

Clarification Sheet for Appendix F – HYDROLOGIC ANALYSIS AND DESIGN

This document contains clarifications for the 2016 City of Seattle Stormwater Manual Final Draft, Appendix F. The 2016 City of Seattle Stormwater Manual documents are available on the following website:

<http://www.seattle.gov/dpd/codesrules/changestocode/stormwatercode/projectdocuments/default.htm>

1. Appendix F, Section F-4, Continuous Rainfall-runoff Methods. After “Flow Control Facility Design” (p. F-17 - F-21) and before “Water Quality Treatment BMP Design” (p. F-21), add the following:

On-site Performance Standard BMP Design

This section provides guidance for sizing BMPs to meet the On-site Performance Standard. If the applicant chooses to use the On-site List Approach, modeling is typically not required (refer to sizing requirements in Chapter 5 of Volume 3). If the applicant chooses to use the On-Site Performance Standard, the modeling procedures will depend upon the applicable target (i.e., forest or pasture). See Volume 1, Section 5.2.1 to determine the target based on the percent of existing hard surface and the type of drainage basin.

If the project discharge durations must match pre-developed **forested** flow durations for from 8 percent to 50 percent of the 2-year pre-developed flow, the procedures outlined above in the *Flow Duration Standard* subsection are generally applicable (with duration bounds revised to 8 percent to 50percent of the 2-year flow). Both WWHM and MGSFlood have the capability to evaluate (and report “pass” and “fail”) for this standard.

If the project discharge durations must match pre-developed **pasture** flow durations for the range of pre-developed discharge rates between the 1 percent and 10 percent exceedance values, the procedures outlined in this section are applicable.

The “frequency of exceedance” or “percent exceedance” (as referenced in the Code), is the percent of time, over the simulation period (e.g., 158 years), that a given flow is equaled or exceeded. MGSFlood and WWHM both report “exceedance probability”- the decimal equivalent of “percent exceedance”. For example, the 1 to 10 percent exceedance range corresponds to the 0.01 and 0.1 exceedance probabilities displayed on the flow duration curves (see Figure F-7a). The standard is achieved if the post-developed flows are less than the pre-developed flows for the 1 to 10 percent exceedance range (red line is beneath the green line for the shaded range of exceedance values).

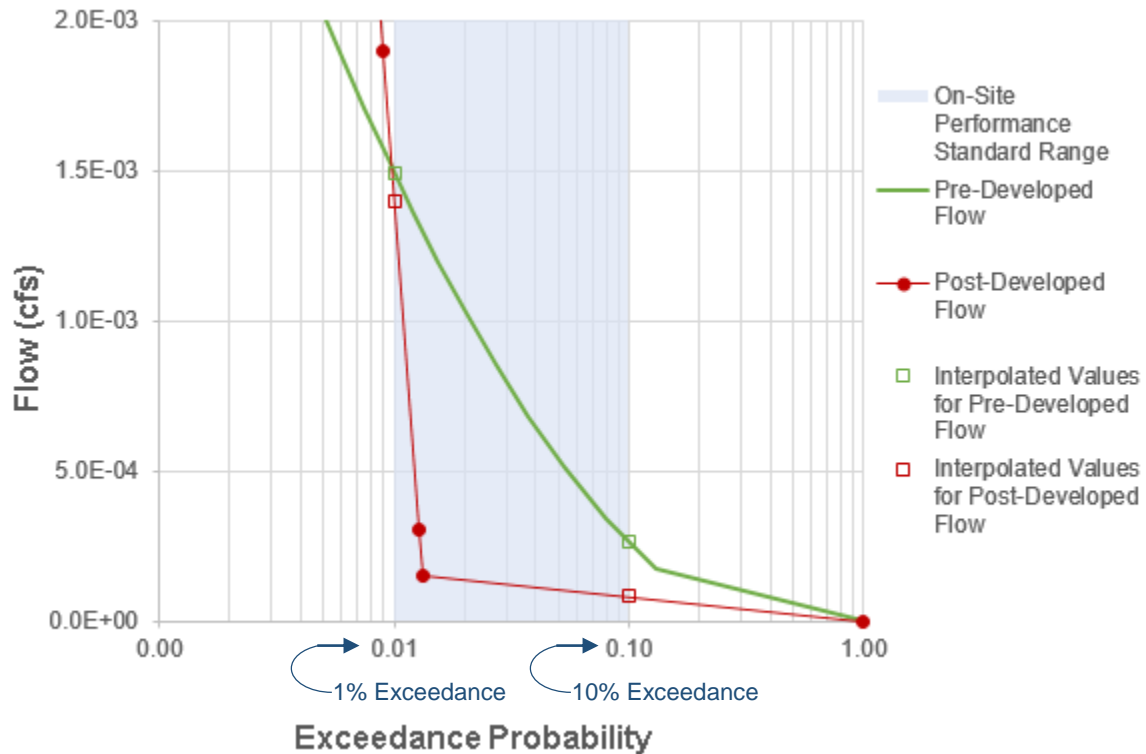


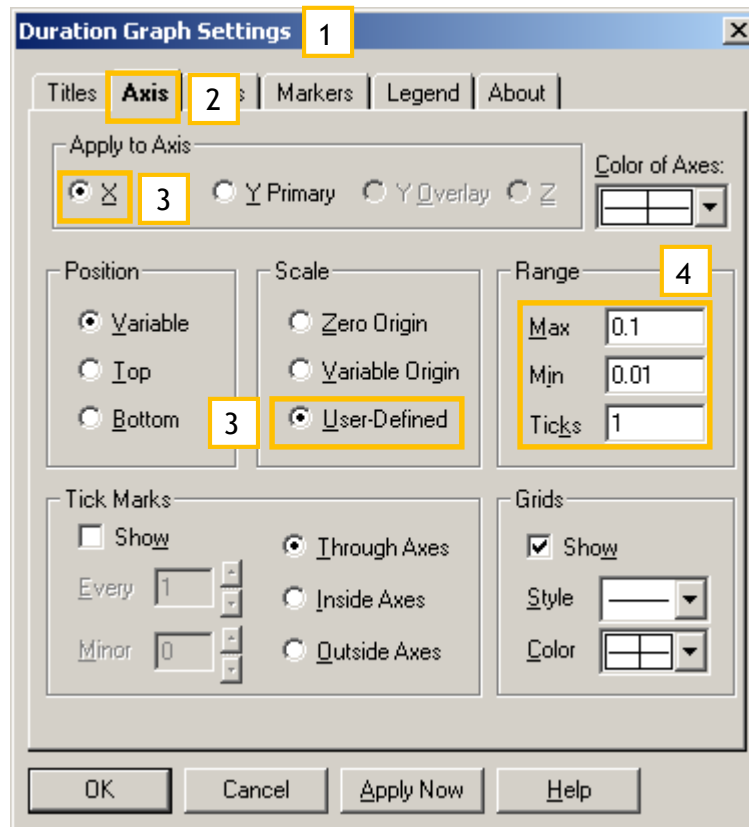
Figure F-7a. On-site Performance Standard Duration Curve

Neither MGSFlood nor WWHM currently (as of February 5th, 2016) report “pass” or “fail” for the 1 to 10 percent exceedance standard. We anticipate that, in the near future, both models will be updated to evaluate this standard internally. In the interim, the following procedures may be used to determine compliance with Seattle Stormwater Code.

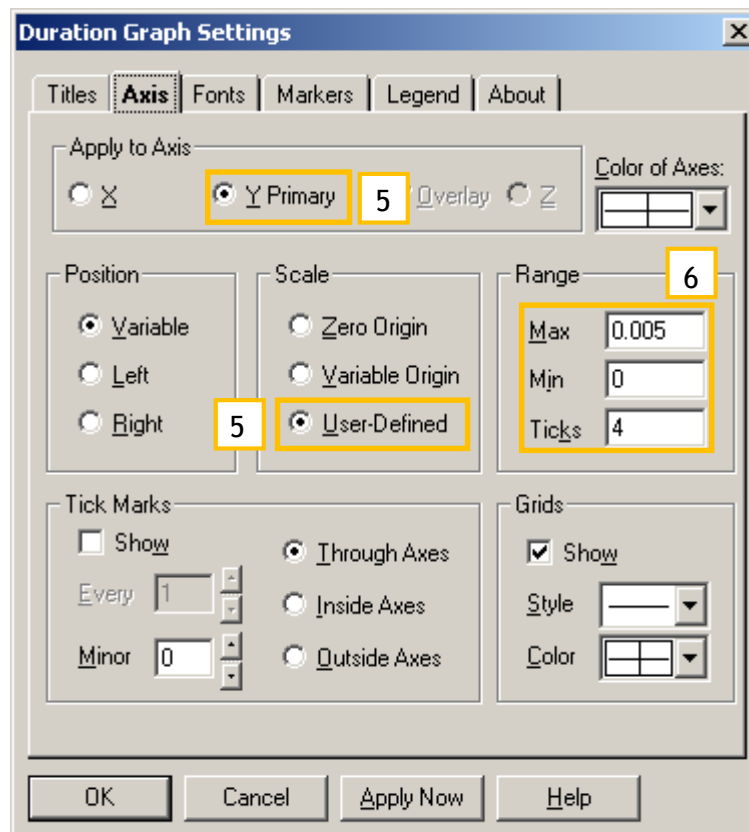
Visual Evaluation of On-site Performance Standard in MGSFlood

Compliance with the 1 to 10 percent exceedance standard may be confirmed by visually observing the MGSFlood Flow Duration Plot. The axes on the plot may be adjusted to clearly display the duration curve from 1 to 10 percent exceedance. Step-by-step instructions are provided below.

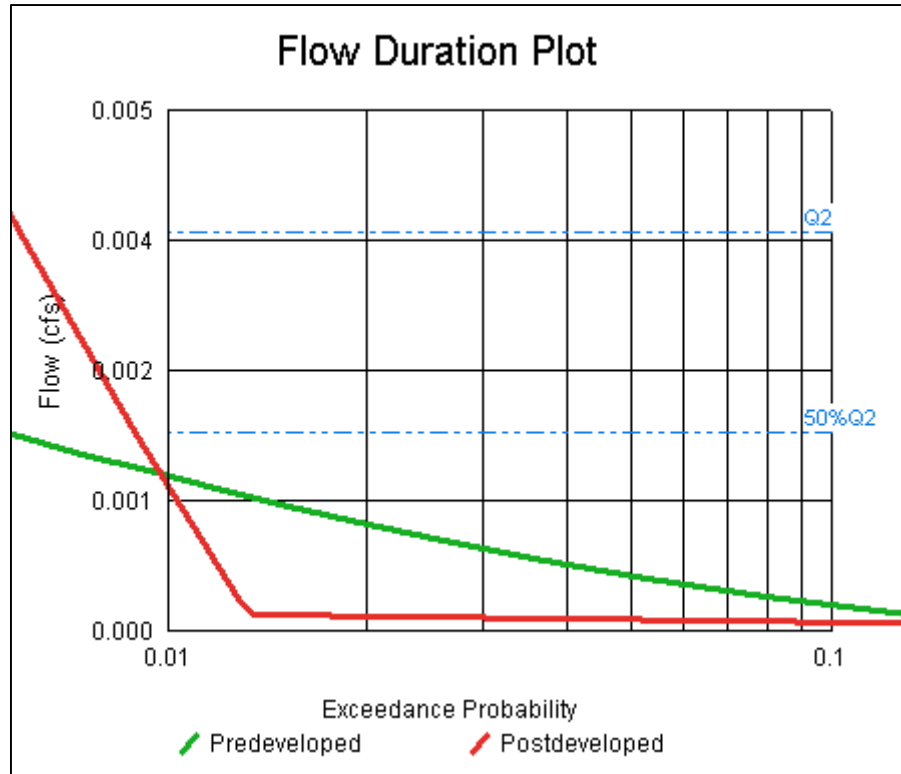
1. Right click on the Flow Duration Plot to open Duration Graph Settings
2. Select “Axis” tab
3. Edit x-axis scale (select “X”, “User Defined”)
4. Update x-axis range of values as follows:
 - a) Max = 0.1
 - b) Min = 0.01
 - c) Ticks = 1



5. Edit y-axis scale (select “Y Primary”, “User Defined”)
6. Update y-axis range of values. Values will vary depending on size of contributing area.



7. Visually inspect to confirm that the post-developed flows are less than the pre-developed flows for the 1 to 10 percent exceedance range (red line is beneath the green line for the range plotted).



Quantitative Evaluation of the On-site Performance Standard in MGSFlood

If the user wishes to fully optimize BMP sizes for the 1 to 10 percent exceedance standard, values must be calculated and evaluated outside of the model. Step-by-step procedures are provided below with an example:

1. Build and run the model
2. View report file (File>View Report)
3. Select “Full Output” to get full detailed report and click “Refresh”
4. Navigate to “Point of Compliance Flow Duration Data”
5. Determine pre-developed flows associated with 1 percent and 10 percent exceedance probability using the steps below. Note that a higher probability of exceedance corresponds to lower, more frequent, flows.
 - a) Identify the exceedance probability values immediately higher and immediately lower than the 1 percent exceedance. Record the exceedance probabilities and the associated flows as shown in the example below:

	Pre-development Runoff Discharge (cfs)	Exceedance Probability
Higher than 1%	1.37E-03	1.19%
Lower than 1%	1.54E-03	0.94%

6. Identify the exceedance probability values immediately higher and immediately lower than the 10 percent exceedance. Record the exceedance probabilities and the associated flows as shown in the example below:

	Pre-development Runoff Discharge (cfs)	Exceedance Probability
Higher than 10%	1.71E-04	13.15%
Lower than 10%	3.42E-04	7.97%

7. Logarithmically interpolate flows associated with the 1 and 10 percent exceedance probabilities using Equation 1 and Equation 2, respectively.

$$Flow_{1\%} = Flow_{lower} + \frac{Flow_{lower} - Flow_{higher}}{\log(Exceedance_{lower}) - \log(Exceedance_{higher})} \times [\log(1\%) - \log(Exceedance_{lower})] \quad \text{Eq 1.}$$

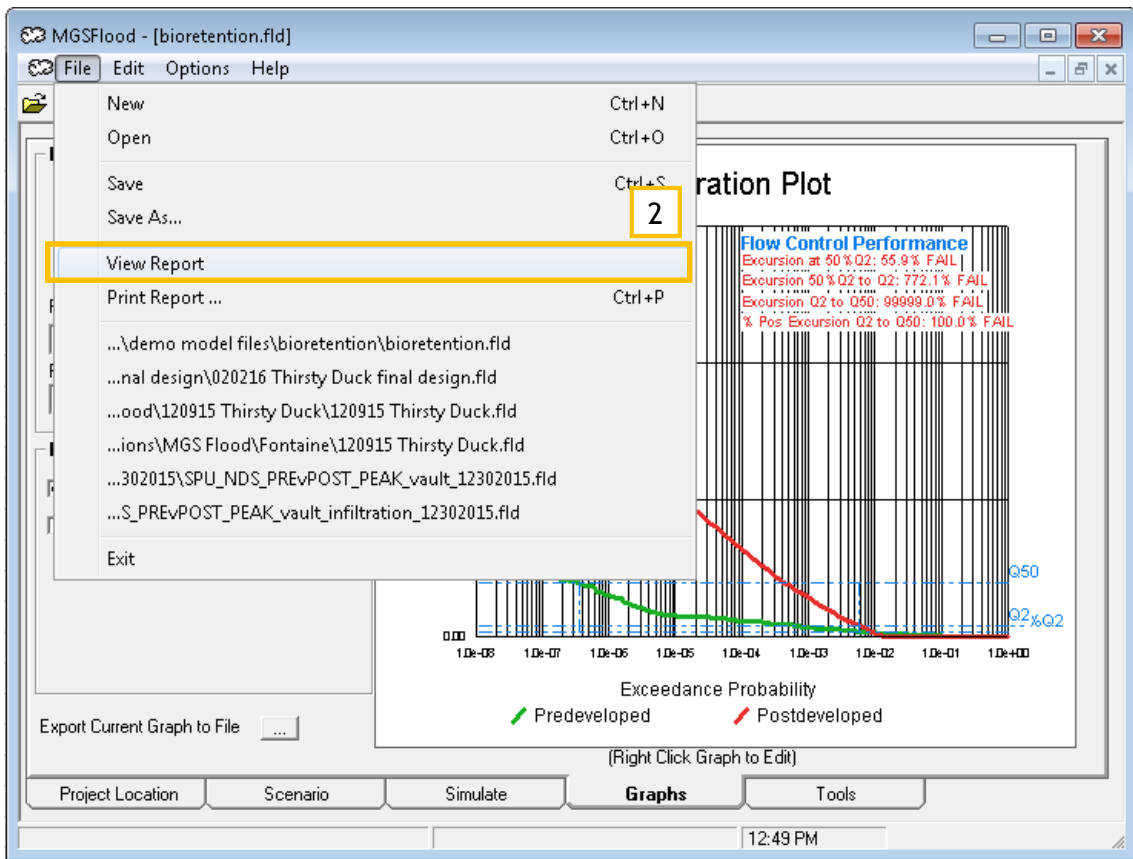
$$Flow_{10\%} = Flow_{lower} + \frac{Flow_{lower} - Flow_{higher}}{\log(Exceedance_{lower}) - \log(Exceedance_{higher})} \times [\log(10\%) - \log(Exceedance_{lower})] \quad \text{Eq 2.}$$

Results for this example are shown below:

	Pre-development Runoff Discharge (cfs)	Exceedance Probability
Interpolated flows at 1%	1.49E-03	1.00%
Interpolated flows at 10%	2.64E-04	10.00%

8. Determine post-developed flows associated with 1 percent and 10 percent exceedance probability. Repeat Step 5a, 5b, and 5c using post-developed flows.

	Post-development Runoff Discharge (cfs)	Exceedance Probability
Interpolated flows at 1%	1.40E-03	1.00%
Interpolated flows at 10%	8.16E-05	10.00%



Summary Report

*** Point of Compliance Flow Duration Data *** 4

Predevelopment Runoff		Postdevelopment Runoff	
Discharge (cfs)	Exceedance Probability	Discharge (cfs)	Exceedance Probability
0.000E+00	1.0000E+00	0.000E+00	1.0000E+00
1.708E-04	1.3153E-01	1.528E-04	1.3408E-02
3.417E-04	7.9651E-02	3.056E-04	1.2772E-02
5.125E-04	5.2827E-02	1.894E-03	8.9475E-03
6.834E-04	3.6934E-02	2.525E-03	7.8439E-03
8.542E-04	2.6978E-02	3.157E-03	6.8966E-03
1.025E-03	2.0119E-02	3.820E-03	5.9901E-03
1.196E-03	1.5285E-02		:03
1.367E-03	1.1882E-02		:03
1.538E-03	9.3564E-03		:03
1.708E-03	7.4473E-03		:03
1.910E-03	5.7199E-03	6.945E-03	3.2085E-03
2.050E-03	4.8110E-03	7.615E-03	2.8183E-03
2.221E-03	3.8998E-03	8.208E-03	2.5351E-03
2.392E-03	3.1807E-03	8.839E-03	2.2812E-03
2.563E-03	2.5968E-03	9.470E-03	2.0536E-03
2.733E-03	2.1169E-03	1.010E-02	1.8602E-03
2.904E-03	1.7104E-03	1.073E-02	1.6888E-03
3.075E-03	1.4057E-03	1.136E-02	1.5407E-03
3.246E-03	1.1695E-03	1.200E-02	1.4010E-03
3.417E-03	9.9161E-04	1.263E-02	1.2808E-03

5a

Higher Probability
Lower Probability

6a

5b Included in table of values, but not shown in screen capture
6b

Report Output Level

Minimal Output (Compliance Statistics Only)

Moderate Output (Includes Stats at All Locations)

Full Output (Includes Stat Tables, Hydraulic Rating Tables) 3

Include Flow Duration Compliance Statistics 3

Include LID Duration Compliance Statistics

Refresh

Close

9. Compare pre-developed flows and post-developed flows at 1 and 10 percent exceedance probabilities and visually confirm, from the flow duration curves in the model, that the post-developed flows are smaller than the pre-developed flows. If post-developed flows at the 1 or 10 percent exceedance probability are higher than the pre-developed flows, or if the post developed flows appear to exceed the pre-developed flows for the 1 to 10 percent exceedance range of the duration curve (refer to procedures for visual observation, above), increase the BMP size(s), run the model, and repeat Steps 2 through 9.

See Figure F-7a for a comparison of pre-and post-developed flow duration curves for the target exceedance probability range. Figure F-7a also includes the interpolated data points described above, shown as hollow squares on the graph. If post-developed flows (shown in red) are smaller than pre-developed flows (shown in green) for the target exceedance probability range (grey hatch), the project satisfies the On-site Performance Standard.

Visual Evaluation of On-site Performance Standard in WWHM

Compliance with the 1 to 10 percent exceedance standard may be estimated by visually observing the WWHM Stream Protection Duration Plot. The axes on the plot must be adjusted and manually evaluated to more clearly display the duration curve from 1 to 10 percent exceedance. Because the graphs are difficult to accurately read, the facility may need to be somewhat oversized to visually confirm compliance. Step-by-step instructions are provided below:

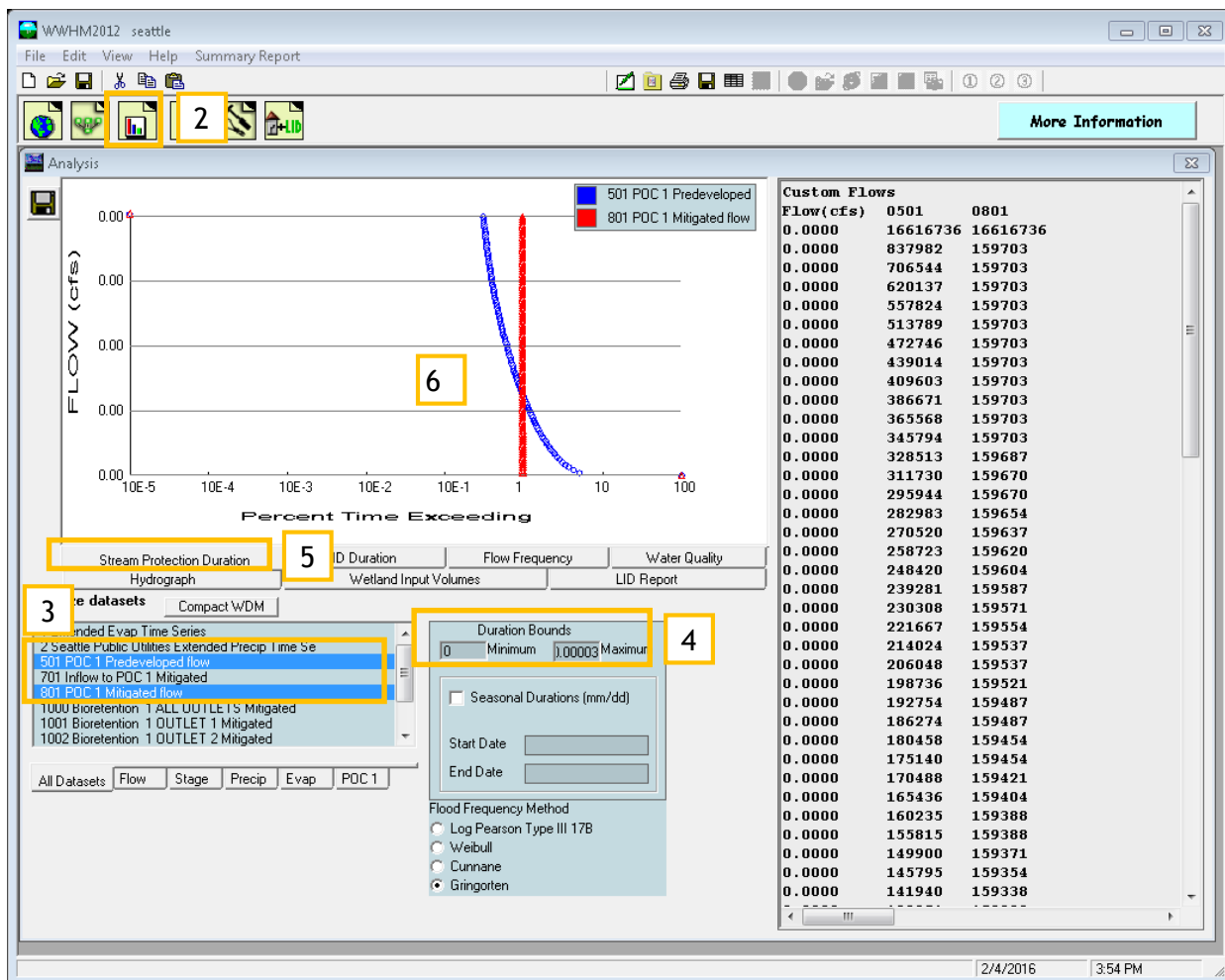
1. Build and run the model
2. View the “Stream Protection Duration” results in the Analysis tab window
3. Select the appropriate points of compliance for the pre-developed scenario and the mitigated (i.e., post-developed) scenario under “All Datasets” (hold CTRL to select more than one)

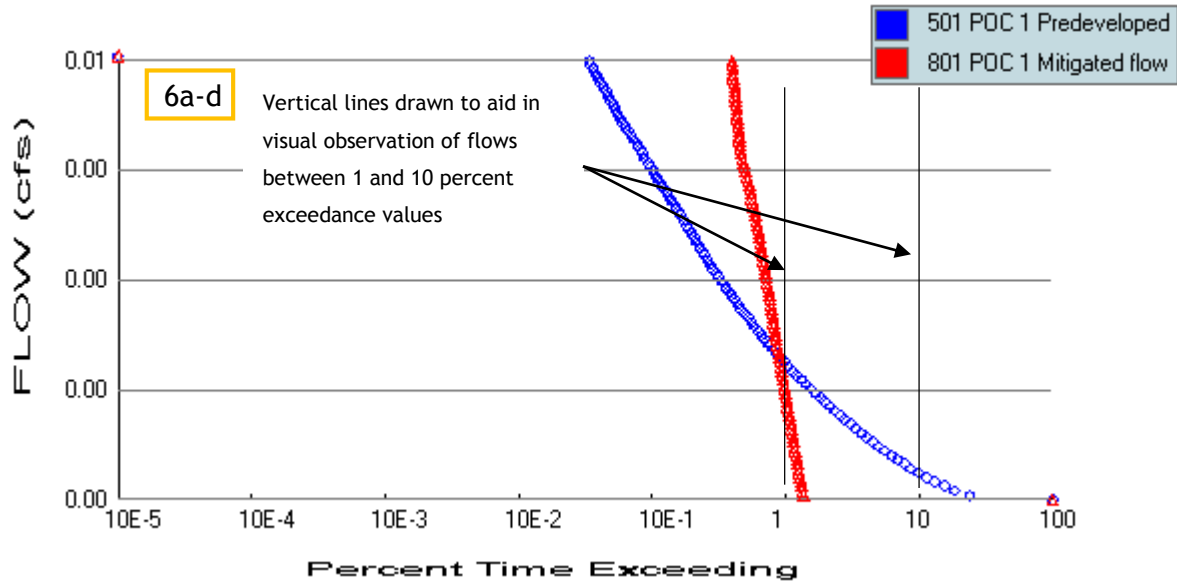
501 POC 1 Predeveloped flow

801 POC 1 Mitigated flow

4. Modify the “Duration Bounds” to include the 1 and 10 percent exceedance values
 - b) Minimum = 0 cfs
 - c) Maximum = established by trial and error until the pre-developed flows corresponding to the 1 percent exceedance are visible on the graph. To optimize the facility size(s), set the maximum value slightly above the predeveloped flow that is exceeded 1 percent of the time. This value can be approximated as the contributing area in acres times 0.00025 cfs per acre.
5. Select the “Stream Protection Duration” tab to re-calculate the results with the new duration bounds
6. Visually inspect the duration plot to confirm that the mitigated flows are smaller than the pre-developed flows for the 1 to 10 percent exceedance range. Because the plots are difficult to accurately read, the following steps are required to confirm compliance with the 1 to 10 percent exceedance standard:
 - a. Take a screenshot of the flow duration curve

- b. Paste the screenshot into a word processing software, e.g. Word
- c. Overlay two vertical lines at the 1% and 10% tick marks
- d. Confirm the mitigated flows (red line) are below the pre-developed flows (blue line) within the range of the two horizontal lines. Note: to visually ensure compliance, the facility may need to be somewhat oversized (the screenshot shown below is 10 percent larger than required when quantitative evaluated using the procedure provided below).





Evaluation of the On-site Performance Standard in WWHM

To quantitatively evaluate and fully optimize BMP sizes for the 1 to 10 percent exceedance standard, values must be calculated and evaluated outside of the model. Step-by-step procedures are provided below with an example:

1. Build and run the model
2. View the “Stream Protection Duration” results in the Analysis tab window
3. Select the appropriate points of compliance for the pre-developed scenario and the mitigated (i.e., post-developed) scenario under “All Datasets” (hold CTRL to select more than one)

501 POC 1 Predeveloped flow

801 POC 1 Mitigated flow

4. Modify the “Duration Bounds” to include the 1 and 10 percent exceedance values
 - d) Minimum = 0 cfs
 - e) Maximum = established by trial and error until the pre-developed flows corresponding to the 1 percent exceedance are visible on the graph. To optimize the facility size(s), set the maximum value slightly above the predeveloped flow that is exceeded 1 percent of the time. This value can be approximated as the contributing area in acres times 0.00025 cfs per acre.

$$0.12 \text{ acres} \times 0.00025 \text{ cfs/acre} = 0.00003$$

5. Select the “Stream Protection Duration” tab to re-calculate the results with the new duration bounds
6. Determine the total number of timesteps calculated by the model. Refer to the first line in the “Custom Flows” table (i.e., number of timesteps associated with a flow of zero cfs (flow at every timestep is greater than or equal to zero cfs)).

Custom Flows		
Flow(cfs)	0501	0801
0.0000	16616736	16616736

7. Calculate the number of timesteps that correspond to the 1 percent and 10 percent exceedance values using equations 3 and 4

$$1 \text{ Percent of Timesteps} = \text{Total number of Timesteps} \times 0.01 \quad \text{Eq 3}$$

$$10 \text{ Percent of Timesteps} = \text{Total number of Timesteps} \times 0.1 \quad \text{Eq 4}$$

$$1 \text{ Percent of Timesteps} = 16,616,736 \times 0.01 = 166,167$$

$$10 \text{ Percent of Timesteps} = 16,616,736 \times 0.1 = 1,661,674$$

8. Compare pre-developed flows and post-developed (i.e., mitigated) flows at the 1 percent exceedance probability. While the flow values themselves are often too small to display in the “Custom Flows” table in WWHM, the number of timesteps a given flow is exceeded can be used to evaluate facility performance relative to the pre-developed condition. For the On-site Performance standard, all flows with a probability of exceedance from 1 to 10 percent should be exceeded at the same frequency, or less frequently than the predeveloped condition. In other words, for a given flow in the target range, the number of timesteps that flow is exceeded should be fewer in the mitigated scenario than the pre-developed scenario. To compare the pre-developed and mitigated flows:
- Identify the flow values immediately higher and immediately lower than the target 1 percent of timesteps (as determined in Step 7) for the pre-developed scenario
 - Compare the number of timesteps these flow values are exceeded in the mitigated scenario to the pre-developed scenario.
 - If the pre-developed scenario is exceeded less frequently than the mitigated scenario, increase facility size and repeat Step 8.
 - Proceed to Step 9.

Custom Flows		
Flow(cfs)	0501	0801
0.0000	170488	159421
0.0000	165436	159404

The first flow is exceeded for 170,488 timesteps (170,488/ 16,616,736 = 1.03%) in the pre-developed condition. The second flow is exceeded for 165,436 timesteps (165,436/ 16,616,736=0.996%) in the pre-developed condition. For these flows, the mitigated scenario is exceeded for a fewer number of timesteps than the pre-developed scenario, therefore the mitigated condition meets the On-site Performance Standard at the 1 percent exceedance value.

9. Compare pre-developed flows and post-developed (i.e., mitigated) flows at the 10 percent exceedance probability:

- a. Identify the flow values immediately higher and immediately lower than the target 10 percent of timesteps (as determined in Step 7) for the pre-developed scenario
- b. Compare the number of timesteps these flow values are exceeded in the mitigated scenario to the pre-developed scenario.
- c. If the pre-developed scenario is exceeded less frequently than the mitigated scenario, increase facility size and repeat Step 9.
- d. Proceed to Step 10.

Custom Flows		
Flow(cfs)	0501	0801
0.0000	16616736	16616736
0.0000	837982	159703

The first flow is exceeded for 16,616,736 timesteps ($16,616,736 / 16,616,736 = 100\%$) for both the pre-developed scenario and the mitigated scenario. The second flow is exceeded for 837,982 timesteps ($837,982 / 16,616,736 = 5.04\%$) in the pre-developed condition and is exceeded for 21,134 timesteps in the mitigated condition. Therefore the mitigated condition meets the on-site standard at the 10% exceedance value.

10. Visually confirm, from the flow duration curves in the model, that the mitigated flows are smaller than the pre-developed flows for the 1 to 10 percent exceedance range. If the post developed flows appear to exceed the pre-developed flows for the 1 to 10 percent exceedance range of the duration curve, increase the BMP size(s) and repeat Steps 8 through 10.

