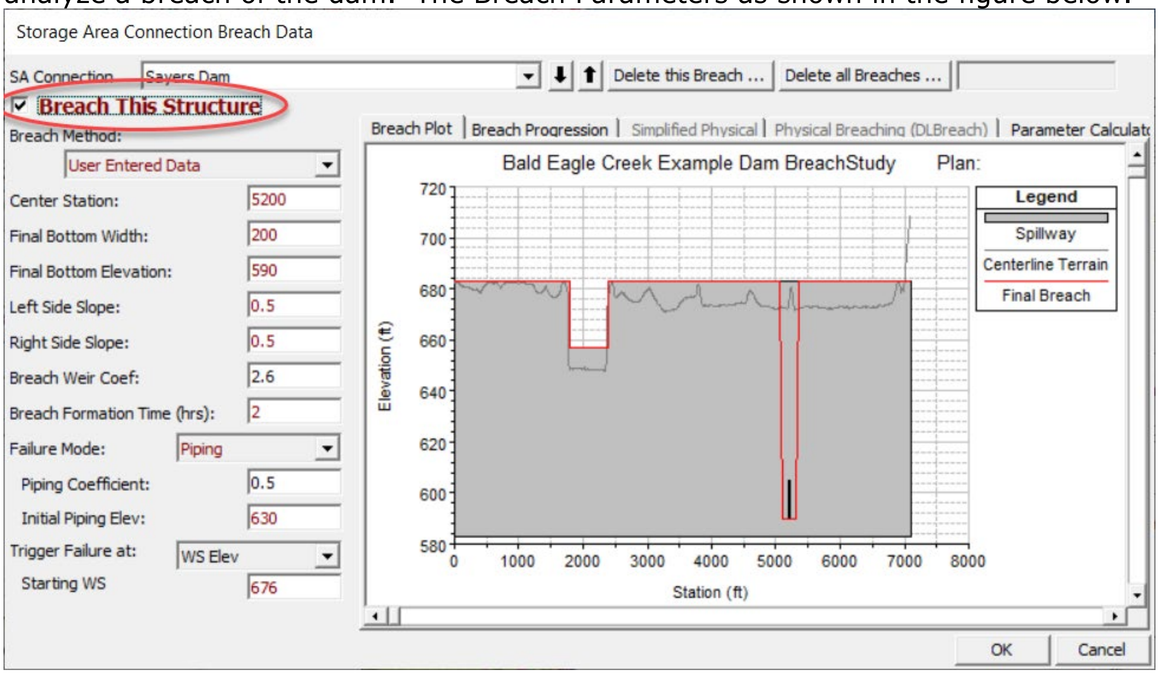
Dam Breach Analysis with 1D and 2D Areas
Solution

Objective

The objective of this workshop is to learn how to use HEC-RAS to model a Reservoir Pool, Dam, and downstream area using 1D and 2D elements. The workshop used a PMF flood event to look at the consequences of a failure of Sayers Dam.

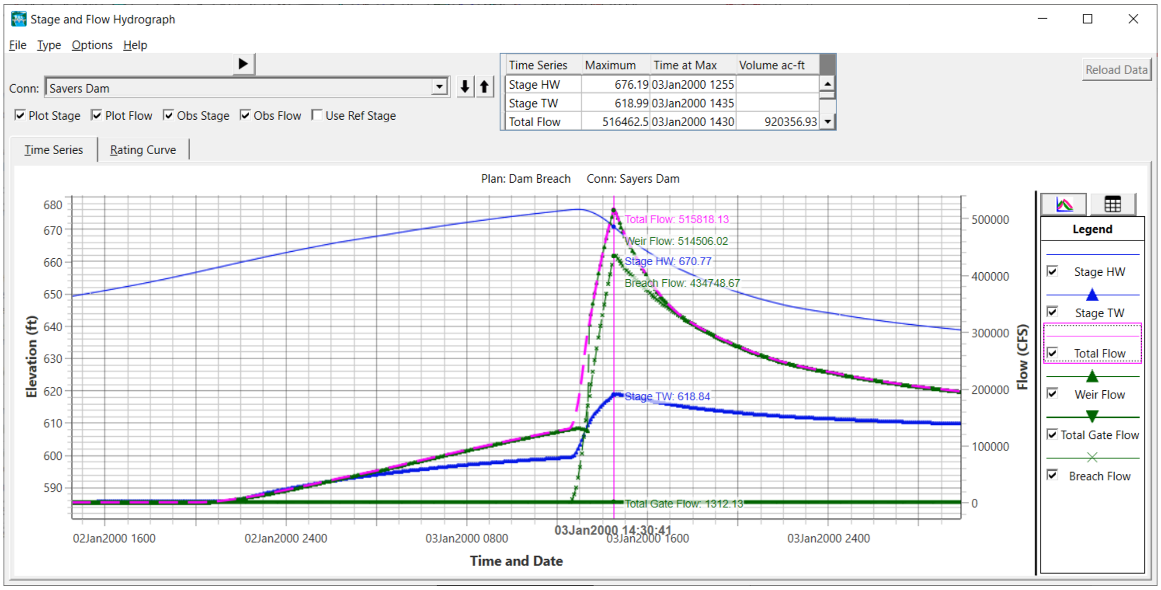
The diffusion wave approximation of the full shallow water equations were used to analyze a breach of the dam. The Breach Parameters as shown in the figure below.



Review Results

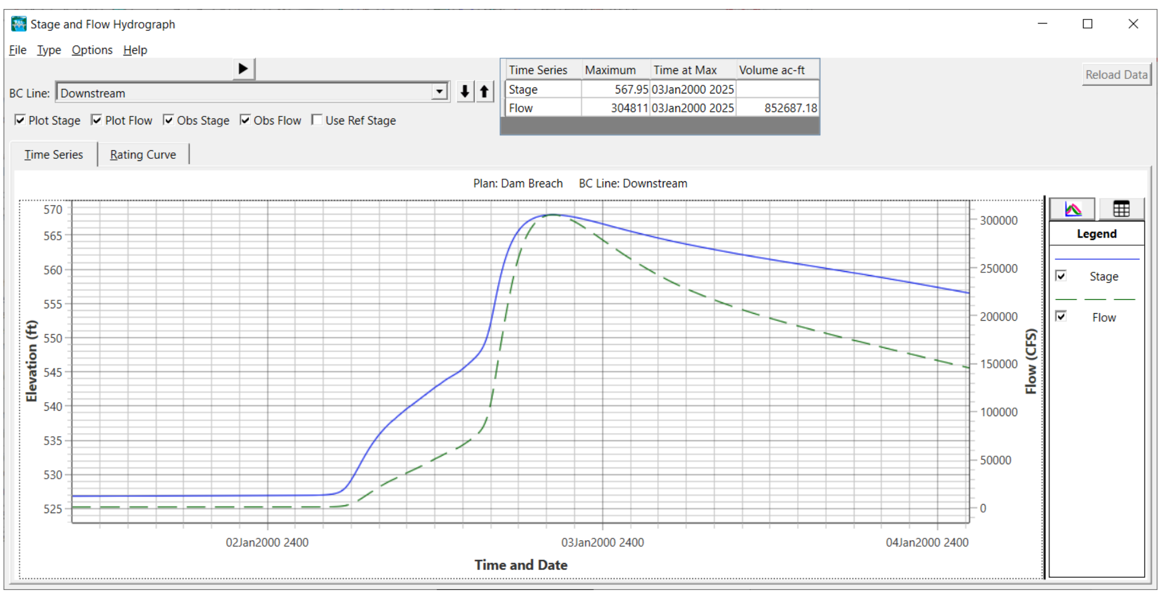
Question: What is the Peak Outflow coming out of the Dam from the PMF event and the breach?

The Peak Outflow is 516,000 cfs (~435,000 cfs is breach flow). The plot below shows the stage and flow hydrograph for the hydraulic structure around the time of the breach.



Question: 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?

The flow hydrograph for the Downstream Boundary shows 305,000 cfs.



This flow is reasonable. Approximately, 200,000 cfs of peak flow was attenutated during the breach. The run time messages indicate a 0.026 percent volume error.

This, however, does not mean the results are accurate. There are many factors that we will need to investigate for model sensitivity that could affect accuracy.

1. Accuracy of the hydrology

2. Breach parameters (size and formation time)
3. Terrain data
4. Representation of the main channel, levees, roads, and high ground barriers
5. Representation of levees, roads, and high ground barriers in the 2D mesh
6. Manning's n values
7. Downstream boundary condition
8. Lateral inflows and local flow (which we didn't use)

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

This initial solution was run with a **20s** time step. Given a 500ft cell size and velocities of up to 25 ft/s, a time step of 20s satisfies a courant condition of 1.0.

We would need to test the model by running a various time steps and evaluating the impact on flow specific locations of interest to identify the impact. For instance, the levees are overwhelmed by the flood event and rapidly overtop. More accurate computation of flow would occur with a smaller time step.

Question: 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?

No! Using a cell size of 500 ft does not accurately pick the details within the Lock Haven leveed area and the levee itself. However, this levee could be modeled with a separate hydraulic structure. The area inside the levee would also benefit from a smaller cell size, and additional break lines.

Bald Eagle Creek gets very constricted through the Lock Haven area. With a cell size of 500ft we only have 1 cell across the entire main channel. While HEC-RAS can route flow this way (due to the fact that the faces are like cross sections, and the cells have a detailed elevation volume curve), the flow is being computed more like 1D flow than 2D. Also, the contraction of the flow is very extreme at this location during high flows. This cell size may be too coarse to pick this up accurately.

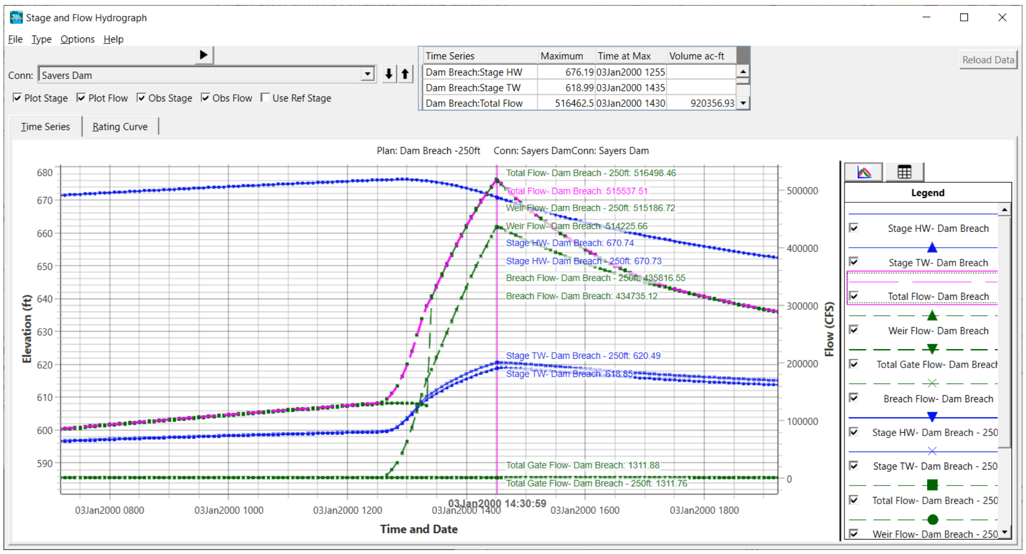
The only true way to know if the cell size is ok is to run a smaller cell size and see if there is a significant difference in the results at various key locations in the model.

Results from a smaller 2D Cell Size

Question: Is the peak outflow from the dam any different than the previous run done with 500ft mesh?

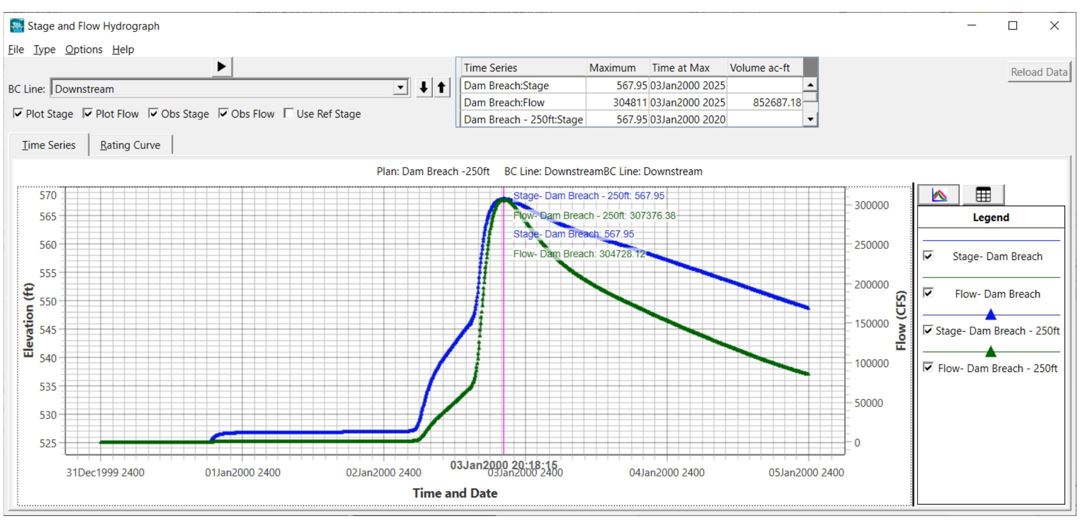
Because we changed the mesh size, we should have also reduced the time step.

Total flow did not appear to change significantly. Any differences would most likely be due to the smaller cell size produces a higher tailwater elevation and submergence differences across the auxiliary spillway.



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

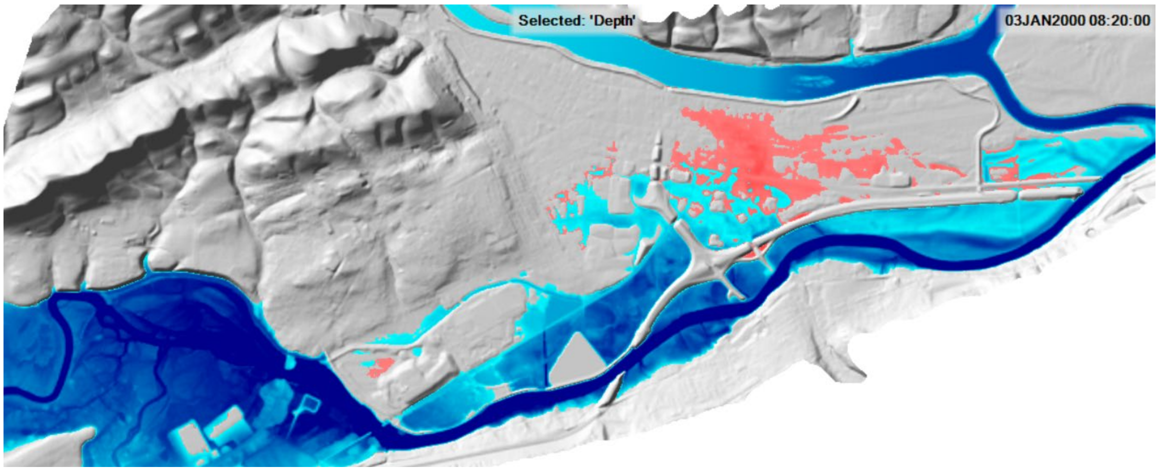
The is very little difference in the outflow.



Question: 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 to answer this question. I changed my 500 ft plan to red and put the 250ft plan (in blue) on top.

You can see the larger cell sizes allow water to spread faster.



There was very little difference in the maximum inudation, which is easily seen with a time series plot of WSE.

Question: 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?

Not really. While the 250ft cell size is better overall for this model, the levee is still not being modeled adequately. Some options to better model this system are discussed below.

- Model the whole system with a very small cell size, such as 5 to 10 ft grids. However, this would still require that the levee be accurately represented in the terrain model. This is not the case for this terrain data set, so this option would not work here. Also, this would generate a tremendous number of cells. A 10ft cell size would end up being 8 million cells for this same area. This would also require an extremely small time step, on the order of 1 second. This would not be feasible for this problem.

- The area inside the levee system could be modeled as a separate 2D Flow Area, with its own cell size, roughness, etc.. The main river and floodplain could also be a separate 2D Flow Area. Then the levee could be modeled with SA/2D Area Hydraulic Connections to represent the levee. This would allow for the analysis of levee overtopping and breaching at any location.

- For the single 2D Flow Area approach, because the terrain is not detailed enough, an interior hydraulic structure could be added on top of the aligned faces to represent the levee more accurately. By putting in a hydraulic structure, the user can enter station elevation data for the structure that may be more accurate than the terrain data. The flow over the hydraulic structure can be computed as 2D over flow, or it can be modeled as 1D weir flow (this is a user choice). Additionally the use of the interior hydraulic structure allows the user to evaluate levee breaches (when using the weir flow option!), which cannot be done without the hydraulic structure added in.

While the modeling of the levee would be much more accurate with an added hydraulic structures, the 250 ft cell size may still be too coarse for the extreme constriction of the flow that occurs due to the Lock Haven levee and the steep mountain side, as well as the extremely rapid rising water surface due to the Dam breach/PMF

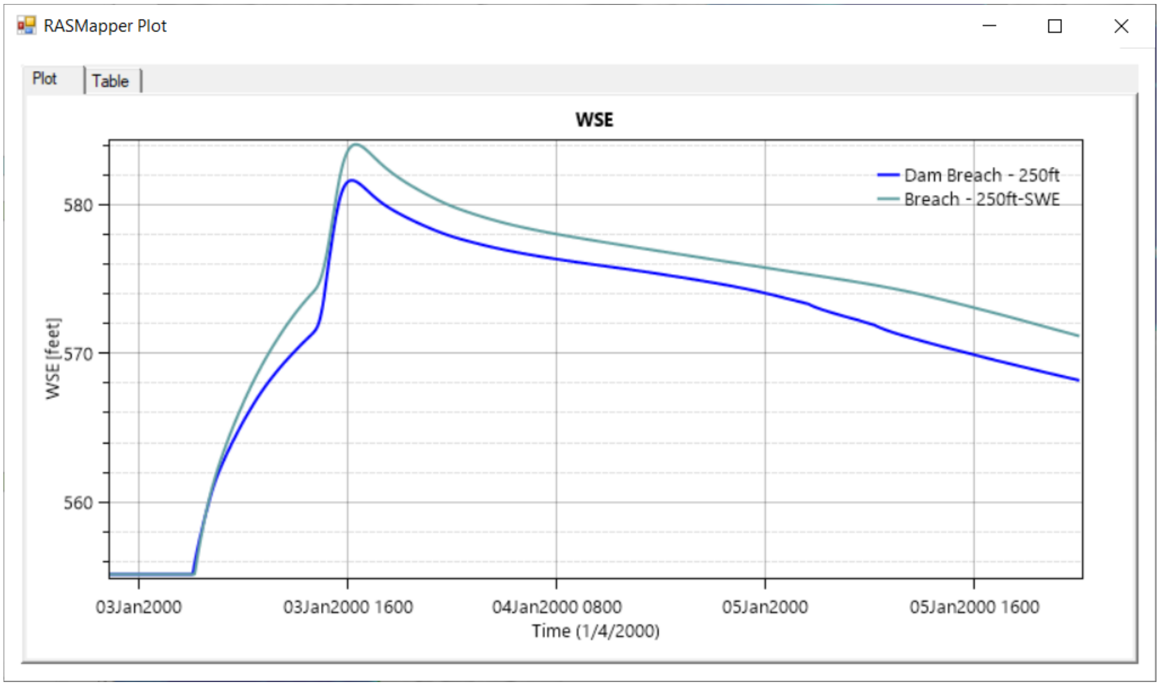
Question: Do you think it is appropriate to use the Diffusion Wave equations or the Full Shallow Water equations for this Dam Breach analysis in the Bald Eagle system? Why or why not?

In general, for a rapidly rising event like a dam breach flood wave, the Full shallow water equations are more accurate. The dam breach will have very high velocities just downstream of the Dam, and the water surface elevations and velocities will be changing rapidly as the floodwave moves downstream from the dam.

However, the only way to really know the significance in the difference between running these two equation sets, is to run them both for the same exact model and flood event. In general, the Full Equations will require a smaller time step for the same cell size and flood event, over the Diffusion Wave equations. This is due to the added complexity of including the acceleration terms and their associated derivatives. The full equations are more difficult to solve in a stable manner, especially for a dam breach flood wave.

Running the 250 ft grid model with the DW and the full SWE equations as two separate plans requires saving the plan, changing the equation set, and setting a reduced time step. In general, the SWE ended up with higher water surfaces upstream of and through the levee system, due to the inclusion of the acceleration terms in the equations. This is due to significant contractions and expansions of flow in this model in many locations, especially in the area of the levee system.

Here is a hydrograph plot just upstream of the river's constriction.



Another plot for the downsteam boundary. Peak stages are similar, however the DW solution has the floodwave arriving a bit sooner.