

Western Washington Hydrology Model 2012

User Manual

November 2012

**Western Washington Hydrology Model
2012**

User Manual

**Prepared by
Clear Creek Solutions, Inc.**

November 2012

To download the Western Washington Hydrology Model
and the electronic version of this user's manual,
please visit our website at:

http://www.ecy.wa.gov/programs/wq/stormwater/wwhm_training/wwhm/wwhm2012/index.html

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INTRODUCTION

The WWHM2012 is the updated edition of the Western Washington Hydrology Model, replacing WWHM3. It was designed by the Washington State Department of Ecology, AQUA TERRA Consultants, and Clear Creek Solutions, Inc. (the successor to the Washington offices of AQUA TERRA Consultants). This version has more options than WWHM3. The user can model almost any hydrologic condition related to stormwater control and design.

This user manual and development of WWHM2012 was funded by the Washington State Department of Ecology Contract No. C1200124 with Clear Creek Solutions, Inc. Clear Creek Solutions staff responsible for the WWHM2012 and this user manual are Joe Brascher, Gary Maxfield, and Doug Beyerlein.

Purpose

The purpose of the WWHM2012 is to size stormwater control facilities to mitigate the effects of increased runoff (peak discharge, duration, and volume) from proposed land use changes that impact natural streams, wetlands, and other water courses.

The WWHM2012 provides:

- A uniform methodology for the 19 counties of Western Washington
- A more accurate methodology than single event design storms
- An easy-to-use software package

The WWHM2012 is based on:

- Continuous simulation hydrology (HSPF)
- Actual long-term recorded precipitation data
- Measured pan evaporation data
- Historic vegetation (for Predeveloped conditions)
- Regional HSPF parameters

Parameter values can be modified for local conditions.

What's New in WWHM2012

WWHM2012 gives the user greater modeling flexibility, options, and accuracy. Version 3 included some simplified approaches to modeling stormwater LID (low impact development) facilities. WWHM2012 includes modeling elements that more accurately represent these stormwater facilities.

Specific changes and additions in Version 2012 include:

- Ability to run on Microsoft Windows 7 operating systems either on a workstation (single computer) or network.
- Updated precipitation data through water year 2009 (September 2009).
- Model simulations using a 15-minute time step in place of an hourly time step.

- 15-minute precipitation data in place of hourly data.
- Updated water quality design flow calculations.
- Improved AutoPond capabilities to optimize sizing of stormwater ponds and vaults.
- New bioretention swale element that accurately represents bioretention and rain gardens with or without underdrains and/or infiltration to the native soil.
- New CAVFS (compost amended vegetated filter strips) element to accurately represent roadside bioretention-based water quality facilities.
- New green roof element to accurately model storage, evapotranspiration, and runoff from vegetated roofs.
- New porous pavement element to accurately model the movement of water through the pavement and subgrade.
- Added SSD Table element options.
- Automated sizing options for infiltration facilities.
- Revised flow duration analysis with two duration standards: (1) Stream Protection Duration, and (2) LID Duration.
- Revised wetland hydroperiod criteria calculations.
- New LID reporting features.

Computer Requirements

- Windows 2000/XP/Vista/7 with 200 MB uncompressed hard drive space
- Internet access (only required for downloading WWHM2012, not required for executing WWHM2012)
- Pentium 3 or faster processor (desirable)
- Color monitor (desirable)

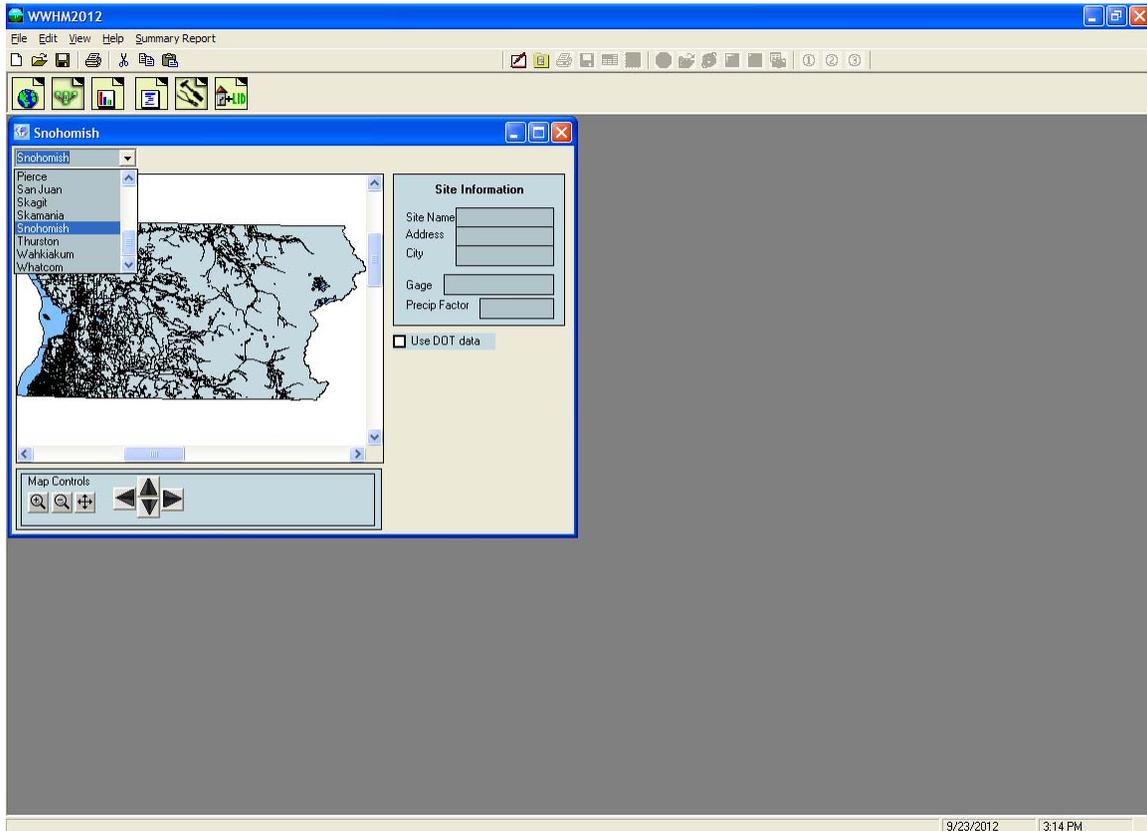
Before Starting the Program

- Knowledge of the site location and/or street address.
- Knowledge of the actual distribution of existing site soil by category (A/B, C, or saturated).
- Knowledge of the planned distribution of the proposed development (buildings, streets, sidewalks, parking, lawn areas) overlying the soil categories.
- An idea of a first approximation of the top surface area for a trapezoidal or irregular-shape pond (if used).

QUICK START

Below is a brief set of steps that show how to use the WWHM2012 to quickly size a stormwater detention pond.

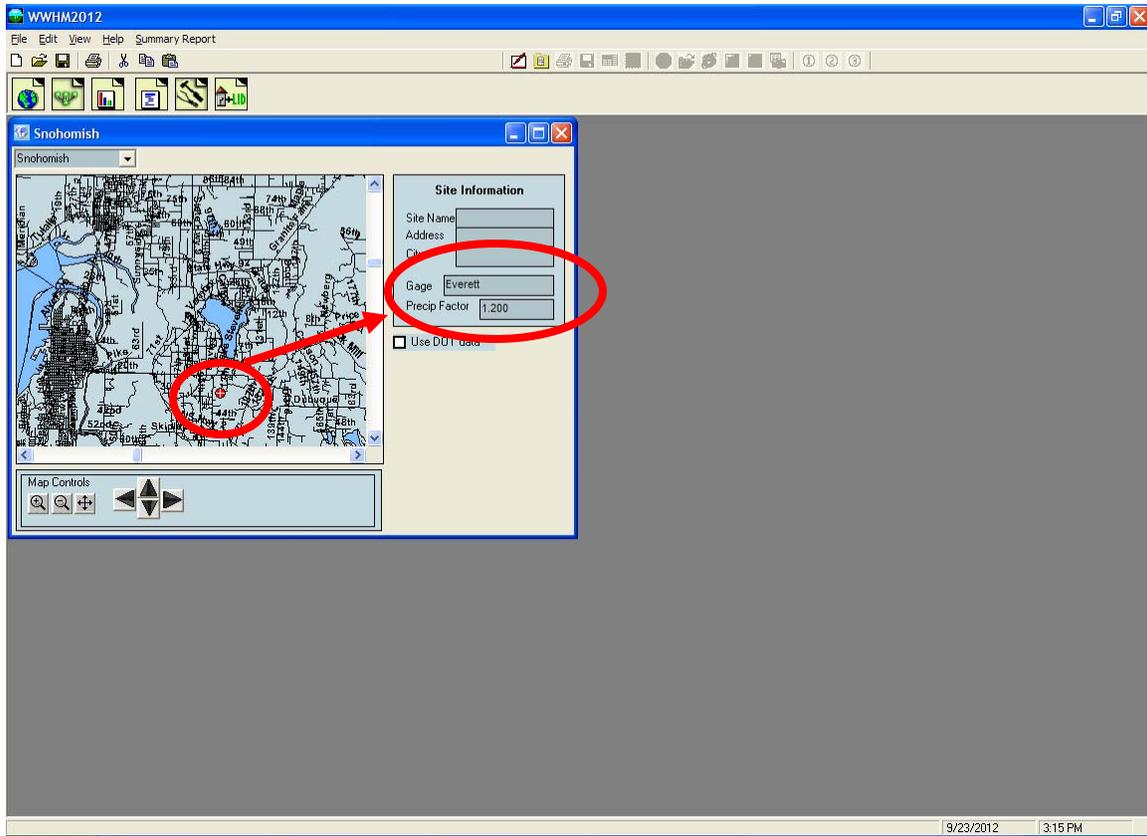
1. Select the county in which the project site is located.



Click the down arrow in the box in the upper left corner. A list of all 19 Western Washington counties is shown. Scroll down to find the county you want. Left click on the county name. The county map will then show on the map screen.

Locate the project site on the map. Use the map controls to magnify a portion of the map, if needed. Select the project site by left clicking on the map location. A red square will be placed on the map identifying the project site.

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The WWHM2012 selects the appropriate rain gage record and precipitation multiplication factor. In this example the rain gage record is Everett and the Everett precipitation data are multiplied by a precip factor of 1.20.

2. Use the tool bar (immediately above the map) to move to the Scenario Editor. Click on the General Project Information button.



The General Project Information button will bring up the Schematic Editor.

The schematic editor screen contains two scenarios: Predeveloped and Mitigated.

Set up first the Predeveloped scenario and then the Mitigated scenario.

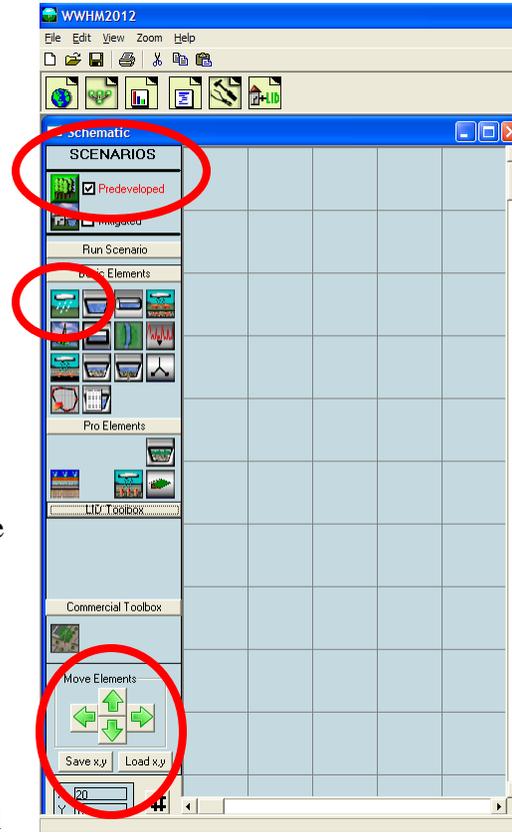
Check the Predeveloped scenario box.

Left click on the Basin element under the Elements heading. The Basin element is the upper left element.

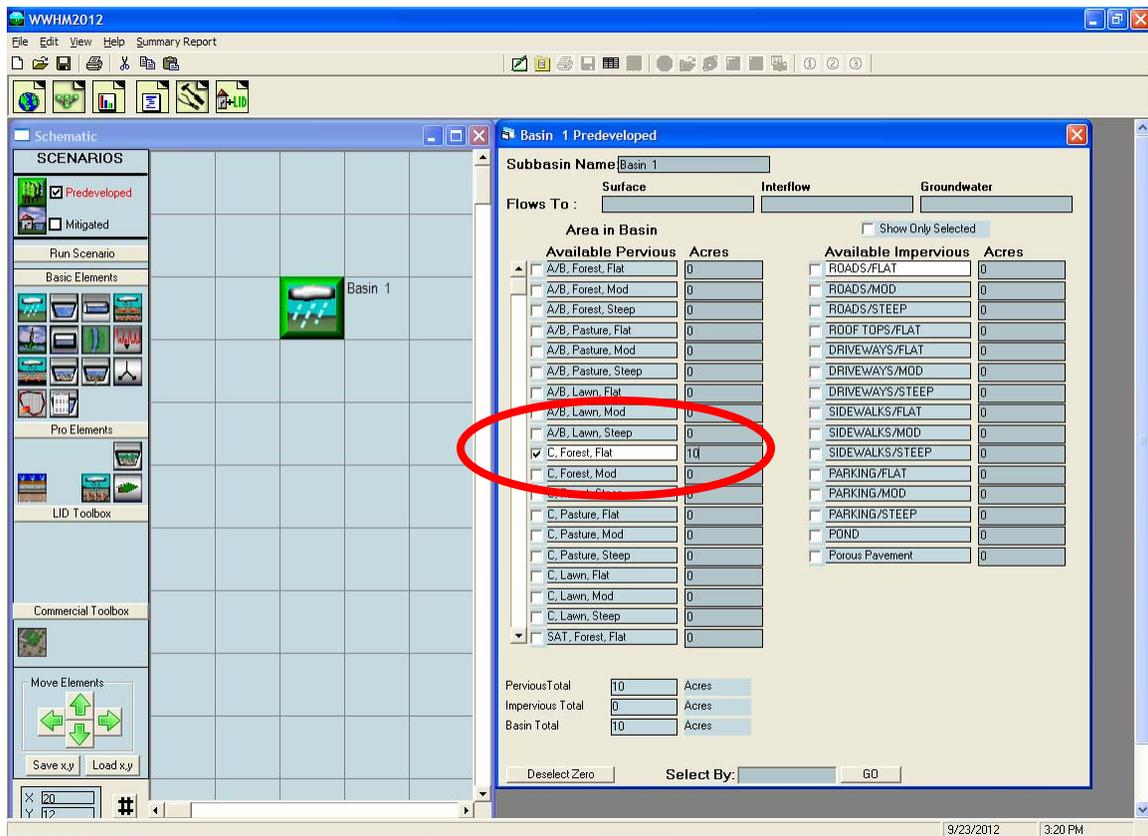
Select any grid cell (preferably near the top of the grid) and left click on that grid. The basin will appear in that grid cell.

The entire grid can be moved up, down, left, or right using the Move Elements arrow buttons.

The grid coordinates from one project can be saved (Save x,y) and used for new projects (Load x,y).

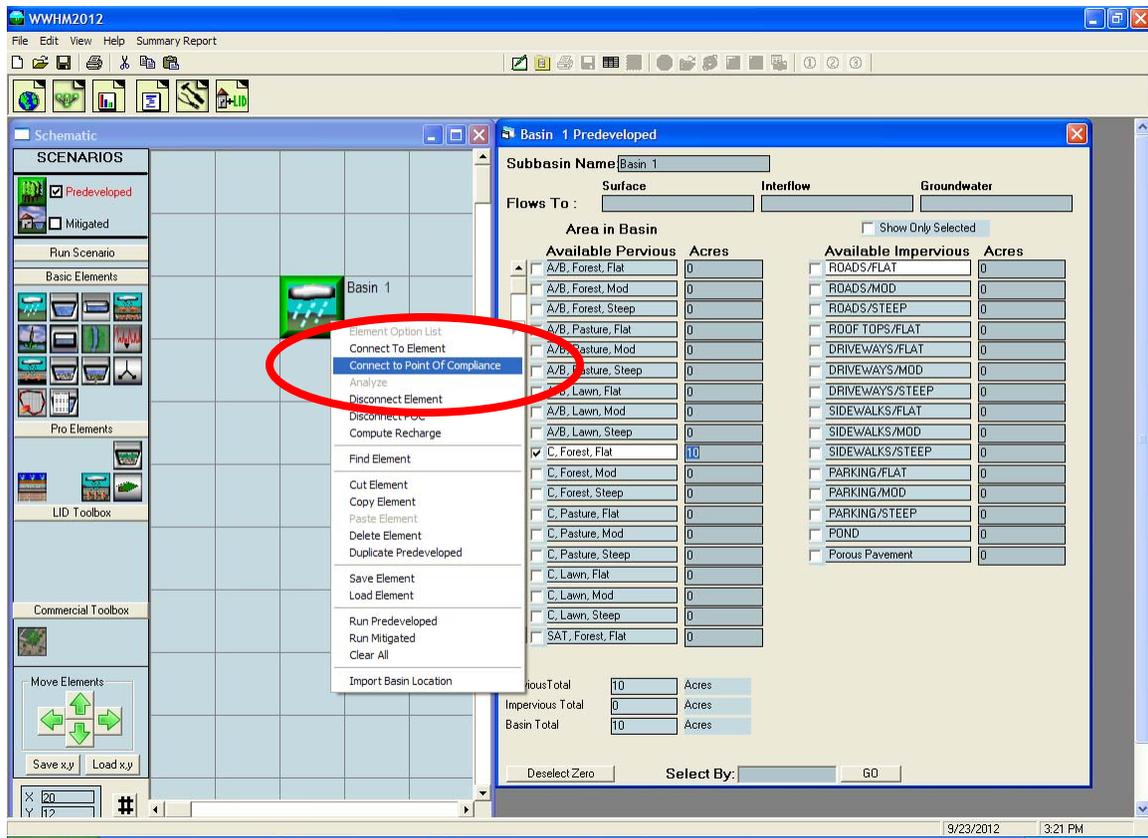


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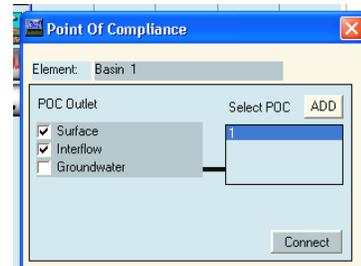
To the right of the grid is the land use information associated with the basin. Select the appropriate soil, vegetation, and land slope for the Predeveloped scenario. For this example we will assume that the Predeveloped land use is 10 acres of C soil (till) with forest vegetation, on a flat (0-5%) slope.

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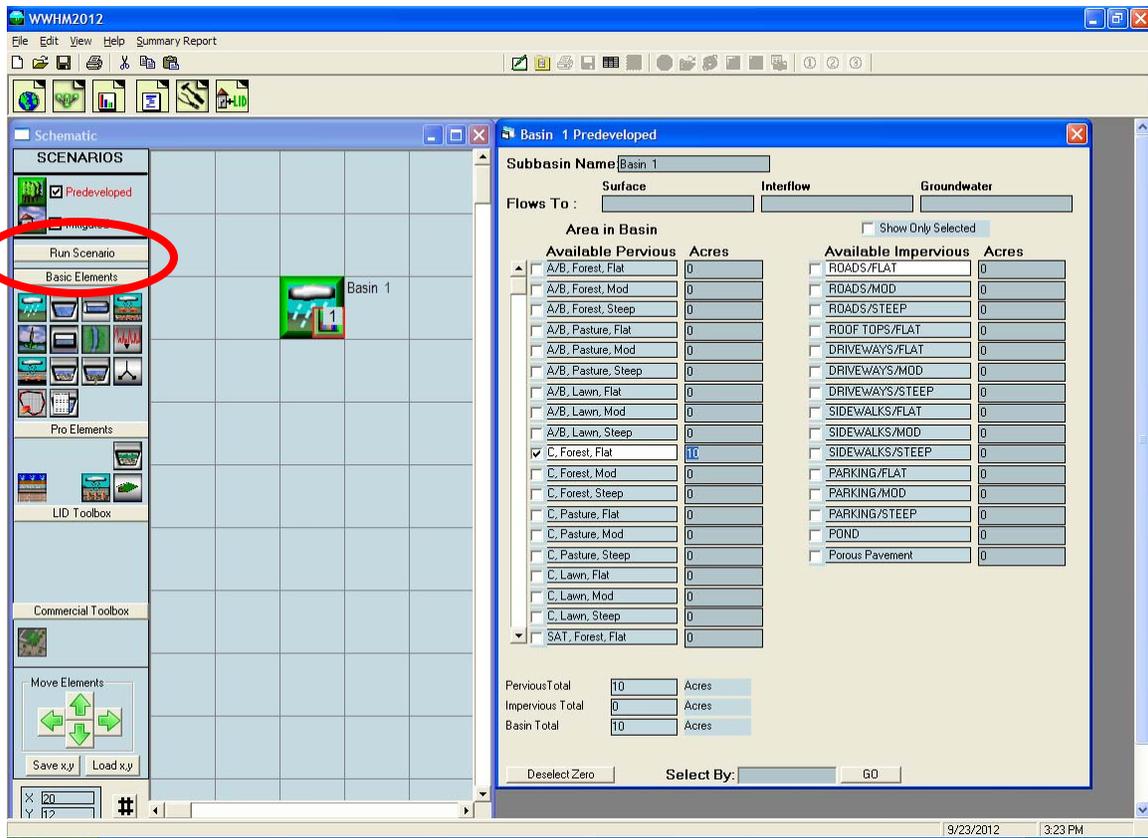


The outlet from this land use drainage basin will be selected as our point of compliance for the Predeveloped scenario. Right click on the basin element and highlight Connect to Point of Compliance.

The Point of Compliance screen will be shown for Predeveloped Basin 1. The POC (Point of Compliance) outlet has been checked for both surface runoff and interflow. These are the two flow components of stormwater runoff. Do not check the groundwater box unless there is observed and documented base flow (spring flow) on the project site.



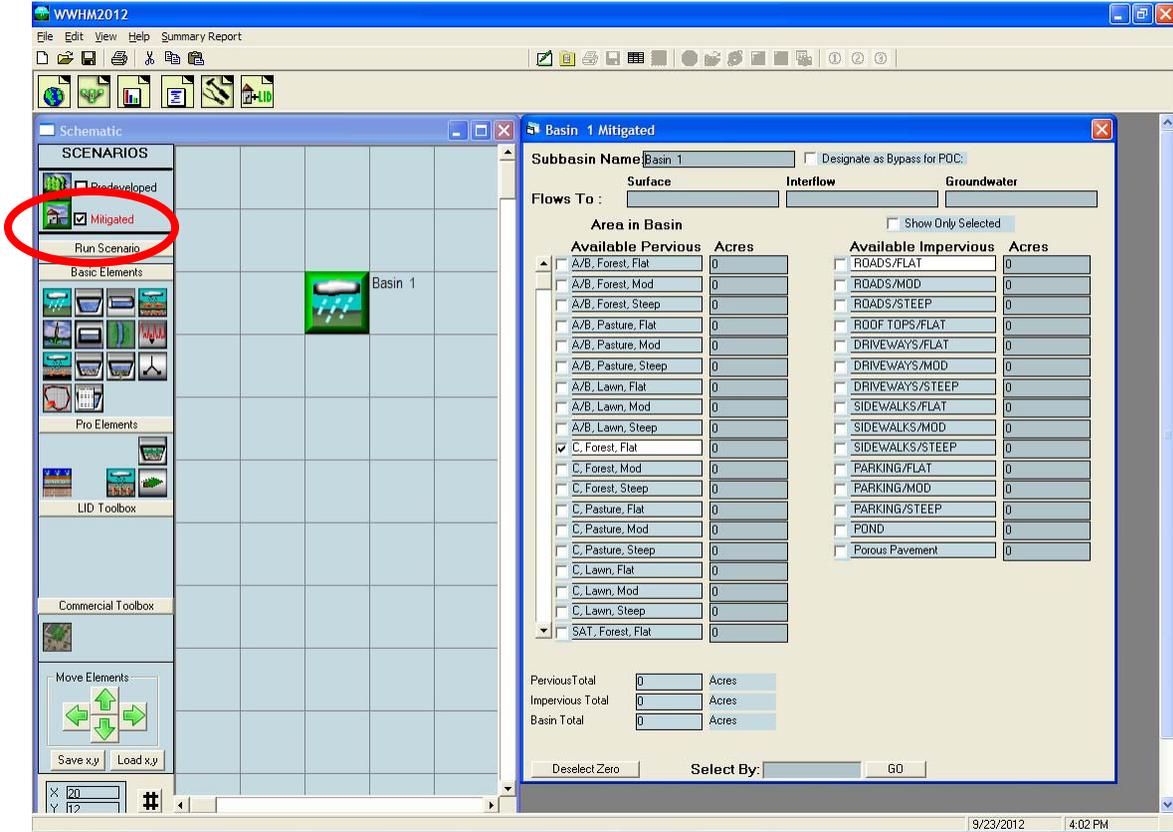
Click the Connect button in the low right corner to connect this point of compliance to the Predeveloped basin.



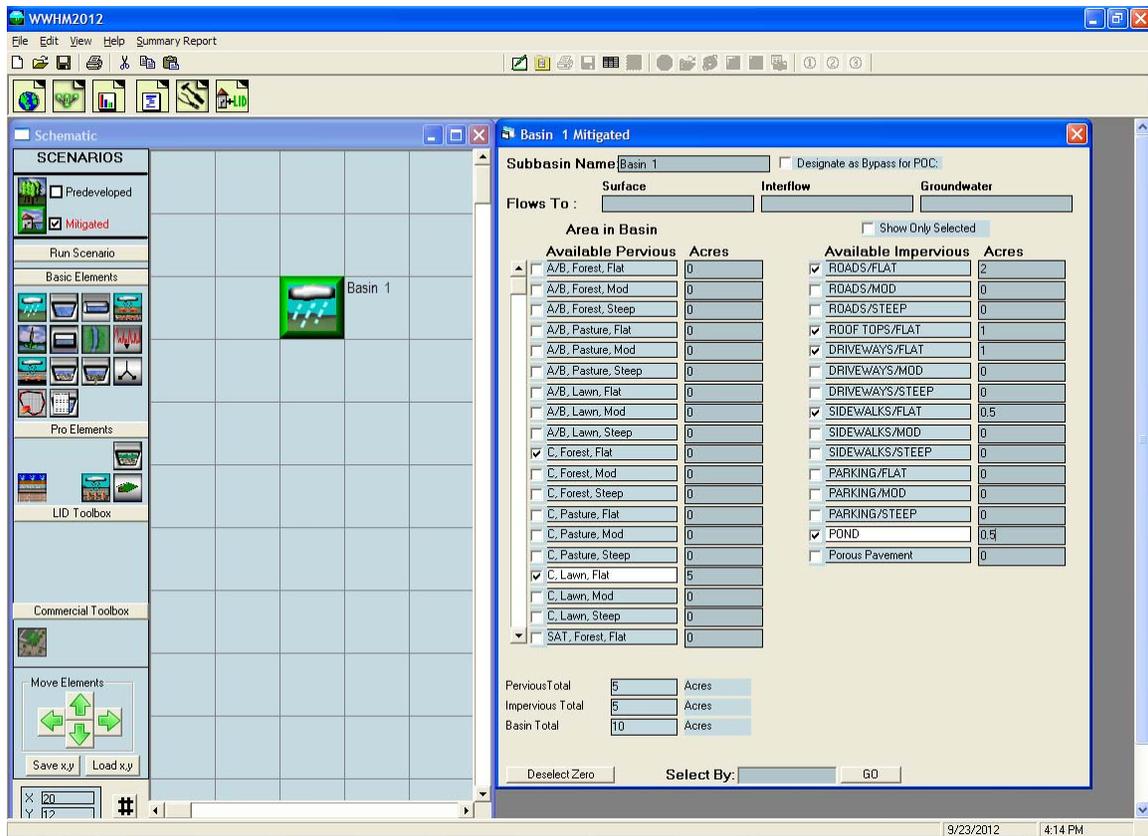
After the point of compliance has been added to the basin, the basin element will change. A small box with a bar chart graphic will be shown in the lower right corner of the basin element. This small POC box identifies this basin as a point of compliance.

To compute the runoff at the POC for the Predeveloped scenario click on the “Run Scenario” button. When “Run Scenario” is clicked WWHM2012 creates an HSPF UCI (User Control Input) file and runs HSPF at a 15-minute time step for the entire length of the precipitation record. Time series output (runoff data) at the POC is saved to the HSPF WDM file for later analysis.

3. Set up the Mitigated scenario.



First, check the Mitigated scenario box and place a basin element on the grid.

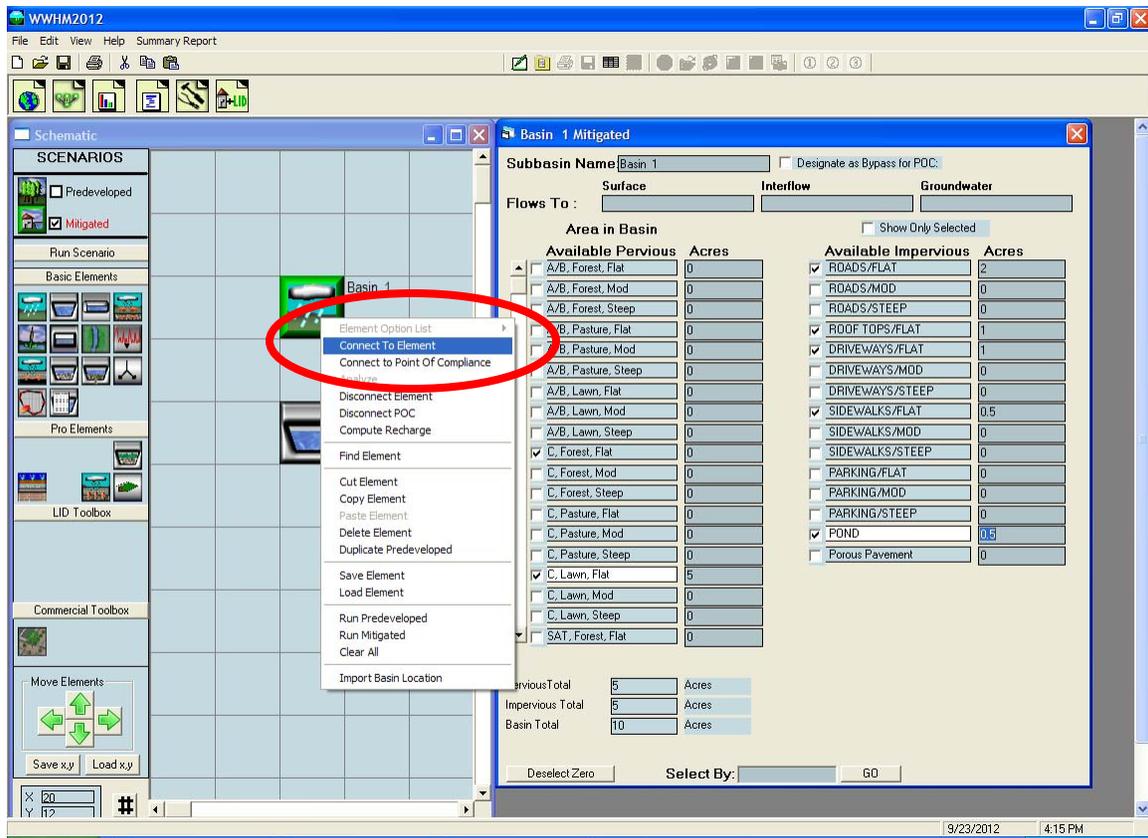


For our 10-acre project site Mitigated land use we have:

- 5 acres of C soil, lawn, flat
- 2 acres of roads, flat
- 1 acre of roof tops
- 1 acre of driveways, flat
- 0.5 acre of sidewalks, flat
- 0.5 acre pond

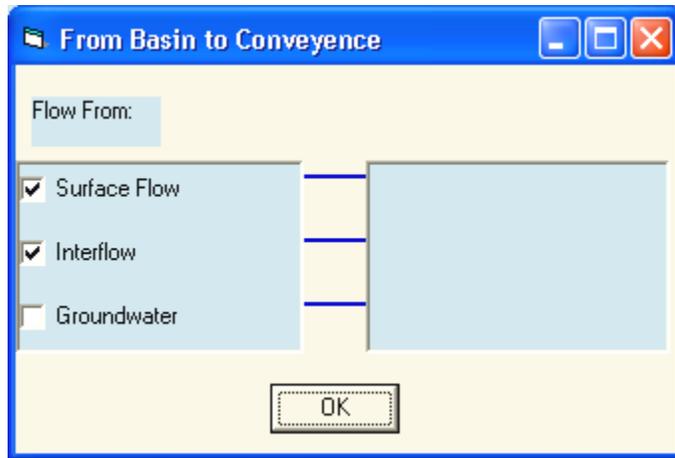
The pond 0.5 acres is an estimate, as we don't really know the size of the surface area of the pond until we size it. But for the purposes of computing the Mitigated scenario runoff we will assume that the pond surface area acts like an impervious surface.

We will add a trapezoidal pond downstream of the basin.

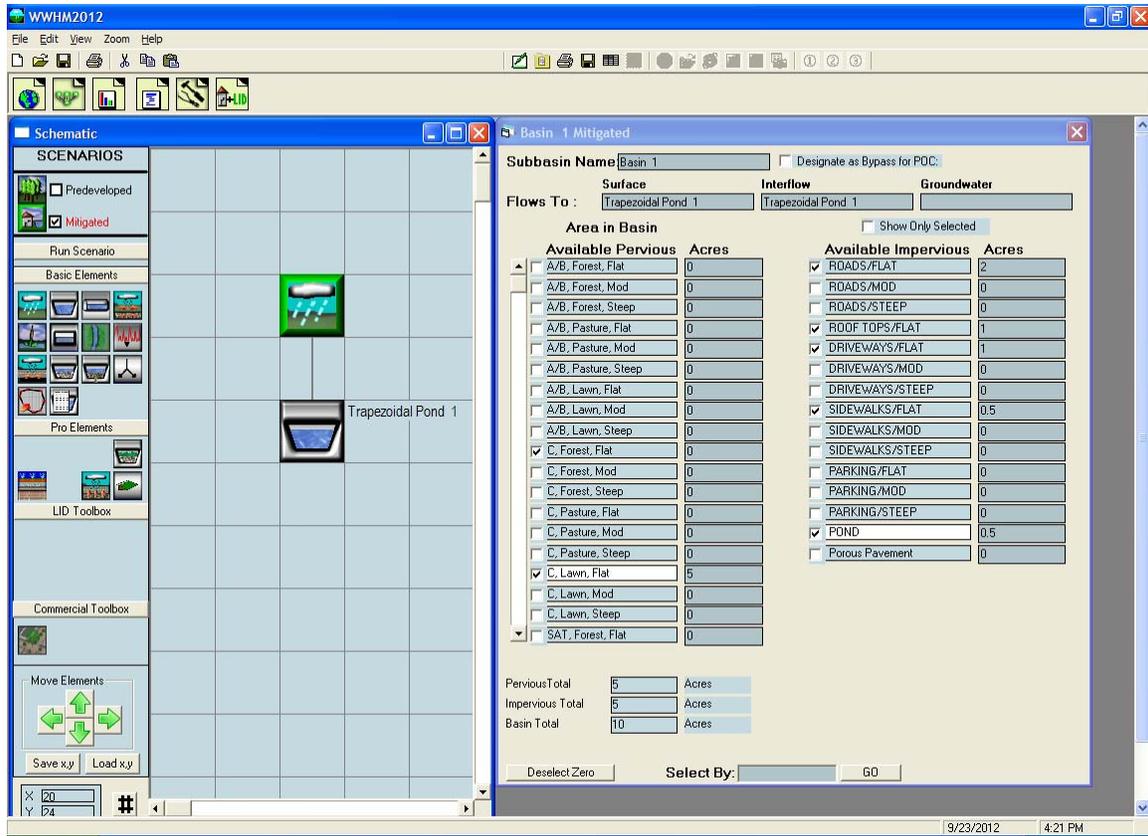


The trapezoidal pond element is placed below the basin element on the grid. All water flows down the grid.

Right click on the basin and select Connect To Element. A green line will appear with one end connected to the basin and the other end connected to a green box. With the mouse pointer pull the other end of the line down so that the green box is on top of the trapezoidal pond and click on the pond. This will bring up the From Basin to Conveyance screen. As with the Predeveloped scenario we want to only connect the surface flow and the interflow from the basin to the pond. Click OK.

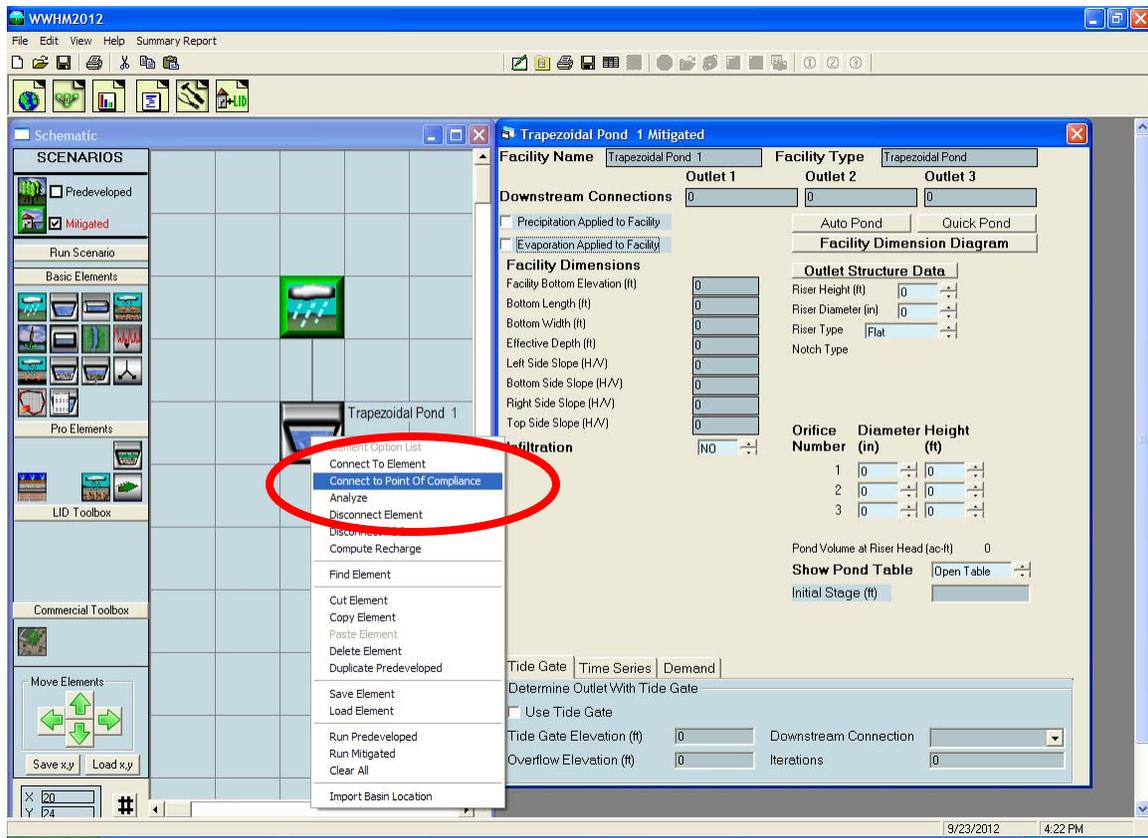


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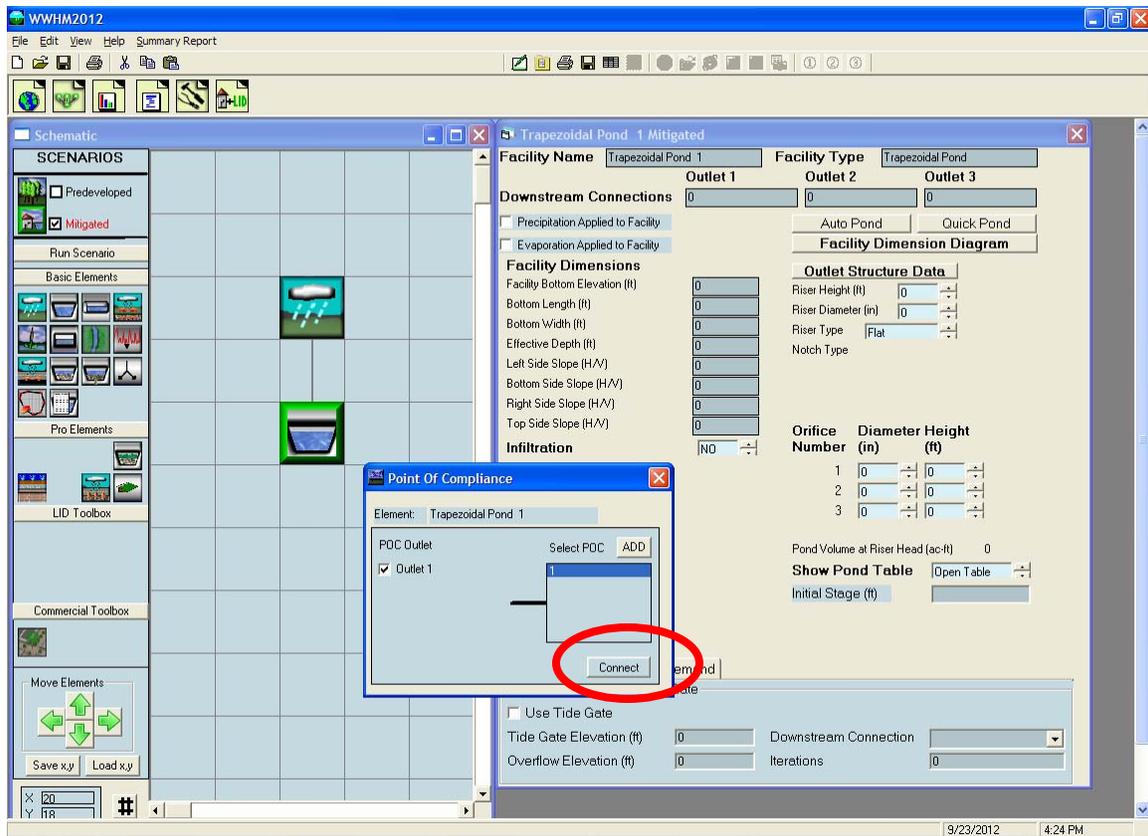
A line will connect the land use basin to the trapezoidal pond.

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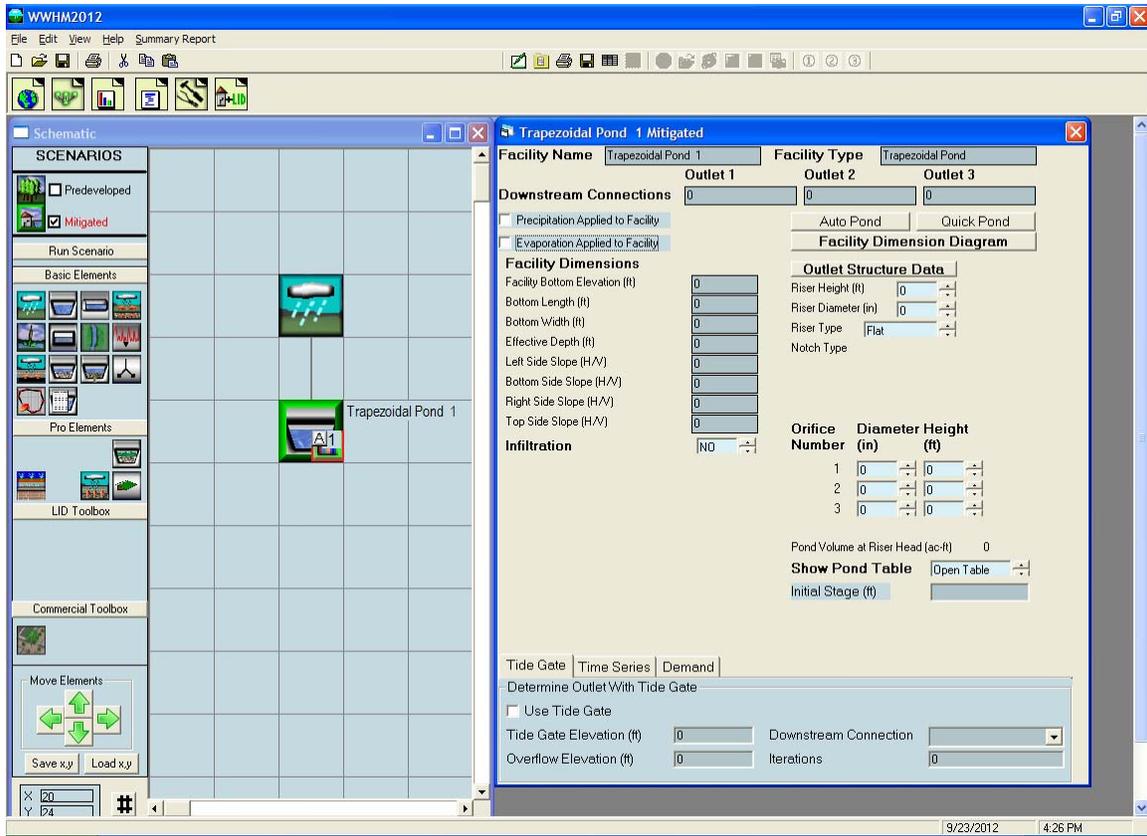
Right click on the trapezoidal pond element to connect the pond's outlet to the point of compliance. Highlight Connect to Point Of Compliance and click.

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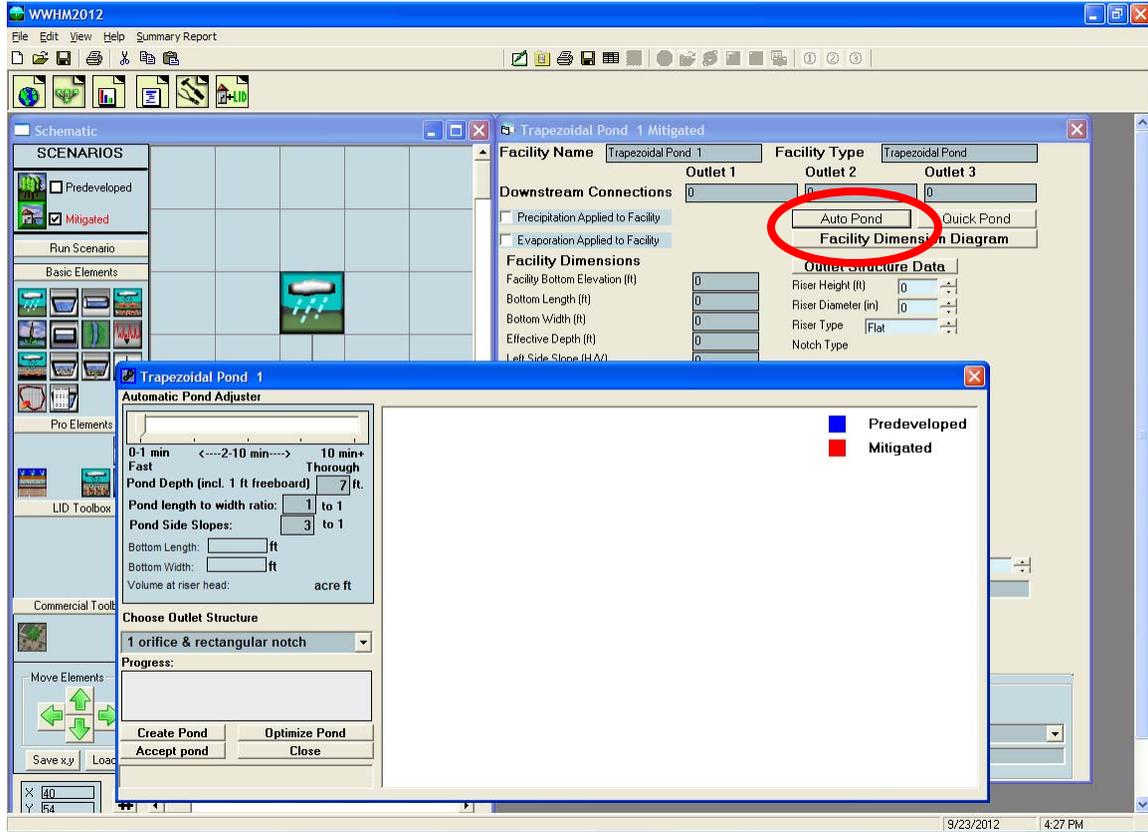
The Point of Compliance screen will be shown for the pond. The pond has one outlet (by default). The outflow from the pond will be compared with the Predeveloped runoff at the same point of compliance. The point of compliance is designated as POC 1 (WWHM2012 allows for multiple points of compliance). Click on the Connect button.

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The point of compliance is shown on the pond element as a small box with the letter “A” and a bar chart symbol in the lower right corner.

4. Sizing the pond.

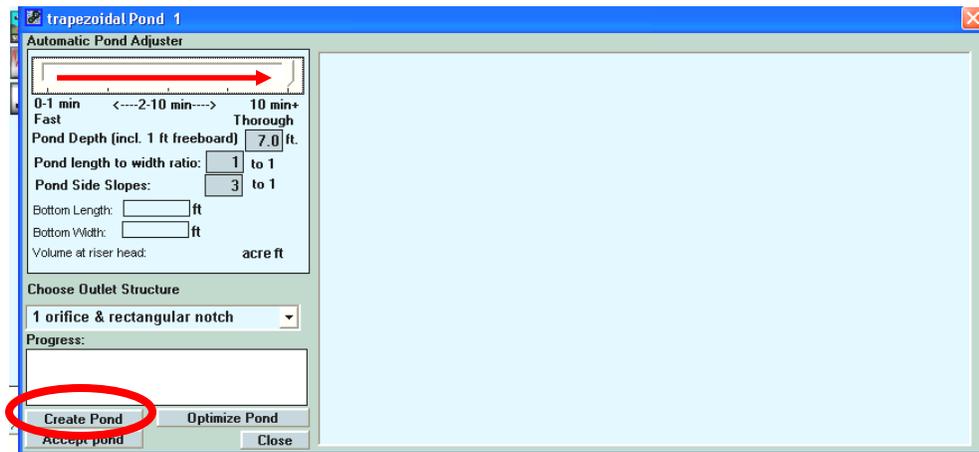


A trapezoidal stormwater pond can be sized either manually or automatically (using AutoPond). AutoPond will be used for this example.

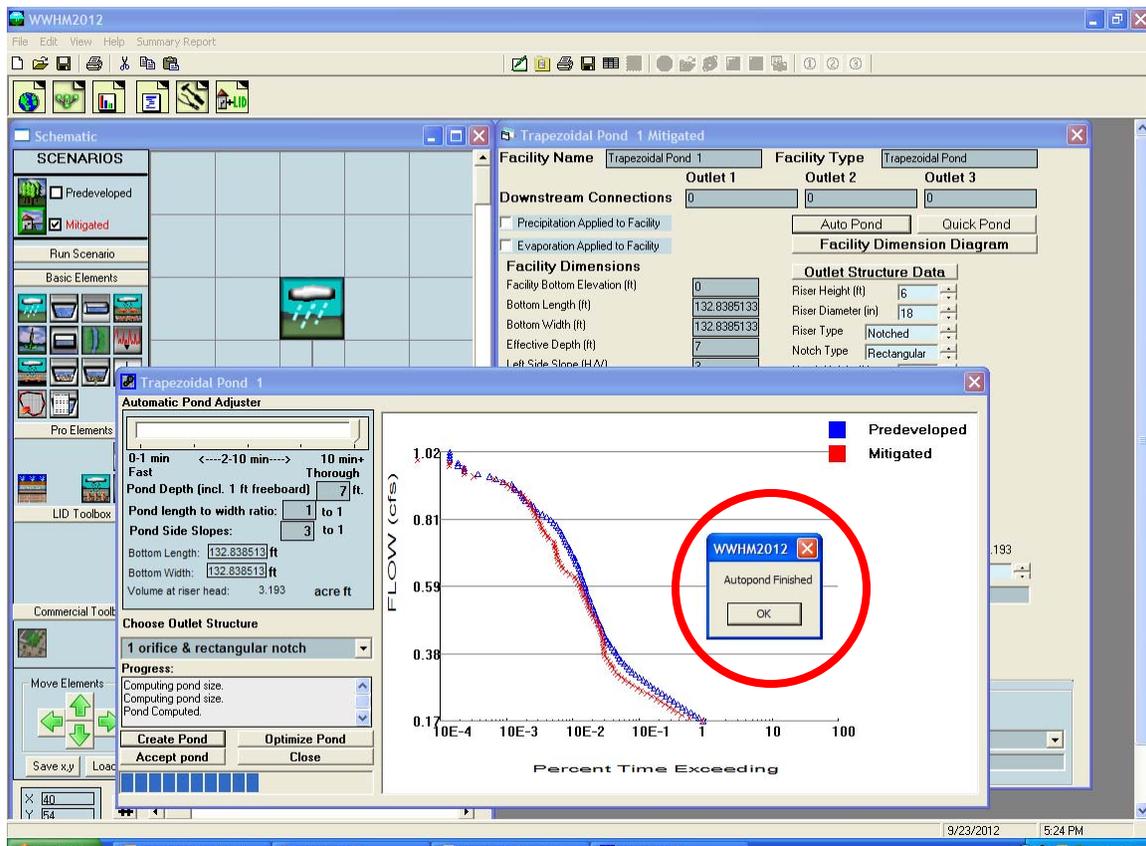
Click on the AutoPond button and the AutoPond screen will appear. The user can set the pond depth (default: 7 feet), pond length to width ratio (default: 1 to 1), pond side slopes (default: 3 to 1), and the outlet structure configuration (default: 1 orifice and riser with rectangular notch weir).

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To optimize the pond design and create the smallest pond possible, move the Automatic Pond Adjuster pointer from the left to the right.



The pond does not yet have any dimensions. Click the “Create Pond” button to create initial pond dimensions and optimize the pond size and outlet structure.



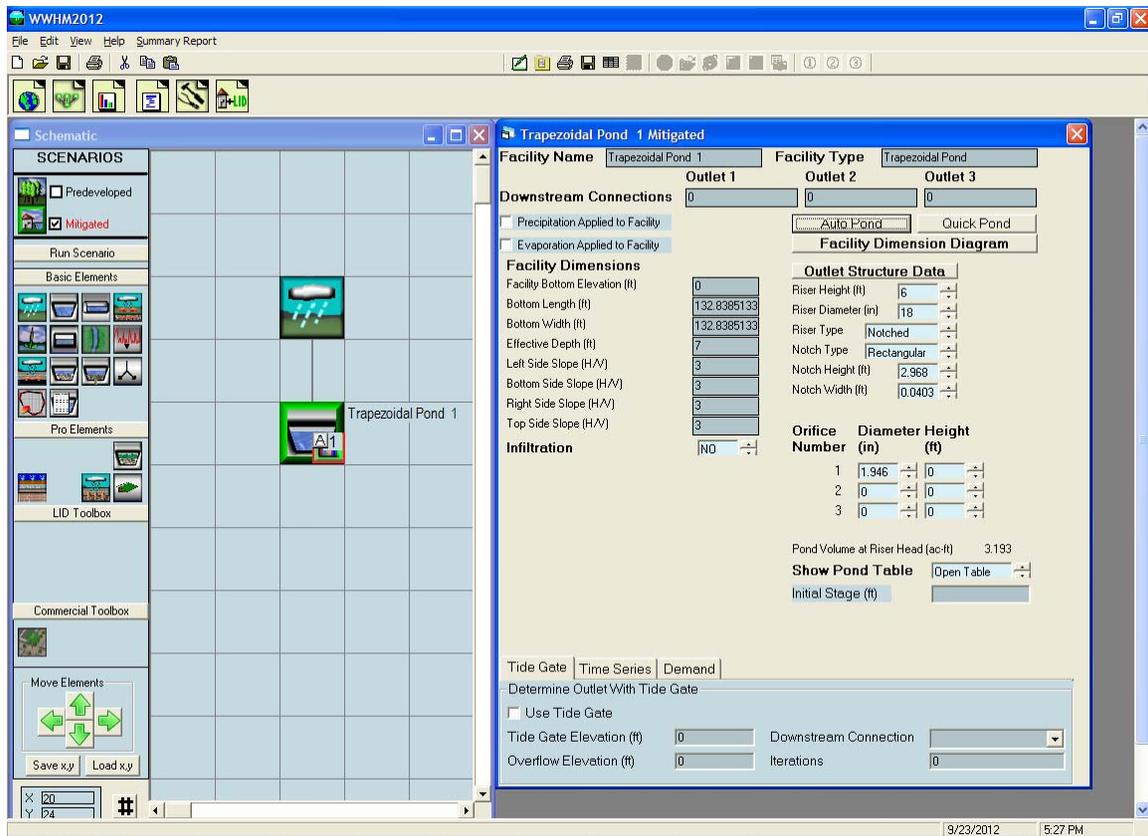
When “Create Pond” is clicked the WWHM2012 first computes the Predeveloped runoff then the flow frequency for the Predeveloped runoff. From the flow frequency results

half of the 2-year and the 50-year flows are identified. This is the range selected for the stream protection flow duration analysis. The Predeveloped flow duration values between half of the 2-year and the 50-year are plotted on the screen in blue.

The WWHM2012 computes Mitigated runoff. AutoPond selects initial pond and outlet structure dimensions and the Mitigated flow is routed through the pond. The outflow from the pond is analyzed and the Mitigated flow duration is plotted on the screen in red.

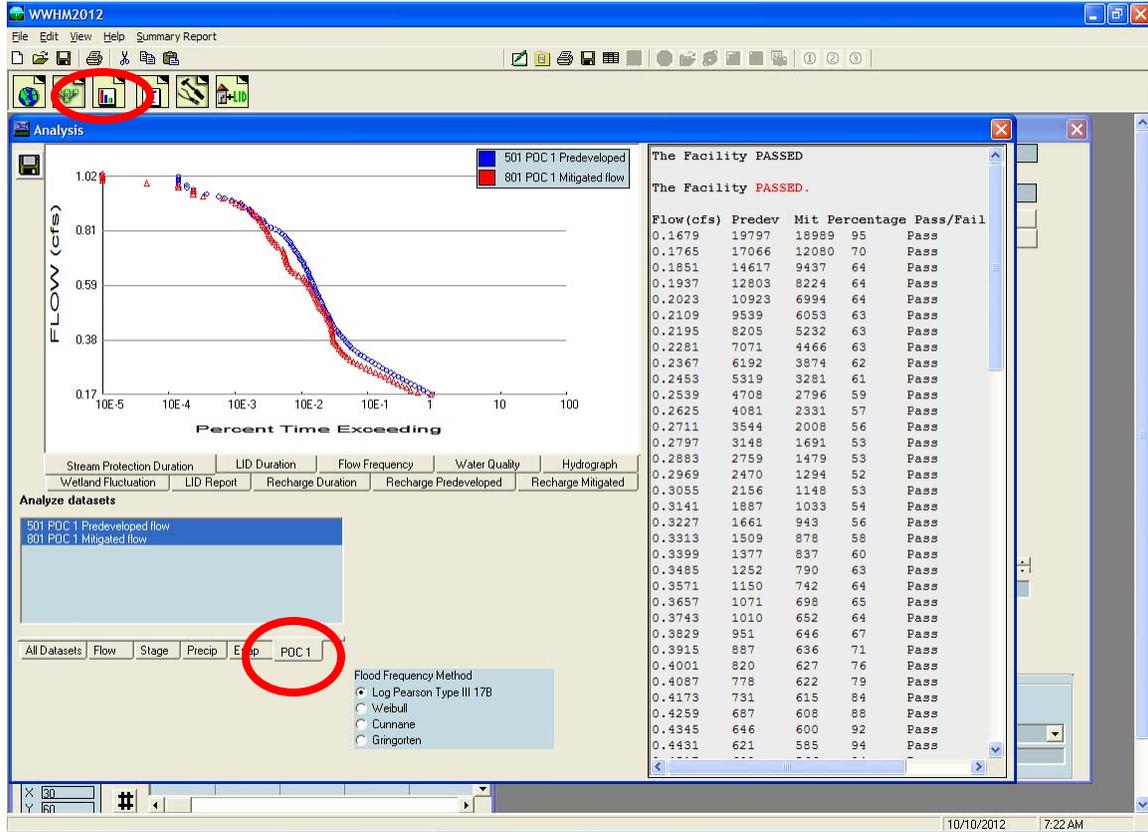
AutoPond compares the Mitigated flow duration results with the Predeveloped flow duration values. If the Mitigated flow duration values are greater than the Predeveloped values AutoPond increases the size of the pond or alters the outlet structure based on predefined rules and automatically reruns the Mitigated runoff through the revised pond. If the Mitigated flow duration values are less than the Predeveloped values AutoPond decreases the size of the pond or alters the outlet structure and automatically reruns the Mitigated runoff through the revised pond. Either way, AutoPond continues this exercise until the smallest possible pond is designed. At that point AutoPond announces that it is finished. Click OK. The pond is now sized.

The user may continue to manually optimize the pond by manually changing pond dimensions and/or the outlet structure configuration. After making these changes the user should click on the “Optimize Pond” button to check the results and see if AutoPond can make further improvements.

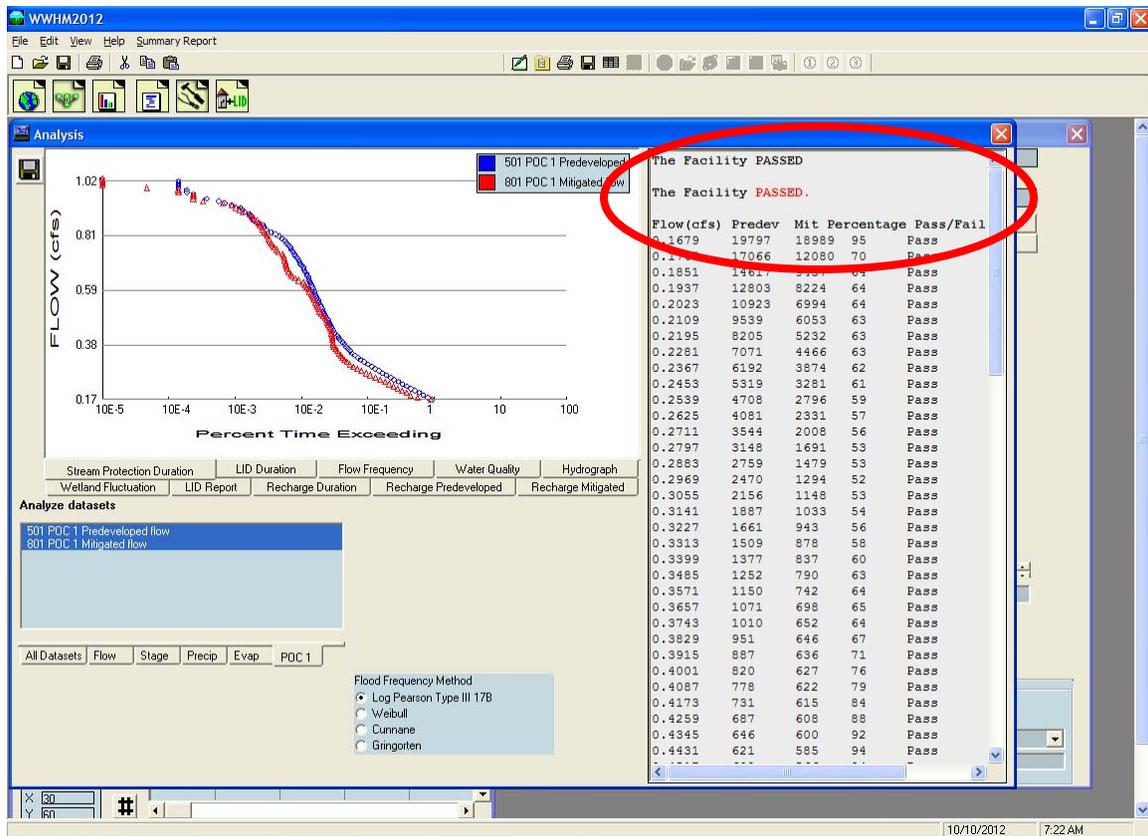


The final pond dimensions (bottom length, bottom width, effective pond depth, and side slopes) and outlet structure information (riser height, riser diameter, riser weir type, weir notch height and width, and orifice diameter and height) are shown on the trapezoidal pond screen to the right of the Schematic grid.

5. Review analysis.

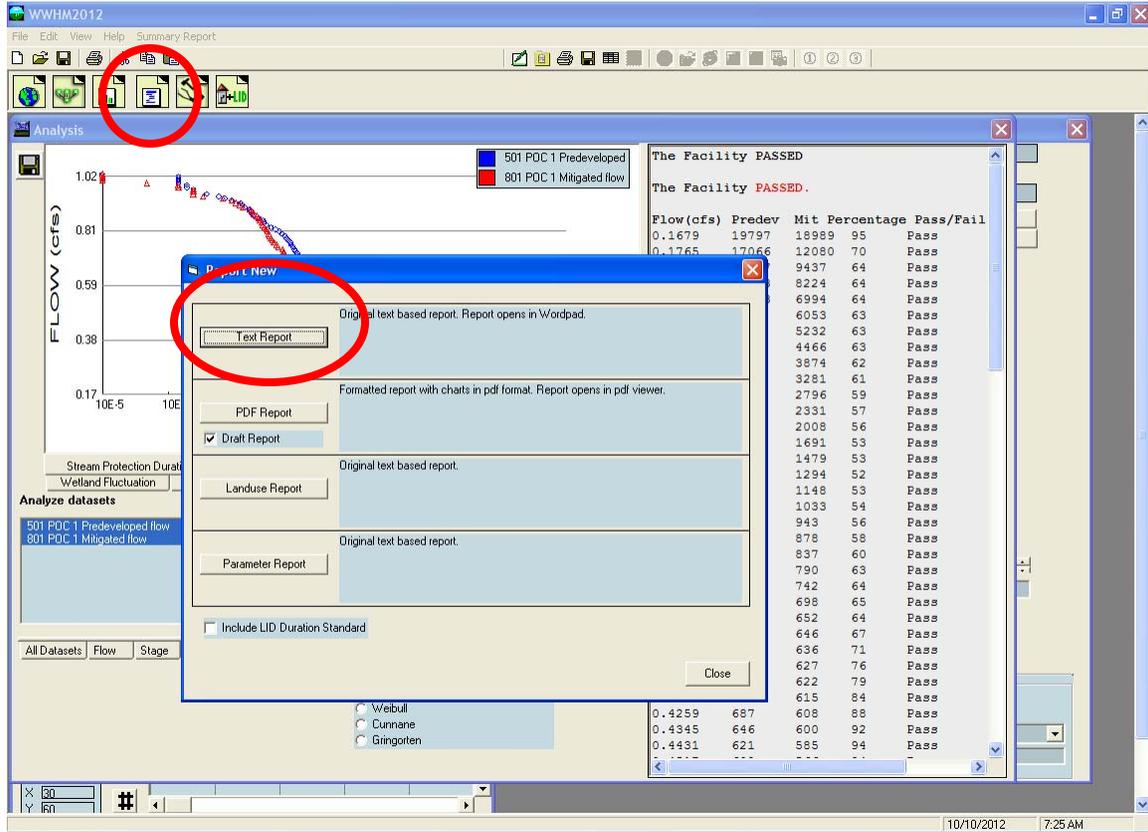


The Analysis tool bar button (third from the left) brings up the Analysis screen where the user can look at the results. Each time series dataset is listed in the Analyze Datasets box in the lower left corner. To review the stream protection flow duration analysis (50% of the 2-year flow to the 50-year flow) at the point of compliance click on the POC 1 tab at the bottom. This will run the stream protection flow duration analysis for both the 501 POC 1 Predeveloped flow and 801 POC 1 Developed flow.



The stream protection flow duration plot for both Predeveloped and Mitigated flows are shown along with the specific flow values and number of times Predeveloped and Mitigated flows exceeded those flow values. The Pass/Fail on the right indicates whether or not at that flow level the Ecology flow control standard criteria were met and the pond passes at that flow level (from half of the 2-year flow to the 50-year). If not, a Fail is shown; one Fail fails the pond design.

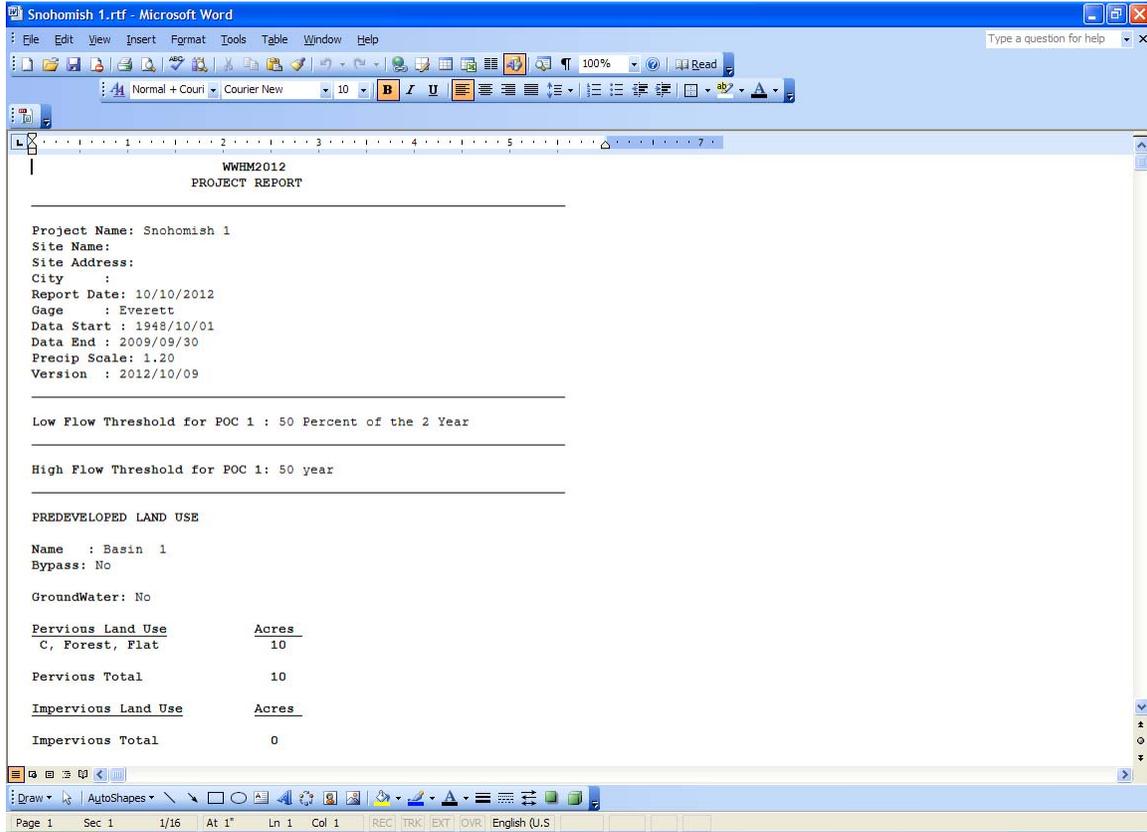
6. Produce report.



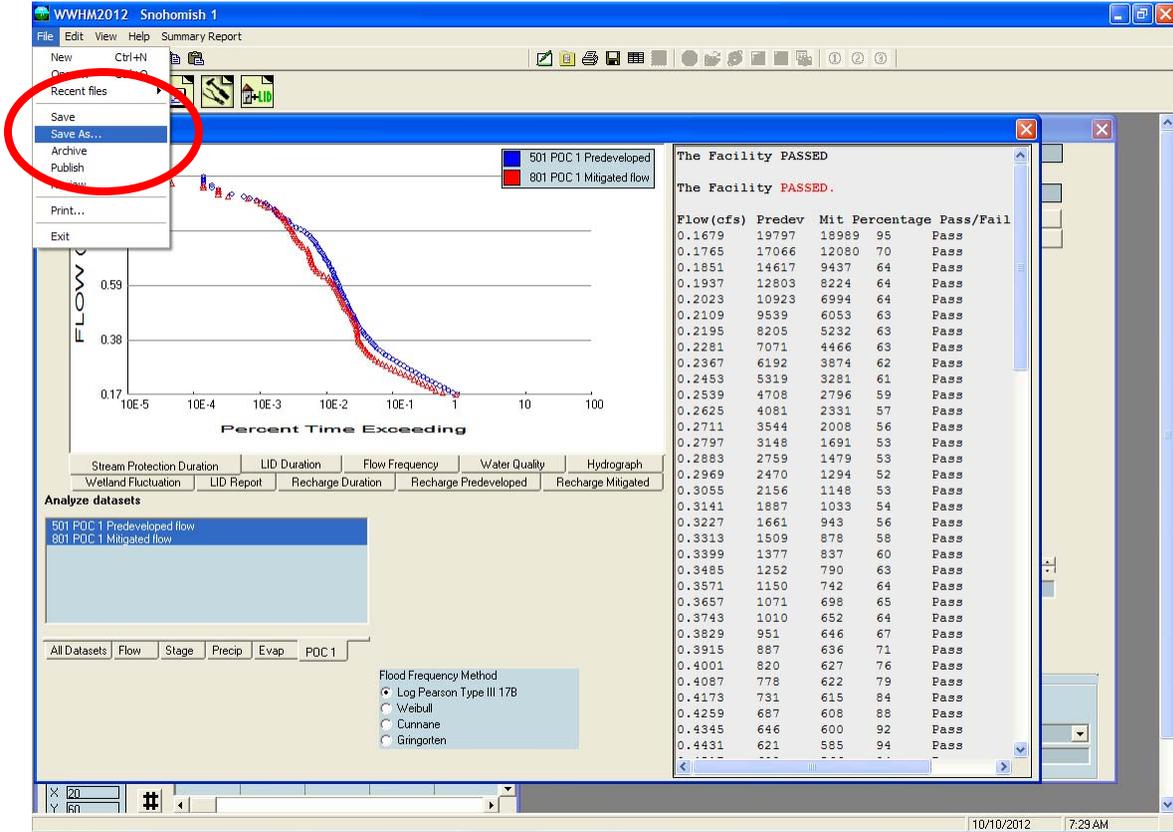
Click on the Reports tool bar button (fourth from the left) to generate a project report. You have the option of producing the report that contains all of the project information and results in a number of different formats. Click on “Text Report” button to generate output file in WordPad format.

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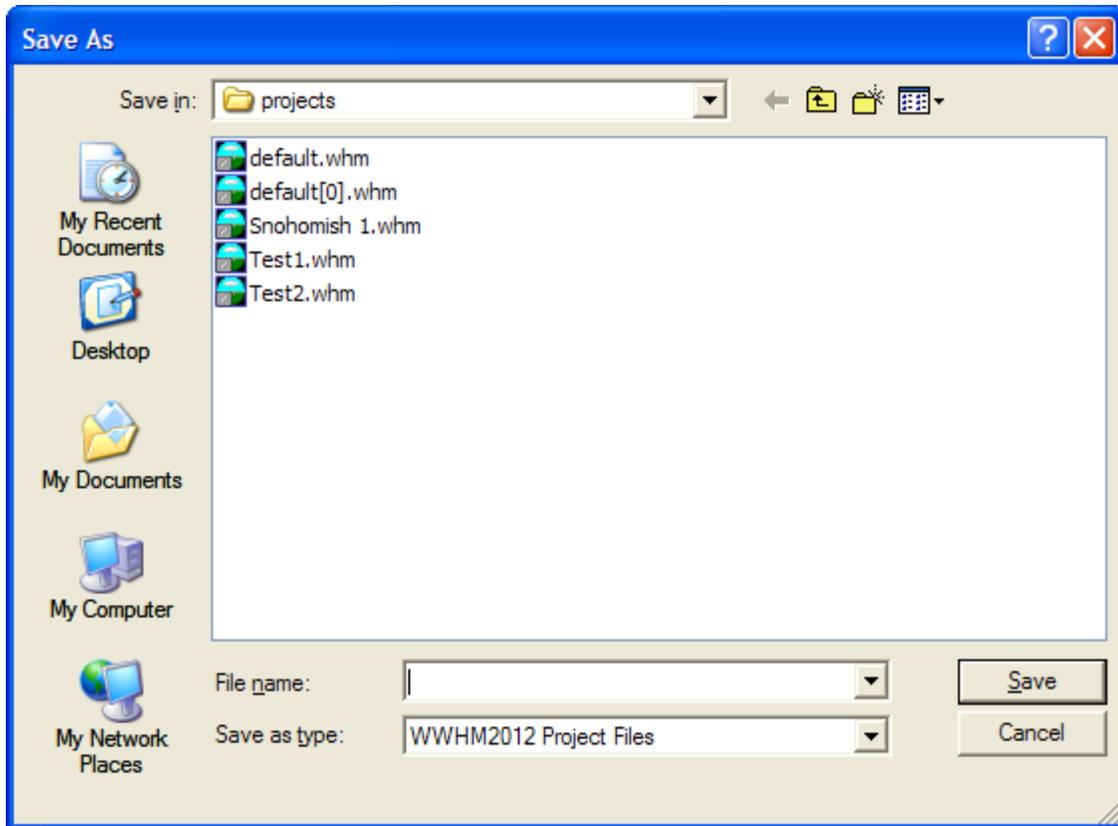
Scroll down the Report screen to see all of the results.



7. Save project.



To save the project click on File in the upper left corner and select Save As.



Select a file name and save the WWHM2012 project file. The WWHM2012 project file will have a file extension name of whm. The user can exit WWHM2012 and later reload the project file with all of its information by going to File, Open.

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MAIN SCREENS



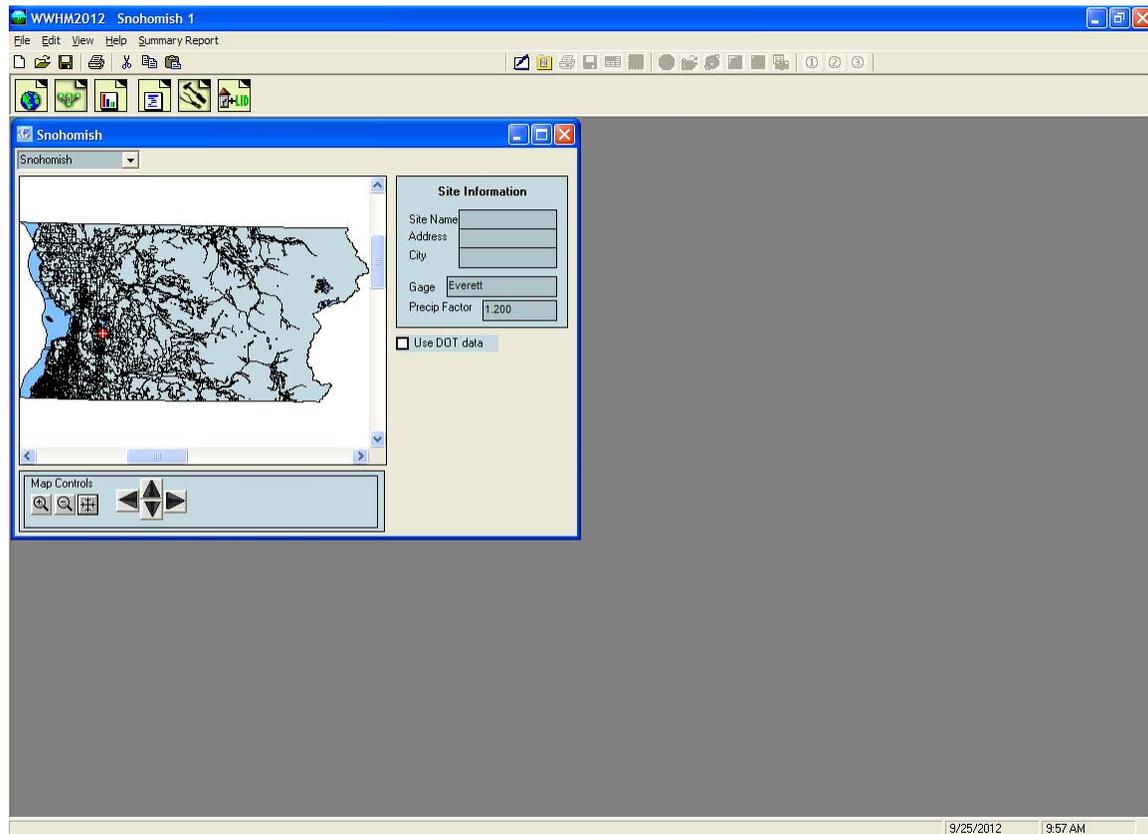
WWHM2012 has six main screens. These main screens can be accessed through the buttons shown on the tool bar above or via the View menu.

The six main screens are:

- Map Information
- General Project Information
- Analysis
- Reports
- Tools
- LID (Low Impact Development) Analysis

Each is discussed in more detail in the following sections.

MAP INFORMATION SCREEN



The Map Screen contains county information. The map is directly linked to the meteorological database that contains precipitation and evaporation data. The precipitation gage and precip factor are shown to the right of the map. They change depending on the project site location.

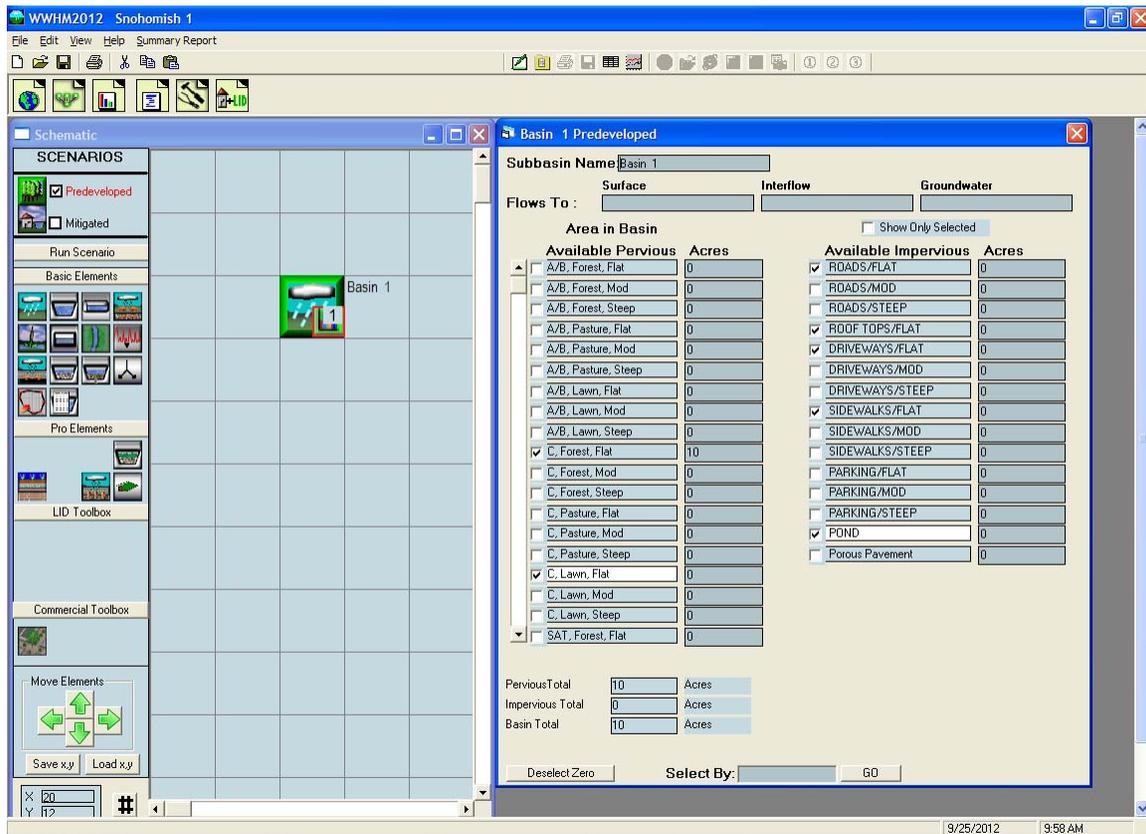
The user can elect to use Washington State Department of Transportation (DOT) precipitation data developed by MGS Consulting by checking the “Use DOT data” box to the right of the map. When the DOT data box is checked the map screen changes to show a map of the entire 19 counties of Western Washington with the area for which the DOT precipitation data are available outlined (the data are not available everywhere).

The county selection can be changed by clicking on the pulldown menu above the map and selecting one of the 19 Western Washington counties.

The user can provide site information (optional).

The user locates the project site on the map screen by using the mouse and left clicking at the project site location. Right clicking on the map re-centers the view. The + and – buttons zoom in and out, respectively. The cross hair button zooms out to the full county view. The arrow keys scroll the map view.

GENERAL PROJECT INFORMATION SCREEN



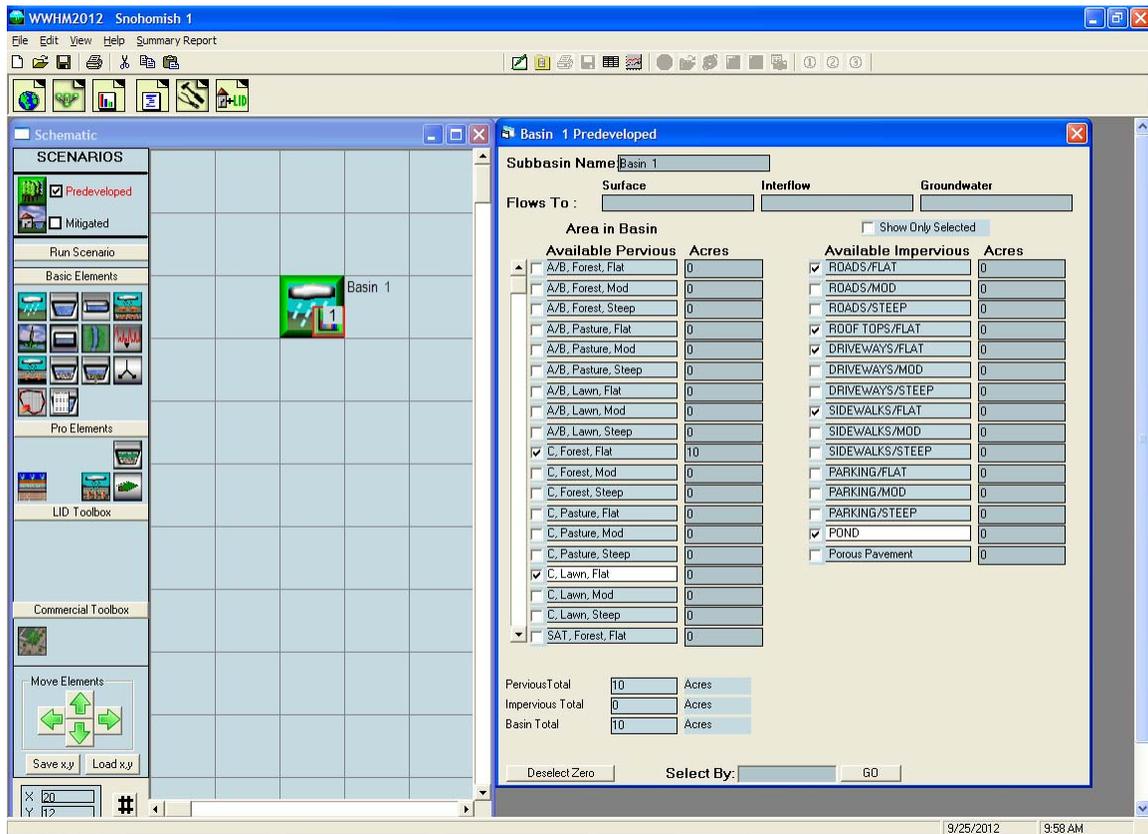
The project screen contains all of the information about the project site for the two land use scenarios: Predeveloped land use conditions and the Mitigated (developed) land use conditions. To change from one scenario to another check the box in front of the scenario name in the upper left corner of the screen.

Predeveloped is defined as the existing conditions prior to land use development. Runoff from the Predeveloped scenario is used as the target for the Mitigated scenario compliance. Unless there are special circumstances, the Department of Ecology requires that Predeveloped land use be Forest. However, the model will accept any land use for this scenario.

Mitigated is defined as the developed land use with mitigation measures (as selected by the user). Mitigated is used for sizing stormwater control and water quality facilities. The runoff from the Mitigated scenario is compared with the Predeveloped scenario runoff to determine compliance with Ecology standards.

Below the scenario boxes are the Elements. Each element represents a specific stormwater feature (basin, pond, etc.) and is described in more detail in the following section.

SCHEMATIC EDITOR



The project screen also contains the Schematic Editor. The Schematic Editor is the grid to the right of the elements. This grid is where each element is placed and linked together. The grid, using the scroll bars on the left and bottom, expands as large as needed to contain all of the elements for the project.

All water movement on the grid must be from the top of the grid down.

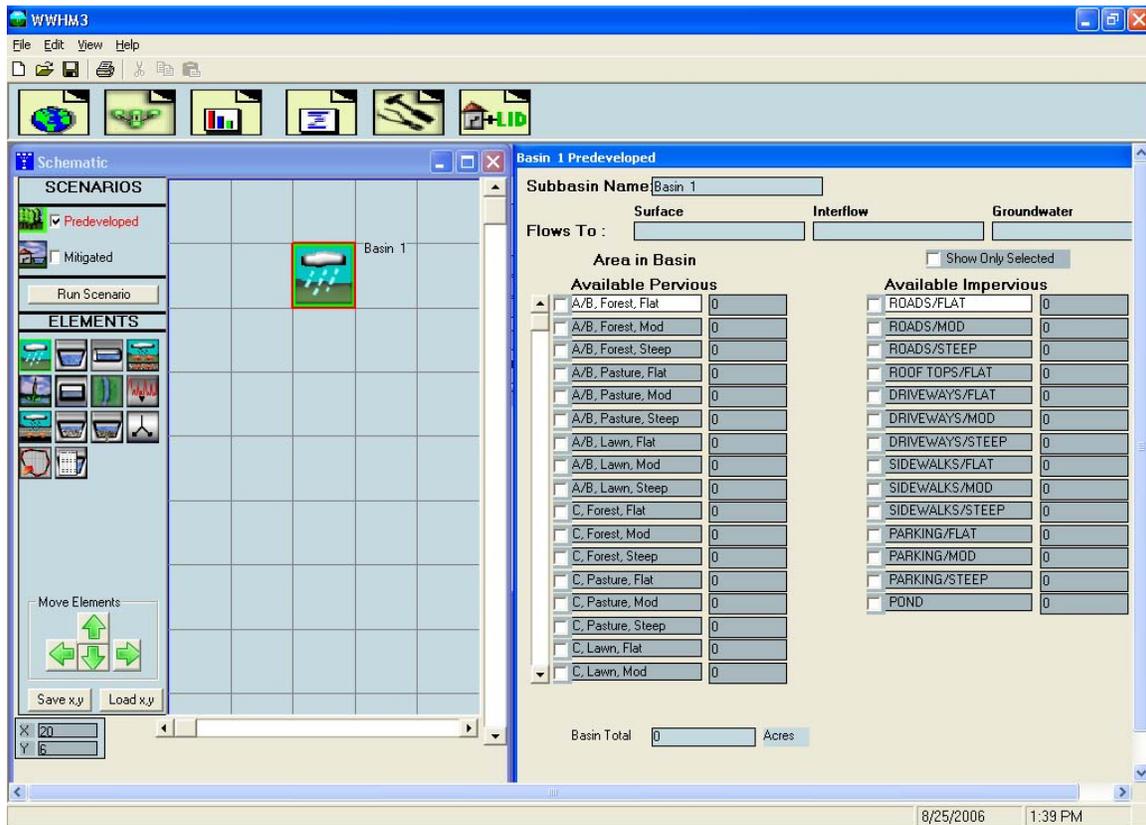
The space to the right of the grid will contain the appropriate element information.

To select and place an element on the grid, first left click on the specific element in the Elements menu and then left click on the selected grid square. The selected element will appear in the grid square.

The entire grid can be moved up, down, left, or right using the Move Elements arrow buttons.

The grid coordinates from one project can be saved (Save x,y) and used for new projects (Load x,y).

LAND USE BASIN



The Basin element represents a drainage area that can have multiple combinations of soils, vegetation, land slopes, and land uses. A basin produces three types of runoff: (1) surface runoff, (2) interflow, and (3) groundwater. Surface runoff is water flow on the surface of the soil. Interflow is shallow, subsurface runoff. Groundwater is deeper movement of water in the soil and may drain into the stream channel downstream of the project site.

The user can specify where each of these three types of runoff should be directed. The default setting is for the surface runoff and interflow to go to the stormwater facility; groundwater should not be connected unless there is observed base flow or spring flow occurring in the project drainage basin.

The user can change the default name “Basin 1” to another more appropriate name, if desired.

The user inputs the number of acres of appropriate basin land use information. Pervious land use information is in the form of soil, vegetation, and land slope. For example, “C, Forest, Flat” means SCS soil type C (till), forest vegetation, and flat (0-5%) land slope.

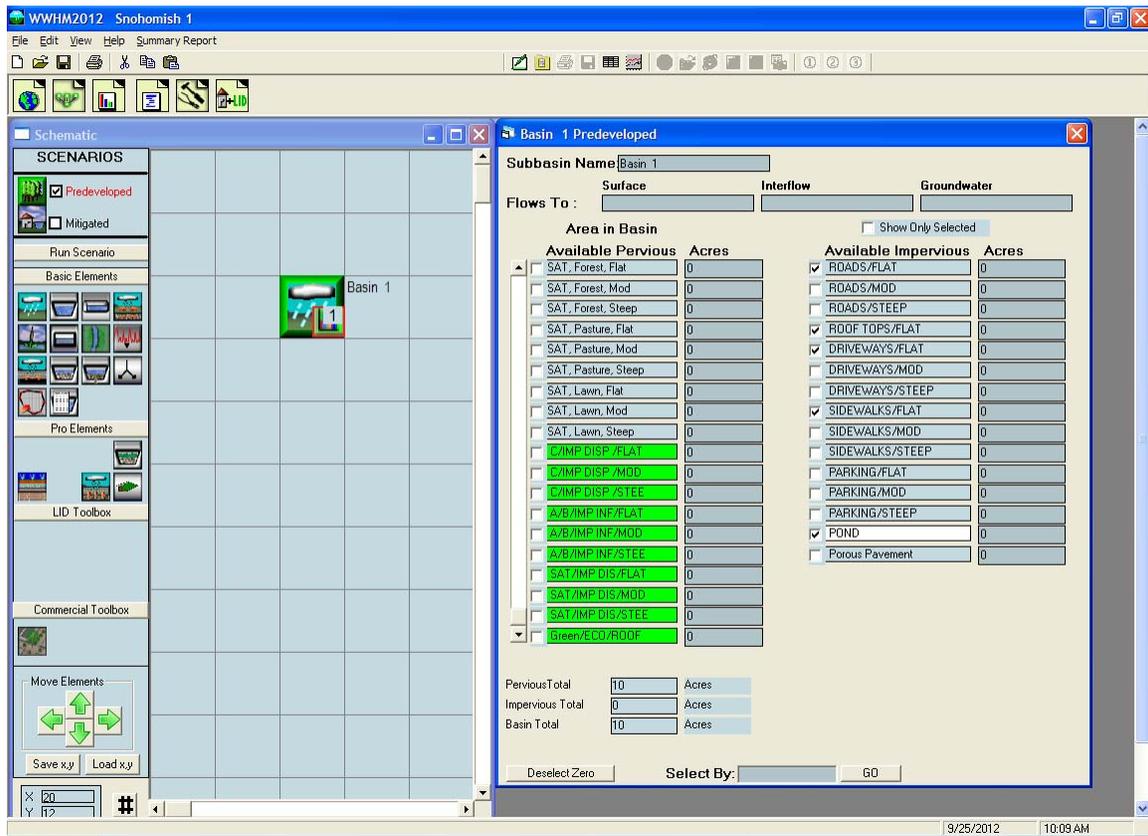
There are three basic soil types: A/B (outwash soils), C (till), and SAT (saturated/wetland/hydric soils).

There are three basic vegetation categories: forest (second growth Douglas Fir), pasture (non-forested natural areas/scrub/shrub rural vegetation), and lawn (sod lawn/grass/landscaped urban vegetation).

There are also three land slope categories: flat (0-5%), moderate (5-15%), and steep (>15%).

Impervious areas are divided into five types with three different slopes. The four types are: roads, roofs, driveways, sidewalks, and parking. The slope categories are the same as for the pervious land use (flat, moderate, steep). Pond area is also listed as an impervious area.

Runoff credits are included in the ten pervious land categories at the bottom of the Available Pervious list (see below).



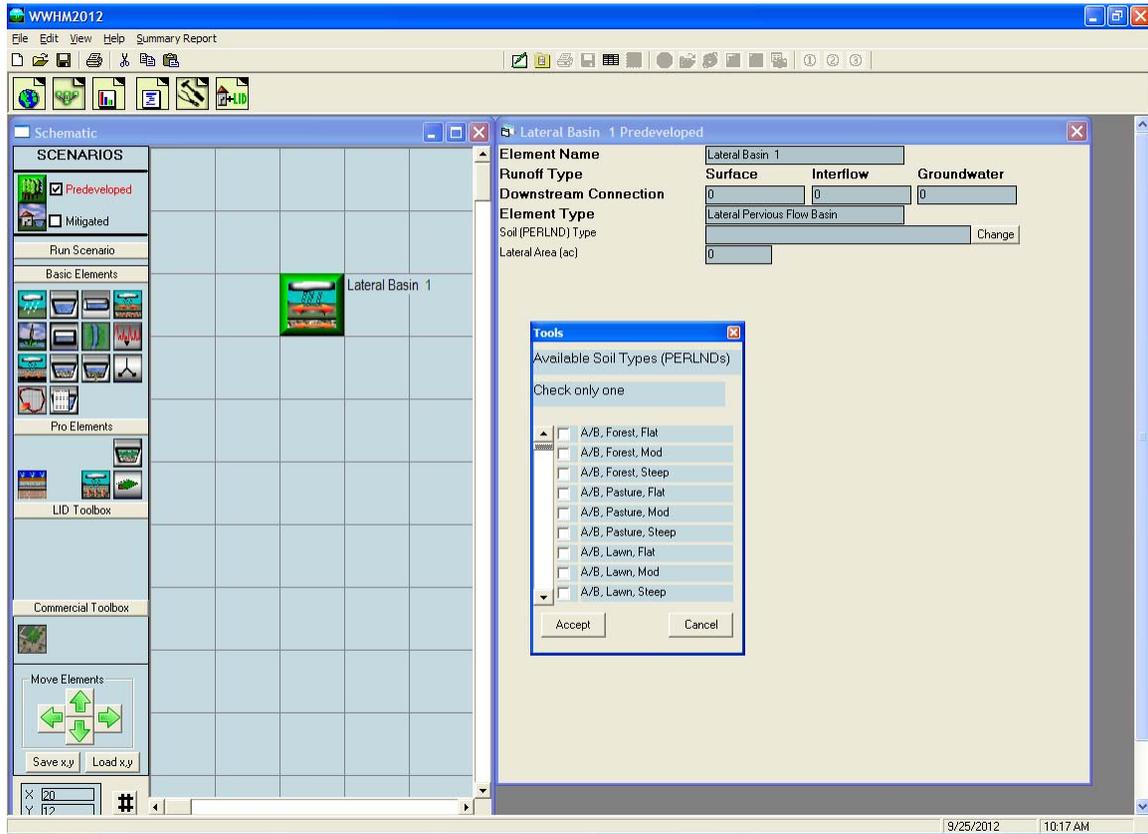
These ten land uses are:

- (1) C/IMP DISP/FLAT = Dispersal of impervious area runoff on C soil with flat slope.
- (2) C/IMP DISP/MOD = Dispersal of impervious area runoff on C soil with moderate slope.
- (3) C/IMP DISP/STEEP = Dispersal of impervious area runoff on C soil with steep slope.

- (4) A/B/IMP INF/FLAT = Infiltration of impervious area runoff on A/B soil with flat slope.
- (5) A/B/IMP INF/MOD = Infiltration of impervious area runoff on A/B soil with moderate slope.
- (6) A/B/IMP INF/STEEP = Infiltration of impervious area runoff on A/B soil with steep slope.
- (7) SAT/IMP DISP/FLAT = Dispersal of impervious area runoff on saturated soil with flat slope.
- (8) SAT/IMP DISP/MOD = Dispersal of impervious area runoff on saturated soil with moderate slope.
- (9) SAT/IMP DISP/STEEP = Dispersal of impervious area runoff on saturated soil with steep slope.
- (10) GREEN/ECO-ROOF = Half impervious; half C soil, lawn, with flat slope.

These runoff credits have been included in WWHM2012, but have been superseded with new elements and are not the recommended approach to use to model these conditions.

PERVIOUS LATERAL BASIN



The pervious lateral basin is similar to the standard basin except that the runoff from the lateral basin goes to another adjacent lateral basin (impervious or pervious) rather than directly to a conveyance system or stormwater facility. By definition, the pervious lateral basin contains only a single pervious land type. Impervious area is handled separately with the impervious lateral basin (Lateral I Basin).

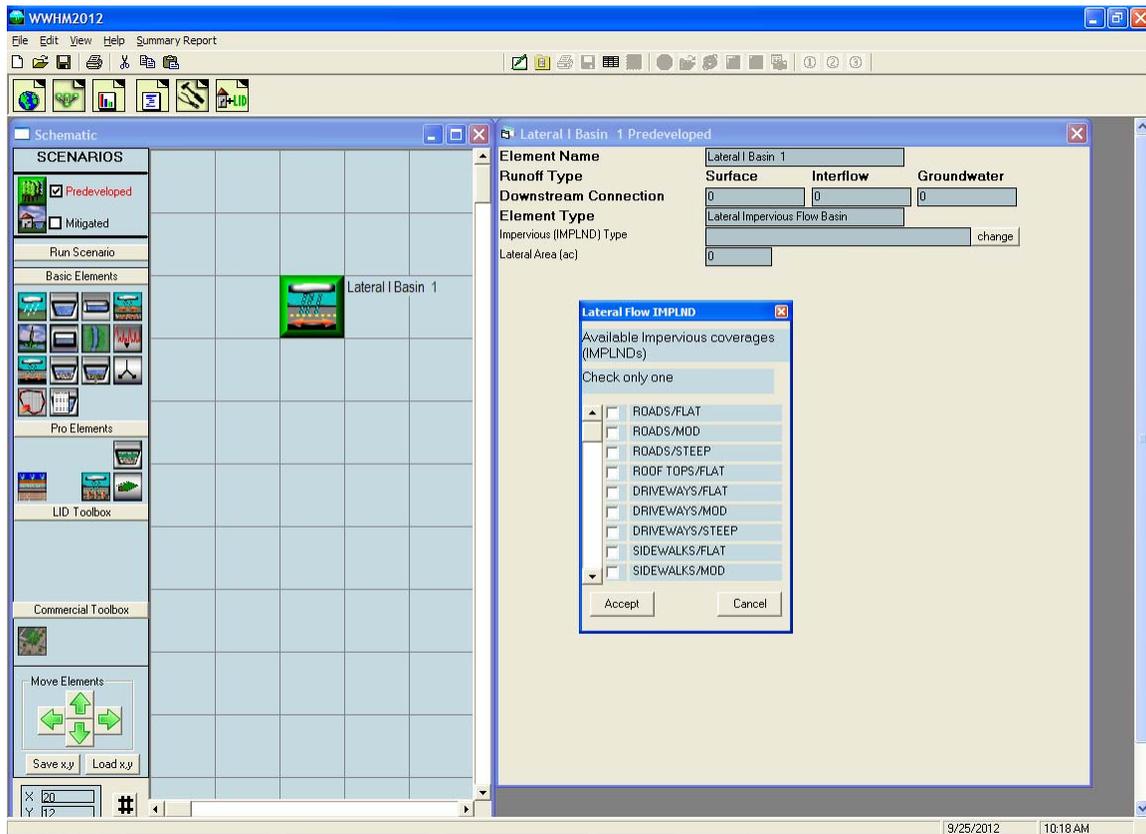
The user selects the pervious lateral basin land type by checking the appropriate box on the Available Soil Types Tools screen. This information is automatically placed in the Soil (PERLND) Type box above. Once entered, the land type can be changed by clicking on the Change button on the right.

The user can change the default name “Lateral Basin 1” to another more appropriate name, if desired.

The user enters the number of acres represented by the lateral basin land type.

If the lateral basin contains two or more pervious land use types then the user should create a separate lateral basin for each.

IMPERVIOUS LATERAL BASIN



The impervious lateral basin is similar to the standard basin except that the surface runoff from the lateral impervious basin goes to another adjacent lateral basin (impervious or pervious) rather than directly to a conveyance system or stormwater facility. By definition, the impervious lateral basin contains only impervious land types. Pervious area is handled separately with the pervious lateral basin (Lateral Basin).

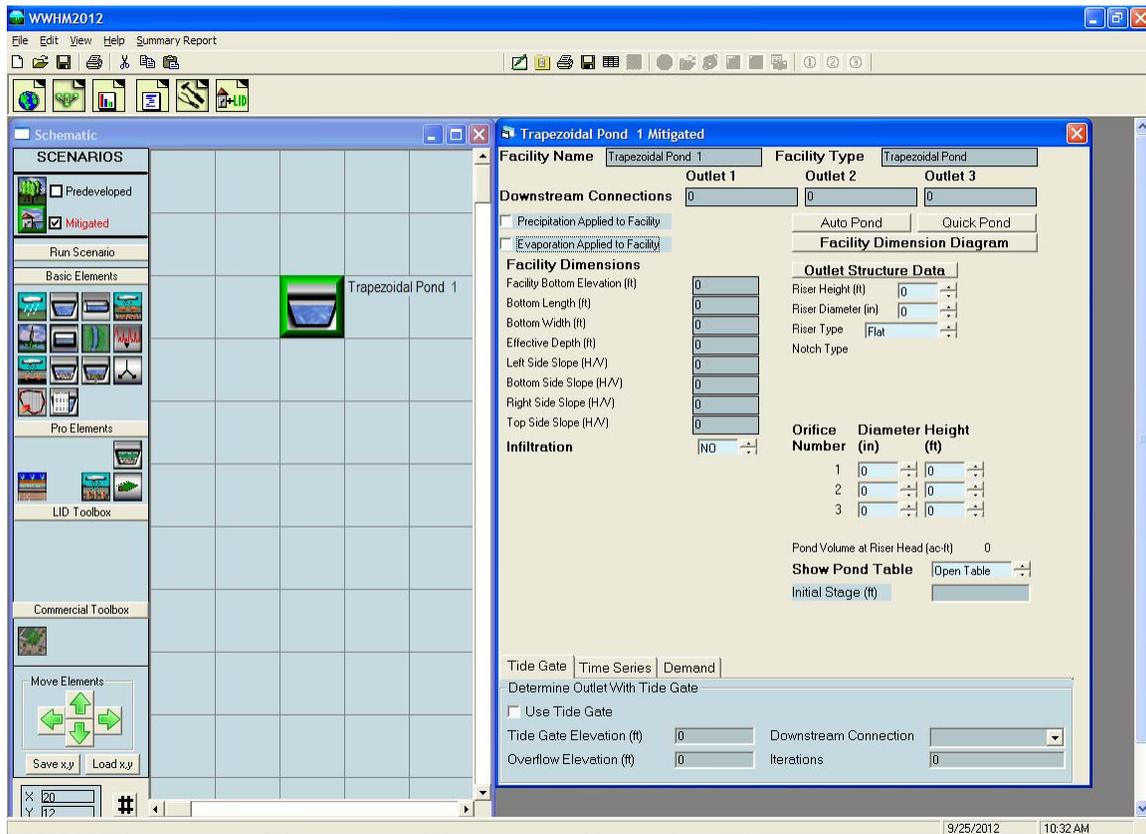
The user selects the impervious lateral basin land type by checking the appropriate box on the Available Impervious Coverages screen. This information is automatically placed in the Impervious (IMPLND) Type box above. Once entered, the land type can be changed by clicking on the Change button on the right.

The user can change the default name “Lateral I Basin 1” to another more appropriate name, if desired.

The user enters the number of acres represented by the lateral impervious basin land type.

If the lateral impervious basin contains two or more impervious land use types then the user should create a separate lateral I basin for each.

TRAPEZOIDAL POND



In WWHM2012 there is an individual pond element for each type of pond and stormwater control facility. The pond element shown above is for a trapezoidal pond. This is the most common type of stormwater pond.

A trapezoidal pond has dimensions (bottom length and width, depth, and side slopes) and an outlet structure consisting of a riser and one or more orifices to control the release of stormwater from the pond. A trapezoidal pond includes the option to infiltrate runoff, if the soils are appropriate and there is sufficient depth to the underlying groundwater table.

The user has the option to specify that different outlets be directed to different downstream destinations, although usually all of the outlets go to a single downstream location.

AutoPond will automatically size a trapezoidal pond to meet Ecology flow control standards. QuickPond will instantly create a pond without checking it for compliancy with Ecology standards.

AutoPond is only available in the Mitigated scenario.

The user can change the default name “Trapezoidal Pond 1” to another more appropriate name, if desired.

Precipitation and evaporation can be applied to the pond. The default standard setting is not to apply precipitation and evaporation, but to treat the pond surface area as an impervious surface.

The pond bottom elevation can be set to an elevation other than zero if the user wants to actual elevations. All pond stage values are relative to the bottom elevation. Negative bottom elevations are not allowed.

The pond effective depth is the pond height (including freeboard) above the pond bottom. It is not the actual elevation of the top of the pond.

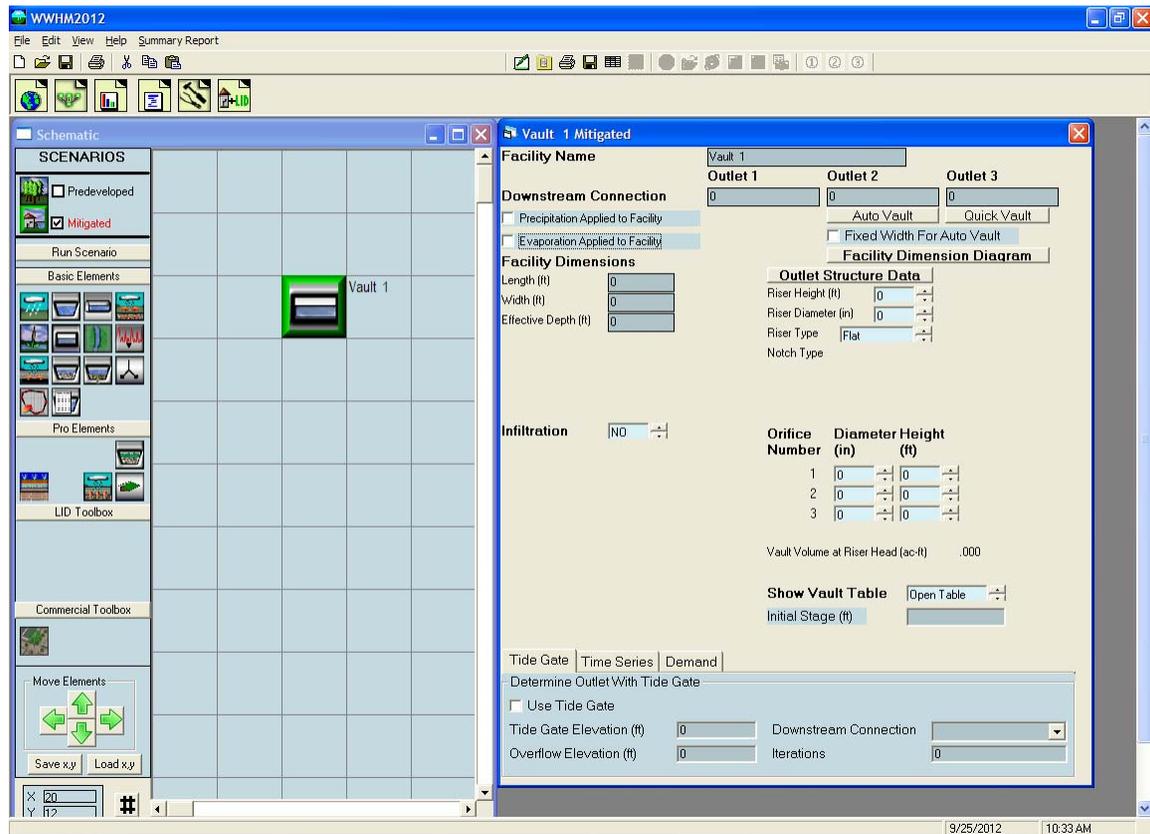
Pond side slopes are in terms of horizontal distance over vertical. A standard 3:1 (H/V) side slope would be given a value of 3. A vertical side slope has a value of 0.

The pond bottom is assumed to be flat.

The pond outlet structure consists of a riser and zero to three orifices. The riser has a height (typically one foot less than the effective depth) and a diameter. The riser can have either a flat top or a weir notch cut into the side of the top of the riser. The notch can be either rectangular, V-shaped, or a Sutro weir. More information on the riser weir shapes and orifices is provided later in this manual.

After the pond is given dimensions and outlet information the user can view the resulting stage-storage-discharge table by clicking on the “Open Table” arrow in the lower right corner of the pond information screen. This table defines the pond’s hydraulic characteristics.

VAULT



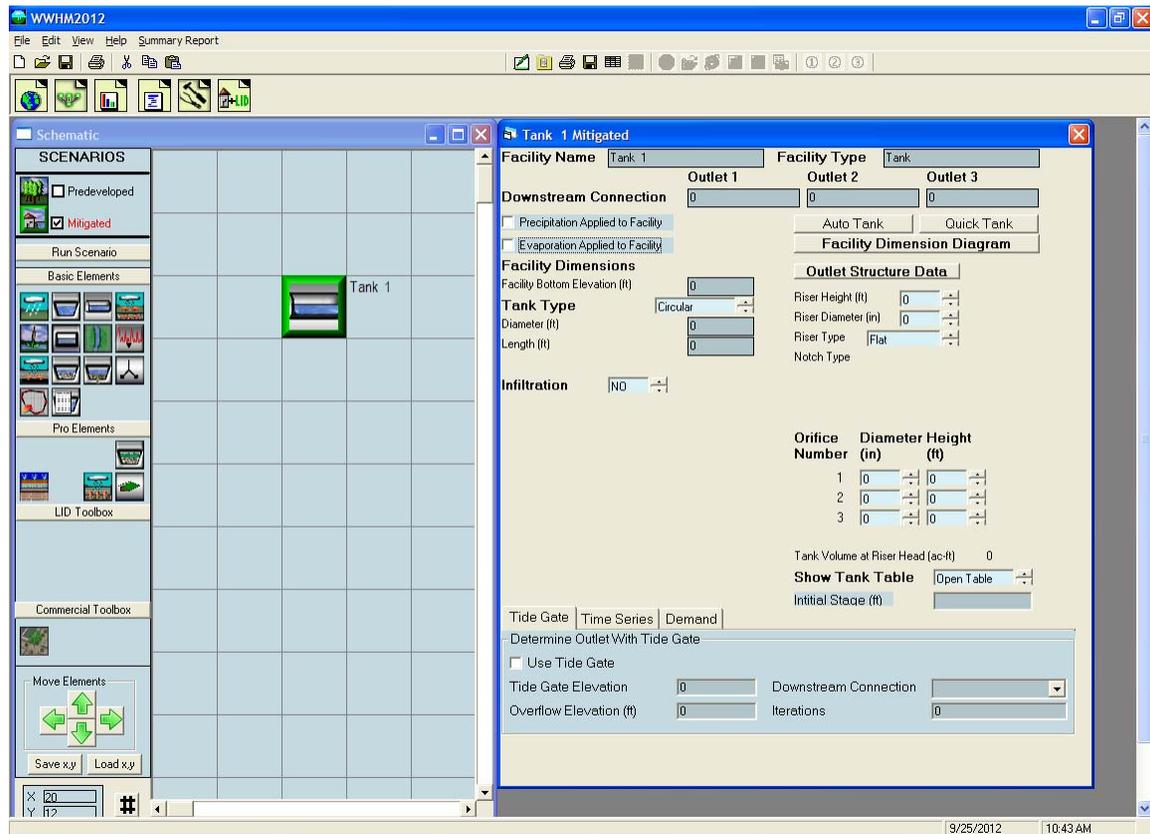
The storage vault has all of the same characteristics of the trapezoidal pond, except that the user does not specify the side slopes (by definition they are zero).

AutoVault and QuickVault work the same way as AutoPond and QuickPond.

AutoVault is only available in the Mitigated scenario.

The user can change the default name “Vault 1” to another more appropriate name, if desired.

TANK



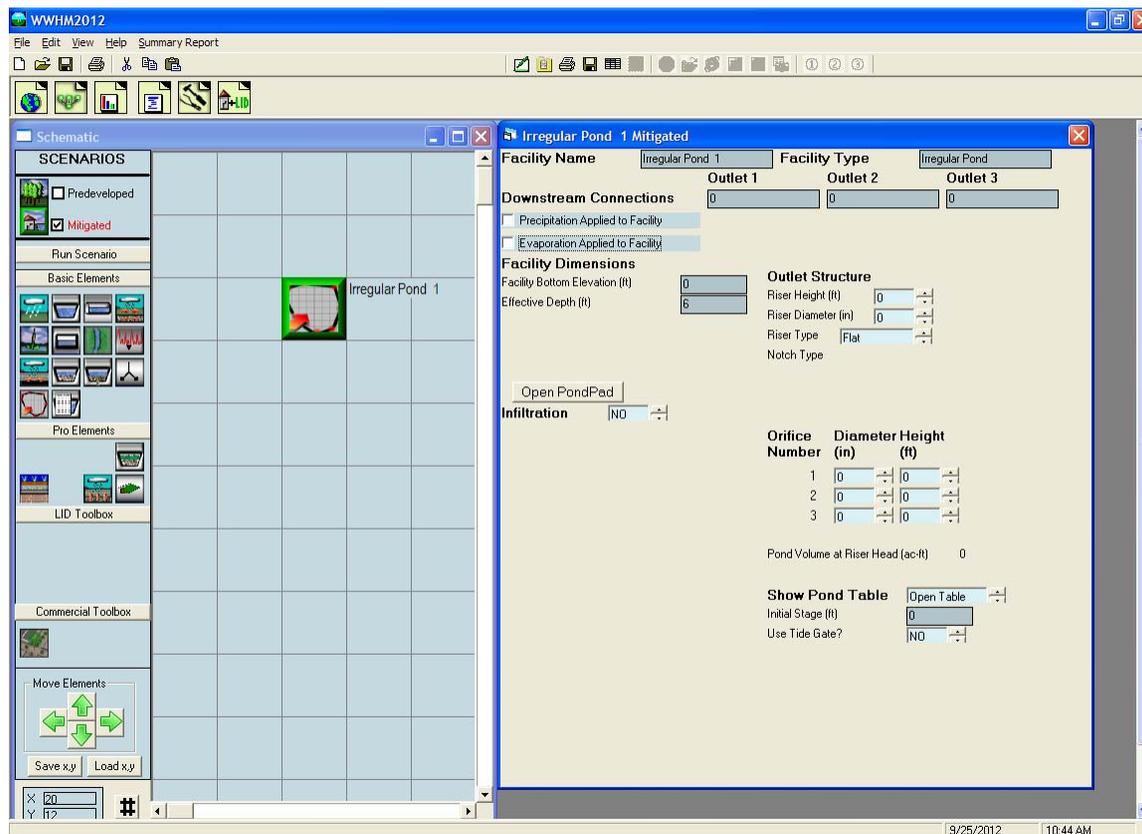
A storage tank is a cylinder placed on its side. The user specifies the tank’s diameter and length.

AutoTank and QuickTank work the same way as AutoPond and QuickPond.

AutoTank is only available in the Mitigated scenario.

The user can change the default name “Tank 1” to another more appropriate name, if desired.

IRREGULAR POND



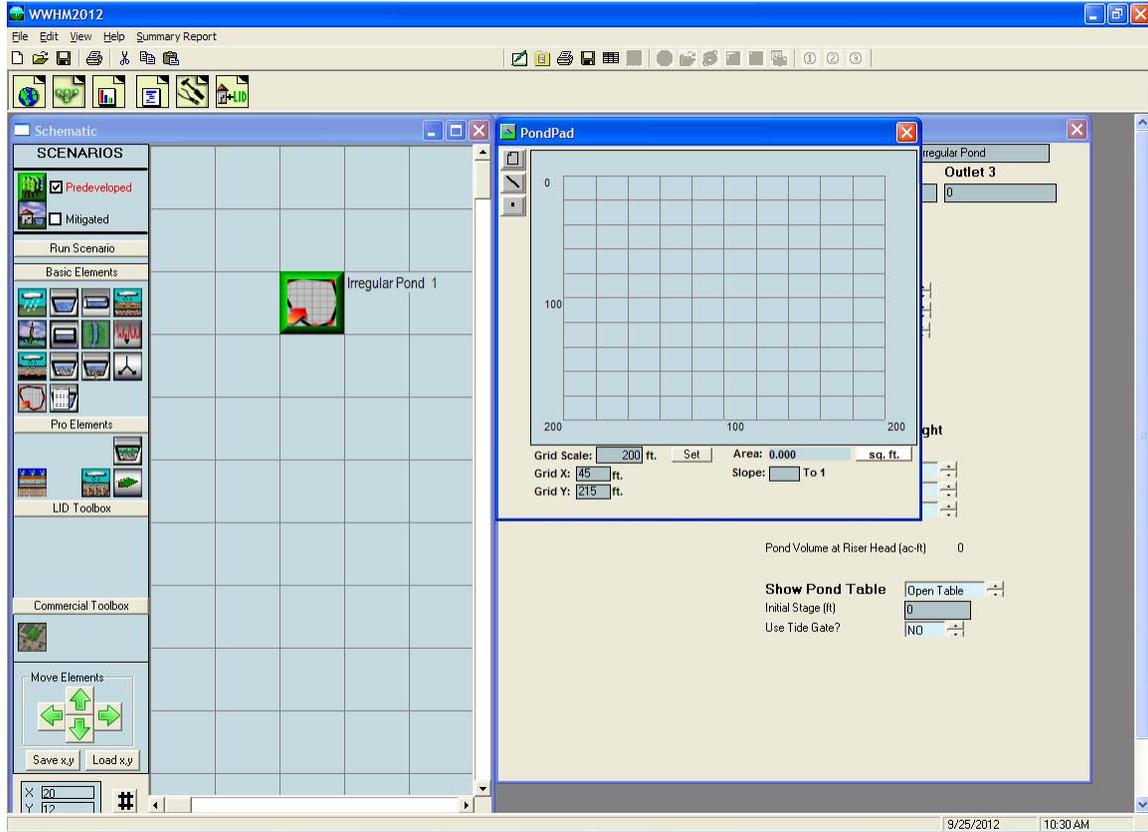
An irregular pond is any pond with a shape that differs from the rectangular top of a trapezoidal pond. An irregular pond has all of the same characteristics of a trapezoidal pond, but its shape must be defined by the user.

There is no AutoPond option for an irregular pond. It is recommended that the user first use the trapezoidal pond element with AutoPond to determine the general dimensions and outlet structure configuration of the pond. With that information a similar-size irregular pond with the same outlet structure configuration as the trapezoidal pond will either meet Ecology flow control standards or require only minor changes in surface area and volume to meet the standards.

The user can change the default name “Irregular Pond 1” to another more appropriate name, if desired.

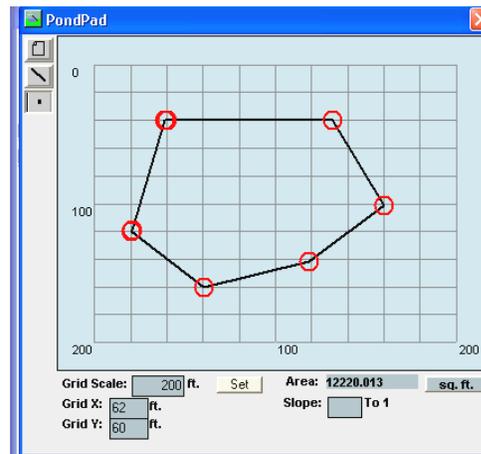
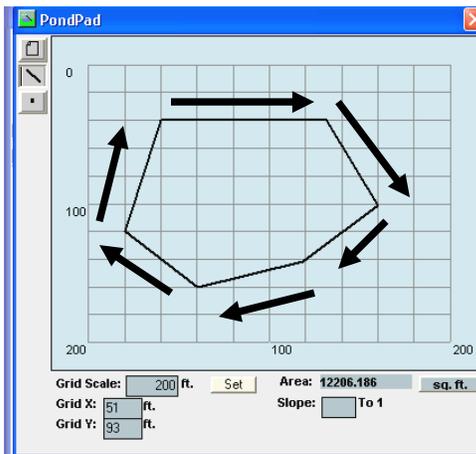
To create the shape of an irregular pond the user clicks on the “Open PondPad” button. This allows the user to access the PondPad interface (see below).

PondPad Interface



The PondPad interface is a grid on which the user can specify the outline of the top of the pond and the pond's side slopes.

The user selects the line button (second from the top on the upper left corner of the PondPad screen). Once the line button is turned on the user moves the mouse over the grid to locate the pond's corner points. The user does this in a clockwise direction to outline the pond's top perimeter. The user can select individual points by clicking on the point button immediately below the line button. Once selected, any individual point can be moved or repositioned.



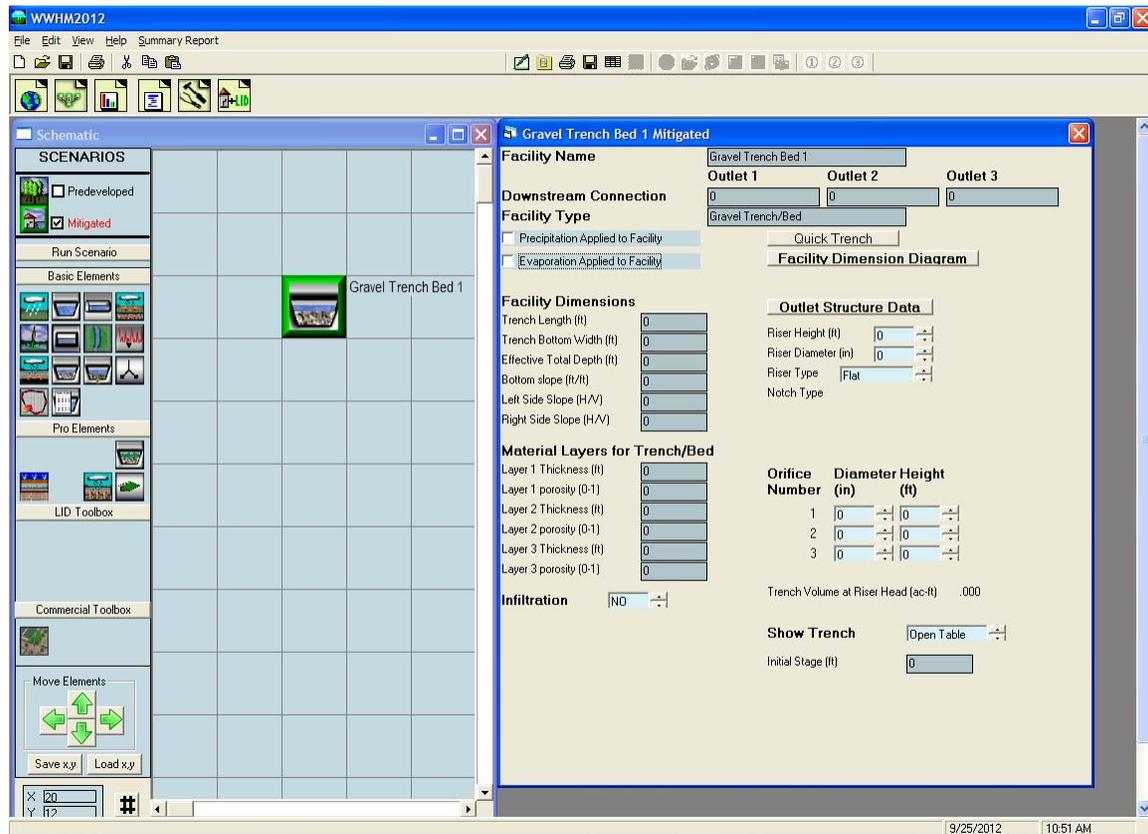
The default side slope value is 3 (3:1). The side slopes can be individually changed by right clicking on the specific side (which changes the line color from black to red) and then entering the individual side slope value in the slope text box.

The grid scale can be changed by entering a new value in the grid scale box. The default value is 200 feet.

PondPad Controls and Numbers

Clear:	The Clear button clears all of the lines on the grid.
Line:	The Line button allows the user to draw new lines with the mouse.
Point:	The Point button allows the user to move individual points to alter the pond shape and size.
Sq Ft:	Converts the computed pond area from square feet to acres and back.
Grid Scale:	Changes the length of a grid line. Default grid scale is 200 feet.
Grid X:	Horizontal location of the mouse pointer on the grid (0 is the upper left corner).
Grid Y:	Vertical location of the mouse pointer on the grid (0 is the upper left corner)
Area:	Top area of the pond (either in square feet or acres).
Slope:	Side slope of the selected line (side of the pond).

GRAVEL TRENCH BED



The gravel trench bed is a trench or bed filled with gravel that is used to spread and infiltrate runoff. It can also have one or more surface outlets represented by an outlet structure with a riser and multiple orifices.

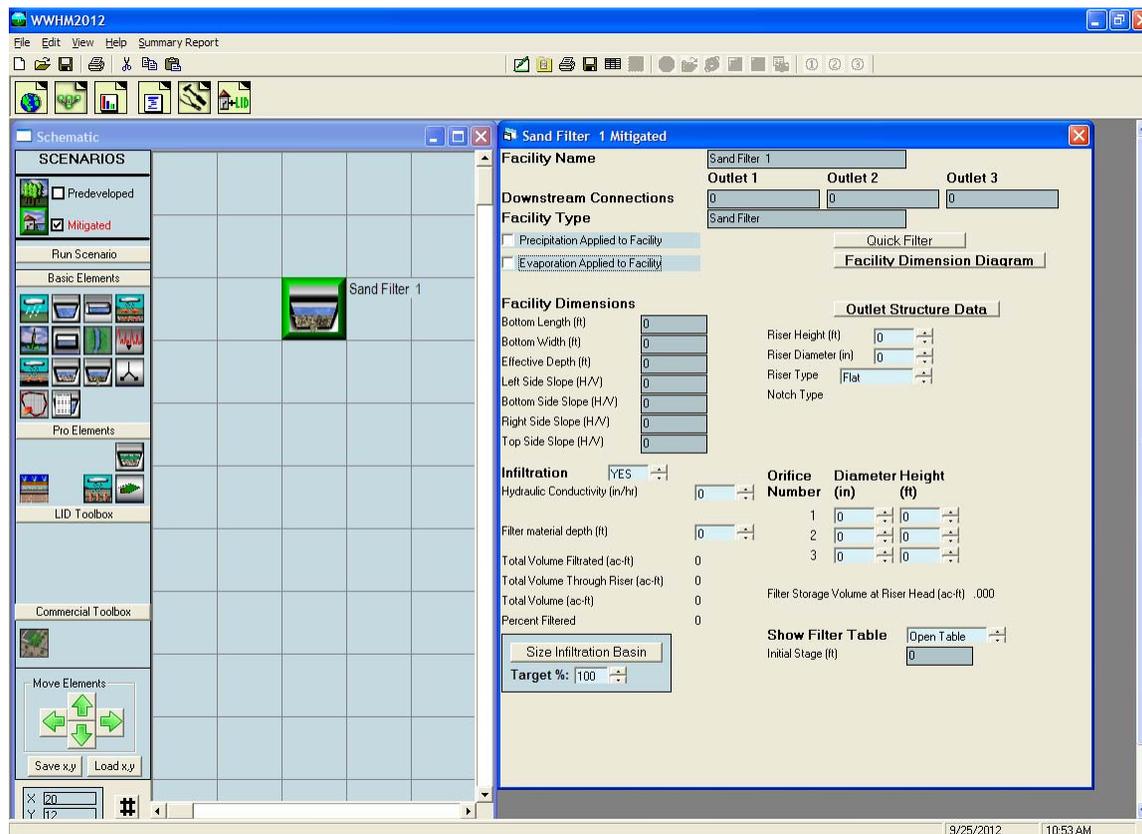
The user can change the default name “Gravel Trench Bed 1” to another more appropriate name, if desired.

The user specifies the trench length, bottom width, total depth, bottom slope, and left and right side slopes.

The material layers represent the amended soils and their design characteristics (thickness and porosity). These are the soil layers added to the gravel trench bed to filter the runoff prior to dispersal.

QuickTrench will create a gravel trench bed with default values without checking it for compliancy with Ecology standards.

SAND FILTER



The sand filter is a water quality facility. It does not infiltrate runoff, but is used to filter runoff through a medium and sent it downstream. It can also have one or more surface outlets represented by an outlet structure with a riser and multiple orifices.

The user can change the default name “Sand Filter 1” to another more appropriate name, if desired.

The user must specify the facility dimensions (bottom length and width, effective depth, and side slopes). The hydraulic conductivity of the sand filter and the filter material depth are also needed to size the sand filter (default values are 1.5 and 2.0, respectively). The goal of the sand filter is meet the Ecology treatment standard of filtering at least 91% of the total runoff volume.

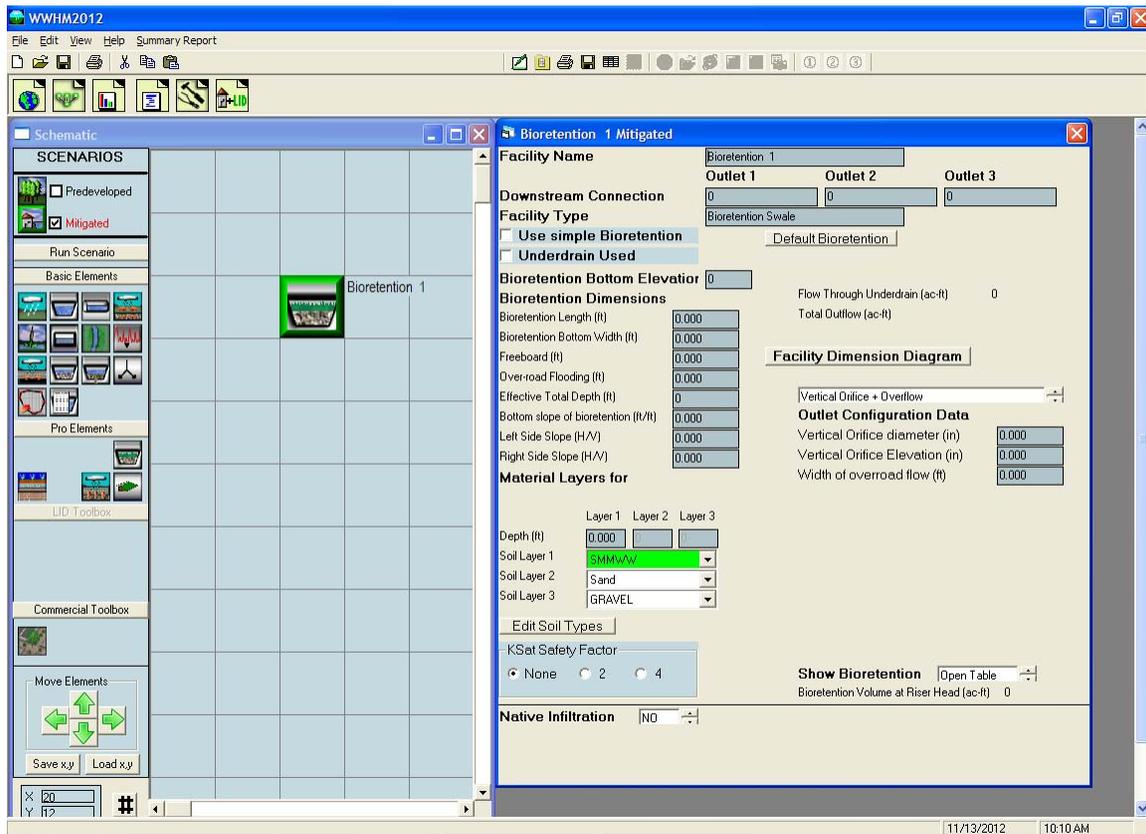
The filter discharge is calculated using the equation $Q = K \cdot I \cdot A$, where Q is the discharge in cubic feet per second (cfs). K equals the hydraulic conductivity (inches per hour). For sand filters $K = 1.5$ in/hr. Sand is the default medium. If another filtration material is used then the design engineer should enter the appropriate K value supported by documentation and approval by the reviewing authority.

Design of a sand filter requires input of facility dimensions and outlet structure characteristics, running the sand filter scenario, and then checking the volume

calculations to see if the Percent Filtered equals or exceeds 91.0%. If the value is less than 91% then the user should increase the size of the sand filter dimensions and/or change the outlet structure.

Similar to AutoPond in the trapezoidal pond element, the sand filter element has an option to automatically size the sand filter. The user can set the target percentage for being filtered (91% of the total runoff volume to meet the Ecology water quality treatment standard).

BIORETENTION



The bioretention element (also called a rain garden) is a depression filled with one to three layers of amended soil that is used to filter runoff. It is a new WWHM2012 element, not previously available in WWHM3. It can also have one or more surface outlets represented by an outlet structure with a riser and multiple orifices or a vertical orifice and weir overflow structure.

The user can change the default name “Bioretention 1” to another more appropriate name, if desired.

The user specifies the bioretention length, bottom width, total depth, bottom slope, and left and right side slopes.

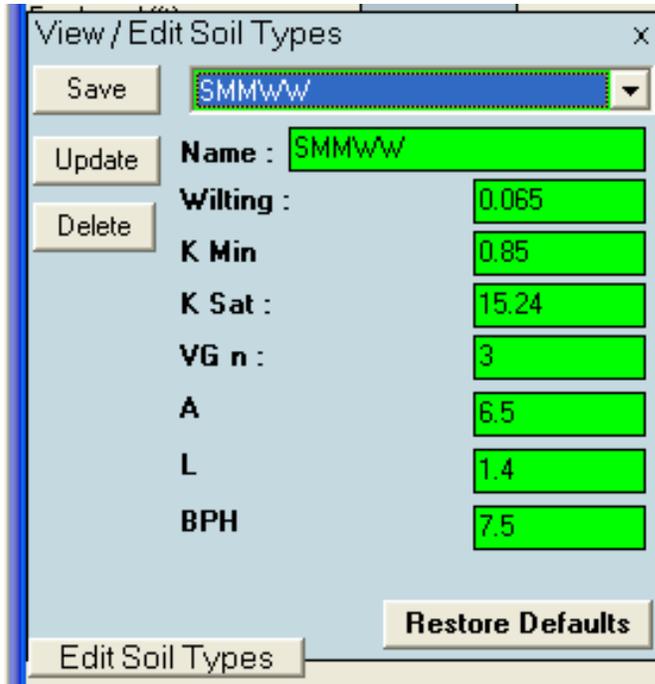
The material layers represent the amended soils and their design characteristics (thickness and vertical water movement). These are the engineered soil layers added to the bioretention facility to filter the runoff prior to dispersal.

Each amended soil type has appropriate drainage characteristics assigned based on literature values. When a soil type is selected by the user then WWHM2012 automatically assigns the appropriate values for:

1. Wilting: wilting point (0-1)

2. K min: minimum hydraulic conductivity (cm/hr)
3. K Sat: maximum saturated hydraulic conductivity (cm/hr)
4. VG n: Van Genuchten number (from literature)
5. A: alpha (constant)
6. L: lambda (constant)
7. BPH: bubbling pressure head (cm)

The user can see the values for any of the soil types by selecting the soil type from the pulldown menu:



If none of the available soil types represents the amended soil planned for use on the site then the user can select a new soil type and input the appropriate values into the above input table.

Note that SMMWW is the required soil mix specified by the Department of Ecology for the top soil layer in bioretention facilities.

The second amended soil layer should be an intermediate material that is intended to prevent loss of fine material out of the engineered top layer soil mix into the gravel underlayer (layer 3).

The third (bottom) amended soil layer should be gravel.

A full list of Ecology-approved soil mixtures is shown in Table 1.

Table 1. WWHM2012 Soil Mixtures

Soil Type	Wilting Point	Kmin (cm/hr)	Ksat (cm/hr)	VG n	A	L	BPH
SMMWW (Ecology standard)	0.0650	0.85	3.00	15.24	6.50	1.40	7.50
GRAVEL	0.0050	0.42	10.00	1260.00	0.50	1.19	0.20
Sand	0.0200	0.42	3.00	23.56	6.00	0.69	7.26
ASTM 1	0.0900	0.41	1.50	2.54	7.50	0.75	8.50
ASTM 2	0.0825	0.42	1.55	5.08	7.30	0.88	8.30
ASTM 3	0.0750	0.43	1.60	7.62	7.10	1.00	8.10
ASTM 4	0.0725	0.44	1.65	10.16	7.00	1.15	8.00
ASTM 5	0.0700	0.45	1.70	12.70	6.90	1.30	7.90
ASTM 6	0.0675	0.46	1.85	15.24	6.50	1.40	7.50
ASTM 7	0.0667	0.47	2.00	17.78	6.45	1.50	7.45
ASTM 8	0.0659	0.48	2.15	20.32	6.43	1.58	7.43
ASTM 9	0.0651	0.49	2.30	22.86	6.41	1.66	7.41
ASTM 10	0.0643	0.50	2.45	25.40	6.39	1.74	7.39
ASTM 11	0.0635	0.51	2.60	27.94	6.37	1.82	7.37
ASTM 12	0.0627	0.52	2.75	30.48	6.35	1.90	7.35
ASTM 13	0.0619	0.53	2.90	33.02	6.33	1.98	7.33
ASTM 14	0.0611	0.54	3.05	35.56	6.31	2.06	7.31
ASTM 15	0.0603	0.55	3.20	39.00	6.30	2.14	7.30
ASTM 24.32	0.0590	0.55	3.20	39.00	6.25	2.25	7.20
ASTM 35.46	0.0550	0.55	3.25	90.10	6.20	2.30	7.00
ASTM 50	0.0500	0.55	3.30	127.00	6.15	2.35	6.80
ASTM 60	0.0490	0.55	3.35	152.40	6.10	2.40	6.40
ASTM 100	0.0450	0.55	3.40	254.00	6.05	2.45	6.00

Wilting: wilting point (0-1)

K min: minimum hydraulic conductivity (cm/hr)

K sat: maximum saturated hydraulic conductivity (cm/hr)

VG n: Van Genuchten number (from literature)

A: alpha (constant)

L: lambda (constant)

BPH: bubbling pressure head (cm)

Table 1 values are from Schaap and Leij, 1998 soil parameter estimations using Rosetta.

As new soil mixtures are approved by Ecology they will be added to WWHM2012.

Check Ecology's 2012 *Stormwater Management Manual for Western Washington* to determine the appropriate Ksat (maximum saturated hydraulic conductivity) safety factor to use.

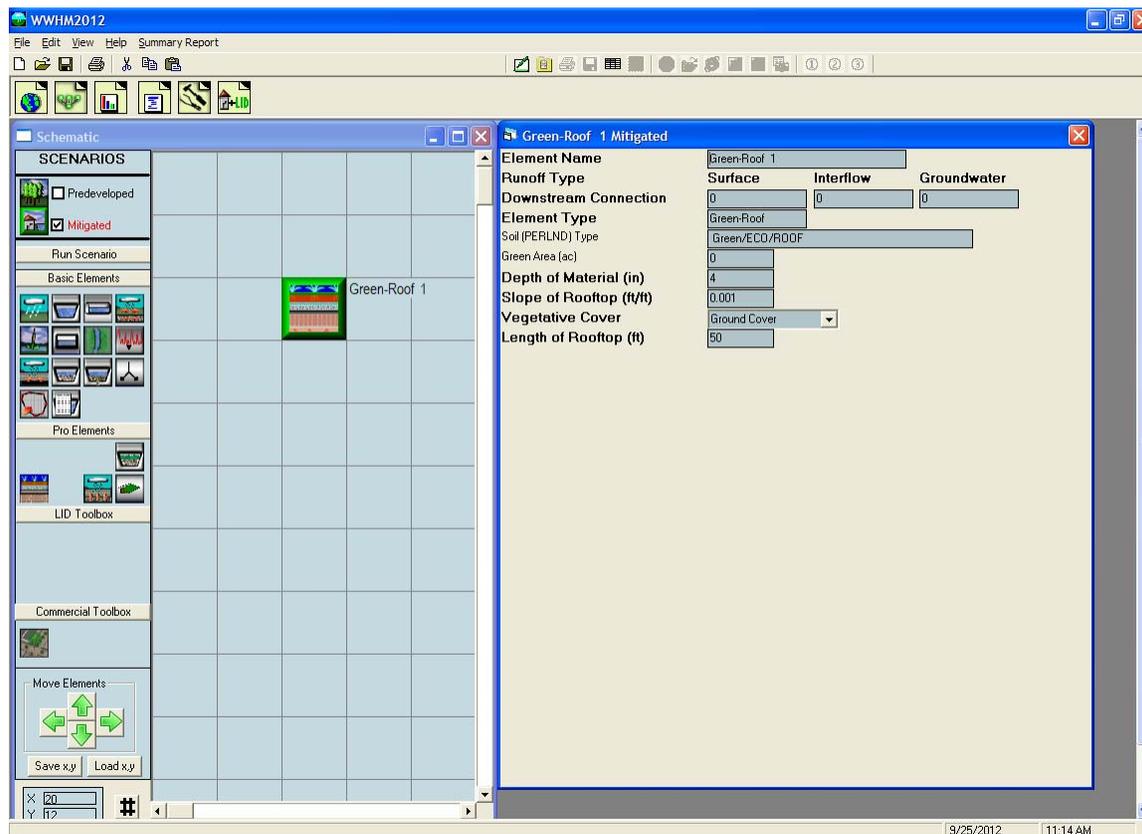
The user has the option of including an underdrain and/or infiltration into the native soil underneath the bottom amended soil layer (soil layer 3).

The bioretention surface area automatically receives rainfall and produces evapotranspiration. Due to this model input the bioretention surface area should be excluded from the basin element's total surface area.

Default Swale will create a bioretention facility with default values without checking it for compliancy with Ecology standards.

The water movement through the soil column calculations are based on the methodology described in Appendix A: Bioretention Modeling Methodology.

GREEN ROOF



The green roof element or vegetated roof (also called an eco-roof) is soil and vegetation placed on top of an impervious roof. It is a new WWHM2012 element, not previously available in WWHM3.

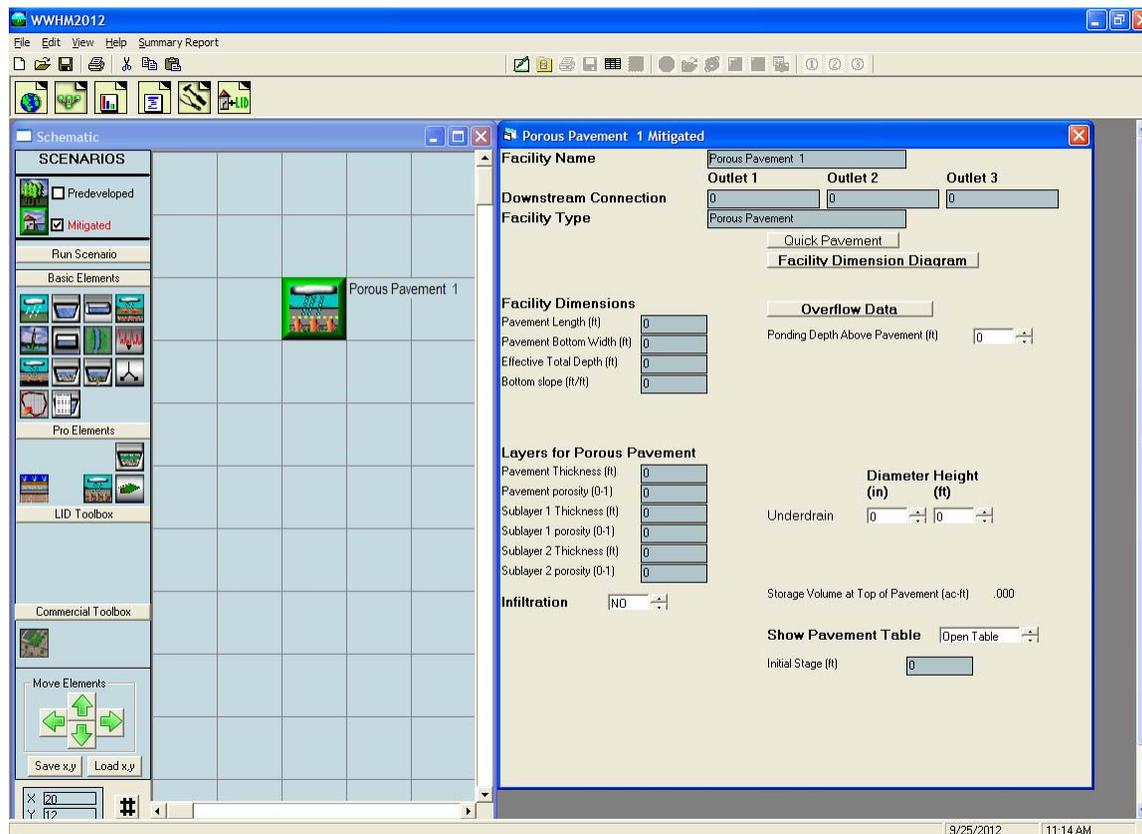
The user can change the default name “Green Roof 1” to another more appropriate name, if desired.

The user specifies the green roof surface area, soil depth, roof slope, type of vegetative cover (ground cover, shrubs, or trees), and length of the longest runoff path to reach a roof drain (length of rooftop). Default input values are automatically included with the element. They should be changed to reflect actual roof conditions.

The green roof surface area automatically receives rainfall and produces evapotranspiration. Due to this model input the green roof surface area should be excluded from the basin element’s total surface area.

If the green roof is connected to a downstream element or is selected as a point of compliance the user should make sure that the groundwater runoff is included. Unlike the other drainage area elements (basin element, etc.), the green roof groundwater always contributes to the total runoff. The groundwater has nowhere else to go.

POROUS PAVEMENT



The porous pavement element (also called permeable pavement) is an impervious basin element that drains directly to storage layer similar to a gravel trench bed. The porous pavement element is a new WWHM2012 element, not previously available in WWHM3.

The user can change the default name “Porous Pavement 1” to another more appropriate name, if desired.

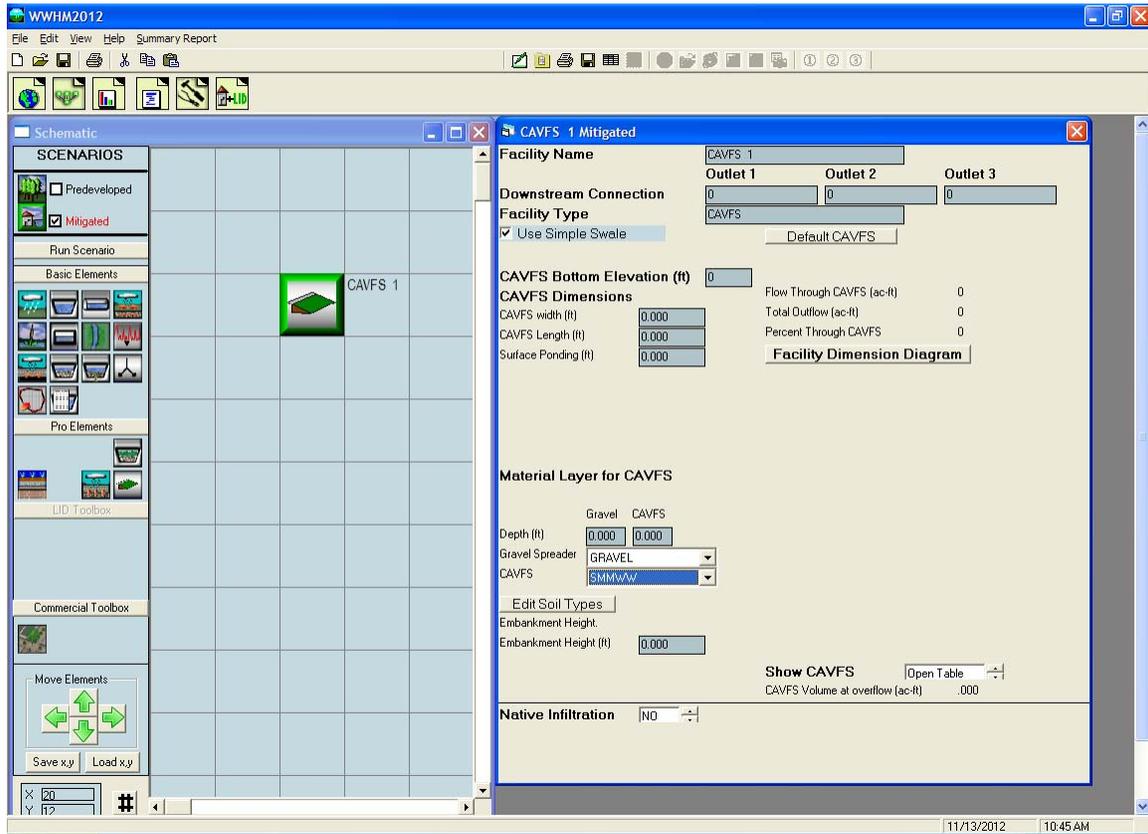
The user specifies the pavement length, bottom width, total depth, and bottom slope.

The porous pavement layers represent the pavement layer and two subgrade layers and their design characteristics (thickness and porosity). The subgrade layers (Sublayer 1 and Sublayer 2) are available to provide storage prior to discharge through infiltration to the native soil or discharge via an underdrain.

QuickPavement will create a porous pavement feature with default values without checking it for compliancy with Ecology standards.

The porous pavement surface area automatically receives rainfall and produces evapotranspiration. Due to this model input the porous pavement surface area should be excluded from the basin element’s total surface area.

CAVFS

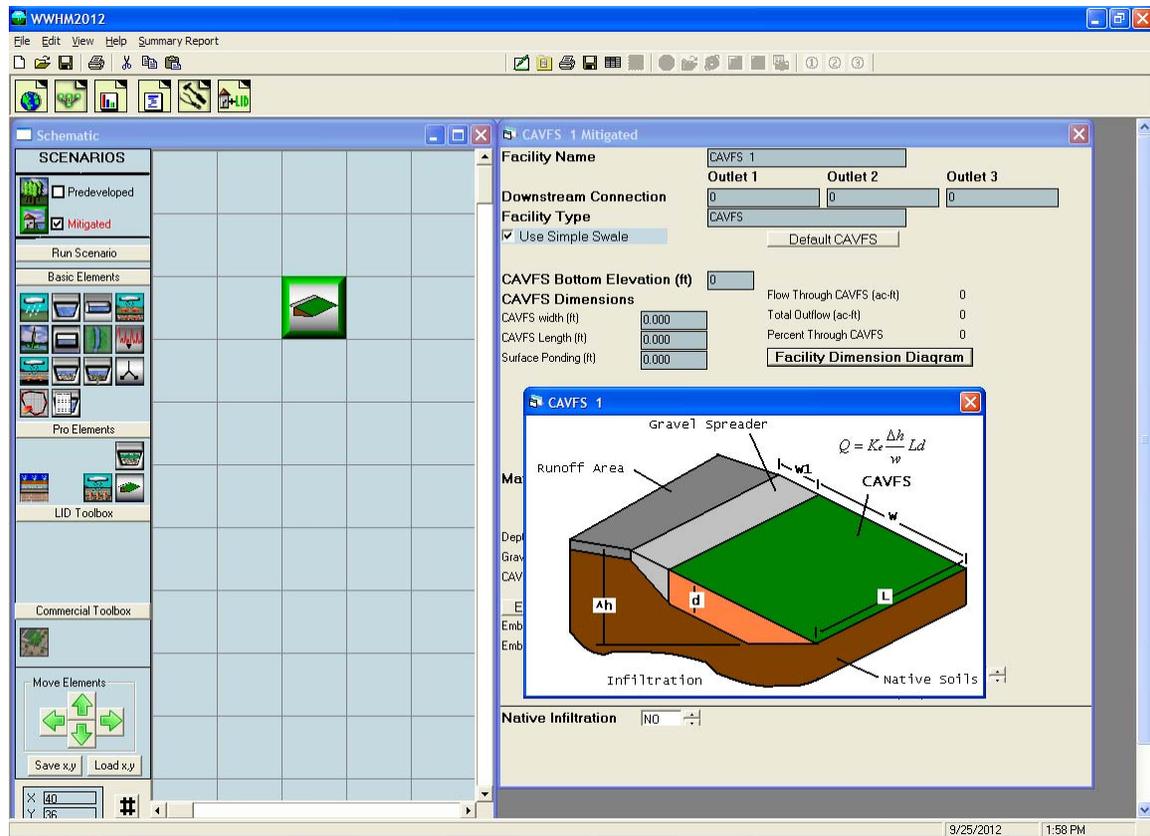


CAVFS stands for Compost Amended Vegetated Filter Strip. The CAVFS element is similar to the bioretention element, but is typically used to provide water quality treatment (filtering of stormwater) on roadway shoulders. Runoff from impervious road surfaces drains to the roadway's shoulder CAVFS area.

The CAVFS element is a new WWHM2012 element, not previously available in WWHM3. CAVFS does not have any surface outlet structure. Runoff travels either through the CAVFS soil column or sheet flows off the CAVFS surface.

The user can change the default name "CAVFS 1" to another more appropriate name, if desired.

The user specifies the CAVFS length, width, and allowed surface ponding depth.

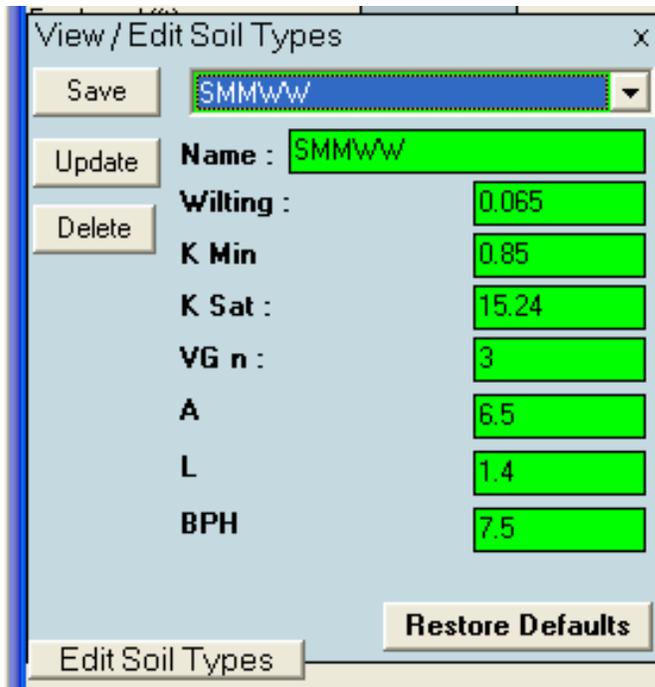


CAVFS has two material layers: one representing the gravel spreader strip at the edge of the pavement and the second represents the amended soil layer through which the runoff is filtered. The user specifies the thickness and material type for each layer and the embankment height.

Each material layer has appropriate drainage characteristics assigned based on literature values. When a material layer type is selected by the user then WWHM2012 automatically assigns the appropriate values for:

1. Wilting: wilting point (0-1)
2. K min: minimum hydraulic conductivity (cm/hr)
3. K Sat: maximum saturated hydraulic conductivity (cm/hr)
4. VG n: Van Genuchten number (from the literature)
5. A: alpha (constant)
6. L: lambda (constant)
7. BPH: bubbling pressure head (cm)

The user can see the values for any of the soil types by selecting the soil type from the pulldown menu:



A full list of Ecology-approved soil mixtures is shown in Table 1 on page 48.

If none of the available soil types represents the amended soil planned for use on the site then the user can select a new soil type and input the appropriate values into the above input table.

The required soil type for the gravel spreader layer is gravel. The CAVFS layer should be the SMMWW soil mix. Note that SMMWW is the required soil mix specified by the Department of Ecology for CAVFS.

The user has the option of including infiltration into the native soil underneath the bottom of the CAVFS amended soil layer.

The CAVFS surface area automatically receives rainfall and produces evapotranspiration. Due to this model input the CAVFS surface area should be excluded from the basin element's total surface area.

Default CAVFS will create a compost amended vegetated filter strip with default values without checking it for compliancy with Ecology standards.

The water movement through the soil column calculations are based on the methodology described in Appendix A: Bioretention Modeling Methodology.

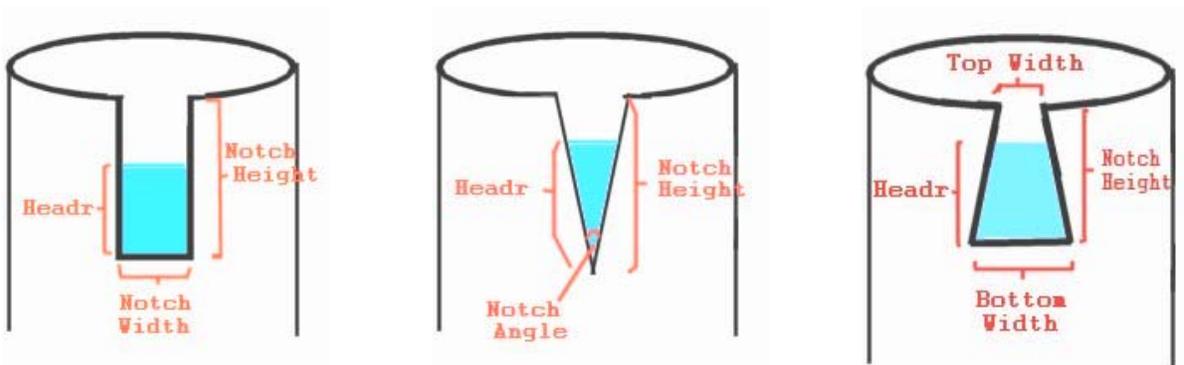
RISER/WEIR

The trapezoidal pond, vault, tank, irregular pond, gravel trench bed, and sand filter all use a riser for the outlet structure to control discharge from the facility.

The riser is a vertical pipe with a height above pond bottom (typically one foot less than the effective depth). The user specifies the riser height and diameter.

The riser can have up to three round orifices. The bottom orifice is usually located at the bottom of the pond and/or above any dead storage in the facility. The user can set the diameter and height of each orifice. The model will automatically calculate the maximum orifice discharge value, QMax (cfs), if the pond dimensions have already been defined.

The user specifies the riser type as either flat or notched. The weir notch can be either rectangular, V-notch, or a Sutro weir. The shape of each type of weir is shown below.



Rectangular Notch

V-Notch

Sutro

By selecting the appropriate notch type the user is then given the option to enter the appropriate notch type dimensions.

Riser and orifice equations used in WWHM2012 are provided below.

Headr = the water height over the notch/orifice bottom.

q = discharge

Riser Head Discharge:

$$\text{Head} = \text{water level above riser}$$
$$q = 9.739 * \text{Riser Diameter} * \text{Head} ^ 1.5$$

Orifice Equation:

$$q = 3.782 * (\text{Orifice Diameter}) ^ 2 * \text{SQRT}(\text{Headr})$$

Rectangular Notch:

$$b = \text{NotchWidth} * (1 - 0.2 * \text{Headr})$$

where $b \geq 0.8$

$$q = 3.33 * b * \text{Headr} ^ 1.5$$

Sutro:

$$\text{Wh} = \text{Top Width} + \{(\text{Bottom Width} - \text{Top Width}) / \text{Notch Height}\} * \text{Headr}$$
$$\text{Wd} = \text{Bottom Width} - \text{Wh} \text{ (the difference between the bottom and top widths)}$$

$$Q1 = \text{(rectangular notch } q \text{ where Notch Width} = \text{Wh)}$$

$$Q2 = \text{(rectangular notch } q \text{ where Notch Width} = \text{Wd)}$$

$$q = Q1 + Q2 / 2$$

V-Notch:

Notch Bottom = height from bottom of riser to bottom of notch

Theta = Notch Angle

$$a = 2.664261 - 0.0018641 * \text{Theta} + 0.00005761 * \text{Theta} ^ 2$$

$$b = -0.48875 + 0.003843 * \text{Theta} - 0.000092124 * \text{Theta} ^ 2$$

$$c = 0.3392 - 0.0024318 * \text{Theta} + 0.00004715 * \text{Theta} ^ 2$$

$$\text{YoverH} = \text{Headr} / (\text{NotchBottom} + \text{Headr})$$

$$\text{Coef} = a + b * \text{Headr} + c * \text{Headr} ^ 2$$

$$q = (\text{Coef} * \text{Tan}(\text{Theta} / 2)) * (\text{Headr} ^ (5 / 2))$$

INFILTRATION

Infiltration of stormwater runoff is a recommended solution if certain conditions are met. These conditions include: a soils report, testing, groundwater protection, pre-settling, and appropriate construction techniques (see Ecology's 2012 *Stormwater Management Manual for Western Washington* for details).

The user clicks on the Infiltration option arrow to change infiltration from NO to YES. This activates the infiltration input options: measured infiltration rate, infiltration reduction factor, and whether or not to allow infiltration through the wetted side slopes/walls.

The screenshot shows the 'Trapezoidal Pond 1 Mitigated' window. It contains several sections of input fields:

- Facility Name:** Trapezoidal Pond 1
- Facility Type:** Trapezoidal Pond
- Downstream Connections:** Outlet 1 (0), Outlet 2 (0), Outlet 3 (0)
- Options:** Precipitation Applied to Facility (checked), Evaporation Applied to Facility (checked), Auto Pond, Quick Pond
- Facility Dimensions:** Facility Bottom Elevation (ft) 0, Bottom Length (ft) 0, Bottom Width (ft) 0, Effective Depth (ft) 0, Left Side Slope (H/V) 0, Bottom Side Slope (H/V) 0, Right Side Slope (H/V) 0, Top Side Slope (H/V) 0
- Infiltration:** YES (selected), Measured Infiltration Rate (in/hr) 0, Reduction Factor (infiltration factor) 0, Use Wetted Surface Area (sidewalls) NO, Total Volume Infiltrated (ac-ft) 0, Total Volume Through Riser (ac-ft) 0, Total Volume Through Facility (ac-ft) 0.00, Percent Infiltrated 0
- Outlet Structure Data:** Riser Height (ft) 0, Riser Diameter (in) 0, Riser Type Flat, Notch Type
- Orifice Table:**

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0
- Other Fields:** Pond Volume at Riser Head (ac-ft) 0, Show Pond Table (Open Table), Initial Stage (ft)
- Buttons:** Size Infiltration Pond, Target %: 100

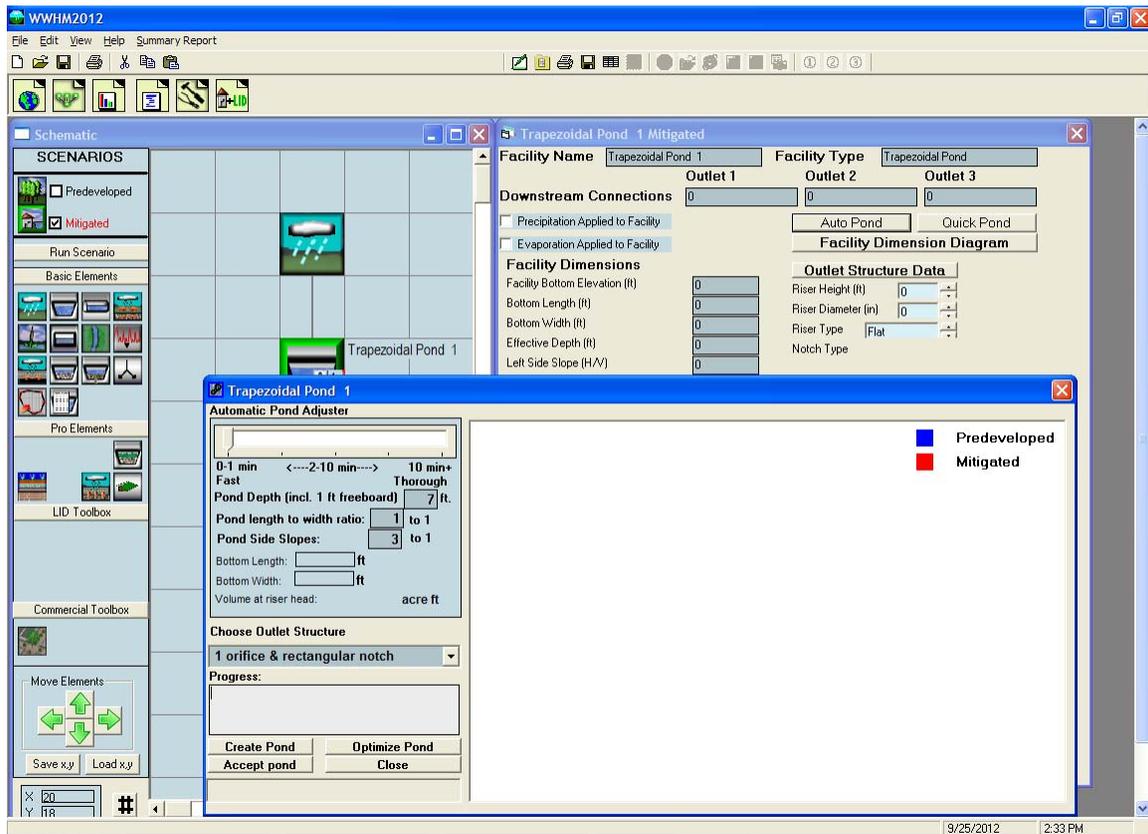
The infiltration reduction factor is a multiplier for the measured infiltration rate and should be less than one. It is the same as the inverse of a safety factor. For example, a safety factor of 2 is equal to a reduction factor of 0.5.

Infiltration occurs only through the bottom of the facility. If the wetted surface area option is turned on then infiltration also occurs through the wetted side walls.

After the model is run and flow is routed through the infiltration facility the total volume infiltrated, total volume through the riser, total volume through the facility, and percent infiltrated are reported on the screen. If the percent infiltrated is 100% then there is no surface discharge from the facility. The percent infiltrated can be less than 100% as long as the surface discharge does not exceed Ecology's flow control standards.

Infiltration facilities have the option to allow users to automatically size the facility to meet an infiltration target percentage. The user can set the target percentage for being filtered/infiltrated to 91% to meet the Ecology water quality treatment standard.

AUTOPOND, AUTOVAULT, AUTOTANK

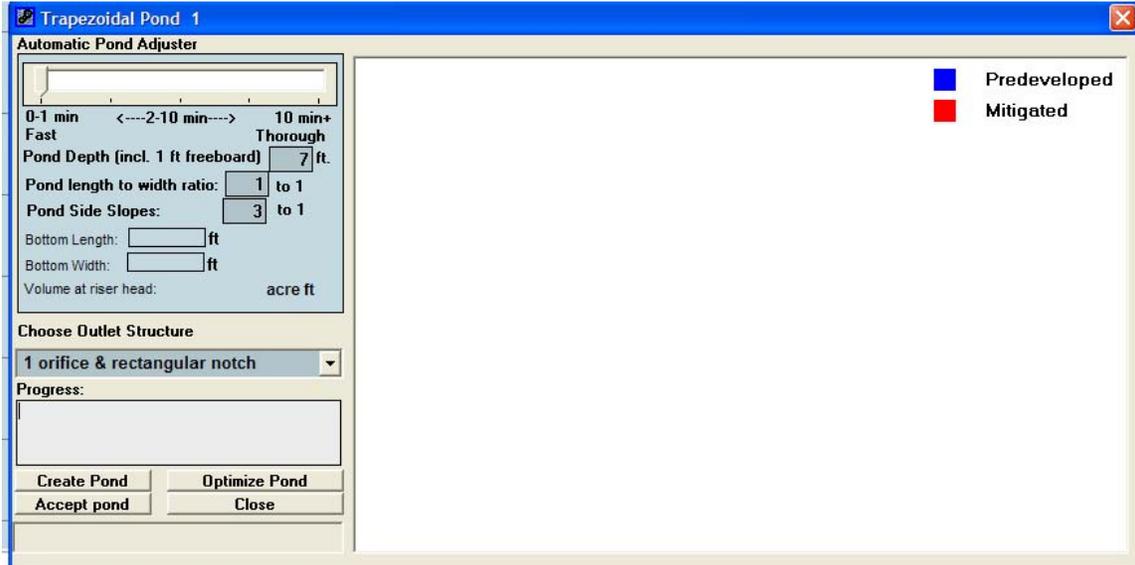


AutoPond, AutoVault, and AutoTank all work the same. Each optimizing routine automatically creates a pond, vault, or tank size and designs the outlet structure to meet Ecology’s flow duration criteria. The user can either create a pond, vault, or tank from scratch or optimize an existing design.

The following information applies to all three optimizing routines (AutoPond, AutoVault, and AutoTank), but for the purposes of simplifying the following documentation the term “AutoPond” applies equally to AutoVault and AutoTank.

AutoPond requires that the Predeveloped and Mitigated basins be defined first. Clicking on the AutoPond button brings up the AutoPond window and the associated AutoPond controls.

AutoPond controls:



Automatic Pond Adjuster: The slider at the top of the AutoPond window allows the user to decide how thoroughly the pond will be designed for efficiency. The lowest setting (0-1 min) at the left constructs an initial pond with checking it for Ecology’s flow duration criteria. The second setting to the right creates and sizes a pond to pass Ecology’s flow duration criteria; however, the pond is not necessarily optimized. The higher settings increase the amount of optimization. The highest setting (farthest left) will size the most efficient (smallest) pond, but will result in longer computational time.

Pond Depth: Pond depth is the total depth of the pond and should include at least one foot of freeboard (above the riser). The pond’s original depth will be used when optimizing an existing pond; changing the value in the Pond Depth text box will override any previous set depth value. The default depth is 7 feet.

Pond Length to Width Ratio: This bottom length to width ratio will be maintained regardless of the pond size or orientation. The default ratio value is 1.0

Pond Side Slopes: AutoPond assumes that all of the pond’s sides have the same side slope. The side slope is defined as the horizontal distance divided by the vertical. A typical side slope is 3 (3 feet horizontal to every 1 foot vertical). The default side slope value is 3.

Choose Outlet Structure: The user has the choice of either 1 orifice and rectangular notch or 3 orifices. If the user wants to select another outlet structure option then the pond must be manually sized.

Create Pond: This button creates a pond when the user does not input any pond dimensions or outlet structure information. Any previously input pond information will be deleted.

Optimize Pond: This button optimizes an existing pond. It cannot be used if the user has not already created a pond.

Accept Pond: This button will stop the AutoPond routine at the last pond size and discharge characteristics that produce a pond that passes Ecology's flow duration criteria. AutoPond will not stop immediately if the flow duration criteria has not yet been met.

The bottom length and width and volume at riser head will be computed by AutoPond; they cannot be input by the user.

There are some situations where AutoPond will not work. These situations occur when complex routing conditions upstream of the pond make it difficult or impossible for AutoPond to determine which land use will be contributing runoff to the pond. For these situations the facility will have to be manually sized.

STAGE-STORAGE-DISCHARGE TABLE

The screenshot shows the WWHM2012 software interface. On the left, a schematic window displays a grid with a trapezoidal pond element labeled 'Trapezoidal Pond 1'. The right window shows the 'Trapezoidal Pond 1' data table with the following columns: Stage (ft), Area (acres), Storage (acre-ft), Dschrge (cfs), and Infilt (cfs). The table contains 91 rows of data, starting from a stage of 0.000000 and increasing in increments of 0.077778 up to 2.644444.

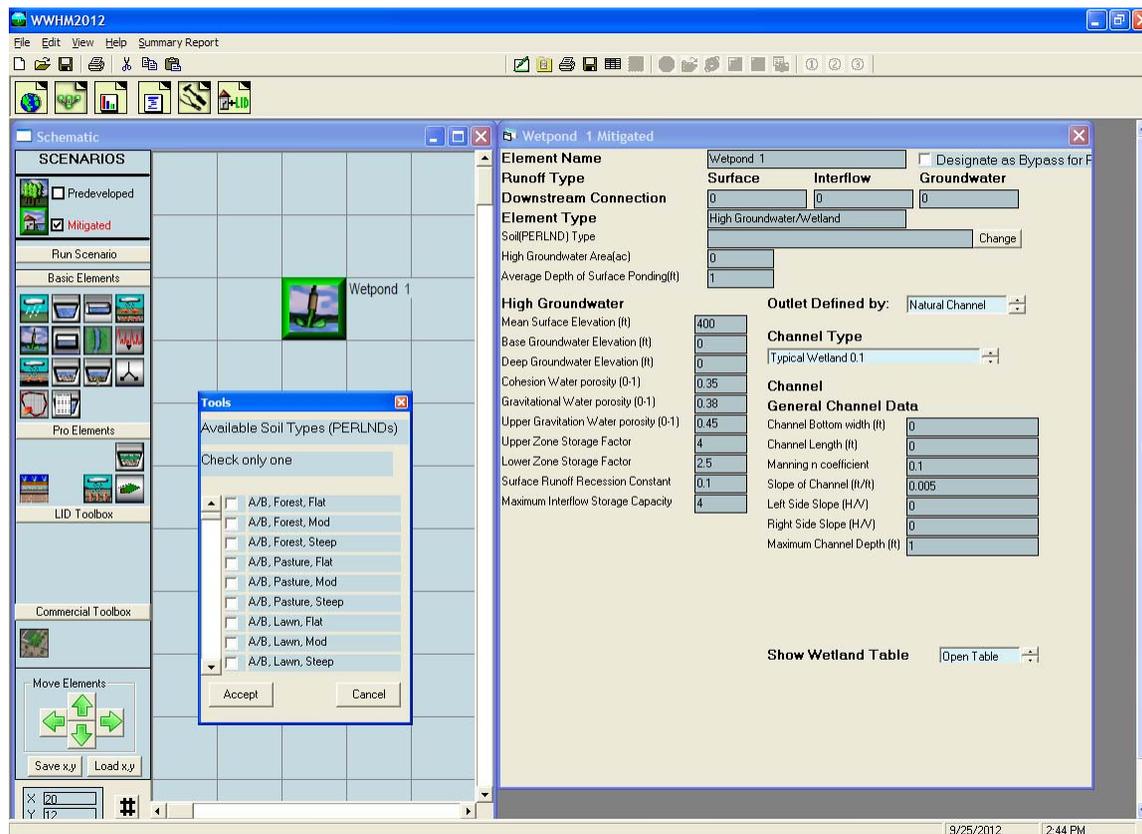
Stage (ft)	Area (acres)	Storage (acre-ft)	Dschrge (cfs)	Infilt (cfs)
0.000000	0.918274	0.000000	0.000000	0.000000
0.077778	0.922564	0.071588	0.065922	0.000000
0.155556	0.926864	0.143510	0.093228	0.000000
0.233333	0.931174	0.215767	0.114180	0.000000
0.311111	0.935495	0.288360	0.131844	0.000000
0.388889	0.939825	0.361289	0.147406	0.000000
0.466667	0.944165	0.434555	0.161475	0.000000
0.544444	0.948516	0.508160	0.174413	0.000000
0.622222	0.952876	0.582103	0.186455	0.000000
0.700000	0.957246	0.656385	0.197766	0.000000
0.777778	0.961626	0.731008	0.208463	0.000000
0.855556	0.966017	0.805972	0.218638	0.000000
0.933333	0.970417	0.881278	0.228360	0.000000
1.011111	0.974827	0.956926	0.237685	0.000000
1.088889	0.979247	1.032918	0.246657	0.000000
1.166667	0.983678	1.109254	0.255314	0.000000
1.244444	0.988118	1.185935	0.263687	0.000000
1.322222	0.992568	1.262961	0.271803	0.000000
1.400000	0.997028	1.340335	0.279683	0.000000
1.477778	1.001499	1.418055	0.287347	0.000000
1.555556	1.005979	1.496124	0.294811	0.000000
1.633333	1.010469	1.574541	0.302092	0.000000
1.711111	1.014969	1.653308	0.309201	0.000000
1.788889	1.019480	1.732426	0.316150	0.000000
1.866667	1.024000	1.811894	0.322950	0.000000
1.944444	1.028530	1.891715	0.329609	0.000000
2.022222	1.033071	1.971888	0.336137	0.000000
2.100000	1.037621	2.052415	0.342540	0.000000
2.177778	1.042181	2.133296	0.348826	0.000000
2.255556	1.046751	2.214533	0.355000	0.000000
2.333333	1.051331	2.296125	0.361069	0.000000
2.411111	1.055922	2.378074	0.367037	0.000000
2.488889	1.060522	2.460380	0.372910	0.000000
2.566667	1.065132	2.543044	0.378692	0.000000
2.644444	1.069752	2.626067	0.384387	0.000000

The stage-storage-discharge table hydraulically represents any facility that requires stormwater routing. The table is automatically generated by WWHM2012 when the user inputs storage facility dimensions and outlet structure information. WWHM2012 generates 91 lines of stage, surface area, storage, surface discharge, and infiltration values starting at a stage value of zero (facility bottom height) and increasing in equal increments to the maximum stage value (facility effective depth).

When the user or WWHM2012 changes a facility dimension (for example, bottom length) or an orifice diameter or height the model immediately recalculates the stage-storage-discharge table.

The user can input to WWHM2012 a stage-storage-discharge table created elsewhere. This is done using the separate SSD Table element. See the SSD Table description below for more information on how to load such a table into WWHM2012.

HIGH GROUNDWATER/WETLAND



The High Groundwater/Wetland element is a complex element that should only be used in special applications by advanced WWHM2012 users. The purpose of the high groundwater/wetland element is to model hydrologic conditions where high groundwater rises to the surface (or near the surface) and reduces the ability of water to infiltrate into the soil.

The element can be used to represent wetland conditions with surface ponding where the discharge from the wetland is via a surface release. The user is given the choice of using either a natural channel, berm/weir, or control structure to determine the release characteristics.

The user can change the default name “Wetpond 1” to another more appropriate name, if desired.

The high groundwater/wetland surface area automatically receives rainfall and produces evapotranspiration. Due to this model input the high groundwater/wetland surface area should be excluded from the basin element’s total surface area.

The element provides default values for some of the parameters, especially as they relate to high groundwater. The user should be fully familiar with these parameters and the

appropriate values for their site prior to attempting to use this element. The high groundwater parameter definitions are shown below.

Cohension water porosity: soil pore space in micropores.

Gravitational water porosity: soil pore space in macropores in the lower and groundwater layers of the soil column.

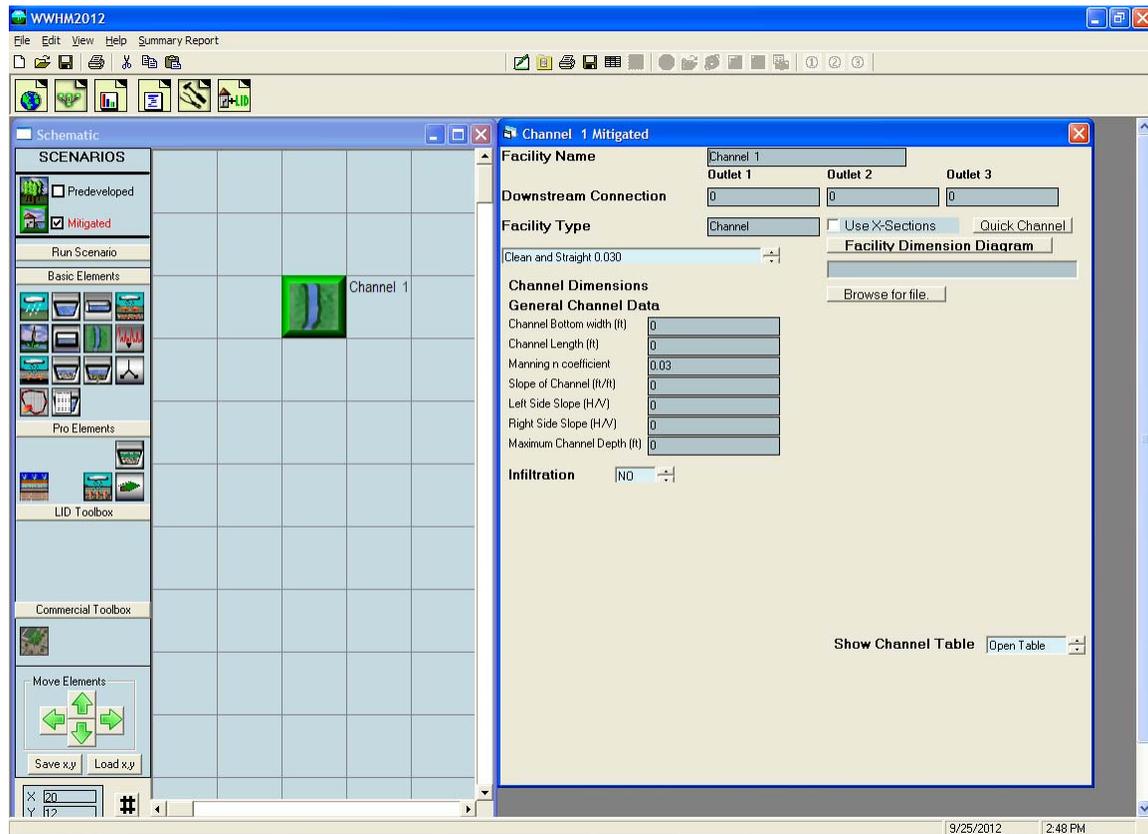
Upper gravitation water porosity: soil pore space in macropores in the upper layer of the soil column.

Upper zone storage factor: portion of the water stored in macropores in the upper soil layer which will not surface discharge, but will percolate, evaporate or transpire.

Lower zone storage factor: portion of the water stored in micropores in the lower soil layer which will not gravity drain, but will evaporate or transpire.

Additional documentation is available in “WVHM3 Description of HSPF High Groundwater Parameters” available from the Washington State Department of Ecology.

CHANNEL



The Channel element allows the user to route runoff from a basin or facility through an open channel to a downstream destination.

The channel cross section is represented by a trapezoid and is used with Manning's equation to calculate discharge from the channel. If a trapezoid does not accurately represent the cross section then the user should represent the channel with an independently calculated SSD Table element or use the Use X-Sections option.

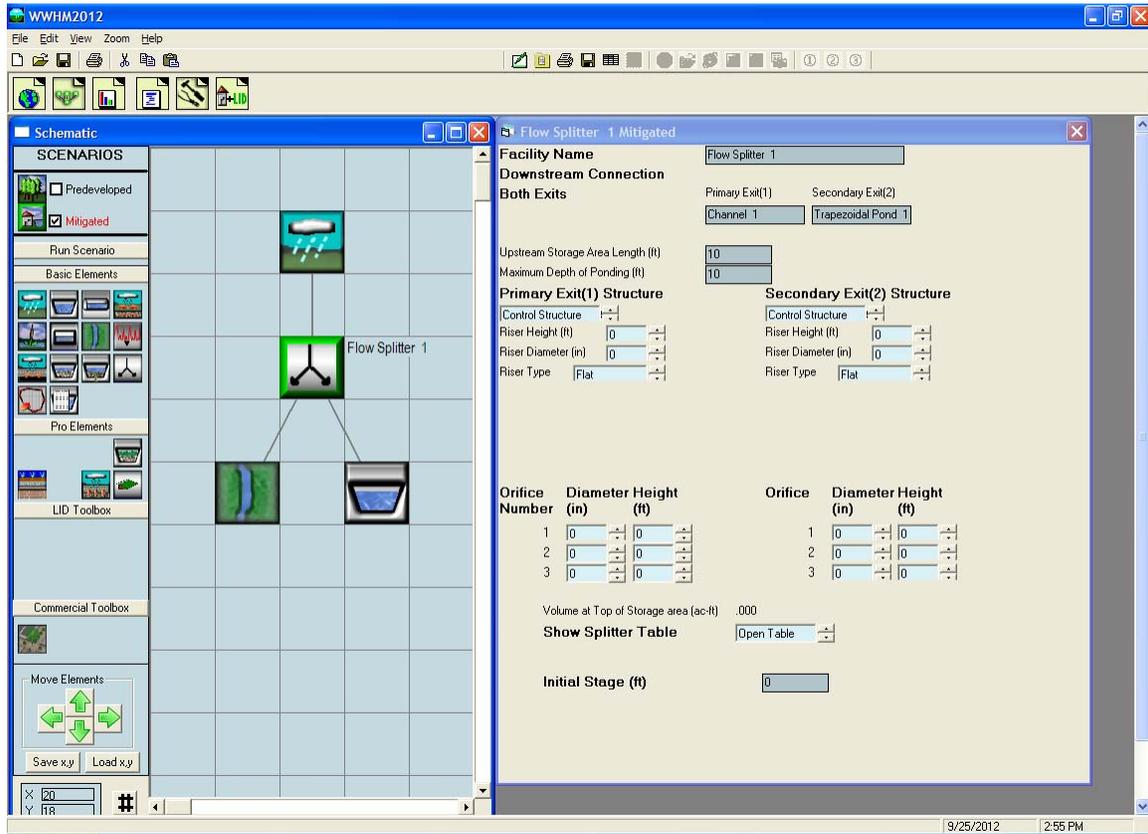
The user can change the default name "Channel 1" to another more appropriate name, if desired.

The user inputs channel bottom width, channel length, channel bottom slope, channel left and right side slopes, maximum channel depth, and the channel's roughness coefficient (Manning's n value). The user can select channel type and associated Manning's n from a table list directly above the Channel Dimensions information or directly input the channel's Manning's n value.

The channel is used to represent a natural or artificial open channel through which water is routed. It can be used to connect a basin to a pond or a pond to a pond or multiple channels can be linked together.

Quick Channel will create a channel with default values without checking it for compliancy with Ecology standards.

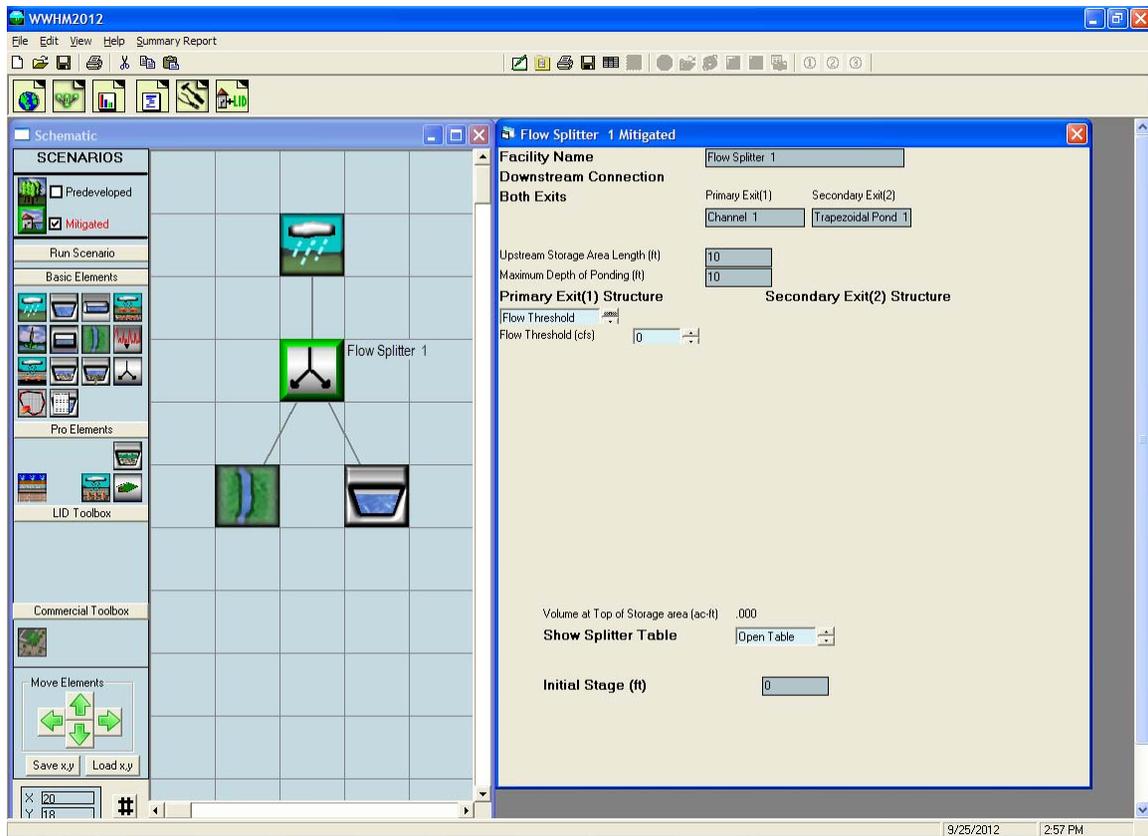
FLOW SPLITTER



The flow splitter divides the runoff and sends it to two different destinations. The splitter has a primary exit (exit 1) and a secondary exit (exit 2). The user defines how the flow is split between these two exits.

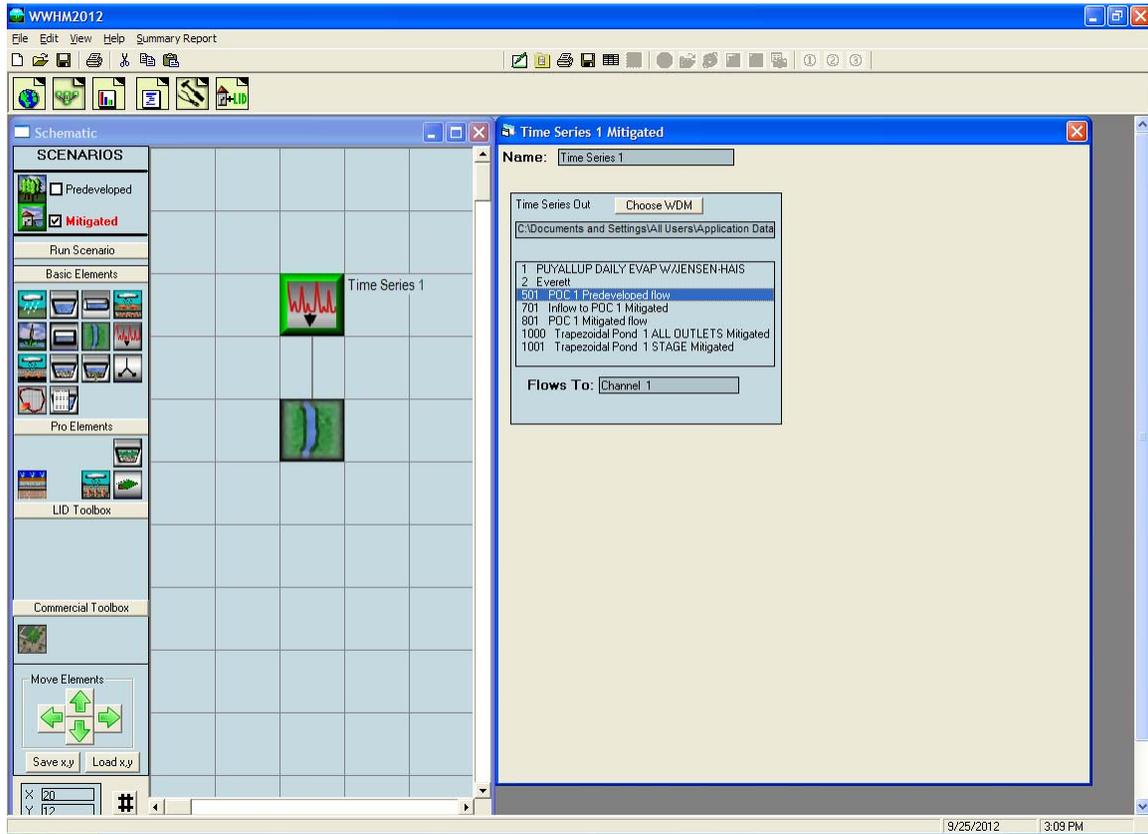
The user can change the default name “Flow Splitter 1” to another more appropriate name, if desired.

The user can define a flow control structure with a riser and one to three orifices for each exit. The flow control structure works the same way as the pond outlet structure, with the user setting the riser height and diameter, the riser weir type (flat, rectangular notch, V-notch, or Sutro), and the orifice diameter and height.



The second option is that the flow split can be based on a flow threshold. The user sets the flow threshold value (cfs) for exit 1 at which flows in excess of the threshold value go to exit 2. For example, if the flow threshold is set to 5 cfs then all flows less than or equal to 5 cfs go to exit 1. Exit 2 gets only the excess flow above the 5 cfs threshold (total flow minus exit 1 flow).

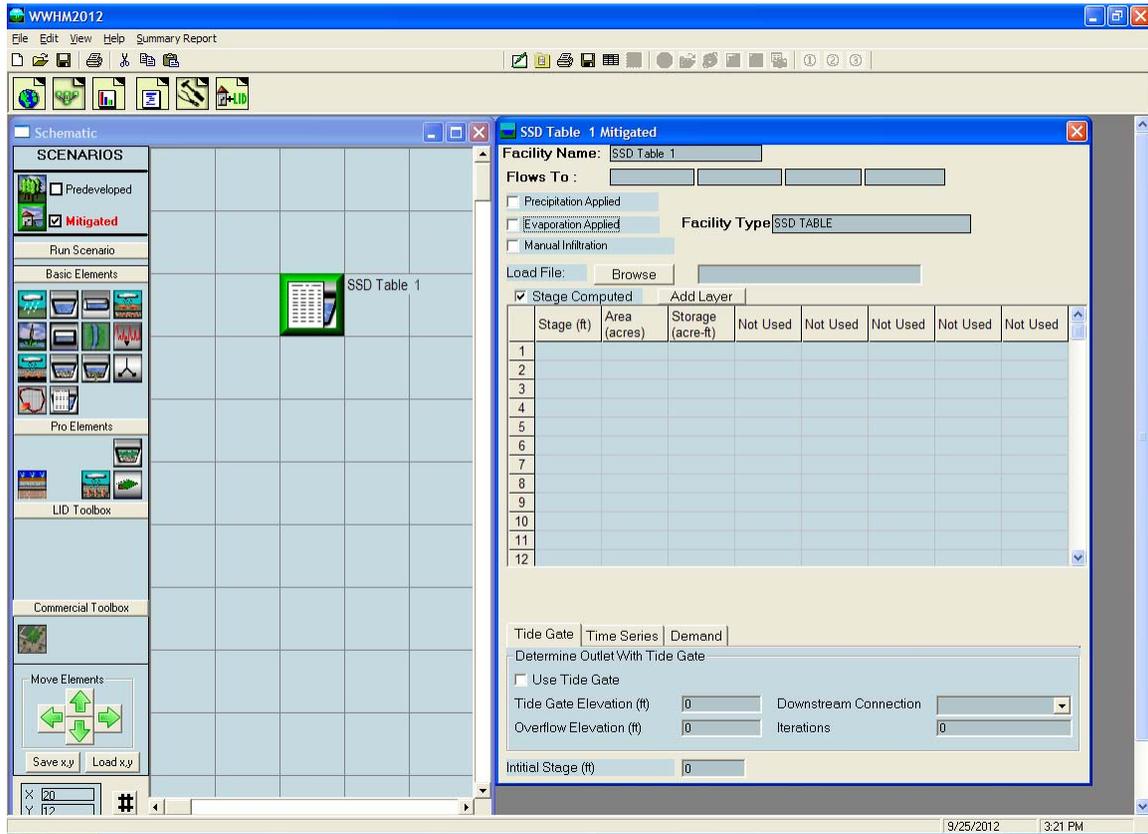
TIME SERIES



The WWHM2012 stores runoff time series data in its database (HSPF WDM file). The user has the option to create or use a time series file external from the current WWHM2012 project file or use a file created as part of the WHM2012 project file. This includes using a time series of flow values created by another HSPF model. An example is offsite runoff entering a project site. If this offsite runoff is in an existing WDM file and is the same period as the WWHM2012 data and the same simulation time step (15-minute) then it can be linked to the WWHM2012 model using the Time Series element.

To link the external time series to the WWHM2012 the user clicks on the “Choose WDM” button and identifies the external WDM file. The external WDM’s individual time series files are shown in the box. The selected input dataset is the time series that will be used by the WWHM2012.

SSD TABLE



The SSD Table is a stage-storage-discharge table externally produced by the user and is identical in format to the stage-storage-discharge tables generated internally by the WWHM2012 for ponds, vaults, tanks, channels, and other conveyance elements.

The user can change the default name “SSD Table 1” to another more appropriate name, if desired.

The easiest way to create a SSD Table outside of the WWHM2012 is to create a spreadsheet with a separate column for stage, surface area, storage, and discharge (in that order). To input an externally generated SSD Table, first create and save the table outside of the WWHM2012. Use the Browse button to locate and load the file into the WWHM2012.

The SSD Table must use the following units:

Stage: feet

Surface Area: acres

Storage: acre-feet

Discharge: cubic feet per second (cfs)

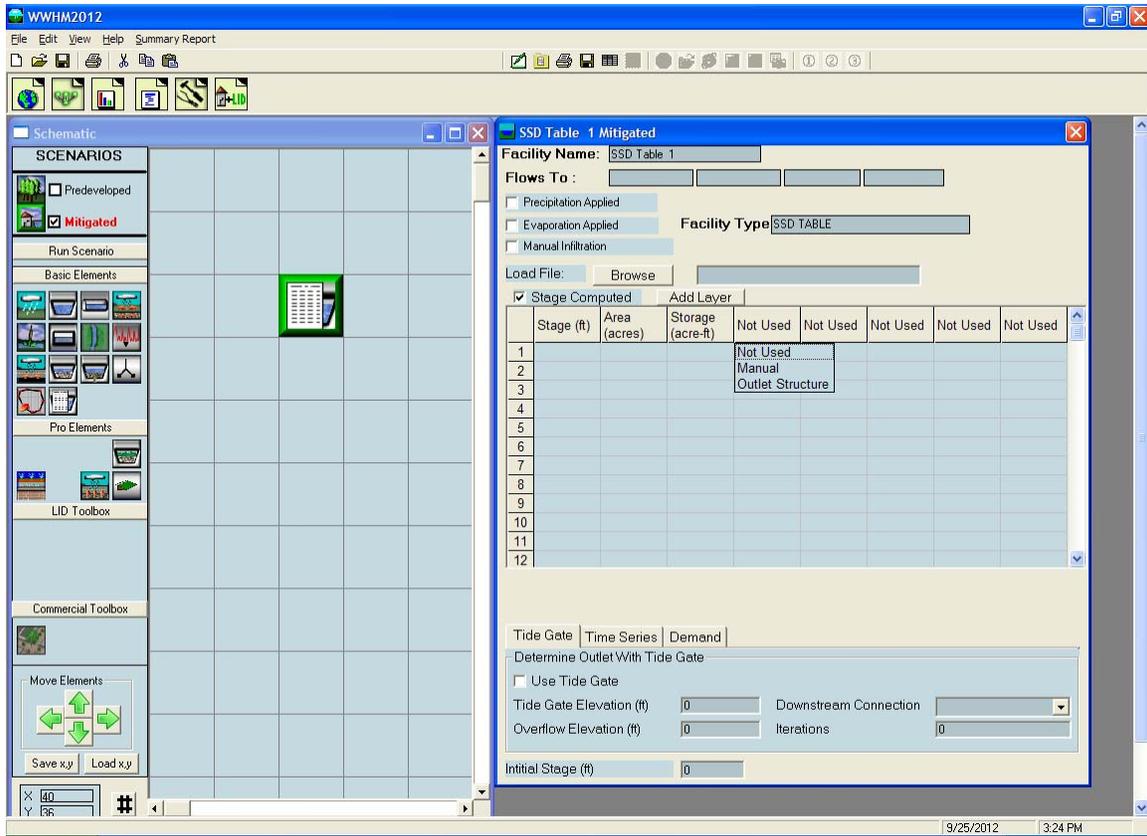
A fifth column can be used to create a second discharge (cfs). This second discharge can be infiltration or a second surface discharge.

Certain rules apply to the SSD Table whether it is created inside or outside of the WWHM2012. These rules are:

1. Stage (feet) must start at zero and increase with each row. The incremental increase does not have to be consistent.
2. Storage (acre-feet) must start at zero and increase with each row. Storage values should be physically based on the corresponding depth and surface area, but the WWHM2012 does not check externally generated storage values.
3. Discharge (cfs) must start at zero. Discharge does not have to increase with each row. It can stay constant or even decrease. Discharge cannot be negative. Discharge should be based on the outlet structure's physical dimensions and characteristics, but the WWHM2012 does not check externally generated discharge values.
4. Surface area (acres) is only used if precipitation to and evaporation from the facility are applied.

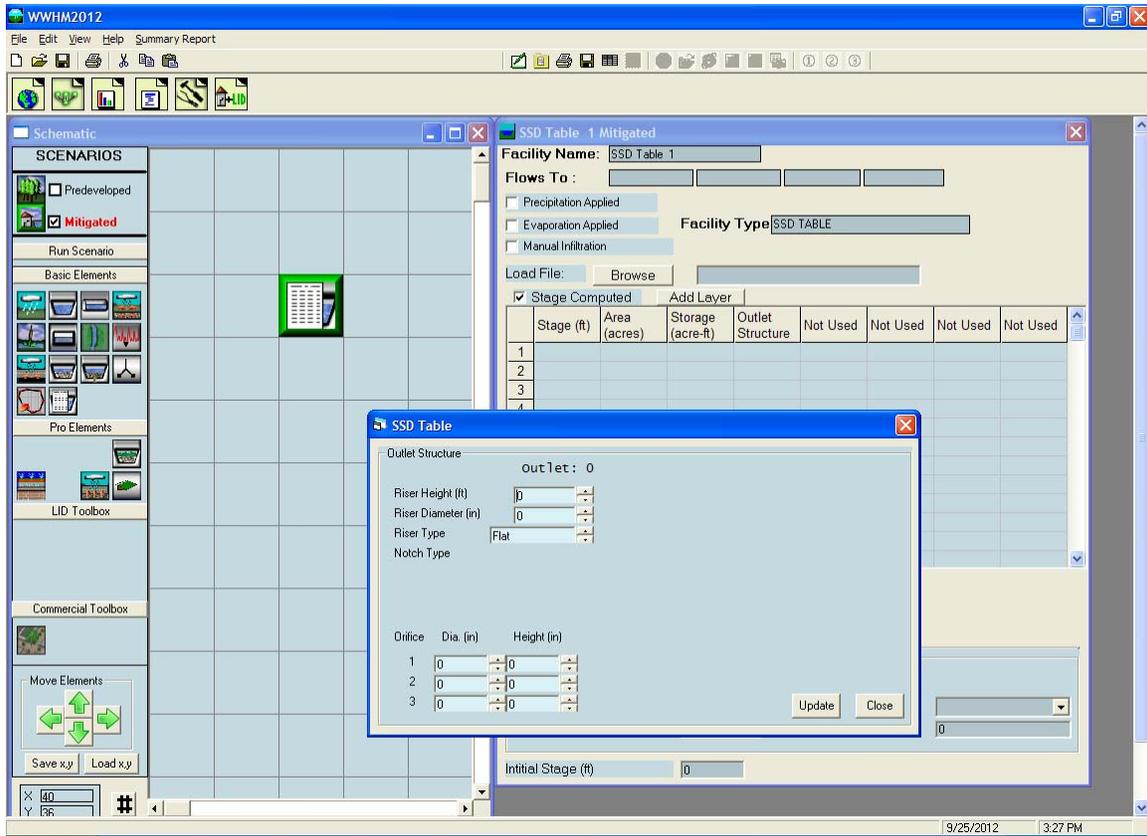
Save the spreadsheet file as a comma-delimited file. A text file can also be created, if more convenient.

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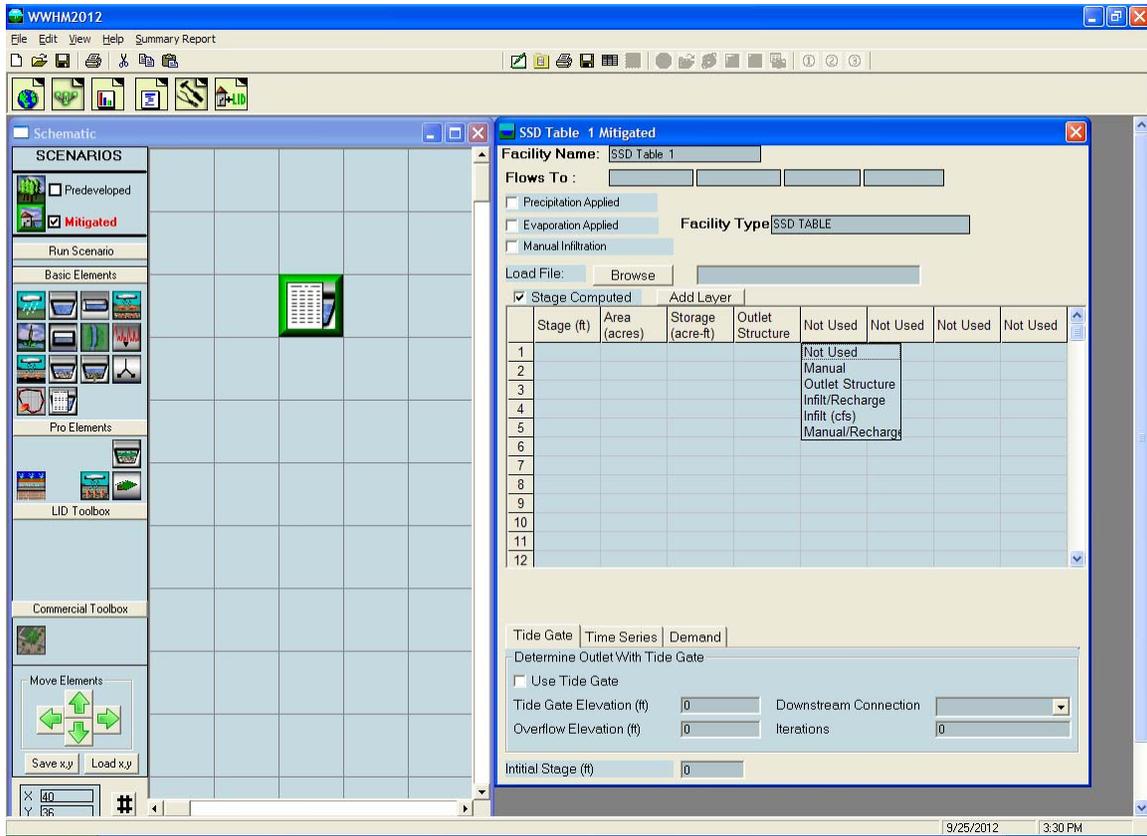
To input columns of values beyond (to the right of) the Storage column click on the “Not Used” title and select the appropriate option. Use “Manual” when the discharge has been included in the external spreadsheet.

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Use “Outlet Structure” to input riser and orifice dimensions.

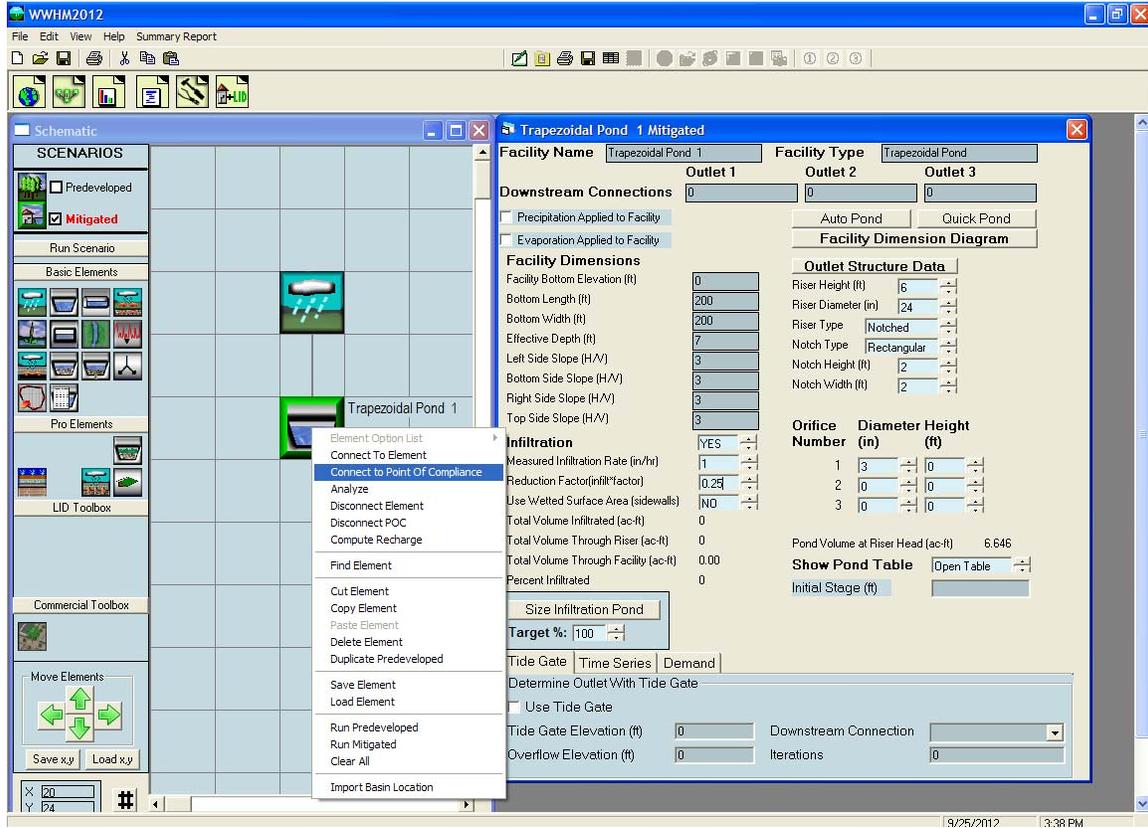
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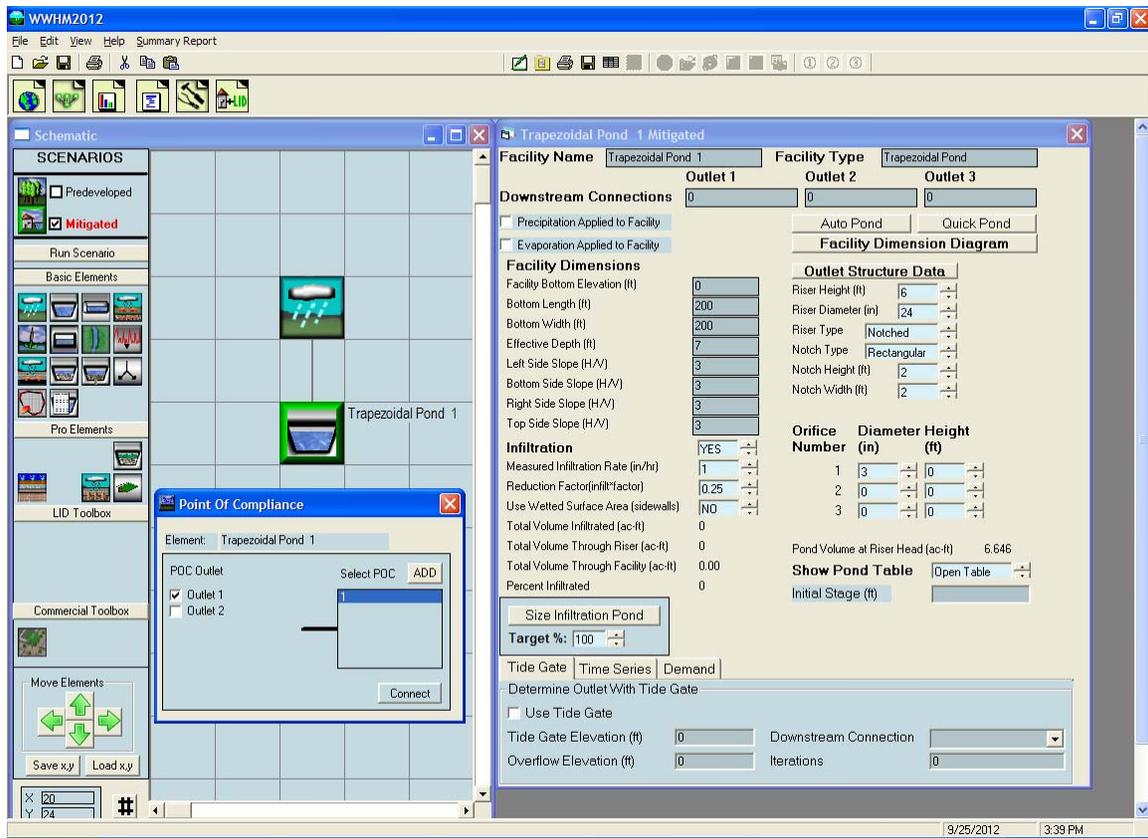
The fifth column can be used for a second surface outlet (manual or outlet structure), infiltration, or aquifer recharge. Aquifer recharge differs from infiltration in how the model separately accounts for it.

POINT OF COMPLIANCE

WWHM2012 allows for multiple points of compliance (maximum of 50) in a single project. A point of compliance is defined as the location at which the Predeveloped and Mitigated flows will analyzed for compliance with Ecology's flow control standard.



The point of compliance is selected by right clicking on the element at which the compliance analysis will be made. In the example above, the point of compliance analysis will be conducted at the outlet of the trapezoidal pond.



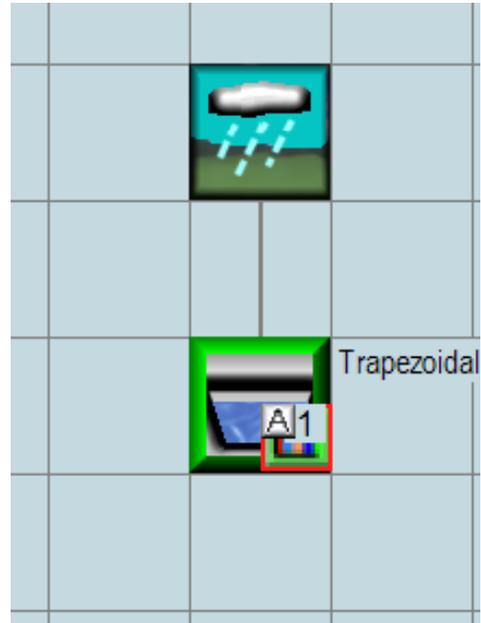
A Point of Compliance (POC) box will allow the user to specify which outlet (if there is more than one) to connect to the point of compliance and corresponding number for the POC.

In the above example, there are two outlets shown (Outlet 1 and Outlet 2). Outlet 1 represents the surface discharge through the outlet structure. Outlet 2 is the infiltration discharge through the bottom of the facility. Only the surface discharge (Outlet 1) should be connected to the POC.

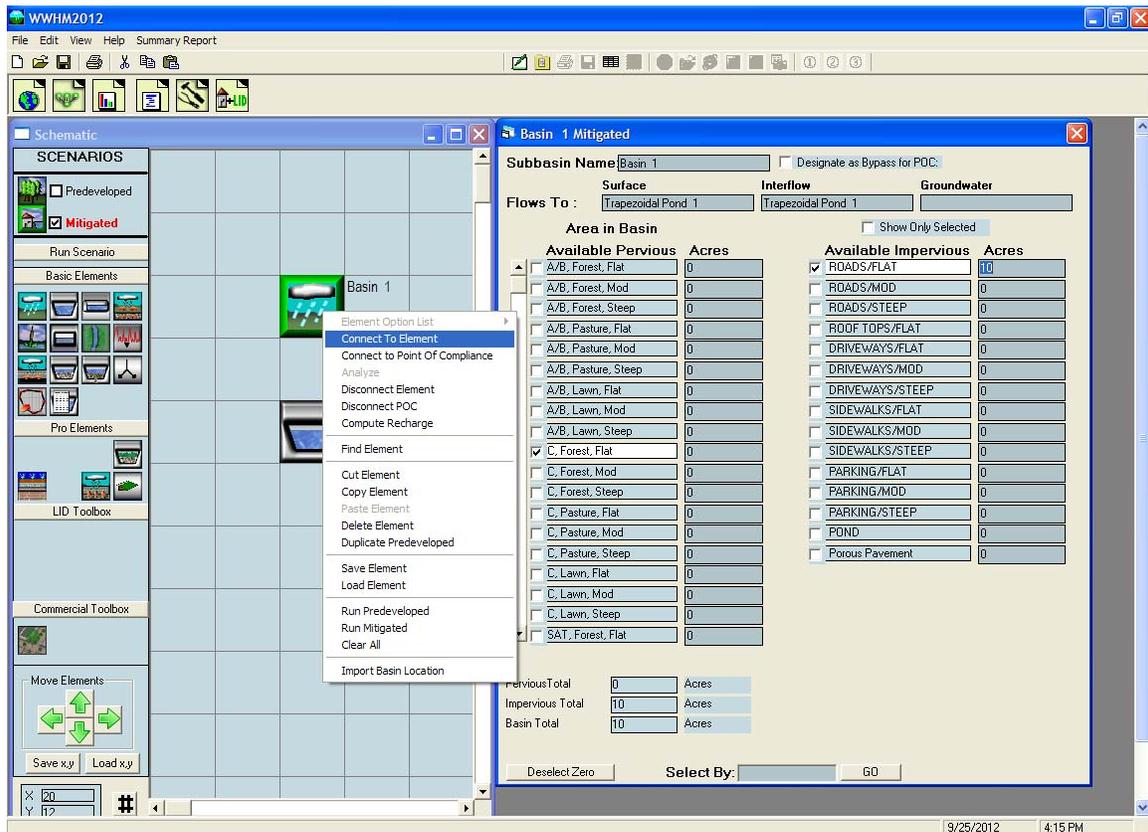
When an underdrain is included in the facility (bioretention or porous pavement) the discharge from the underdrain will be considered part of the Outlet 1 total discharge.

A sand filter should include the discharge from both Outlet 1 (surface discharge not filtered by the sand filter) and Outlet 2 (surface discharge filtered by the sand filter) connected to the POC, assuming that the POC is immediately downstream of the sand filter.

Once the point of compliance has been selected the element is modified on the Schematic screen to include a small box with the POC number (1 in this example) and the letter “A” (for Analysis) in the lower right corner. This identifies the outlet from this element as a point of compliance.

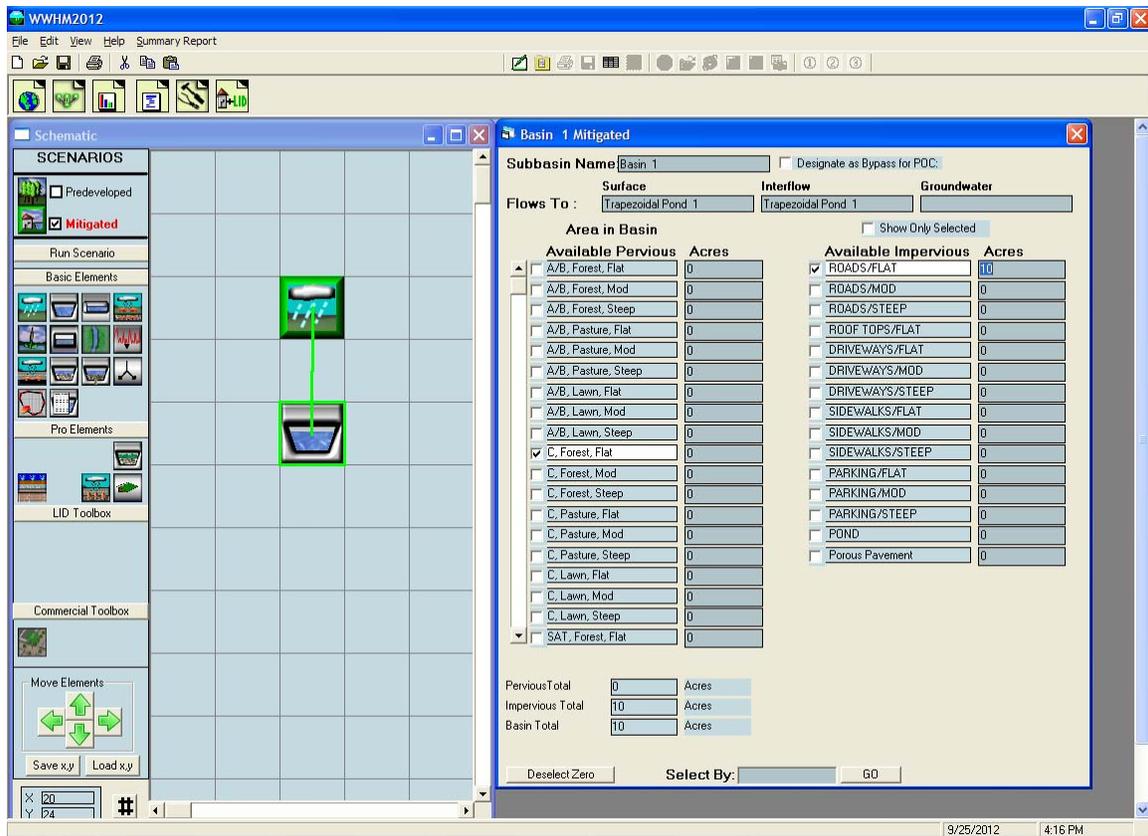


CONNECTING ELEMENTS

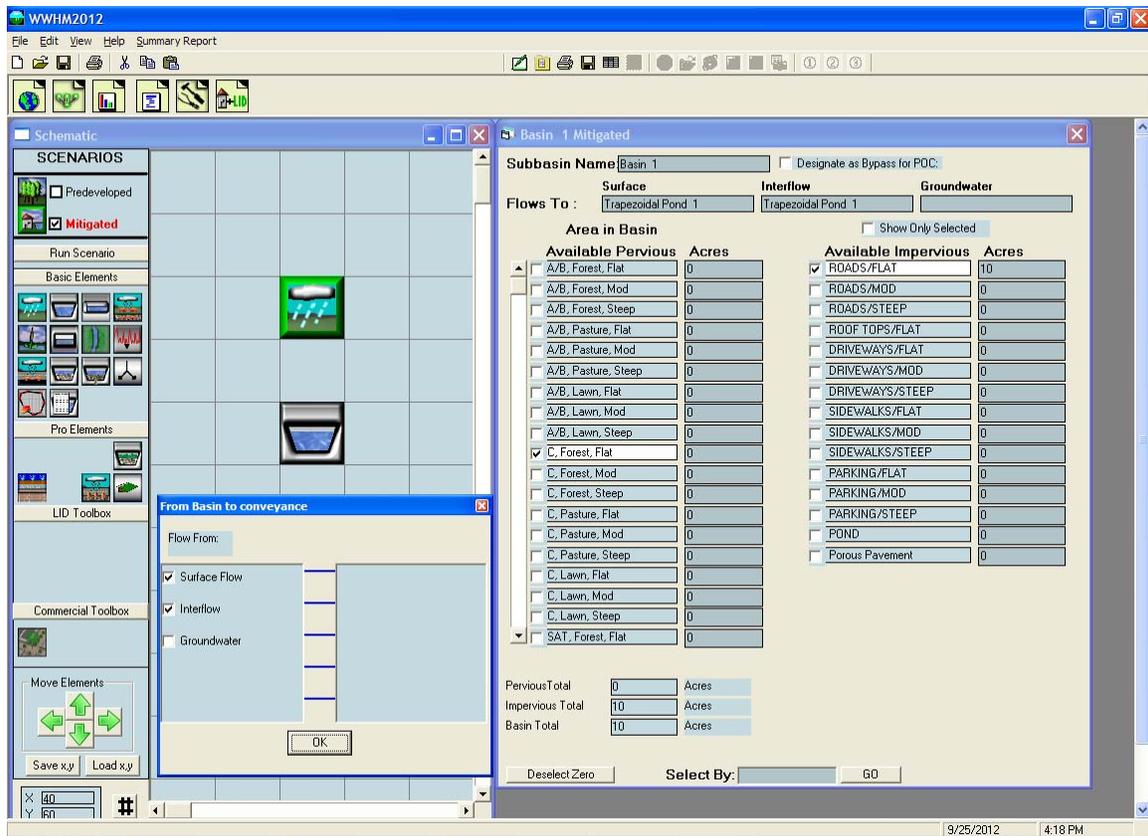


Elements are connected by right clicking on the upstream element (in this example Basin 1) and selecting and then left clicking on the Connect To Element option. By doing so the WWHM2012 extends a green line from the upstream element to wherever the user wants to connect that element.

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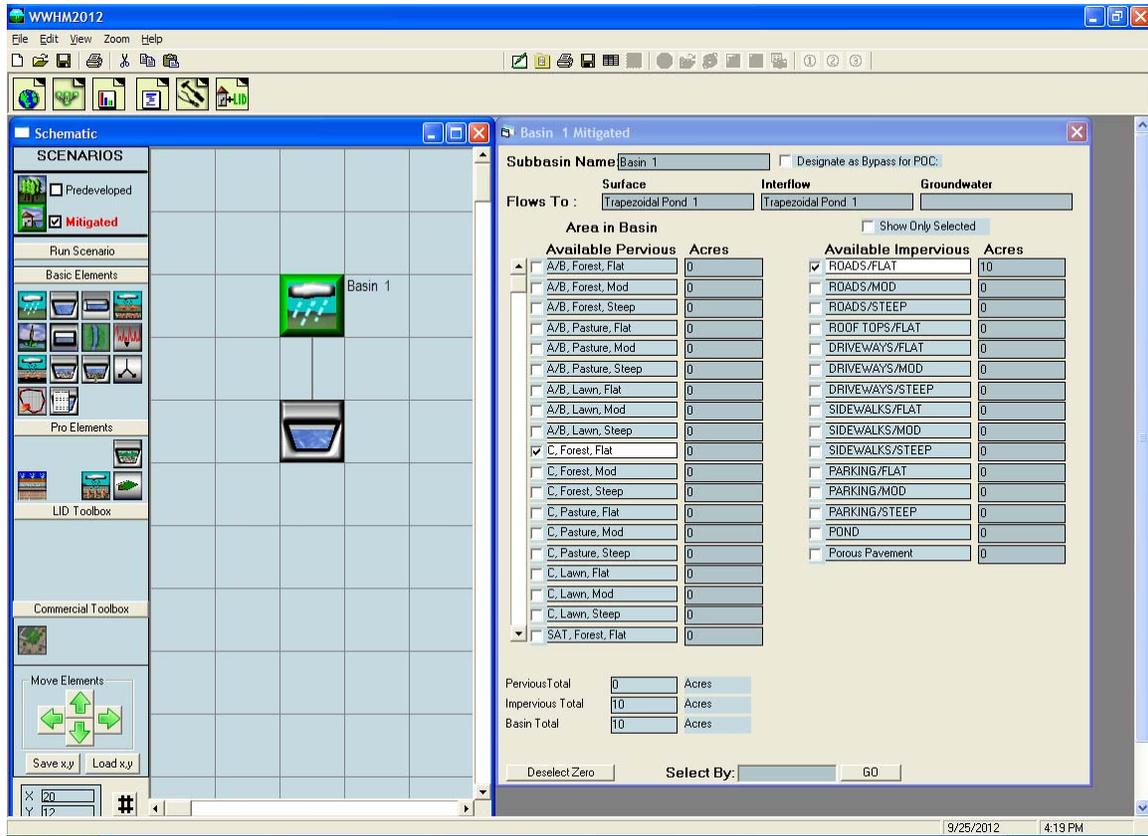
The user extends the green connection line and box to the downstream element (in this example, a pond) and left clicks on the destination element. This action brings up the From Basin to Conveyance box that allows the user to specify which runoff components to route to the downstream element.



Stormwater runoff is defined as the sum of surface flow and interflow. Both boxes should be checked. Groundwater should not be checked for the standard land development mitigation analysis. Groundwater should only be checked when there is observed and documented base flow or spring flow occurring from the upstream basin.

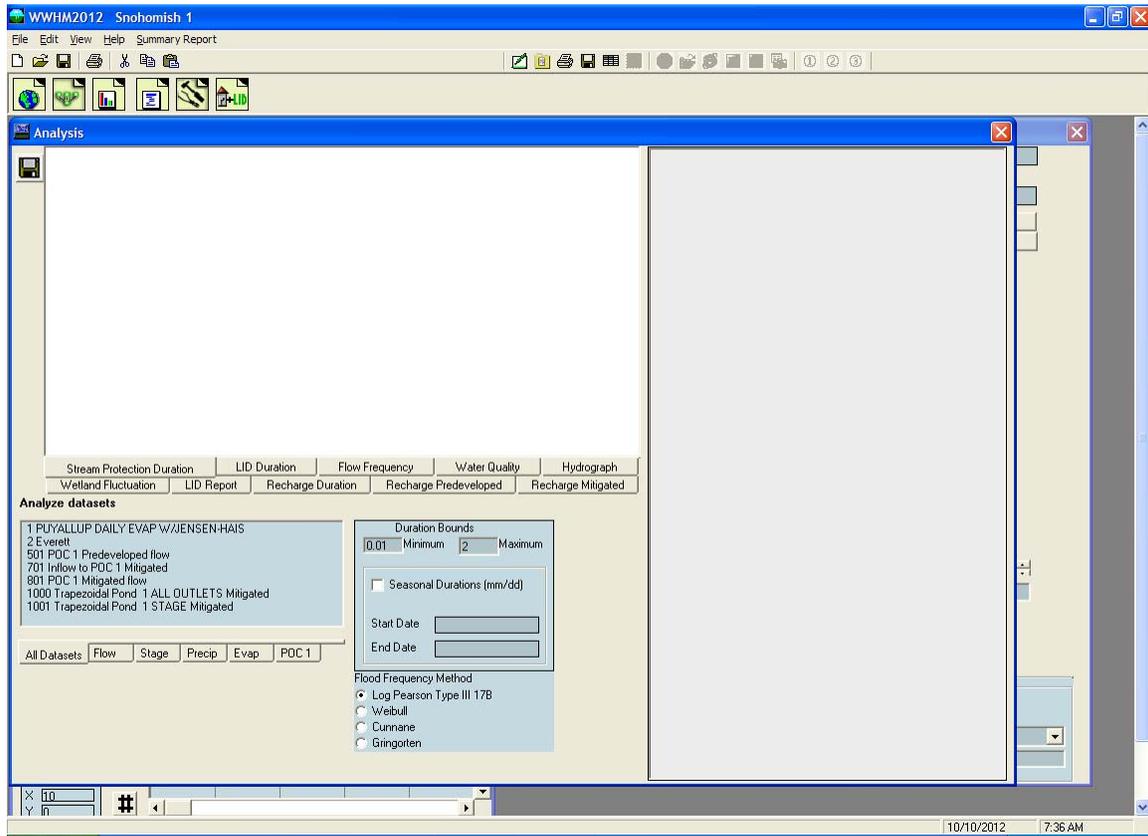
After the appropriate boxes have been checked click the OK button.

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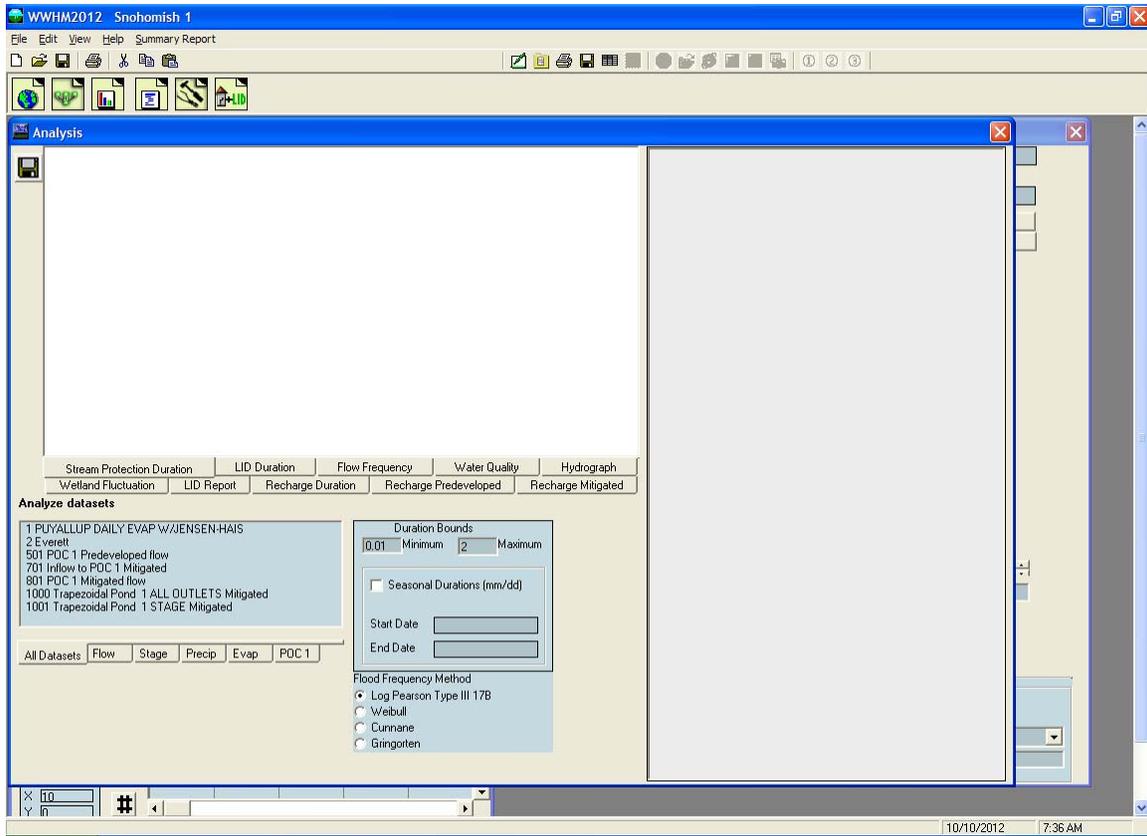
The final screen will look like the above screen. The basin information screen on the right shows that Basin 1 surface and interflow goes to Trapezoidal Pond 1; groundwater is not connected.

ANALYSIS SCREEN



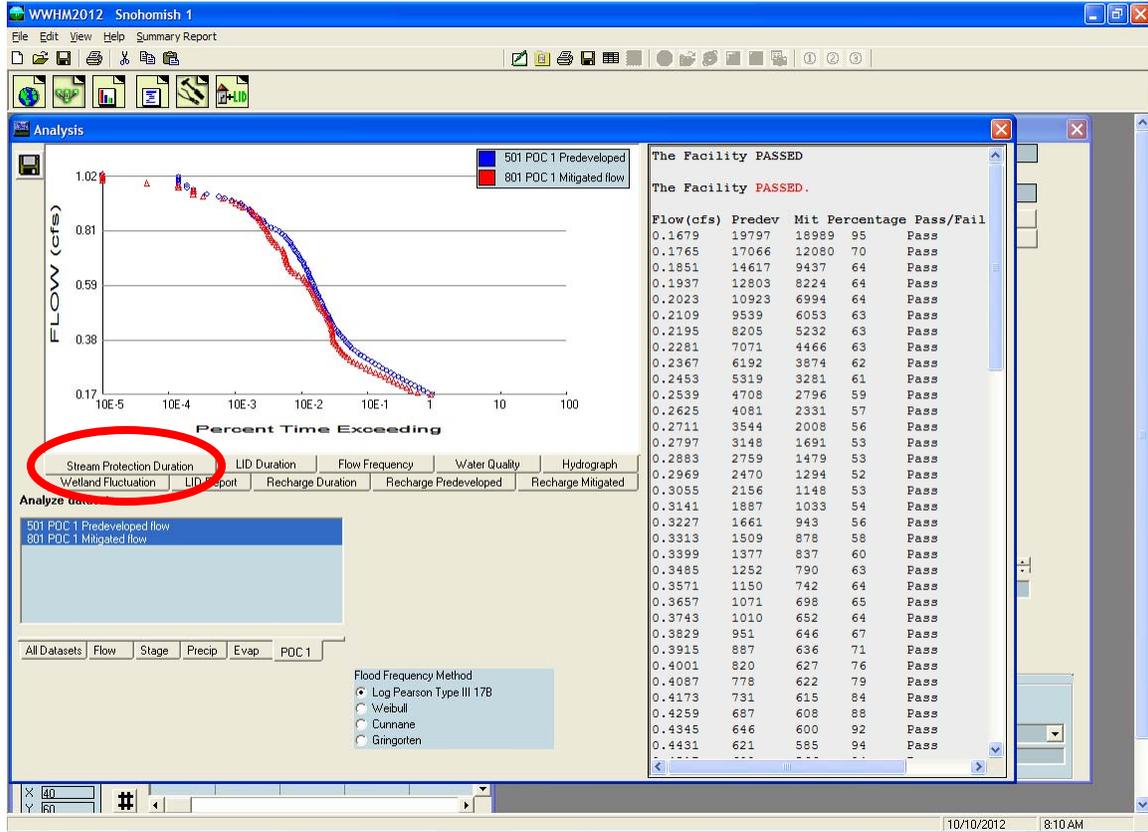
The Analysis tool bar button (third from the left) brings up the Analysis screen where the user can look at the results. The Analysis screen allows the user to analyze and compare stream protection flow duration, LID flow duration, flow frequency, water quality, hydrographs, wetland fluctuations, and recharge, as needed. In addition, the LID report is automatically generated in the Analysis window.

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The user can analyze all time series datasets or just flow, stage, precipitation, evaporation, or point of compliance (POC) flows by selecting the appropriate tab below the list of the different datasets available for analysis.

Stream Protection Duration



Flow duration has been divided into stream protection duration and LID duration. The stream protection duration standard is to meet Ecology’s flow control minimum requirement (#7). The LID duration standard is to meet Ecology’s on-site stormwater management minimum requirement (#5).

Stream protection flow duration at the point of compliance (POC 1) is the most common analysis. A plot of the stream protection flow duration values is shown on the left, the flow values on the right.

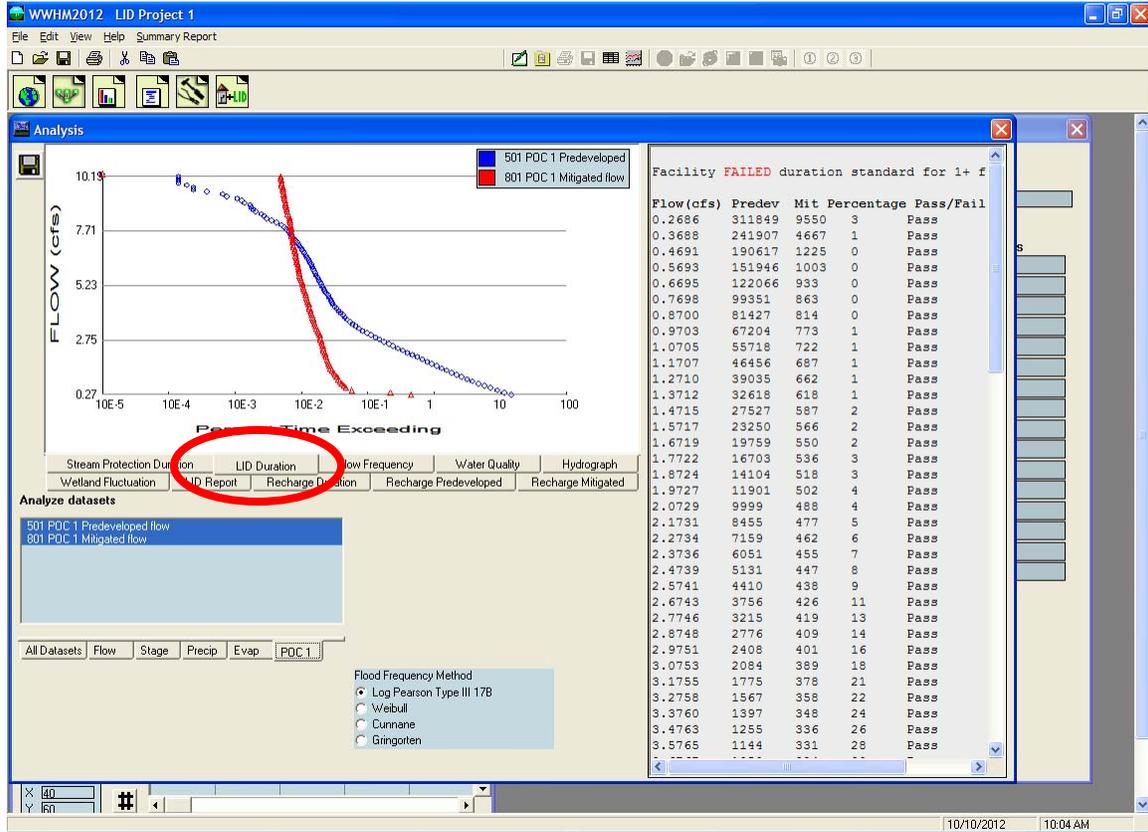
The blue stream protection flow duration curve is a plot of the percent of time that the predevelopment flows (time series 501 for POC 1) are between the lower erosive flow threshold of 50% of the 2-year flow (0.50Q2) and the upper erosive flow threshold of the 50-year flow (Q50). Q2 and Q50 are determined by the flow frequency calculations.

The red stream protection flow duration curve is the mitigated developed flow (time series 801 for POC 1).

The table to the right of the stream protection flow duration curves shows the individual flow levels (starting at 0.50Q2) and the corresponding number of time intervals that the predevelopment and mitigated flows exceed those flow levels. The number of mitigated flows at any specific flow level cannot exceed the number of predevelopment flows at the

same flow level between 0.5Q2 and Q2. Between Q2 and Q50 the number of mitigated flows at any specific flow level cannot exceed the number of predevelopment flows by more than 10% no more than at 50% of the levels. WWHM2012 automatically checks these stream protection flow duration criteria when determining whether or not a stormwater facility passes the Ecology flow control standard.

LID Duration



The LID duration standard is to meet Ecology’s on-site stormwater management minimum requirement (#5).

LID flow duration analysis is a requirement for low impact development facilities (bioretention, porous pavement, green roof, etc). A plot of the LID flow duration values is shown on the left, the flow values on the right.

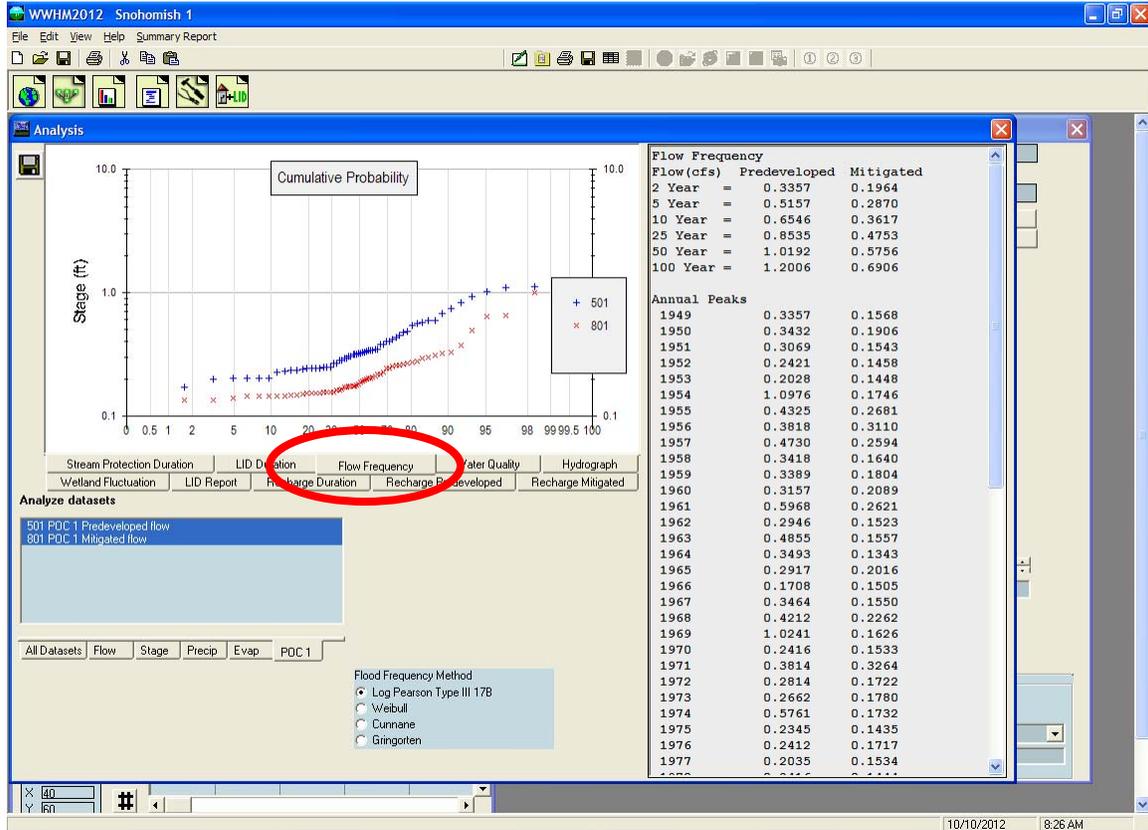
The LID flow duration analysis output includes the stream protection flow duration analysis at the POC. For this reason the blue LID flow duration curve is a plot of the percent of time that the predevelopment flows (time series 501 for POC 1) are between 8% of the 2-year flow (0.08Q2) and the 50-year flow (Q50). Q2 and Q50 are determined by the flow frequency calculations.

The red LID flow duration curve is the mitigated developed flow (time series 801 for POC 1).

The table to the right of the LID flow duration curves shows the individual flow levels (starting at 0.08Q2) and the corresponding number of time intervals that the predevelopment and mitigated flows exceed those flow levels. The number of mitigated flows at any specific flow level cannot exceed the number of predevelopment flows at the same flow level between 0.08Q2 and 0.50Q2. Above 0.5Q2 the stream protection

duration criteria is used to determine whether or not the project flow at the POC meets Ecology's requirements. WWHM2012 automatically checks these flow duration criteria when determining whether or not a stormwater facility passes the Ecology on-site stormwater management standard and the flow control standard.

Flow Frequency

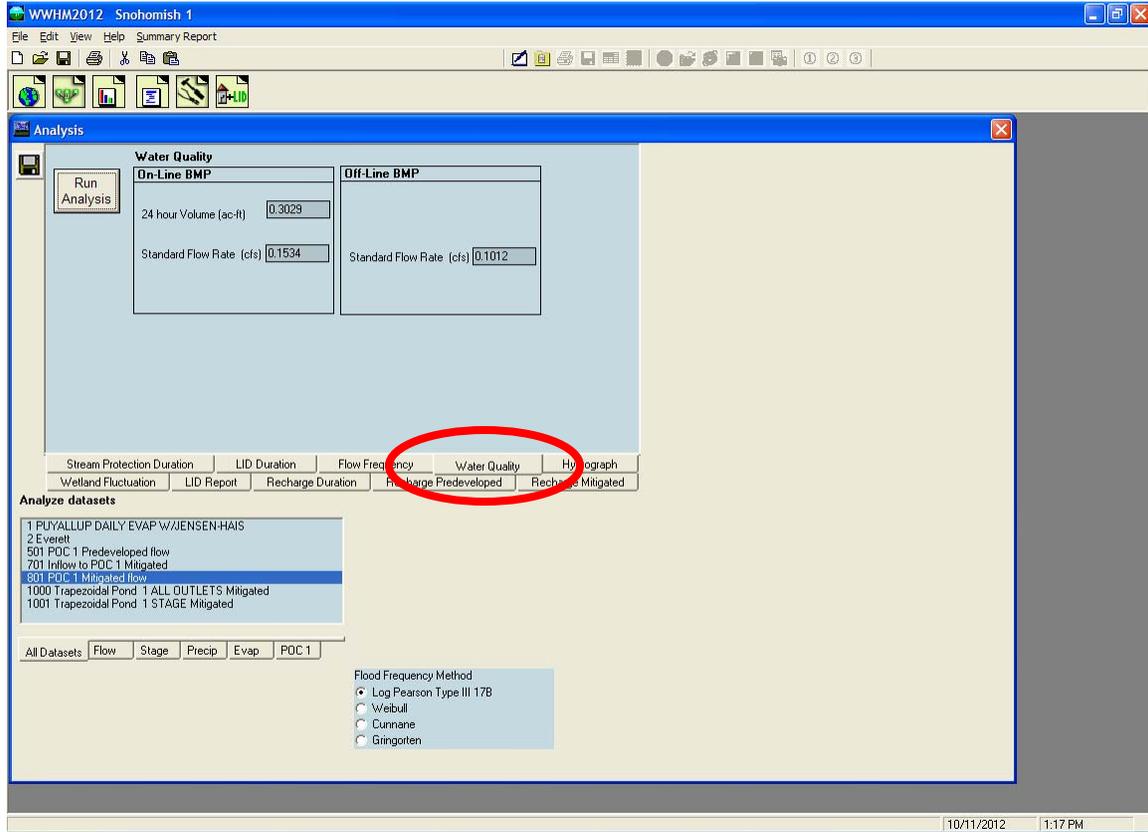


Flow frequency plots are shown on the left and the 2-, 5-, 10-, 25-, 50-, and 100-year frequency values are on the right. Flow frequency calculations are based on a Log Pearson Type III distribution of yearly peak flow values.

It is possible, although unusual, for the mitigated frequency values to be greater than the predeveloped frequency values for the 25-, 50-, and 100-year flow frequency events. This can happen when the mitigated 2-year value is much smaller than the predeveloped frequency value.

The Log Pearson Type III methodology uses the annual peak statistics to compute the mean, standard deviation, and skew of the log of the peak flows. Small mitigated 2-year events can produce a large standard deviation and skew which, in turn, produce large mitigated 25-, 50-, and 100-year flow frequency values. This is okay as long as the stream protection flow control standard (based on flow duration criteria, not flow frequency) is met.

Water Quality



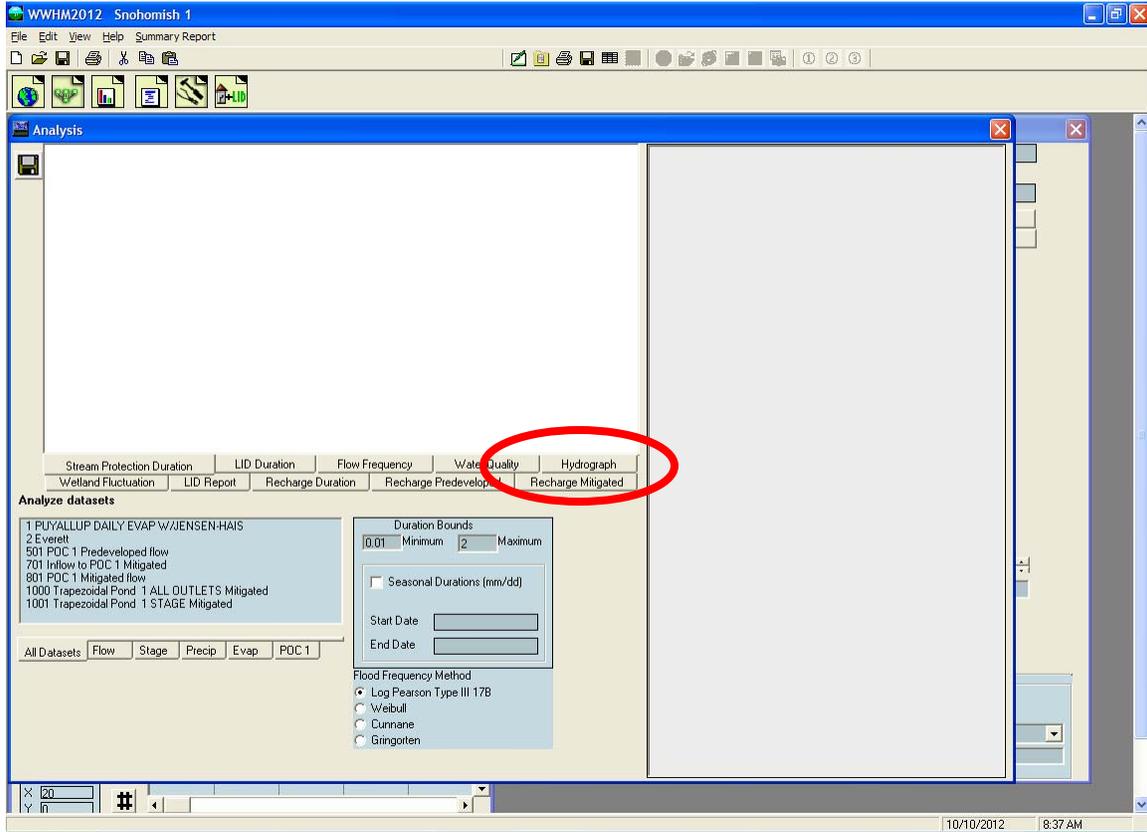
The water quality screen allows the user to compute the target volumes and flows for offline and online water quality facilities.

Select the dataset 801 POC 1 Mitigated flow for the water quality analysis for a water quality facility downstream of the project flow control facility. Click on the “Run Analysis” button on the left side of the Water Quality analysis results for the WWHM2012 to compute volumes and flows based on Ecology’s water quality facility sizing criterion (91% of total runoff volume) or a criterion selected by the user via View, Options, Scaling Factor Water Quality.

Select the 701 Inflow to POC 1 Mitigated flow time series for the water quality analysis for a water quality facility upstream of the project flow control facility.

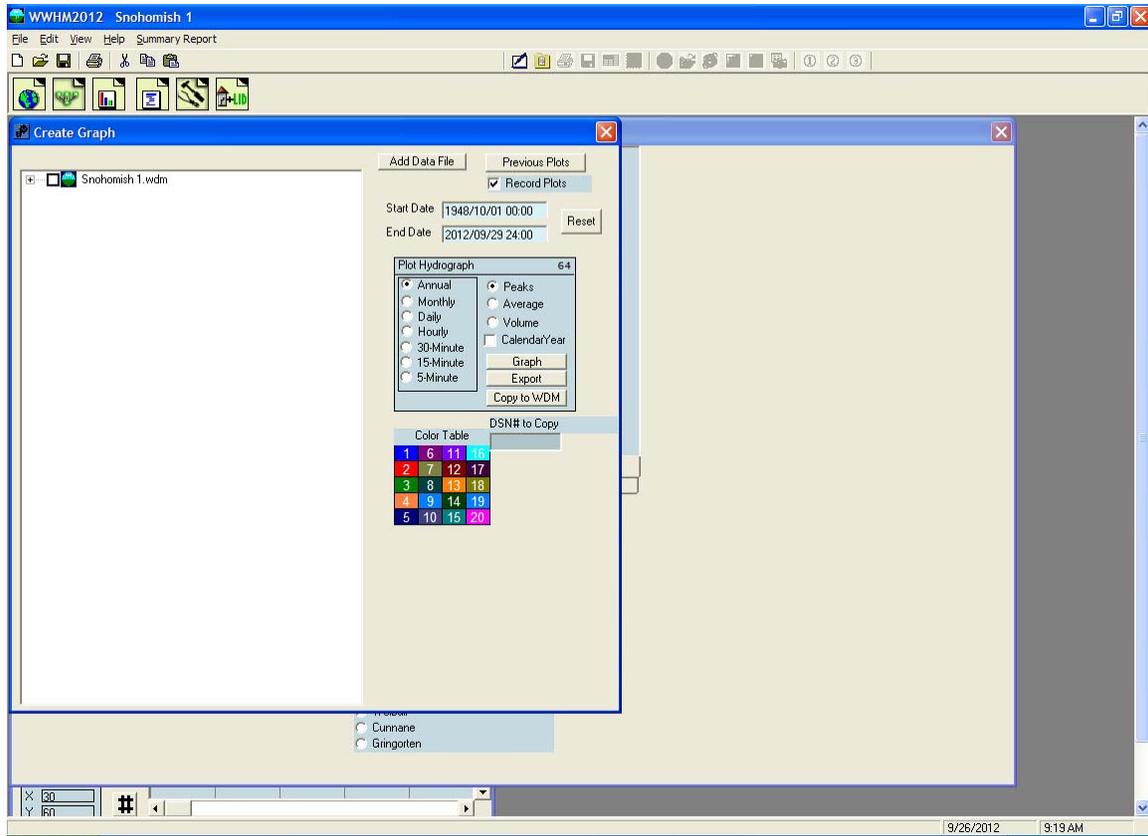
An online water quality facility is downstream of the project flow control facility; all of the runoff is routed through an online facility. An offline facility receives only a portion of the total runoff.

Hydrographs

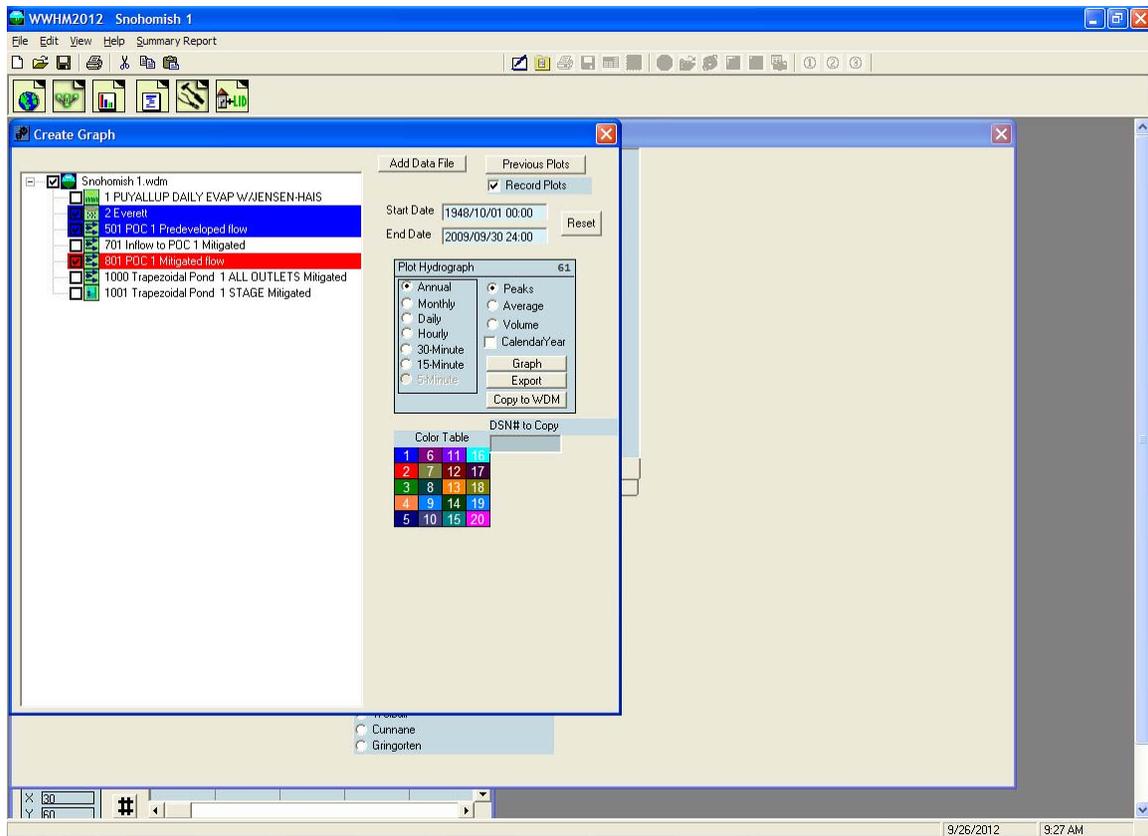


The user can graph/plot any or all time series data by selecting the Hydrograph tab.

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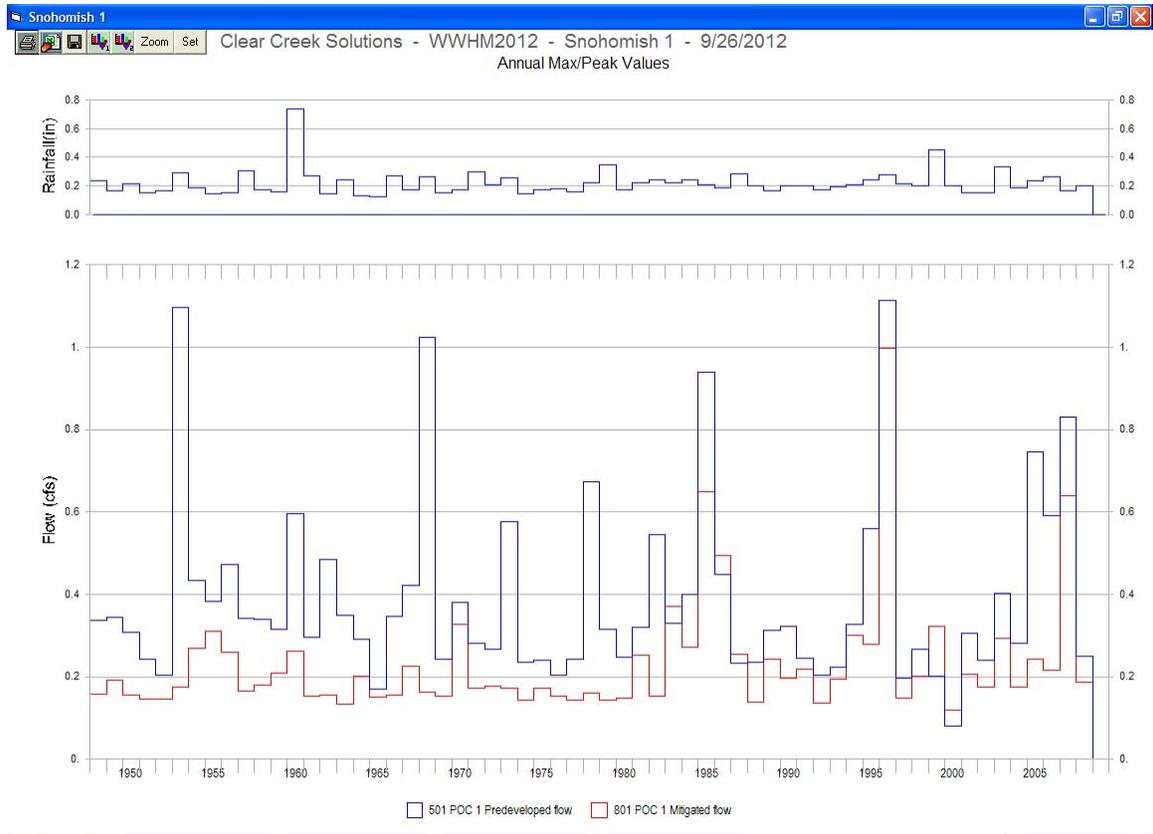
The Create Graph screen is shown and the user can select the time series to plot, the time period (start date and end date), the time interval (yearly, monthly, daily, hourly, 30-minute, or 15-minute), and type of data (peaks, average, or volume).



Click on the “+” to the left of the WDM file name (in this example: “Snohomish 1.wdm”). The selected time series are then shown. Check the box(es) for the time series to be plotted. Multiple time series can be plotted together as long as they are the same data type. Precipitation data can also be plotted at the same time as flow data.

To graph the selected time series the user clicks on the Graph button.

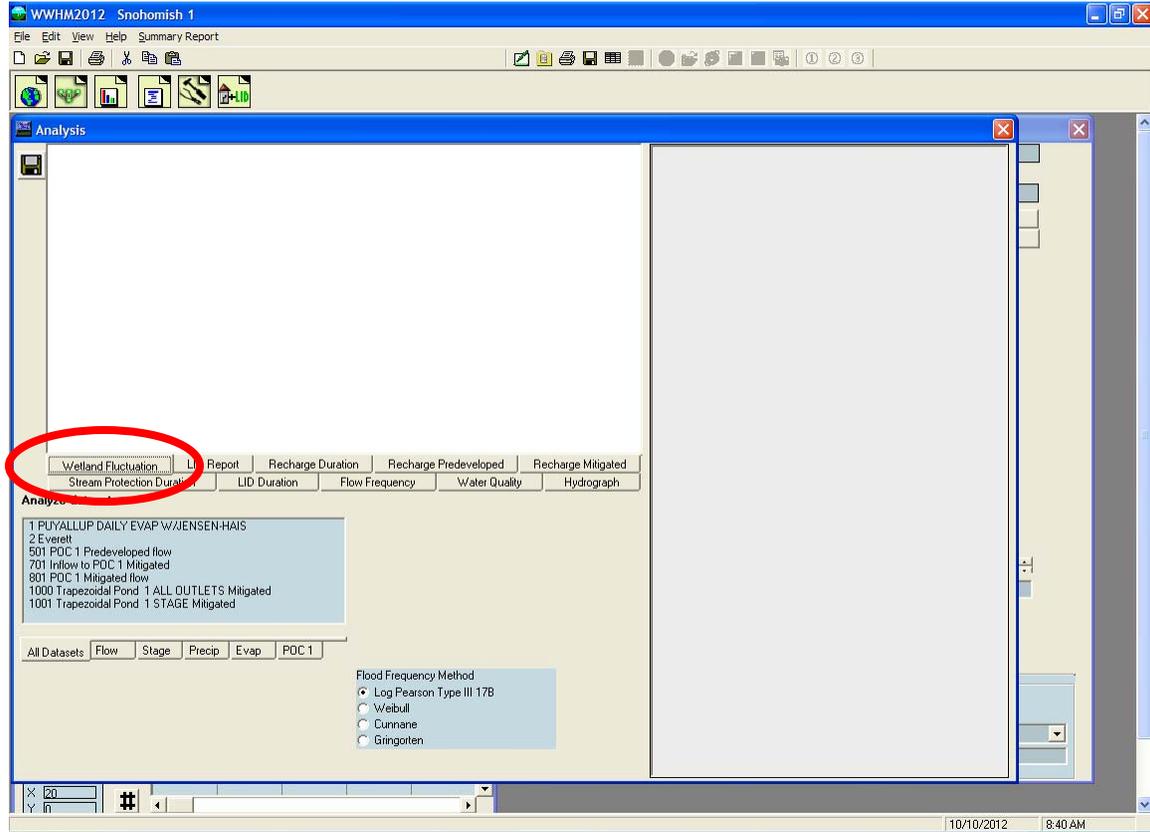
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The hydrograph shows the yearly maximum/peak flow values for each time series for the entire simulation period (in this example, from 1949 through 2009).

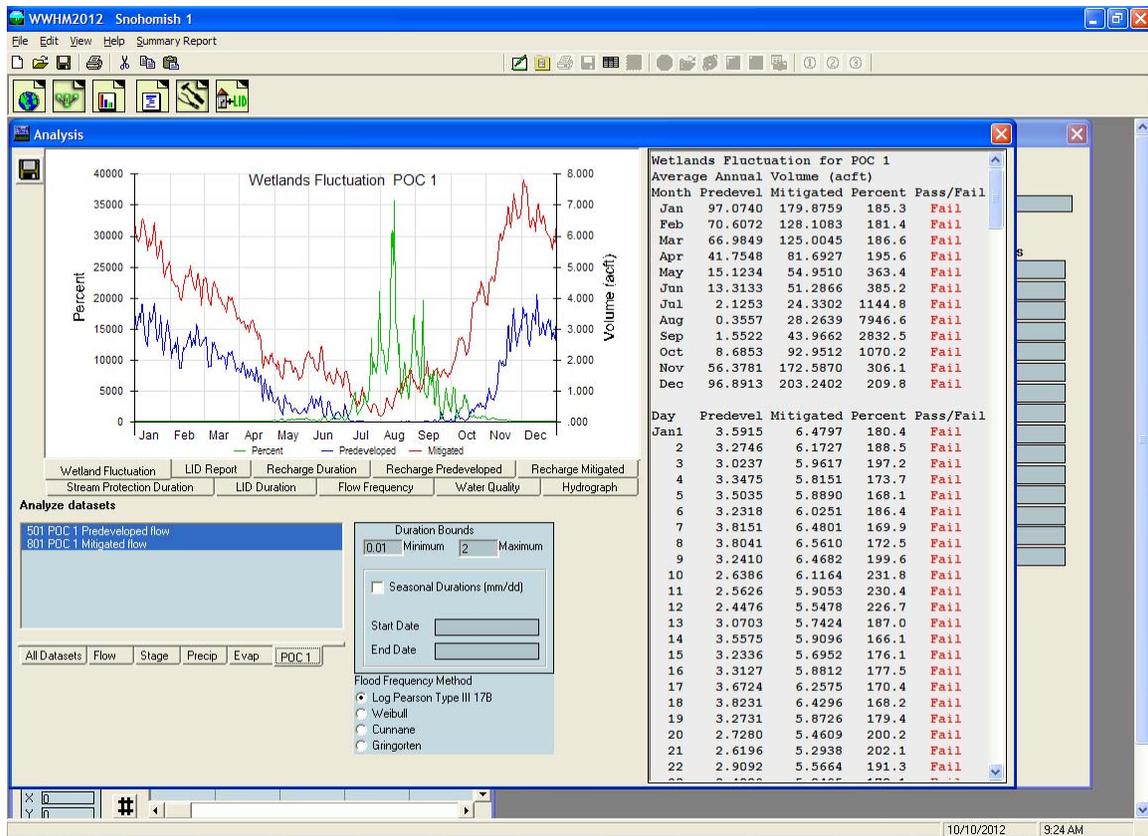
The graph can be either saved or printed or copied to an Excel spreadsheet for additional analysis.

Wetland Fluctuation



The wetland fluctuation option in the Analysis screen is selected by clicking on the “Wetland Fluctuation” tab.

The analysis is done at the point of compliance based on the assumption that this is the location at which runoff enters the wetland of interest. If the wetland is upstream of the POC then a new POC should be added to represent the flows entering the upstream wetland.



The wetland fluctuation calculations are done for the POC-related flow time series by selecting the appropriate POC tab.

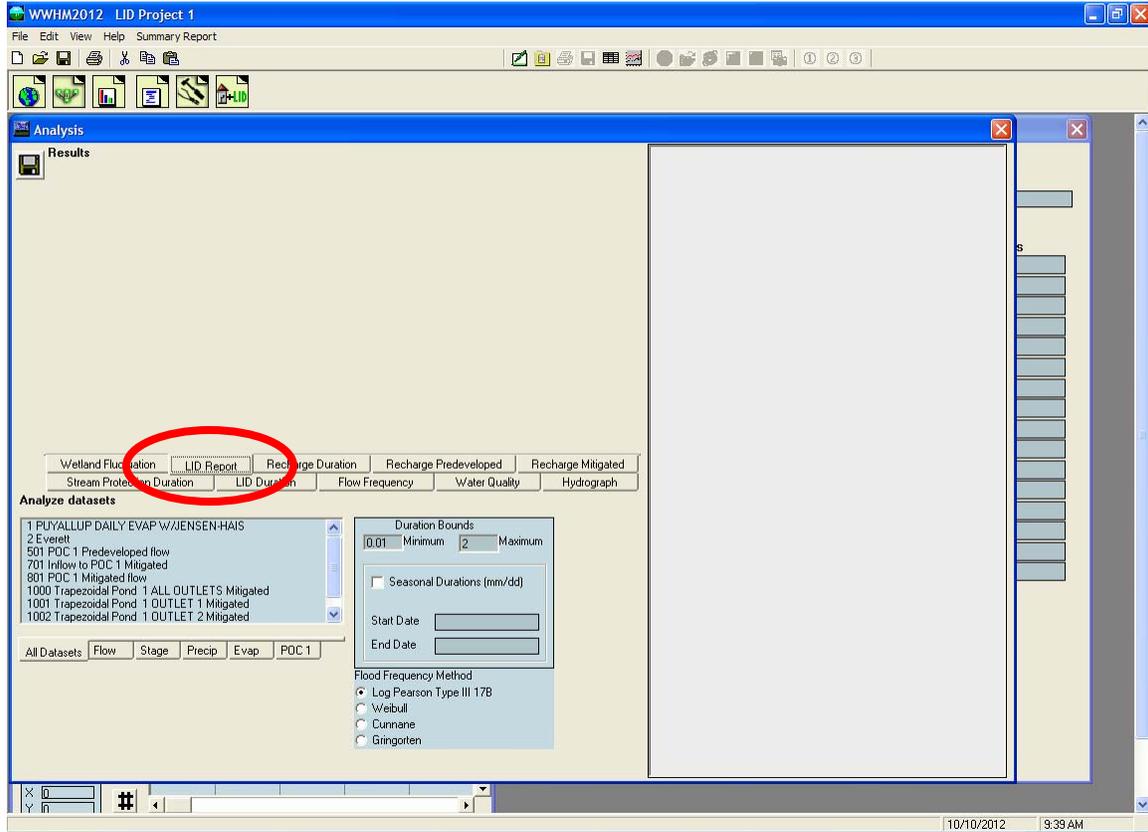
WWHM2012 checks the flow time series using two criteria:

1. Daily mitigated flow volumes cannot change by more than 20% compared to the same daily predevelopment flow volumes.
2. Monthly mitigated flow volumes cannot change by more than 15% compared to the same monthly predevelopment flow volumes.

The wetland fluctuation results are shown in both graphical and tabular format. The graph shows the volumes (scale on the right) for the predevelopment daily flows in blue, the mitigated developed daily flows in red, and the percentage of the predevelopment volume values (scale on the left) in green.

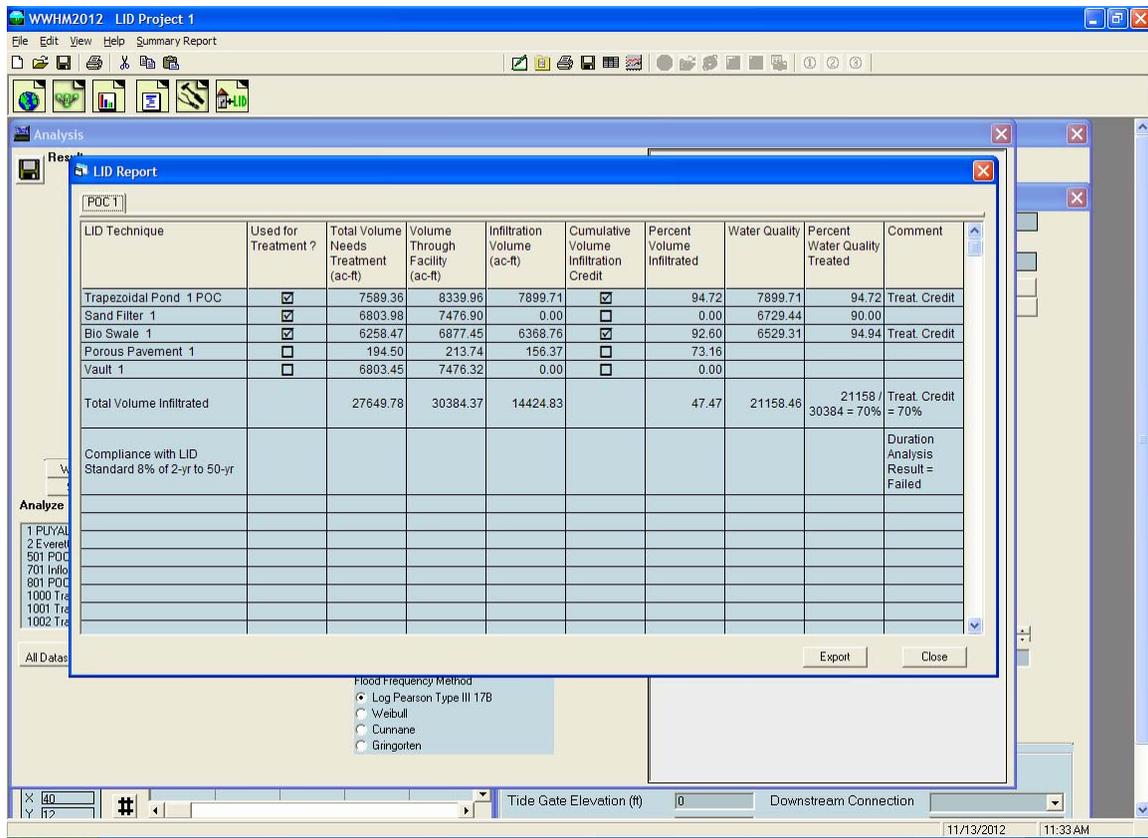
In the above example there is too much daily and monthly mitigated development flow and neither wetland fluctuation criterion is not passed, as shown in the table on the right. As with flow duration, one “Fail” is all that is needed to fail the standard. In this situation the only way to meet the wetland fluctuation standard is to infiltrate or evaporate some of the excess mitigated flow volume so that the reduced mitigated flow volume is more in the range of the predevelopment flows.

LID Analysis



Note that the LID Report can be accessed from both the Analysis screen and the LID Scenario Generator screen.

The LID Report has been created to determine if the modeled LID facilities meet Washington State Department of Ecology (DOE) requirements for low impact development.



Clicking on the “LID Report” tab produces the LID Report that lists all of the LID facilities in the Mitigated scenario and their performance.

The column “Total Volume Needs Treatment (ac-ft)” is volume that equals 91% of the total runoff volume through the facility for the entire model simulation period.

The column “Volume Through Facility (ac-ft)” is the actual total runoff volume through the facility for the entire model simulation period.

“Infiltration Volume (ac-ft)” is the actual total runoff volume that is infiltrated for the entire model simulation period. In the case of the sand filter the infiltration volume is actually the volume that is filtered and then continues downstream to the next stormwater facility.

“Percent Volume Infiltrated” is the percentage of the “Infiltration Volume” column volume to the “Volume Through Facility” column volume.

“Water Quality” is the actual total runoff volume that is filtered through the soil column. This is not necessarily the same as the infiltration volume. For this example, the bioretention facility has more water quality volume than infiltration volume. This is because some of the flow through the bioretention amended soil layers was then discharged via an underdrain to the next downstream facility (in this case, a stormwater pond with infiltration).

“Percent Water Quality Treated” is the percentage of the “Water Quality” column volume to the “Volume Through Facility” column volume.

The Comment column reports “Treat Credit” if the LID facility water quality treatment meets Ecology’s water quality treatment standard of treating at least 91% of the total runoff volume through the facility. In this example only the bioretention and pond meet the treatment standard.

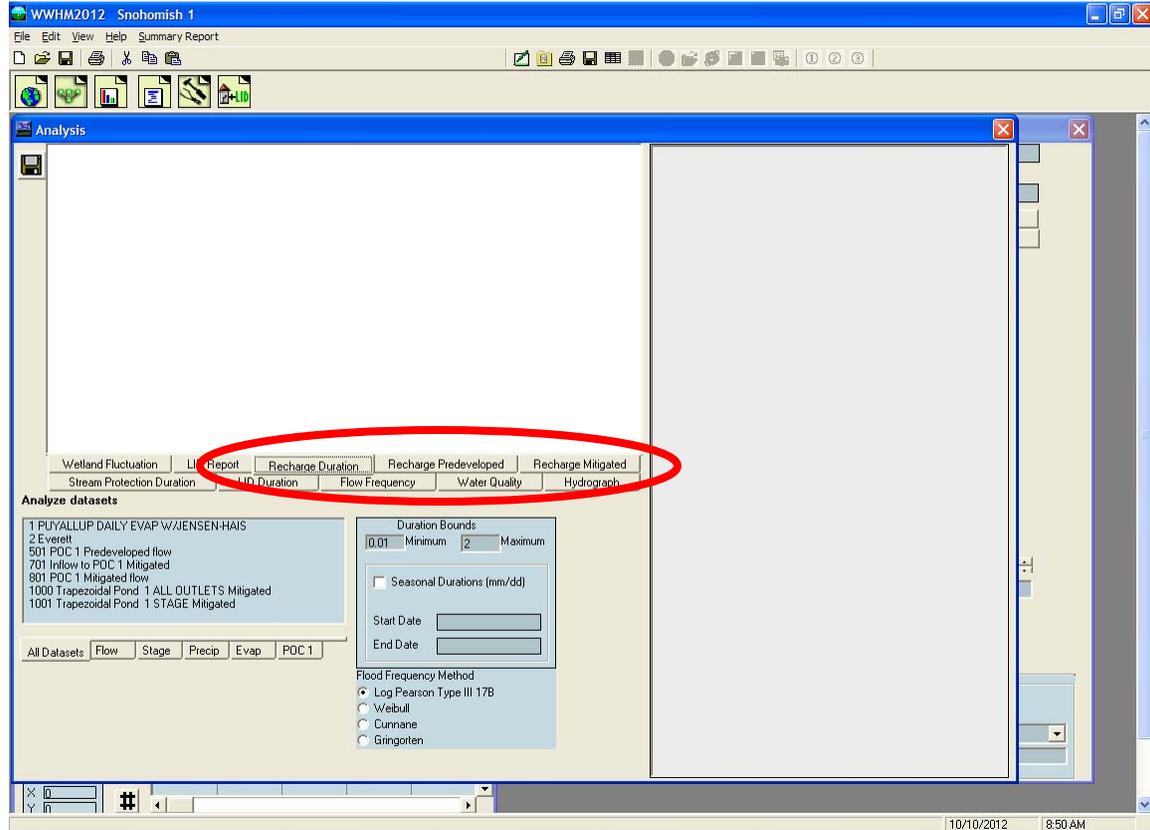
If a facility is used for water quality treatment then the corresponding box in the “Used for Treatment” column is checked.

In this example the “Used for Treatment” boxes for the trapezoidal pond, sand filter, and bioretention swale are checked. The percent water quality treated values are 94.72, 90.00, and 94.94, respectively. (The sand filter did not meet the minimum treatment requirement of 91.00 and therefore it does not receive the “Treat Credit” designation.) The total runoff volume treated is 70%.

Note that Porous Pavement 1 facility’s “Used for Treatment” box was left unchecked. If porous pavement is going to be used for water quality treatment then soil mix must be used in the sublayers under the porous pavement layer. See the Ecology 2012 *Stormwater Management Manual for Western Washington* for specific details.

The LID flow duration is automatically calculated.

Recharge

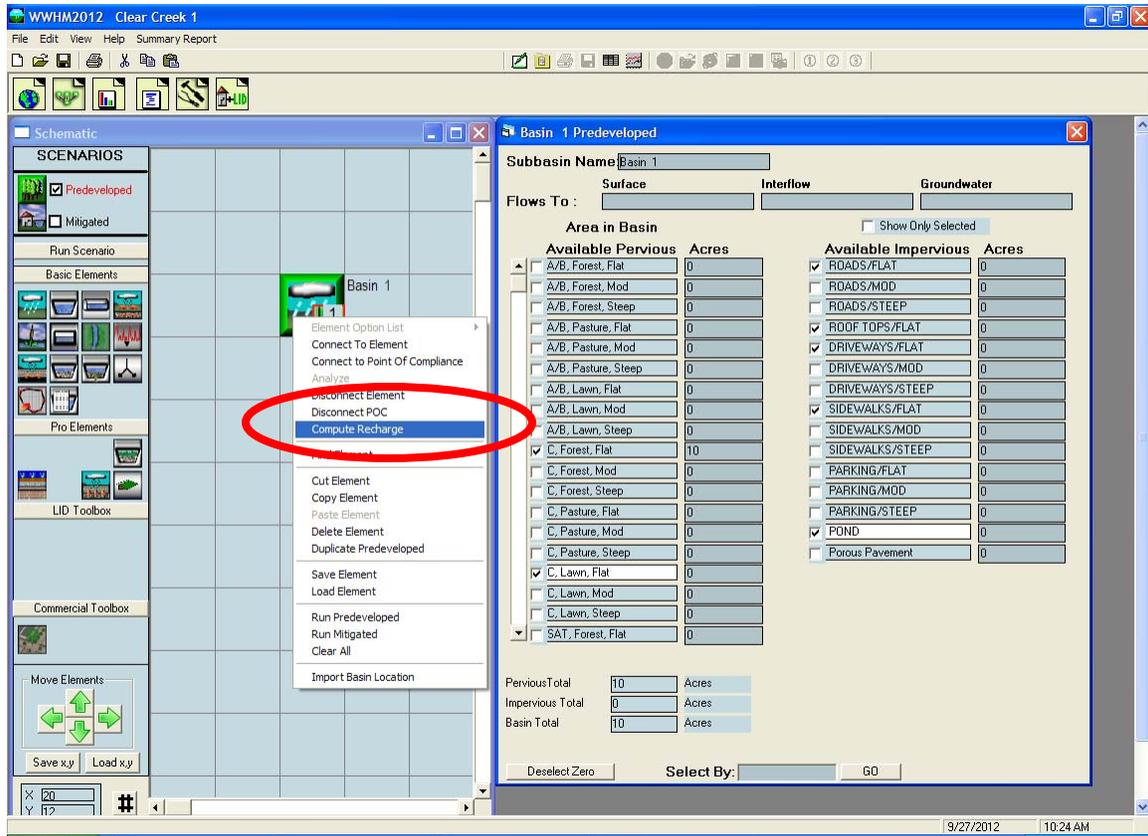


Recharge is the amount of water that becomes groundwater. Recharge can occur both through land use basins (groundwater component of runoff) and conveyance facilities (infiltration discharge).

Groundwater recharge is not a Department of Ecology stormwater requirement. However, some local jurisdictions (for example, Kitsap County) do have a groundwater recharge requirement. Contact the local permitting agency to determine whether or not recharge analysis is required.

There are three recharge tabs in the Analysis screen: Recharge Duration, Recharge Predeveloped, and Recharge Mitigated.

Before recharge can be calculated for any of the three recharge tabs it needs to be turned on for the elements for which recharge data are needed.



Recharge must be turned on for each individual element for which recharge calculations are required. This is done by right clicking on the element of interest and then selecting the “Compute Recharge” option.

Once “Compute Recharge” is selected the element will include a small “R” in the element picture.

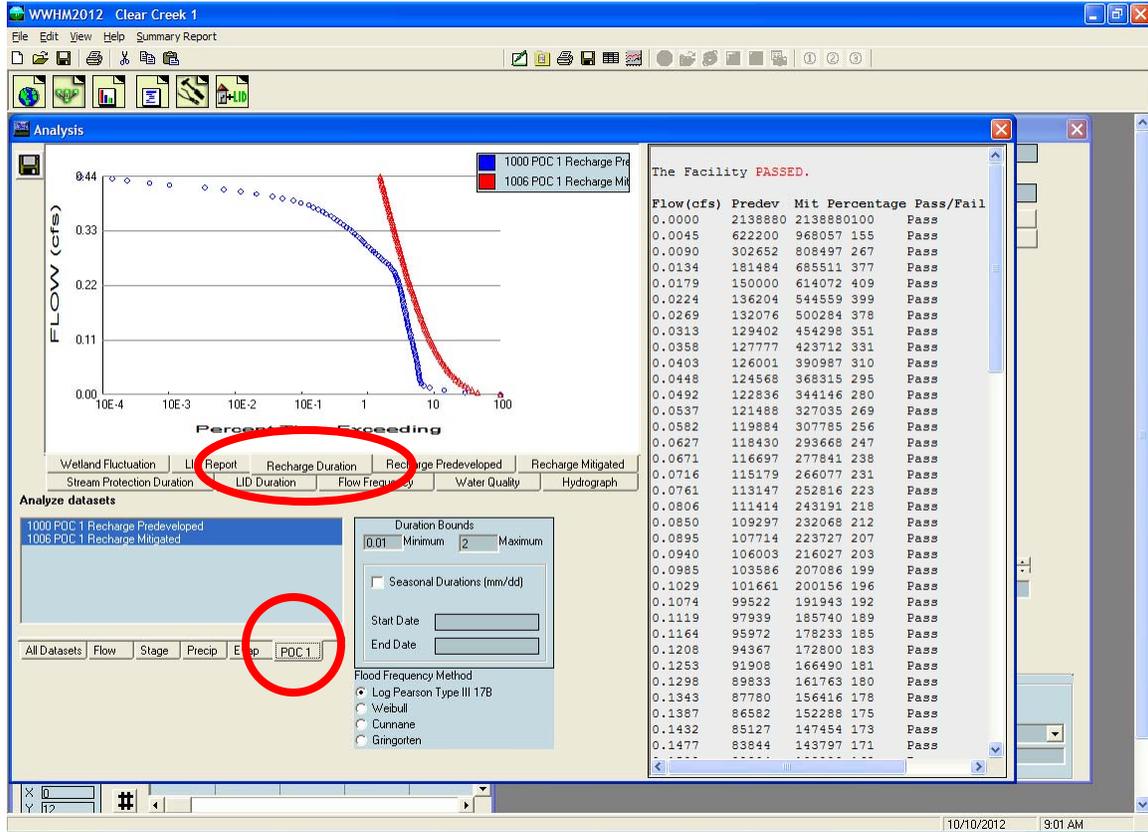
To compute the total recharge for a scenario then all of the elements should have “Compute Recharge” turned on.

If the scenarios have been run prior to turning on the recharge option then they need to be rerun to generate the recharge data. This is done by clicking on the “Run Scenario” button for each of the two scenarios (Predeveloped and Mitigated).

The “Compute Recharge” box in the Options, Recharge screen must also be checked before recharge is calculated.



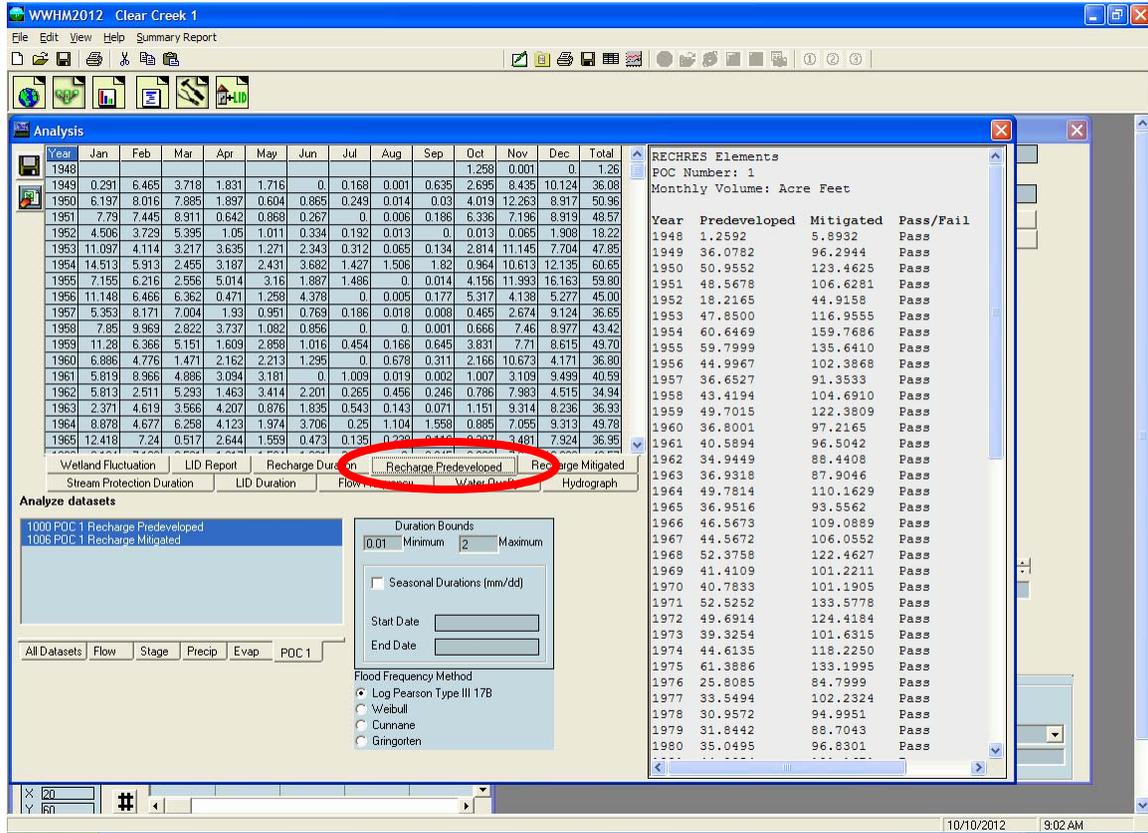
Recharge Duration



Recharge duration is similar to flow duration except that the goal is to have the Mitigated recharge greater than or equal to the Predeveloped recharge, rather than less than or equal to for erosive flows in the flow duration analysis.

The user selects “Recharge Duration” and then the POC 1 tab to compute recharge duration. WWHM2012 selects the appropriate recharge time series (in this example, 1000 and 1006) for the duration comparison. This example passes the recharge duration criteria because all of the Mitigated recharge flows occurs more often than the Predeveloped recharge flows.

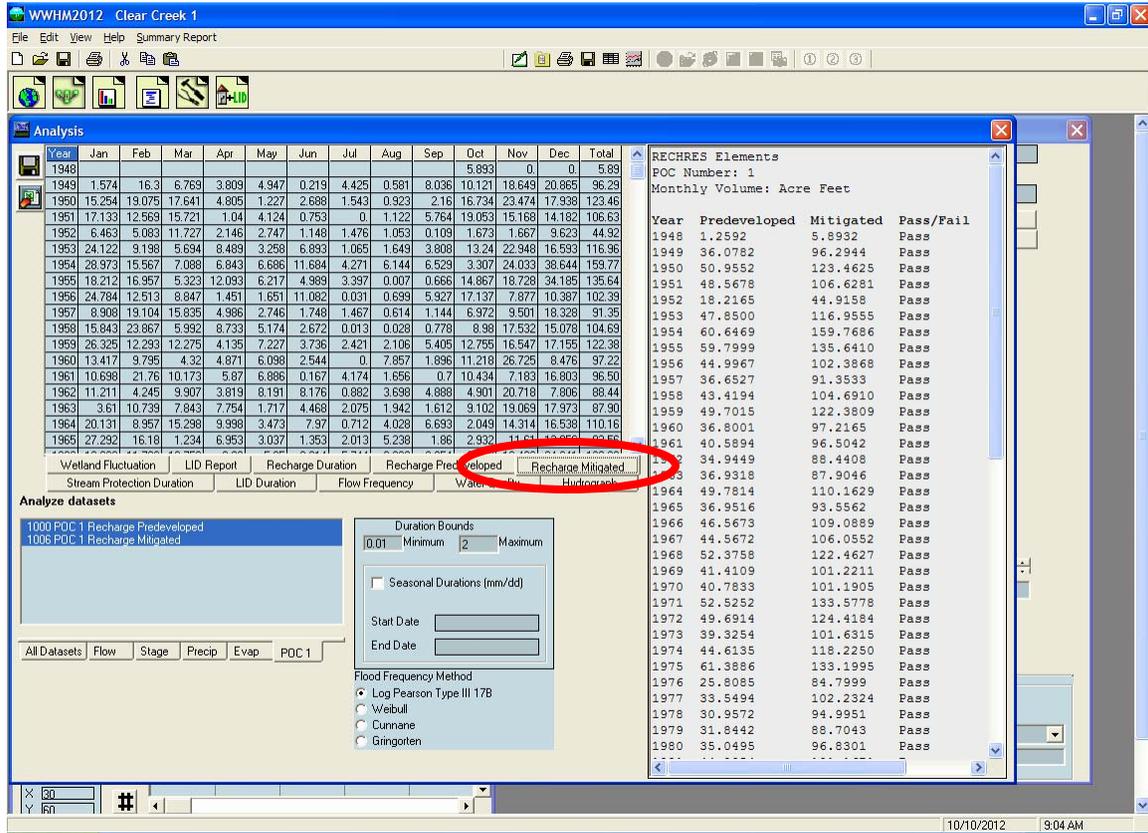
Recharge Predeveloped



The “Recharge Predeveloped” tab shows a monthly summary of the Predevelopment recharge (in acre-feet) for each simulation year on a calendar-year basis.

The table at the right provides a comparison of the Predeveloped and Mitigated recharge for each calendar year. “Pass” means that the Mitigated recharge is greater than or equal to the Predeveloped recharge.

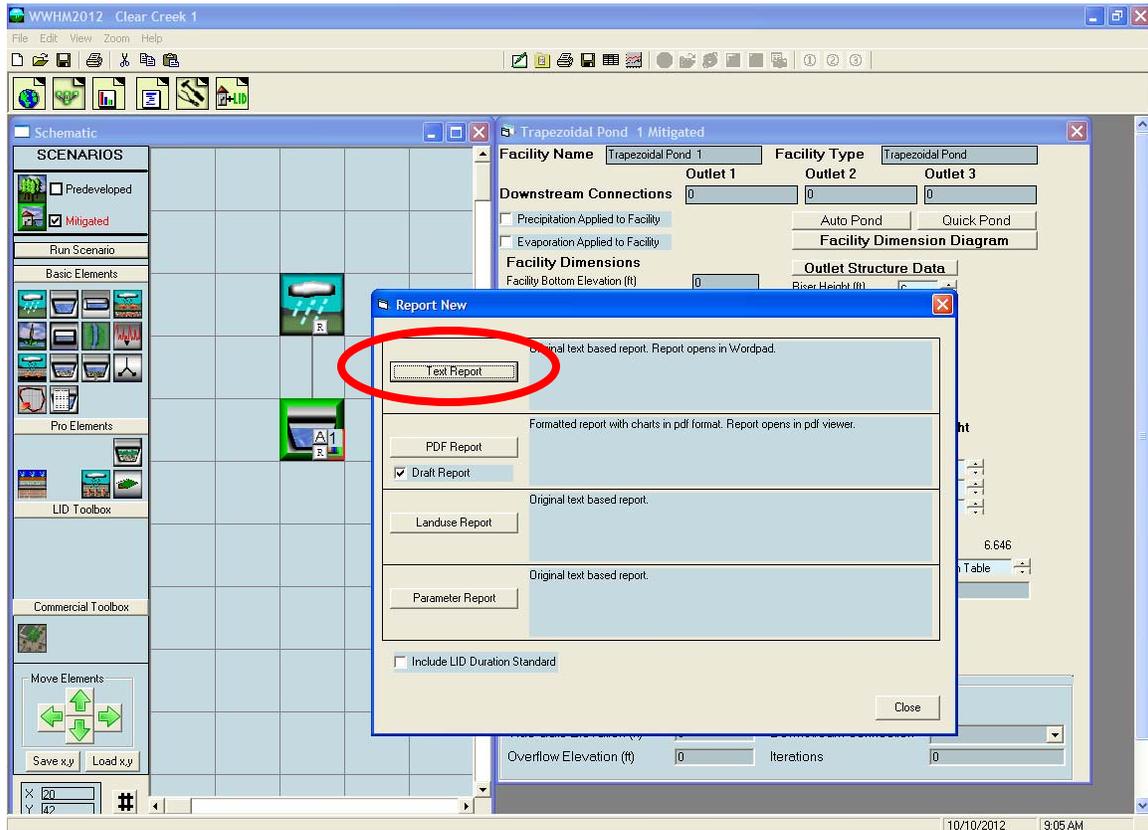
Recharge Mitigated



The “Recharge Mitigated” tab shows a monthly summary of the Mitigated recharge (in acre-feet) for each simulation year on a calendar-year basis.

The table at the right provides a comparison of the Predeveloped and Mitigated recharge for each calendar year. “Pass” means that the Mitigated recharge is greater than or equal to the Predeveloped recharge.

REPORTS SCREEN



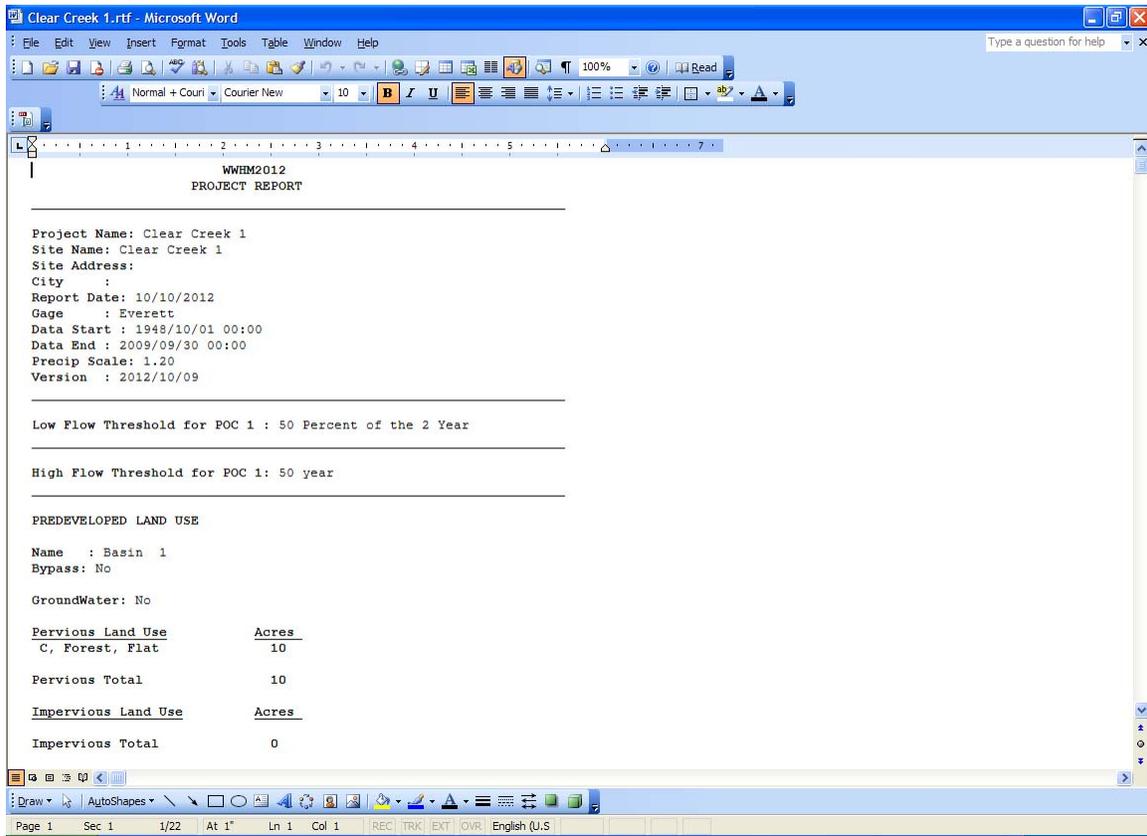
Click on the Reports tool bar button (fourth from the left) to generate a project report.

The project report is a separate file that contains all of the user-provided input and a summary of the model output. The project report file can be saved or printed.

The user has the option of producing the report file in a number of different formats.

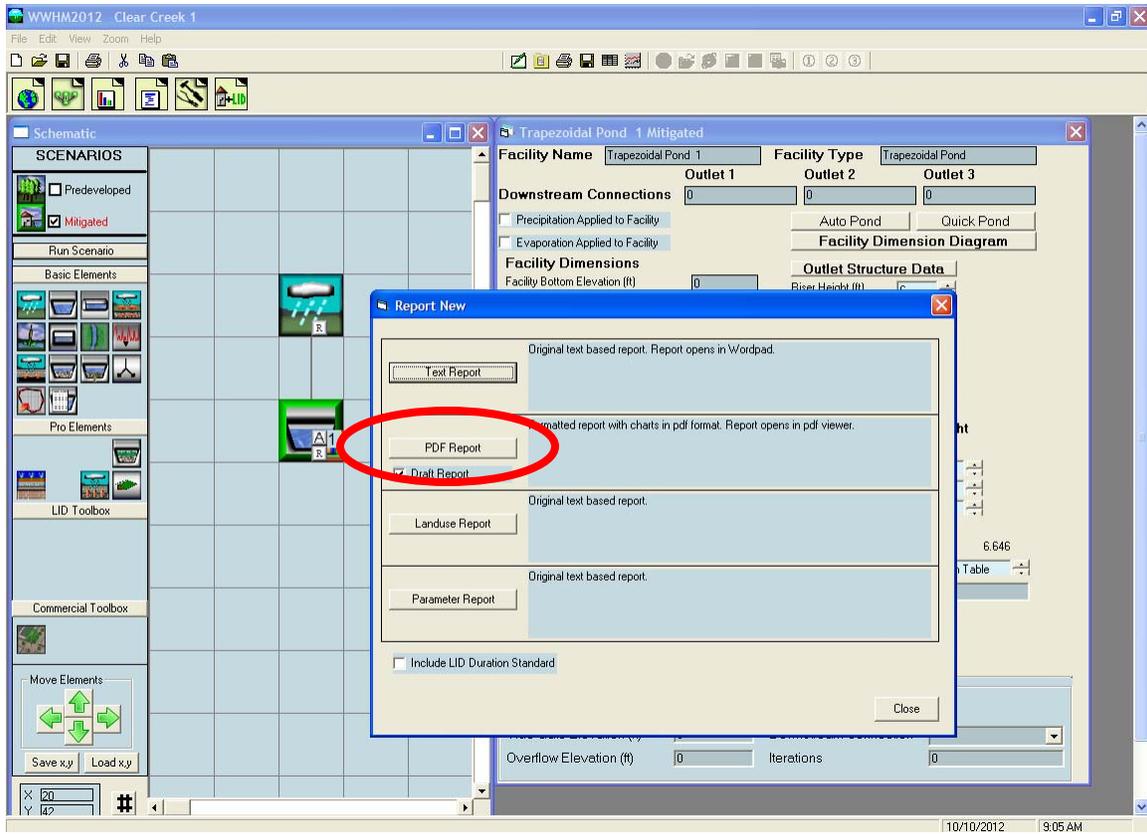
Click on “Text Report” button to generate the report file in WordPad RTF format.

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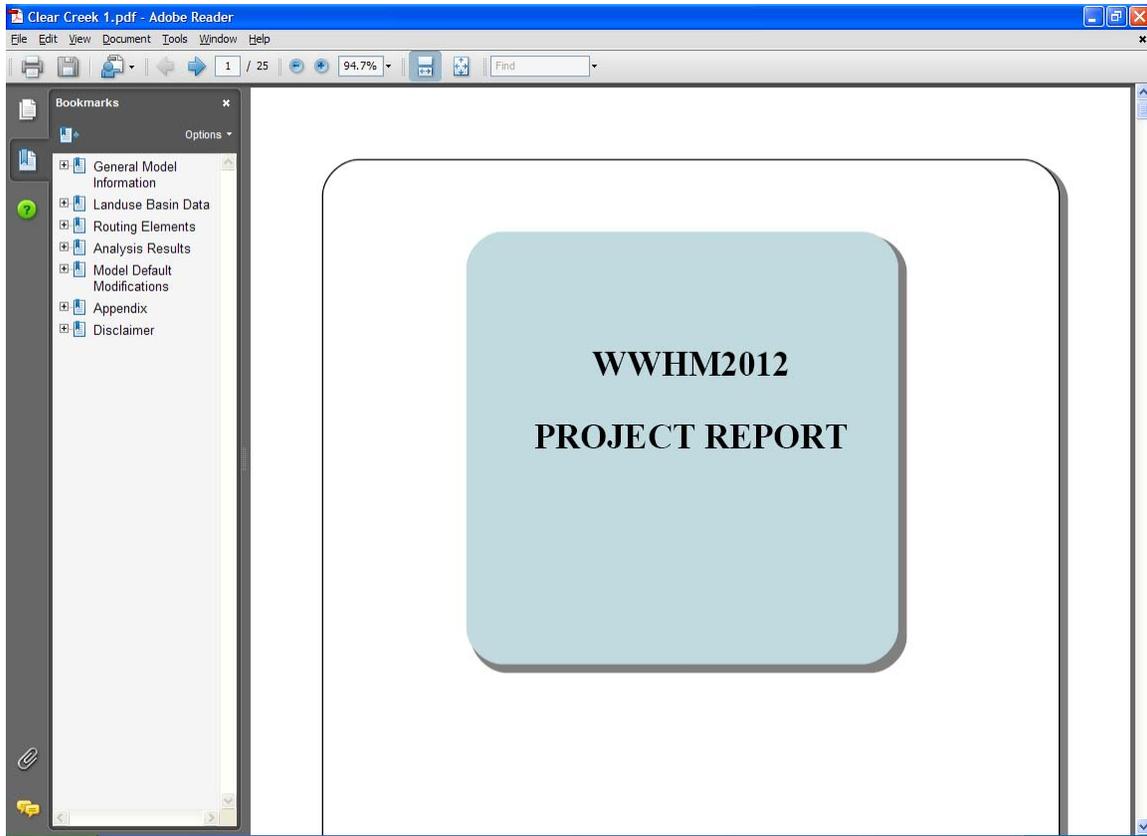


Scroll down the WordPad screen to see all of the results.

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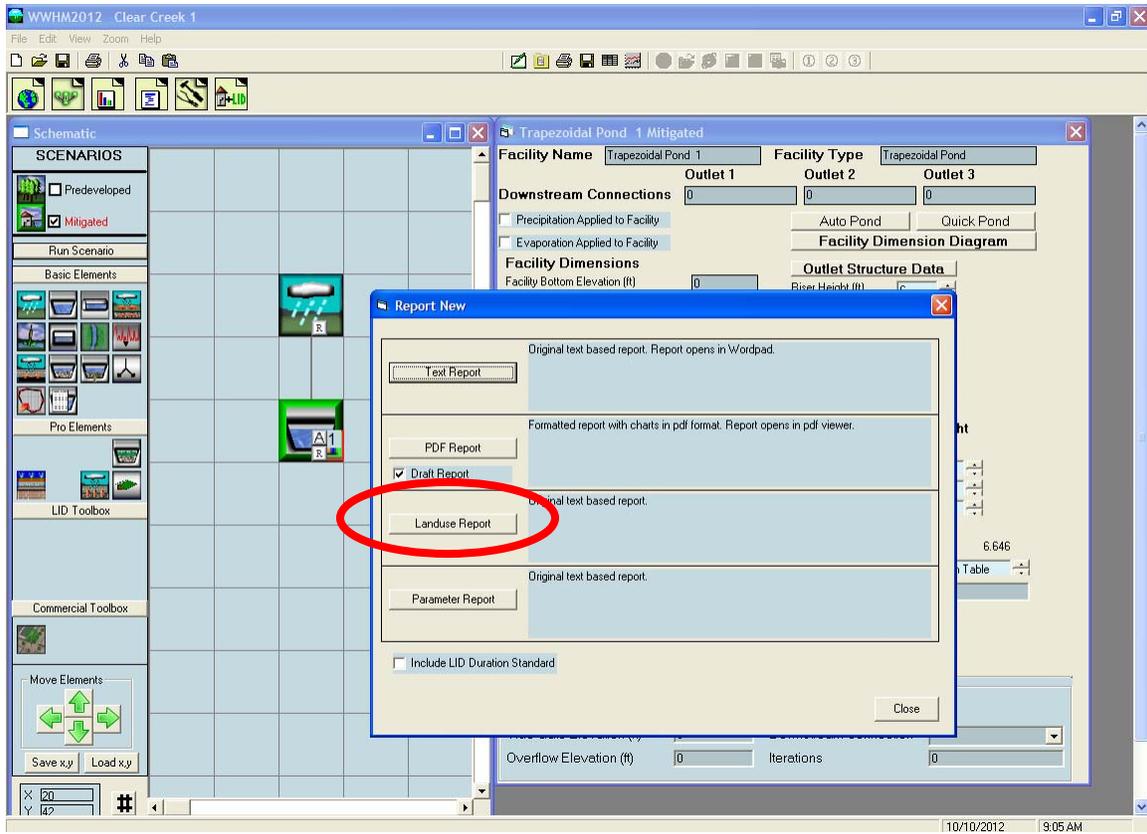


Click on “PDF Report” button to generate the report file in PDF format.



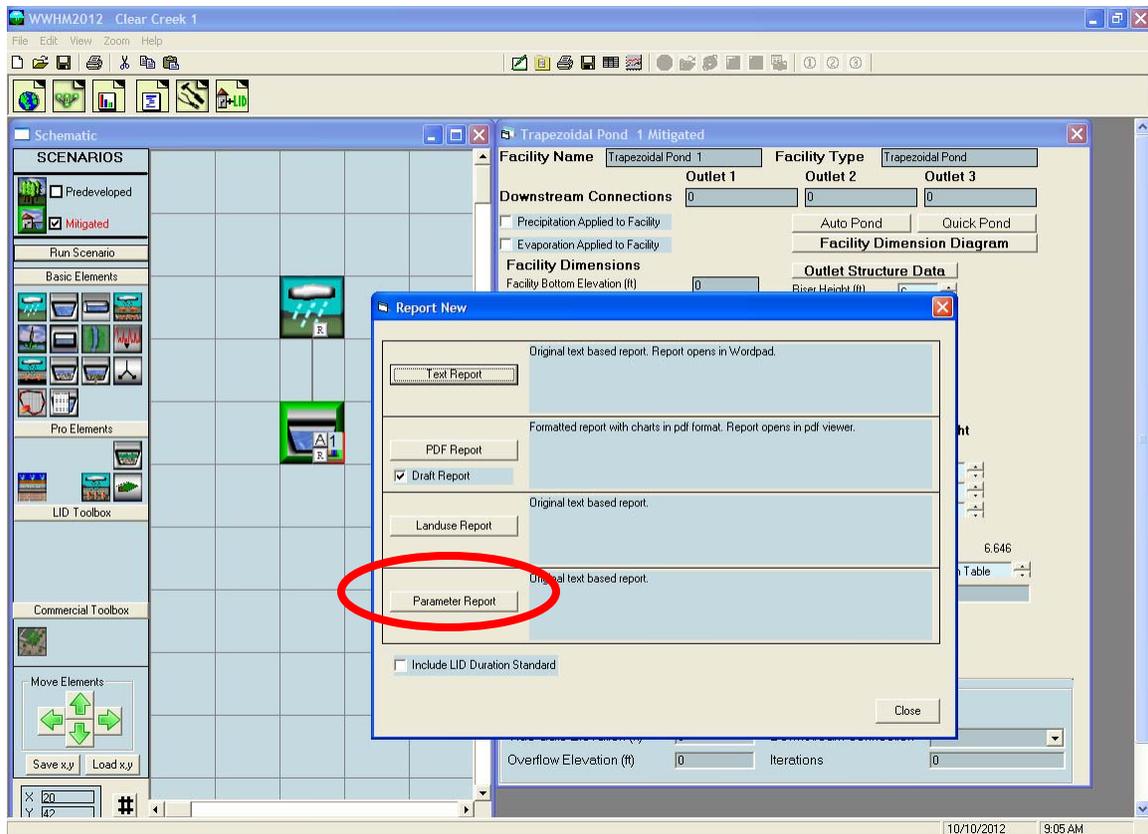
Scroll down the PDF screen to see all of the results or select specific sections using the bookmarks at the left.

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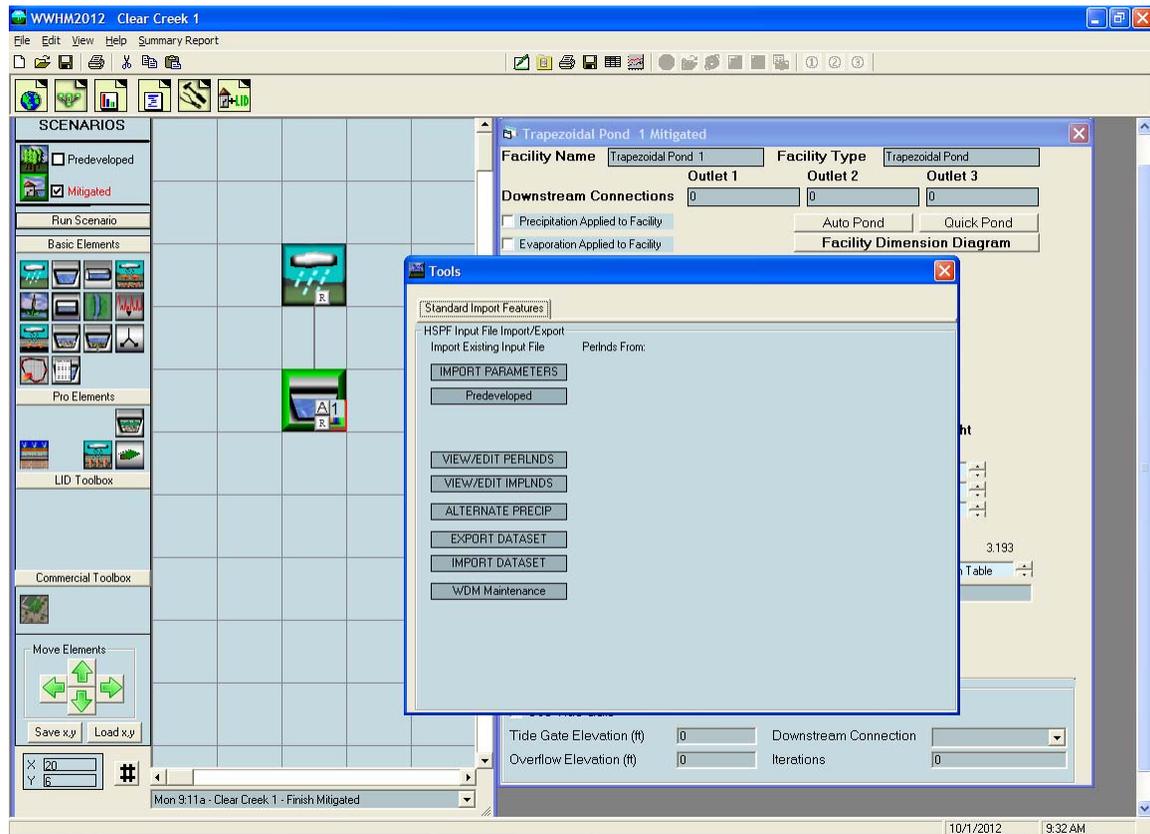
Click on “Landuse Report” button to generate a listing of the input basin land use data in WordPad RTF format.

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Click on “Parameter Report” button to generate a listing of the HSPF input parameter values that have been reported from their default values. The listing is in WordPad RTF format. If the listing is blank then there have been no HSPF input parameter value changes made.

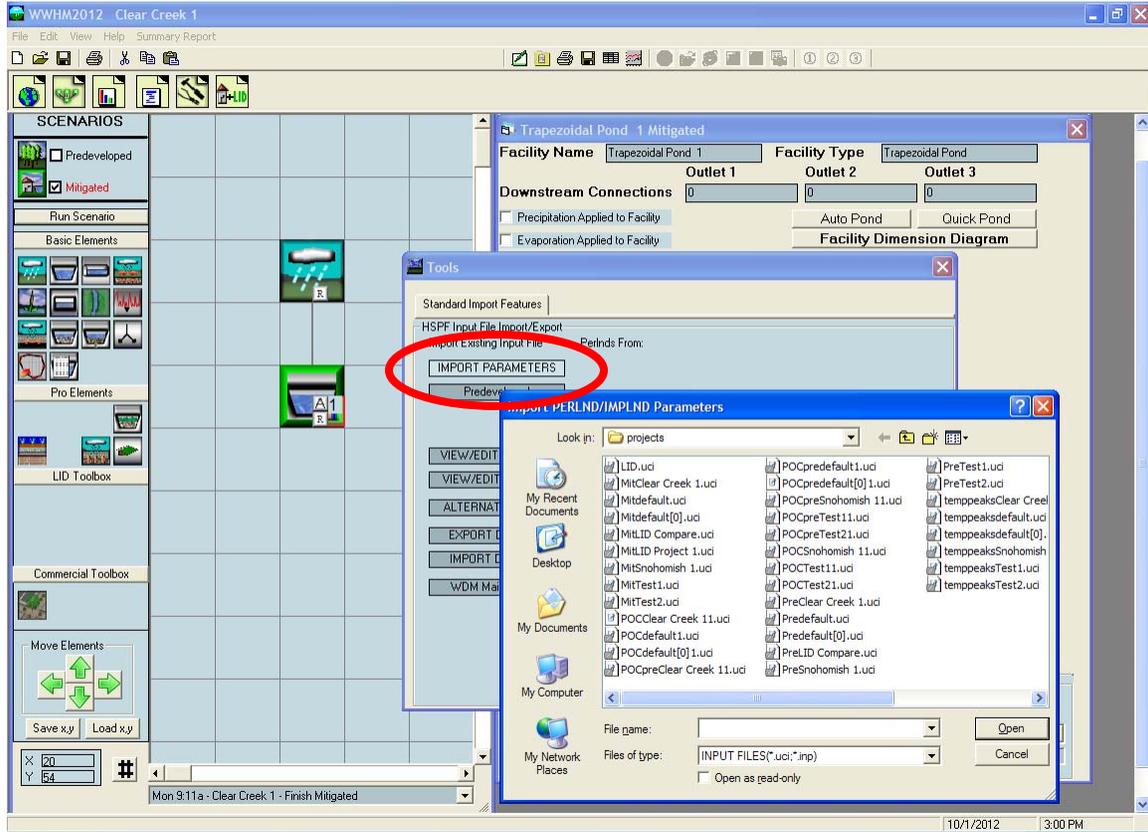
TOOLS SCREEN



The Tools screen is accessed with the Tools tool bar (second from the right). The purposes of the Tools screen are:

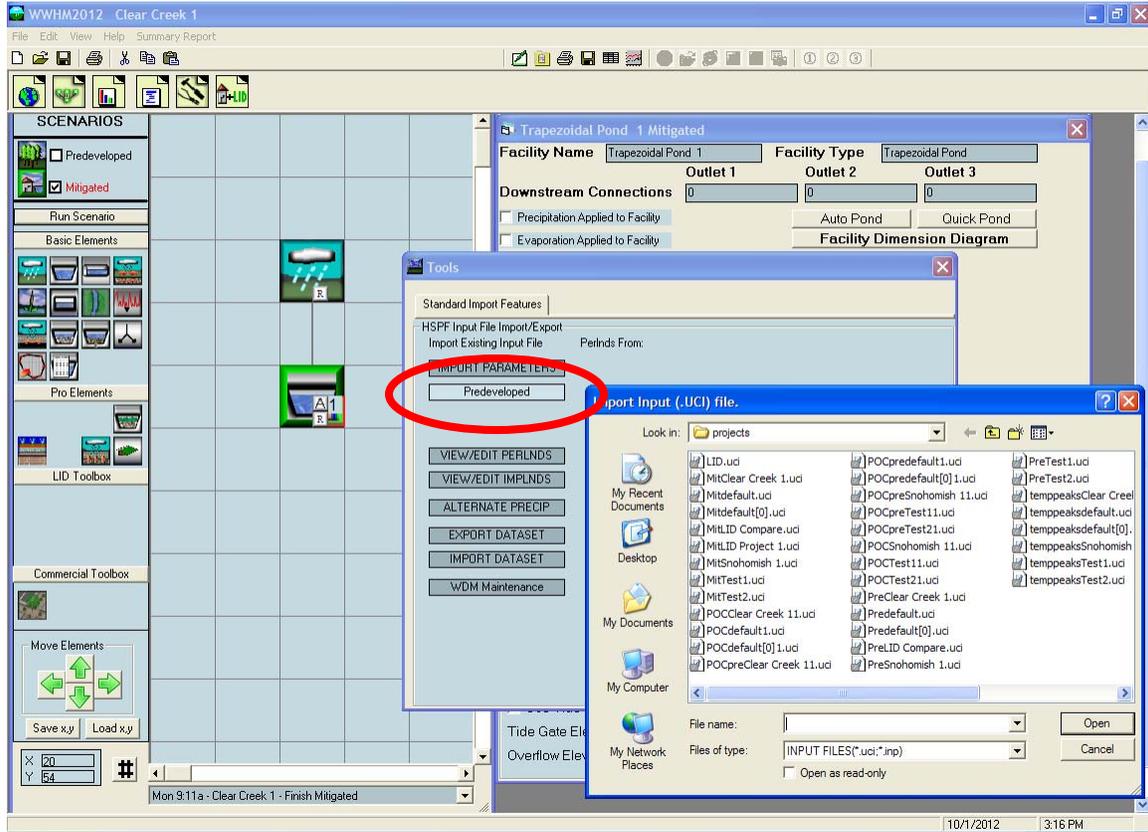
- (1) To allow users to import HSPF PERLND from existing HSPF UCI files and/or view and edit WWHM2012 PERLND parameter values.
- (2) To allow users to use alternate precipitation time series data.
- (3) To allow users to import or export time series datasets.
- (4) To allow users to do HSPF WDM maintenance tasks, as needed.

Import Parameters



Import Parameters allows the user to import the HSPF parameter values from an HSPF UCI (User Control Input) file that has been created outside of WWHM2012. This UCI file must have a file name with an UCI or INP extension.

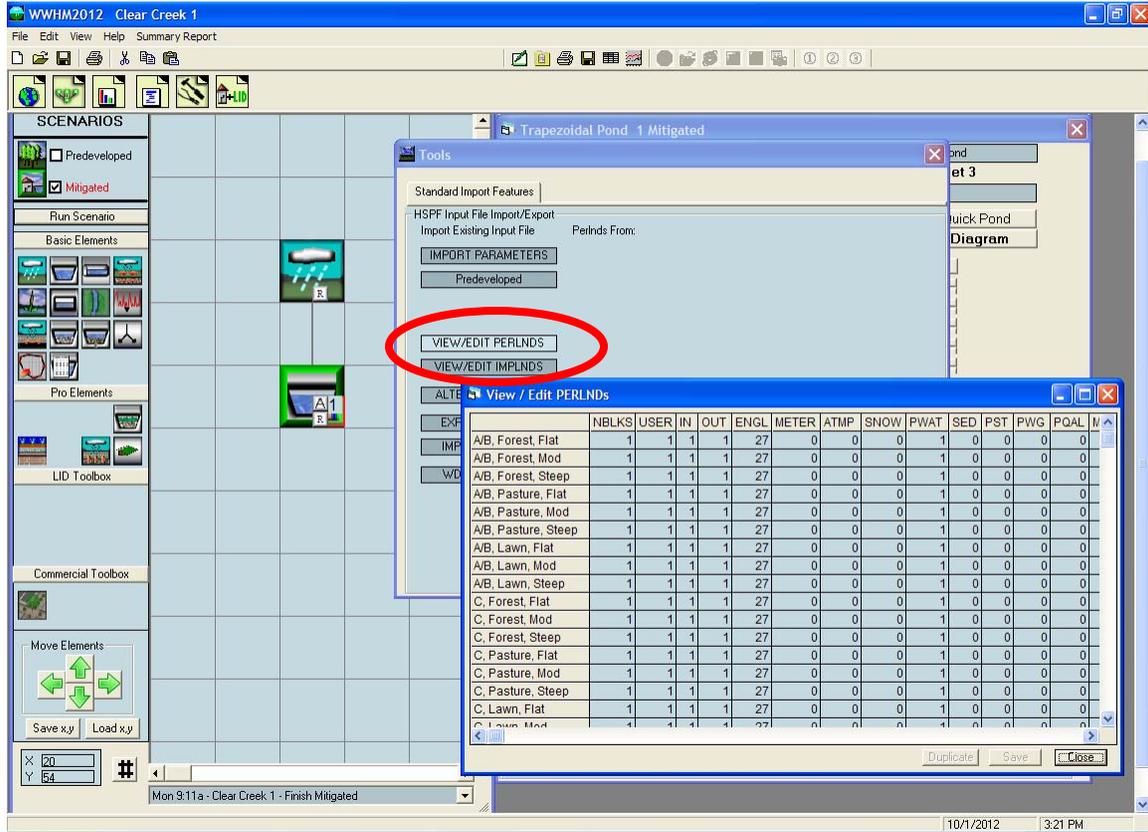
Predeveloped



Predeveloped allows the user to import an entire HSPF UCI (User Control Input) file that has been created outside of WWHM2012. This UCI file is input to the Predeveloped scenario. All HSPF RCHRES are translated into SSD Table elements.

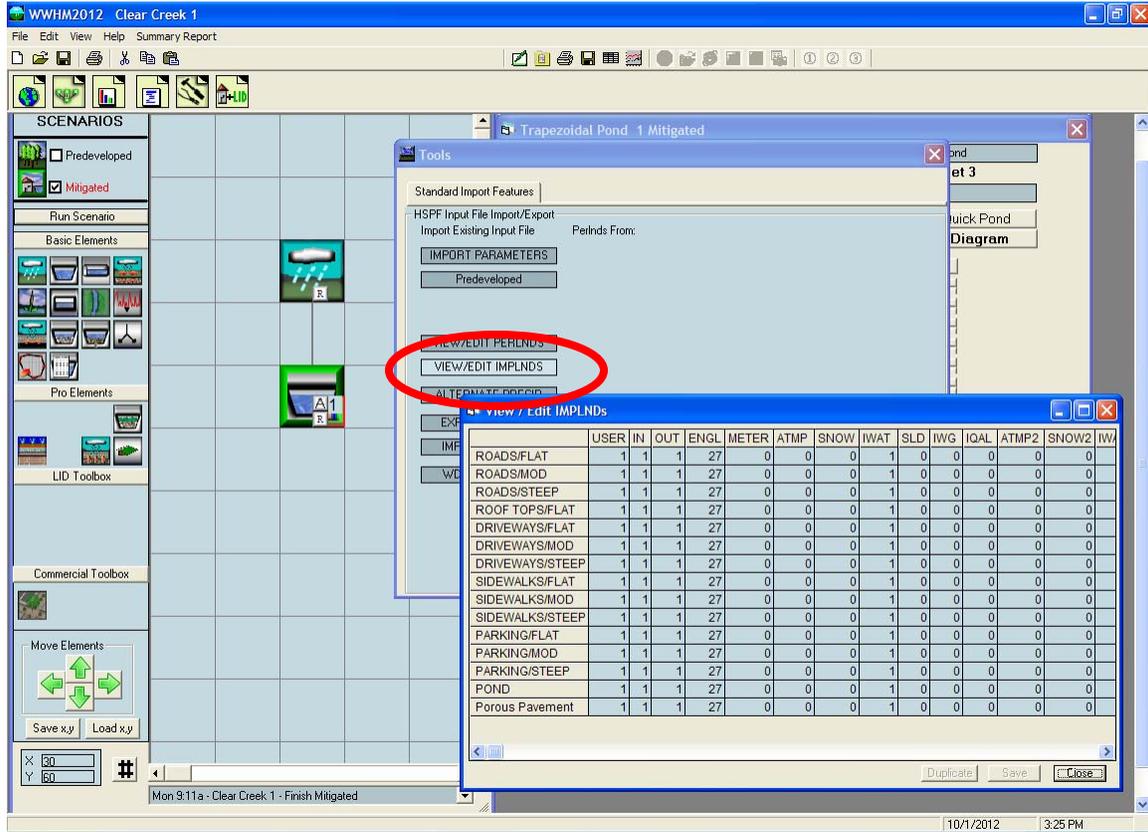
This UCI file must have a file name with an UCI or INP extension.

View/Edit PERLNDS



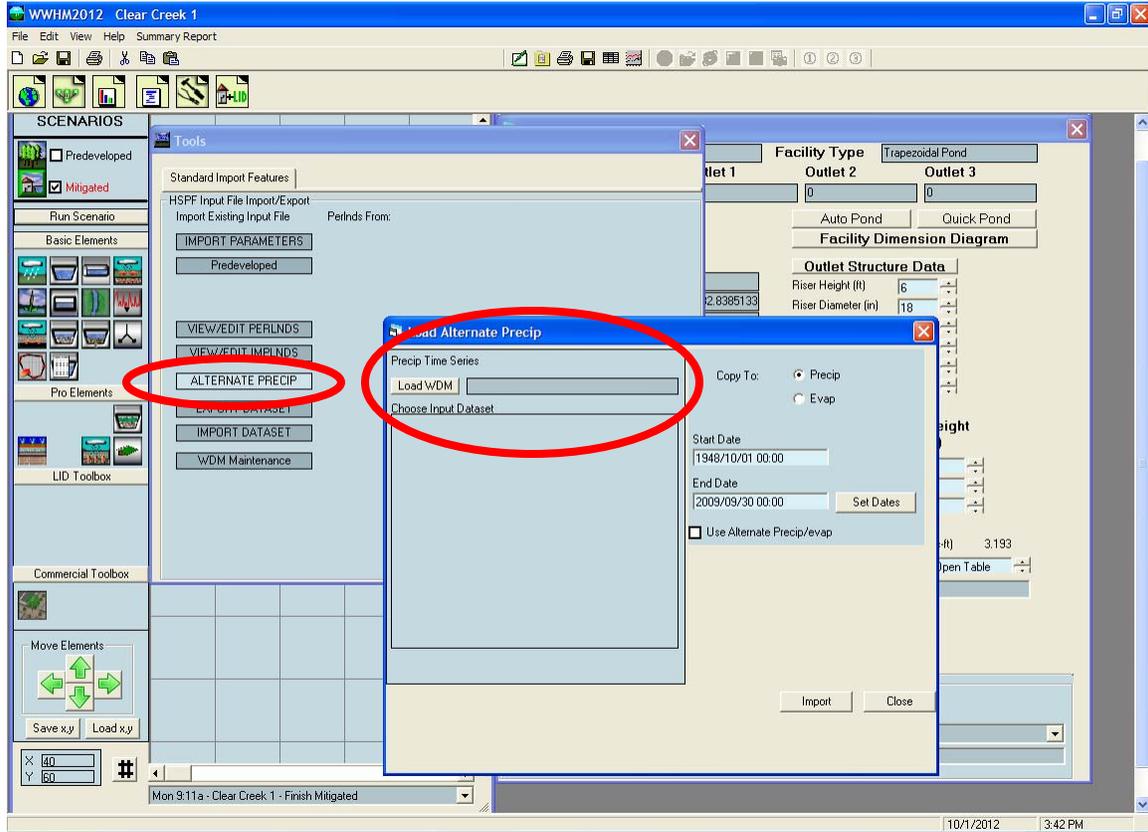
View/Edit PERLNDS allows the user to view and edit the HSPF PERLND Block values used in WWHM2012. Any changes to these values should be approved by the reviewing/permitting agency. All changes will be reported in the Parameter Report file created in the Reports menu.

View/Edit IMPLNDS



View/Edit IMPLNDS allows the user to view and edit the HSPF IMPLND Block values used in WWHM2012. Any changes to these values should be approved by the reviewing/permitting agency. All changes will be reported in the Parameter Report file created in the Reports menu.

Alternate Precip



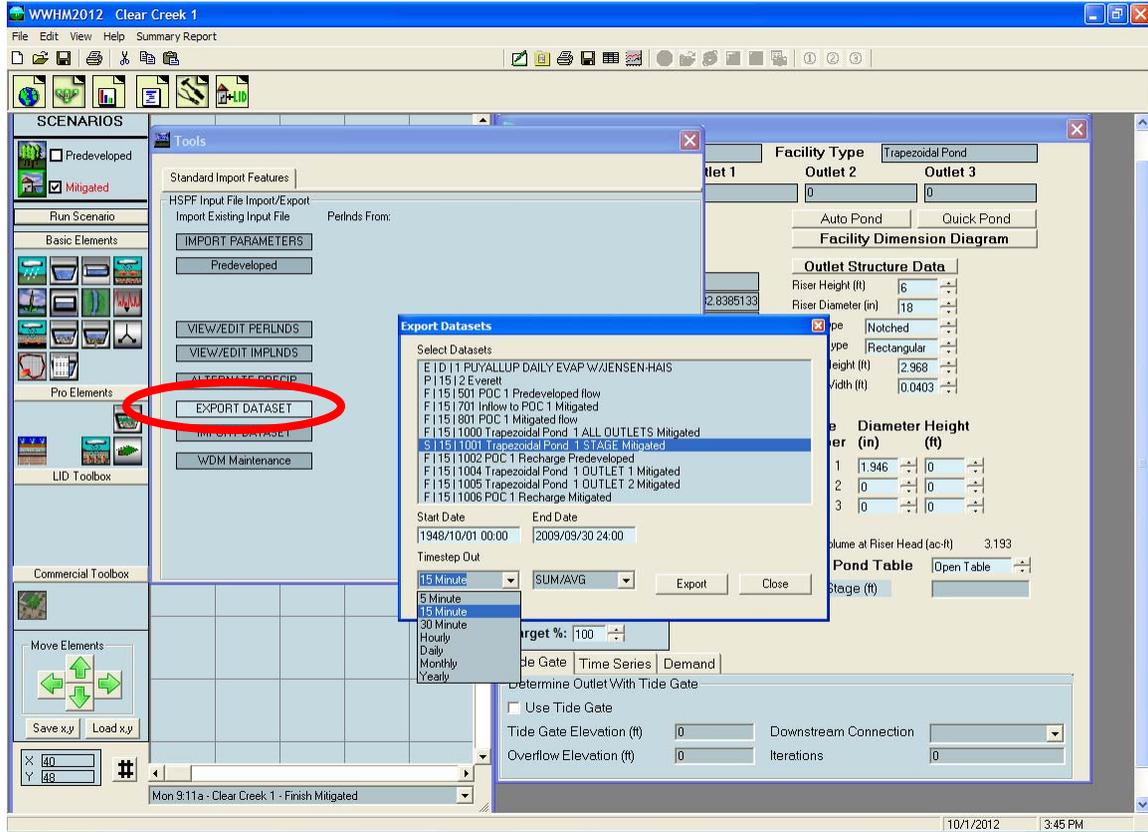
Alternate Precip allows the user to replace the default precipitation time series data file and/or evaporation (potential evapotranspiration) time series data file with a different file created and stored in a separate HSPF WDM file.

Click on “Load WDM” to select the HSPF WDM file that contains the appropriate alternate precipitation and/or evaporation file. Select the alternate file and whether the file is to be copied to Precip or Evap. If needed, the model simulation run start and/or end dates can be changed to match the start and end dates of the alternate files. Check the “Use Alternate Precip/Evap” box and then click on the “Import” button to import the data.

Once the new data are imported it is always a good idea to plot the new data using Analysis, Hydrograph to double check that the data were imported successfully.

Any changes to either the precipitation or evaporation data should be approved by the reviewing/permitting agency.

Export Dataset

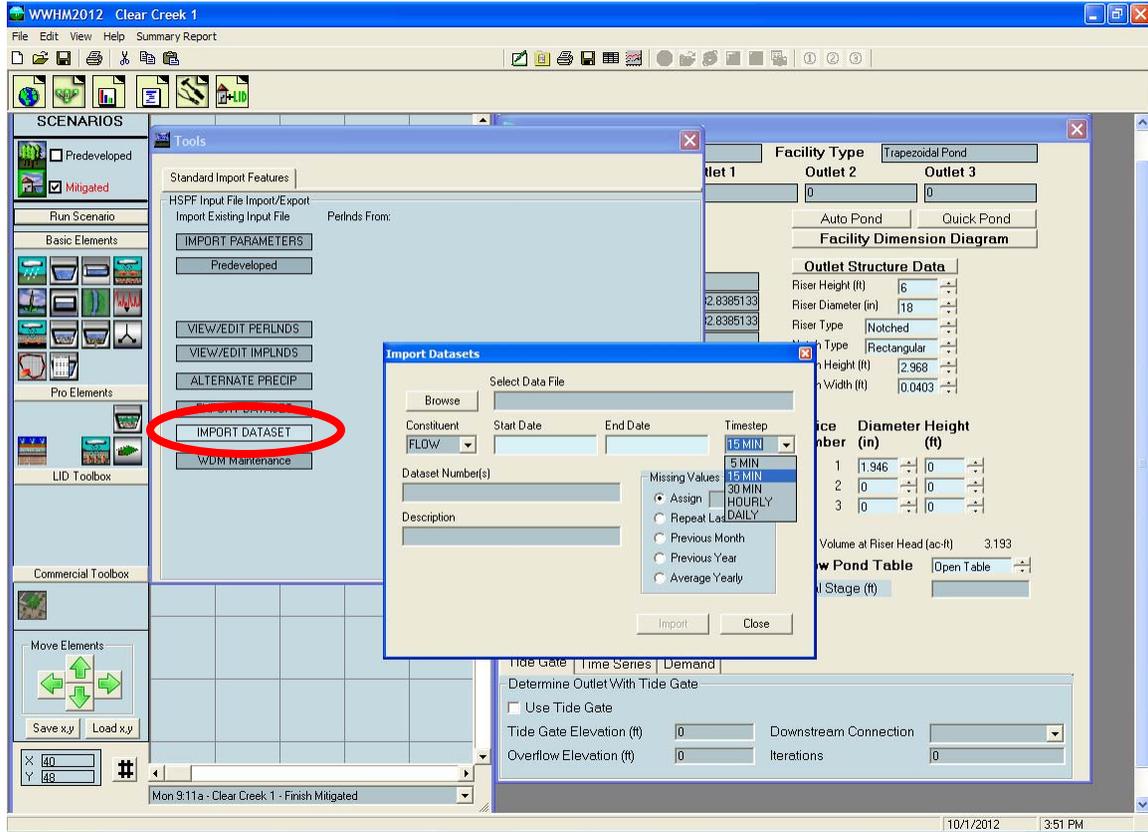


Export Dataset allows the user to export any time series data stored in the WWHM2012 WDM file. This includes precipitation, evaporation, flow, and stage data time series.

Start and end dates can be selected along with the time step and the output option if the time step is greater than the simulation time step. Data can be summed, averaged, or the maximum or minimum selected.

Click on the “Export” button to output the data to a text file for future viewing.

Import Dataset



Import Dataset allows the user to import any time series data stored in an external text file or Excel comma-delimited file into the WWHM2012 WDM file. This includes precipitation, evaporation, flow, and stage data time series.

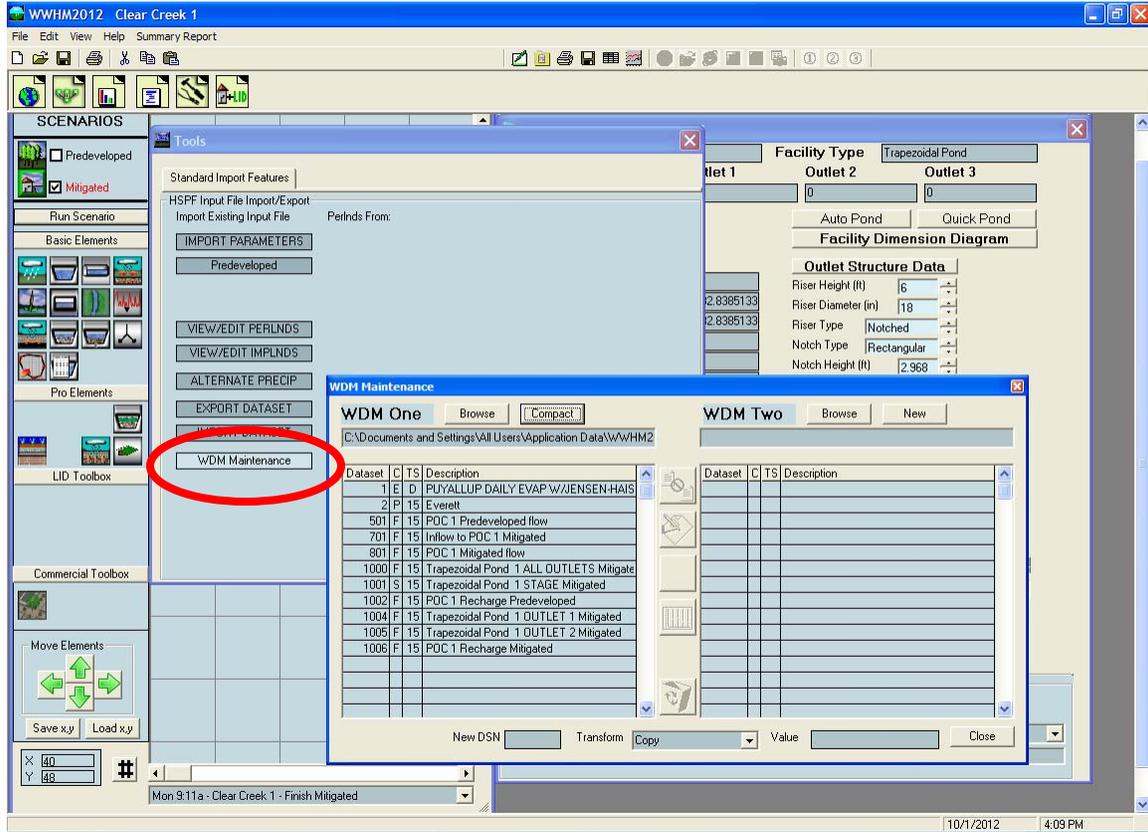
The Constituent (data type), Start Date, End Date, and Timestep all must be specified. A WDM data set number between 1 and 9999 must be assigned to the time series file. This data set number should be unique and not in current use in the WDM file. A description of the data set is optional, but highly recommended.

Missing values must be filled in with some appropriate value. This can be -1 to identify them as missing values or zero or some other number.

Click on the “Import” button to input the data to the WWHM2012 WDM file.

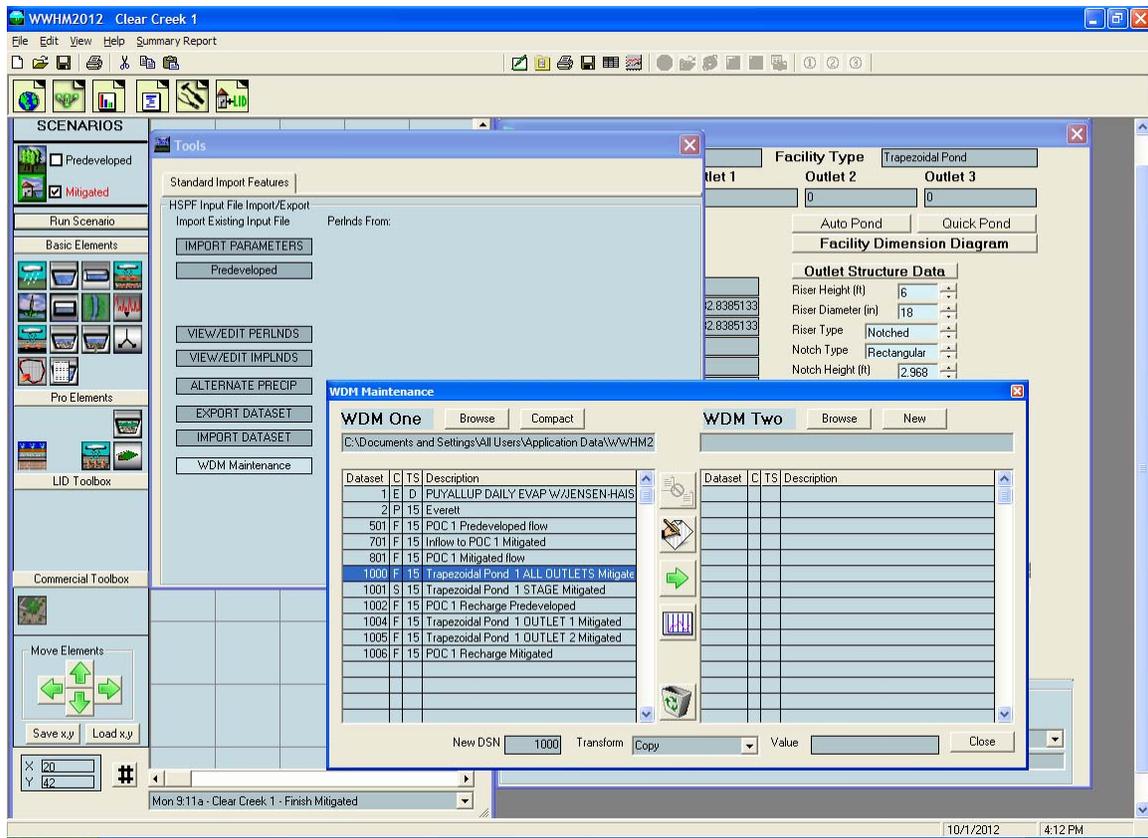
Once the new data are imported it is always a good idea to plot the new data using Analysis, Hydrograph to double check that the data were imported successfully.

WDM Maintenance



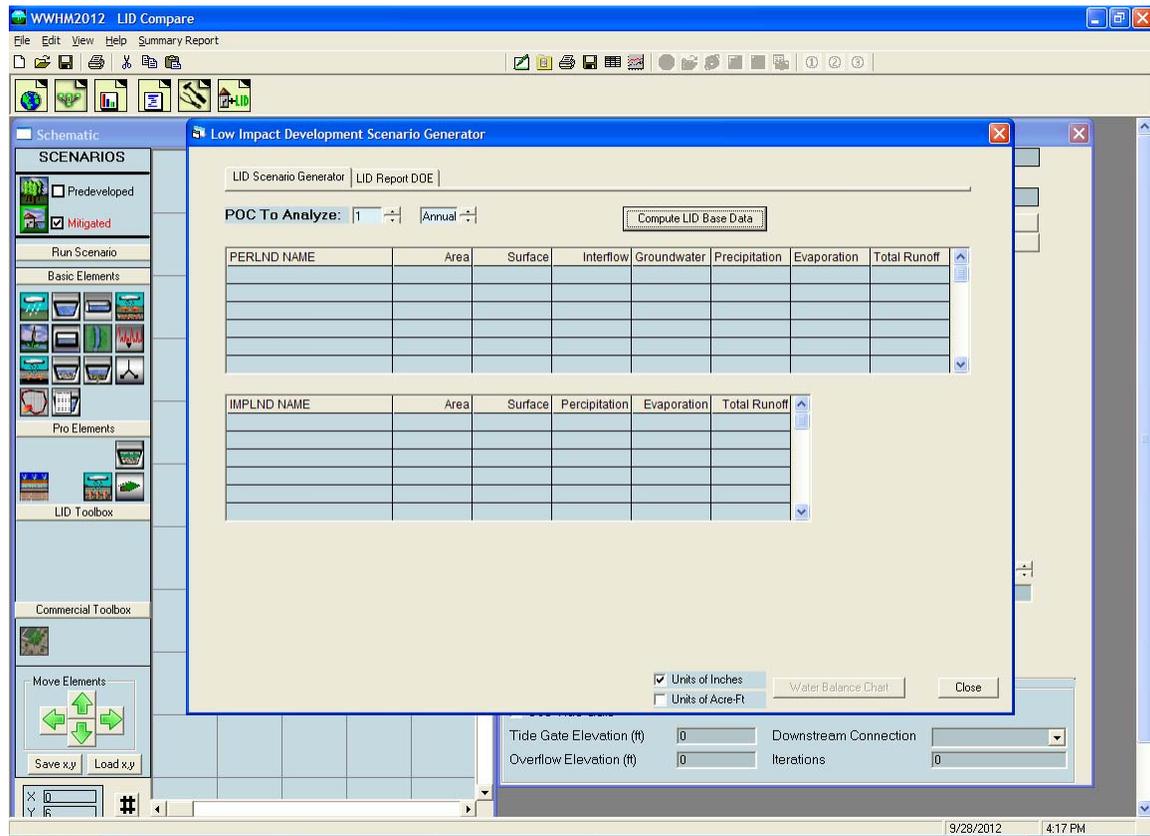
WDM Maintenance allows the user to make changes to the WWHM2012 WDM file data sets and copy time series data files from one WDM to another.

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Selection of a data set time series produces the user with a large range of options, similar to those options available in the EPA HSPF utility program WDMUtil.

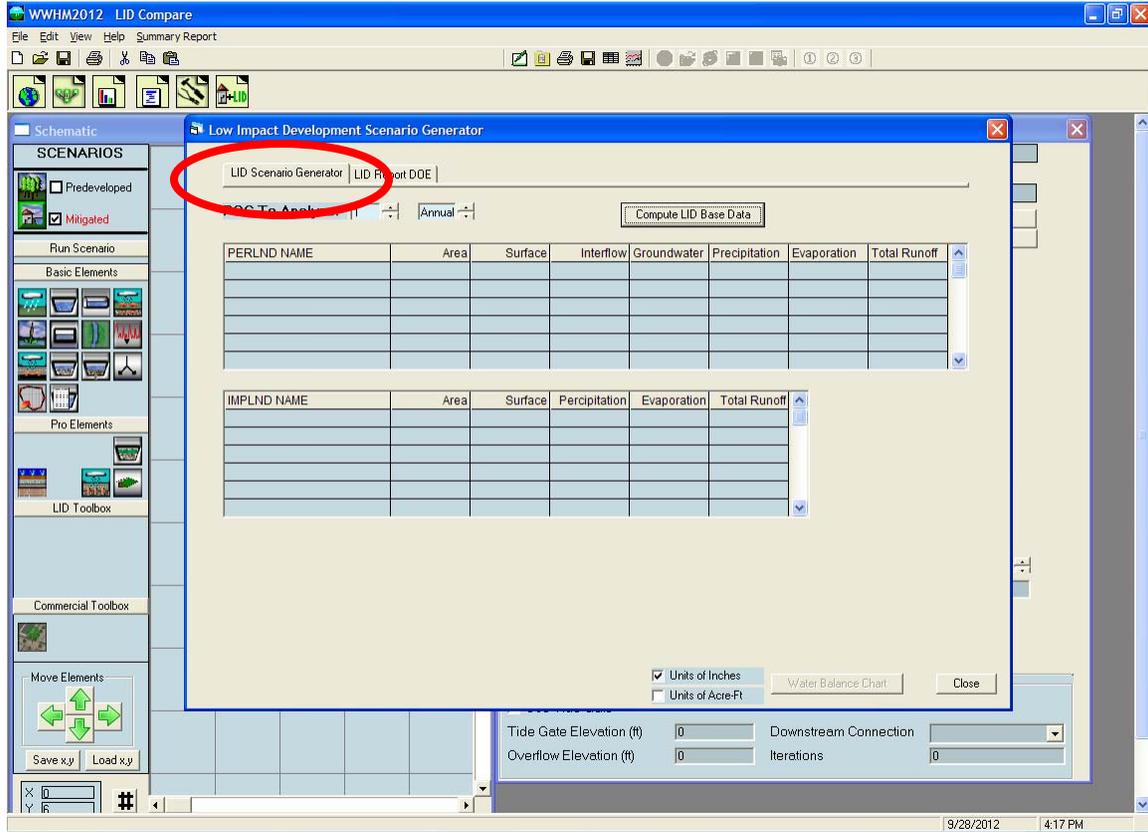
LID ANALYSIS SCREEN



The LID tool bar button (farthest on the right) brings up the LID Analysis screen and gives the user two LID Analysis options:

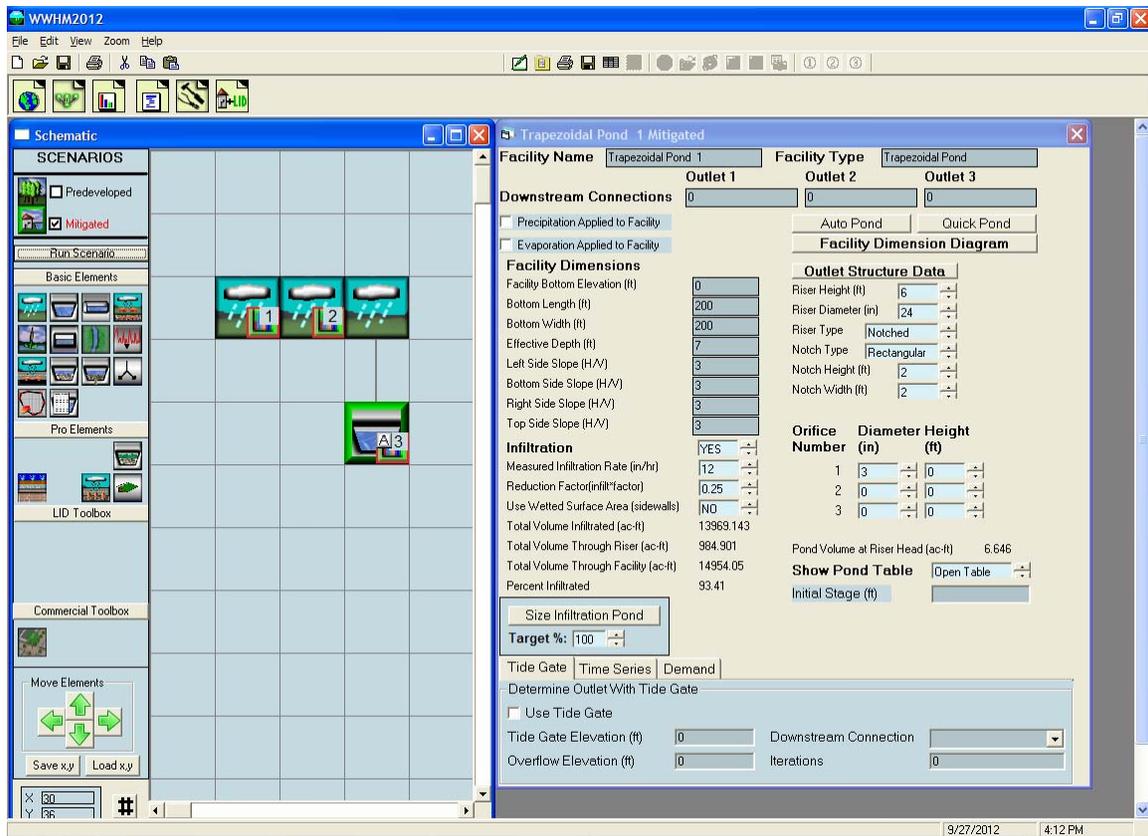
1. LID Scenario Generator
2. LID Report DOE

LID Scenario Generator



The LID scenario generator can be used to compare the amount of runoff from different land types and combinations. The user can quickly see how changing the land use affects surface runoff, interflow, groundwater, and evapotranspiration.

The LID scenario generator runoff from different land types and combinations for the Mitigated scenario only.



The easiest way to compare different land use scenarios is to place all of them on the same Schematic Editor screen grid. Each basin can then represent a different land use scenario.

For this example the three basins are assigned the following land uses:

Basin 1: 100 acres C, Forest, Flat

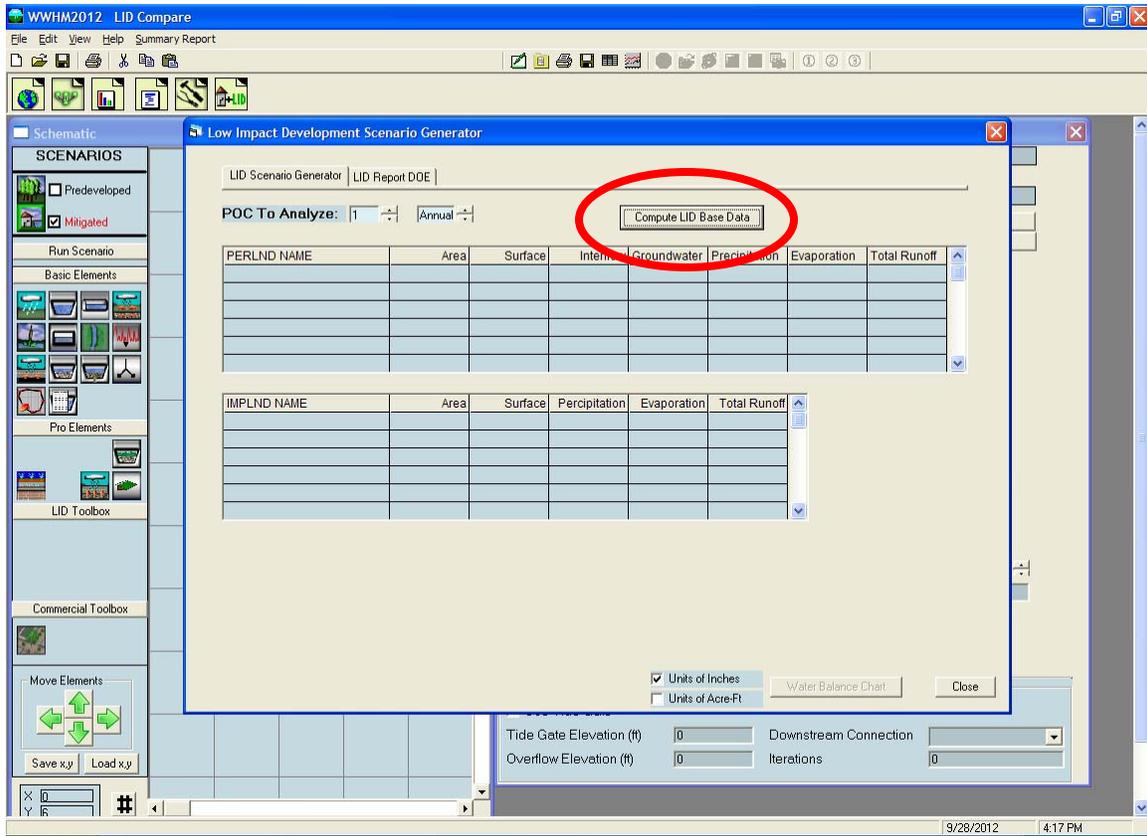
Basin 2: 100 acres C, Lawn, Flat

Basin 3: 50 acres C, Lawn, Flat; 50 acres Parking Flat

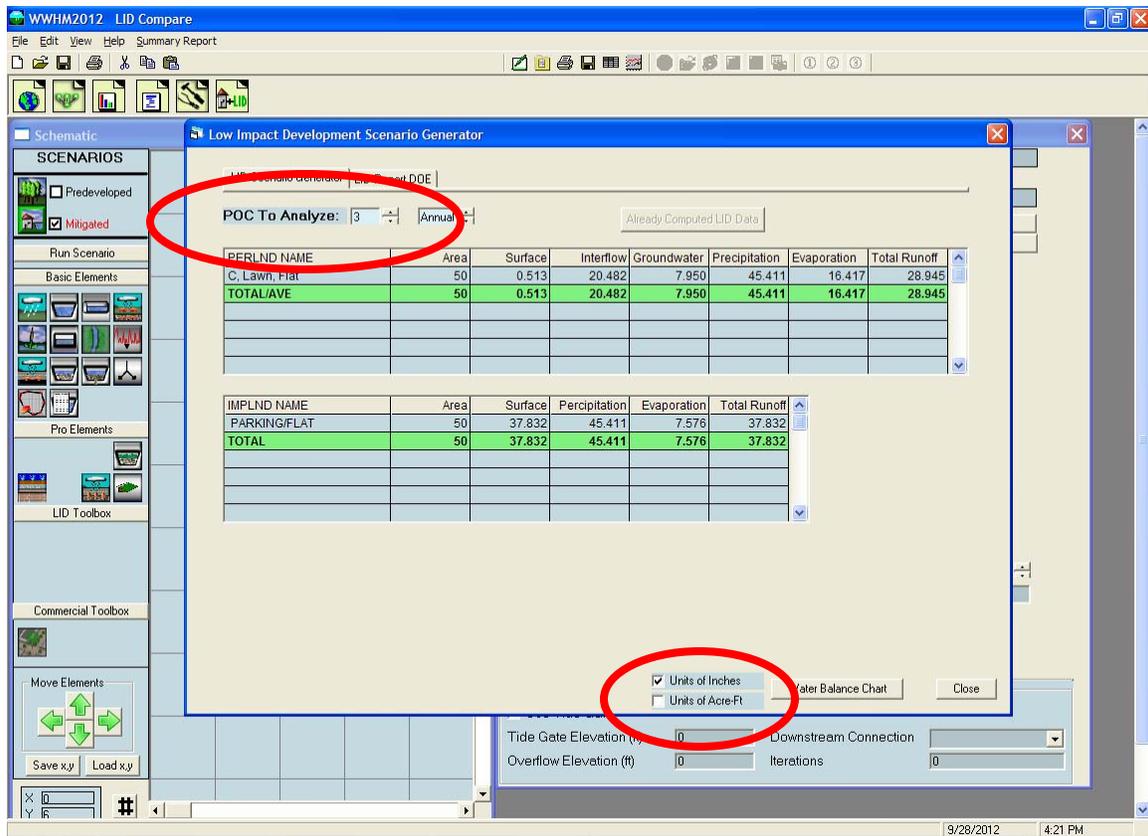
Basin 3 is connected to a pond that includes infiltration.

Basin 1 is assigned to POC 1 for the LID analysis; Basin 2 to POC 2; and the surface discharge from the Basin 3 pond to POC 3.

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Click on the Compute LID Base Data button to generate the LID analysis data and summarize the surface runoff, interflow, groundwater, precipitation, evaporation, and total runoff for all of the basins. The results will be shown for each basin in terms of its POC.



For the pervious portion of Basin 3 (50 acres of C, Lawn, Flat) the distribution of the precipitation is:

- Surface runoff = 0.513 inches per year
- Interflow = 20.482 inches per year
- Groundwater = 7.950 inches per year
- Evaporation = 16.417 inches per year

This is from a drainage area with an average annual precipitation of 45.411 inches.

For the impervious portion of Basin 3 (50 acres of Parking, Flat) the distribution of the precipitation is:

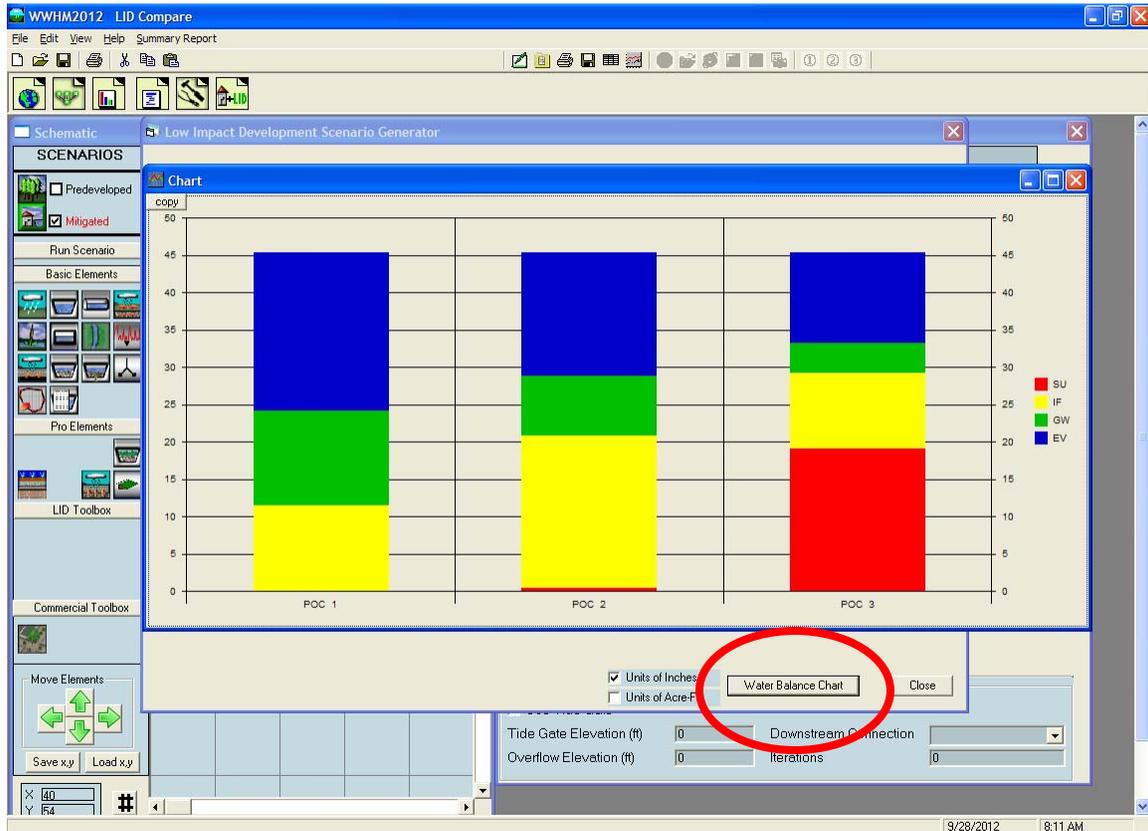
- Surface runoff = 37.832 inches per year
- Evaporation = 7.576 inches per year

There is no interflow or groundwater from impervious areas.

To look at the other basins click on the “POC To Analyze” arrow and select the basin of interest.

The LID analysis results can be presented in terms of either inches per year or acre-feet per year by checking the appropriate box in the lower right portion of the LID analysis screen.

To compare the different scenarios side-by-side in a graphical format click on the “Water Balance Chart” button.



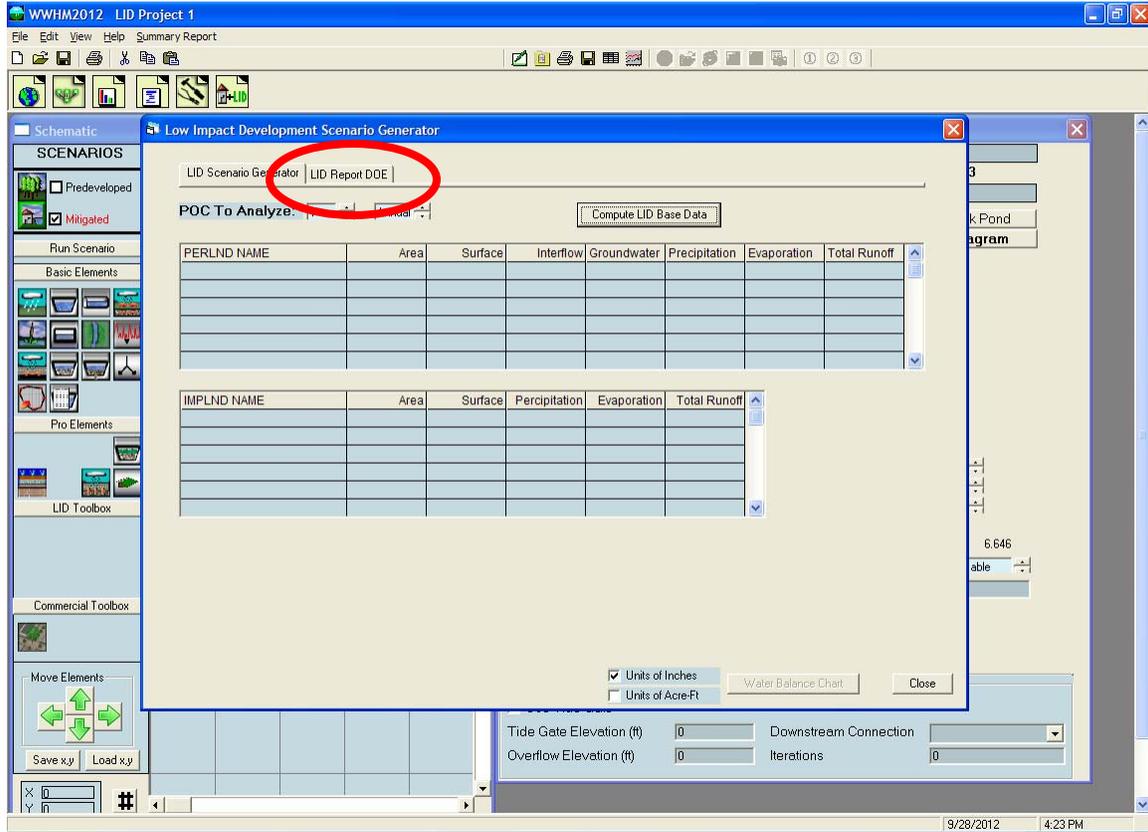
The water balance chart graphically displays the runoff distribution for all three land use scenarios side-by-side.

The bottom red is the surface runoff. Above in yellow is interflow; then green for groundwater and blue for evaporation.

Basin 1 (Scenario 1) is all forest and produces the least amount of surface runoff and interflow (the sum of surface and interflow is the total stormwater runoff). Basin 2 is all lawn; it produces more surface runoff and interflow than Basin 1. Basin 3 is 50% lawn and 50% impervious and produces the largest amount of surface runoff and interflow and the smallest amount of groundwater and evaporation.

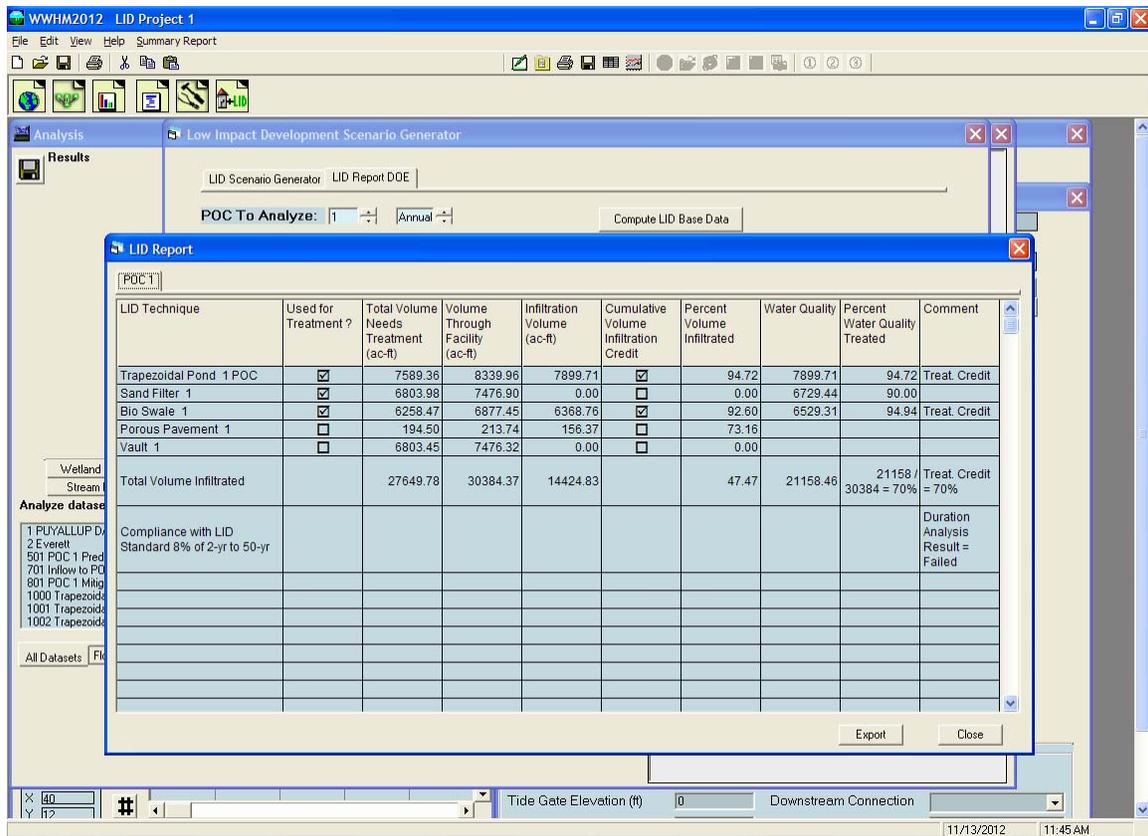
A maximum of seven scenarios can be graphed at one time.

LID Report DOE



The “LID Report DOE” option has been created to determine if the modeled LID facilities meet Washington State Department of Ecology (DOE) requirements for low impact development.

Clicking on the “LID Report DOE” tab produces the LID Report that lists all of the LID facilities in the Mitigated scenario and their performance.



The column “Total Volume Needs Treatment (ac-ft)” is volume that equals 91% of the total runoff volume through the facility for the entire model simulation period.

The column “Volume Through Facility (ac-ft)” is the actual total runoff volume through the facility for the entire model simulation period.

“Infiltration Volume (ac-ft)” is the actual total runoff volume that is infiltrated for the entire model simulation period. In the case of the sand filter the infiltration volume is actually the volume that is filtered and then continues downstream to the next stormwater facility.

“Percent Volume Infiltrated” is the percentage of the “Infiltration Volume” column volume to the “Volume Through Facility” column volume.

“Water Quality” is the actual total runoff volume that is filtered through the soil column. This is not necessarily the same as the infiltration volume. For this example, the bioretention facility has more water quality volume than infiltration volume. This is because some of the flow through the bioretention amended soil layers was then discharged via an underdrain to the next downstream facility (in this case, a stormwater pond with infiltration).

“Percent Water Quality Treated” is the percentage of the “Water Quality” column volume to the “Volume Through Facility” column volume.

The Comment column reports “Treat Credit” if the LID facility water quality treatment meets Ecology’s water quality treatment standard of treating at least 91% of the total runoff volume through the facility. In this example only the bioretention and pond meet the treatment standard.

If a facility is used for water quality treatment then the corresponding box in the “Used for Treatment” column should be checked.

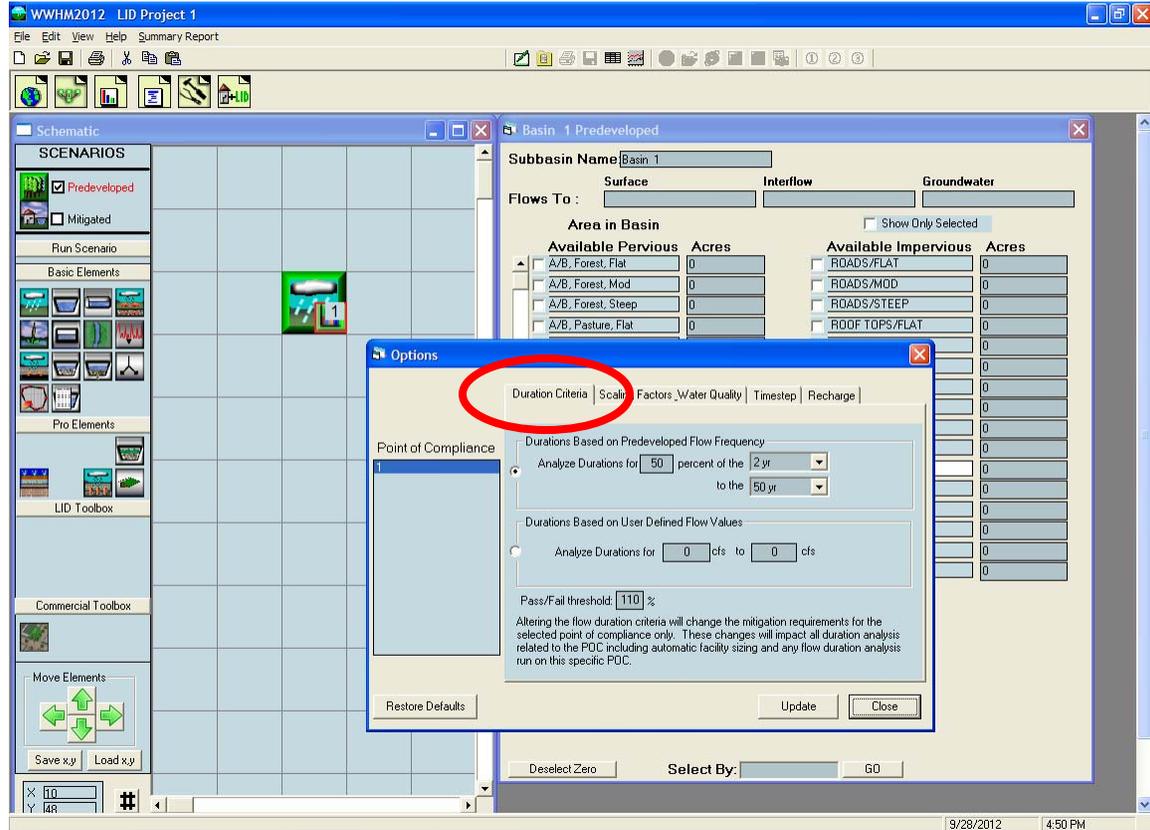
In this example the “Used for Treatment” boxes for the trapezoidal pond, sand filter, and bioretention swale are checked. The percent water quality treated values are 94.72, 90.00, and 94.94, respectively. The total runoff volume treated is 70%.

Note that Porous Pavement 1 facility’s “Used for Treatment” box was left unchecked. If porous pavement is going to be used for water quality treatment then soil mix must be used in the sublayers under the porous pavement layer. See the Ecology 2012 *Stormwater Management Manual for Western Washington* for specific details.

The LID flow duration is automatically calculated.

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Duration Criteria



The Washington State Department of Ecology’s flow control standard is based on flow duration. The duration criteria are:

1. If the post-development flow duration values exceed any of the predevelopment flow levels between 50% and 100% of the two-year predevelopment peak flow values (100 Percent Threshold) then the flow control standard requirement has not been met.
2. If the post-development flow duration values exceed any of the predevelopment flow levels between 100% of the two-year and 100% of the 50-year predevelopment peak flow values more than 10 percent of the time (110 Percent Threshold) then the flow control standard has not been met.
3. If more than 50 percent of the flow duration levels exceed the 100 percent threshold then the flow control standard has not been met.

The duration criteria in the WWHM2012 can be modified by the user if appropriate and the permitting/reviewing agency allows.

The user can conduct the duration analysis using either (1) durations based on Predeveloped flow frequency, or (2) durations based on user defined flow values.

If using durations based on Predeveloped flow frequency the percent of the lower limit can be changed from the default of the 2-year flow event to a higher or lower percent value. The lower and upper flow frequency limits (2-year and 50-year) also can be changed.

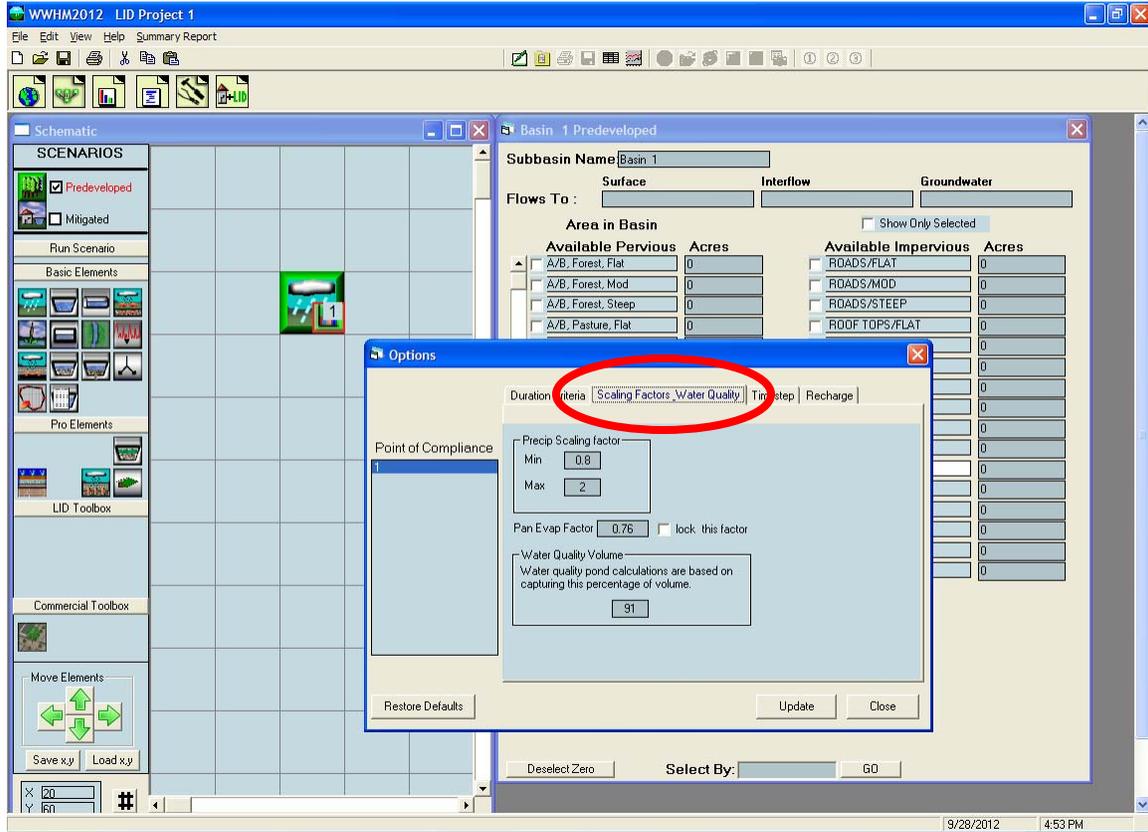
If using durations based on user defined flow values click on that option and input the lower and upper flow values.

The default pass/fail threshold is 110%. This value can be changed by the user.

The duration standards can be changed for each individual point of compliance. Click on the Update button once all of the changes have been made. To return to the default values click on the Restore Defaults button.

Any change(s) to the default duration standards must be approved by the reviewing/permitting agencies.

Scaling Factors

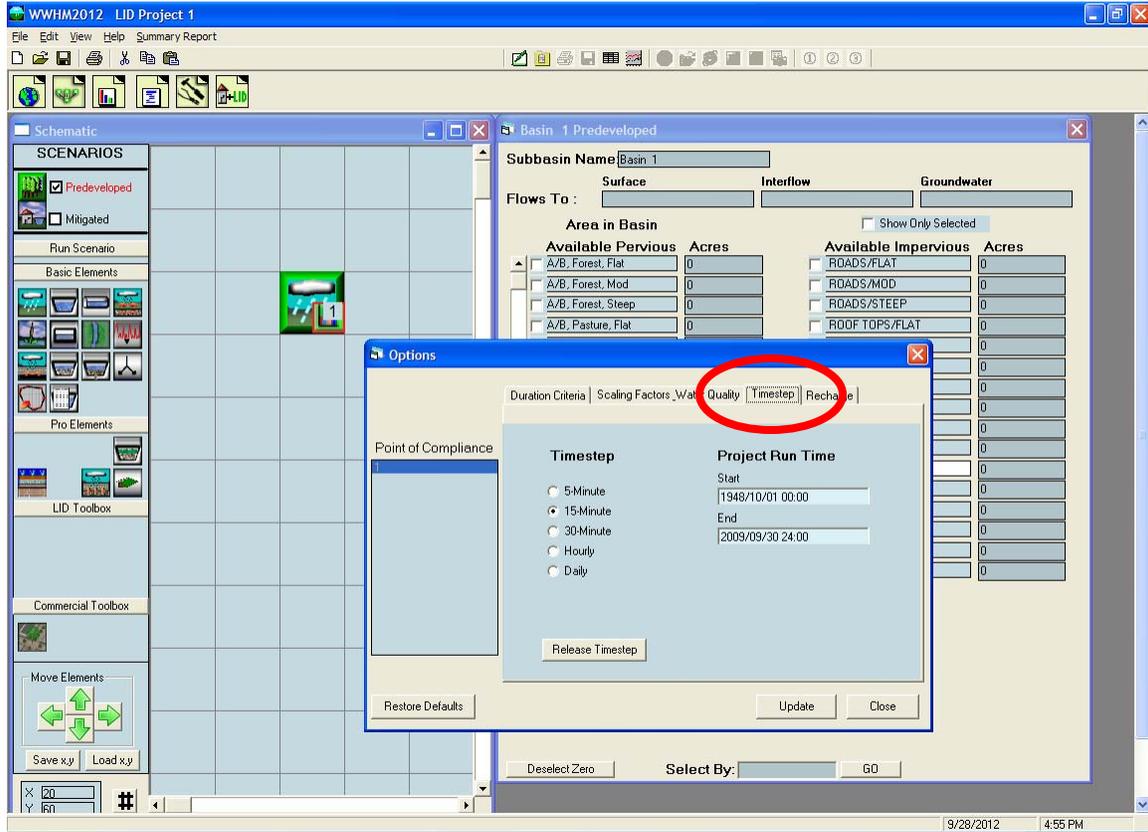


The user can change the scaling factors for precipitation (minimum and maximum) and pan evaporation. Neither should be changed without agency approval.

The water quality volume percentage is set to 91% of the total runoff volume. If allowed, this percent value can be changed by the user.

Click on the Update button once all of the changes have been made. To return to the default values click on the Restore Defaults button.

Time Step

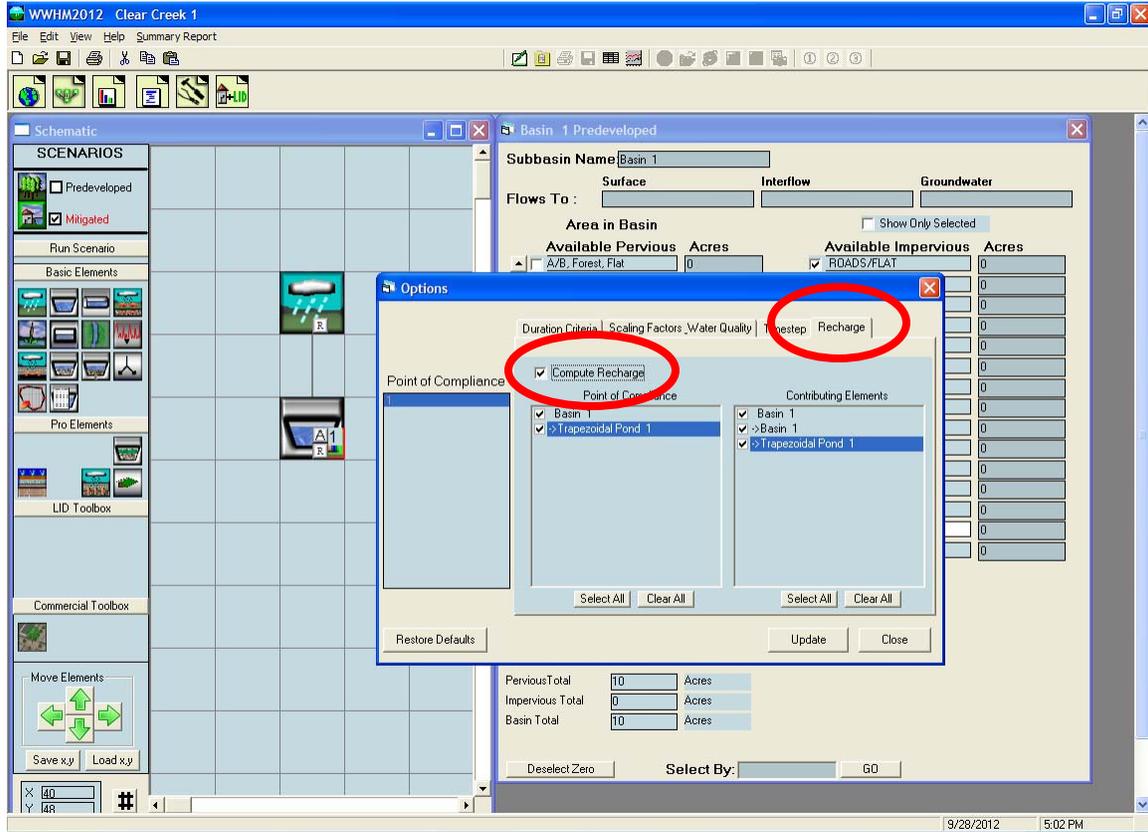


The default HSPF model simulation time step for all counties is 15 minutes. (The City of Seattle model time step is 5 minutes.)

The model simulation time step can be changed from the default value if approved by the reviewing/permitting agencies.

Note that changing the time step will change the model simulation results.

Recharge



Recharge is the amount of water that becomes groundwater. Recharge can occur both through land use basins (groundwater component of runoff) and conveyance facilities (infiltration discharge).

Recharge is only calculated by WWHM2012 if the “Compute Recharge” box is checked. The recharge boxes for the individual elements must also be checked for those elements for which recharge will be calculated. This can be done by either selecting the appropriate elements from the list on the Options, Recharge screen or by individually right clicking on the elements and selecting “Compute Recharge” from the pulldown menu. See Analysis, Recharge for more details.

If the scenarios have been run prior to turning on the recharge option then they need to be rerun to generate the recharge data. This is done by clicking on the “Run Scenario” button for each of the two scenarios (Predeveloped and Mitigated).

APPENDIX A: BIORETENTION MODELING METHODOLOGY

Water Movement Through The Soil Column

Water movement through the soil column is dependent on soil layer characteristics and saturation rates for different discharge conditions.

Consider a simple two-layered bioretention facility designed with two soil layers with different characteristics. As water enters the facility at the top, it infiltrates into the soil based on the modified Green Ampt equation (Equation 1). The water then moves through the top soil layer at the computed rate, determined by Darcy's and Van Genuchten's equations. As the soil approaches field capacity (i.e., gravity head is greater than matric head), we can determine when water will begin to infiltrate into the second layer (lower layer) of the soil column. This occurs when the matric head is less than the gravity head in the first layer (top layer).

Since the two layers have different soil characteristics, water will move through the two layers at different rates. Once both layers have achieved field capacity then the layer that first becomes saturated is determined by which layer is more restrictive. This is determined by using Darcy's equation to compute flux for each layer at the current level of saturation. The layer with the more restrictive flux is the layer that becomes saturated for that time step. The next time step the same comparison is made.

The rate and location of water discharging from the soil layer is determined by the discharge conditions selected by the user.

There are four possible combinations of discharge conditions:

1. There is no discharge from the subsurface layers (except for evapotranspiration). This means that there is no underdrain and there is no infiltration into the native soil. Which this discharge condition is unlikely, we still need to be able to model it.
2. There is an underdrain, but no native infiltration. Discharge from the underdrain is computed based on head conditions for the underdrain. The underdrain is configured to have an orifice. (It is possible for the orifice to be the same diameter as the underdrain.) With a maximum of three soil layers determining head conditions for the orifice is complicated. Each modeled layer must overcome matric head before flow through the underdrain can begin. Once matric head is overcome by gravity head for all of the layers then the underdrain begins to flow. The flow rate is determined based on the ability of the water to move through the soil layers and by the discharge from the orifice, whichever is smaller. Head conditions are determined by computing the saturation level of the lowest soil layer first. Once the lowest soil layer is saturated and flow begins then the gravity head is considered to be at the saturation level of the lowest soil layer. Once the lowest soil layer is saturated completely then the head will include the gravity head from the next soil layer above until gravity head from all soil layers is included. Gravity head from ponding on the

surface is included in the orifice calculations only if all of the intervening soil layers are saturated.

3. There is native infiltration but no underdrain. Discharge (infiltration) into the native soil is computed based a user entered infiltration rate in units of inches per hour. Specific head conditions are not used in determining infiltration into the native soil. Any impact due to head on the infiltration rate is considered to be part of the determination of the native soil infiltration rate. Because it is possible to have a maximum of three soil layers, each modeled layer must overcome matric head before infiltration to the native soil can begin. Once matric head is overcome by gravity head for all modeled layers then infiltration begins at a maximum rate determined either by the ability of the water to move through the soil layers or by the ability of the water to infiltrate into the native soil, whichever is limiting.
4. There is both an underdrain and native infiltration. Underdrain flow and native infiltration are computed as discussed above. However, there is one other limitation to consider. In the case where the flow through the soil layer is less than the sum of the discharge through the underdrain and the native infiltration then the flow through the soil layer becomes the limiting flow and must be divided between the native infiltration and the underdrain. This division is done based on the relative discharge rates of each.

Note that wetted surface area can be included in the discharge calculations by adding the infiltration through the wetted surface area to the lower soil layer and the upper surface layer individually. This is done by computing the portion of the wetted surface area that is part of the upper surface layer and computing the infiltration independently from the portion of the wetted surface area that is part of the lower soil layers.

Water Movement Equations

There are several equations used to determine water movement from the surface of the bioretention facility, through the soil layers, and into an underdrain or native infiltration. The water movement process can be divided into three different zones:

- 1) Surface ponding and infiltration into the top soil layer (soil layer 1)
- 2) Percolation through the subsurface layers
- 3) Underdrain flow and native infiltration

Surface ponding and infiltration into the top subsurface layer

The modified Green Ampt equation (Equation 1) controls the infiltration rate into the top soil layer:

$$f = K \left(1 + \frac{(\phi - \theta)(d + \varphi)}{F} \right) \quad \text{(Equation 1; Ref: Rossman, 2009)}$$

f = soil surface infiltration rate (cm/hr)

ϕ = soil porosity of top soil layer

θ = soil moisture content of top soil layer

φ = suction head at the wetting front (cm)

F = soil moisture content of the top soil layer (cm)

d = surface ponding depth (cm)

K = hydraulic conductivity based on saturation of top soil layer (cm/hr)

K (relative hydraulic conductivity) can be computed using the following Van Genuchten approximation equation:

Van Genuchten approximation of relative hydraulic conductivity

$$\frac{K(\theta)}{K_{sat}} = \left(\frac{\theta - \theta_r}{\phi - \theta_r} \right)^{1/2} \left[1 - \left(1 - \left(\frac{\theta - \theta_r}{\phi - \theta_r} \right)^{1/m} \right)^m \right]^2 \quad \text{(Equation 2; Ref: Blum et al, 2001)}$$

where $K(\theta)$ = relative hydraulic conductivity,
 K_{sat} = saturated hydraulic conductivity,
 θ = water content, θ_r = residual water content,
 ϕ = porosity, α = constant, n = constant, m = constant

A few issues arise when dealing with multiple subsurface soil layers. The K value used in Equation 1 must be computed from the top soil layer. Infiltration into the upper soil layer must not exceed the lesser of the maximum percolation rates for each of the soil layers. Finally, the rate of percolation of the top layer may be reduced because the layer or layers beneath the top layer cannot accept the percolation flux because of existing saturation levels.

Percolation through the subsurface layers

Water storage and movement through the three subsurface layers will be computed using Darcy's equation as shown below:

$$q = -K \frac{\partial h}{\partial z} \quad \text{(Equation 3)}$$

Where:

q = Darcy flux (cm/hr)

K = hydraulic conductivity of the porous medium (cm/hr)

h = total hydraulic head (cm)

z = elevation (cm)

The total head, h , is the sum of the matric head, ψ , and the gravity head, z :

$$h = \psi + z . \quad \text{(Equation 4)}$$

Substituting for h yields:

$$q = -K \frac{d(\psi + z)}{dz} . \quad \text{(Equation 5)}$$

Hydraulic conductivity and matric head vary with soil moisture content. These values can be computed by solving the Van Genuchten's equation (Equation 6) for both values. Note that $\psi = 0$ when the soil is saturated.

Van Genuchten Equation to calculate total head

$$h = -\frac{1}{\alpha} \left[\frac{1}{SE^{1/m}} - 1 \right]^{1/n} + z \quad \text{(Equation 6; Ref: Blum et al, 2001)}$$

where h = total hydraulic head, α = constant, SE = effective saturation,
 m = constant, n = constant, and z = elevation head

Effective saturation (SE) can be computed using the following Van Genuchten equation:

Van Genuchten Equation to calculate effective saturation

$$\frac{\theta - \theta_r}{\phi - \theta_r} = \left[\frac{1}{1 + (\alpha\psi)^n} \right]^m = SE \quad \text{(Equation 7; Ref: Blum et al, 2001)}$$

where θ = water content, θ_r = residual water content,
 ϕ = porosity,
 α = constant = $y_b - 1$,
 n = constant = $\lambda + 1$,
 m = constant = $1 - \frac{1}{\lambda + 1}$,
 λ = pore size distribution index,
 y_b = bubbling pressure
 ψ = pressure head = $h - z$, h = total hydraulic head,
 z = elevation head, and SE = effective saturation

Ignoring z (elevation head) results in $h = hm$ (matric head).

Evapotranspiration from the Soil Column

Evapotranspiration is an important component of the bioretention facility's hydrologic processes. Evapotranspiration removes water from bioretention surface ponding and the soil column during non-storm periods. The routine will satisfy potential evapotranspiration (PET) demands in the same sequence as implemented in HSPF:

1. Water available from vegetation interception storage
2. Water available from surface ponding
3. Water available from the bioretention soil layers (top layer first)

Water will be removed from vegetation interception storage and surface ponding and the bioretention soil layers (starting at the top layer) down to the rooting depth at the potential rate. Water is taken from the soil layers below the rooting depth based on a percentage factor to be determined. Without this factor there will be no way to remove water from below the rooting depth once it becomes completely saturated.

References

Blum, V.S., S. Israel, and S.P. Larson. 2001. *Adapting MODFLOW to Simulate Water Movement in the Unsaturated Zone*. MODFLOW 2001 and Other Modeling Odysseys, International Groundwater Modeling Center (IGWMC), Colorado School of Mines, Golden, Colorado, September 11-14, 2001. In MODFLOW 2001 and Other Modeling Odysseys, Proceedings. pp.60-65.

Rossman, L.A. 2009. *Modeling Low Impact Development Alternatives with SWMM*. Presented at CHI International Stormwater and Urban Water Systems Conference, Toronto, Ontario, Canada, February 20, 2009.

APPENDIX B: DEFAULT WWHM2012 HSPF PVIOUS PARAMETER VALUES (except CLARK COUNTY)

The default WWHM2012 HSPF pervious parameter values are found in the WWHM2012 file defaultpers.uci.

The default WWHM2012 HSPF pervious parameter values for all counties except Clark County are based on the USGS report:

Dinicola, R.S. 1990. *Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington*. Water-Resources Investigations Report 89-4052. U.S. Geological Survey. Tacoma, WA.

For some parameters the default WWHM2012 HSPF pervious parameter values have been modified from the values listed in the USGS report. These modifications are based on the professional judgment and experience of Clear Creek Solutions staff in modeling Western Washington watersheds with HSPF.

The default WWHM2012 HSPF pervious parameter values for Clark County are based on the report:

Beyerlein, D.C. 2010. *Hydrologic Modeling of Clark County Watersheds with the U.S. EPA Hydrologic Simulation Program – FORTRAN (HSPF) Final Report (Revised)*. Clear Creek Solutions, Inc., Mill Creek, WA.

HSPF parameter documentation is found in the document:

Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr, T.H. Jobes, and A.S. Donigian Jr. 2001. *Hydrological Simulation Program – Fortran, User's Manual for Version 12*. AQUA TERRA Consultants. Mountain View, CA.

Table 1. WWHM2012 Pervious Land Types

PERLND No.	Soil	Vegetation/Surface	Slope
1	A/B	Forest	Flat
2	A/B	Forest	Moderate
3	A/B	Forest	Steep
4	A/B	Pasture	Flat
5	A/B	Pasture	Moderate
6	A/B	Pasture	Steep
7	A/B	Lawn	Flat
8	A/B	Lawn	Moderate
9	A/B	Lawn	Steep
10	C	Forest	Flat
11	C	Forest	Moderate
12	C	Forest	Steep
13	C	Pasture	Flat
14	C	Pasture	Moderate
15	C	Pasture	Steep
16	C	Lawn	Flat
17	C	Lawn	Moderate
18	C	Lawn	Steep
19	Saturated	Forest	Flat
20	Saturated	Forest	Moderate
21	Saturated	Forest	Steep
22	Saturated	Pasture	Flat
23	Saturated	Pasture	Moderate
24	Saturated	Pasture	Steep
25	Saturated	Lawn	Flat
26	Saturated	Lawn	Moderate
27	Saturated	Lawn	Steep
28	C	Impervious dispersed on Lawn	Flat
29	C	Impervious dispersed on Lawn	Moderate
30	C	Impervious dispersed on Lawn	Steep
31	A/B	Impervious infiltrated on Lawn	Flat
32	A/B	Impervious infiltrated on Lawn	Moderate
33	A/B	Impervious infiltrated on Lawn	Steep
34	Saturated	Impervious dispersed on Lawn	Flat
35	Saturated	Impervious dispersed on Lawn	Moderate
36	Saturated	Impervious dispersed on Lawn	Steep
37	n/a	Green/Eco-Roof	user defined

Table 2. WWHM2012 HSPF Pervious Parameter Values – Part I

PERLND No.	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
1	5.0	2.00	400	0.050	0.3	0.996
2	5.0	2.00	400	0.100	0.3	0.996
3	5.0	2.00	400	0.150	0.3	0.996
4	5.0	1.50	400	0.050	0.3	0.996
5	5.0	1.50	400	0.100	0.3	0.996
6	5.0	1.50	400	0.150	0.3	0.996
7	5.0	0.80	400	0.050	0.3	0.996
8	5.0	0.80	400	0.100	0.3	0.996
9	5.0	0.80	400	0.150	0.3	0.996
10	4.5	0.08	400	0.050	0.5	0.996
11	4.5	0.08	400	0.100	0.5	0.996
12	4.5	0.08	400	0.150	0.5	0.996
13	4.5	0.06	400	0.050	0.5	0.996
14	4.5	0.06	400	0.100	0.5	0.996
15	4.5	0.06	400	0.150	0.5	0.996
16	4.5	0.03	400	0.050	0.5	0.996
17	4.5	0.03	400	0.100	0.5	0.996
18	4.5	0.03	400	0.150	0.5	0.996
19	4.0	2.00	100	0.001	0.5	0.996
20	4.0	2.00	100	0.010	0.5	0.996
21	4.0	2.00	100	0.100	0.5	0.996
22	4.0	1.80	100	0.001	0.5	0.996
23	4.0	1.80	100	0.010	0.5	0.996
24	4.0	1.80	100	0.100	0.5	0.996
25	4.0	1.00	100	0.001	0.5	0.996
26	4.0	1.00	100	0.010	0.5	0.996
27	4.0	1.00	100	0.100	0.5	0.996
28	4.5	0.03	400	0.050	0.5	0.996
29	4.5	0.03	400	0.100	0.5	0.996
30	4.5	0.03	400	0.150	0.5	0.996
31	5.0	0.80	400	0.050	0.3	0.996
32	5.0	0.80	400	0.100	0.3	0.996
33	5.0	0.80	400	0.150	0.3	0.996
34	4.0	1.00	100	0.001	0.5	0.996
35	4.0	1.00	100	0.010	0.5	0.996
36	4.0	1.00	100	0.100	0.5	0.996
37	1.0	0.05	50	0.001	0.5	0.100

LZSN: Lower Zone Storage Nominal (inches)

INFILT: Infiltration (inches per hour)

LSUR: Length of surface flow path (feet)

SLSUR: Slope of surface flow path (feet/feet)

KVARY: Variable groundwater recession

AGWRC: Active Groundwater Recession Constant (per day)

Table 3. WWHM2012 HSPF Pervious Parameter Values – Part II

PERLND No.	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
1	2	2	0	0	0.00
2	2	2	0	0	0.00
3	2	2	0	0	0.00
4	2	2	0	0	0.00
5	2	2	0	0	0.00
6	2	2	0	0	0.00
7	2	2	0	0	0.00
8	2	2	0	0	0.00
9	2	2	0	0	0.00
10	2	2	0	0	0.00
11	2	2	0	0	0.00
12	2	2	0	0	0.00
13	2	2	0	0	0.00
14	2	2	0	0	0.00
15	2	2	0	0	0.00
16	2	2	0	0	0.00
17	2	2	0	0	0.00
18	2	2	0	0	0.00
19	10	2	0	0	0.70
20	10	2	0	0	0.70
21	10	2	0	0	0.70
22	10	2	0	0	0.50
23	10	2	0	0	0.50
24	10	2	0	0	0.50
25	10	2	0	0	0.35
26	10	2	0	0	0.35
27	10	2	0	0	0.35
28	2	2	0	0	0.00
29	2	2	0	0	0.00
30	2	2	0	0	0.00
31	2	2	0	0	0.00
32	2	2	0	0	0.00
33	2	2	0	0	0.00
34	10	2	0	0	0.35
35	10	2	0	0	0.35
36	10	2	0	0	0.35
37	2	2	0	0	0.80

INFEXP: Infiltration Exponent

INFILD: Infiltration ratio (maximum to mean)

DEEPFR: Fraction of groundwater to deep aquifer or inactive storage

BASETP: Base flow (from groundwater) Evapotranspiration fraction

AGWETP: Active Groundwater Evapotranspiration fraction

Table 4. WWHM2012 HSPF Pervious Parameter Values – Part III

PERLND No.	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
1	0.20	0.50	0.35	0.0	0.7	0.70
2	0.20	0.50	0.35	0.0	0.7	0.70
3	0.20	0.50	0.35	0.0	0.7	0.70
4	0.15	0.50	0.30	0.0	0.7	0.40
5	0.15	0.50	0.30	0.0	0.7	0.40
6	0.15	0.50	0.30	0.0	0.7	0.40
7	0.10	0.50	0.25	0.0	0.7	0.25
8	0.10	0.50	0.25	0.0	0.7	0.25
9	0.10	0.50	0.25	0.0	0.7	0.25
10	0.20	0.50	0.35	6.0	0.5	0.70
11	0.20	0.50	0.35	6.0	0.5	0.70
12	0.20	0.30	0.35	6.0	0.3	0.70
13	0.15	0.40	0.30	6.0	0.5	0.40
14	0.15	0.40	0.30	6.0	0.5	0.40
15	0.15	0.25	0.30	6.0	0.3	0.40
16	0.10	0.25	0.25	6.0	0.5	0.25
17	0.10	0.25	0.25	6.0	0.5	0.25
18	0.10	0.15	0.25	6.0	0.3	0.25
19	0.20	3.00	0.50	1.0	0.7	0.80
20	0.20	3.00	0.50	1.0	0.7	0.80
21	0.20	3.00	0.50	1.0	0.7	0.80
22	0.15	3.00	0.50	1.0	0.7	0.60
23	0.15	3.00	0.50	1.0	0.7	0.60
24	0.15	3.00	0.50	1.0	0.7	0.60
25	0.10	3.00	0.50	1.0	0.7	0.40
26	0.10	3.00	0.50	1.0	0.7	0.40
27	0.10	3.00	0.50	1.0	0.7	0.40
28	0.10	0.25	0.25	6.0	0.5	0.25
29	0.10	0.25	0.25	6.0	0.5	0.25
30	0.10	0.15	0.25	6.0	0.3	0.25
31	0.10	0.50	0.25	0.0	0.7	0.25
32	0.10	0.50	0.25	0.0	0.7	0.25
33	0.10	0.50	0.25	0.0	0.7	0.25
34	0.10	3.00	0.50	1.0	0.7	0.40
35	0.10	3.00	0.50	1.0	0.7	0.40
36	0.10	3.00	0.50	1.0	0.7	0.40
37	0.10	0.10	0.55	1.0	0.1	0.80

CEPSC: Interception storage (inches)

UZSN: Upper Zone Storage Nominal (inches)

NSUR: Surface roughness (Manning's n)

INTFW: Interflow index

IRC: Interflow Recession Constant (per day)

LZETP: Lower Zone Evapotranspiration fraction

Table 5. WWHM2012 HSPF Pervious Parameter Values – Part IV

PERLND No.	MELEV	BELV	GWDATM	PCW	PGW	UPGW
1	400	0	0	0.35	0.38	0.45
2	400	0	0	0.35	0.38	0.45
3	400	0	0	0.35	0.38	0.45
4	400	0	0	0.33	0.35	0.42
5	400	0	0	0.33	0.35	0.42
6	400	0	0	0.33	0.35	0.42
7	400	0	0	0.31	0.33	0.40
8	400	0	0	0.31	0.33	0.40
9	400	0	0	0.31	0.33	0.40
10	400	0	0	0.20	0.23	0.28
11	400	0	0	0.20	0.23	0.28
12	400	0	0	0.20	0.23	0.28
13	400	0	0	0.18	0.20	0.25
14	400	0	0	0.18	0.20	0.25
15	400	0	0	0.18	0.20	0.25
16	400	0	0	0.15	0.17	0.20
17	400	0	0	0.15	0.17	0.20
18	400	0	0	0.15	0.17	0.20
19	400	0	0	0.17	0.20	0.25
20	400	0	0	0.17	0.20	0.25
21	400	0	0	0.17	0.20	0.25
22	400	0	0	0.15	0.17	0.22
23	400	0	0	0.15	0.17	0.22
24	400	0	0	0.15	0.17	0.22
25	400	0	0	0.12	0.15	0.18
26	400	0	0	0.12	0.15	0.18
27	400	0	0	0.12	0.15	0.18
28	400	0	0	0.15	0.17	0.20
29	400	0	0	0.15	0.17	0.20
30	400	0	0	0.15	0.17	0.20
31	400	0	0	0.31	0.33	0.40
32	400	0	0	0.31	0.33	0.40
33	400	0	0	0.31	0.33	0.40
34	400	0	0	0.12	0.15	0.18
35	400	0	0	0.12	0.15	0.18
36	400	0	0	0.12	0.15	0.18
37	400	0	0	0.12	0.15	0.18

MELEV: Mean surface elevation of the land segment (feet)

BELV: Base elevation for active groundwater (feet)

GWDATM: Datum for the groundwater elevation (feet)

PCW: Cohesion Water Porosity (fraction)

PGW: Gravitational Water Porosity (fraction)

UPGW: Upper Gravitational Water porosity (fraction)

Table 6. WWHM2012 HSPF Pervious Parameter Values – Part V

PERLND No.	STABNO	SRRC	SREXP	IFWSC	DELTA	UELFAC	LELFAC
1	1	0.1	0	4	0.2	4	2.5
2	1	0.1	0	4	0.2	4	2.5
3	1	0.1	0	4	0.2	4	2.5
4	1	0.1	0	4	0.2	4	2.5
5	1	0.1	0	4	0.2	4	2.5
6	1	0.1	0	4	0.2	4	2.5
7	1	0.1	0	4	0.2	4	2.5
8	1	0.1	0	4	0.2	4	2.5
9	1	0.1	0	4	0.2	4	2.5
10	1	0.1	0	4	0.2	4	2.5
11	1	0.1	0	4	0.2	4	2.5
12	1	0.1	0	4	0.2	4	2.5
13	1	0.1	0	4	0.2	4	2.5
14	1	0.1	0	4	0.2	4	2.5
15	1	0.1	0	4	0.2	4	2.5
16	1	0.1	0	4	0.2	4	2.5
17	1	0.1	0	4	0.2	4	2.5
18	1	0.1	0	4	0.2	4	2.5
19	1	0.1	0	4	0.2	4	2.5
20	1	0.1	0	4	0.2	4	2.5
21	1	0.1	0	4	0.2	4	2.5
22	1	0.1	0	4	0.2	4	2.5
23	1	0.1	0	4	0.2	4	2.5
24	1	0.1	0	4	0.2	4	2.5
25	1	0.1	0	4	0.2	4	2.5
26	1	0.1	0	4	0.2	4	2.5
27	1	0.1	0	4	0.2	4	2.5
28	1	0.1	0	4	0.2	4	2.5
29	1	0.1	0	4	0.2	4	2.5
30	1	0.1	0	4	0.2	4	2.5
31	1	0.1	0	4	0.2	4	2.5
32	1	0.1	0	4	0.2	4	2.5
33	1	0.1	0	4	0.2	4	2.5
34	1	0.1	0	4	0.2	4	2.5
35	1	0.1	0	4	0.2	4	2.5
36	1	0.1	0	4	0.2	4	2.5
37	1	0.1	0	4	0.2	4	2.5

STABNO: User's number for the FTABLE in the FTABLES block which contains the outflow properties from the surface storage

SRRC: Surface Runoff Recession Constant (per hour)

SREXP: Surface Runoff Exponent

IFWSC: Maximum Interflow Storage Capacity when the groundwater elevation is greater than the upper influence elevation (inches)

DELTA: groundwater tolerance level used to determine transition between regions when high water table conditions are being simulated

UELFAC: multiplier on UZSN which gives the upper zone capacity

LELFAC: multiplier on LZSN which gives the lower zone capacity

The selection of the Table 5 and Table 6 default parameter values is based on limited application of these parameters in Western Washington by the staff of Clear Creek Solutions, Inc. The parameter values should be used with caution and only after consultation with the Department of Ecology. Different values should only be selected following detailed local soil analysis, a thorough understanding of the parameters and algorithms, and consultation with the Department of Ecology.

A description of the Table 5 and Table 6 parameters and algorithms is in a separate document titled “WWHM2012 Description of HSPF High Groundwater Parameters” available from the Washington State Department of Ecology.

Table 7. WWHM2012 HSPF Pervious Parameter Values – Part VI

PERLND No.	CEPS	SURS	UZS	IFWS	LZS	AGWS	GWVS
1	0	0	0	0	3.0	1	0
2	0	0	0	0	3.0	1	0
3	0	0	0	0	3.0	1	0
4	0	0	0	0	3.0	1	0
5	0	0	0	0	3.0	1	0
6	0	0	0	0	3.0	1	0
7	0	0	0	0	3.0	1	0
8	0	0	0	0	3.0	1	0
9	0	0	0	0	3.0	1	0
10	0	0	0	0	2.5	1	0
11	0	0	0	0	2.5	1	0
12	0	0	0	0	2.5	1	0
13	0	0	0	0	2.5	1	0
14	0	0	0	0	2.5	1	0
15	0	0	0	0	2.5	1	0
16	0	0	0	0	2.5	1	0
17	0	0	0	0	2.5	1	0
18	0	0	0	0	2.5	1	0
19	0	0	0	0	4.2	1	0
20	0	0	0	0	4.2	1	0
21	0	0	0	0	4.2	1	0
22	0	0	0	0	4.2	1	0
23	0	0	0	0	4.2	1	0
24	0	0	0	0	4.2	1	0
25	0	0	0	0	4.2	1	0
26	0	0	0	0	4.2	1	0
27	0	0	0	0	4.2	1	0
28	0	0	0	0	2.5	1	0
29	0	0	0	0	2.5	1	0
30	0	0	0	0	2.5	1	0
31	0	0	0	0	3.0	1	0
32	0	0	0	0	3.0	1	0
33	0	0	0	0	3.0	1	0
34	0	0	0	0	4.2	1	0
35	0	0	0	0	4.2	1	0
36	0	0	0	0	4.2	1	0
37	0	0	0	0	0.5	0	0

CEPS: Initial interception storage (inches)

SURS: Initial surface runoff (inches)

UZS: Initial Upper Zone Storage (inches)

IFWS: Initial interflow (inches)

LZS: Initial Lower Zone Storage (inches)

AGWS: Initial Active Groundwater storage (inches)

GWVS: Initial Groundwater Vertical Slope (feet/feet)

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APPENDIX C: DEFAULT WWHM2012 HSPF IMPERVIOUS PARAMETER VALUES (except CLARK COUNTY)

The default WWHM2012 HSPF impervious parameter values are found in the WWHM2012 file defaultpers.uci.

The default WWHM2012 HSPF impervious parameter values are based on the USGS report:

Dinicola, R.S. 1990. *Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington*. Water-Resources Investigations Report 89-4052. U.S. Geological Survey. Tacoma, WA.

For some parameters the default WWHM2012 HSPF impervious parameter values have been modified from the values listed in the USGS report. These modifications are based on the professional judgment and experience of Clear Creek Solutions staff in modeling Western Washington watersheds with HSPF.

HSPF parameter documentation is found in the document:

Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr, T.H. Jobes, and A.S. Donigian Jr. 2001. *Hydrological Simulation Program – Fortran, User’s Manual for Version 12*. AQUA TERRA Consultants. Mountain View, CA.

Table 1. WWHM2012 Impervious Land Types

IMPLND No.	Impervious Surface	Slope
1	Roads	Flat
2	Roads	Moderate
3	Roads	Steep
4	Roofs	Flat
5	Driveways	Flat
6	Driveways	Moderate
7	Driveways	Steep
8	Sidewalks	Flat
9	Sidewalks	Moderate
10	Sidewalks	Steep
11	Parking	Flat
12	Parking	Moderate
13	Parking	Steep
14	Pond	Flat
15	Porous Pavement	user defined

Table 2. WWHM2012 HSPF Impervious Parameter Values – Part I

IMPLND No.	LSUR	SLSUR	NSUR	RETSC
1	400	0.01	0.10	0.10
2	400	0.05	0.10	0.08
3	400	0.10	0.10	0.05
4	400	0.01	0.10	0.10
5	400	0.01	0.10	0.10
6	400	0.05	0.10	0.08
7	400	0.10	0.10	0.05
8	400	0.01	0.10	0.10
9	400	0.05	0.10	0.08
10	400	0.10	0.10	0.05
11	400	0.01	0.10	0.10
12	400	0.05	0.10	0.08
13	400	0.10	0.10	0.05
14	400	0.01	0.10	0.10
15	400	0.01	0.10	0.00

LSUR: Length of surface flow path (feet) for impervious area

SLSUR: Slope of surface flow path (feet/feet) for impervious area

NSUR: Surface roughness (Manning's n) for impervious area

RETSC: Surface retention storage (inches) for impervious area

Table 3. WWHM2012 HSPF Impervious Parameter Values – Part II

IMPLND No.	RETS	SURS
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0

RETSC: Initial surface retention storage (inches) for impervious area

SURS: Initial surface runoff (inches) for impervious area

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APPENDIX D: DEFAULT WWHM2012 HSPF PERVIOUS PARAMETER VALUES FOR CLARK COUNTY

The default WWHM2012 HSPF pervious parameter values are found in the WWHM2012 file defaultpers.uci.

The default WWHM2012 HSPF pervious parameter values for Clark County are based on the report:

Beyerlein, D.C. 2010. *Hydrologic Modeling of Clark County Watersheds with the U.S. EPA Hydrologic Simulation Program – FORTRAN (HSPF) Final Report (Revised)*. Clear Creek Solutions, Inc., Mill Creek, WA.

HSPF parameter documentation is found in the document:

Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr, T.H. Jobes, and A.S. Donigian Jr. 2001. *Hydrological Simulation Program – Fortran, User's Manual for Version 12*. AQUA TERRA Consultants. Mountain View, CA.

The soils of Clark County were classified into five different groups based on soil characteristics. From a hydrologic calibration perspective, the most important soil characteristic is infiltration. Therefore, infiltration rates and soil moisture storage capability played the major role in the selection of the soils for each of the five groups. The five groups are:

- Soil Group 1: Excessively Drained Soils (Hydrologic Soil Groups A & B)
- Soil Group 2: Well Drained Soils (Hydrologic Soil Group B)
- Soil Group 3: Moderately Drained Soils (Hydrologic Soil Groups B & C)
- Soil Group 4: Poorly Drained Soils (Slowly Infiltrating C Soils, As Well As D Soils)
- Soil Group 5: Wetlands Soils (Mucks)

Table 1 lists the soils within each group.

Land slopes were divided into three groups: flat (0-5%), moderate (5-15%), and steep (>15%).

Table 1. Clark County Soil Groups

Map Symbol	Soil Name	HSG	SCS Permeability (in/hr)	Dominant USDA Texture	Depth from surface
Soil Group 1					
LeB	LAUREN	B	0.63 - 2.0 (6.3 - 20 deeper than 33in)	Very Gravelly Coarse Sandy Loam	33-70
LgB	LAUREN	B	0.63 - 2.0 (6.3 - 20 deeper than 33in)	Very Gravelly Coarse Sandy Loam	33-70
LgD	LAUREN	B	0.63 - 2.0 (6.3 - 20 deeper than 33in)	Very Gravelly Coarse Sandy Loam	33-70
LgF	LAUREN	B	0.63 - 2.0 (6.3 - 20 deeper than 33in)	Very Gravelly Coarse Sandy Loam	33-70
LIB	LAUREN	B	0.63 - 2.0 (6.3 - 20 deeper than 33in)	Very Gravelly Coarse Sandy Loam	33-70
Ro	ROUGH BROKEN LAND	A	Too variable		
SvA	SIFTON	B	2.0 - 6.3 (>20 deeper than 16in)	Very Gravelly Loamy Coarse Sand and Very Gravelly Coarse Sand	10-60 inches
WnB	WIND RIVER VARIANT	B	6.3 - 20	Loamy Coarse Sand and Coarse Sand	24-62 inches
WnD	WIND RIVER VARIANT	B	6.3 - 20	Loamy Coarse Sand and Coarse Sand	24-62 inches
WnG	WIND RIVER VARIANT	B	6.3 - 20	Loamy Coarse Sand and Coarse Sand	24-62 inches
WrB	WIND RIVER VARIANT	B	6.3 - 20	Loamy Coarse Sand and Coarse Sand	24-62 inches
WrF	WIND RIVER VARIANT	B	6.3 - 20	Loamy Coarse Sand and Coarse Sand	24-62 inches
	PITS	A			
	BONNEVILLE STONY SAND LOAM	A			

Soil Group 2

BpB	BEAR PRARIE	B	0.63 - 2.0	Gravelly Loam	51-75 inches
BpC	BEAR PRARIE	B	0.63 - 2.0	Gravelly Loam	51-75 inches
CnB	CINEBAR	B	0.63 - 2.0	Silt Loam and Loam	0-65 inches
CnD	CINEBAR	B	0.63 - 2.0	Silt Loam and Loam	0-65 inches
CnE	CINEBAR	B	0.63 - 2.0	Silt Loam and Loam	0-65 inches
CnG	CINEBAR	B	0.63 - 2.0	Silt Loam and Loam	0-65 inches

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Map Symbol	Soil Name	HSG	SCS Permeability (in/hr)	Dominant USDA Texture	Depth from surface
CrE	CINEBAR	B	0.63 - 2.0	Silt Loam	0-60 inches
CrG	CINEBAR	B	0.63 - 2.0	Silt Loam	0-60 inches
CsF	CISPUS	B	> 20	Very Cobbly Sand	24-53 inches
CtA	CLOQUATO	B	> 6.3	Sandy loam and sand	40-72 inches
HIA	HILLSBORO	B	2.0 - 6.3	Sandy loam and sand	36-62 inches
HIB	HILLSBORO	B	2.0 - 6.3	Sandy loam and sand	36-62 inches
HIC	HILLSBORO	B	2.0 - 6.3	Sandy loam and sand	36-62 inches
HID	HILLSBORO	B	2.0 - 6.3	Sandy loam and sand	36-62 inches
HIE	HILLSBORO	B	2.0 - 6.3	Sandy loam and sand	36-62 inches
HIF	HILLSBORO	B	2.0 - 6.3	Sandy loam and sand	36-62 inches
KeC	KINNEY	B	0.63 - 2.0	Gravelly silt loam, gravelly silty clay loam, and gravelly clay loam	0-60 inches
KeE	KINNEY	B	0.63 - 2.0	Gravelly silt loam, gravelly silty clay loam, and gravelly clay loam	0-60 inches
KeF	KINNEY	B	0.63 - 2.0	Gravelly silt loam, gravelly silty clay loam, and gravelly clay loam	0-60 inches
KnF	KINNEY	B	0.63 - 2.0	Gravelly silt loam, gravelly silty clay loam, and gravelly clay loam	0-60 inches
LaE	LARCHMOUNT	B	0.63 - 2.0	Cobbly Silt Loam and Clay Loam	0-62 inches
LaG	LARCHMOUNT	B	0.63 - 2.0	Cobbly Silt Loam and Clay Loam	0-62 inches
LcG	LARCHMOUNT	B	0.63 - 2.0	Silty Loam and Clay Loam	0-62 inches
MsB	MOSSYROCK	B	0.63 - 2.0	Silt Loam	23-60 inches
NbA	NEWBERG	B	2.0 - 6.3	Fine Sandy Loam and Sandy Loam	7-52 inches
NbB	NEWBERG	B	2.0 - 6.3	Fine Sandy Loam and Sandy Loam	7-52 inches
PhB	PILCHUCK	C	6.3 - 20	Fine Sand	0-60 inches
PuA	PUYALLUP	B	6.3 - 20	Gravelly Sand	27-60 inches
SaC	SALKUM	B	0.06 - 0.20	Heavy Silty Clay Loam	31-55 inches
VaB	VADER	B	2.0 - 6.3	Silt Loam and Loam	0-30 inches
VaC	VADER	B	2.0 - 6.3	Silt Loam and Loam	0-30 inches

Map Symbol	Soil Name	HSG	SCS Permeability (in/hr)	Dominant USDA Texture	Depth from surface
WaA	WASHOUGAL	B	0.63 - 2.0	Very Gravelly Loam and Very Gravelly Coarse Sandy Loam	22-36 inches
WgB	WASHOUGAL	B	0.63 - 2.0	Very Gravelly Loam and Very Gravelly Coarse Sandy Loam	22-36 inches
WgE	WASHOUGAL	B	0.63 - 2.0	Very Gravelly Loam and Very Gravelly Coarse Sandy Loam	22-36 inches
WhF	WASHOUGAL	B	0.63 - 2.0	Very Gravelly Loam and Very Gravelly Coarse Sandy Loam	22-36 inches
YaA	YACOLT	B	0.63 - 2.0	Cobbly Loam	39-61 inches
YaC	YACOLT	B	0.63 - 2.0	Cobbly Loam	39-61 inches
YcB	YACOLT	B	0.63 - 2.0	Cobbly Loam	39-61 inches

Soil Group 3

DoB	DOLLAR	C	<0.06	Loam	32-60 inches
HcB	HESSON	C	0.2 - 0.63	Clay	22-91 inches
HcD	HESSON	C	0.2 - 0.63	Clay	22-91 inches
HcE	HESSON	C	0.2 - 0.63	Clay	22-91 inches
HcF	HESSON	C	0.2 - 0.63	Clay	22-91 inches
HgB	HESSON	C	0.2 - 0.63	Gravelly Clay	22-91 inches
HgD	HESSON	C	0.2 - 0.63	Gravelly Clay	22-91 inches
HhE	HESSON	C	0.2 - 0.63	Gravelly Clay	22-91 inches
HoA	HILLSBORO	B	0.63 - 2.0	Silt Loam	0-86 inches
HoB	HILLSBORO	B	0.63 - 2.0	Silt Loam	0-86 inches
HoC	HILLSBORO	B	0.63 - 2.0	Silt Loam	0-86 inches
HoD	HILLSBORO	B	0.63 - 2.0	Silt Loam	0-86 inches
HoE	HILLSBORO	B	0.63 - 2.0	Silt Loam	0-86 inches
HoG	HILLSBORO	B	0.63 - 2.0	Silt Loam	0-86 inches
HsB	HILLSBORO	B	0.63 - 2.0	Silt Loam	0-86 inches
McB	McBEE	C	0.63 - 2.0	Silty Clay Loam, Clay	0-65 inches
MeA	McBEE	C	0.63 - 2.0	Silty Clay Loam, Clay	0-65 inches

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Map Symbol	Soil Name	HSG	SCS Permeability (in/hr)	Dominant USDA Texture	Depth from surface
MIA	McBEE	C	0.63 - 2.0 (>20 deeper than 44in)	Gravelly Fine Sandy Loam	19-44 inches
OeD	OLEQUA	B	0.2 - 0.63	Heavy Silt Loam and Silty Clay Loam	17-90 inches
OeE	OLEQUA	B	0.2 - 0.63	Heavy Silt Loam and Silty Clay Loam	17-90 inches
OeF	OLEQUA	B	0.2 - 0.63	Heavy Silt Loam and Silty Clay Loam	17-90 inches
OIB	OLYMPIC	B	0.2 - 0.63	Gravelly Clay Loam	44-59 inches
OID	OLYMPIC	B	0.2 - 0.63	Gravelly Clay Loam	44-59 inches
OIE	OLYMPIC	B	0.2 - 0.63	Gravelly Clay Loam	44-59 inches
OIF	OLYMPIC	B	0.2 - 0.63	Gravelly Clay Loam	44-59 inches
OmE	OLYMPIC	B	0.2 - 0.63	Gravelly Clay Loam	44-59 inches
OmF	OLYMPIC	B	0.2 - 0.63	Gravelly Clay Loam	44-59 inches
OpC	OLYMPIC VARIANT	C	0.2 - 0.63	Heavy Clay Loam and Heavy silty Clay Loam	0-33 inches
OpE	OLYMPIC VARIANT	C	0.2 - 0.63	Fractured Basalt	0-33 inches
OpG	OLYMPIC VARIANT	C	0.2 - 0.63	Fractured Basalt	0-33 inches
OrC	OLYMPIC VARIANT	C	0.2 - 0.63	Fractured Basalt	0-33 inches
PoB	POWELL	C	0.06 - 0.20	Silt Loam	23-63 inches
PoD	POWELL	C	0.06 - 0.20	Silt Loam	23-63 inches
PoE	POWELL	C	0.06 - 0.20	Silt Loam	23-63 inches
SmA	SAUVIE	B	0.2 - 0.63	Silty Clay Loam and Silt Loam	0-63 inches
SmB	SAUVIE	B	0.2 - 0.63	Silty Clay Loam and Silt Loam	0-63 inches
SnA	SAUVIE	D	2.0 - 6.3	Fine Sandy Loam	36-63 inches
SpB	SAUVIE	B	0.2 - 0.63	Silty Clay Loam and Silt Loam	0-63 inches

Soil Group 4

CvA	COVE	D	0.06 - 0.20	Gravelly Silty Clay Loam	21-60 inches
CwA	COVE	D	0.06 - 0.20	Silt Loam	21-60 inches
GeB	GEE	C	<0.06	Silty Clay Loam	22-72 inches

Map Symbol	Soil Name	HSG	SCS Permeability (in/hr)	Dominant USDA Texture	Depth from surface
GeD	GEE	C	<0.06	Silty Clay Loam	22-72 inches
GeE	GEE	C	<0.06	Silty Clay Loam	22-72 inches
GeF	GEE	C	<0.06	Silty Clay Loam	22-72 inches
GuB	GUMBOOT	D	0.06 - 0.2	Gravelly Silty Clay Loam, Clay Loam	12-50 inches
HtA	HOCKINSON	D	0.06 - 0.2	Fine Sandy Loam and Loam	23-51 inches
HuB	HOCKINSON	D	0.06 - 0.2	Fine Sandy Loam and Loam	23-51 inches
HvA	HOCKINSON	D	0.06 - 0.2	Fine Sandy Loam and Loam	23-51 inches
LrC	LAUREN	C	<0.06	Very Gravelly Clay Loam	14-60 inches
LrF	LAUREN	C	<0.06	Very Gravelly Clay Loam	14-60 inches
MnA	MINNIECE	D	<0.06	Silty Clay and Clay Basalt Bedrock	0-48 inches
MnD	MINNIECE	D	<0.06	Silty Clay and Clay Basalt Bedrock	0-48 inches
MoA	MINNIECE VARIANT	D	<0.06	Very Gravelly Clay Loam	22-60 inches
OdB	ODNE	D	<0.06	Silt Loam, silty Clay Loam, Clay Loam, and Loam	0-50 inches
OhD	OLEQUA VARIANT	C	<0.06	Silty Clay and Clay	32-82 inches
OhF	OLEQUA VARIANT	C	<0.06	Silty Clay and Clay	32-82 inches
SIB	SARA	D	<0.06	Heavy Silty Clay Loam and Silty Clay	10-70 inches
SID	SARA	D	<0.06	Heavy Silty Clay Loam and Silty Clay	10-70 inches
SIF	SARA	D	<0.06	Heavy Silty Clay Loam and Silty Clay	10-70 inches

Soil Group 5

Sr	SEMAIHM00	C	0.63 - 2.0	Muck	0-40 inches
Su	SEMAIHM00 VARIANT	D	0.63 - 2.0	Muck	0-30 inches
ThA	TISCH	D	0.2 - 0.63	Muck	31-45 inches

Table 2. WWHM2012 Pervious Land Types

PERLND No.	Soil	Vegetation/Surface	Slope
1	Soil Group 1	Forest	Flat
2	Soil Group 1	Forest	Moderate
3	Soil Group 1	Forest	Steep
4	Soil Group 1	Field	Flat
5	Soil Group 1	Field	Moderate
6	Soil Group 1	Field	Steep
7	Soil Group 1	Lawn	Flat
8	Soil Group 1	Lawn	Moderate
9	Soil Group 1	Lawn	Steep
10	Soil Group 2	Forest	Flat
11	Soil Group 2	Forest	Moderate
12	Soil Group 2	Forest	Steep
13	Soil Group 2	Field	Flat
14	Soil Group 2	Field	Moderate
15	Soil Group 2	Field	Steep
16	Soil Group 2	Lawn	Flat
17	Soil Group 2	Lawn	Moderate
18	Soil Group 2	Lawn	Steep
19	Soil Group 3	Forest	Flat
20	Soil Group 3	Forest	Moderate
21	Soil Group 3	Forest	Steep
22	Soil Group 3	Field	Flat
23	Soil Group 3	Field	Moderate
24	Soil Group 3	Field	Steep
25	Soil Group 3	Lawn	Flat
26	Soil Group 3	Lawn	Moderate
27	Soil Group 3	Lawn	Steep
28	Soil Group 4	Forest	Flat
29	Soil Group 4	Forest	Moderate
30	Soil Group 4	Forest	Steep
31	Soil Group 4	Field	Flat
32	Soil Group 4	Field	Moderate
33	Soil Group 4	Field	Steep
34	Soil Group 4	Lawn	Flat
35	Soil Group 4	Lawn	Moderate
36	Soil Group 4	Lawn	Steep
37	Soil Group 5	Forest	Flat
38	Soil Group 5	Forest	Moderate
39	Soil Group 5	Forest	Steep
40	Soil Group 5	Field	Flat
41	Soil Group 5	Field	Moderate
42	Soil Group 5	Field	Steep
43	Soil Group 5	Lawn	Flat
44	Soil Group 5	Lawn	Moderate
45	Soil Group 5	Lawn	Steep
46	n/a	Green/Eco-Roof	user defined

Table 3. WWHM2012 HSPF Pervious Parameter Values – Part I

PERLND No.	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
1	12.0	2.00	400	0.050	0.0	0.960
2	12.0	2.00	400	0.100	0.0	0.960
3	12.0	2.00	400	0.150	0.0	0.960
4	12.0	1.50	400	0.050	0.0	0.960
5	12.0	1.50	400	0.100	0.0	0.960
6	12.0	1.50	400	0.150	0.0	0.960
7	12.0	1.00	400	0.050	0.0	0.960
8	12.0	1.00	400	0.100	0.0	0.960
9	12.0	1.00	400	0.150	0.0	0.960
10	11.0	0.20	400	0.050	0.0	0.960
11	11.0	0.20	400	0.100	0.0	0.960
12	11.0	0.20	400	0.150	0.0	0.960
13	11.0	0.15	400	0.050	0.0	0.960
14	11.0	0.15	400	0.100	0.0	0.960
15	11.0	0.15	400	0.150	0.0	0.960
16	11.0	0.10	400	0.050	0.0	0.960
17	11.0	0.10	400	0.100	0.0	0.960
18	11.0	0.10	400	0.150	0.0	0.960
19	6.0	0.08	100	0.050	0.0	0.960
20	6.0	0.08	100	0.100	0.0	0.960
21	6.0	0.08	100	0.150	0.0	0.960
22	6.0	0.06	100	0.050	0.0	0.960
23	6.0	0.06	100	0.100	0.0	0.960
24	6.0	0.06	100	0.150	0.0	0.960
25	6.0	0.05	100	0.050	0.0	0.960
26	6.0	0.05	100	0.100	0.0	0.960
27	6.0	0.05	100	0.150	0.0	0.960
28	6.0	0.04	400	0.050	0.0	0.960
29	6.0	0.04	400	0.100	0.0	0.960
30	6.0	0.04	400	0.150	0.0	0.960
31	6.0	0.03	400	0.050	0.0	0.960
32	6.0	0.03	400	0.100	0.0	0.960
33	6.0	0.03	400	0.150	0.0	0.960
34	6.0	0.02	400	0.050	0.0	0.960
35	6.0	0.02	400	0.100	0.0	0.960
36	6.0	0.02	400	0.150	0.0	0.960
37	6.0	0.50	100	0.001	0.0	0.960
38	6.0	0.50	100	0.010	0.0	0.960
39	6.0	0.50	100	0.100	0.0	0.960
40	6.0	0.40	100	0.001	0.0	0.960
41	6.0	0.40	100	0.010	0.0	0.960
42	6.0	0.40	100	0.100	0.0	0.960
43	6.0	0.30	100	0.001	0.0	0.960
44	6.0	0.30	100	0.010	0.0	0.960
45	6.0	0.30	100	0.100	0.0	0.960
46	1.0	0.05	50	0.001	0.5	0.100

LZSN: Lower Zone Storage Nominal (inches)

INFILT: Infiltration (inches per hour)

LSUR: Length of surface flow path (feet)

SLSUR: Slope of surface flow path (feet/feet)

KVARY: Variable groundwater recession

AGWRC: Active Groundwater Recession Constant (per day)

Table 4. WWHM2012 HSPF Pervious Parameter Values – Part II

PERLND No.	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
1	2.0	2	0	0	0.00
2	2.0	2	0	0	0.00
3	2.0	2	0	0	0.00
4	2.0	2	0	0	0.00
5	2.0	2	0	0	0.00
6	2.0	2	0	0	0.00
7	2.0	2	0	0	0.00
8	2.0	2	0	0	0.00
9	2.0	2	0	0	0.00
10	2.0	2	0	0	0.00
11	2.0	2	0	0	0.00
12	2.0	2	0	0	0.00
13	2.0	2	0	0	0.00
14	2.0	2	0	0	0.00
15	2.0	2	0	0	0.00
16	2.0	2	0	0	0.00
17	2.0	2	0	0	0.00
18	2.0	2	0	0	0.00
19	2.5	2	0	0	0.00
20	2.5	2	0	0	0.00
21	2.5	2	0	0	0.00
22	2.5	2	0	0	0.00
23	2.5	2	0	0	0.00
24	2.5	2	0	0	0.00
25	2.5	2	0	0	0.00
26	2.5	2	0	0	0.00
27	2.5	2	0	0	0.00
28	3.0	2	0	0	0.00
29	3.0	2	0	0	0.00
30	3.0	2	0	0	0.00
31	3.0	2	0	0	0.00
32	3.0	2	0	0	0.00
33	3.0	2	0	0	0.00
34	3.0	2	0	0	0.00
35	3.0	2	0	0	0.00
36	3.0	2	0	0	0.00
37	10.0	2	0	0	0.70
38	10.0	2	0	0	0.70
39	10.0	2	0	0	0.70
40	10.0	2	0	0	0.50
41	10.0	2	0	0	0.50
42	10.0	2	0	0	0.50
43	10.0	2	0	0	0.35
44	10.0	2	0	0	0.35
45	10.0	2	0	0	0.35
46	2.0	2	0	0	0.80

INFEXP: Infiltration Exponent

INFILD: Infiltration ratio (maximum to mean)

DEEPFR: Fraction of groundwater to deep aquifer or inactive storage

BASETP: Base flow (from groundwater) Evapotranspiration fraction

AGWETP: Active Groundwater Evapotranspiration fraction

Table 5. WWHM2012 HSPF Pervious Parameter Values – Part III

PERLND No.	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
1	0.20	1.50	0.35	0.0	0.4	0.70
2	0.20	1.50	0.35	0.0	0.4	0.70
3	0.20	1.50	0.35	0.0	0.4	0.70
4	0.15	1.50	0.30	0.0	0.4	0.40
5	0.15	1.50	0.30	0.0	0.4	0.40
6	0.15	1.50	0.30	0.0	0.4	0.40
7	0.10	1.30	0.25	0.0	0.4	0.25
8	0.10	1.30	0.25	0.0	0.4	0.25
9	0.10	1.30	0.25	0.0	0.4	0.25
10	0.20	1.40	0.35	1.0	0.4	0.70
11	0.20	1.40	0.35	1.0	0.4	0.70
12	0.20	1.40	0.35	1.0	0.4	0.70
13	0.15	1.40	0.30	1.0	0.4	0.40
14	0.15	1.40	0.30	1.0	0.4	0.40
15	0.15	1.40	0.30	1.0	0.4	0.40
16	0.10	1.20	0.25	1.0	0.4	0.25
17	0.10	1.20	0.25	1.0	0.4	0.25
18	0.10	1.20	0.25	1.0	0.4	0.25
19	0.20	1.00	0.35	4.0	0.4	0.70
20	0.20	1.00	0.35	4.0	0.4	0.70
21	0.20	1.00	0.35	4.0	0.4	0.70
22	0.15	1.00	0.30	4.0	0.4	0.40
23	0.15	1.00	0.30	4.0	0.4	0.40
24	0.15	1.00	0.30	4.0	0.4	0.40
25	0.10	0.80	0.25	4.0	0.4	0.25
26	0.10	0.80	0.25	4.0	0.4	0.25
27	0.10	0.80	0.25	4.0	0.4	0.25
28	0.20	0.40	0.35	2.0	0.4	0.70
29	0.20	0.40	0.35	2.0	0.4	0.70
30	0.20	0.40	0.35	2.0	0.4	0.70
31	0.15	0.40	0.30	2.0	0.4	0.40
32	0.15	0.40	0.30	2.0	0.4	0.40
33	0.15	0.40	0.30	2.0	0.4	0.40
34	0.10	0.20	0.25	2.0	0.4	0.25
35	0.10	0.20	0.25	2.0	0.4	0.25
36	0.10	0.20	0.25	2.0	0.4	0.25
37	0.20	3.00	0.50	1.0	0.7	0.80
38	0.20	3.00	0.50	1.0	0.7	0.80
39	0.20	3.00	0.50	1.0	0.7	0.80
40	0.15	3.00	0.50	1.0	0.7	0.60
41	0.15	3.00	0.50	1.0	0.7	0.60
42	0.15	3.00	0.50	1.0	0.7	0.60
43	0.10	3.00	0.50	1.0	0.7	0.40
44	0.10	3.00	0.50	1.0	0.7	0.40
45	0.10	3.00	0.50	1.0	0.7	0.40
46	0.10	0.10	0.55	1.0	0.1	0.80

CEPSC: Interception storage (inches)
UZSN: Upper Zone Storage Nominal (inches)
NSUR: Surface roughness (Manning's n)
INTFW: Interflow index
IRC: Interflow Recession Constant (per day)
LZETP: Lower Zone Evapotranspiration fraction

Table 6. WWHM2012 HSPF Pervious Parameter Values – Part IV

PERLND No.	MELEV	BELV	GWDATM	PCW	PGW	UPGW
1	400	0	0	0.35	0.38	0.45
2	400	0	0	0.35	0.38	0.45
3	400	0	0	0.35	0.38	0.45
4	400	0	0	0.33	0.35	0.42
5	400	0	0	0.33	0.35	0.42
6	400	0	0	0.33	0.35	0.42
7	400	0	0	0.31	0.33	0.40
8	400	0	0	0.31	0.33	0.40
9	400	0	0	0.31	0.33	0.40
10	400	0	0	0.35	0.38	0.45
11	400	0	0	0.35	0.38	0.45
12	400	0	0	0.35	0.38	0.45
13	400	0	0	0.33	0.35	0.42
14	400	0	0	0.33	0.35	0.42
15	400	0	0	0.33	0.35	0.42
16	400	0	0	0.31	0.33	0.40
17	400	0	0	0.31	0.33	0.40
18	400	0	0	0.31	0.33	0.40
19	400	0	0	0.20	0.23	0.28
20	400	0	0	0.20	0.23	0.28
21	400	0	0	0.20	0.23	0.28
22	400	0	0	0.18	0.20	0.25
23	400	0	0	0.18	0.20	0.25
24	400	0	0	0.18	0.20	0.25
25	400	0	0	0.15	0.17	0.20
26	400	0	0	0.15	0.17	0.20
27	400	0	0	0.15	0.17	0.20
28	400	0	0	0.20	0.23	0.28
29	400	0	0	0.20	0.23	0.28
30	400	0	0	0.20	0.23	0.28
31	400	0	0	0.18	0.20	0.25
32	400	0	0	0.18	0.20	0.25
33	400	0	0	0.18	0.20	0.25
34	400	0	0	0.15	0.17	0.20
35	400	0	0	0.15	0.17	0.20
36	400	0	0	0.15	0.17	0.20
37	400	0	0	0.17	0.20	0.25
38	400	0	0	0.17	0.20	0.25
39	400	0	0	0.17	0.20	0.25
40	400	0	0	0.15	0.17	0.22
41	400	0	0	0.15	0.17	0.22
42	400	0	0	0.15	0.17	0.22
43	400	0	0	0.12	0.15	0.18
44	400	0	0	0.12	0.15	0.18
45	400	0	0	0.12	0.15	0.18
46	400	0	0	0.12	0.15	0.18

MELEV: Mean surface elevation of the land segment (feet)

BELV: Base elevation for active groundwater (feet)

GWDATM: Datum for the groundwater elevation (feet)

PCW: Cohesion Water Porosity (fraction)

PGW: Gravitational Water Porosity (fraction)

UPGW: Upper Gravitational Water porosity (fraction)

Table 7. WWHM2012 HSPF Pervious Parameter Values – Part V

PERLND No.	STABNO	SRRC	SREXP	IFWSC	DELTA	UELFAC	LELFAC
1	1	0.1	0	4	0.2	4	2.5
2	1	0.1	0	4	0.2	4	2.5
3	1	0.1	0	4	0.2	4	2.5
4	1	0.1	0	4	0.2	4	2.5
5	1	0.1	0	4	0.2	4	2.5
6	1	0.1	0	4	0.2	4	2.5
7	1	0.1	0	4	0.2	4	2.5
8	1	0.1	0	4	0.2	4	2.5
9	1	0.1	0	4	0.2	4	2.5
10	1	0.1	0	4	0.2	4	2.5
11	1	0.1	0	4	0.2	4	2.5
12	1	0.1	0	4	0.2	4	2.5
13	1	0.1	0	4	0.2	4	2.5
14	1	0.1	0	4	0.2	4	2.5
15	1	0.1	0	4	0.2	4	2.5
16	1	0.1	0	4	0.2	4	2.5
17	1	0.1	0	4	0.2	4	2.5
18	1	0.1	0	4	0.2	4	2.5
19	1	0.1	0	4	0.2	4	2.5
20	1	0.1	0	4	0.2	4	2.5
21	1	0.1	0	4	0.2	4	2.5
22	1	0.1	0	4	0.2	4	2.5
23	1	0.1	0	4	0.2	4	2.5
24	1	0.1	0	4	0.2	4	2.5
25	1	0.1	0	4	0.2	4	2.5
26	1	0.1	0	4	0.2	4	2.5
27	1	0.1	0	4	0.2	4	2.5
28	1	0.1	0	4	0.2	4	2.5
29	1	0.1	0	4	0.2	4	2.5
30	1	0.1	0	4	0.2	4	2.5
31	1	0.1	0	4	0.2	4	2.5
32	1	0.1	0	4	0.2	4	2.5
33	1	0.1	0	4	0.2	4	2.5
34	1	0.1	0	4	0.2	4	2.5
35	1	0.1	0	4	0.2	4	2.5
36	1	0.1	0	4	0.2	4	2.5
37	1	0.1	0	4	0.2	4	2.5
38	1	0.1	0	4	0.2	4	2.5
39	1	0.1	0	4	0.2	4	2.5
40	1	0.1	0	4	0.2	4	2.5
41	1	0.1	0	4	0.2	4	2.5
42	1	0.1	0	4	0.2	4	2.5
43	1	0.1	0	4	0.2	4	2.5
44	1	0.1	0	4	0.2	4	2.5

45	1	0.1	0	4	0.2	4	2.5
46	1	0.1	0	4	0.2	4	2.5

STABNO: User's number for the FTABLE in the FTABLES block which contains the outflow properties from the surface storage

SRRC: Surface Runoff Recession Constant (per hour)

SREXP: Surface Runoff Exponent

IFWSC: Maximum Interflow Storage Capacity when the groundwater elevation is greater than the upper influence elevation (inches)

DELTA: groundwater tolerance level used to determine transition between regions when high water table conditions are being simulated

UELFAC: multiplier on UZSN which gives the upper zone capacity

LELFAC: multiplier on LZSN which gives the lower zone capacity

The selection of the Table 6 and Table 7 default parameter values is based on limited application of these parameters in Western Washington by the staff of Clear Creek Solutions, Inc.. The parameter values should be used with caution and only after consultation with the Department of Ecology. Different values should only be selected following detailed local soil analysis, a thorough understanding of the parameters and algorithms, and consultation with the Department of Ecology.

A description of the Table 6 and Table 7 parameters and algorithms is in a separate document titled "WWHM2012 Description of HSPF High Groundwater Parameters" available from the Washington State Department of Ecology.

Table 8. WWHM2012 HSPF Pervious Parameter Values – Part VI

PERLND No.	CEPS	SURS	UZS	IFWS	LZS	AGWS	GWVS
1	0	0	0	0	3.0	1	0
2	0	0	0	0	3.0	1	0
3	0	0	0	0	3.0	1	0
4	0	0	0	0	3.0	1	0
5	0	0	0	0	3.0	1	0
6	0	0	0	0	3.0	1	0
7	0	0	0	0	3.0	1	0
8	0	0	0	0	3.0	1	0
9	0	0	0	0	3.0	1	0
10	0	0	0	0	3.0	1	0
11	0	0	0	0	3.0	1	0
12	0	0	0	0	3.0	1	0
13	0	0	0	0	3.0	1	0
14	0	0	0	0	3.0	1	0
15	0	0	0	0	3.0	1	0
16	0	0	0	0	3.0	1	0
17	0	0	0	0	3.0	1	0
18	0	0	0	0	3.0	1	0
19	0	0	0	0	3.0	1	0
20	0	0	0	0	3.0	1	0
21	0	0	0	0	3.0	1	0
22	0	0	0	0	3.0	1	0
23	0	0	0	0	3.0	1	0
24	0	0	0	0	3.0	1	0
25	0	0	0	0	3.0	1	0
26	0	0	0	0	3.0	1	0
27	0	0	0	0	3.0	1	0
28	0	0	0	0	2.5	1	0
29	0	0	0	0	2.5	1	0
30	0	0	0	0	2.5	1	0
31	0	0	0	0	2.5	1	0
32	0	0	0	0	2.5	1	0
33	0	0	0	0	2.5	1	0
34	0	0	0	0	2.5	1	0
35	0	0	0	0	2.5	1	0
36	0	0	0	0	2.5	1	0
37	0	0	0	0	4.2	1	0
38	0	0	0	0	4.2	1	0
39	0	0	0	0	4.2	1	0
40	0	0	0	0	4.2	1	0
41	0	0	0	0	4.2	1	0
42	0	0	0	0	4.2	1	0
43	0	0	0	0	4.2	1	0
44	0	0	0	0	4.2	1	0
45	0	0	0	0	4.2	1	0
46	0	0	0	0	0.5	0	0

CEPS: Initial interception storage (inches)

SURS: Initial surface runoff (inches)

UZS: Initial Upper Zone Storage (inches)

IFWS: Initial interflow (inches)

LZS: Initial Lower Zone Storage (inches)

AGWS: Initial Active Groundwater storage (inches)

GWVS: Initial Groundwater Vertical Slope (feet/feet)

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APPENDIX E: DEFAULT WWHM2012 HSPF IMPERVIOUS PARAMETER VALUES FOR CLARK COUNTY

The default WWHM2012 HSPF impervious parameter values are found in the WWHM2012 file defaultpers.uci.

The default WWHM2012 HSPF impervious parameter values for Clark County are based on the report:

Beyerlein, D.C. 2010. *Hydrologic Modeling of Clark County Watersheds with the U.S. EPA Hydrologic Simulation Program – FORTRAN (HSPF) Final Report (Revised)*. Clear Creek Solutions, Inc., Mill Creek, WA.

HSPF parameter documentation is found in the document:

Bicknell, B.R., J.C. Imhoff, J.L. Kittle Jr, T.H. Jobes, and A.S. Donigian Jr. 2001. *Hydrological Simulation Program – Fortran, User’s Manual for Version 12*. AQUA TERRA Consultants. Mountain View, CA.

Table 1. WWHM2012 Impervious Land Types

IMPLND No.	Impervious Surface	Slope
1	Roads	Flat
2	Roads	Moderate
3	Roads	Steep
4	Roofs	Flat
5	Driveways	Flat
6	Driveways	Moderate
7	Driveways	Steep
8	Sidewalks	Flat
9	Sidewalks	Moderate
10	Sidewalks	Steep
11	Parking	Flat
12	Parking	Moderate
13	Parking	Steep
14	Pond	Flat
15	Porous Pavement	user defined

Table 2. WWHM2012 HSPF Impervious Parameter Values – Part I

IMPLND No.	LSUR	SLSUR	NSUR	RETSC
1	400	0.01	0.10	0.10
2	400	0.05	0.10	0.08
3	400	0.10	0.10	0.05
4	400	0.01	0.10	0.10
5	400	0.01	0.10	0.10
6	400	0.05	0.10	0.08
7	400	0.10	0.10	0.05
8	400	0.01	0.10	0.10
9	400	0.05	0.10	0.08
10	400	0.10	0.10	0.05
11	400	0.01	0.10	0.10
12	400	0.05	0.10	0.08
13	400	0.10	0.10	0.05
14	400	0.01	0.10	0.10
15	400	0.01	0.10	0.00

LSUR: Length of surface flow path (feet) for impervious area

SLSUR: Slope of surface flow path (feet/feet) for impervious area

NSUR: Surface roughness (Manning's n) for impervious area

RETSC: Surface retention storage (inches) for impervious area

Table 3. WWHM2012 HSPF Impervious Parameter Values – Part II

IMPLND No.	RETS	SURS
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0

RETSC: Initial surface retention storage (inches) for impervious area

SURS: Initial surface runoff (inches) for impervious area