

## 2D Connections in HEC-RAS

### Workshop Solution

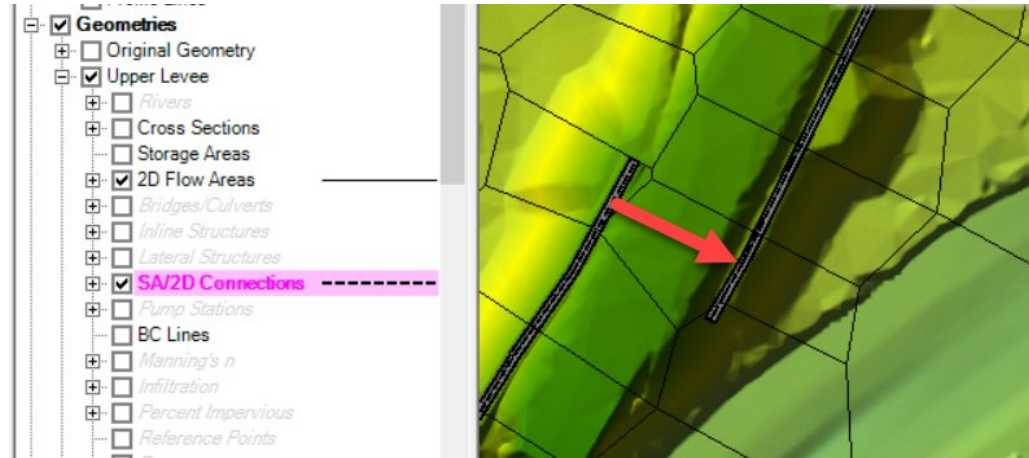
#### Objective

This workshop will help students learn how to use the 2D Connections feature of HEC-RAS to model a levee and a levee breach that is inside of a 2D Area. The Bald Eagle Creek hydraulics model is used for this analysis – focus on the levee system and the town of Lock Haven.

#### Add the Upper Levee

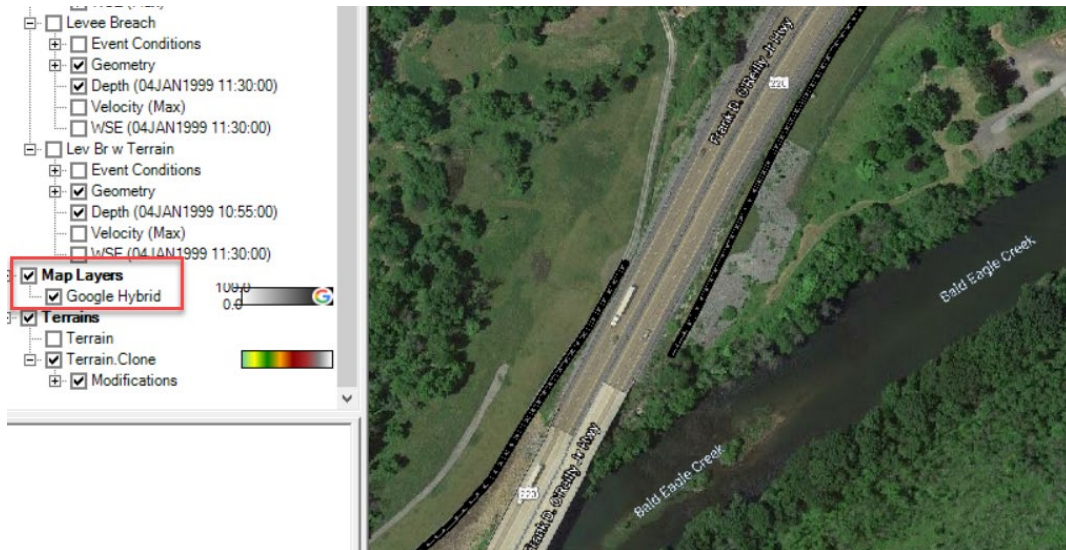
**Question:** *What is the situation at the downstream end of the structure? Does the Upper Levee connect to the Middle Levee?*

There is a gap between the Upper Levee and the Middle Levee.



**Question:** *What is the cause of this situation? (Hint: turn on Google Hybrid under Map Layers.) For this model, the downstream end of the structure is not a problem and no changes are necessary. However, how would the user establish that? If it was a problem, what would be the solution?*

As shown in the figures above and below, there is a gap in the breaklines that were downloaded from the NLD. Sometimes there are gaps that are caused by missing or bad data. In this case, the levee actually starts and stops on either side of a highway embankment and the breaklines show this.



One option to see if it was a problem, would be to inspect the elevation of the terrain by using the tools in RAS Mapper. Plotting the profile of the face that is next to the red arrow in the figure above, it can be seen that the elevation of the face stays above 572 feet. This is actually as high as the user entered station/elevation data for the Middle hydraulic structure in this location. A second option would be to run the model and see if water made it through the gap before it should. (It does not.) If the terrain data was lower, or if the cell boundaries/faces had happened to be in a different location, water may have been able to make it through this gap when it should not have.

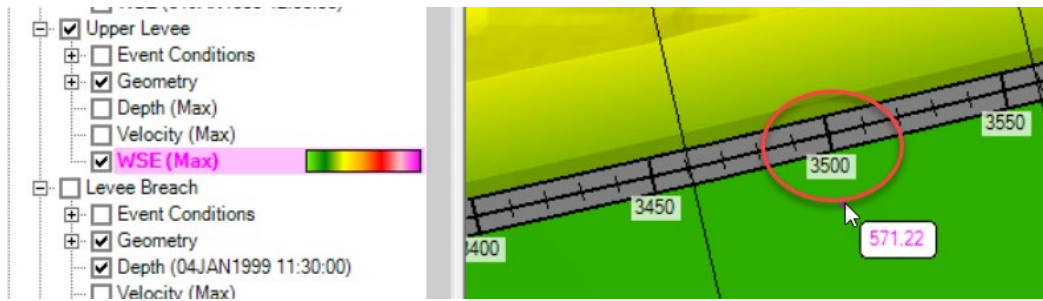
If there was a problem, the location of either hydraulic structure could be adjusted so that the ends of the structure (as drawn by RAS with the red dotted lines) touched. (If the structure starts or stops in a new location, the user may need to make adjustments to the length and the station/elevation data of the weir.) Another option would be to raise the terrain in this location using the terrain modification tools.

**When adding a hydraulic structure to a RAS model, it is important to add it in a manner that makes hydraulic sense, as opposed to blindly following the centerline.**

*Question: Is the levee overtopped?*

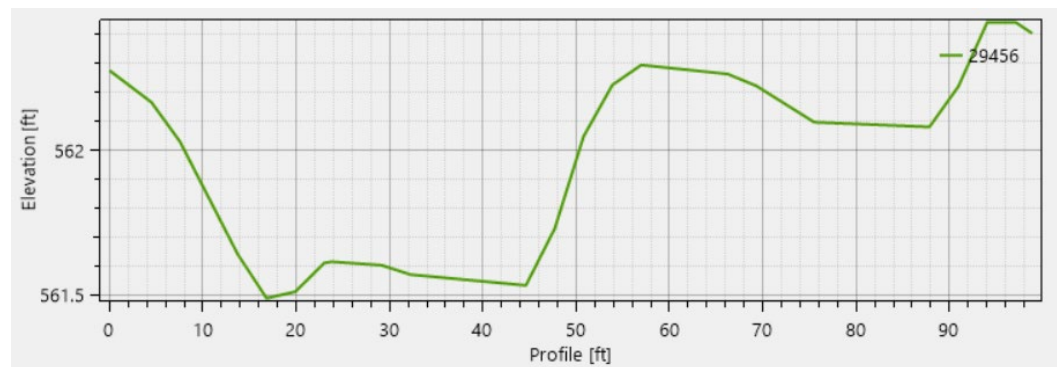
No.

*Question: What is the maximum water surface elevation at station 3500 (circled below)?*

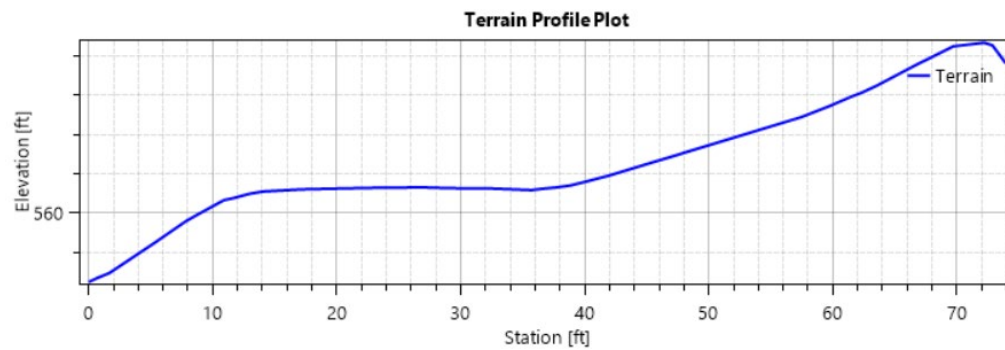


The water surface is 571.22 feet.

**Question:** *What is the approximate levee height at this location? How much freeboard is there on the levee for the maximum water surface?*

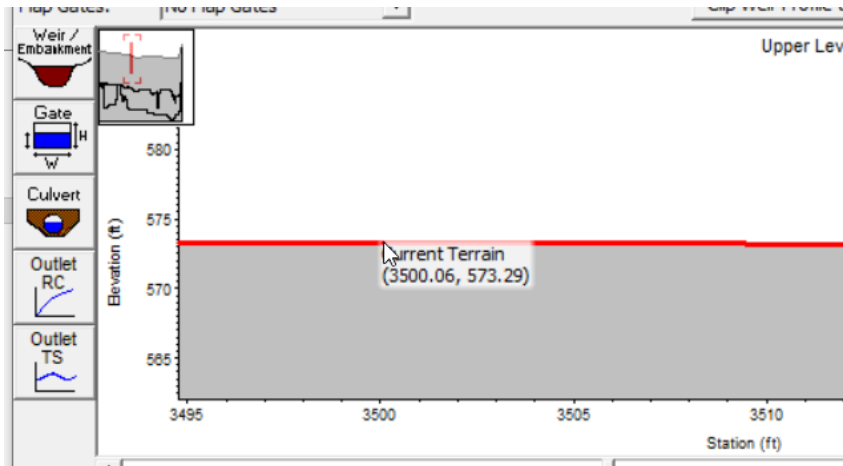


The face profile plot was checked in this location and as can be seen in the figure above, the elevation ranges from around 561.5 to 562.5. However, this cell boundary/face does not appear to match up with the high point of the terrain. Spot checking along the face, by drawing a profile line perpendicular to the levee (as shown in the two figures below), shows the high point to be around 564.5 feet.



However, this is only the terrain data. The actual levee is based on the user entered station/elevation data. The user entered station/elevation data does not show up in RAS Mapper, because RAS Mapper is based on the original underlying terrain. So to determine the elevation of the levee in this location, the station/elevation data of the user entered weir needs to be checked.

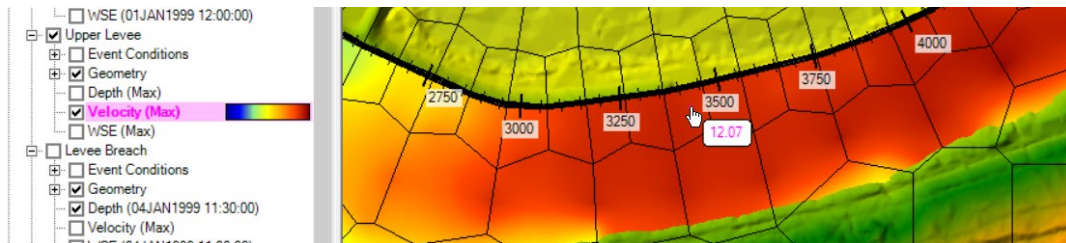
Bringing up the Connection Data Editor, zooming in, and then clicking on the top of the line:



It looks like the top of the levee is 573.29 feet. With the maximum stage 571.23, the freeboard is around 2.1 feet.

**Question:** *What are the maximum velocities along the toe of the levee in this location?*

It is around 12 ft/s, depending on what point is selected as the “toe” of the levee.



**Question:** *What changes could be made to the model to improve the accuracy of the velocities along the toe of the levee?*

The model is being run with the diffusion wave equation and the channel at this location is only two cells wide. While this might give reasonable results for water surfaces and arrival times, it is probably insufficient for velocity profiles.

The most important would be to use smaller cells, especially where the channel necks down next to the levee. The smaller cells would more

accurately model the overall hydrodynamics and the smaller cells would better capture the maximum velocity. Smaller cells would probably need a shorter time step. Even the current model might benefit from a shorter time step.

Switching to the Full Momentum equation might produce better results that could have different maximum velocities. Diffusion Wave models run faster. For many data sets, diffusion wave will give results that are comparable (and satisfactory) to the Full Momentum. And even for data sets that need Full Momentum, Diffusion Wave may be useful during the data entry stage of development. But in any event, it is advisable to check the Diffusion Wave answers against the Full Momentum solution at some point.

If the Full Momentum gives a different answer, it is not automatically better. Switching to Full Momentum may require other changes such as smaller cells and shorter time steps for accuracy. However, if the Full Momentum is different, then it may mean that further investigation is warranted.

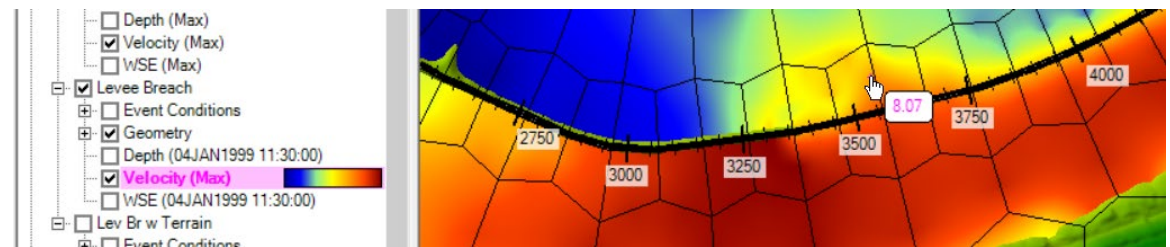
## Add the Levee Breach

**Question:** *When does the breach occur?*

By looking at the Stage and Flow Hydrograph, the first flow is at 04Jan at 10:57. The time can also be determined by animating the results in RASMapper (although this output is only at a 5 minute interval).

**Question:** *What is the maximum velocity on the toe of the Lock Haven side of the levee?*

Around 8 ft/s.



## Add the Levee using the Terrain Modification Tools

**Question:** *What are the benefits of incorporating the elevation data directly into the terrain?*

By using the Terrain Modification, we can see exactly what HEC-RAS is going to use for the elevations. If we use the option to use a user-specified weir elevation, we need to look at the SA/2D Connection editor to see the entered elevations. Further, after we simulate and we plot depths/water surface elevations, we can see the direct impact of the terrain modification. For



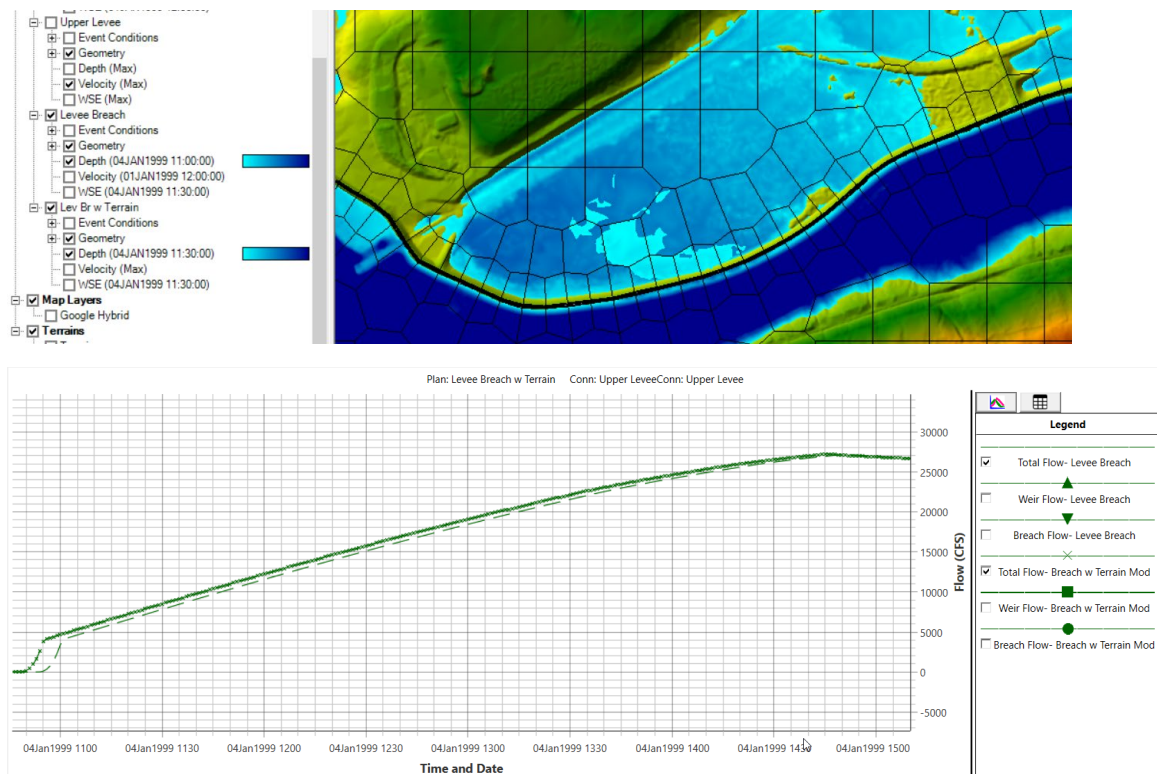
instance, if the weir is overtopped, we can see the depth of flow over the top of the weir.

By using the Terrain Modification, what is shown in RASMapper [mostly\*] matches what is used for the computations. It would have been easier to determine the amount of freeboard on the Upper levee for the Upper Levee plan. If the weir is overtopped, it would be easier to directly see the depth of flow over the top of the weir. The terrain modification can improve the accuracy of the model, see next question/answer below.

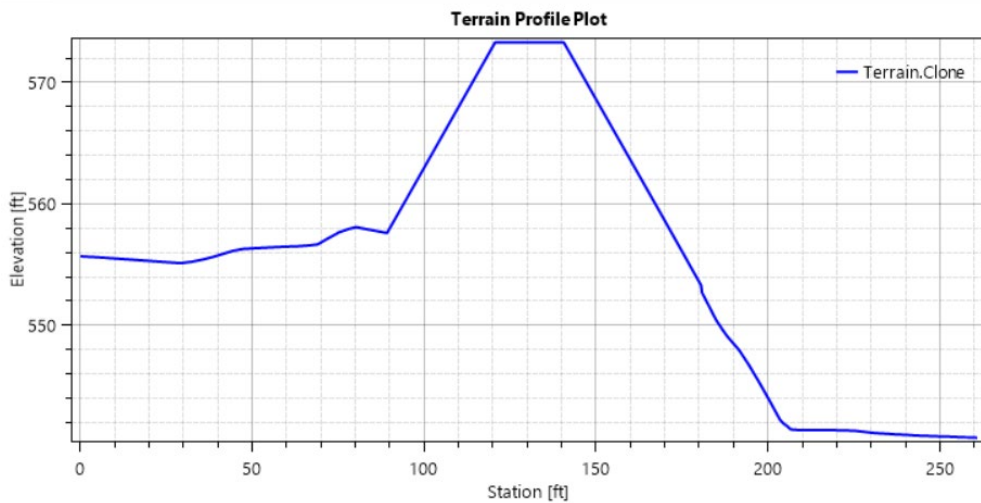
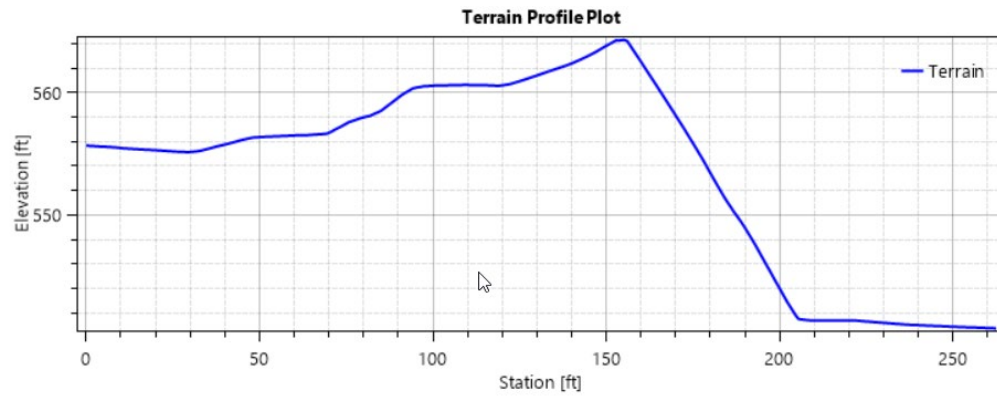
\*The starting terrain does not match the ending terrain because of the levee breach. RASMapper does not currently have a provision to render terrains that change over time, so the terrain does not include the levee breach. However, this is on the wish list.

**Question: How does the run with the terrain modification compare with the run without the modification? What is the most likely cause of the difference and which would be more hydraulically accurate?**

The breach where the levee has been added to the terrain starts sooner. This makes for a dramatic difference at the start, but over the entire run the difference is rather minor.



The terrain modification added in the levee as a trapezoidal shape.



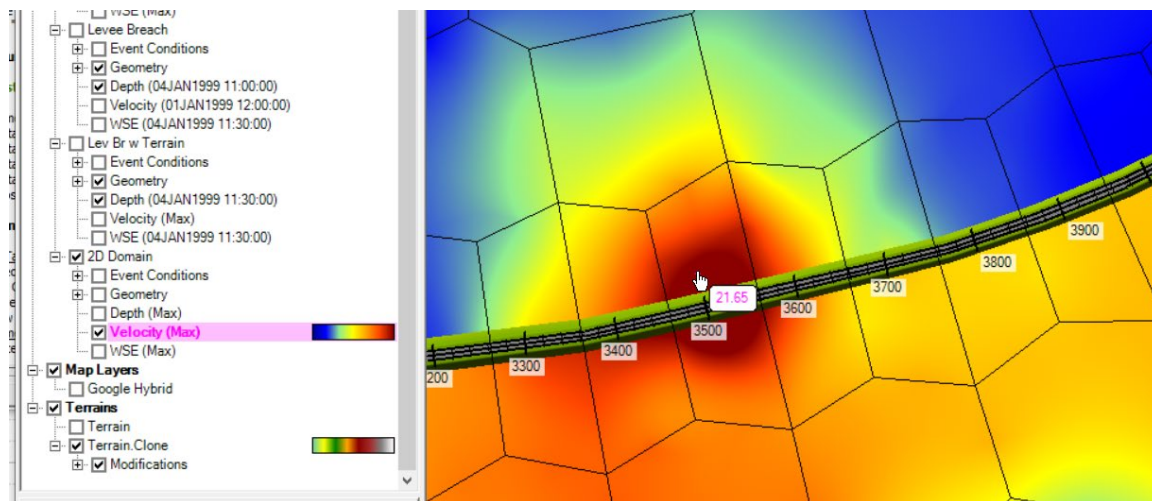
This is fully incorporated into the 2D solver. Adding the levee to the terrain has further constricted the channel at this location and caused a difference in results. If this is an accurate representation of the levee, then it is desirable to include it in the terrain, and it should generally lead to more hydraulically accurate results.

However (there is frequently a however), it is not a given that the shapefile is a 100% accurate location of the levee centerline. Nor that the levee is the same width and slope along the entire length. For an actual study, additional investigation would be warranted, especially in an area where the levee is up against a narrow and high velocity part of the channel.

## Run the Model with Alternatives

If you have time, you can model the levee breach using the 2D domain equation (which is selected from the 2D area Connection Editor). Additionally, try modeling the levee breach using a 5 second time step [using the weir equation]. For both runs, use the terrain that includes the levee modification.

**Question: How does the maximum velocity from the 2D domain equation compare to the weir equation? Which is likely more accurate?**



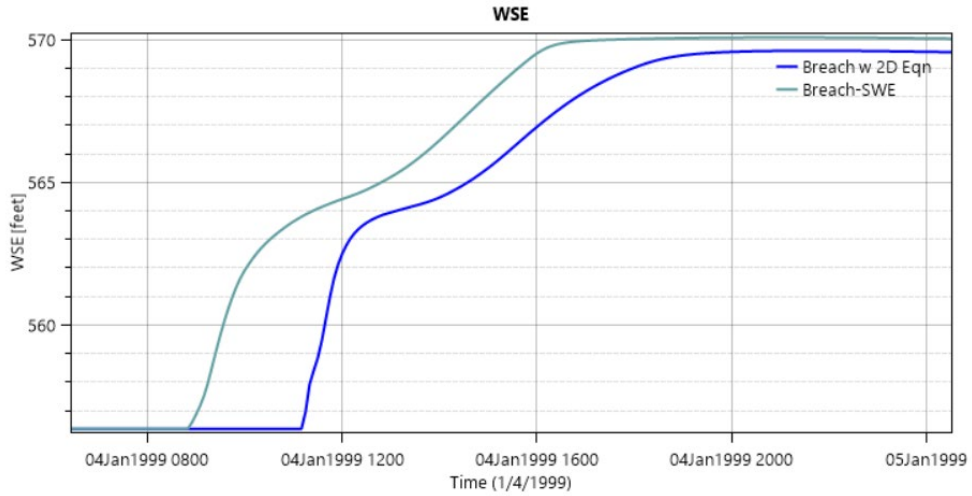
The 2D domain is getting velocities that are over 20 feet/s. The weir equation got velocities around 8 feet/s which seem more probable given the amount of energy head available. The 2D domain can compute velocities that are too high for weir

It is a little hard to tell what a residential neighborhood is as compared to a commercial one. However, selecting what is clearly a house, the 2D domain arrival time was 11:25 compared to 12:10 - around 45 minutes earlier. This is a significant difference. Given the height of the weir, the weir equation results are probably more accurate. However, if the interior of the levee area fills up, and the river water surface drops, at some point the choice might not be so clear cut.

**Question: Is there a difference between DF and SWE?**

The max WSE results are similar (~0.5ft, SWE is higher) down in Lock Haven with the SWE floodwave arriving a couple hours sooner (~2hrs) depending on where you look. There is a difference, so final simulation results should be provided using the SWE.





**Question: How does the 5 second run compare to the 20 second run? Turn Google Hybrid on and compare the arrival time to the residential neighborhood of Lock Haven between the two runs.**

The 5 second run appears to be the same as the 20 second run.