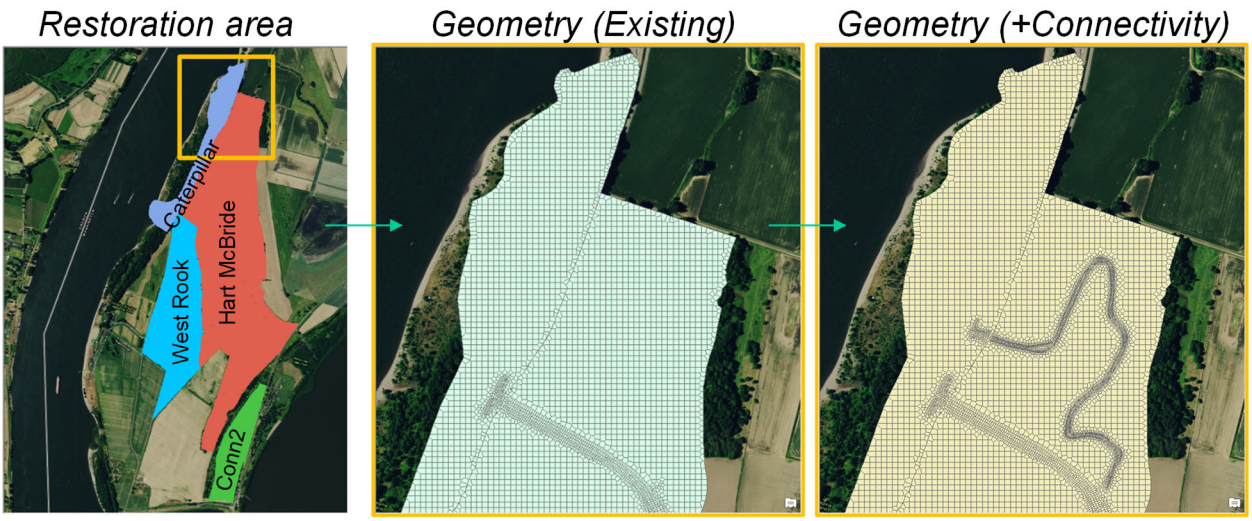
Workshop – Using EFM with 2D river hydraulics model output

EFM helps study teams determine ecological responses to changes in the flow regime of a river or connected wetland. EFM uses the same computational process whether flow regimes are defined at one or more gages, river cross sections, or spatial elements in a 2D computation mesh.

In this workshop, we will use output from a 2D river hydraulics model. Data are adapted from a restoration project on the Columbia River designed to improve floodplain habitats for fish by increasing connectivity between the river and floodplain and internally, within the floodplain area. Two scenarios are considered: existing conditions and increased connectivity.

The restoration area is approximately 800 acres. It is divided into 4 separate 2D flow areas in the river hydraulics model. We will analyze the 2D area named West Rook.



While the primary motivation for restoration is salmon habitat, stakeholders are also concerned about how increased connectivity will affect the area's diverse mix of wetland and riparian habitats whose vegetation provides habitat for an array of insects, birds, and mammals. Your task is to define and test EFM relationships to: 1) characterize vegetation and 2) show salmon habitat. Existing conditions and increased connectivity will be investigated and compared.

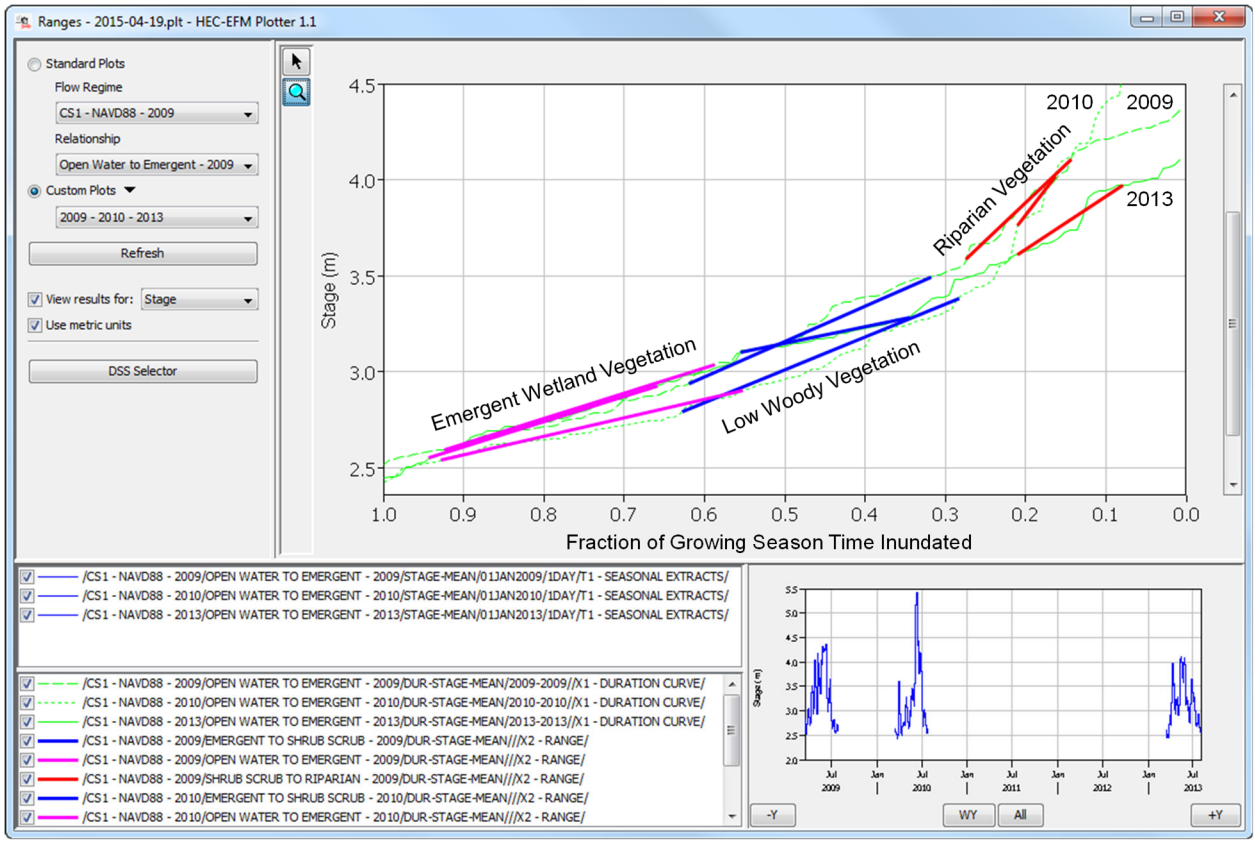
Resources provided:

1) Time series of depth for 2009 (ExistingConditions.hdf and IncreasedConnectivity.hdf)
2) A GIS project that includes geometry of the 2D elements for both scenarios
3) A spreadsheet with element areas for West Rook for both scenarios.

Defining EFM Relationships: Vegetation

Insects, birds, and mammals use different plant communities as habitats for nesting, shelter, and forage. Distributions of floodplain vegetation are significantly affected by the timing and duration of inundation

during the formative growing season, **February through July** (for this project). An EFM analysis of field data collected near the restoration site produced the following summary of inundation and vegetation:



Inundation-driven vegetative communities in the study area include emergent wetlands, low woody shrubs, and floodplain riparian. Lands inundated for a greater **percentage of time** than emergent wetlands are open water. Lands inundated for a lesser **percentage of time** than riparian are upland terrestrial. Based on the image above, fill in the following modeling logic table:

Modeling Logic: Percent Time Inundated (early growing season) for Vegetation										
	Open Water		Emergent Wetlands		Low Woody Veg		Floodplain Riparian		Upland	
	Start	End	Start	End	Start	End	Start	End	Start	End
Values										

1) Define an EFM relationship to compute percent inundation within the study area.

Season:
Duration: 1-day
% Exceedance Setting (frequency or duration, *pick one* - see hint 1):
Reverse Lookup (see hint 2):

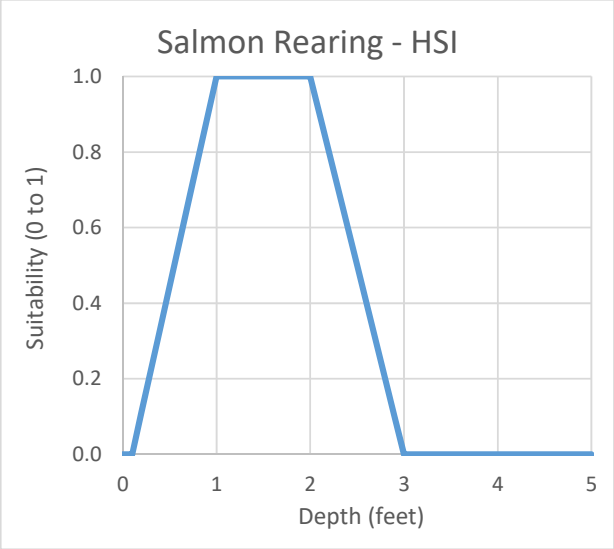
Hint 1: Flow <u>duration</u> considers percentage of time; flow <u>frequency</u> considers percentage of years.

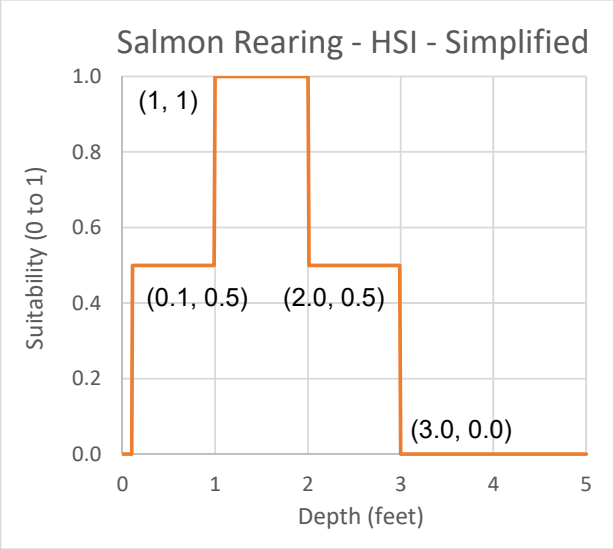
Hint 2: Consider the reverse lookup feature that allows users to compute the percentage of time a value is equaled or exceeded. What value of depth would separate inundated and non-inundated lands?

Salmon Rearing

Juvenile salmonids use inundated floodplain areas as rearing habitat during their outmigration to the sea. In the Columbia River Basin, young chinook and steelhead utilize these areas as important forage sources and excellent cover from **February to June**.

Habitat suitability indices (HSI) relate quality of habitat to values of a variable. Typically, HSI are species and life stage specific. Suitabilities are expressed on a scale from 0 (unsuitable) to 1 (ideal). Depth, velocity, substrate, and cover are common HSI variables for aquatic species. A habitat suitability index for Salmon Rearing - Depth follows:





Whereas a single distribution of vegetation is shaped by conditions throughout the early growing season, consideration of fish habitat occurs intermittently **in time** and space.

2) Use the simplified HSI and a set of EFM relationships to calculate of salmon rearing habitat in terms of the **number of suitable habitat days** provided.

Modeling Logic: Suitabilities for Salmon Rearing										
	Suit =		Suit =		Suit =		Suit =		Suit =	
	Start	End	Start	End	Start	End	Start	End	Start	End
Depth										

EFM Relationships:

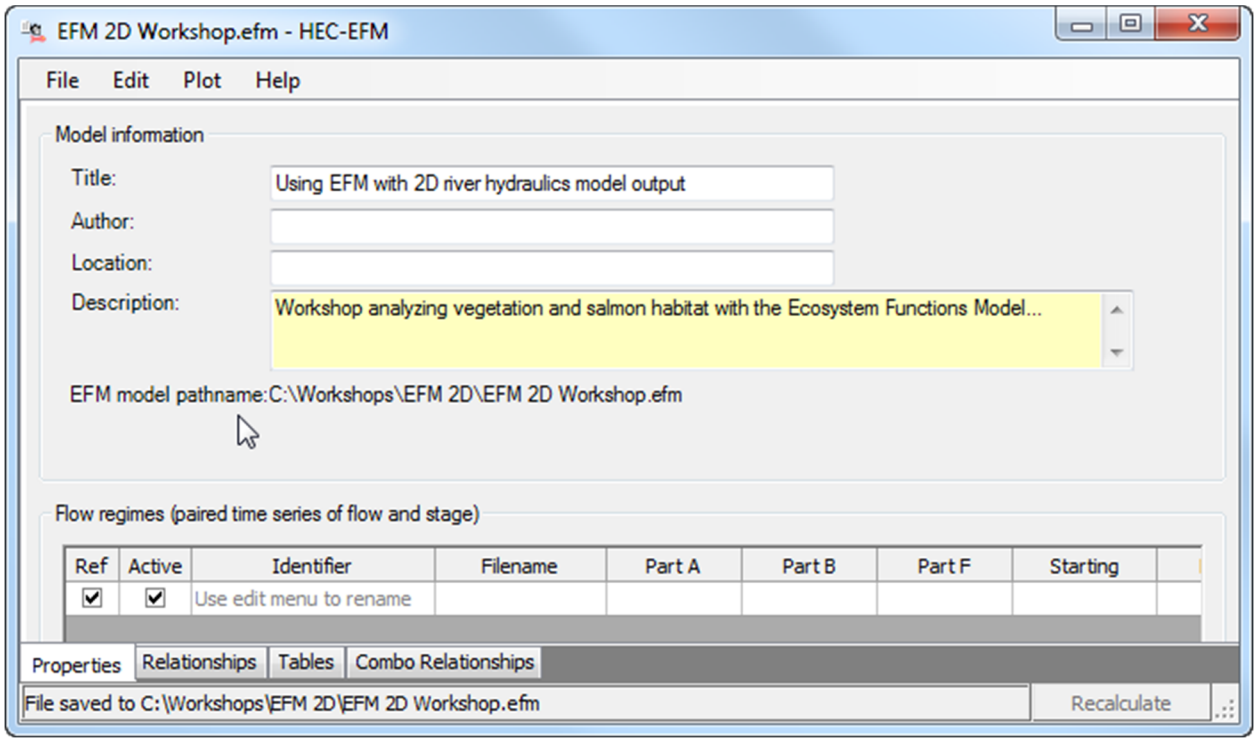
Season:
Duration: 1-day
% Exceedance Setting (frequency or duration, *pick one* - see hint 1):
Reverse Lookup:

Hint 1: Flow <u>duration</u> considers percentage of time; flow <u>frequency</u> considers percentage of years.

Hint 2: EFM can compute the percentage of time spent within a range of depths.

Using EFM

1) Now let's use EFM to test the relationships for vegetation and salmon rearing. Open EFM and use the "File – New" menu option to create a new application. Enter any model information on the Properties tab. Save application to a directory on your computer.

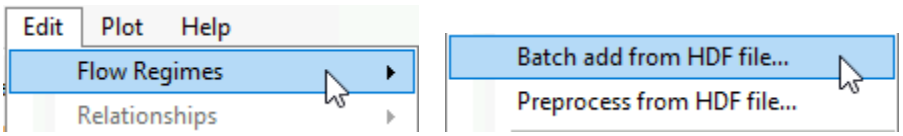


2) The hydraulic data for this workshop are stored in files called "ExistingConditions.hdf" and "IncreasedConnectivity.hdf". HDF stands for Hierarchical Data Format. HDF files can include many different data tables.

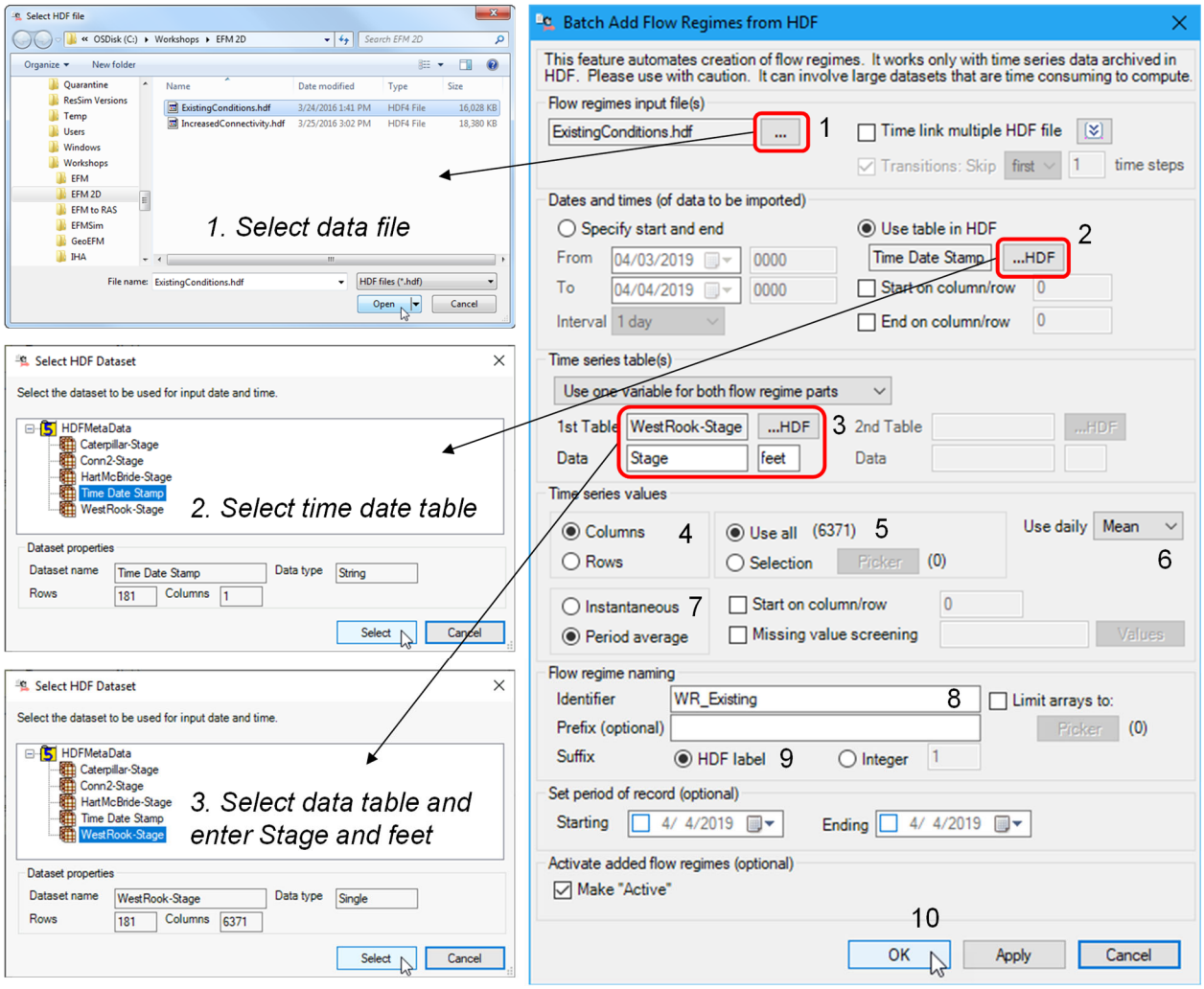
   Data for this exercise are:

   - Period average values
   - Daily time step
   - Stage (in feet)
   - Stored in columns in HDF

3) The next step is to add the flow regimes. Adding flow regimes from HDF is different than adding from text files or DSS. Use the "Edit - Flow Regimes - Batch add from HDF file…" menu option.



Follow the 10 steps in the image below to add the flow regime for Existing conditions:



4) Repeat this process for the Increased Connectivity flow regime (name this WR_Restored). For now, only activate the Existing flow regime. The Flow Regimes table in EFM should look like:

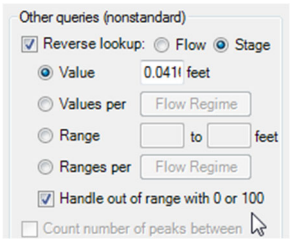
Flow regimes (paired time series of flow and stage)

Ref	Active	Identifier	Filename	Part A	Part B	Part F	Starting	Ending
☐	☑	WR_Existing	ExistingConditions.	WR_Existing-H	(6371)		02/01/2009	07/31/2009
☐	☐	WR_Restored	IncreasedConnecti	WR_Restored-	(6393)		02/01/2009	07/31/2009

The numbers in the Part B column correspond to the number of elements in the West Rook 2D area. Essentially, these are "compound flow regimes", each with over 6000 parts - one for each element.

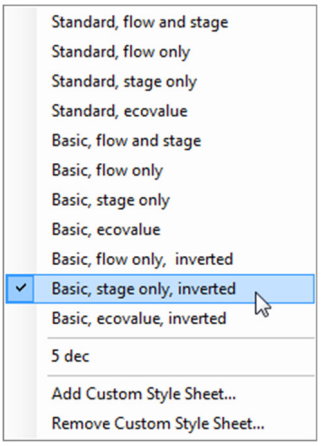
5) Go to the Relationships tab. Use the "Edit - Relationships - Add…" menu option to add a new relationship named "Veg - Percent time inundated". Enter the statistical settings proposed in the "Vegetation" section of this workshop. Settings should be similar to:

Statistical Settings	**Veg - Percent time inundated**
Season	2/1 to 7/31
Duration	1 day
% Exceedance	Flow duration
Reverse lookup (stage, value)	0.041667 feet (0.5 inches)
Handle out of range with 0/100	**On**



Note: This is a simple relationship. The value of 0.5 inches separates inundated and not inundated. This value is open to debate based on hydraulic model considerations (with no infiltration, water persists in elements at very small depths like a film of water) and ecological considerations (depths of water may influence dynamics like germination) contributing to the conversation.

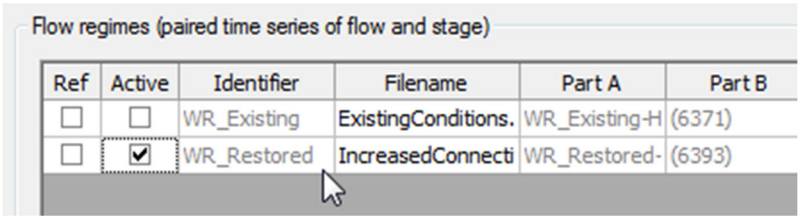
6) Go to the "File - Select Style Sheets - Results" menu and select the "Basic, stage only, inverted" style sheet. Style sheets control the format of EFM results. In this case, "inverted" means that flow regimes will be tabulated in rows and relationships will be in columns.



7) When complete, save the EFM project and then click Recalculate.

8) Copy results (use Ctrl A to select all) into the "EFM 2D Workshop.xlsx" spreadsheet provided in the workshop folder.

9) Go to the Properties tab, deselect the "WR_Existing" flow regime and select the "WR_Restored" flow regime. Recalculate. Copy results and paste into the spreadsheet.



Reverse Look-ups - Flow Duration

	Veg - Percent time inundated
Flow Regime	**% X, of time**
WR_Existing-0	0
WR_Existing-1	0
WR_Existing-2	0
WR_Existing-3	0
WR_Existing-4	0
WR_Existing-5	0
WR_Existing-6	0
WR_Existing-7	0
WR_Existing-8	0
WR_Existing-9	0
WR_Existing-10	0
WR_Existing-11	0
WR_Existing-12	0
WR_Existing-13	0
WR_Existing-14	0
WR_Existing-15	0
WR_Existing-16	0
WR_Existing-17	0
WR_Existing-18	0
WR_Existing-19	0
WR_Existing-20	0
WR_Existing-21	0
WR_Existing-22	11.3
WR_Existing-23	10.8

10) Go to the Relationships tab. Deactivate the "Veg" relationship. Use the "Edit - Relationships - Add…" menu to add a relationship named "Salmon HSI - 0.1to1". Enter the statistical settings proposed in the "Salmon Rearing" part of this workshop. Settings should be similar to:

Statistical Settings	**Salmon HSI - 0.1to1**
Season	2/1 to 6/30
Duration	1 day
% Exceedance	Flow duration
Reverse lookup (stage, range)	0.1 to 1 feet
Handle out of range with 0/100	**On**

11) Use the “Edit - Relationships - Duplicate…” menu to create relationships named “Salmon HSI - 1to2” and “Salmon HSI - 2to3”. Remember to update the range values for each. Save your project.

12) Click recalculate. Copy results into the spreadsheet…remember you’re likely on “WR_Restored”.

13) Go to the Properties tab. Deselect the "WR_Restored" flow regime and select the "WR_Existing" flow regime. Recalculate. Copy results into the spreadsheet.

Analyzing EFM Results in Spreadsheet

All EFM calculations should now be complete. Over 8 million data values were used to generate the results you are about to analyze. Fill in the tables and respond to the questions below using the EFM results and the element areas to assess the restoration plan.

Vegetation

Use your vegetation modeling logic to fill in the habitat area table. Logic should be similar to:

Modeling Logic: Percent Time Inundated (early growing season) for Vegetation										
	Open Water		Emergent Wetlands		Low Woody Veg		Floodplain Riparian		Upland	
	Start	End	Start	End	Start	End	Start	End	Start	End
Values	100	93	93	60	60	30	30	10	10	0

Vegetation habitat area table.

Habitat Types	Existing (acres)	Restored (acres)	Change (acres)	Percent Change
Open Water				
Emergent Wetlands				
Low Woody Shrub				
Floodplain Riparian				
Upland Terrestrial				

1) Which habitat type gained the most area in West Rook?

2) Which habitat type lost the most area in West Rook?

3) Waterfowl are common in the restoration area. Emergent wetlands are their preferred habitat. Waterfowl predators (hawks and falcons) roost and nest in upland habitats. Based on the habitat responses detailed above, how will the restoration affect waterfowl within the West Rook area?

4) Describe the overall trend in habitat change from Existing to Restored.

Salmon Rearing

Fill in the tables and respond to the questions below using the EFM results and the element areas to assess the restoration plan. Modeling logic should be similar to:

Modeling Logic: Suitabilities for Salmon Rearing										
	Suit = 0		Suit = 0.5		Suit = 1		Suit = 0.5		Suit = 0	
	Start	End	Start	End	Start	End	Start	End	Start	End
Depth	0.0	0.1	0.1	1.0	1.0	2.0	2.0	3.0	3.0	>3.0

Suitable habitat area provided for salmon rearing:

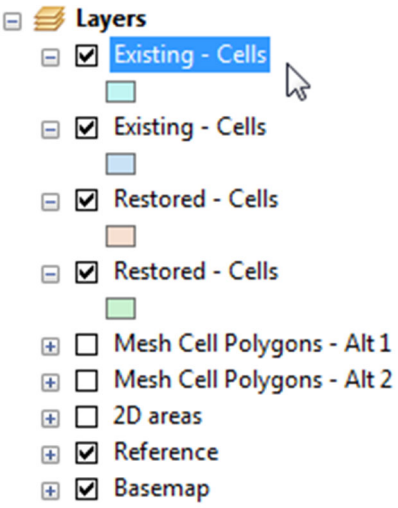
Habitat Type	Existing (acres)	Restored (acres)	Change (acres)	Percent Change
Salmon Rearing				

Hint: The progression of calculations used to obtain these values in the solution was: % time in each range (EFM results), number of days in each range, number of suitable habitat days in each range, total suitable habitat days, and total suitable habitat provided.

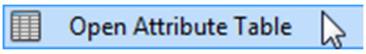
5) In West Rook, would the Restored alternative generate more salmon rearing suitable habitat?

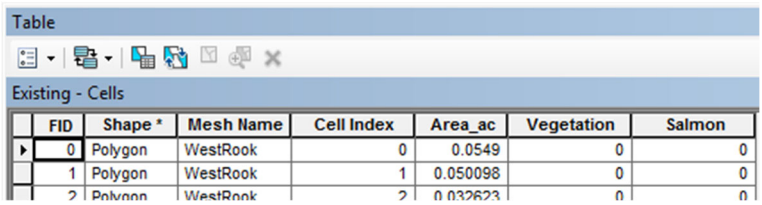
Using GIS

Let's investigate the EFM results in GIS. In the workshop folder, there is a map file called "EFM 2D - Workshop.mxd". Open it in ArcMap. Several layers are provided: 1) two copies of "Existing - Cells" and "Restored - Cells" shapefiles that have the cell layouts for their respective scenarios, West Rook area only, 2) "Mesh Cell Polygons" that has cells for all 2D areas in both scenarios (Alt 1 = Existing and Alt 2 = Restored), 3) a layer with the 2D areas, and 4) basemap imagery with labeling.



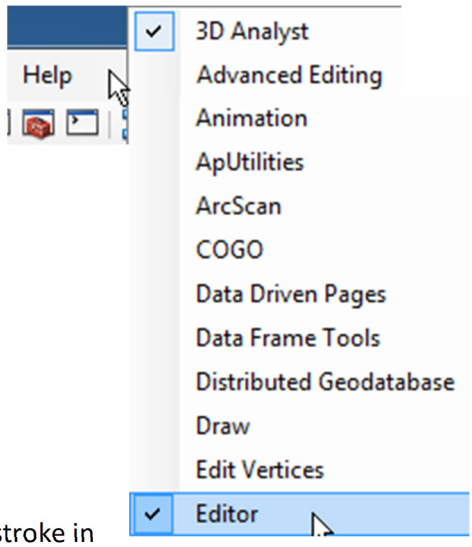
Right click on the "Existing - Cells" layer and open its attribute table. Note that the cells are labeled WestRook with a cell number, just like the EFM results.



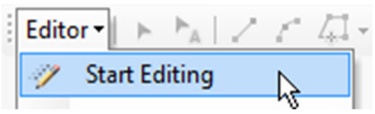


Fields named “Vegetation” and “Salmon” have already been added to the attributes tables for both scenarios. Let’s add the EFM results to the Vegetation field.

1) Verify that the ArcMap Editor toolbar is activated on your computer by right clicking on empty space in the toolbar area of the ArcMap interface, perhaps next to the Help menu shown →



2) Go to the Editor tool bar and select “Start Editing”…



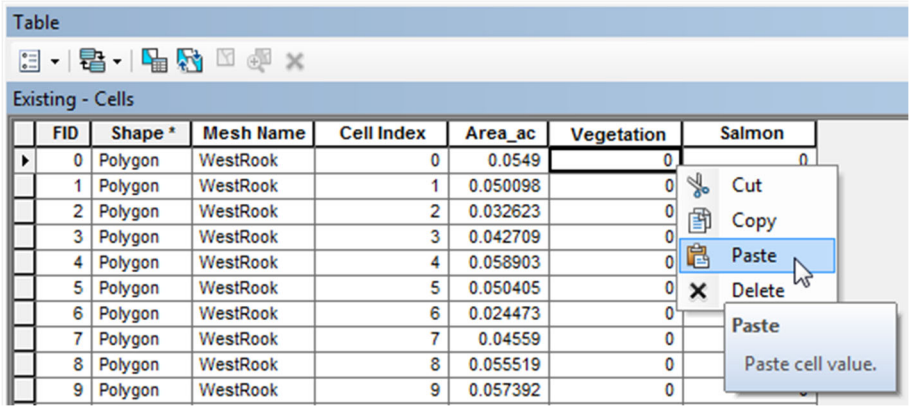
…if asked which portion to edit, select the first “Existing - Cells” layer.

3) Go to the workshop spreadsheet. Navigate to the EFM results for Vegetation. Select the WR_Existing statistical results. A handy key stroke in Excel is, with the top cell highlighted, press “Control - Shift - Down Arrow” to select the data column →

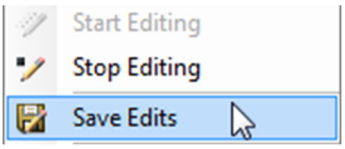
   When selected, copy it.

	Veg - Percent time inundated
Flow Regime	**% X, of time**
WR_Existing-0	0
WR_Existing-1	0
WR_Existing-2	0
WR_Existing-3	0
WR_Existing-4	0
WR_Existing-5	0
WR_Existing-6	0
WR_Existing-7	0
WR_Existing-8	0
WR_Existing-9	0
WR_Existing-10	0
WR_Existing-11	0
WR_Existing-12	0
WR_Existing-13	0
WR_Existing-14	0
WR_Existing-15	0
WR_Existing-16	0
WR_Existing-17	0
WR_Existing-18	0
WR_Existing-19	0
WR_Existing-20	0
WR_Existing-21	0
WR_Existing-22	11.3
WR_Existing-23	10.8

4) Go to the attribute table. Paste the EFM Results into the Vegetation field.



5) Verify that the EFM results pasted successfully. If so, go to the Editor menu and save edits.

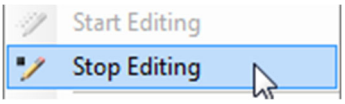


6) Repeat this process (steps 3-5) for Existing - Salmon.

For salmon, EFM results were computed for 3 ranges of depth because habitat value was a function of depth. Range values were then aggregated to compute a single value of suitable habitat provided by each scenario. For mapping purposes, a tally of habitat provided per cell is needed. Review your spreadsheet and identify a dataset to map.

Hint: In the solution spreadsheet, range results were aggregated into values of "total suitable habitat days" per cell. These values are per cell (one column per scenario) and are useful for mapping.

7) After pasting salmon data into the attribute table and verifying that the paste was successful, use the Editor menu to save edits. Then stop the editing session.

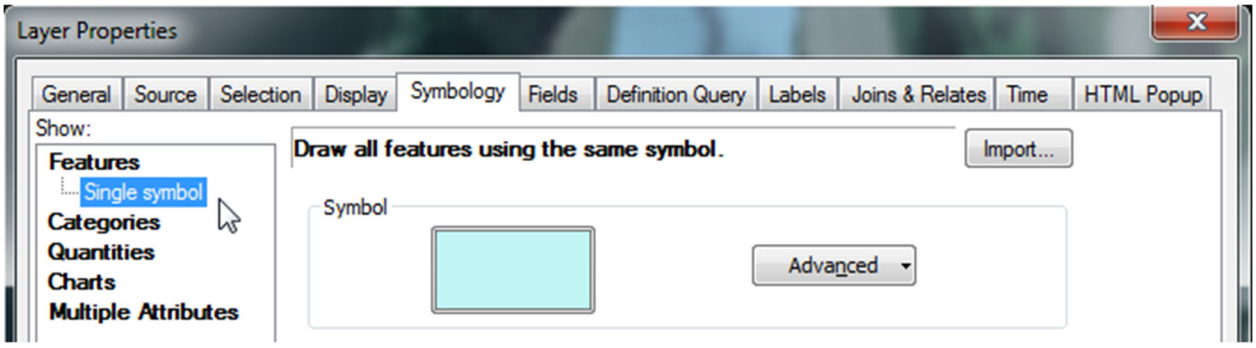


8) Right click on the "Restored – Cells" and open its attribute table. Use the Editor menu to start editing (select the Restored layer if prompted) and repeat this process (steps 3-6) for the Restored scenario.

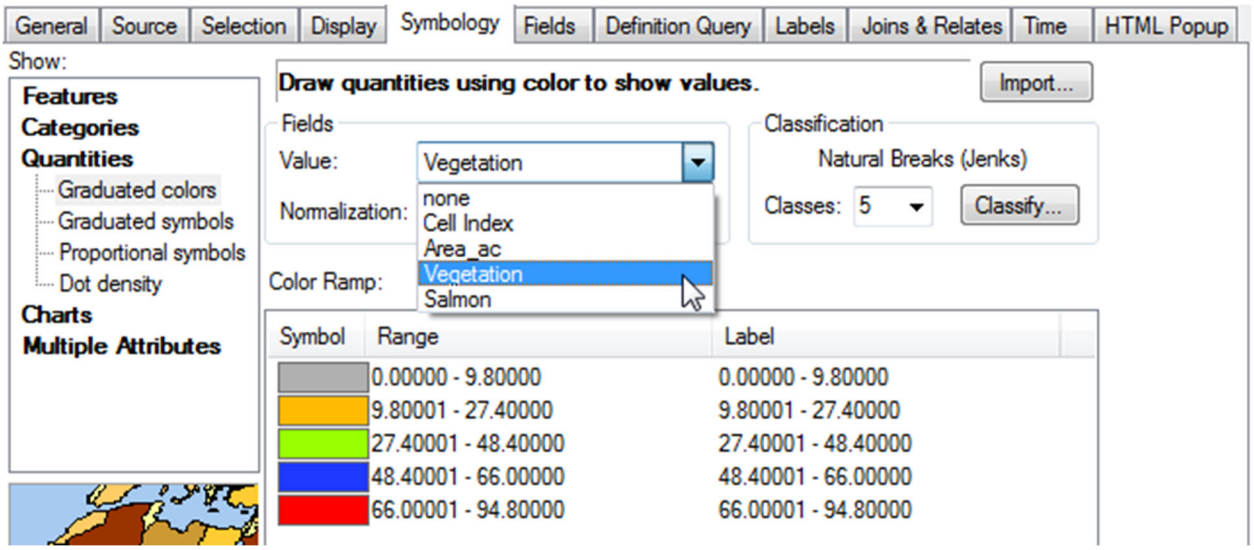
9) Save edits and stop the editing session when complete.

10) The last step in the mapping process is symbology. Right click on the "Existing – Cells" layer. Select "Properties" from the bottom of the menu.

Currently the Existing (and Restored) layers are set to the default, "Features - Single symbol".

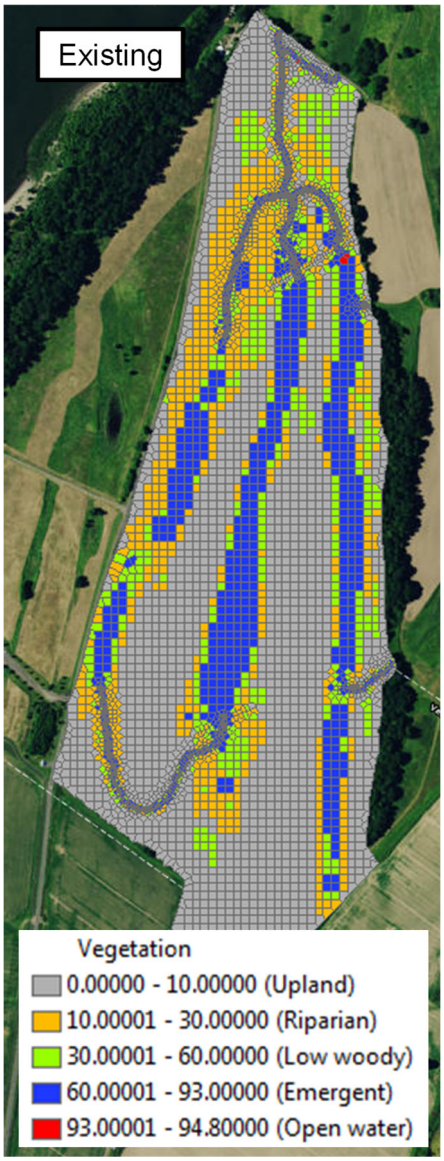


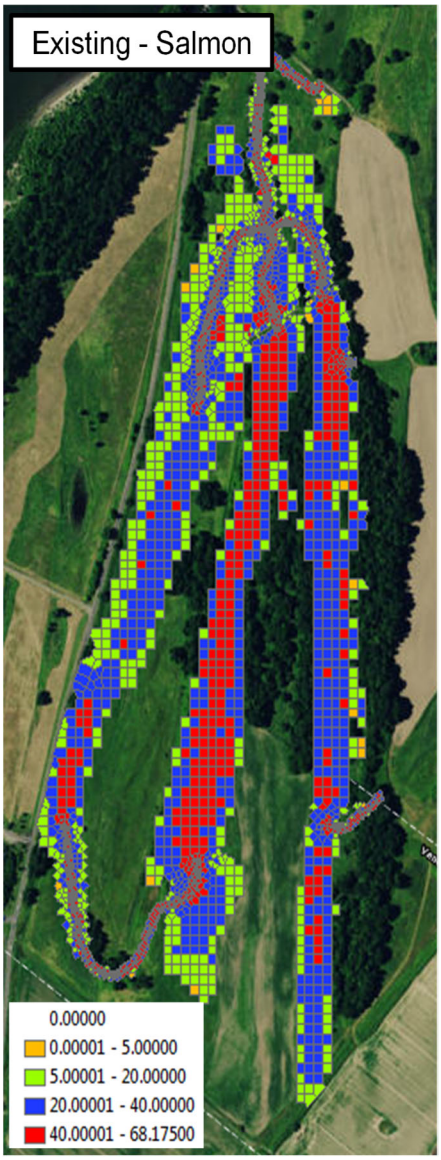
Switch this to "Quantities - Graduated colors" and display values from the Vegetation field.



The default ranges are editable by clicking on them and entering a new number. Enter numbers pertinent for the vegetation analysis.

There are two layers for Existing and two for Restored. Adjust their symbology to make vegetation and salmon rearing habitat maps for each scenario.





Analyzing EFM Results in GIS

All EFM habitat mapping should now be complete. Each vegetation map entailed analysis of over one million data values. Roughly three million data values were processed for each salmon map. Visually compare the maps (Existing versus Restored for vegetation and salmon habitats). Respond to the following questions:

1) Describe the visual differences in vegetation between Existing and Restored conditions. Do these agree with the spreadsheet analysis?

2) Describe the visual differences in salmon habitat between Existing and Restored conditions. Do these agree with the spreadsheet analysis? Note any areas of noticeable increase and decrease. Please explain your observations and connect your thinking with the spreadsheet analysis.

Part of the proposed restoration involves a learning objective about understanding the effects of the project in terms of vegetation and salmon responses. Roughly 40,000 square feet of space (~1 acre) is to be established as a test area to monitor changes that occur after implementation.

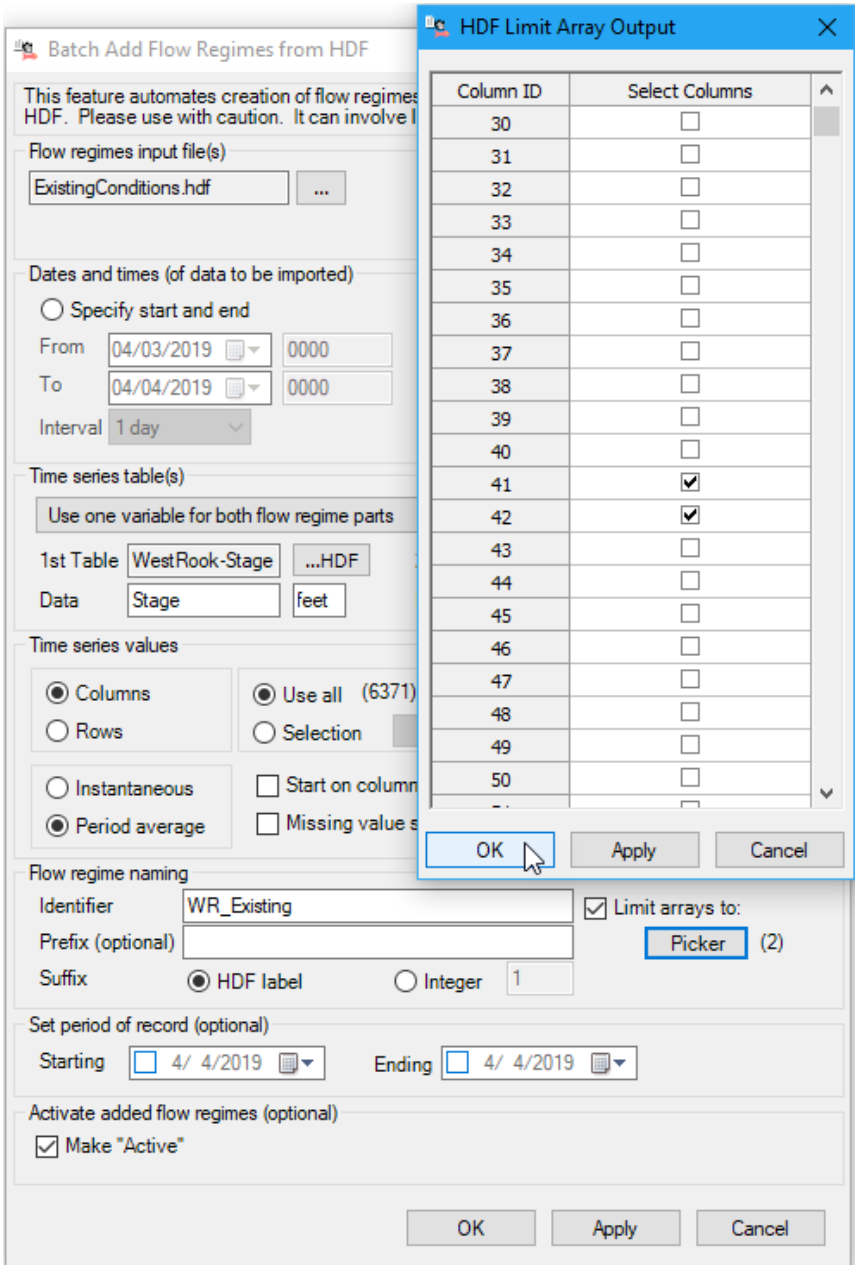
3) Based on the spatial model results, where would you establish a test plot or monitoring location (would require roughly 40,000 square feet) to measure change? What changes would be expected at that location following implementation?

New Feature…Ecovalue Summations!

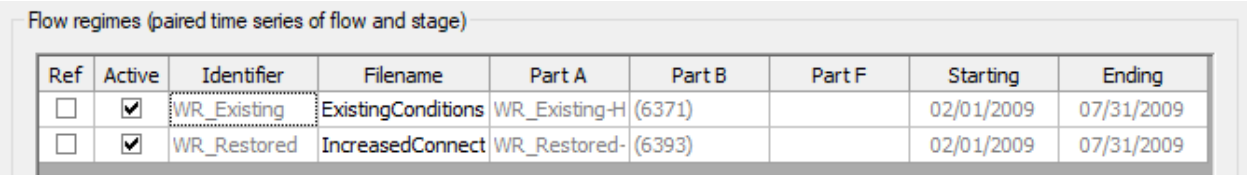
EFM can now perform much of the math done earlier in this workshop via spreadsheet. Let's revisit salmon habitat to explore the new summations feature.

1) Go to the Properties tab. Click on the table row for the WR_Existing flow regime and then click on the "Open Batch Add HDF…" button. Use the "Limit arrays to:" picker to select a few non-zero salmon elements (refer to your spreadsheet results) such as 41 and 42. Repeat for WR_Restored.

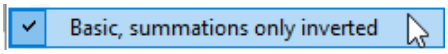
52	WR_Existing-40	0	0	0		WR_Restored-40	6.7	0	0
53	WR_Existing-41	12.7	0	0		WR_Restored-41	8.9	5.6	0
54	WR_Existing-42	12.2	0.7	0		WR_Restored-42	9.7	6.4	0
55	WR_Existing-43	0	0	0		WR_Restored-43	3.1	0	0

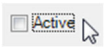


2) Make both flow regimes active.


Flow regimes (paired time series of flow and stage)

Ref	Active	Identifier	Filename	Part A	Part B	Part F	Starting	Ending
☐	☑	WR_Existing	ExistingConditions	WR_Existing-H	(6371)		02/01/2009	07/31/2009
☐	☑	WR_Restored	IncreasedConnect	WR_Restored-	(6393)		02/01/2009	07/31/2009

3) Go to the File – Select Style Sheets – Results and switch the style sheet to "Basic, summations only inverted". 

4) Click on Relationships tab. Deactivate all relationships including "Veg". 

5) Use the "Edit - Relationships - Add…" menu to add a relationship named "Salmon Summation". Use the following statistical settings:

Statistical Settings	**Salmon Summation**
Season	2/1 to 6/30
Duration	1 day
% Exceedance	50% - Flow duration

6) Turn on the "Write computation arrays" option.

7) Turn on the "Hypothesis tracking" option and switch its setting to Curve.

8) Enter the following Curve to represent the HSI for salmon.

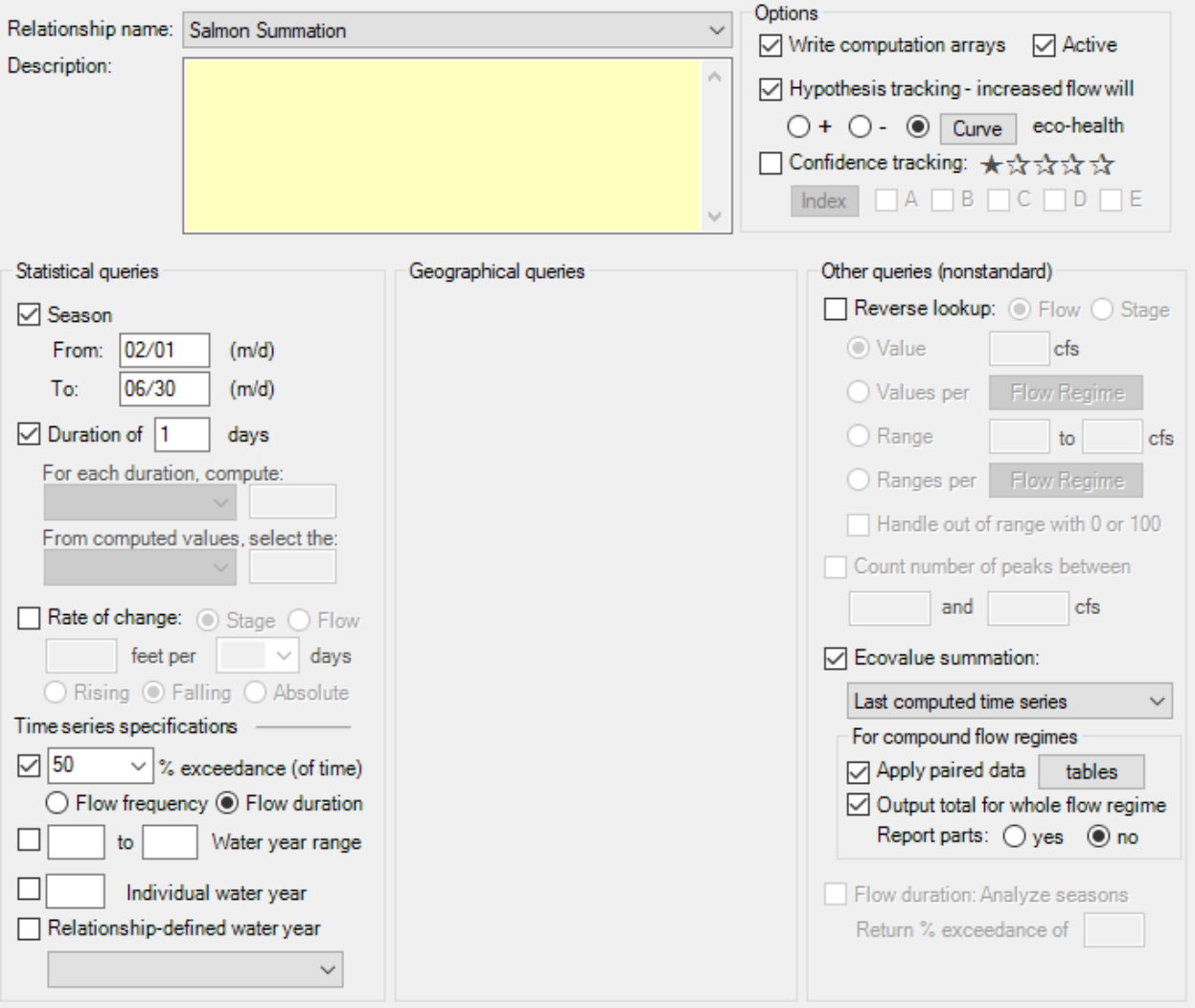
Flow *(even though it's stage)*	**Ecovalue**
0	0
0.1	0
1	1
2	1
3	0
20	0

9) Turn on the "Ecovalue summation" option.

10) Turn on the "Apply paired data" option and copy in the element areas from the "WestRook Element Areas" worksheet for both WR_Existing and WR_Restored. Click ok.

11) Turn on the "Output total for the whole flow regime" option and decline the report parts option.

12) Save your project. Your relationship should now look like this:



13) Click recalculate.

14) Detailed results can be viewed in EFM Plotter.

15) How do the ecovalue summation results agree with the salmon habitat areas computed in the spreadsheet?

16) Did you follow the computational process for the ecovalue summation?

17) Any thoughts on why they are different?