STRATACELL® AND STRATAVAULT™ – USING THE WESTERN WASHINGTON HYDROLOGY MODEL (WWHM 2012) TO SIZE AND EVALUATE WATER QUALITY AND FLOW CONTROL PERFORMANCE

Prepared for
CityGreen® Systems

Prepared by
Herrera Environmental Consultants, Inc.

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Introduction

StrataCell® and Stratavault™ are interlocking soil cells that provides high strength support for pavements and traffic loads while providing large volumes of uncompacted soil for tree root systems and stormwater storage. The engineered plastic modules interlock to create void space beneath pavement. Similar to bioretention systems, StrataCell® and Stratavault™ provide treatment and reduce peak flows and durations as water ponds and infiltrates through the soil media.

This document includes hydrologic modeling procedures for evaluating compliance of StrataCell® and Stratavault™ systems with the Ecology stormwater requirements presented in the 2012 Stormwater Management Manual for Western Washington (SWMMWW) using the Western Washington Hydrologic Model (WWHM) 2012. This guidance provides step-by-step instructions for sizing StrataCell® and Stratavault™ to meet Ecology's Minimum Technical Requirements for on-site stormwater management (#5), water quality treatment (#6), and flow control (#7).

For guidance on general model setup, including selection of precipitation series, representation of pre-developed and post-developed (mitigated) land covers, and general model framework, refer to the WWHM2012 Manual and Appendix III-B of the 2012 SWMMWW.

Applicability and Compliance

The applicability of Ecology's Minimum Requirements to a particular project is determined based on the type and size of the proposed development relative to Ecology-defined thresholds outlined in the 2012 SWMMWW. Refer to Volume 1, Chapter 2, of the 2012 SWMMWW to determine stormwater requirements for a particular project.

The following sections supplement the 2012 SWMMWW by providing additional guidance to support designers in using StrataCell® and Stratavault™ to partially or fully comply with the Minimum Requirements. On sites where multiple requirements are triggered for a given surface, the designer must meet each of the requirements at the designated point of compliance.

Minimum Requirement #6 - Water Quality Treatment

Per the 2012 SWMMWW, sites triggering Minimum Requirement #6 must infiltrate or filter at least 91 percent of the total runoff volume through a soil mix that meets Ecology's requirements for bioretention soil media. Using continuous hydrologic modeling (described in the *Modeling Guidance* section, below), the designer can size StrataCell® or Stratavault™ to provide basic, enhanced, and oil control treatment for a contributing pollution-generating surface provided the soil media meets the criteria for Default Bioretention Soil Media (BSM) or Custom Bioretention Soil Mixes as described in Volume V of the 2012 SMMWW.

Minimum Requirement #7 – Flow Control

Per the 2012 SWMMWW, sites triggering Minimum Requirement #7 (Flow Control) are required to match pre-developed condition stormwater discharge durations for the range of pre-developed discharge rates from 50 percent of the 2-year peak flow up to the 50-year peak

flow. A forested land cover is typically the target pre-developed condition; however, the 2012 SWMMWW outlines criteria for matching alternate "pre-project" conditions. Should a project satisfy those criteria, it would be subject to a less protective (e.g., pasture or existing) flow control standard. Refer to the 2012 SWMMWW to determine if a project qualifies for these provisions.

For infiltrating StrataCell® and Stratavault™ systems, facilities are sized to meet the prescribed range of stormwater discharge durations using the methods described in the *Modeling Guidance* section, below. Where infiltration is infeasible, underdrains may be used to collect and convey filtered water. In these cases, designers can use a treatment train and/or an orifice to restrict flow from the underdrain to meet flow control requirements. Guidance for sizing facilities with an underdrain is provided in the *Modeling Guidance* section.

In addition to the Ecology-prescribed flow control requirements, many jurisdictions have other flow control standards to target their specific needs. One common requirement for combined sewer overflow control involves reducing the 1-year storm to a specified percentage of the unmanaged runoff (e.g., 95 percent reduction in the 1-year peak flow). The designer should evaluate these standards via continuous hydrologic modeling as described below.

Minimum Requirement #5 – On-site Stormwater Management

Per the 2012 SWMMWW, sites triggering Minimum Requirement #5 (On-site Stormwater Management) are required to either:

- Meet the Low Impact Development (LID) Performance Standard (i.e., match pre-developed-condition [typically forest] stormwater discharge durations for the range of pre-developed discharge rates from 8 percent of the 2-year peak flow up to 50 percent of the 2-year peak flow).
- Implement BMPs from Ecology's prescribed Lists 1 and 2 (provided in the 2012 SWMMWW) for each surface type (e.g., roofs, roadway).

For infiltrating StrataCell® and Stratavault™ systems, facilities are sized to meet the prescribed range of stormwater discharge durations using the methods described in the *Modeling Guidance* section, below. As with the flow control standard, it is difficult to meet the LID Performance Standard requirements with underdrained facilities. Further, it is infeasible to fully satisfy these requirements with underdrained facilities on sites where the pre-developed condition is forest. However, on sites where the requirement is to match existing flow durations, an underdrained StrataCell® or Stratavault™ can be sized to meet the LID Performance Standard (provided the contributing area is sufficiently large). The designer should determine the required facility footprint and orifice diameter based on the area contributing runoff to the StrataCell® or Stratavault™ using continuous hydrologic modeling as described in the *Modeling Guidance* section, below.

As an alternative to complying with the quantitative LID Performance Standard, the designer may specify a StrataCell® or Stratavault™ to partially or fully satisfy the On-site Stormwater Management requirements per Ecology's prescribed lists. To meet the list requirements for

bioretention, the StrataCell® or Stratavault™ facility area must be 5 percent of the contributing area.

Modeling Guidance

The following guidelines apply to the sizing and evaluation of StrataCell® and Stratavault™ systems in WWHM 2012 using the "Bioretention" element. CityGreen does not recommend using earlier versions of the model (e.g., WWHM4) to size or evaluate the performance of StrataCell® or Stratavault™ because the bioretention swale element in older versions of the software has limited functionality. Specifically, the WWHM2012 element allows for explicit representation of the detention function of both the bioretention soil (via infiltration into the soil media) and orifice control at the underdrain, yielding more accurate estimates of the flow control performance of StrataCell® and Stratavault™.

For additional information on WWHM assumptions and modeling guidance, including background information on precipitation and evaporation series selection and scaling, soil classification, HSPF parameter values, guidance for flow and water quality related standards, and other model features, refer to the following documents:

- Volume III and Volume V of the 2012 SWMMWW
- Volume III, Appendix III-B, and Appendix III-C (Part 2) of the 2012 SWMMWW
- WWHM 2012 User's Manual

This document serves as supplementary guidance to that provided in the WWHM User's Manual and 2012 SWMMWW. Users are responsible for ensuring that they adhere to the standards and modeling requirements outlined in current versions of the 2012 SWMMWW and the WWHM User's Manual.

Part 1: Select Precipitation and Define the "Pre-Developed" Scenario

1. **Define site precipitation**:
   a. Click the location of the project on the map to select the site precipitation series in the "Map Information" dialog box.
2. **Add and characterize the pre-developed area**:
   a. Click the "General Project Information" button in the toolbar to open the Schematic window.
   b. Select the "Predeveloped Scenario**"** in the Schematic window.
   c. Drag and drop the "Land Use Basin**"** element (listed under "Basic Elements") into the schematic editor (denoted as a grid to the right of the Scenarios toolbar).
   d. Click on the basin and enter the pre-developed area by land use type (e.g., acres of roof).

For evaluation of StrataCell® and Stratavault™ performance relative to Ecology Minimum Requirements #5 and #7 determine the appropriate target "pre-developed" condition for the development site. Note the target pre-developed land cover is typically forested;

however, the 2012 SWMMWW outlines criteria for matching alternate "pre-project" conditions.

3. **Set the "point of compliance" at the pre-developed land use basin outlet**:
   a. Right click on the Basin and select "Connect to Point of Compliance**".**
   b. Verify appropriate outlets are checked and click "Connect".

      Always select both surface flow and interflow, and select groundwater flow only when observations of groundwater expression on the site support modeling of groundwater.

Part 2: Define the "Mitigated" Scenario

Figure 1 shows the "Mitigated" scenario schematic editor screen.

1. **Add and characterize the area contributing runoff to the StrataCell® or Stratavault™**:
   a. Selected the "Mitigated Scenario" in the Schematic window.
   b. Drag and drop the "Land Use Basin" element (listed under "Basic Elements") into the schematic editor (denoted as a grid to the right of the Scenarios toolbar).
   c. Click on the basin and enter the mitigated area by land use type (e.g., acres of roof).
2. **Add the StrataCell® or Stratavault™ BMP**:
   a. Drag and drop the "Bioretention" element (listed under "Pro Elements") into the schematic editor.
3. **Route flows from the contributing drainage area (denoted by the Land Use Basin element) to the StrataCell® or Stratavault™ in the Schematic editor**:
   a. Right click the "Land Use Basin" element, select "Connect to Element**".**
   b. Click on the bioretention element defined in Step 5 to connect the basin element to the bioretention element.
   c. Select desired flows to route from basin to bioretention swale in the "From Basin to Conveyance" pop-up dialog box (options include surface flow, interflow, and groundwater).

      Always select both surface flow and interflow, and select groundwater flow only when observations of groundwater expression on the site support modeling of groundwater.
   d. Click "OK" to return to the Schematic editor.

Note: If the design includes a diversion structure to limit the peak inflow rate of water to the StrataCell® or Stratavault™ system, include a flow splitter in the model to allow only certain flows to be directed to the bioretention element. Drag and drop the Flow Splitter element (listed under "Basic Elements") into the schematic editor. Connect the basin to the

flow splitter and connect the flow splitter to the bioretention element. Click on the flow splitter to set either a flow threshold or the specific dimensions of the control structure. Note which flow splitter outlet is being directed to the bioretention element when connecting the two elements in the schematic editor. Set a simultaneous point of compliance at both the outlet of the bioretention element and the flow splitter outlet that is <u>not</u> connected to the bioretention element to ensure analysis of performance reflects total runoff from the site, not just the diverted fraction. Refer to the WWHM 2012 User's Manual for more information on modeling flow splitters.

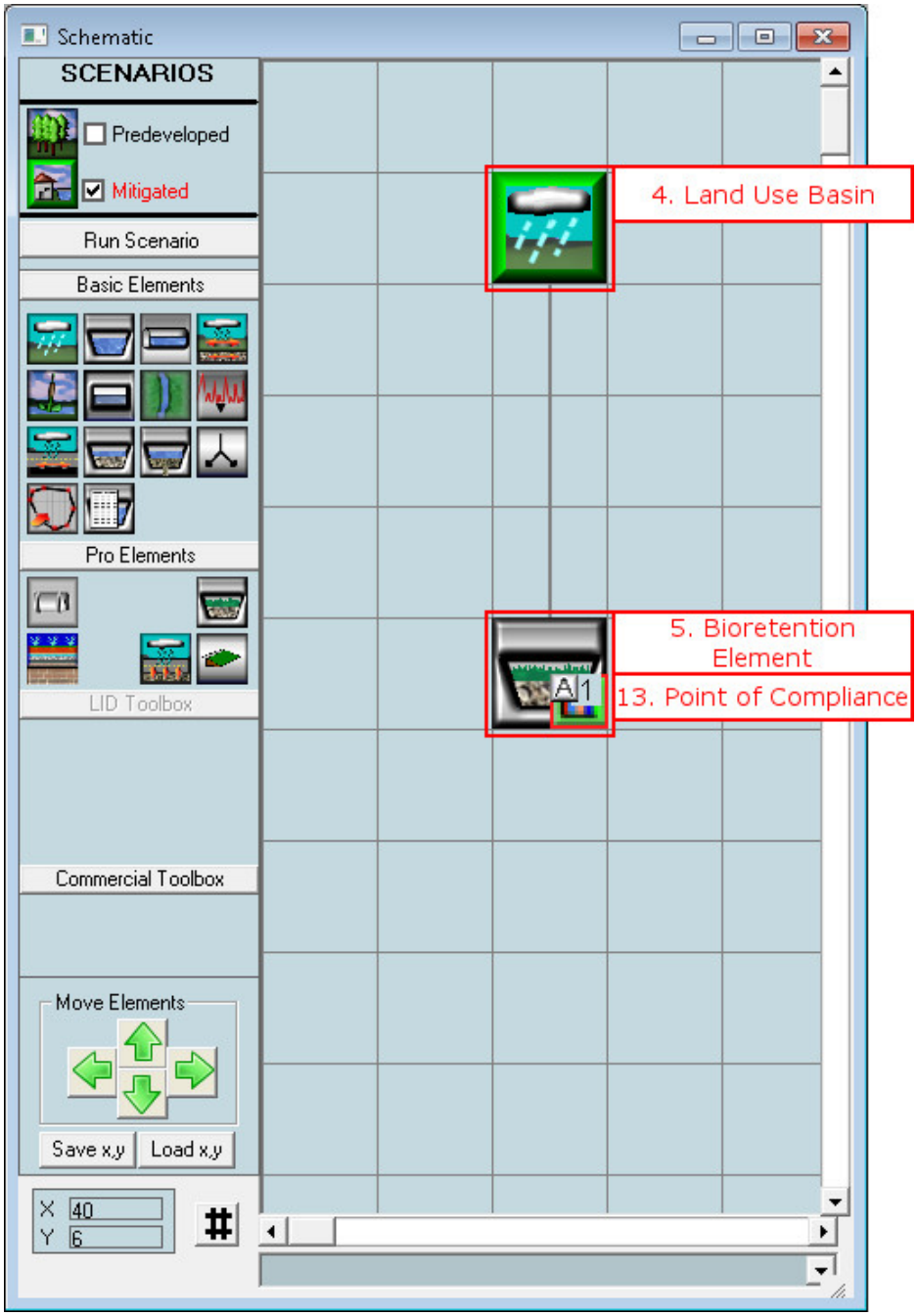

Figure 1. Schematic Editor for the "Mitigated" Scenario.

Part 3: Define the StrataCell® or Stratavault™ System

1. **Define the facility type**:
   a. Click on the "Bioretention" element to bring up the Bioretention editor (see Figure 2).
   b. Ensure the "Use Simple Bioretention" box is unchecked.

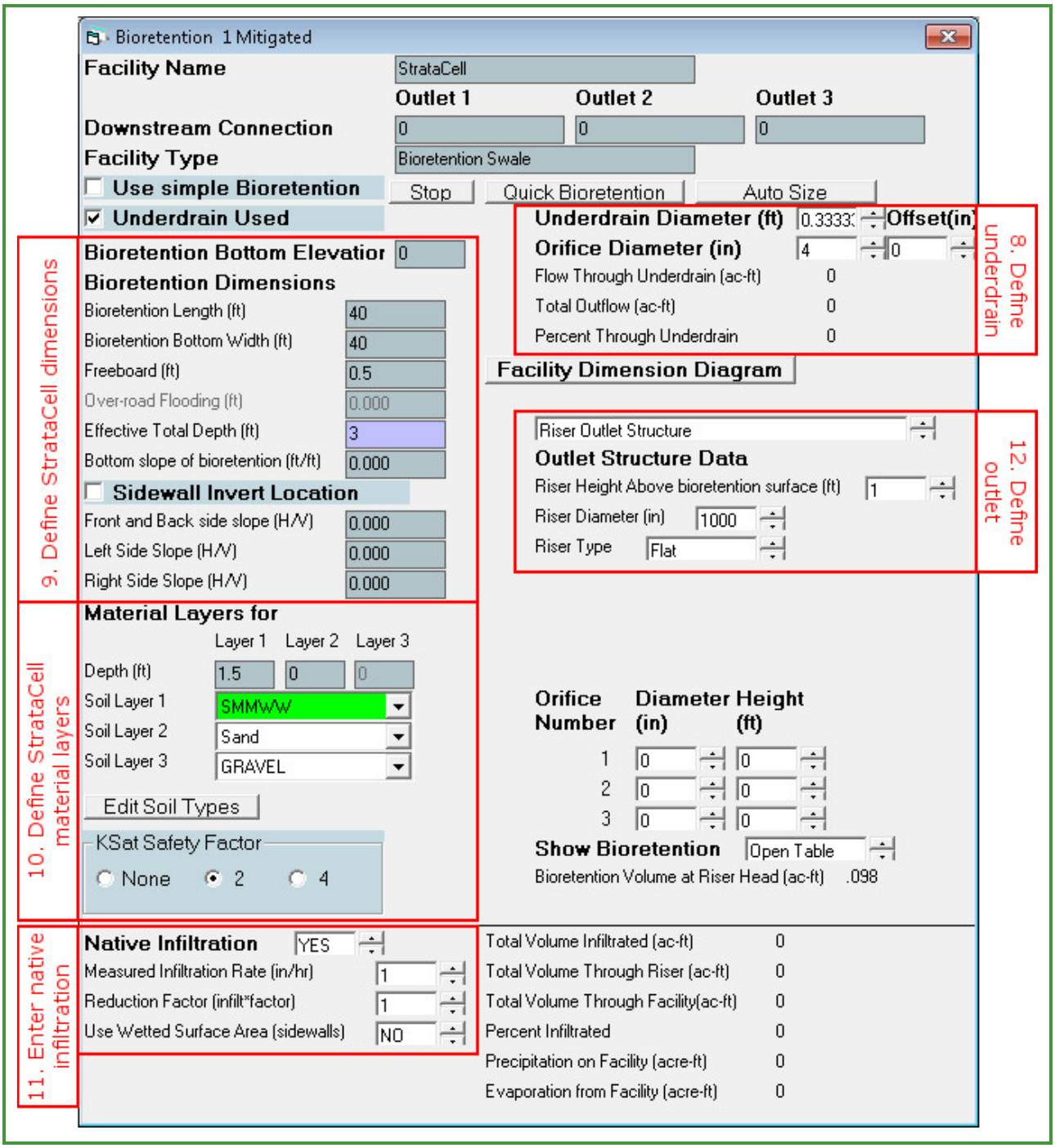

Figure 2. Bioretention Element Screen.

2. **Define underdrain parameters (if applicable)**:

   a. Check "Underdrain Used" box.

   b. Enter the underdrain pipe diameter in feet.

   c. Enter the orifice diameter. If there is no orifice in the design, set the orifice diameter equal to the underdrain pipe diameter (note the dimensions for orifice diameter are in inches while the pipe diameter is in feet).

   d. Enter an orifice offset height, measured from invert of underdrain (if applicable). Typically this value is 0 inches.

3. **Define StrataCell® or Stratavault™ dimensions**:

   a. Enter StrataCell® or Stratavault™ dimensions in the "Bioretention Bottom Elevation" and "Bioretention Dimensions" section of the dialog box, as follows:

      - **Bioretention Bottom Elevation (ft)** - Set elevation at the model default value of zero or enter the actual elevation of the proposed facility.

        The bottom elevation represents the bottom of the StrataCell® or Stratavault™ facility and serves as a reference elevation for all other facility dimensions.

      - **Bioretention Length (ft)** – Enter the nominal length of the StrataCell® or Stratavault™ system.

        The nominal length of the StrataCell® or Stratavault™ system will be less than the true length of the system due to the volume lost to the StrataCell® or Stratavault™ structure. According to the manufacturer a maximum of 10 percent of StrataCell® and Stratavault™ volume is attributed to the structure. Apply a correction factor to the design length and width of the StrataCell® or Stratavault™ facility. Do <u>not</u> apply a correction factor to the height of the facility as this may affect the hydraulic performance of the system.

      - **Bioretention Bottom Width (ft)** – Enter the nominal width of the StrataCell® or Stratavault™ system.

        Apply correction factor to the design width of the StrataCell® or Stratavault™ system as described in the Bioretention Length section above.

      - **Freeboard (ft)** – Enter the freeboard required per the design or by local jurisdiction requirements

        Freeboard calculated as the depth of storage available from the top of the StrataCell® or Stratavault™ to the outlet riser crest.

      - **Over-road Flooding (ft)** - If applicable, enter the maximum depth of water above the emergency spillway

This design parameter does not apply StrataCell® or Stratavault™ systems because the riser outlet controls overflow from the system instead of a weir or other surface overflow. The model greys out this cell when the user selects "Riser Outlet Structure" as the outlet structure.

- **Effective Total Depth (ft)** – no data entry required

  This value represents the total depth of the facility including the filter media depth, ponding depth (riser height), and freeboard. The model automatically populates this field.

- **Bottom slope of bioretention (ft/ft)** – Set to 0 for a flat bottom facility.

  If the model produces error messages during simulation set bottom slope at a minimum value of 0.001 to reduce model instability.

- **Top and Bottom side slope (H:V)** – Enter a value of 0 to represent vertical side walls

- **Left Side Slope (H:V)** - Enter a value of 0 to represent vertical side walls

- **Ride Side Slope (H:V)** - Enter a value of 0 to represent vertical side walls

4. **Define StrataCell® and Stratavault™ material layers**:

   a. Enter StrataCell® or Stratavault™ material layer types/dimensions, as follows:

   - **Layer 1 Depth (ft) – Enter a depth that represents the soil media depth:**

     Soil layer depth depends on the number of StrataCell® or Stratavault™ units stacked on top of each other and the thickness of the void space (ponding depth) above the media. CityGreen recommends a minimum soil depth of 30 inches for tree root growth. Ecology requires a minimum of 12 inches of bioretention soil media to meet the flow control requirements and a minimum of 18 inches to meet water quality requirements. A maximum void space (ponding depth) of 36 inches is recommended.

   - **Layer 2 and Layer 3 Depth (ft)** – Enter 0 feet

   - **Soil Layer 1** – Select the "SWMMWW" soil type which represents approved criteria for default bioretention soil media. Do not edit this soil type.

   - **Soil Layer 2 and 3 –** NA

   - **KSat Safety Factor** – Select the appropriate safety factor to meet the required hydraulic conductivity

     In accordance with SWMMWW 2012 requirements, use a safety factor of 2 for facilities with a contributing drainage area that is less than 10,000 square feet of impervious surface, less than 5,000 square feet of pollution generating hard surface, or less than 3/4 acre of native vegetation converted to lawn or landscaping. If the contributing drainage area exceeds any of these thresholds apply a safety factor of 4.

5. **Enter native infiltration parameters**:

   a. Enter native soil characteristics, as follows:

      - If native soil is used for infiltration as per the design select "yes" for native infiltration
      - **Measured Infiltration Rate (in/hr)** – Enter measured infiltration rate.
      - **Reduction Factor** – Enter a multiplier reduction factor if applicable, otherwise leave as 1.
      - **Use Wetted Surface Area (sidewalls)** – Select "no" since StrataCell® and Stratavault™ systems have vertical walls.

6. **Define the outlet riser configuration**:

   a. Enter outlet structure characteristics, as follows:

      - Toggle the outlet structure to "Riser Outlet Structure".
      - **Riser Height Above bioretention (ft)** – Enter a riser height equal to the void space (ponding depth) above the soil media layer within the StrataCell® or Stratavault™ system.

        Riser height is equal to the StrataCell® or Stratavault™ system height (10 inches per cell for StrataCell® or 16 inches per cell for Stratavault multiplied by the number of cell layers) minus the soil media depth used in the material layers section. CityGreen recommends a minimum soil depth of 30 inches for tree root growth. Ecology requires a minimum of 12 inches of bioretention soil media to meet the flow control requirements and a minimum of 18 inches to meet water quality requirements. A maximum void space (ponding depth) of 36 inches is recommended.

      - **Riser Diameter (in)** – Enter a very large value for the riser diameter, e.g., 1,000 inches, to ensure capacity is available in the case of high flows when the StrataCell® or Stratavault™ system is saturated.
      - **Riser Type** – Select the flat riser type.

7. **Set "point of compliance" at appropriate outlet(s)**:

   a. In the Schematic window right click the Bioretention element and select "Connect to Point of Compliance", verify appropriate outlets are selected, and click "Connect".

      Note: As described in Step 1, if a flow splitter was used to limit flows to the bioretention element ensure the same point of compliance is also set at the outlet of the flow splitter that is <u>not</u> directed to the bioretention element.

Part 4: Analyze the StrataCell® or Stratavault™ System Performance

This section includes protocol for evaluating StrataCell® and Stratavault™ performance relative to the performance standard prescribed in Minimum Requirements #5, #6, and #7. For a complete summary of Ecology's performance standards and methodologies, see the 2012 SWMMWW and the WWHM User's Manual.

1. **Evaluate water quality performance**:

   Per the 2012 SWMMWW, sites triggering Minimum Requirement #6 (Water Quality Treatment) are required to infiltrate or filter at least 91 percent of the total runoff volume through a media that meets Ecology's requirements for bioretention soil media. Evaluate water quality performance using the following procedure.

   a. Run both the pre-developed and mitigated scenarios in the schematic editor.
   b. Click on the "Bioretention" element in the mitigated scenario schematic editor to bring up the Bioretention editor.
   c. If an underdrain is used, check that the "Percent Through Underdrain" value is equal to or greater than 91 percent. If an underdrain is not used, check that the "Percent Infiltrated" is equal to or greater than 91 percent.

   If the facility does not infiltrate or filter 91 percent, increase the size of the StrataCell® or Stratavault™ system or reduce the basin area draining to the facility until the standard is met.

2. **Evaluate flow control performance**:

   Per the 2012 SWMMWW sites triggering Minimum Requirement #7 (Flow Control) are required to match pre-developed stormwater discharge durations for the range of pre-developed discharge rates from 50 percent of the 2-year peak flow up to the full 50-year peak flow. The target pre-developed land cover is typically forested; however, the 2012 SWMMWW outlines criteria for matching alternative pre-project conditions. Evaluate flow control performance using the following procedure.

   a. Run both the pre-developed and mitigated scenarios in the schematic editor.
   b. Click the "Analysis" button in the toolbar to open the Analysis window.
   c. Select the desired point of compliance from the tabs in the bottom left portion of the "Analyze datasets" dialog box (e.g., POC 1).
   d. Select the "Stream Protection Duration" standard from the tabs below the analysis screen.

   WWHM 2012 plots the duration curves for the pre-developed and mitigated scenarios and reports whether the facility meets (or "passes") the requirement. Additionally, the WWHM 2012 report file contains information about pre-developed and mitigated flow frequencies, maximum water surface elevations within facilities, and other information relative to common performance standards.

If the facility does not meet the duration standard, increase the size of the StrataCell® or Stratavault™ system, adjust the orifice diameter on the underdrain (if applicable), provide another BMP as part of a treatment train, or reduce the basin area draining to the facility until the standard is met.

3. **Evaluate LID performance**:

   Per the 2012 SWMMWW, sites triggering Minimum Requirement #5 (On-Site Stormwater Management) are required to either meet the LID Performance Standard or implement BMPs from Ecology's prescribed Lists 1 and 2 for each surface type. Evaluate LID performance using the following procedure.

   a. Run both the pre-developed and mitigated scenarios in the schematic editor.

   b. Click the "Analysis" button in the toolbar to open the Analysis window.

   c. Select the desired point of compliance from the tabs in the bottom left portion of the "Analyze datasets" dialog box (e.g., POC 1).

   d. Select the "LID Duration" standard from the tabs below the analysis screen.

   WWHM 2012 plots the duration curves for the pre-developed and mitigated scenarios and reports whether the facility meets or passes the requirement. Additionally, the WWHM 2012 report file contains information about pre-developed and mitigated flow frequencies, maximum water surface elevations within facilities, and other information relative to common performance standards.

   If the facility does not meet the LID duration standard, increase the size of the StrataCell® or Stratavault™ system, adjust the orifice diameter on the underdrain (if applicable), provide another BMP as part of a treatment train, or reduce the basin area draining to the facility until the standard is met.