Workshop Solution
Dam Break Analysis with 1D and 2D Areas

Introduction

This workshop will help students learn how to use HEC-RAS to model a Reservoir Pool, Dam, and downstream area using 1D and 2D elements. Students will learn how to put a model together quickly using a Storage area for the Reservoir pool; a SA/2D Area Hydraulic connection to represent the Dam; and a 2D Flow Area to model the downstream area below the dam.

NOTE: While this data is from an actual river system, the model and results of this workshop do not represent current or future conditions of the river. The United States Army Corps of Engineers has granted access to the information in this model for instructional purposes only. Do not copy, forward, or release the information without United States Army Corps of Engineers approval.

Background

Figure 1 shows the extent of the terrain data that was used in developing the HEC-RAS model for this Dam Breaching analysis. As shown in Figure 1, the reservoir pool and downstream floodplain runs through a narrow corridor within the Appalachian Mountain range. Bald eagle creek flows from Southwest to Northeast and terminates into the West Branch of the Susquehanna River just downstream of the town of Lock Haven, PA. The model represents about 26 miles of the river, with the dam located about 15.4 miles upstream from the confluence with the West Branch of the Susquehanna. The area downstream of the dam is heavily populated, with the largest population at the town of Lock Haven, which is located at the very downstream end on the north side of the stream. The town of lock Haven is protected with a system of levees that was designed for the 500 year (0.2% Chance) event. Figure 2 is an aerial photo showing some of the populated areas, as well as the levee system that protects Lock Haven.

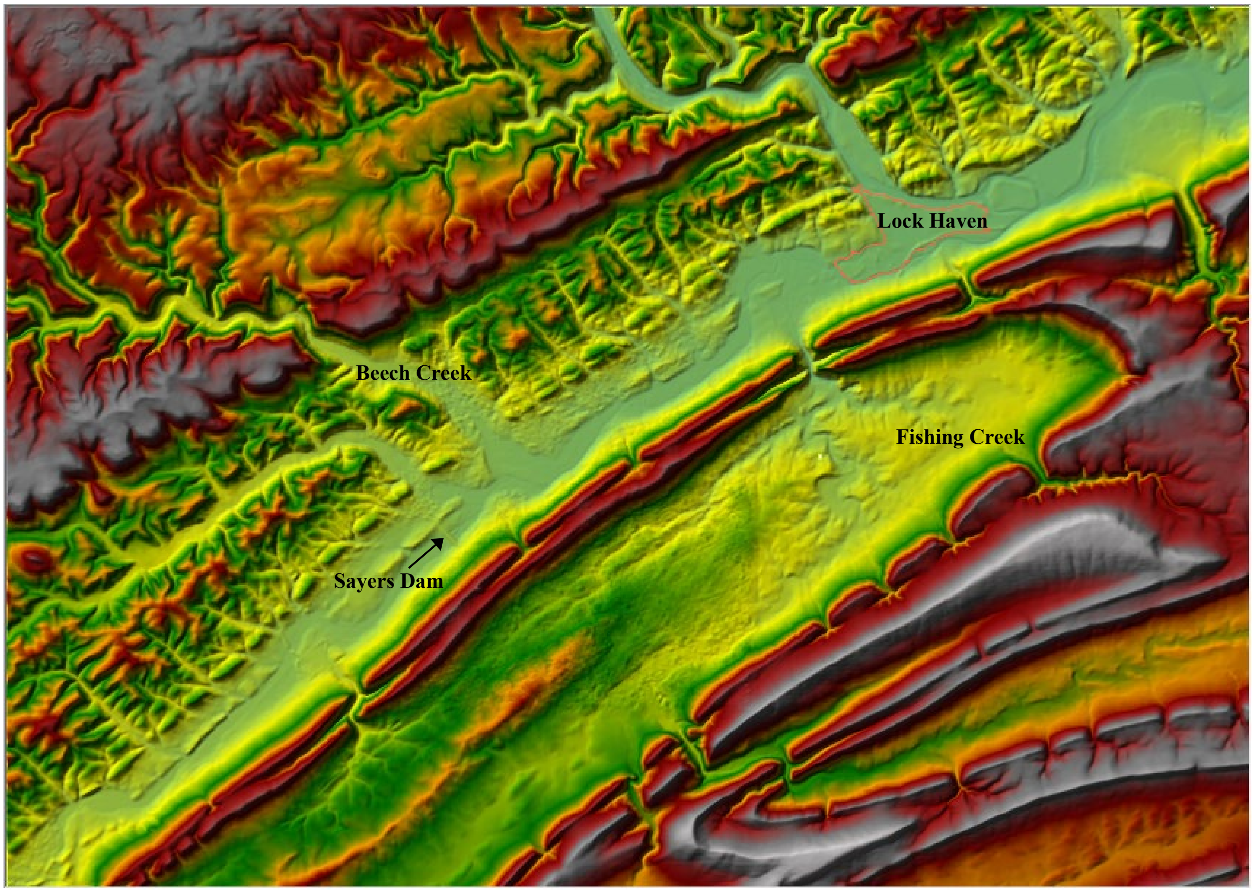


Figure 1. Terrain Model for Bald Eagle Creek Study.

In this workshop we will be analyzing an event that is larger than the levee design event (PMF flood event). The purpose of looking at this event is to determine the consequences of a failure of Sayers dam. Generally, an analysis of this type would look at the full range of events, up to and above the design event in order to determine risk and uncertainty of the dam. However, given the limits on time for a class workshop, we are only going to look at the design event for the dam, the PMF flood.

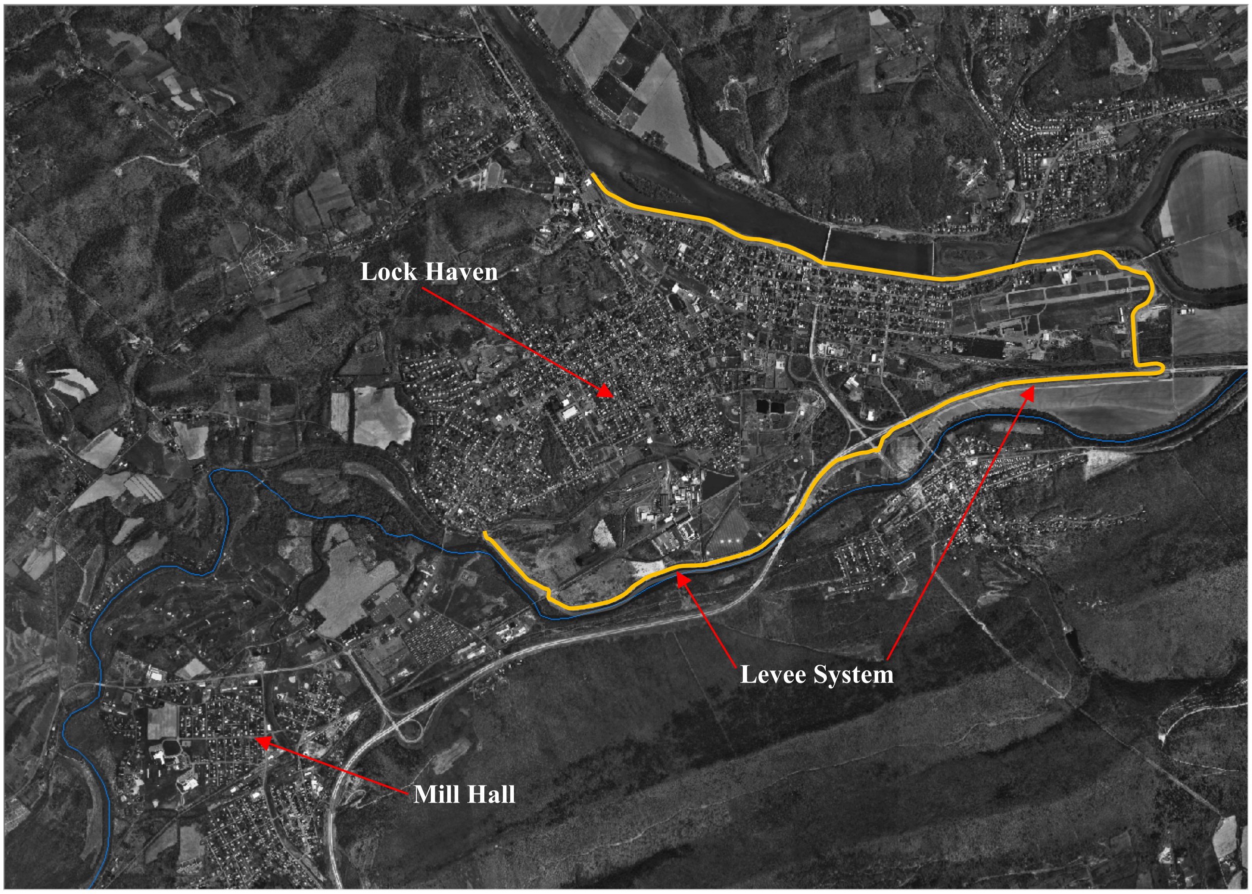


Figure 2. Aerial Photo of Downstream Populated Areas.

Problem Summary

A project file (**BaldEagleDamBrk.prj**) with the title "**Bald Eagle Creek Example Dam Break Study**" has been loaded on your workshop computers. This file contains the basic file structure for this workshop. However, students will be doing most of this workshop starting from scratch. The following is a summary of the required tasks for each group:

1. Open the project file and create the geometry data for the Dam Breaching study using a single storage area for the pool, hydraulic structure for the dam, and a 2D Flow Area for the downstream area.

2. Enter the necessary flow data and boundary conditions.

3. Make a Plan and run the PMF event. Review the output, then answer some questions

4. Change the 2D Flow Area Computational Cell size. Save the Geometry Data as a second file, make a new Plan, and run the new Plan.

5. Answer some additional questions

6. **Optional Task:** If you have time, make a new Plan and change the equations to the Full Saint Venant Equations. Then run the model and review the Output.

Tasks

1. Open the Project and Create the Geometry Data

Open the Project (**BaldEagleDamBrk.prj**) from the workshop directory. Enter all of the necessary Geometry data. The following is a description of each step and the necessary data:

A. <u>**Reservoir Storage Area**</u>: Open RAS Mapper and select the Geometry layer you will be editing. Turn on the storage area and 2D Flow Area layers. Right click on the Storage area layer and select **Edit Geometry**.

There are a few ways to lay out geometric features. You can:

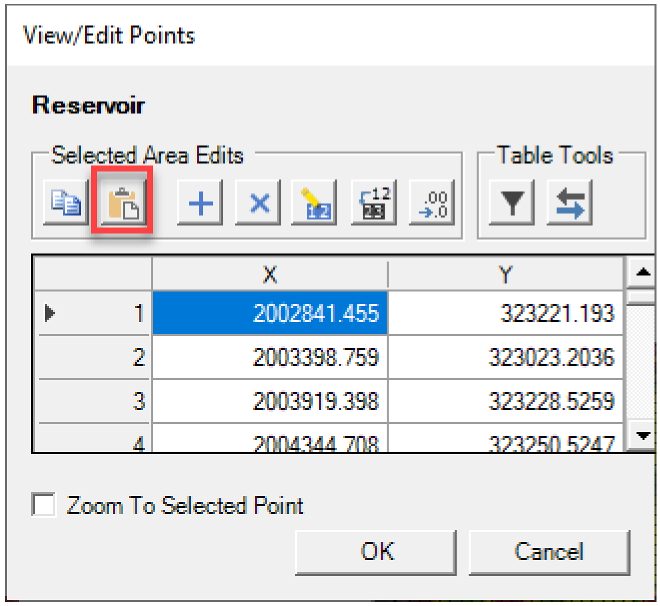
- Draw them
- Copy-and-Paste Coordinates
- Import a Shape File

In this workshop you will copy-and-paste the reservoir and then import shape files for the rest.[1] Using the **Add New Feature** drawing tool , drawn in the storage area to represent the reservoir pool. To speed up this process, simply drawn a storage area polygon with three or four points, then give it the name "Reservoir Pool".

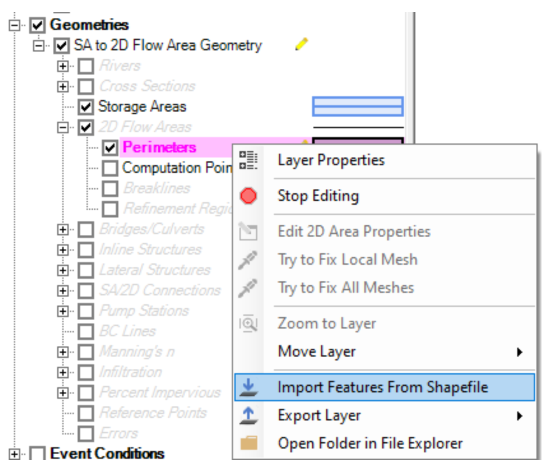
An Excel file with the coordinates of the storage Area is in your project directory. The Excel file is called "**BaldEagleDamBrkData.xlsx".**

Copy all of the X and Y coordinates in the Excel file to the Windows Clipboard. Select the simple polygon you just drew using the editing tool. Then go to the **Tools** dropdown Tools (or right click on the polygon) and select the option called **Edit/View Points** View/Edit Points. This will bring up the Table shown below. Paste the X and Y coordinates from the Excel file into this table. This will reduce the time required to enter the bounding polygon for the storage area. You may need to press the **Paste** button: .

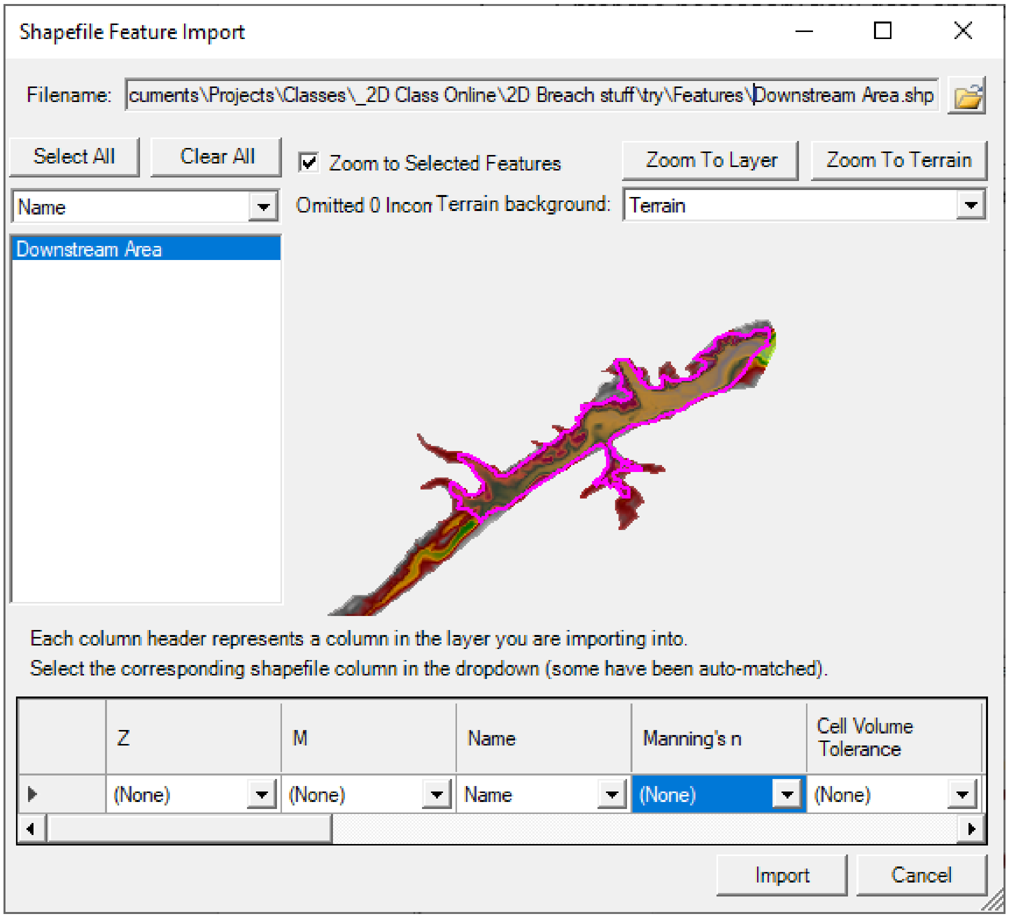
1 Importing a shape file is the more common work flow, so the project comes with a **"Reservoir.shp"** file if you would prefer to just import this layer too.



B. <u>**Downstream 2D Area**</u>: Expand the **2D Flow Areas** layer, then select the **Perimeters** layer. Using the **Add New Features** drawing tool, draw in the 2D Flow Area boundary to represent the downstream Area below the dam. Right click on **Perimeter** and select **Import Features From Shapefile.**



Press the file navigation button  and import the reservoir outline from the shape file "**Downstream Area.shp**." Press the **Import Button.** Right click on the **Perimeter**, select **Stop Editing**, and **Save.**

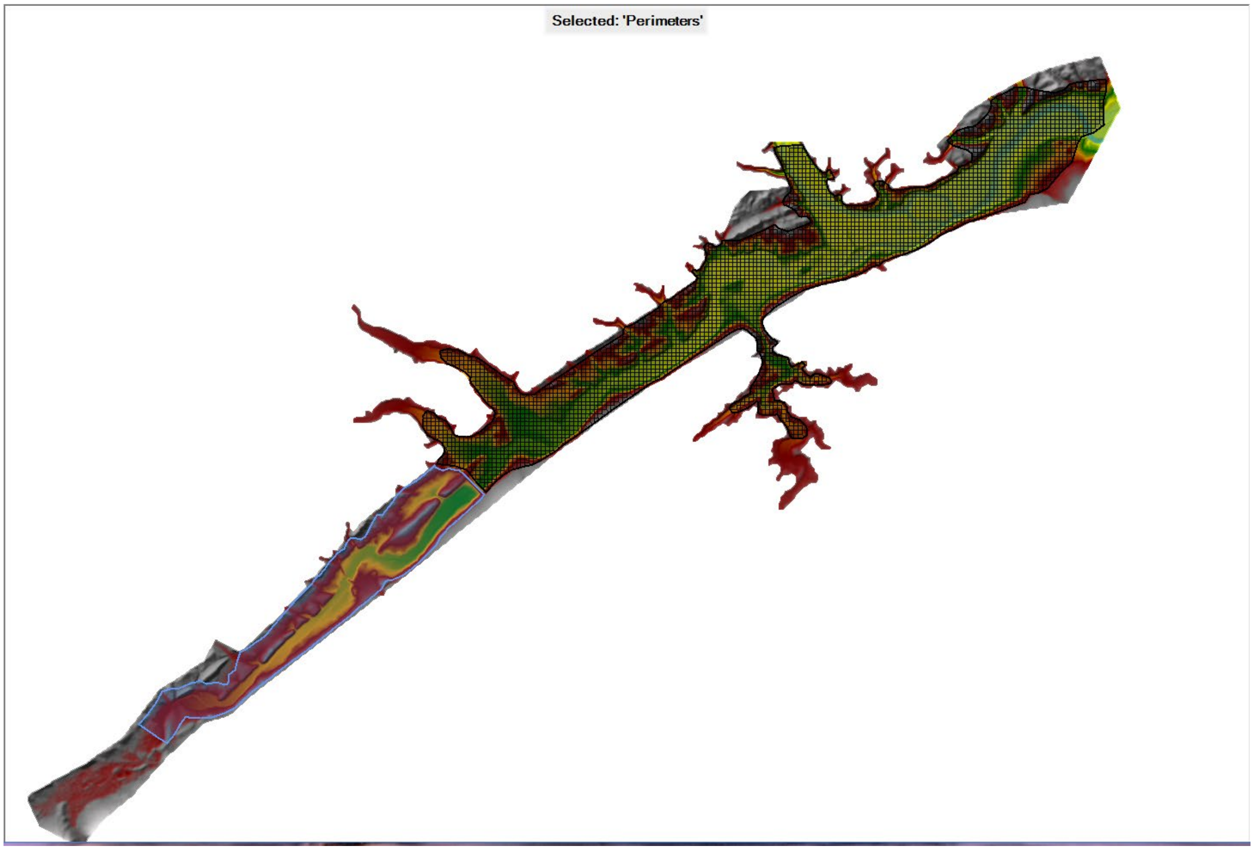


Right click on the 2D Flow Area, and select **Edit 2D Area Properties**, then create a 2D computational mesh with the following properties:

Cell size = 500 X 500 ft
Manning's n = 0.04

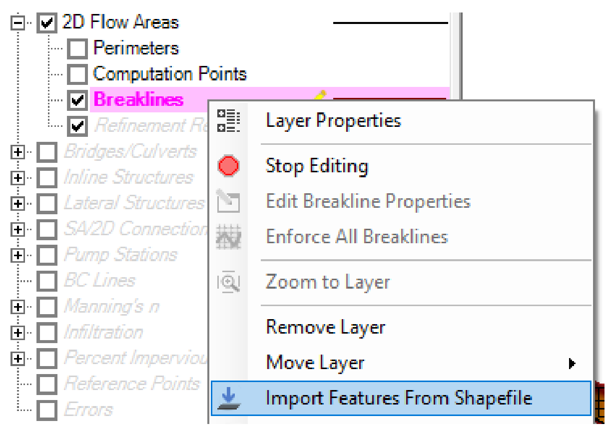
Enter the DX and DY Point Spacing values and the Default Manning's n value. The click the button called **Generate Computation Points** to create the base computational mesh. See the Figure below for what it should look like when finished.

NOTE: Review the Outer boundary cells of the computational mesh to see if there are any bad cells, faces, or cell centers. Correct any problems you see by either adding, deleting, or moving computational points.



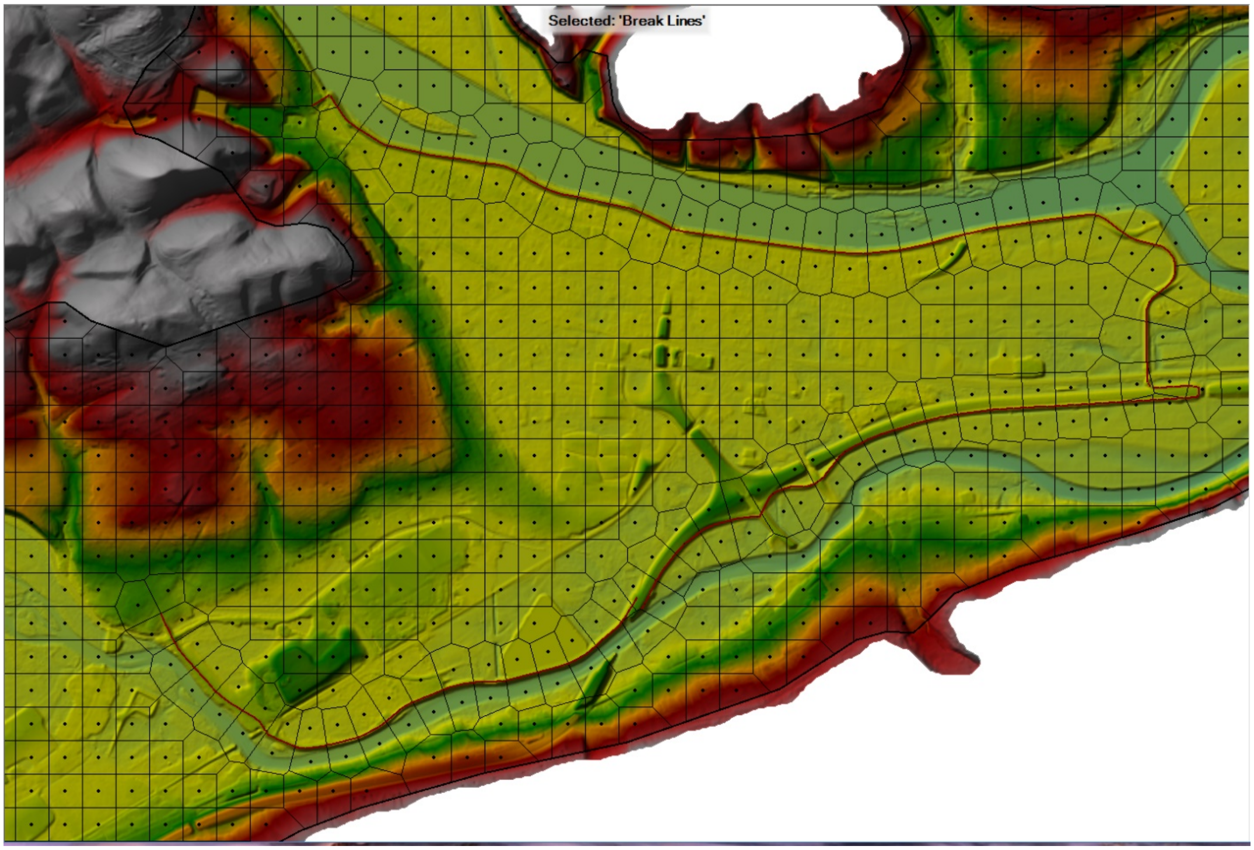
C. **<u>Levee Break Lines</u>**: Add Break Lines into the computational Mesh. Left click on the 2D Flow Areas **Break Lines** layer to activate that layer. The project comes with three shape files that define these three levees:

Upper Levee.shp
Middle Levee.shp
Lower Levee.shp



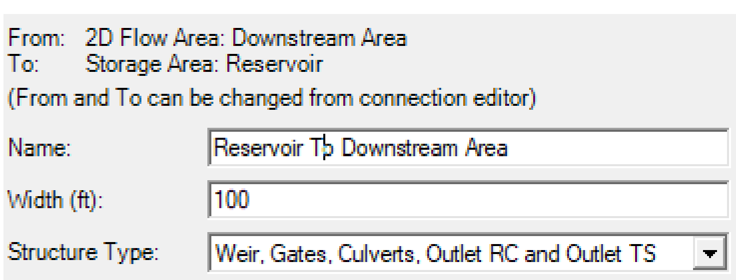
Import these shape files as breaklines.

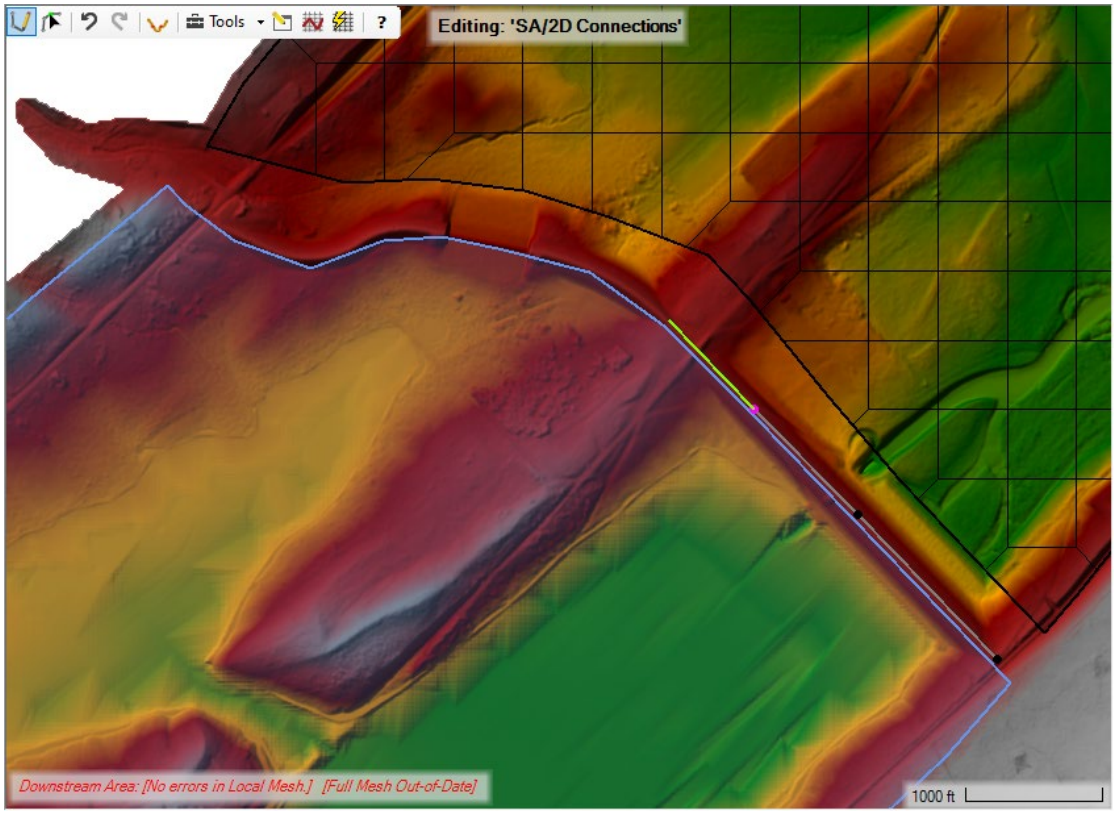
After the break lines are in the geometry, Right click on each one and select the option called **Enforce Breakline** or press the **Enforce all Breaklines** button in the tools editor. This will modify the mesh around the break lines. Once you are done enforcing the breaklines the mesh should look like the one in the Figure below:



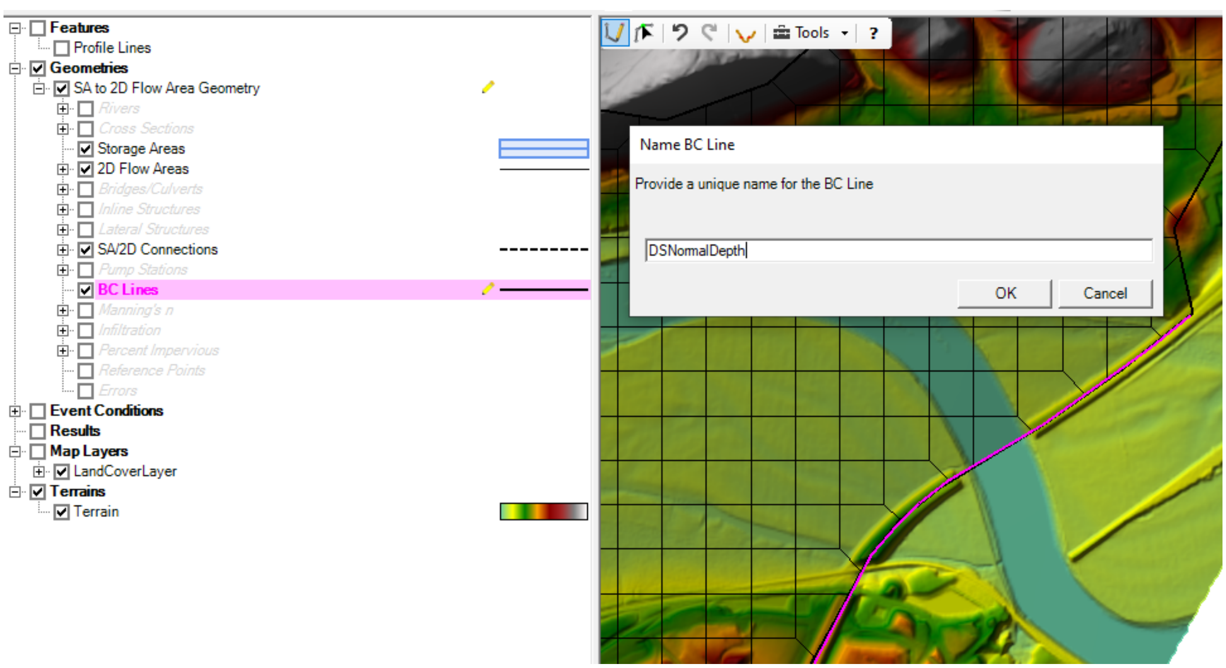
D. **<u>Draw Dam</u>**: The final step in mapper is to draw the dam. We will edit the actual dam profile in the geometry editor so it is not imperative that we trace the precise high ground. But try to trace the top of the structure in the Lidar as much as possible.

Click on **SA/2D Connections** in the geometry tree to activate it. Right click on this layer and start editing. Then choose the draw tool and trace the structure between the Reservoir Storage Area and the Downstream 2D Area (see figure on next page). Make sure you digitize from LEFT to RIGHT. The default descriptions and data in the dialog box will work fine.



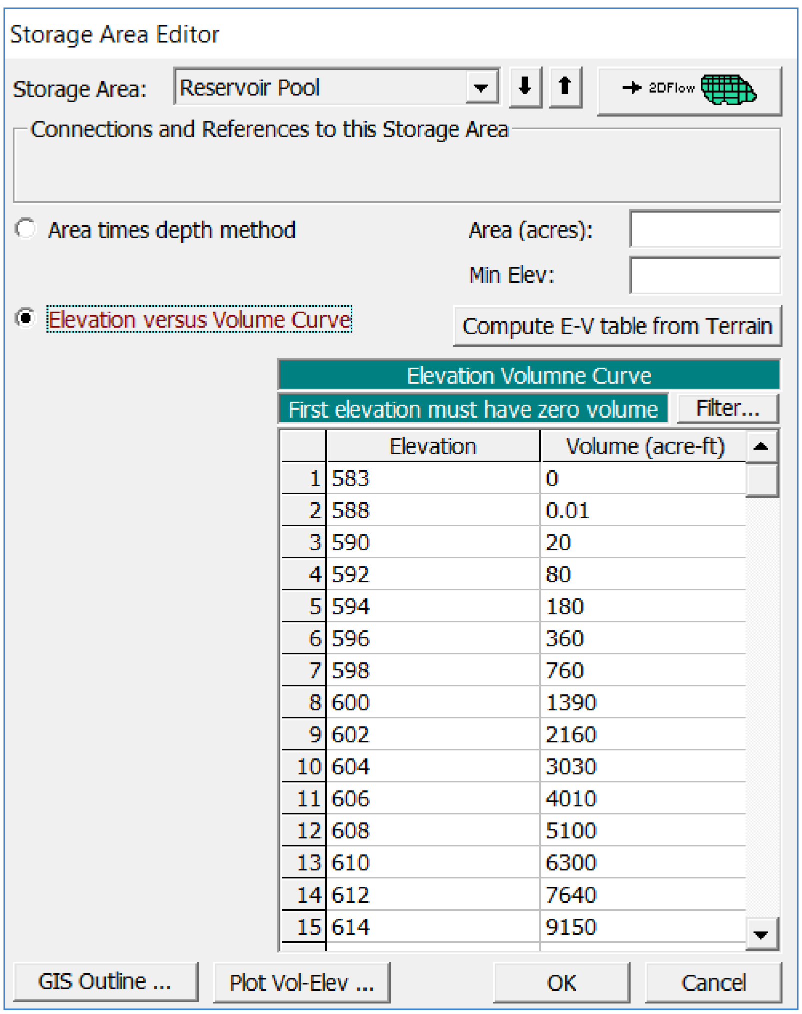


E. **<u>Draw Downstream Boundary</u>**: Click on the **BC Lines** feature, and right click on it to **Start Editing**. Label the boundary condition something like "DSNormalDepth". See the graphic below for where to draw the line:

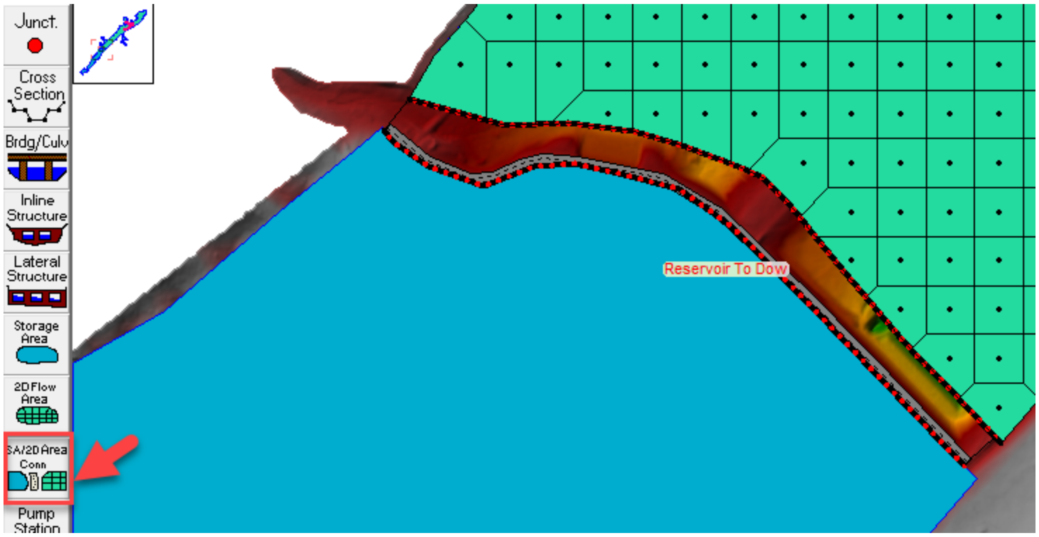


F. **<u>Stop Editing and Save</u>**: Right Click on the active layer of the 2D Flow Area (should be Break Lines), and select **Stop Editing**. **SAVE THE DATA!!!** Then close RAS Mapper and Bring up the HEC-RAS **Geometric Data** editor**.** The rest of the data entry/editing will be done in the Geometric Data editor.

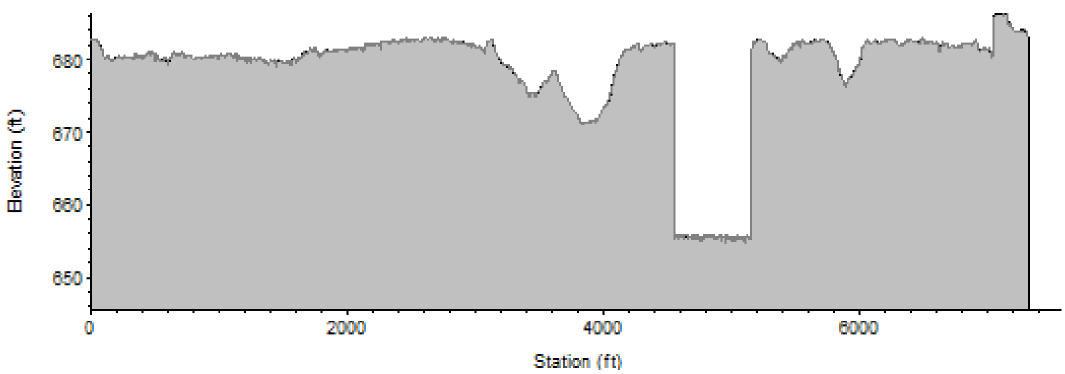
G. **<u>Enter Reservoir Data</u>**: Left click on the storage area and select **Edit Storage Area**, this will bring up the editor shown below. Enter the elevation-volume data for the Reservoir Pool storage area. This data is contained in the Excel file. Delete any elevation volume points that may have automatically been extracted from the terrain data. We will be using the published elevation-volume curve from the reservoirs control manual for this dam. Make sure you select the option labeled "**Elevation versus Volume Curve**" as the active method for defining the storage area elevation-volume data and not the "Area times depth method".



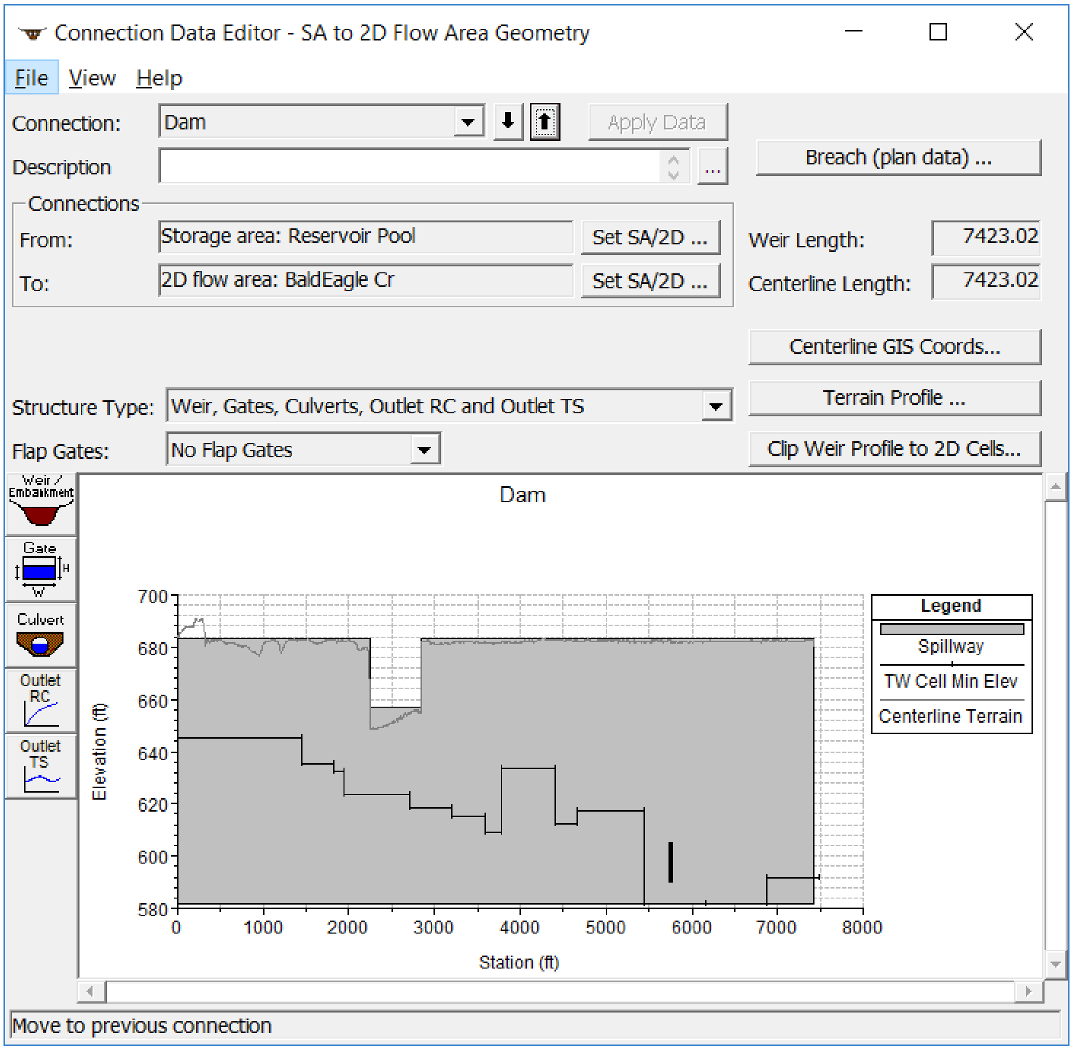
H. **Enter Data for Dam**: Open the **SA/2D Area Conn** editor from the editors on the left side of the Geometry Data editor window.



If you look at the profile of the dam, it does not match the design specs. The LiDAR is not precise, which will affect your simulation.

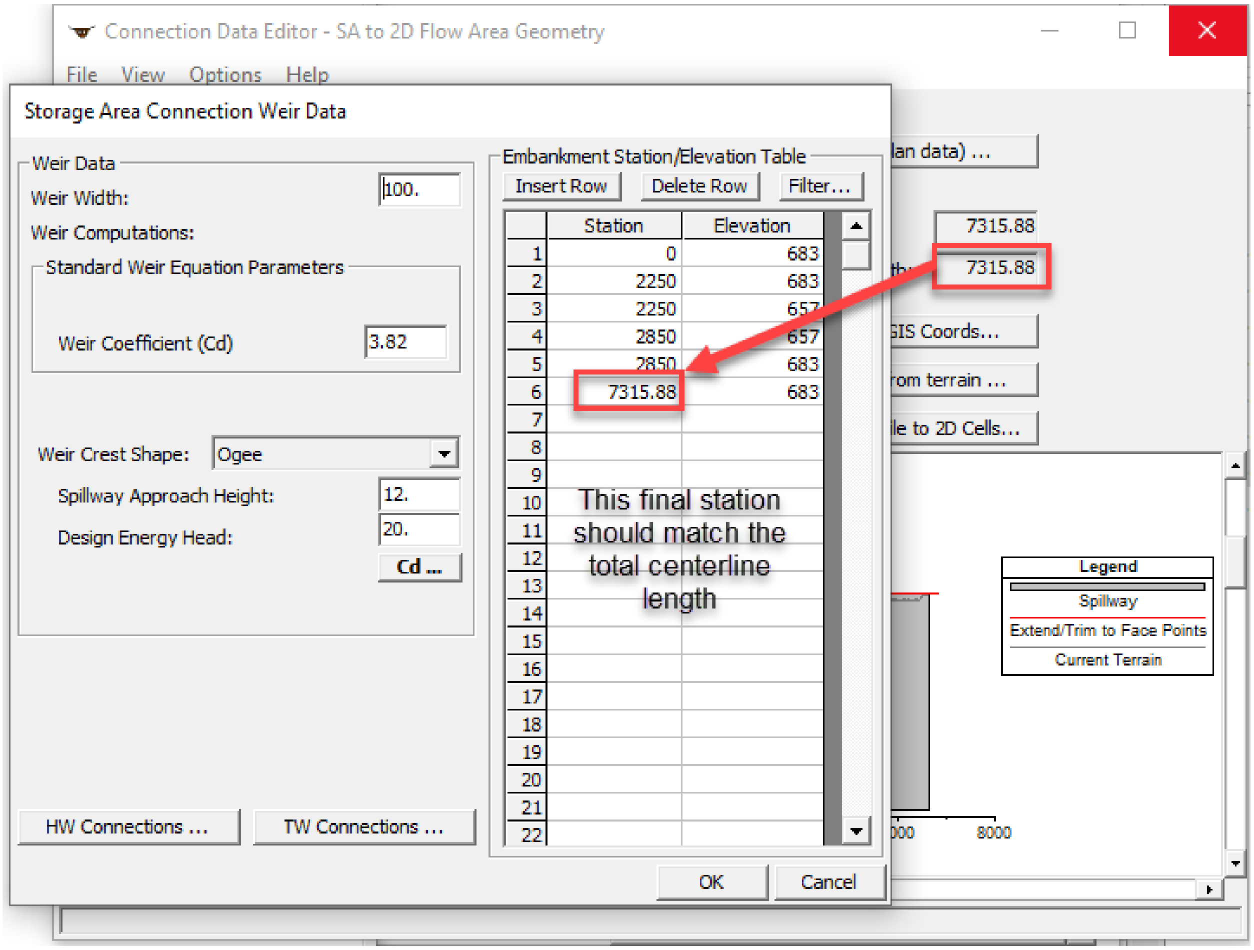


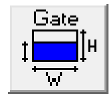
We will override the dam elevations from the DEM with the actual dam crest profile. Enter all the necessary data for the Dam and low flow gates. The data are included in the following two figures.



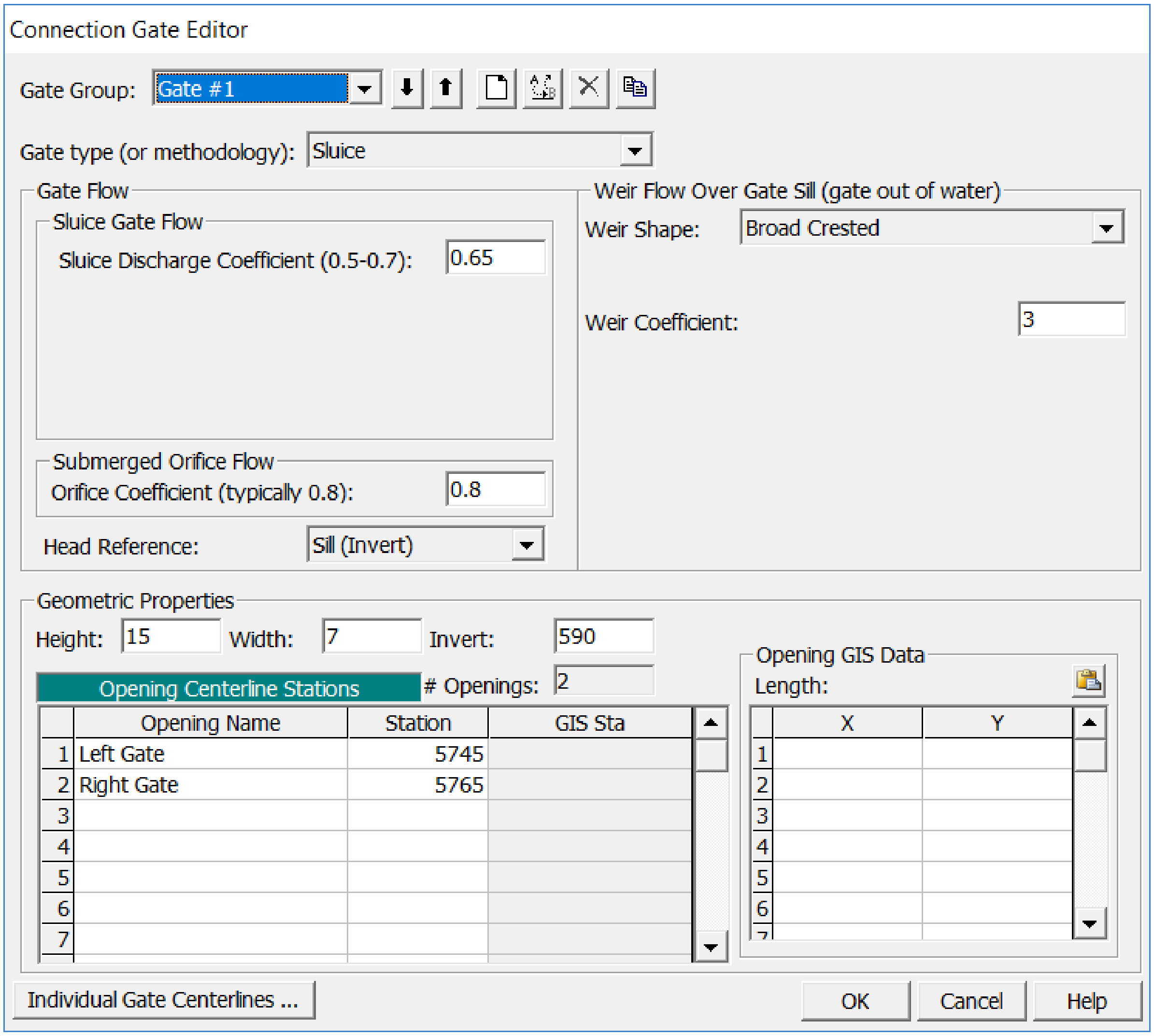
Press the Weir/Embankment button to define the embankment data:

Delete the Station-Elevation data from the terrain and replace it with the profile below. Use the GIS Centerline length in the main editor to determine the total length of your dam (largest station should match centerline length).

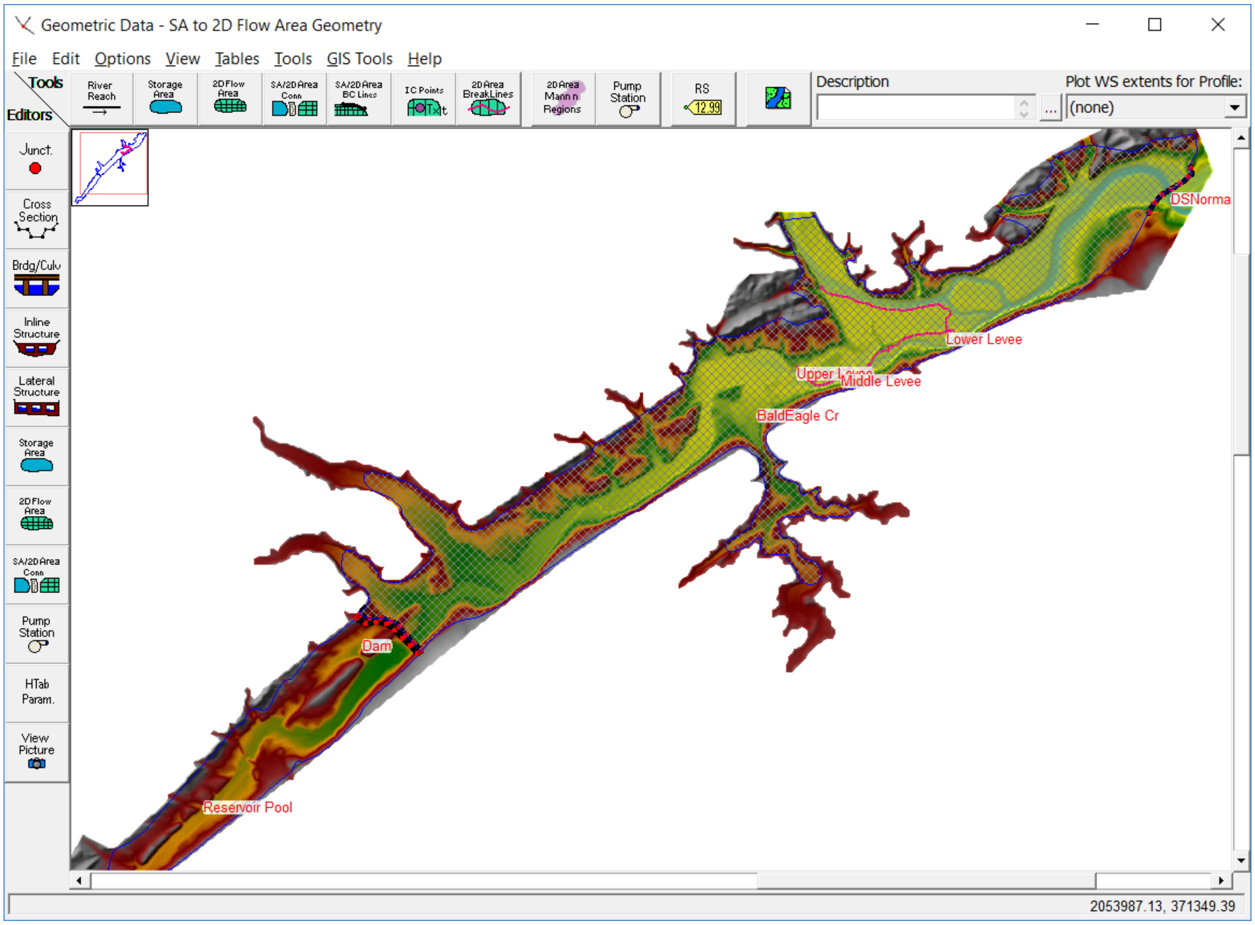


Press the Gate button to add gates: 

(next Figure)



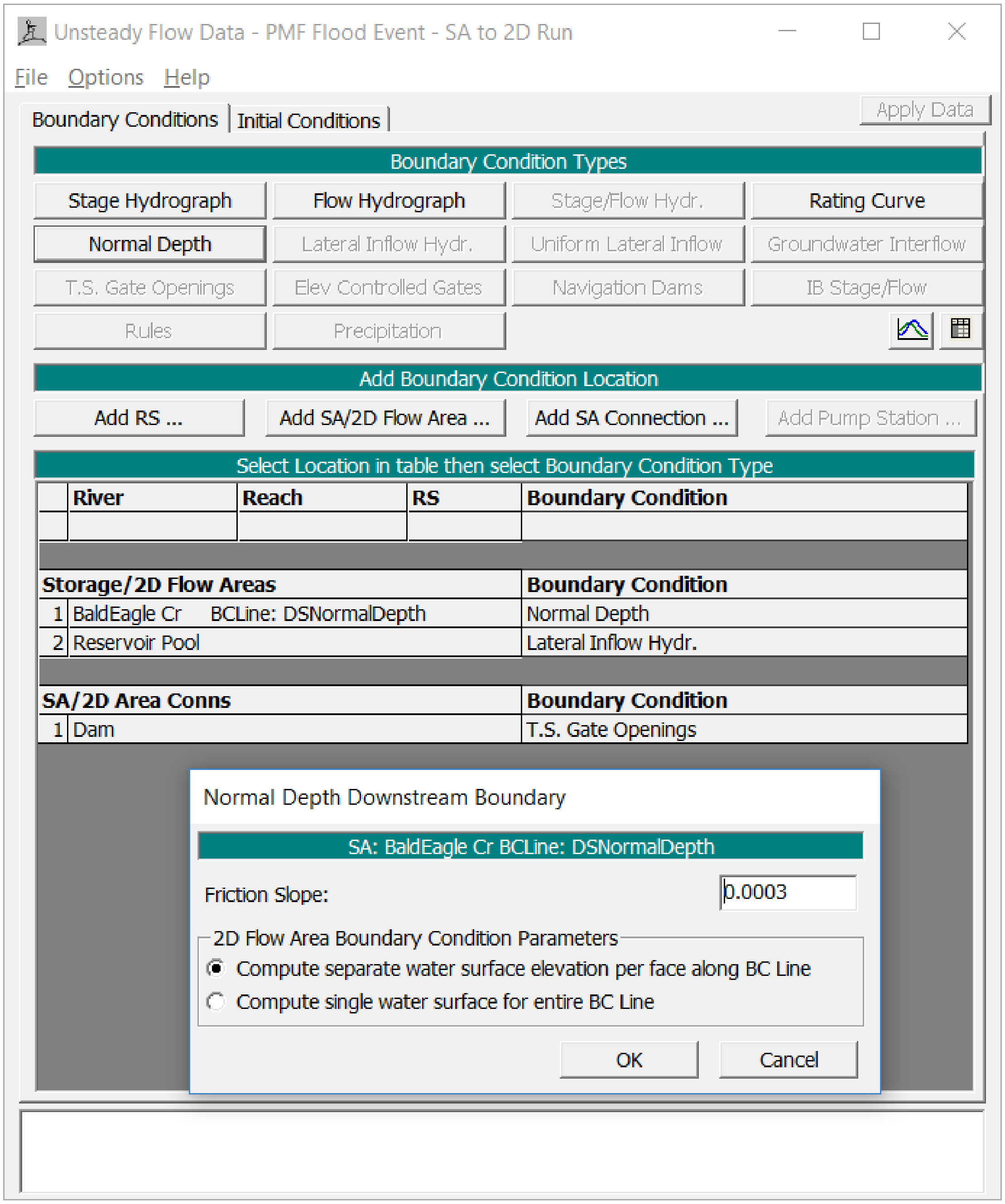
I. **SAVE THE GEOMETRY DATA.** It should look about like this:



2. **Enter the Necessary Flow Data and Boundary Conditions**

   A. **Normal Depth Boundary Condition**. The outlet that will allow water to leave the BaldEagleCr 2D Flow Area will be modeled with Normal Depth Boundary conditions. Use a

   Friction slope = 0.0003.



B. **PMF Inflow Hydrograph**. Add in a lateral Inflow Hydrograph as the boundary condition for the “Reservoir Pool” storage area. To add the Lateral Inflow Hydrograph to the storage area, first select the button labeled **Add SA/2D Flow Area**, [Add SA/2D Area Conn ...] and then select the storage area called **Reservoir Pool**. This will add the Reservoir Pool to the “Storage/2D Flow Areas” table. Click into the blank field in the table next to the Reservoir Pool row and then select the **Later Inflow Hydr.** [Lateral Inflow Hydr.]

	Storage/2D Flow Areas	Boundary Condition
1	Downstream Area BCLine: DSNormalDepth	Normal Depth
2	Reservoir	Lateral Inflow Hydr.

Boundary condition option. From the same Excel data file (**BaldEagleDamBrkData.xlsx**), there is a Tab labeled “Flow and Boundary Conditions”. On this Tab there is a column of data labeled “PMF Inflow in cfs (hourly Values)”.

Note: You will have to add rows to the flow editor because there are 200 hourly flows. Press the No. Ordinates button [No. Ordinates] and change the number to 200.

This is the PMF inflow hydrograph. Copy and paste it into the HEC-RAS Lateral Inflow hydrograph editor for the storage area boundary condition.

C. **Time Series of Gate Opening for Dam**. The Hydraulic structure representing the Dam has two low flow gates modeled in a single gate group. Select the boundary condition type for the **Dam** as **T.S. of Gate Openings**. [T.S. Gate Openings] Change the Data Time interval to “1 Hour” and the Number of ordinates for the table to 200.

Data time interval: [1 Hour]

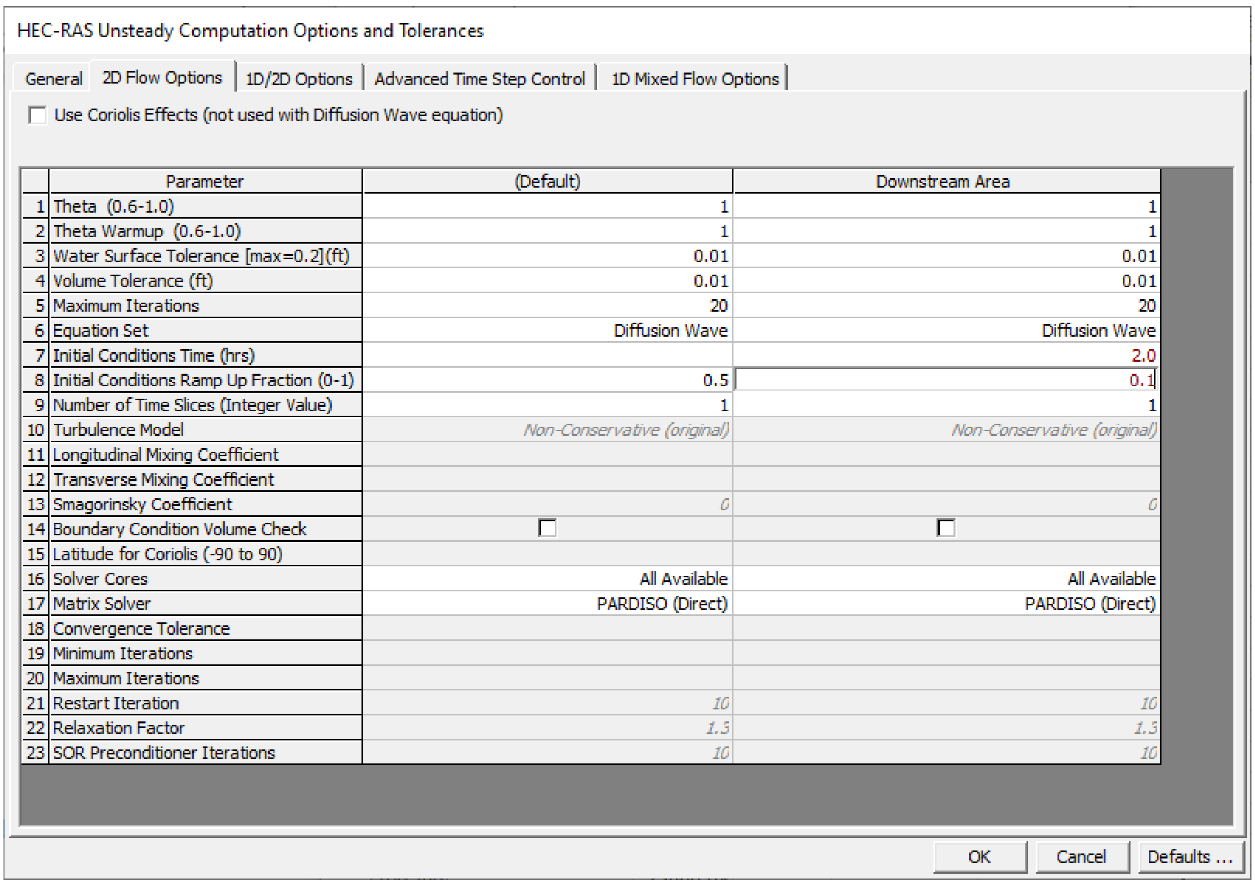
Copy the Gate opening time series data from the Excel file and paste it into the Time Series of Gate Openings editor in HEC-RAS.

D. Initial Conditions Data. From the Initial Conditions Tab in the HEC-RAS Unsteady Flow Data editor, set the initial elevation of the Reservoir Pool storage area to 630.0 ft. Leave the BaldEagleCr 2D Flow Area blank, which means it will start out in a dry condition. We will handle the 2D Flow Area initial conditions with some of the 2D Flow Area warmup up and Ramp up options, from the Computational Setting’s.

	Storage Area/2D Flow Area	Initial Elevation
1	2D: Downstream Area	
2	SA: Reservoir	630

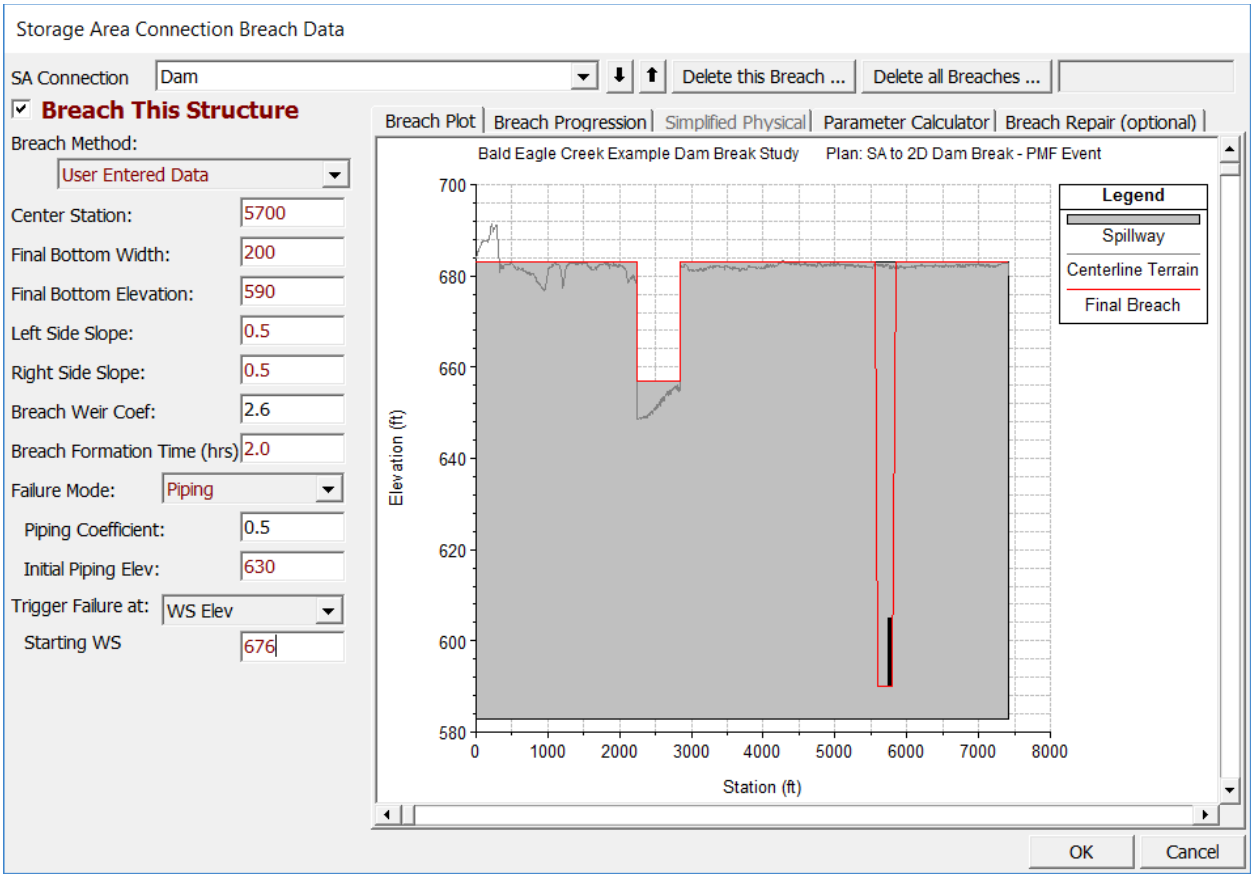
3. **Enter some Computational Settings and Dam Breach data, Run the Model, then Answer Questions.**

A. Open The Unsteady Flow Analysis window. Then go to the **Options|Calculation Options and Tolerances** window. Go to the "**2D Flow Options"** Tab and set the Initial Conditions Ramp up Time to 2.0 hours, and the **Boundary Condition Ramp up Fraction** to 0.1 (which means 10% of the 2Hours will be used in Ramping up the boundary condition flows from zero to their first value, and the other 90% of the time will run the 2D model at constant boundary conditions). See Below:



	Parameter	(Default)	Downstream Area
1	Theta (0.6-1.0)	1	1
2	Theta Warmup (0.6-1.0)	1	1
3	Water Surface Tolerance [max=0.2](ft)	0.01	0.01
4	Volume Tolerance (ft)	0.01	0.01
5	Maximum Iterations	20	20
6	Equation Set	Diffusion Wave	Diffusion Wave
7	Initial Conditions Time (hrs)		2.0
8	Initial Conditions Ramp Up Fraction (0-1)	0.5	0.1
9	Number of Time Slices (Integer Value)	1	1
10	Turbulence Model	Non-Conservative (original)	Non-Conservative (original)
11	Longitudinal Mixing Coefficient		
12	Transverse Mixing Coefficient		
13	Smagorinsky Coefficient	0	0
14	Boundary Condition Volume Check	☐	☐
15	Latitude for Coriolis (-90 to 90)		
16	Solver Cores	All Available	All Available
17	Matrix Solver	PARDISO (Direct)	PARDISO (Direct)
18	Convergence Tolerance		
19	Minimum Iterations		
20	Maximum Iterations		
21	Restart Iteration	10	10
22	Relaxation Factor	1.3	1.3
23	SOR Preconditioner Iterations	10	10

B. Enter The Dam Breaching Data. Select the **Options|SA Connection Breach** option and enter all of the necessary Dam Breaching information. See the screen shot below for all the data to enter:



C. SAVE THE PLAN and Run the Model. After a successful run review the output and then answer the following questions.

1) **What is the Peak Outflow coming out of the Dam from the PMF event and the breach?**

2) **What is the peak flow coming out of the 2D Flow Area for the downstream Normal Depth boundary condition outlet? Does this flow make sense given the upstream inflow from the Dam breach, the terrain data, and the computational mesh used?**

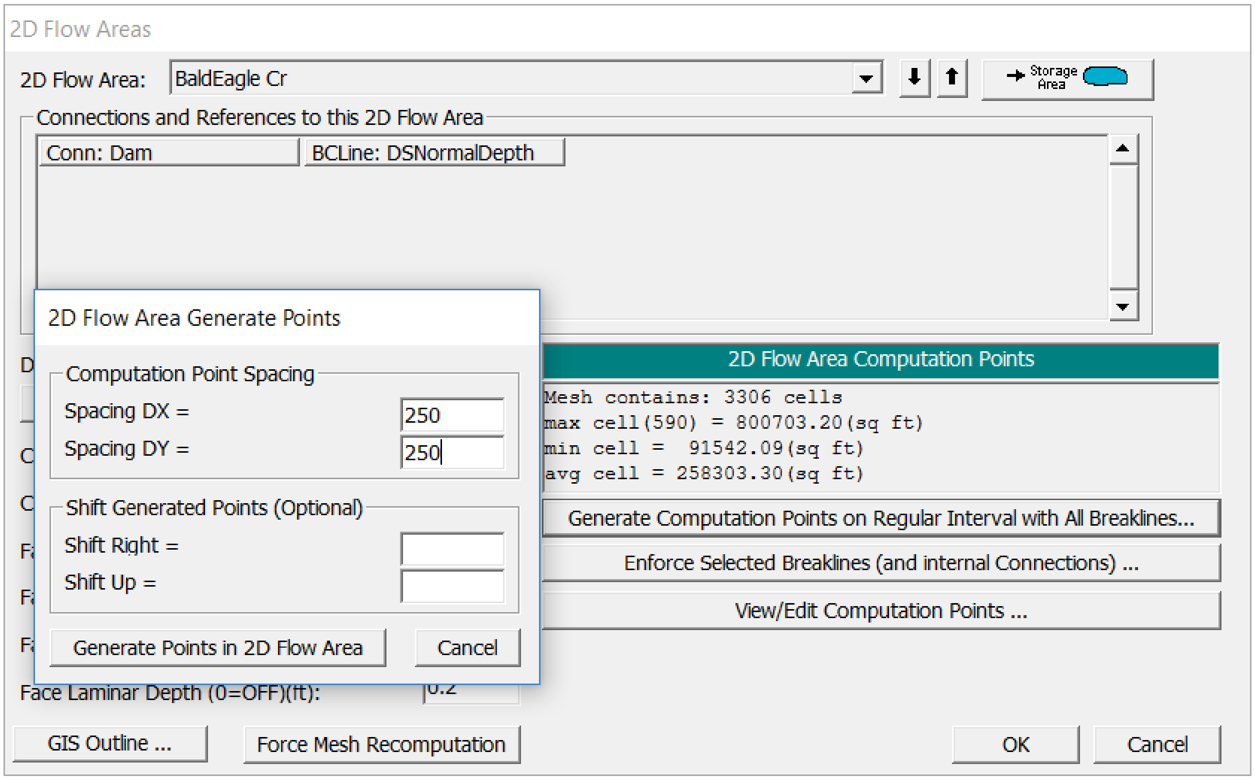
3) **Is the Computational Time Step appropriate for the selected 2D Flow Area cell size and the floodwave being routed through it?**

4) **Is the Computational cell size in the 2D Flow Area adequate for modeling the terrain, levees, and roads in this area? If not, briefly describe why not?**

4. **Change the 2D Flow Area Computational Cell Size.**

   A. Go to the Geometric Data editor and Save the Geometry using the "**Save As**" option. Given the new Geometry a name something like "SA to 2D Flow Area 250 ft Cell size.

   B. Using the 2D Flow Area editor, change the computational cell size to 250 ft. See Below:



Make sure you click the button labeled "**Generate Points in 2D Flow Area"** in order for the new cell size to be generated. After the mesh is generated, check the mesh to make sure there were no mesh generation mistakes. If there are fix them. Also make sure the break lines were enforced for creating cells and cell faces that line up along the levee. Modify the cell spacing around the break lines if you think it is needed.

SAVE THE GEOMETRY DATA!!!

C. Go into RAS Mapper, and Associate the new Geometry data with the Terrain Layer. Then run the 2D Pre-processor in order to have the computational tables built for this new geometry file and computational mesh. This will automatically be done at run time if you do not do it here.

D. Go to the Unsteady Flow Data editor and save this as a new Plan labeled something like "**SA-2D Dam Break – PMF 250ft cells**". All of the computational options and settings should still be the same as what was previously set, so you should not have to change anything. **However, the Computational time step may need to be changed, given the smaller computational cell size.**

E. Run the model and review the results.

5. **Answer Some Additional Questions.**

A. Is the peak outflow from the dam any different than the previous run done with 500 ft grids?

B. Has the Peak outflow coming out of the 2D Flow Area changed? If so, why?

C. Are there any differences in the inundation mapping between the two runs? Look at the Max Depth inundation, as well as different time steps during the event in order to answer this question. It will also be helpful to change the color of one of the plans to something other than Blue. I changed my 250 ft Plan to Red/green, and moved it to be the top layer, which made it easier to see differences between the two plans.

D. Does the smaller cell size better represent the downstream terrain and the levee system protecting Lock Haven? Is it detailed enough with this cell size? If not, what are the options you could use to model the Lock Haven levee system more accurately than it is currently represented in this model?

E. Do you think it is appropriate to use the Diffusion Wave equations or the Full Saint Venant equations for this Dam Break analysis in the Bald Eagle system? Why or why not?