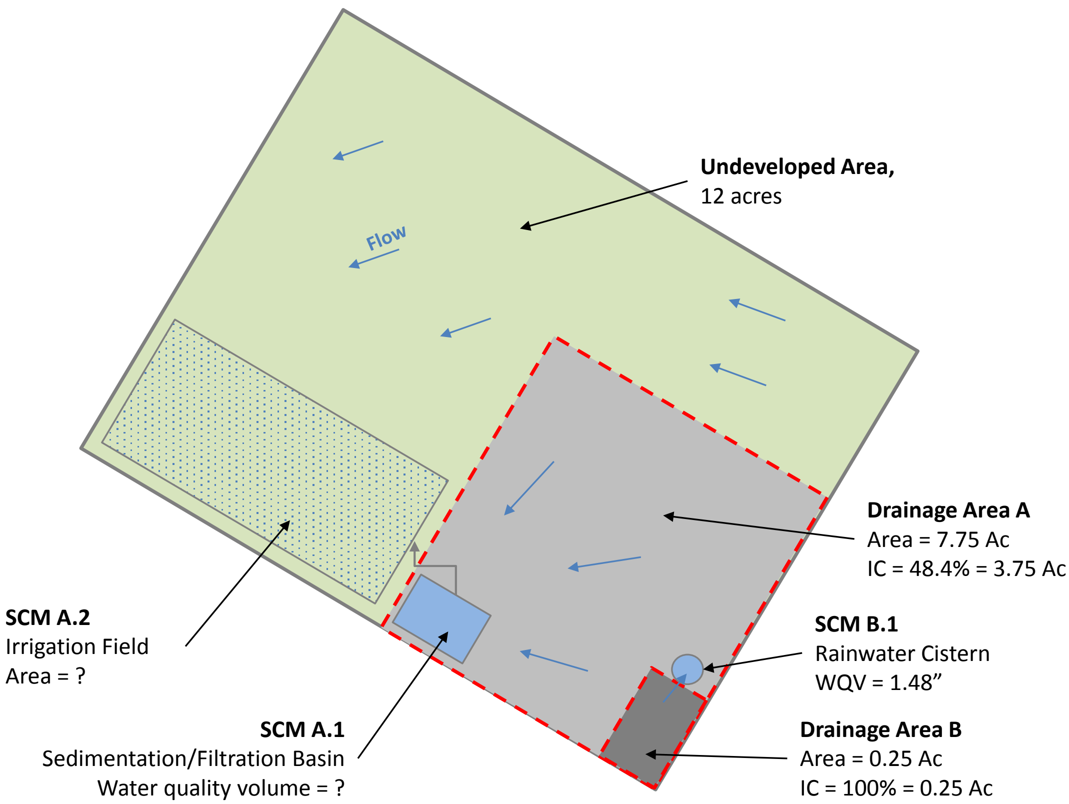


Figure 4: Simplified layout of example site with two drainage areas

The designer begins by filling in the general site information. When they select "2" in row 15 for the number of drainage areas, the columns for Drainage Area A and Drainage Area B become highlighted. The designer then continues to fill out all information in the column for Drainage Area A, progressing from top to bottom.

The designer enters the drainage area characteristics in rows 17 through 19, inputting 7.75 (row 17), 0 (row 18), and 48.4 (row 19). They then move down to enter information about the first SCM, a sedimentation/filtration basin (row 26) that is offline (row 27). The designer is not sure yet what the water quality volume will need to be in order to achieve load compliance, so they enter 1.50 inches in row 28 as a first guess, which is well above the minimum of 0.78" that is required by the "half-inch-plus" rule (row 29). This volume translates to an actual volume of 56,265 ft^3 as shown in row 30. The designer inputs 48 hours as the drawdown time in row 31, as they wish to minimize bypass and this is the minimum drawdown time allowed. The designer allows SLAT to calculate the runoff capture efficiency by entering "No" in row 32. SLAT then calculates a runoff capture efficiency of 98.3% (row 34), which translates to an annual average treated volume of 10.37 inches per year (row 35), or 80.3 Acre-inches per year if accounting for the drainage area size. Because the site contours do not allow gravity-draining, the system will be pumped (row 38) and thus is required to have a 12 hour lag time after the rain event ends (row 39).

For the second, volume reduction-type control for Drainage Area A, water will be irrigated on a natural area (similar to a traditional retention/irrigation system), so the designer inputs "Infiltration Field" in row 42. They plan to route all captured water from SCM 1 to be irrigated, so they enter 100 in row 43, "Yes" in row 46, "No; infiltrate all routed water" in row 47, and "Irrigation" in row 51. Per ECM requirements, there will be two zones that receive alternating irrigation, so they enter 2 in row 52. Percolation tests from the site show that the infiltration rate is 0.15 in/hr, which the designer enters in row 53. SLAT assumes that irrigation will continue for the duration of the drawdown period, so row 54 is automatically populated with the SCM 1 drawdown time of 48 hours. Finally, the designer wants SLAT to calculate the infiltration field area, so they input "No; calculate area" for row 55. Row 57 shows that 3.229 acres are needed to irrigate the full volume.

The designer then moves to the column for Drainage Area B and fills out the appropriate drainage area information, inputting 0.25 (row 17), 0 (row 18), and 100 (row 19) since the cistern will be capturing runoff from the roof only. The control is designed to be "Off-line" and the designer has selected a 10,000 gallon (1337 ft^3) underground cistern. Based on the 0.25-acre drainage area, this volume represents a water quality volume of 1.48 inches, which is entered on row 28; the actual volume of 1337 ft^3 is shown in row 30. The cistern will provide water for an irrigated landscaped area, and the designer has calculated, based on the irrigation schedule, that the cistern can be completely drawn down in 3.5 days (84 hours). They input 84 hours for the drawdown time in row 31. They then leave row 32 as "No" and allow SLAT to calculate the runoff capture efficiency, which is shown in row 34 to be 85.8%.

The cistern will be pumped and must comply with the 12 hour lag time requirement, and row 39 and 40 are input as such. The designer then enters “Beneficial Reuse” for the SCM 2 type in row 42. Since all of the captured water will be used for irrigation of the landscaped area, they enter 100 in row 43, “Yes” in row 46, and leave the default “No; infiltrate all routed water” in row 47. They then enter “N/A” in row 51; rows 52 through 58 apply to infiltration fields and are not necessary for the SLAT load calculations.

Figure 5 shows a screenshot of the information described above as input in SLAT. Once the user inputs all of the above information, they scroll down to the bottom of the worksheet and click the “View Full Results” button. This button takes them to the “2. RESULTS” worksheet, which is shown as a screenshot in Figure 6.

Step 1: Input site characteristics in yellow highlighted cells				
Site Name	Editor Name		Date	*SLAT Beta - 7/2014*
Is your site within the Barton Springs Zone?	Yes			
How many drainage areas, n_{max}, does your site have?	2			
	Drainage Area A	*Drainage Area B*	*Drainage Area C*	*Drainage Area D*
Drainage area to the control, A_n (Acres)	7.75	0.25	1.00	1.00
Base impervious cover of the drainage area, IC_B (%)	0.0	0.0	0.0	0.0
Developed impervious cover of the drainage area, IC_D (%)	48.4	100.0	0.0	0.0
Annual average runoff for existing site, V_{Ex} (in/yr)	1.18	1.18	0.00	0.00
Annual average runoff for developed site, V_d (in/yr)	10.54	22.91	0.00	0.00
Step 2: Input SCM characteristics in yellow highlighted cells				
	Drainage Area A	*Drainage Area B*	*Drainage Area C*	*Drainage Area D*
SCM 1 (First in Series)	SCM A1	SCM B1	SCM C1	SCM D1
SCM Type	**Retention Basin**	**Retention Basin**	**Retention Basin**	**Retention Basin**
Is SCM 1 off-line?	Yes (Off-Line)	Yes (Off-Line)	Yes (Off-Line)	Yes (Off-Line)
What is the water quality volume, *WQV*, (in)?	**1.50**	**1.48**	**2.50**	**2.50**
Minimum water quality volume (1/2" Plus Rule)	*0.78*	*1.30*	*0.50*	*0.50*
SCM 1 Actual Volume (ft^3)	42199	1343	9075	9075
Drawdown Time, *DDT* (hrs)	**48**	**84**	**60**	**60**
Do you already know the runoff capture efficiency?	No	No	No	No
User Entered Runoff Capture Efficiency, RCE (%)	0.0	0.0	0.0	0.0
Runoff Capture Efficiency, RCE (%)	97.4	88.0	100.0	100.0
Annual average volume treated by SCM 1, $V_{T,1}$ (in/yr)	10.27	20.17	0.00	0.00
Annual average bypass volume, $V_{by,1}$ (in/yr)	0.27	2.74	0.00	0.00
Conveyance				
How is effluent from SCM 1 discharged?	**Pumped**	**Pumped**	**Pumped**	**Pumped**
Delay after end of rainfall before discharging SCM 1 (hrs)	12	12	12	12
SCM 2 (Second in Series)	SCM A2	SCM B2	SCM C2	SCM D2
SCM Type	**Infiltration Field**	**Beneficial Reuse**	**Infiltration Field**	**Infiltration Field**
Percent of SCM 1's WQV routed to SCM 2	**100**	**100**	**100**	**100**
Water quality volume routed to SCM 2 (in)	1.50	1.48	2.50	2.50
Annual volume routed to SCM 2, $V_{T,2}+V_{inf}$ (in/yr)	10.27	20.21	0.00	0.00
Does SCM 2 reduce volume, such as by infiltration?	Yes	Yes	Yes	Yes
Do you already know the infiltrated water quality volume?	No; infiltrate all routed water	No; infiltrate all routed water	No; infiltrate all routed water	No; infiltrate all routed water
User-entered infilt. water quality volume, WQV_{inf} (in)	0.00	0.00	0.00	0.00
Annual Infiltrated Volume, V_{inf} (in/yr)	10.27	20.21	0.00	0.00
Annual Non-Infilt. Volume Treated by SCM 2, $V_{T,2}$ (in/yr)	0.00	0.00	0.00	0.00
How is water applied to the infiltration field?	Irrigation	N/A	Irrigation	Irrigation
Number of application zones	2	2	2	2
Soil infiltration rate (in/hr)	0.15	0.2	0.2	0.2
Total application time, t_{app} (hrs)	48	84	60	60
Do you know the infiltration field area?	No; calculate area	No; calculate area	No; calculate area	No; calculate area
User-Entered Infiltration Field Area (Ac)	0.00	0.00	0.00	0.00
Calculated Field Area for Given Volume (Ac)	3.23	0.04	0.42	0.42
Min. Field Area for Load Compliance (Ac)	*1.87*	*0.30*	*0.00*	*0.00*

Figure 5: Screenshot of example project from the SLAT worksheet "1. ENTER DATA."

STORMWATER LOAD ANALYSIS TOOL 1.0 1/2

Site Name: User Manual Example Site By: Editor Name Date: Date

RESULTS: COMPLIANCE TABLE *SLAT 1.0 - 12/2014*

POLLUTANT		DEVELOPED LOAD, WITH CONTROLS					EXISTING LOAD	LOAD EQUIV. FACTOR, *LEF*	FULLY COMPLIES?
		Drainage Area A	Drainage Area B	Drainage Area C	Drainage Area D	TOTAL LOAD, L_{out}			
COD	lbs/yr	1.98E+01	6.53E+00	0.00E+00	0.00E+00	2.63E+01	8.36E+01	0.32	YES
E. coli	10^6 MPN/yr	2.83E+04	9.32E+03	0.00E+00	0.00E+00	3.76E+04	8.15E+04	0.46	YES
Pb	lbs/yr	4.08E-03	1.35E-03	0.00E+00	0.00E+00	5.43E-03	9.20E-03	0.59	YES
TN	lbs/yr	8.32E-01	2.73E-01	0.00E+00	0.00E+00	1.10E+00	2.56E+00	0.43	YES
TOC	lbs/yr	5.47E+00	1.79E+00	0.00E+00	0.00E+00	7.27E+00	2.80E+01	0.26	YES
TP	lbs/yr	1.28E-01	4.21E-02	0.00E+00	0.00E+00	1.70E-01	2.66E-01	0.64	YES
TSS	lbs/yr	2.33E+01	7.74E+00	0.00E+00	0.00E+00	3.10E+01	3.57E+02	0.09	YES
Zn	lbs/yr	2.47E-02	8.12E-03	0.00E+00	0.00E+00	3.28E-02	5.06E-02	0.65	YES

COMPLIANT

SUMMARY OF INPUTS

Site Location	Within Barton Springs Zone - Compare to Existing Loads				
	Drainage Area A	Drainage Area B	Drainage Area C	Drainage Area D	TOTALS
Drainage Area, A_n (Ac)	7.75	0.25	N/A	N/A	8.00
Developed IC, IC_D (%)	48.4	100.0	N/A	N/A	50%
SCM 1	Retention Basin	Retention Basin	N/A	N/A	-
Water Qual. Vol, *WQV* (in)	1.50	1.48	N/A	N/A	-
Actual Volume (ft^3)	42199	1343	N/A	N/A	43542
Drawdown Time, *DDT* (hrs)	48	84	N/A	N/A	-
SCM 2	Infiltration Field	Beneficial Reuse	N/A	N/A	-
Infiltration Rate (in/hr)	0.15	0.20	N/A	N/A	-
Infiltration Field Area (Ac)	3.23	0.04	N/A	N/A	3.27
Error with Input Values?	NO	NO	NO	NO	

Change Inputs

Print Results

STORMWATER LOAD ANALYSIS TOOL 1.0 2/2

Site Name: User Manual Example Site By: Editor Name Date: Date

RESULTS: PLOTS *SLAT 1.0 - 12/2014*

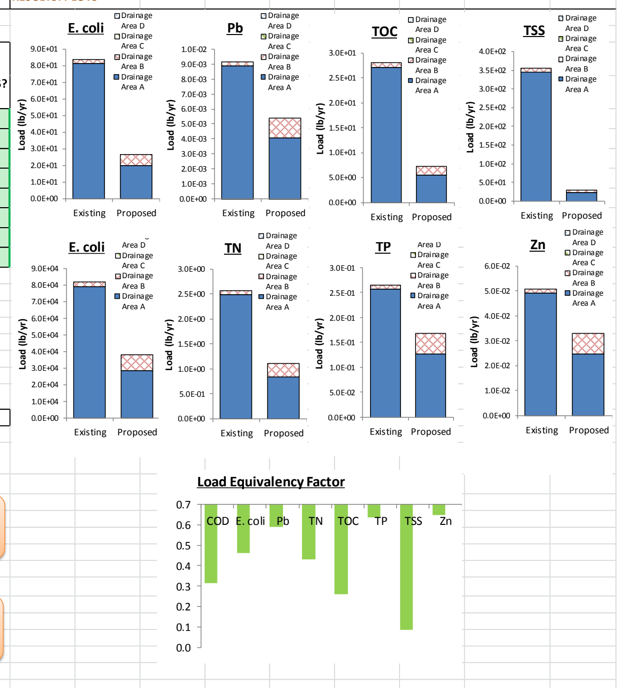


Figure 6: Screenshot of worksheet "2. RESULTS" showing that proposed design complies with SOS requirements.

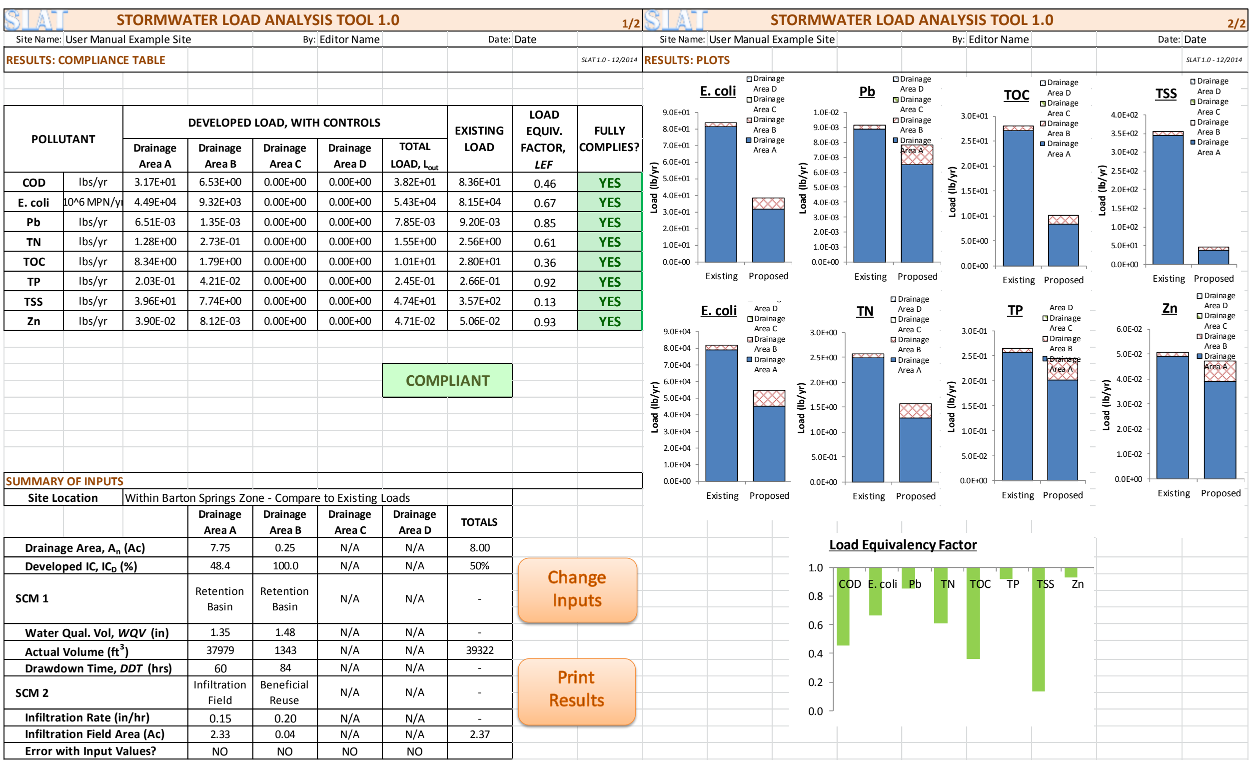
As shown in the results page in Figure 6, the design meets the SOS ordinance load requirements. Considering both drainage areas, the load for all pollutants is less than the existing load, and therefore the load equivalency factor (LEF) is less than 1.0 for all pollutants. One may note, by looking at the results plots, that the proposed load for Drainage Area B (the rainwater cistern) is greater than the existing load for Drainage Area B. This means that, on its own, the rainwater cistern would undersized. However, the large treatment volume of Drainage Area A (the sedimentation/filtration system) compensates for the undersized cistern; therefore the overall site is compliant.

At this point, the designer could stop because their proposed design complies. However, they may wish to modify their design and shrink the controls. Since the rainwater harvesting system has more design constraints, the designer chooses to iterate with design parameters for Drainage Area A, while leaving Drainage Area B alone.

The designer would like to decrease the size of the infiltration field for Drainage Area A. To do so, they first increase the drawdown time of SCM 1, which correspondingly increases the application time of irrigation, from 48 hours to 60 hours (row 31). This causes the infiltration field size to decrease from 3.23 acres to 2.58 acres (row 57). After this change, the Results worksheet shows that while the load equivalency factors have increased, the design is still compliant.

The designer then decides to shrink the size of the retention basin by decreasing the water quality volume from 1.50 inches to 1.20 inches (row 28); this also helps to decrease the infiltration field size. Checking the Results worksheet reveals that the proposed design is no longer compliant, as some of the pollutants (lead, total phosphorus, and zinc) now have load equivalency factors greater than 1. So, the designer iterates on the water quality volume in row 28, and settles on a water quality volume of 1.35 inches for the basin. For the updated design, zinc has the highest load equivalency factor (LEF) of all pollutants at 0.95, which is still less than 1.0. Therefore, the proposed design is compliant, as shown in Figure 7.

Note that in cases where the proposed design results in a LEF of exactly 1.00, then the results plots may display a skewed y-axis scale. In this case, the plots should be ignored.


STORMWATER LOAD ANALYSIS TOOL 1.0 1/2

Site Name: User Manual Example Site By: Editor Name Date: Date

RESULTS: COMPLIANCE TABLE SLAT 1.0 - 12/2014

POLLUTANT		DEVELOPED LOAD, WITH CONTROLS					EXISTING LOAD	LOAD EQUIV. FACTOR, *LEF*	FULLY COMPLIES?
		Drainage Area A	Drainage Area B	Drainage Area C	Drainage Area D	TOTAL LOAD, L_{out}			
COD	lbs/yr	3.17E+01	6.53E+00	0.00E+00	0.00E+00	3.82E+01	8.36E+01	0.46	YES
E. coli	10^6 MPN/yr	4.49E+04	9.32E+03	0.00E+00	0.00E+00	5.43E+04	8.15E+04	0.67	YES
Pb	lbs/yr	6.51E-03	1.35E-03	0.00E+00	0.00E+00	7.85E-03	9.20E-03	0.85	YES
TN	lbs/yr	1.28E+00	2.73E-01	0.00E+00	0.00E+00	1.55E+00	2.56E+00	0.61	YES
TOC	lbs/yr	8.34E+00	1.79E+00	0.00E+00	0.00E+00	1.01E+01	2.80E+01	0.36	YES
TP	lbs/yr	2.03E-01	4.21E-02	0.00E+00	0.00E+00	2.45E-01	2.66E-01	0.92	YES
TSS	lbs/yr	3.96E+01	7.74E+00	0.00E+00	0.00E+00	4.74E+01	3.57E+02	0.13	YES
Zn	lbs/yr	3.90E-02	8.12E-03	0.00E+00	0.00E+00	4.71E-02	5.06E-02	0.93	YES

COMPLIANT

SUMMARY OF INPUTS

Site Location	Within Barton Springs Zone - Compare to Existing Loads				
	Drainage Area A	Drainage Area B	Drainage Area C	Drainage Area D	TOTALS
Drainage Area, A_n (Ac)	7.75	0.25	N/A	N/A	8.00
Developed IC, IC_D (%)	48.4	100.0	N/A	N/A	50%
SCM 1	Retention Basin	Retention Basin	N/A	N/A	-
Water Qual. Vol, *WQV* (in)	1.35	1.48	N/A	N/A	-
Actual Volume (ft^3)	37979	1343	N/A	N/A	39322
Drawdown Time, *DDT* (hrs)	60	84	N/A	N/A	-
SCM 2	Infiltration Field	Beneficial Reuse	N/A	N/A	-
Infiltration Rate (in/hr)	0.15	0.20	N/A	N/A	-
Infiltration Field Area (Ac)	2.33	0.04	N/A	N/A	2.37
Error with Input Values?	NO	NO	NO	NO	

Figure 7: Screenshot of worksheet "2. RESULTS" showing that updated proposed design, with modified drawdown time and water quality volume for Drainage Area 1, complies with SOS load requirements.

Note that in cases where the proposed design results in a LEF of exactly 1.00, then the results plots may display a skewed y-axis scale. In this case, the plots should be ignored.

The designer then decides to print worksheets “1. ENTER DATA” and “2. RESULTS” as evidence of the engineering analysis which can be submitted to the drainage reviewer. (Exact submittal requirements are subject to the Planning & Development Review Department.) The layout is set to print on two sheets of paper, assuming the printer settings for an 8.5”x11” sheet with 0.5” margins.

VII. REFERENCES

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APPENDIX A: DEFAULT INPUT VALUES

Row	Description	Value
14	Is your site within the Barton Springs Zone?	Yes
15	How many drainage areas does your site have?	1
17	Drainage Area to the control (Acres)	1
18	Base impervious cover of the drainage area (%)	0
19	Developed impervious cover of the drainage area (%)	0
26	SCM Type	Retention Basin
27	Is SCM 1 off-line?	Yes (Off-Line)
28	What is the water quality volume (in)?	2.50
31	Drawdown Time (hours)	60
32	Do you already know the runoff capture efficiency?	No
33	User Entered Runoff Capture Efficiency (%)	0
38	How is effluent from SCM 1 discharged?	Pumped
39	Delay after end of rainfall before discharging SCM 1 (hrs)	12
42	SCM Type	Infiltration Field
43	Percent of SCM 1's water quality volume routed to SCM 2	100
46	Does SCM 2 reduce volume, such as by infiltration?	Yes
47	Do you already know the infiltrated water quality volume?	No; infiltrate all routed water
48	User-entered infiltrated water quality volume (in)	0
51	How is water applied to the infiltration field?	Irrigation
52	Number of application zones	2
53	Soil infiltration rate (in/hr)	0.2
55	Do you know the infiltration field area?	No; calculate area
56	User-Entered Infiltration Field Area (Acres)	0.00
64-71	Effluent concentrations for the eight pollutants for alternative SCM 1	Blank
74-81	Effluent concentrations for the eight pollutants for alternative SCM 2	Blank