Using the Western Washington Hydrology Model (Version 4.0) to Size Silva Cells for Runoff Treatment and Flow Control

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DeepRoot® HDR

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Introduction

These guidelines present hydrologic modeling procedures for sizing Silva Cell Best Management Practices (BMPs) to meet Washington State Department of Ecology (Ecology) minimum stormwater requirements outlined in the 2012 Ecology *Stormwater Management Manual for Western Washington* (SMMWW) using the Western Washington Hydrology Model, Version 4.0 (WWHM4). The remainder of this text provides background information and step-by-step instructions for using WWHM4 to size Silva Cells to meet water quality treatment (Minimum Requirement #6) and flow control (Minimum Requirement #7) requirements in accordance with the 2012 SMMWW. Appendix A provides examples to graphically illustrate the methodology for two hypothetical projects. The first hypothetical project includes Silva Cells sized for flow control and water quality treatment, and the second project includes Silva Cells sized for water quality treatment only.

Background

Ecology has approved Silva Cells as being functionally equivalent to a "rain garden" (Ecology 2009). It is important to note that the definition of rain gardens changed in the 2012 SMMWW.   Whereas the 2005 SMMWW included rain gardens in the definition of engineered bioretention facilities, rain gardens are now defined as non-engineered facilities only. For the remainder of this document, the term bioretention will be used in place of the term rain garden in reference to this functional equivalency.

These guidelines are intended to supplement the "Using the Western Washington Hydrology Model to Size Silva Cells for Stormwater Filtration", dated November 24, 2009. The 2009 guidelines provide instructions for sizing Silva Cells to meet treatment requirements using only a sand filter to represent the Silva Cell BMP.

This document provides step-by-step instructions for modeling Silva Cells using the bioretention element in WWHM4. The benefit of using the bioretention element instead of the sand filter element is that both flow control and treatment performance can be evaluated. Silva Cells provide treatment by filtering stormwater runoff through a soil media that meets Ecology's filter medium criteria. Similar to bioretention, Silva Cells also provide flow control by promoting infiltration to native soils in areas that are suitable for infiltration. Because Silva Cells support the growth of large, healthy trees, they also offer additional flow control benefits through canopy interception, evapotranspiration, and enhanced infiltration as the roots grow and develop macropores in the soil. For purposes of sizing Silva Cells to meet Minimum Requirement #7 (Flow Control), only storage and infiltration into native soils are modeled. The additional flow control benefits provided by tree canopy interception, evapotranspiration, and enhanced infiltration are not included in the model.

Applicability

These guidelines are applicable to sizing Silva Cell BMPs to satisfy Ecology's minimum stormwater requirements for treatment (Minimum Requirement #6) and flow control (Minimum Requirement #7) using WWHM4 in accordance with the 2012 SMMWW. WWHM4 is a professional version of the model, requiring a license for use. These instructions do not apply to other versions of the model, such as WWHM3, which can be downloaded for free from Ecology's website. If using WWHM3 or previous versions of the model, follow the appropriate bioretention sizing instructions in Volume III, Appendix III-C of the 2012 SMMWW.

The user is responsible for verifying that their work is consistent with current versions of the documents listed below, upon which these guidelines are based:

- Volume III and Volume V of the 2012 SMMWW

- Appendix III-C of the 2012 SMMWW

- WWHM4 Users Manual

Refer to Volume V of the 2012 SMMWW, *BMP T7.30: Bioretention Cells, Swales, and Planter Boxes, Design Criteria for Bioretention* for the Silva Cell soil media design criteria. The soil media in the Silva Cell shall match criteria for the default bioretention soil media (BSM) or the custom BSM soil mixes.

Refer to Volume V of the 2012 SMMWW, *BMP T7.30 Determining Subgrade Infiltration Rates* to determine the native soil infiltration rate. Refer to Volume of the SMMWW, *BMP T7.30, Determining Bioretention Soil Mix Infiltration Rate* to determine the infiltration rate of the Ecology default BSM mix or for a custom BSM mix.

Modeling Procedures

For basic instructions on how to set up the model, refer to the WWHM4 Users Manual. The following text provides instructions on how to define precipitation data, pre- and mitigated (developed) land use conditions, the proposed Silva Cell BMP configuration, and how to verify whether the proposed design meets the applicable stormwater requirements. Sizing BMPs is typically an iterative procedure, in which multiple model runs are needed in order to define the most cost-effective solution that meets all requirements.

Step 1 - Define Precipitation Data

a. **Click on the map information toolbar button.**

The map information button is the first toolbar button on the left (the toolbar is located at the top of the screen below the pulldown menus). This will bring up the map information screen where the user chooses the county or city and the project site location.

b. **Click the down arrow on the pulldown menu located in the upper left corner directly above the map.**

Left click on the county or city name in which the project site is located. This will bring up the map screen. The map is directly linked to the meteorological database that contains precipitation and evaporation data.

Alternatively, the user can elect to use Washington State Department of Transportation (DOT) precipitation data by checking the "Use DOT data" box to the right of the map. When the DOT data box is checked, the map screen changes to show a map of the counties of Western Washington with the areas outlined where DOT precipitation data are available (DOT data are not available for all locations).

c.   **Locate the project site on the map screen and left click on the project site location.**

A red circle will be placed on the map identifying the project site. The precipitation gage and precipitation multiplication factor are shown to the right of the map and will vary depending on the project site location. For users that elect to use DOT data, the DOT zone and isohyetal value are shown to the right of the DOT map.

Clicking the + and – buttons located in the lower left corner of the map screen will zoom the map in and out, respectively. Clicking the cross hair button zooms the map out to the full county view, and clicking on the arrow keys scrolls the map view.

Step 2 - Define Land Use for Predeveloped Scenario

a.   **Click on the General Project Information toolbar button (second toolbar button from the left).**

This will bring up the schematic screen where the user defines the information about the project site for predeveloped and/or mitigated land use conditions.

b.   **Check the box in front of the predeveloped scenario in the upper left corner of the schematic screen.**

Predeveloped is defined as the historical condition of the project site and is a required input when Silva Cells are used to meet Minimum Requirement #7 (Flow Control). Per Section 2.5.7 of the 2012 SMMWW, stormwater discharge durations from the developed site shall match predeveloped durations. The flow control performance standard is discussed in more detail in Step 7. See the 2012 SMMWW and local jurisdiction requirements for information on how to define the predeveloped condition.

The Land Use Basin element is the upper left element in the Basic Elements array. Each element represents a specific feature (basin, pond, etc.). The Land Use Basin element represents the tributary drainage area to the Silva Cell.

c.   **Drag and drop the Land Use Basin element onto any grid cell in the schematic editor.**

Left click on the Land Use Basin element under the Basic Elements heading.

Drag and drop the Land Use Basin element onto any empty grid cell in the grid to the right. This grid, called the schematic editor, is where elements are placed and linked together. The scroll bars on the left and bottom of the grid expands the grid as large as needed to contain all of the elements for the project.

d.   **Input the land use area in acres of the predeveloped basin.**

Left click on the Land Use element and a list of available pervious and impervious land use types will appear to the right of the grid. Fill in the appropriate areas into the boxes located to the right of each item on the list.

Pervious land uses are categorized by soil, vegetation, and slope, as follows:

- *Soil type categories: A/B (outwash soils), C (till), and SAT (saturated/wetland/hydric soils)*

- *Vegetation categories: forest (second growth Douglas Fir), pasture (non-forested natural areas/scrub/shrub rural vegetation), and lawn (sod lawn/grass/landscaped urban vegetation)*

- *Land slope categories: flat (0-5%), moderate (5-15%), and steep (>15%).*

Impervious land uses are divided into seven types: roads, roofs, driveways, sidewalks, parking, ponds, and porous pavement. The roads, driveways, and parking categories are subdivided by different slopes, which are the same as for the pervious land use (flat, moderate, steep). Porous pavement is defined as a "hard surface" and should be modeled in accordance with Volume III of the 2012 SMMWW, Appendix III-C, Section C.1.

For most projects, the predeveloped land condition should be forested based on the soil type(s) found on the project site.

e. **In the schematic editor, right click on the Land Use Basin element and select "Connect to Point of Compliance".**

The Point of Compliance is where the model computes all hydrologic statistics, and compares predeveloped discharge rates and durations to mitigated discharged rates and durations for conformance with state flow control standards.

Step 3 - Define Land Use for Mitigated Scenario

a. **Check the box in front of the mitigated scenario in the upper left corner of the schematic screen.**

The mitigated scenario is defined as the mitigated land use condition with stormwater mitigation measures in place.

b. **Define land uses for the mitigated scenario.**

In the schematic editor for the mitigated scenario, drag and drop a Land Use Basin element onto the grid, left click the element, and define the land use types and area for the basin, similar to Steps 2c-2d.

Unlike the predeveloped scenario, do not connect the mitigated Land Use Basin to the Point of Compliance. Instead, connect the mitigated Land Use Basin to the Silva Cell (modeled as bioretention). The Silva Cell will be connected to the Point of Compliance, as described below.

Step 4 - Define the Silva Cell

Instructions are provided below for defining Silva Cells using the bioretention element in WWHM4, both with and without underdrains. Underdrains may be needed in areas that are not suitable for infiltration. Underdrains may also help improve water quality treatment performance in areas with marginal infiltration rates. Similar to bioretention facilities, underdrains may not be needed in areas that are suitable for infiltrating stormwater runoff.

a. **Drag and drop a Bioretention Swale element under the Pro Elements heading and place this element in the grid below the Land Use Basin element.**

The Bioretention Swale is located in the first row of Pro Elements, on the far right.

The Bioretention Swale element is used to model the Silva Cell from the invert of the underdrain to the top of the cell. Stormwater runoff will be treated as it filters through this layer.

b. **Connect the Bioretention Swale element to the Land Use Basin element.**

Right click on the Land Use Basin element and select Connect to Element in the pulldown menu. A green line will appear with one end connected to the basin element and the other end connected to the mouse pointer. With the mouse pointer, pull the line down to the Bioretention Swale element and left click on the element. This will bring up the From Basin to Conveyance window that allows the user to specify which runoff components to route to the Bioretention Swale element. Both the surface runoff and interflow should always be checked. Groundwater should only be checked when there is observed and documented groundwater surfacing from the upstream basin. After the appropriate boxes have been checked, click the OK button.

A line will appear on the grid between the Bioretention Swale and the basin.

The Basin screen will show that surface and interflow flows to the Bioretention Swale (groundwater will also be shown, if checked).

c. **Click on the Bioretention Swale element that was placed in the grid. This will bring up a screen to the right of the grid where the Silva Cell parameters will be defined.**

d. **Enter the dimensions of the Silva Cell in the boxes under the Swale Dimensions heading, as follows:**

- *Swale Bottom Elevation (ft): Represents the bottom of the Silva Cell facility. This is a reference elevation, not tied to any real-world datum. May leave at 0 or enter elevation per design plans.*

- *Swale Length (ft): Enter the length of the Silva Cells.*

- *Swale Bottom Width (ft): Enter the width of the Silva Cells, typically the width of the sidewalk if used in a roadway application.*

- *Freeboard (ft): Enter the minimum freeboard required by local jurisdiction, or the actual freeboard proposed if greater than the minimum.*

- *Overroad Flooding (ft): Represents maximum depth of water above the emergency spillway. This could be a driveway, roadway, or weir. This value automatically populates and updates based on inputs specified elsewhere. No user input is needed for this cell.*

- *Effective Total Depth (ft): Represents the total facility depth, including filter media, freeboard, and riser height. This value automatically populates and updates based on inputs specified elsewhere. No user input is needed, but the user must check that the effective depth equals the Silva Cell depth (filter media plus air gap; see steps below).*

- ***Bottom Slope of Swale (ft/ft):*** *Set to minimum value of 0.001. IMPORTANT NOTE: Must provide positive bottom slope, even if the Silva Cell bottom is flat because WWHM4 model will not perform correctly with 0 ft/ft slope and may produce erroneous results.*

- ***Left Side Slope (H:V):*** *Set to 0 to represent vertical side slopes.*

- ***Right Side Slope (H:V):*** *Set to 0 to represent vertical side slopes.*

e. **Include underdrain pipe (if applicable based on design).**

If applicable, check the box next to "Underdrain Used" and input the underdrain pipe diameter in feet. Set the underdrain orifice equal to the pipe diameter. Note that the dimensions for the underdrain pipe are in feet, while the orifice diameter is in inches.

f. **Enter the Silva Cell filter media depth and type under the Material Layers for Swale heading.**

Enter a depth (in feet) for Layer 1 that represents the filter media depth. Leave the Layer 2 and Layer 3 depths as 0.

The actual depth for Soil Layer 1 depends on the number of Silva Cells stacked on top of each other and the depth of the air gap (or air space above the top of the media). The manufacturer recommends a minimum 1-inch air gap, but larger air gaps may be used and are preferred to help meet flow control requirements by allowing for more ponding of stormwater runoff above the media. Larger air gaps also help prevent model instabilities.

For example, if a stack of two Silva Cell frames are chosen with a 6-inch air gap at the top, then the Layer 1 depth input should be 2.17 feet (Silva Cell frame height is 16 inches; two frames give a total height of 32 inches. A 6-inch air gap leaves 26 inches of filter media, or 2.17 feet).

Note that the SWWMM requires a minimum BSM mix depth of 12 inches for flow control and 18 inches for treatment (for bioretention facilities).

If designs do not include an underdrain, specify the filter media type as follows:

- *If the contributing drainage area is less than 5,000 square feet of pollution generating impervious surface, less than 10,000 square feet of impervious surface, and less than ¾ acres of lawn/landscaping, select "Amended 3.0 in/hr" in the Soil Layer 1 pulldown menu.*

- *If the influent drainage area exceeds any of the above referenced thresholds, use a design infiltration rate of 1.5 inches per hour. Note that the Soil Layer 1 pulldown menu only includes amended soil for the following design infiltration rates: 2.5, 3, 5, 10, and 15 inches per hour. To specify 1.5 inches per hour, select "Edit Soil Types" and edit the soil type parameters as follows:*

    1. *Edit the K Sat value to match the custom design infiltration rate. Note that K Sat is entered in units of centimeters per hour. For example, to specify a custom design infiltration rate of 1.5 inches per hour, enter a K Sat value of 3.81 centimeters per hour.*

    2. *Maintain the default values for the remaining parameters, as appropriate.*

    3. *Enter a name for the new soil type and click Save. For example, to specify a design infiltration rate of 1.5 inches per hour, input 3.81 centimeters per hour for K Sat and name "Amended 1.5 in/hr".*

If designs do include an underdrain, specify the soil media type as follows:

- *If Silva Cells designed for water quality treatment (Minimum Requirement #6) only, the above guidance applies.*

- *If Silva Cells designed for flow control (Minimum Requirement #7), a design infiltration rate of 6 inches per hour must be used. Follow the directions above for "Edit Soil Type" to define an amended soil with infiltration rate of 6 inches per hour.*

If designs utilize a custom soil mix, select "Edit Soil Type" and enter the initial saturated hydraulic conductivity (K Sat) and other parameters using the methods identified in Volume V, Chapter 7 of the 2012 SMMWW. For design purposes, in instances where the Silva Cell is not underdrained, the initial K Sat value must be reduced by a factor of 2 if the contributing drainage area is less than 5,000 square feet of pollution generating impervious surface, less than 10,000 square feet of impervious surface, and less than ¾ acres of lawn/landscaping. The K Sat value must be reduced by 4 if the contributing drainage area exceeds any of these thresholds. If the Silva Cell is underdrained, follow the guidance in the preceding sentence to determine treatment capability. To determine flow control benefits of an underdrained facility, run the model again using an infiltration rate of 6 inches per hour with no correction factor applied.

g. Enter the height (in feet), diameter (in inches), and type of riser under the Outlet Structure Data heading.

The Bioretention Swale element must have an overflow riser defined to model overflows that may occur if the available storage volume is exceeded. Toggle the outlet structure type menu to Riser Outlet Structure.

Enter a riser height equal to the air gap depth. See the above discussion on air gap depth and model stability.

Enter a large value (e.g.10,000 inches) for the riser diameter to ensure that there is ample capacity should overflows occur. Assume a flat riser type without a weir notch. Leave the inputs for the orifice diameter and height table as 0.

h. Enter native soil infiltration rates.

If design includes an underdrain:

    1. *Toggle the Native Infiltration to "NO".*

If design does not include an underdrain and if native soils are suitable for infiltration:

    1. *Toggle the Native Infiltration to "YES".*

    2. *Input the measured infiltration rate in inches per hour.*

3. Input a reduction factor to represent the factor of safety. Note that the reduction factor works as a multiplier (i.e., a reduction factor of 0.5 reduces the input infiltration rate by half).

4. Toggle the use wetted surface area (sidewalls) to "NO".

Guidelines and criteria for determining design infiltration rates are provided in Volume III of the 2012 SMMWW, Section 3.3.6.

Step 5 - Connect the Silva Cell to the Point of Compliance

a. **Right click on the Bioretention Swale element and select "Connect to Point of Compliance".**

If the project design includes additional treatment or flow control facilities downstream of the Silva Cell facility to meet the water quality and/or flow control requirements, then connect the Silva Cell to the downstream facility by right clicking on the Bioretention Swale element, selecting "Connect to Element," and then selecting the downstream facility. Note that selecting "Connect to Element" will route both the overflow and underdrained flow from the Silva Cell facility to the downstream facility.

Set the Point of Compliance at the most downstream facility in the design.

Step 6 - Run the model (predeveloped and mitigated scenarios)

a. **Click on the Run Scenario button located in the upper left corner of the schematic screen for the predeveloped scenario and then again for the mitigated scenario (total of two runs needed).**

Step 7a – Evaluate whether designs meet flow control requirements (if applicable)

a. **Click on the Analysis toolbar button.**

The Analysis button is the third toolbar button on the left.

b. **Under the Analyze Datasets menu located at the bottom left of the screen, click the POC 1 tab and check that the flow control duration standard is being met.**

The flow duration table on the right will say either "The Facility PASSED" or "The Facility FAILED". If the facility fails, revise designs and re-run the scenario until it passes.

Step 7b - Evaluate whether designs meet treatment requirements (if applicable)

a. **If an underdrain is NOT included:**

In the General Project Information schematic screen, click on the Bioretention Swale element located in the grid.

Check that the Percent Infiltrated in the lower right corner of the Bioretention Swale screen equals or exceeds 91%. If the value is less than 91%, then increase the size of the Silva Cell or reduce the amount of tributary drainage area until the facility passes.

Note that Silva Cells that are properly sized to meet flow control requirements will generally exceed the minimum water quality treatment requirements.

b. If an underdrain is included:

In the General Project Information schematic screen, click on the Bioretention Swale element located in the grid.

Check that the Percent Through Underdrain equals or exceeds 91%. If the value is less than 91%, then increase the size of the Silva Cell or reduce the amount of tributary drainage area until the facility passes.

Step 8 - Determine Final Silva Cell Configuration

a. Using the modeled Bioretention Swale geometry that meets the applicable requirements, determine the final Silva Cell configuration, taking into account frame nominal lengths, widths, depths, and any other site constraints.

Step 9 - Save Project

a. To save the project, click on File in the upper left corner and select Save As. Select a file name and save the WWHM4 project file.

The user can exit WWHM4 and later reload the project file with all of its information by going to File, Open.

References

Ecology 2009. Letter from Douglas Howie, Program Development Services, Water Quality Program, Washington State Department of Ecology, addressed to Brenda Guglielmina of DeepRoot Green Infrastructure, LLC, regarding Silva Cells for stormwater runoff filtration. Downloaded on October 8, 2012 from (http://www.ecy.wa.gov/programs/wq/stormwater/newtech/Equivalent/091015SilvaCellsEquivalencyapproval.pdf). October 20, 2009.

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Appendix A - Project Examples

Example 1 - Size Silva Cells to meet Minimum Requirement #6 (Runoff Treatment) and Minimum Requirement #7 (Flow Control)

Assumptions:

- Project location: King County

- Project type: 200-foot-long, 50-foot-wide roadway improvement

- Tributary drainage area: 10,000 square feet impervious (0.23 acres)

- Available area for Silva Cells: 40-foot-long, 4-foot-wide section of planter strip

- Soil type: Outwash

- Long-term design infiltration rate: 1.0 inch/hour

Follow the step-by-step process described in the main body of the text as illustrated below.

Step 1 - Define Precipitation Data

Select the Map Information Toolbar in the upper left corner (1) and select King County from the County/City Map Pulldown (2). Click on the project location (3). You may zoom in and out of the map to find the project location as needed. Based on the input project location, the model automatically populates the precipitation gauge and precipitation factor (4).
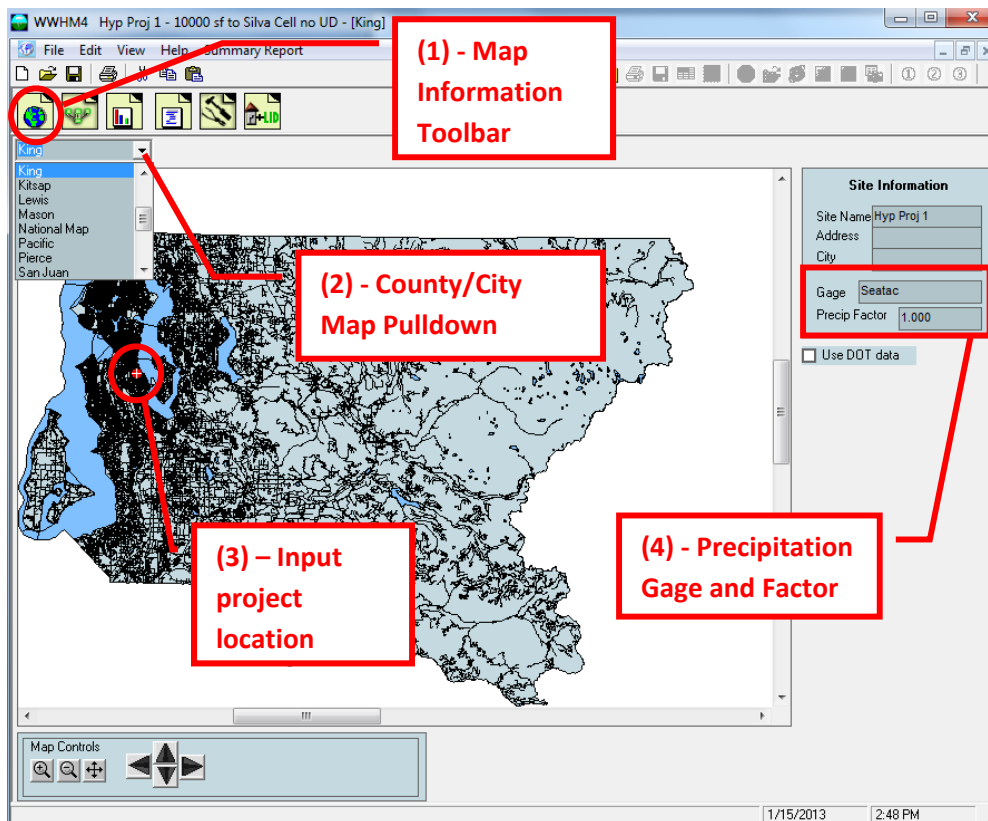
Step 2 - Define Land Use for Predeveloped Scenario

Select the General Project Information toolbar in the upper left corner (1), and then select the Predeveloped scenario (2). Drag and drop a Basin element (3) onto the grid to the right. Left click the basin to bring up the land use input window to the right and input the area in the appropriate boxes. Check the pervious, impervious, and basin totals at the bottom to verify that input areas match designs. Right click on the basin element and connect to the Point of Compliance. A symbol will appear in the lower right corner of the basin element indicating that it has been connected to the Point of Compliance (5).

Step 3 - Define Land Use for Mitigated Scenario

While still in the General Project Information tab from Step 2, now select the mitigated scenario (1) and drag and drop a Basin element onto the grid to the right. Left click the basin to bring up the land use input window to the right and input the area in the appropriate boxes (2). Check the pervious, impervious, and basin totals at the bottom to verify that input areas match designs.
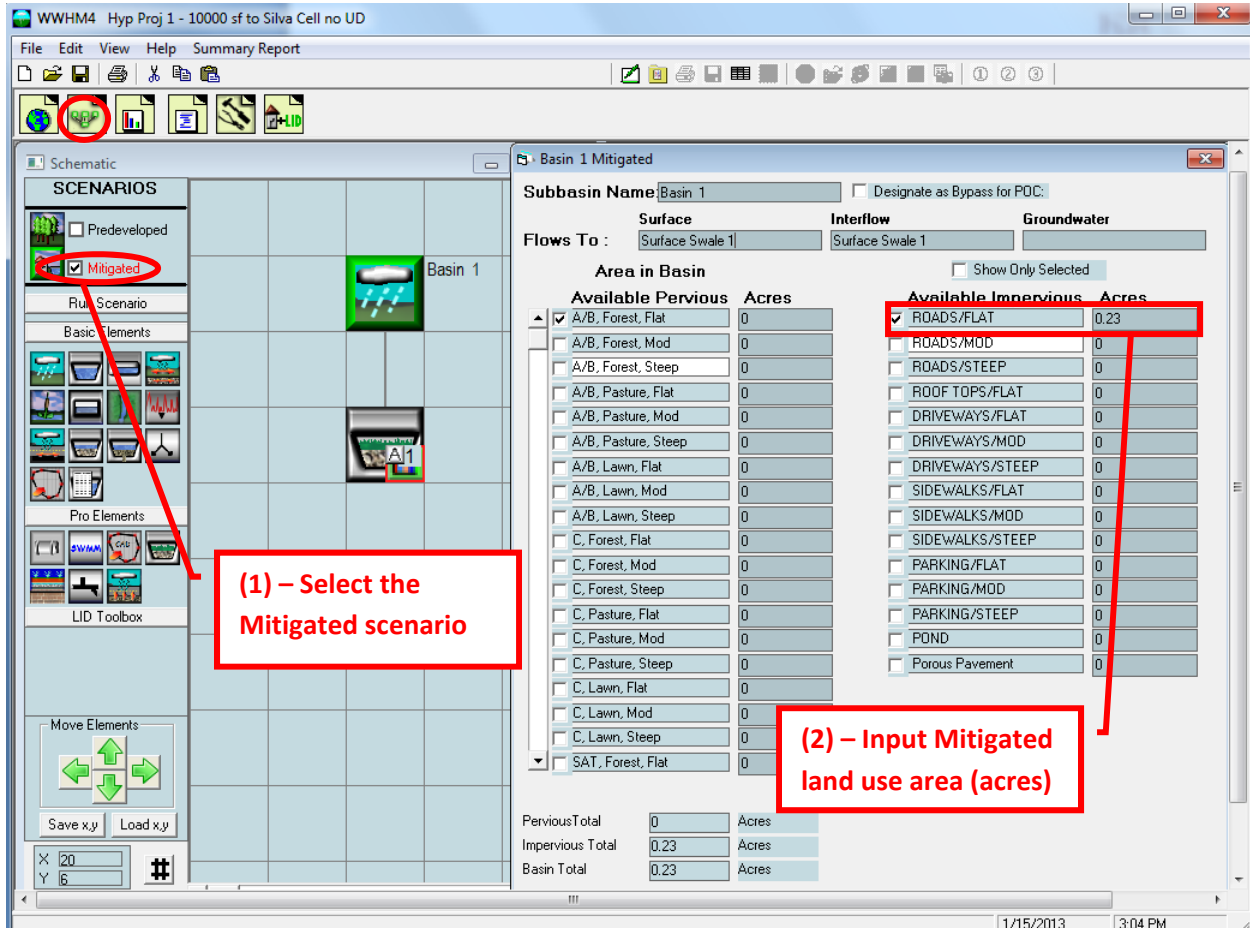
Step 4 - Define the Silva Cell

Drag and drop a Bioretention element onto the grid and place it beneath the Basin element (1). Left click the Bioretention element to bring up a window to the right where the Silva Cell configuration can be defined. Input the Silva Cell geometry into the Swale Dimensions section (2) and the soil media properties in the Material Layers for Swale section (3). Since we are sizing the Silva Cell for water quality treatment, a stack of two Silva Cells frames are needed to provide the minimum 1.5-foot soil media depth required for treatment. Each Silva Cell frame is 16-inches-tall (1.33 feet). With two frames stacked on top of each other, the total height is (32 inches) 2.67 feet. Accounting for a 6-inch air gap per the design, a soil media depth of 2.17 feet (2.67 feet – 0.5 feet) is entered. Because the drainage area is 10,000 square feet of impervious surface, the soil media design infiltration rate is set to 1.5 inches per hour. To do this, click the Edit Soil Types button (3a) to open the View/Edit Soil Types menu (3b) and input a K Sat value of 3.81 centimeters per hour. Next, input the native soil infiltration information (4). In this example, we assume that a hydrogeologist provided the measured infiltration rate of 1 inch per hour, with a factor of safety already included. Therefore, we input a Reduction Factor of 1. Define the outlet structure as a Riser Outlet Structure with a 6-inch air gap (entered as Riser Height Above Swale Surface) and 10,000-inch diameter, with flat riser type (5).

Step 5 – Connect the Silva Cell to the Point of Compliance

Right click the Bioretention element in the grid space and connect it to the Point of Compliance. A symbol will appear in the lower right corner of the Basin element indicating it has been connected (1).
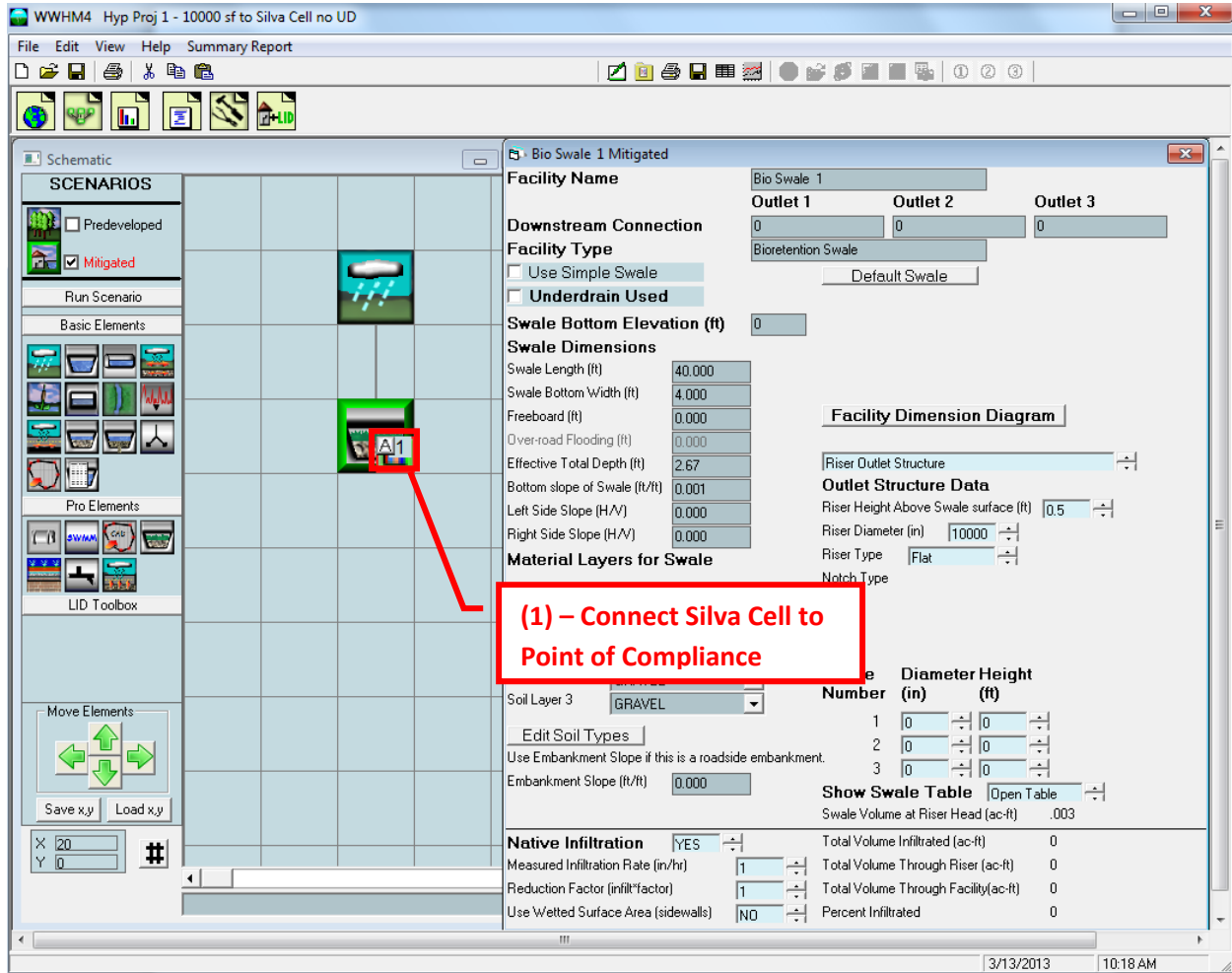
Step 6 - Run the model (predeveloped and mitigated scenarios)

First click on the Predeveloped scenario and click Run Scenario (1). Then click on the Mitigated scenario and click Run Scenario again.

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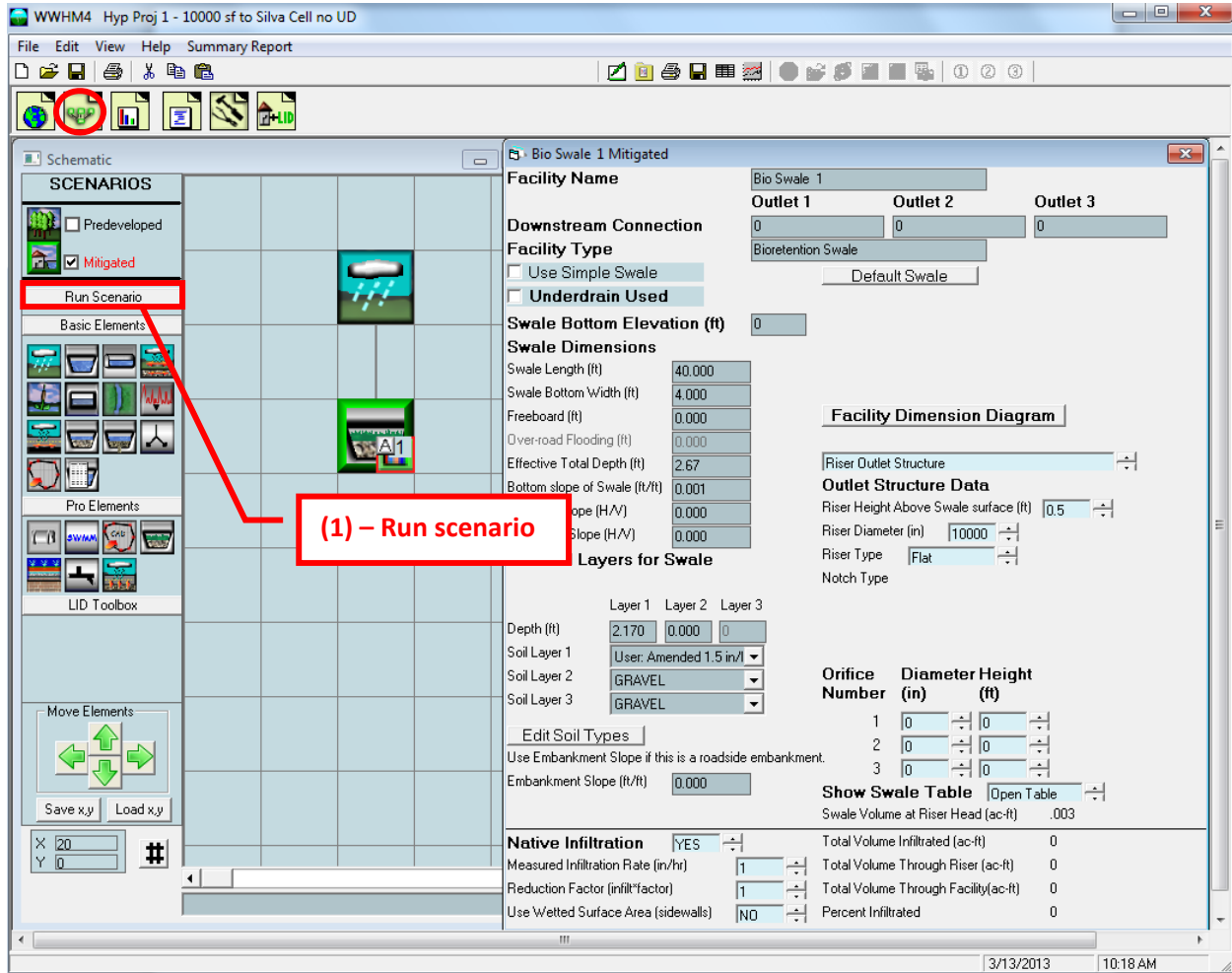
Step 7a – Evaluate whether designs meet flow control requirements

Select the analysis toolbar in the upper left corner of the screen (1), and then select the "POC1" tab in the lower left corner (2). POC1 stands for Point of Compliance 1, which is the Point of Compliance that the predeveloped basin and Silva Cell were connected to in previous steps. If the Silva Cell was sized to infiltrate a significant percentage of the tributary stormwater runoff, then you may see a message stating "Can't compute flow frequency analysis. There are too many zero flows" (3). Click OK. Flow frequency analysis is not needed to evaluate flow control performance relative to the Ecology flow duration standard.
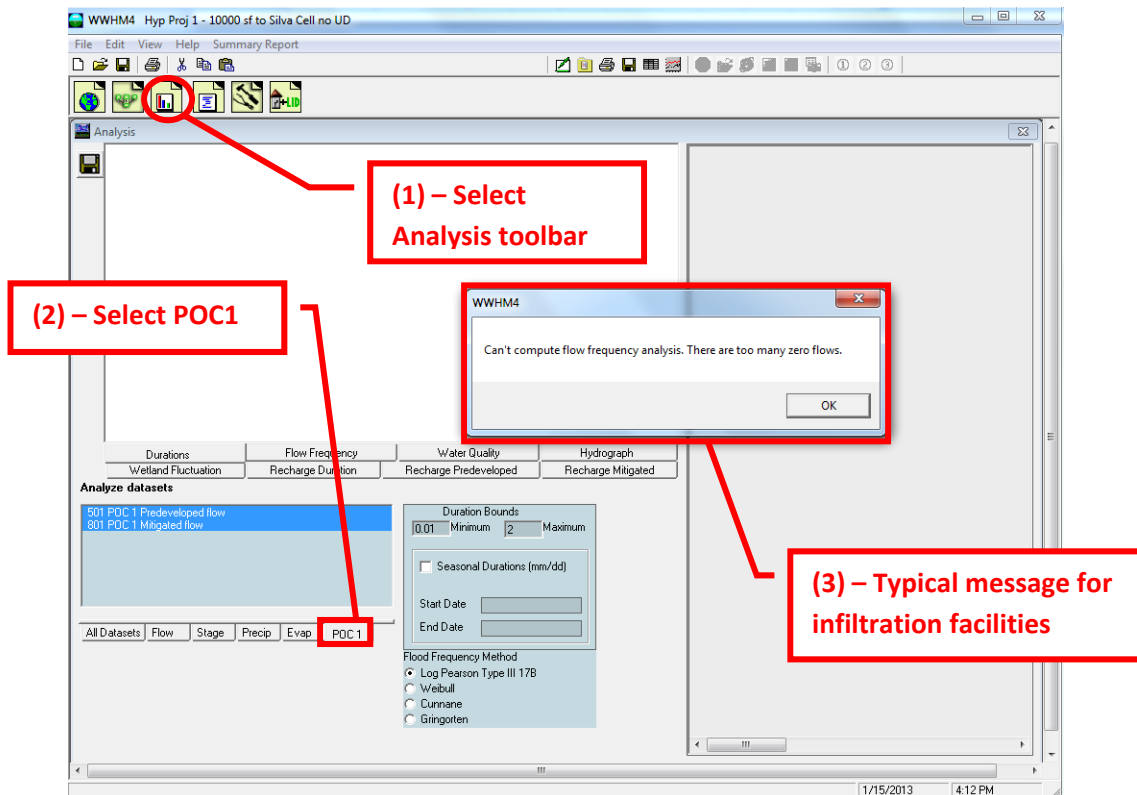
A window will pop up showing the results of flow duration analysis (4). In this example, the facility passes as-is. If the facility does not pass, change the design and re-run the model until a passing result is obtained.
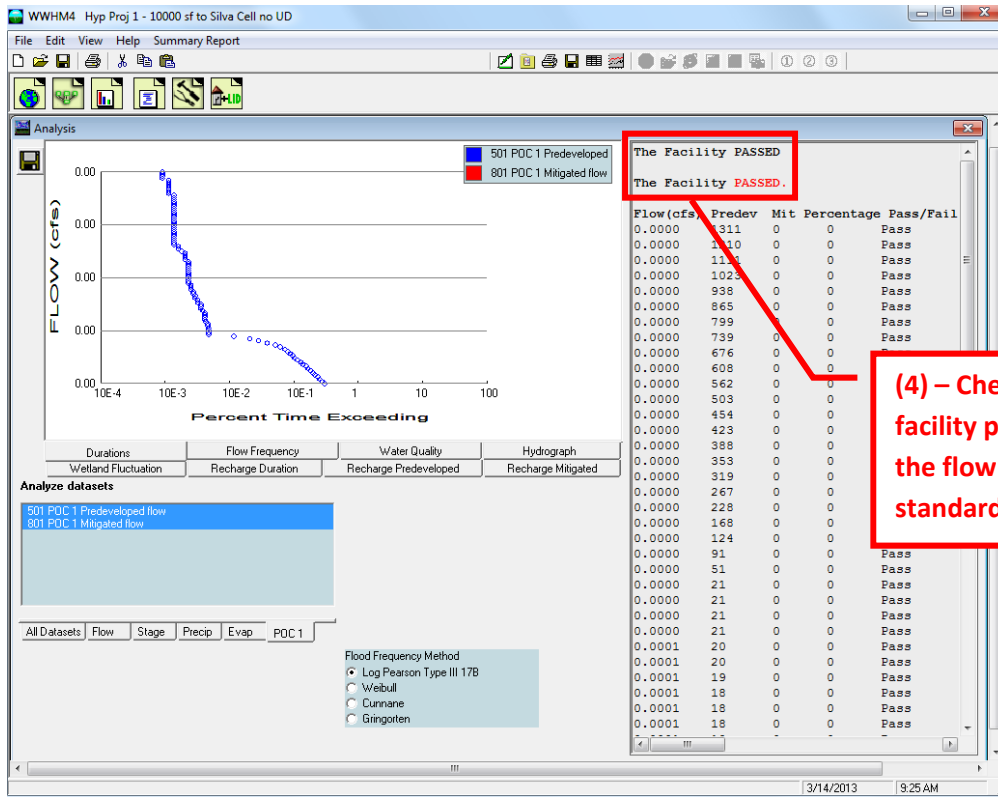
Step 7b - Evaluate whether designs meet treatment requirements

Switch back to the General Project Information tab and select the Mitigated scenario (1). Left click on the Bioretention element. The same window that was used to define the facility will pop up to the right, but results will now be populated in the lower right corner of the window. Check that at least 91% of the stormwater volume infiltrated (2). In this example, 100% of the stormwater volume infiltrated. Therefore, this facility meets water quality treatment requirements.

Note that facilities that are sized to meet the flow control requirements will generally exceed the minimum water quality treatment requirement. If the Silva Cells are being designed to meet treatment requirements only, and if native soils are not suitable for infiltration, then an underdrain may be desired. Facilities sized for treatment only will generally be smaller than facilities sized for flow control, as illustrated in Example 2.


Step 8 - Determine Final Silva Cell Configuration

Using the modeled Bioretention Swale geometry that passes both Minimum Requirement #6 (Runoff Treatment) and Minimum Requirement #7 (Flow Control), determine the final Silva Cell configuration taking into account frame nominal lengths, widths, and depths, and any other site constraints.

The standard Silva Cell frame is 24-inches (2-feet) wide, 48-inches (4-feet) long, and 16-inches (1.33-feet) deep. The modeled Bioretention Swale geometry that meets both treatment and flow control standards is 4-feet wide and 40-feet long. The modeled effective depth is 2.67 feet, including 2.17 feet of amended soil depth and 0.5 feet ponding (air gap).

Accordingly, the Silva Cell facility will include a total of 40 frames, arranged 2-frames-wide (4 feet divided by 2 feet), 2-frames-deep (2.67 feet divided by 1.33 feet, rounded up to the nearest whole number of frames), and 10-frames-long (40 feet divided by 4 feet).

Step 9 – Save Project
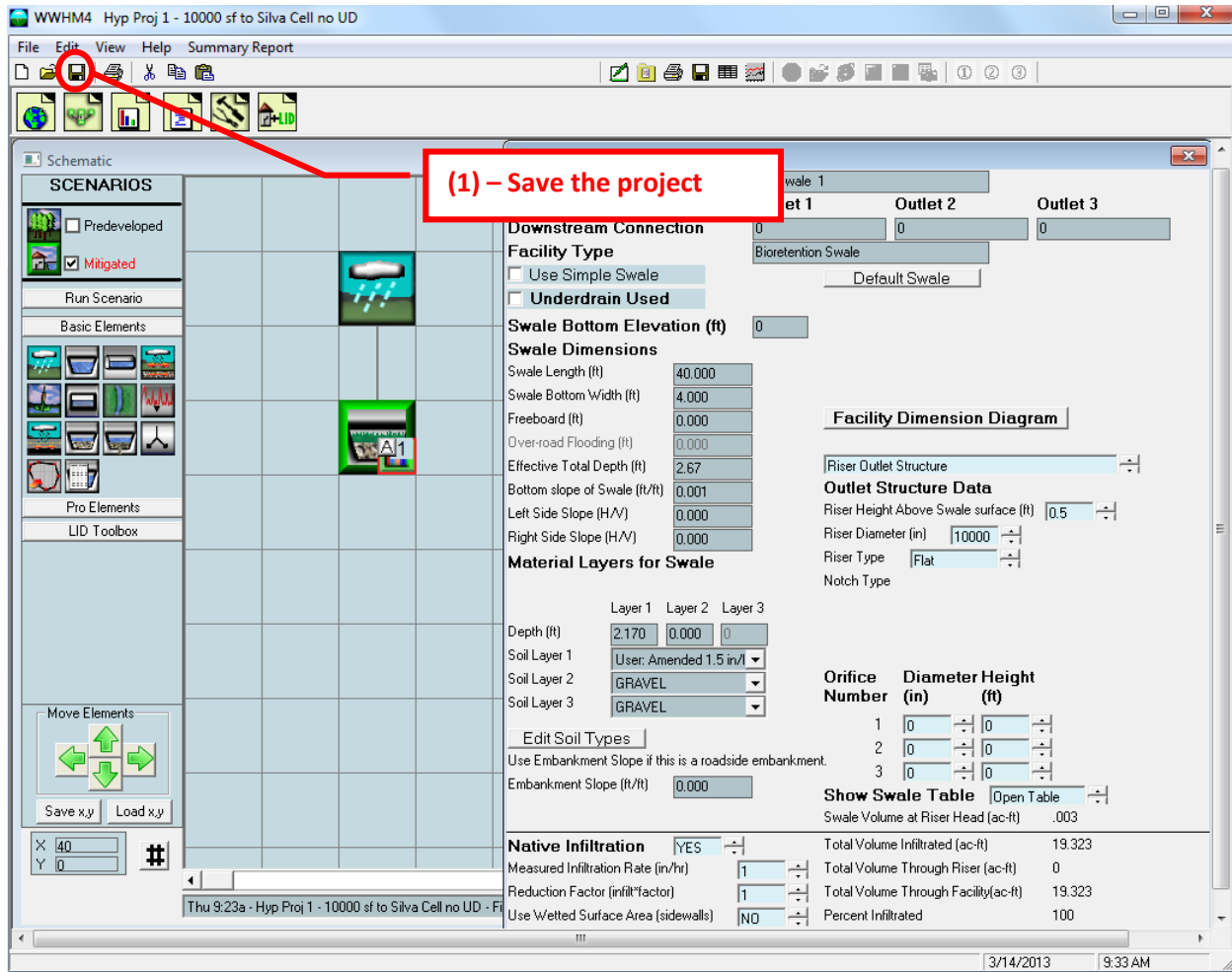
Example 2 - Size Silva Cells to meet Minimum Requirement #6 (Runoff Treatment) only

In this example, the same project that was illustrated in Example 1 is resized to meet treatment requirements only. A 6-inch diameter underdrain is added to the design (1). The orifice diameter is set equal to the underdrain pipe diameter to not restrict flows, since flow control is not needed in this example. Because an underdrain is included, the native infiltration menu is toggled to "NO."

Iteratively reduce the Swale Dimensions until the treatment requirement is met. In this case, the width is kept equal to the available width (4 feet) and the length is reduced (2).
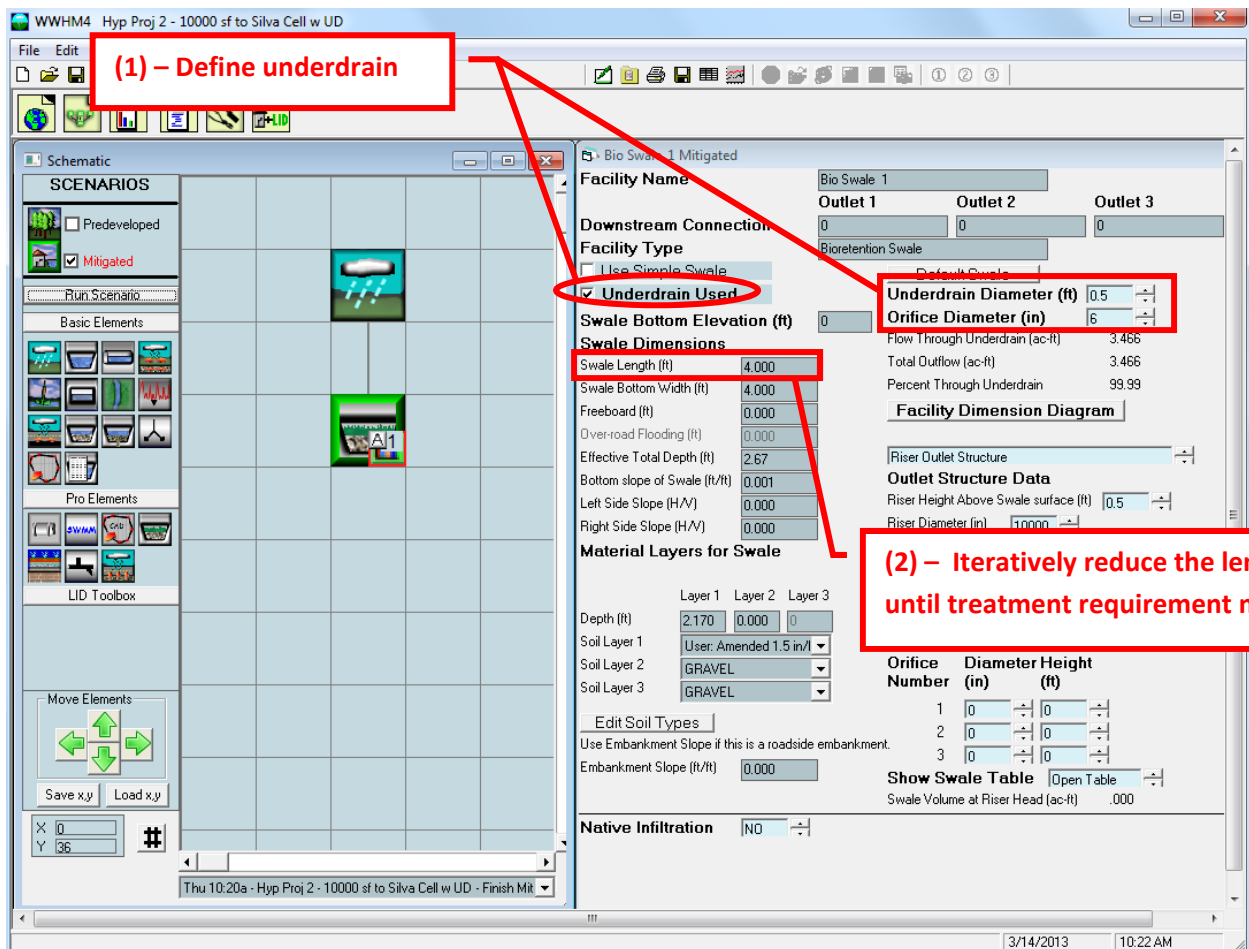
Navigate back to the General Project Information tab and select the Mitigated schematic (1).   Re-run the Mitigated scenario with the new Silva Cell configuration. Left click the bioretention element. Model results will populate the space beneath the underdrain input (2). Check that the Percent Through Underdrain is at least 91%.
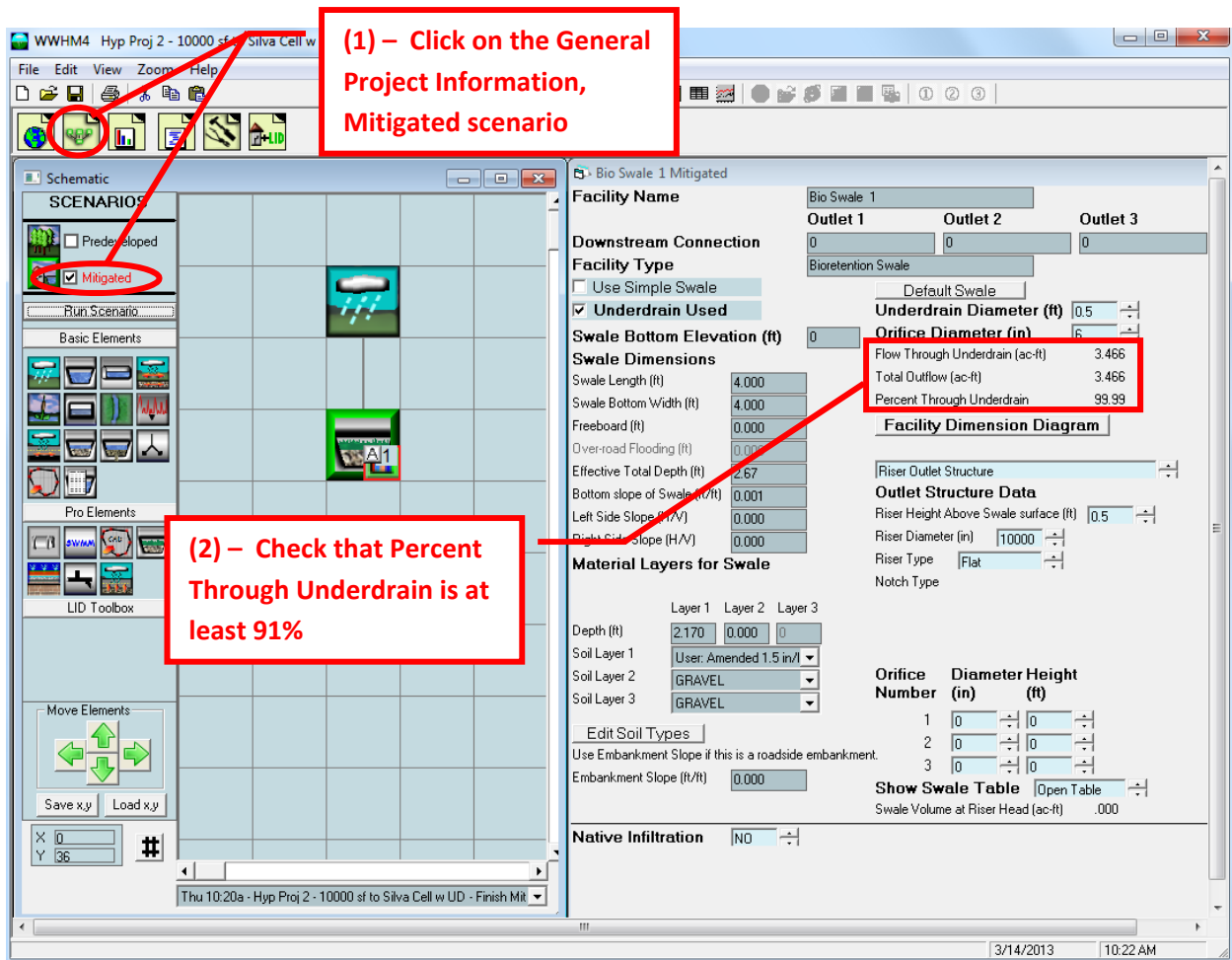
The resulting length that passed the treatment requirement was 4 feet in this example. Note that this is approximately one-tenth the length that is available for Silva Cells based on the Project Example assumptions.