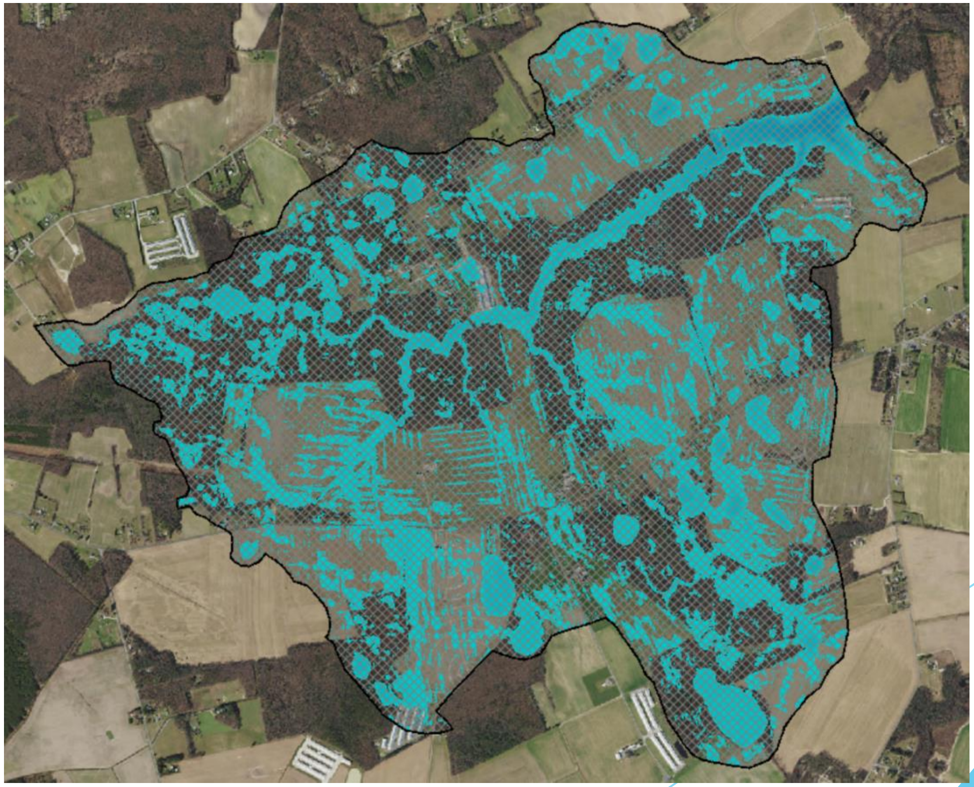
A Distributed 2D Modeling Approach to Watershed SCS Peak Rate Factors



DISCLAIMER!!!

This presentation is not an academic paper…

This presentation was not a comprehensive study…

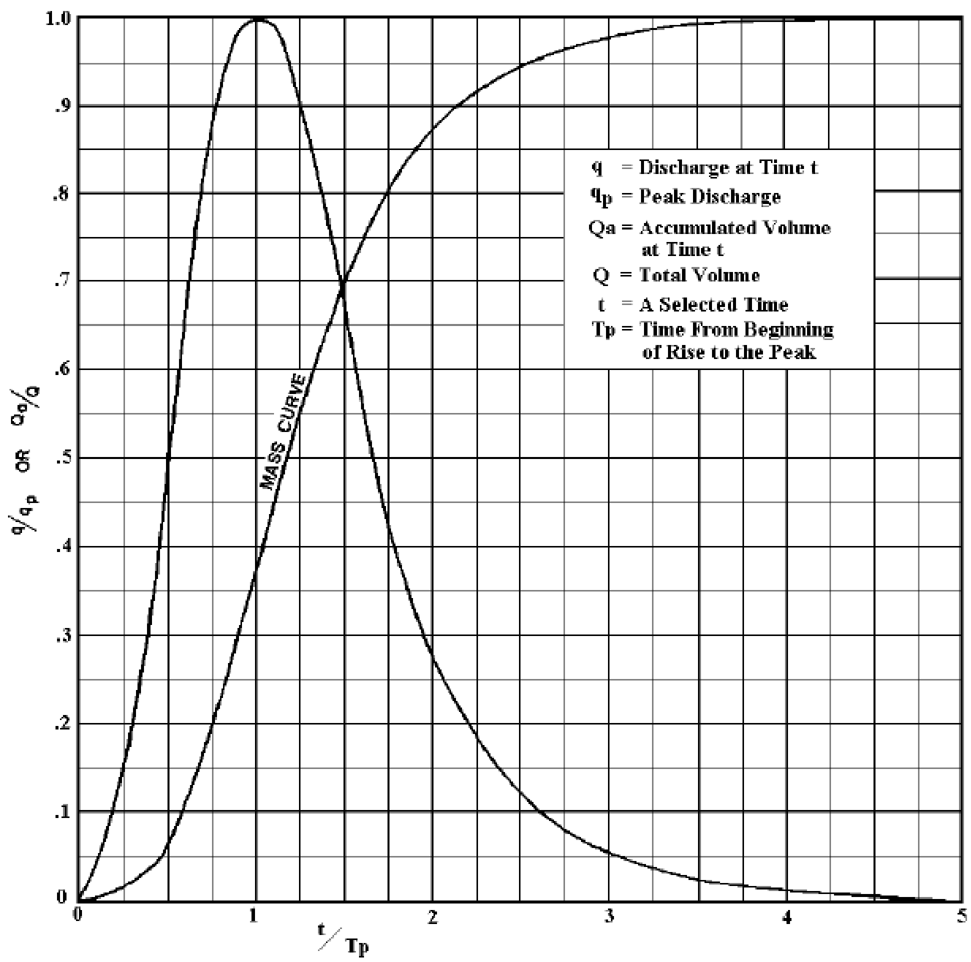
This presentation does not state that two-dimensional modeling should replace standard hydrologic methods…

The primary purpose of this presentation is to advance the discussion on understanding how the latest tools can help us better understand hydrologic study approaches

Soil Conservation Service (SCS) Unit Hydrograph

PROS
- Simple Input
  (single parameter – T of C)
- Significant Agency Acceptance
- Long Track Record (est. 1957)

CONS
- Empirical
- Too simplistic?



Soil Conservation Service (SCS) Unit Hydrograph

$$U_P = C\frac{A}{T_P}$$

C – Peak Rate Factor
A – Basin Area
Tp – Time to Peak

Peak Rate Factor

- HEC-HMS – until recent versions only allowed the use of 484 in watershed analysis – Default value
- Studies have shown Peak Rate Factors from 200-300 in Coastal areas to 600 in steep terrain
- What is your local Peak Rate Factors???

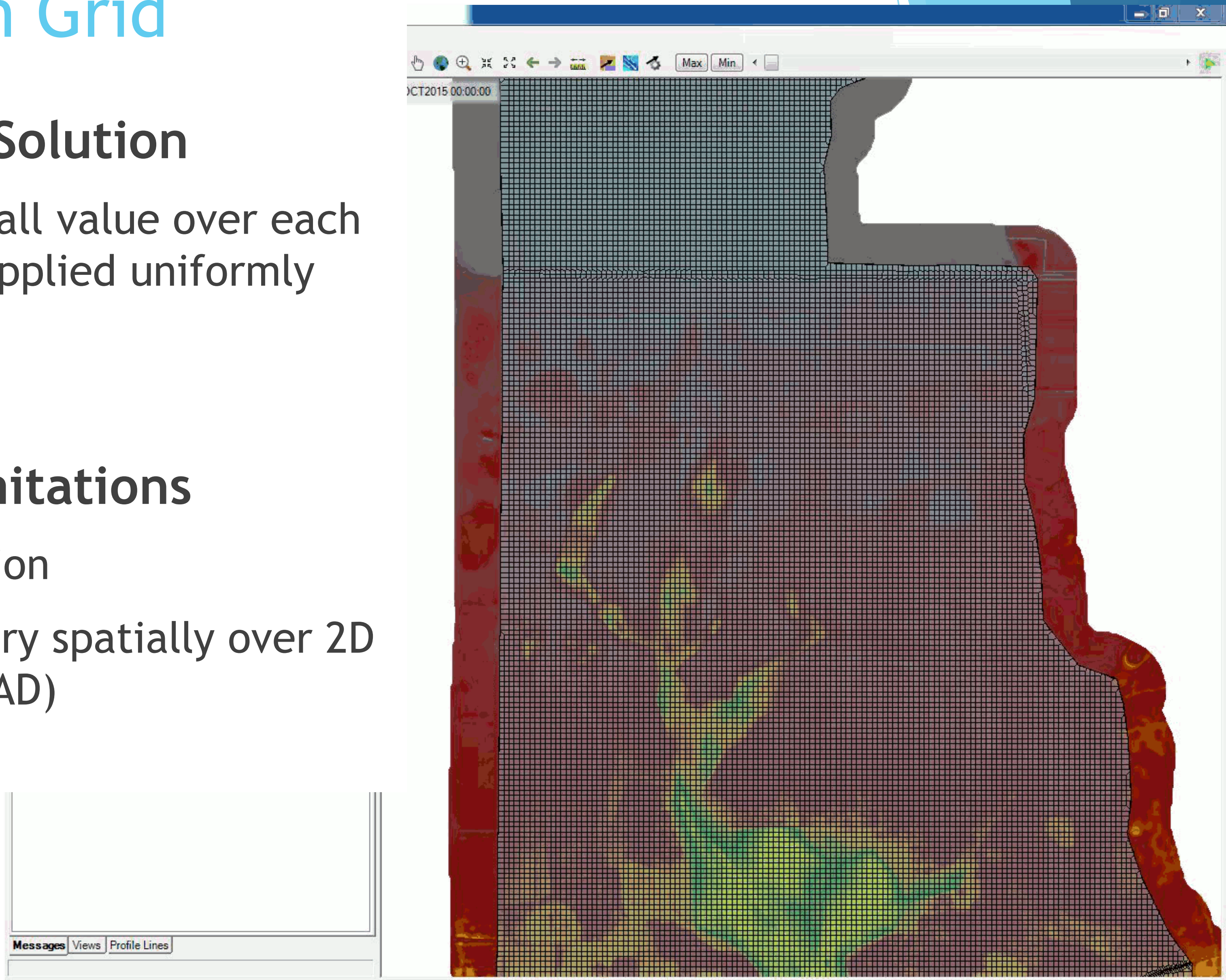
HEC-RAS 5.0
2D Rain on Grid

Hydrologic Solution

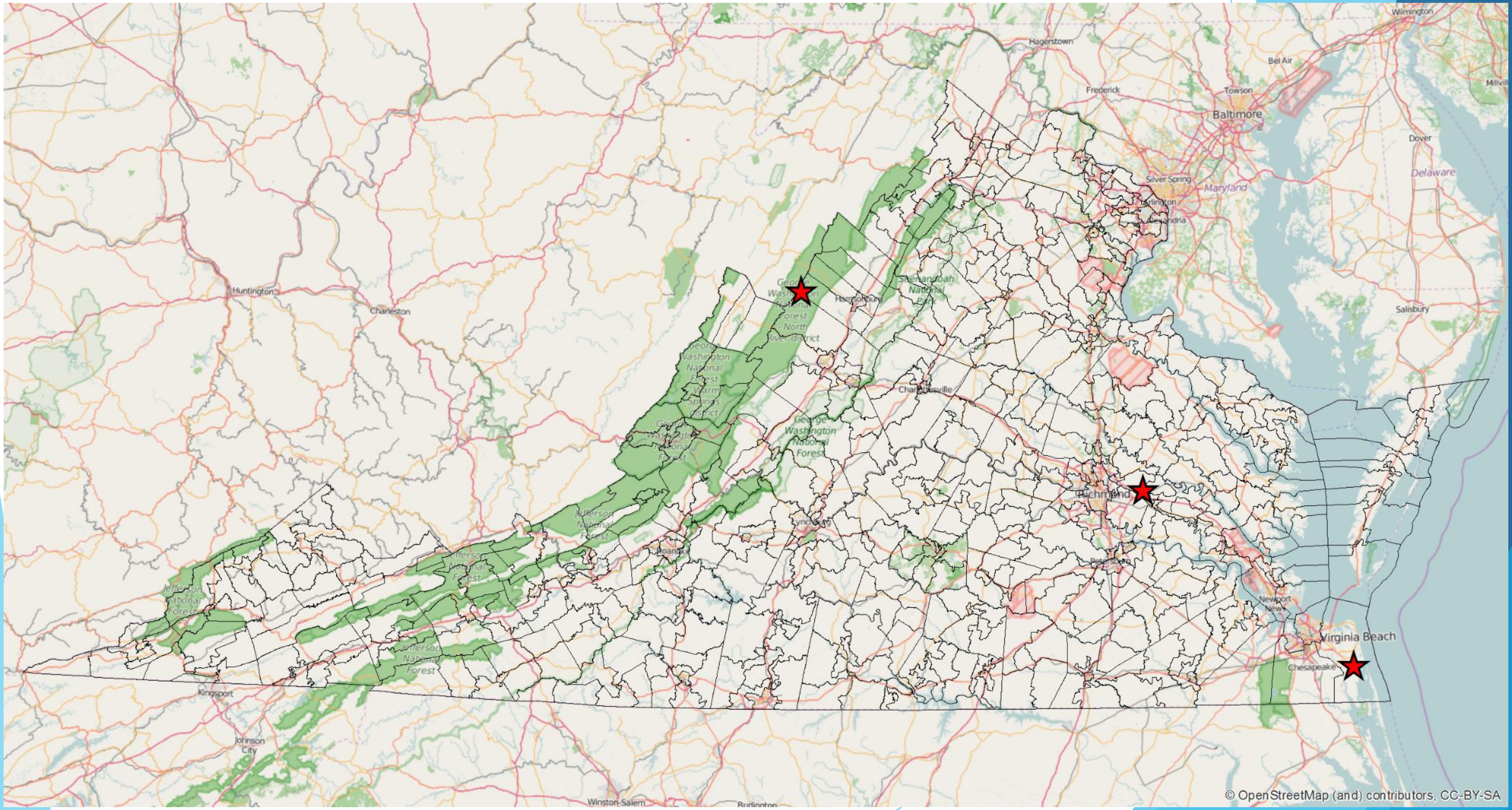
- Single rainfall value over each time step applied uniformly

Current Limitations

- No infiltration
- Does not vary spatially over 2D area (NEXRAD)

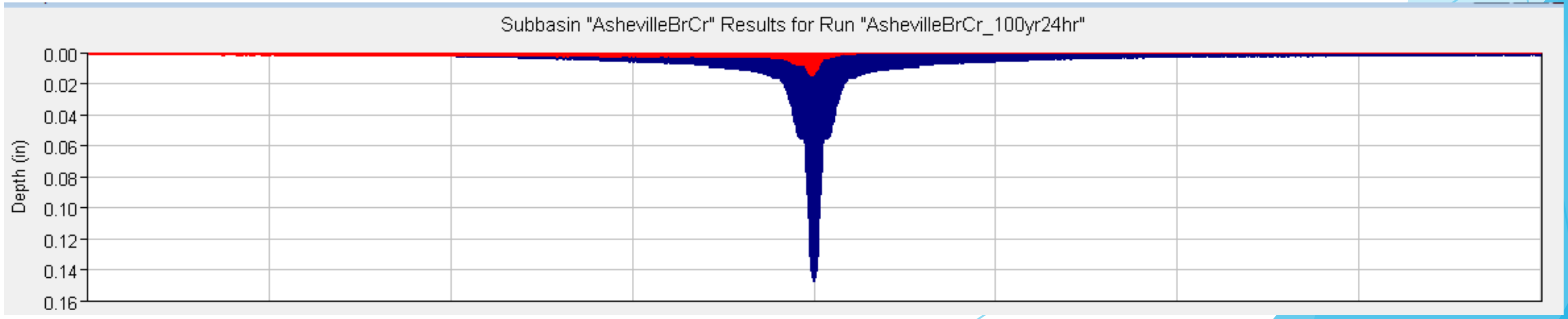


Initial Comparison

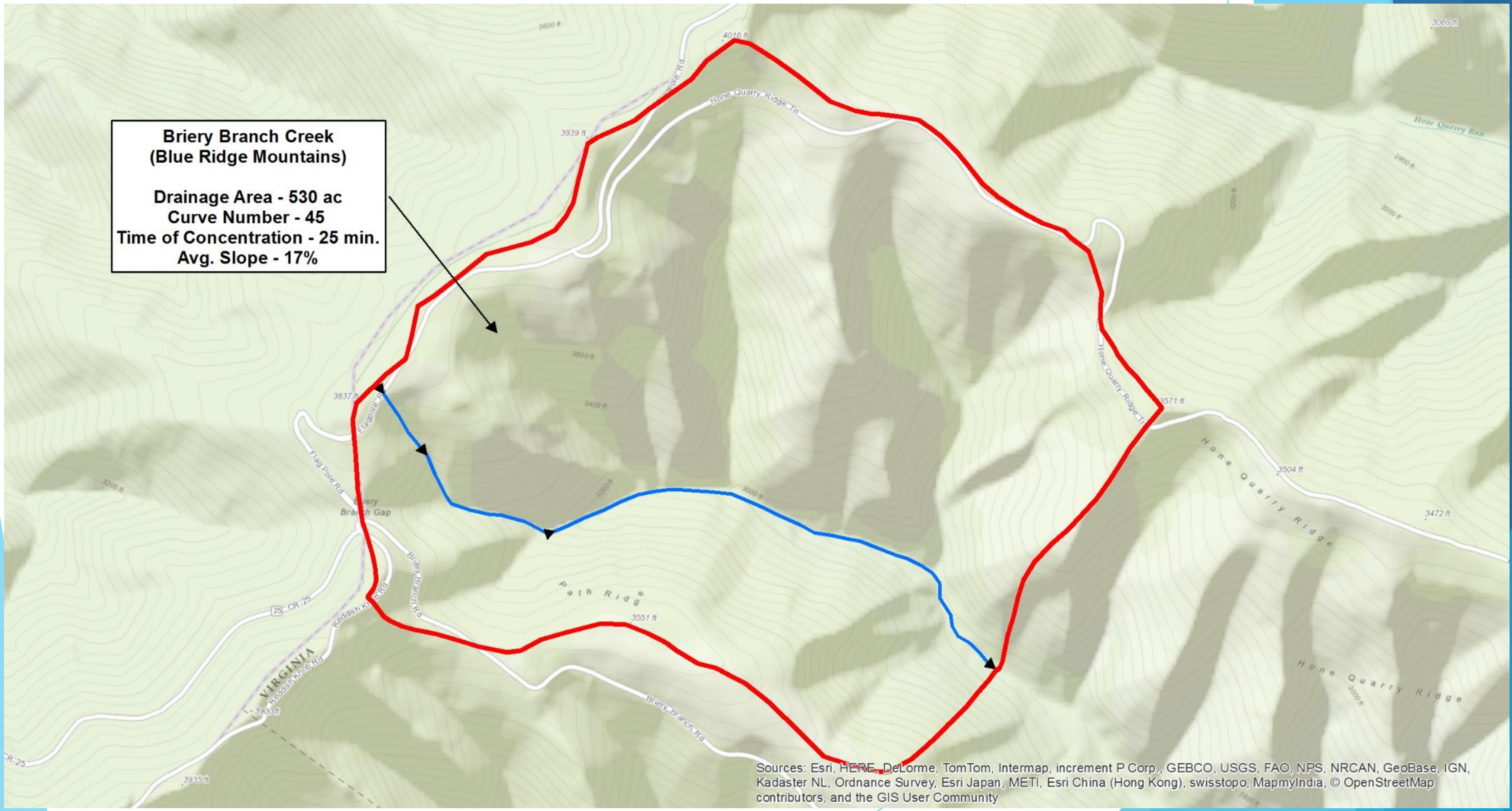


Initial Comparison Steps for Each Watershed

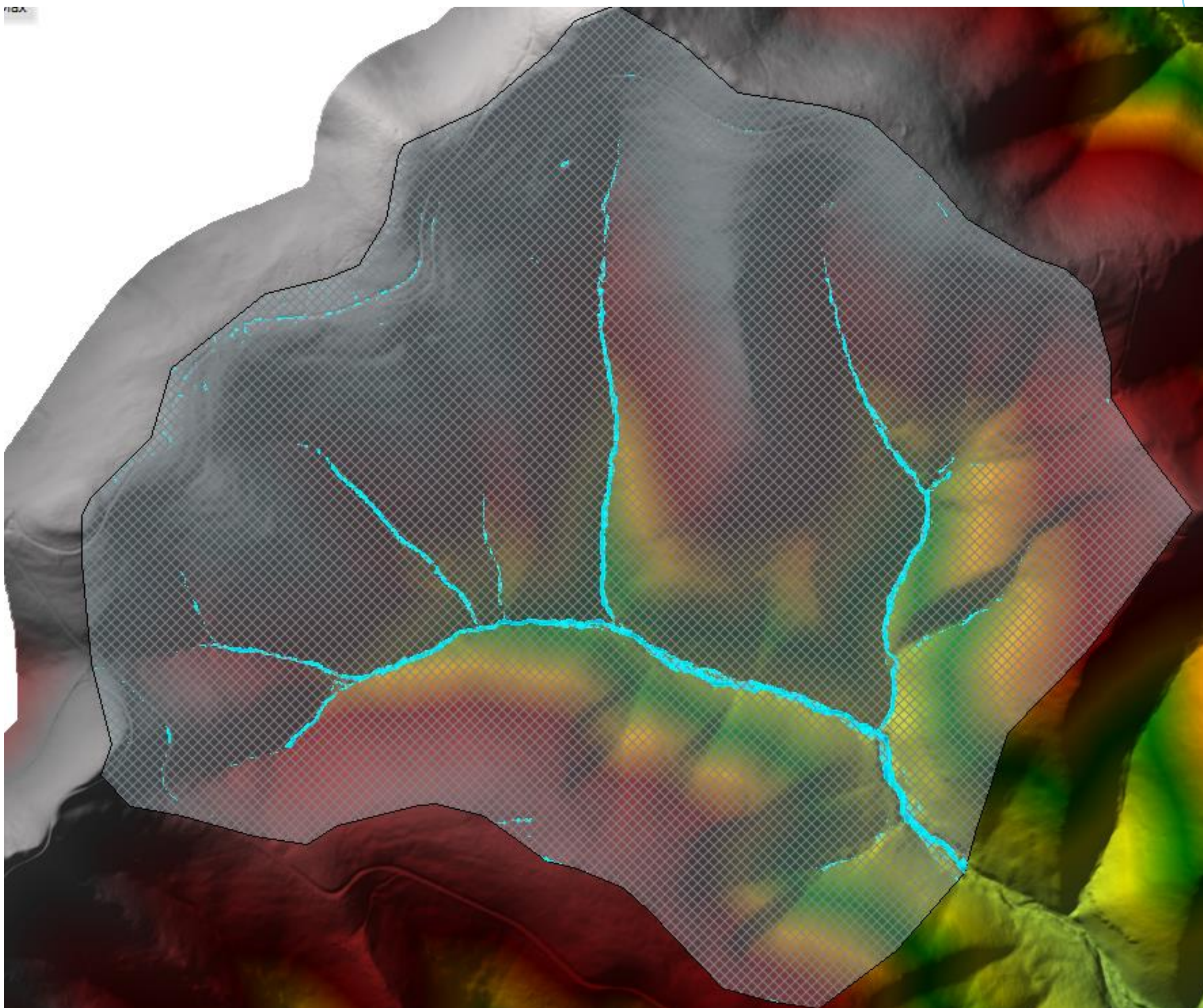
1. Calculate watershed parameters
2. Create a HEC-HMS model and run the 10-, 100-, and 500-year SCS runoff hydrographs
3. Use the runoff loss in inches over each time step from the SCS hydrograph, and input it into a HEC-RAS 2D model as rainfall
4. Compare the results between the 2D model outfall and SCS runoff hydrograph



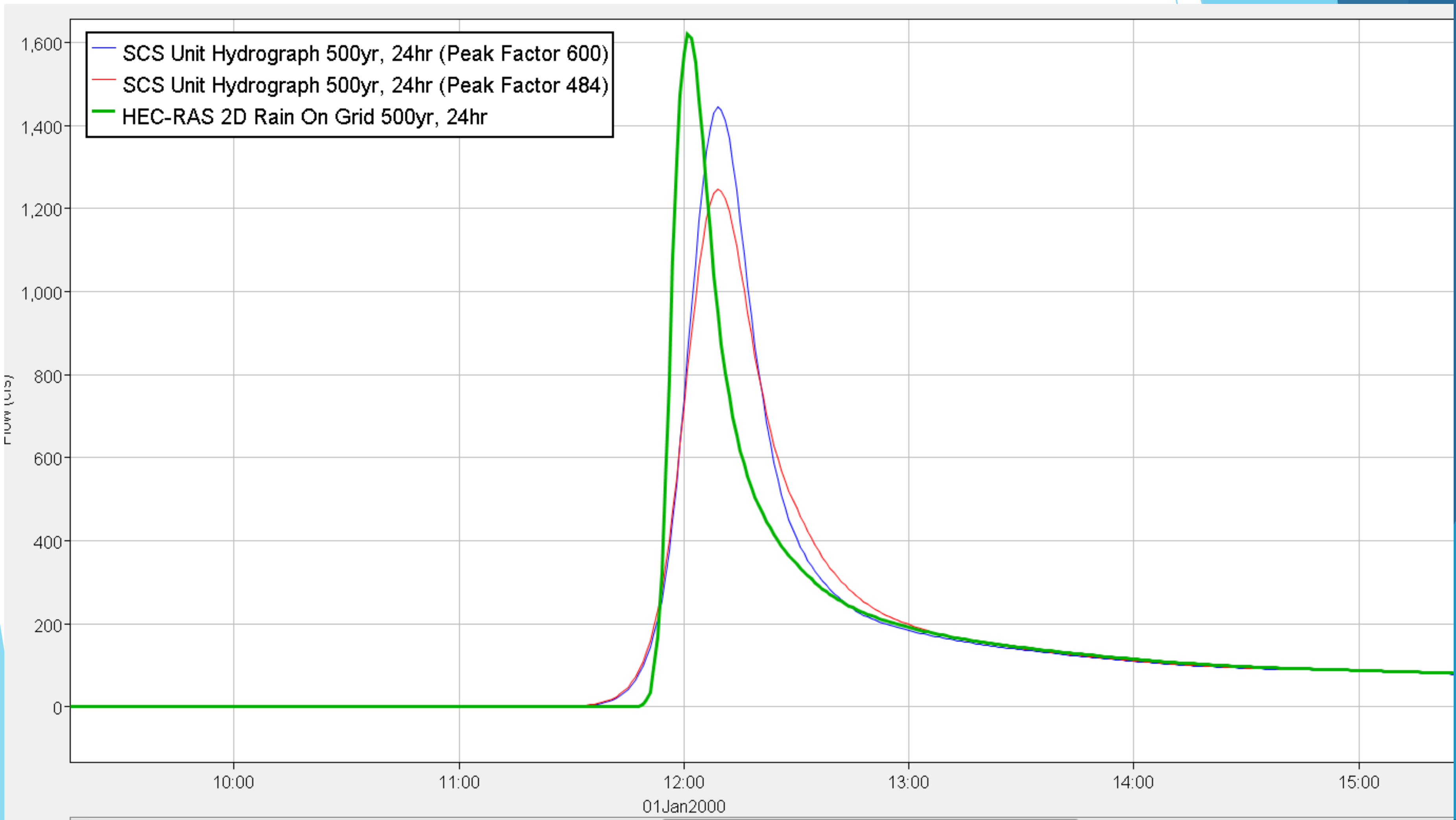
Blue Ridge Watershed



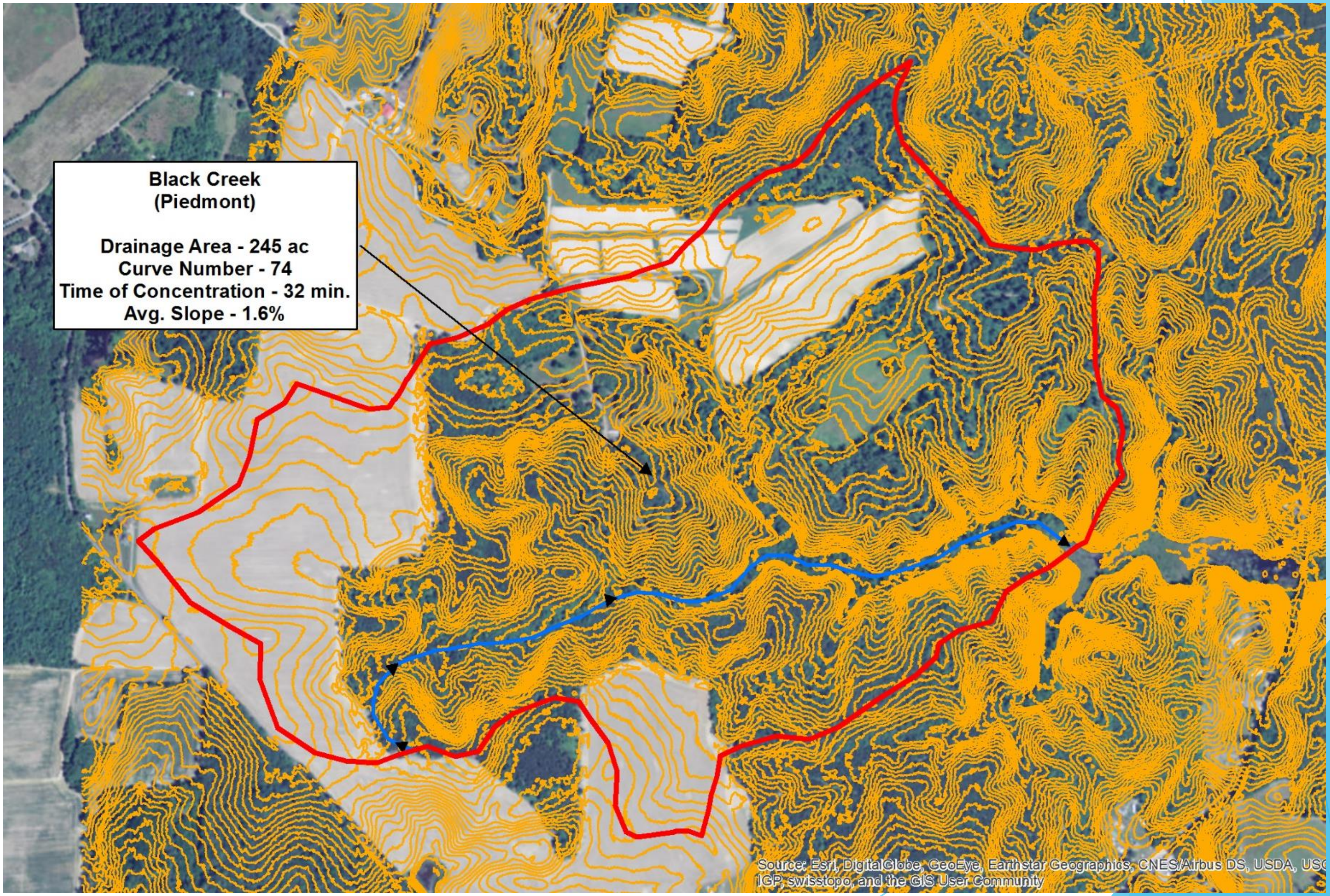
Blue Ridge Watershed



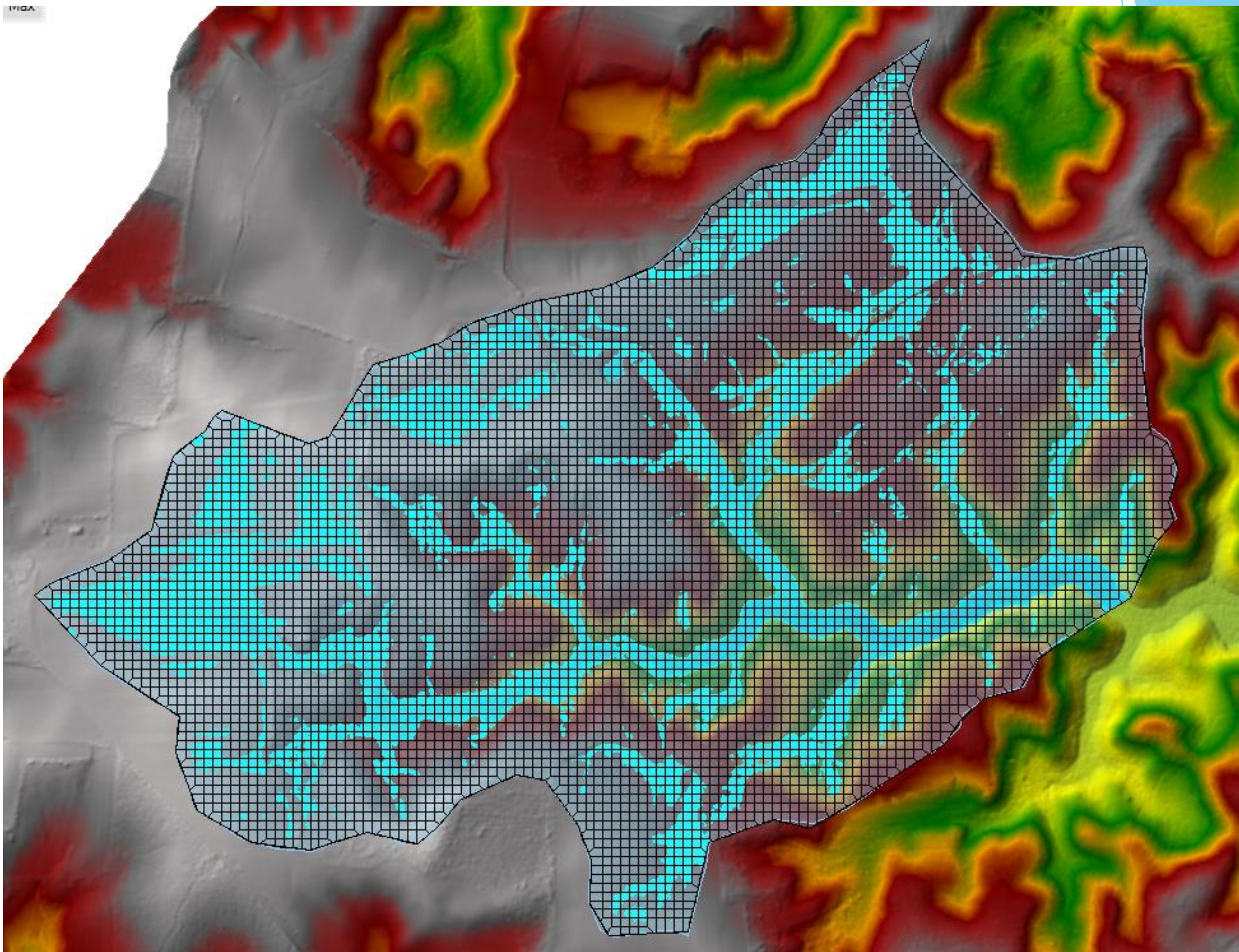
Blue Ridge Watershed
500-year, 24 hour Results – Peak Rate Factor



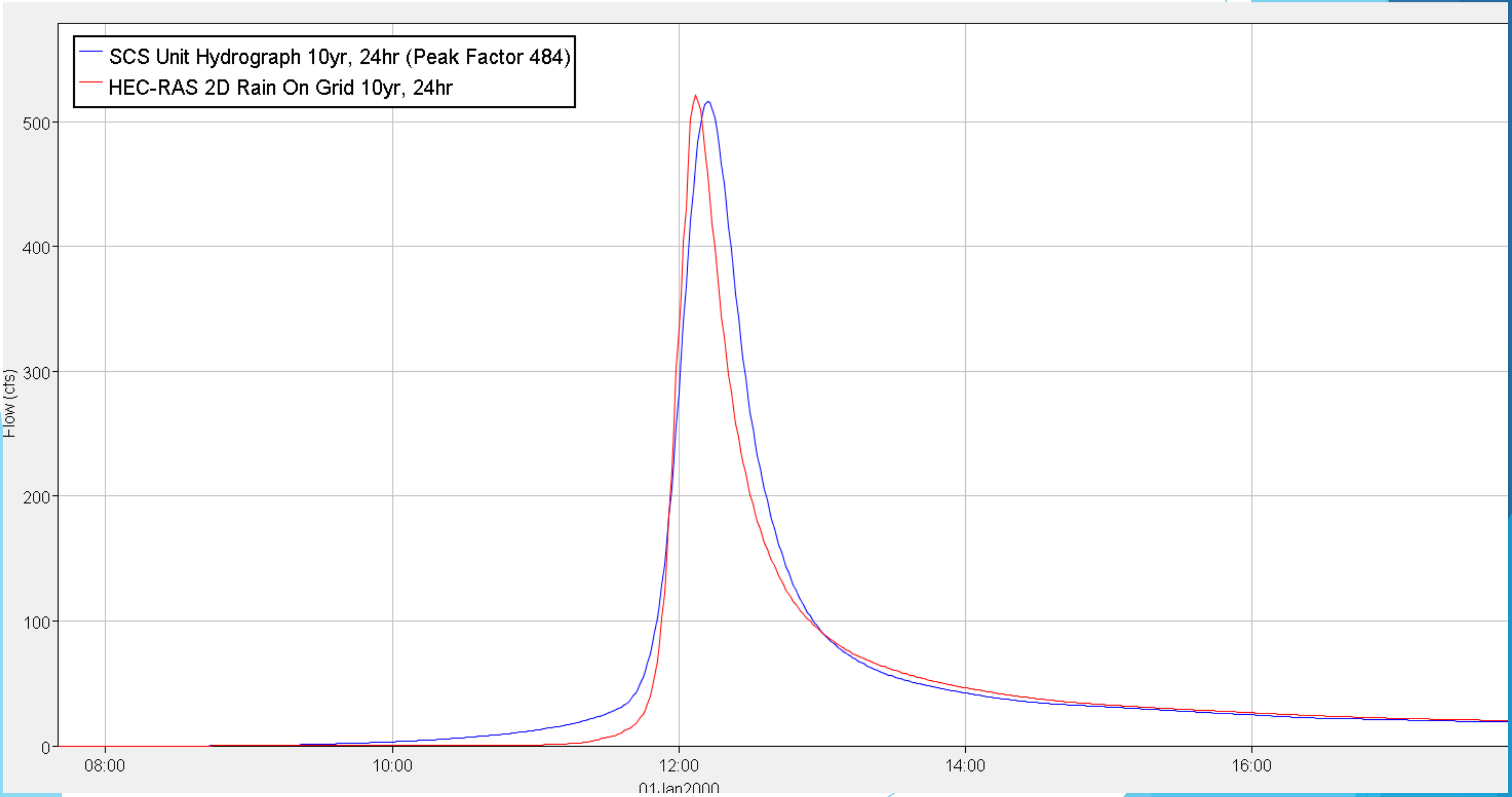
Piedmont Watershed



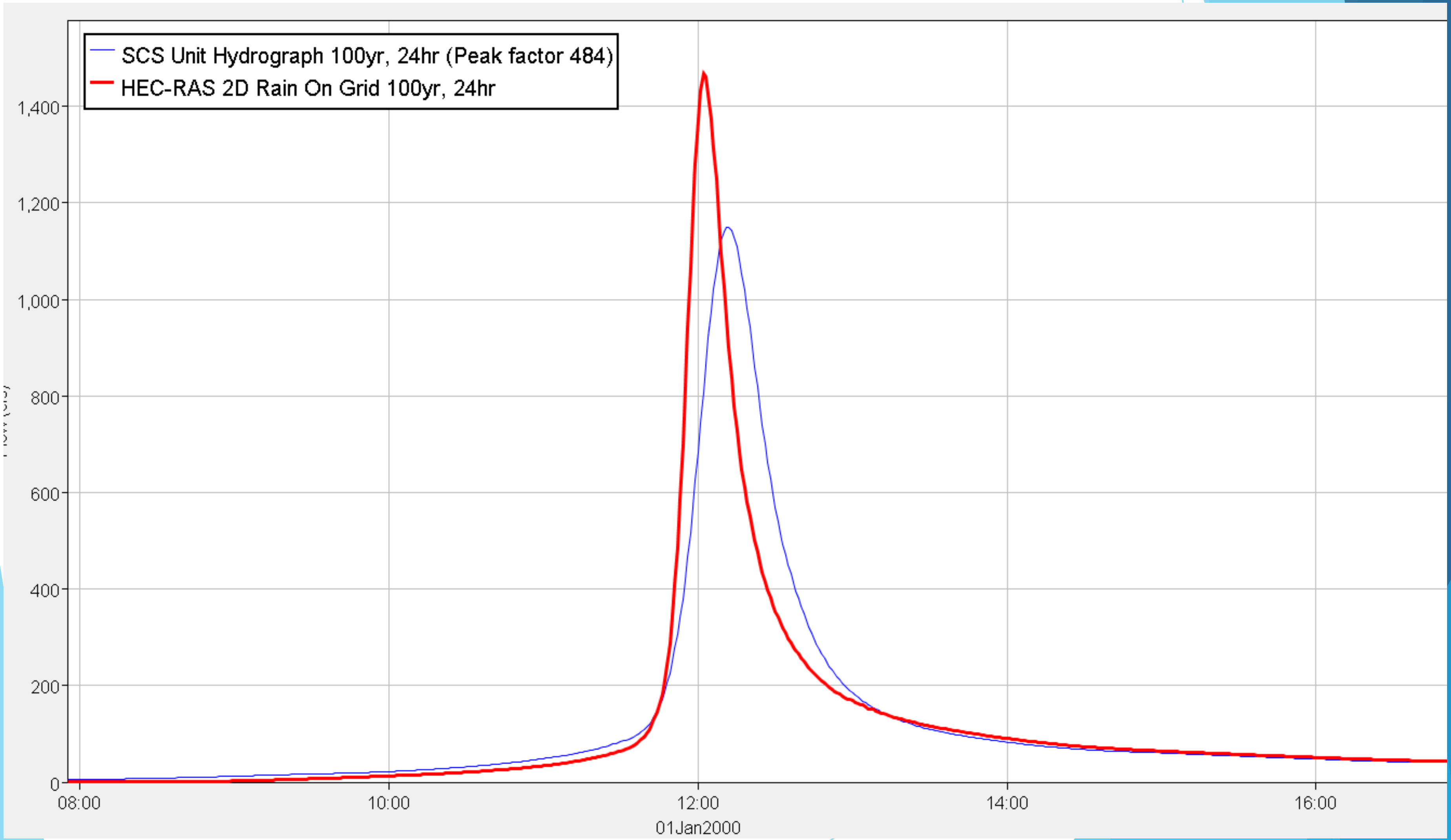
Piedmont Watershed



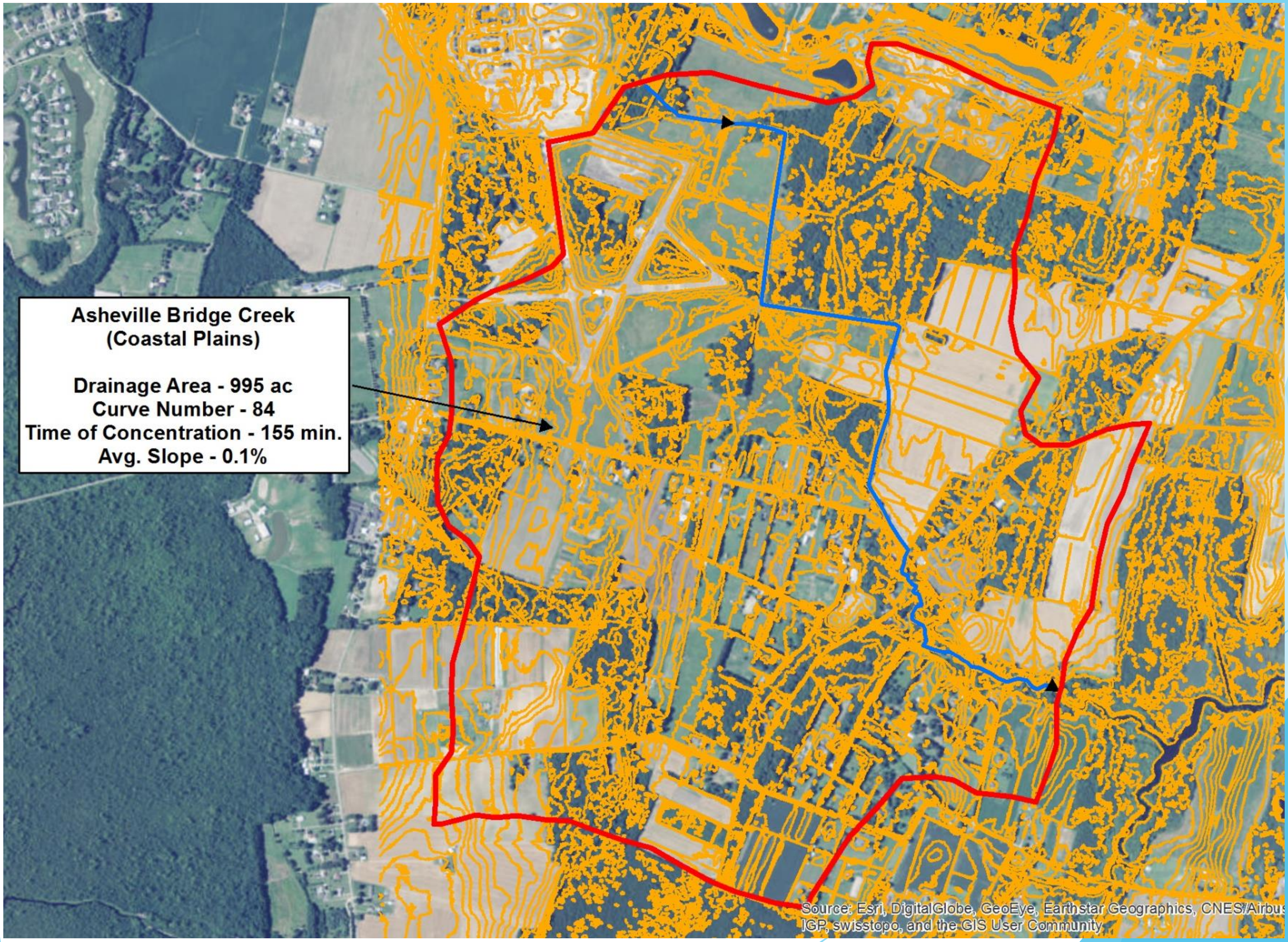
Piedmont Watershed
10-year, 24 hour Results



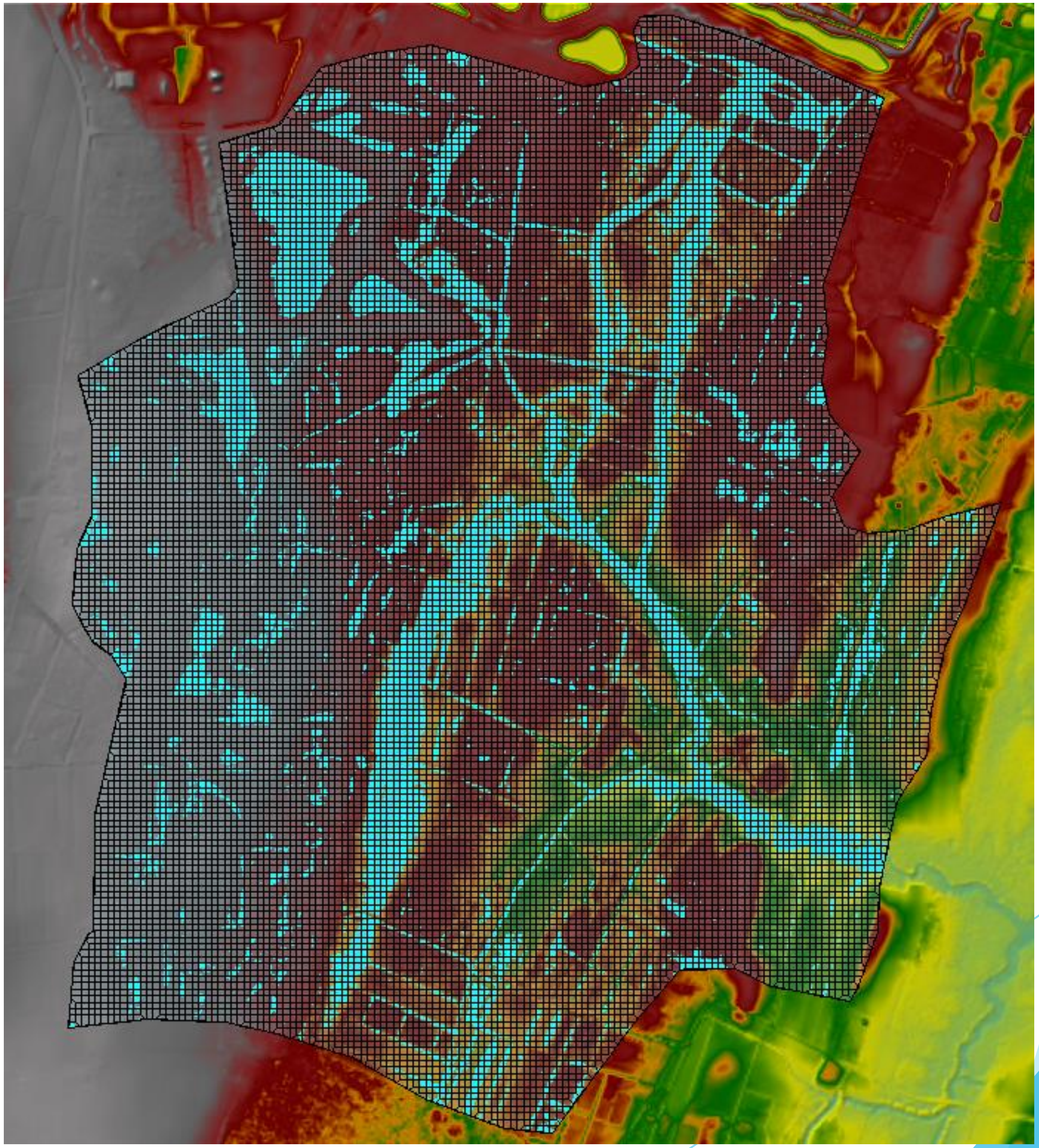
Piedmont Watershed
100-year, 24 hour Results – Peak Rate Factor



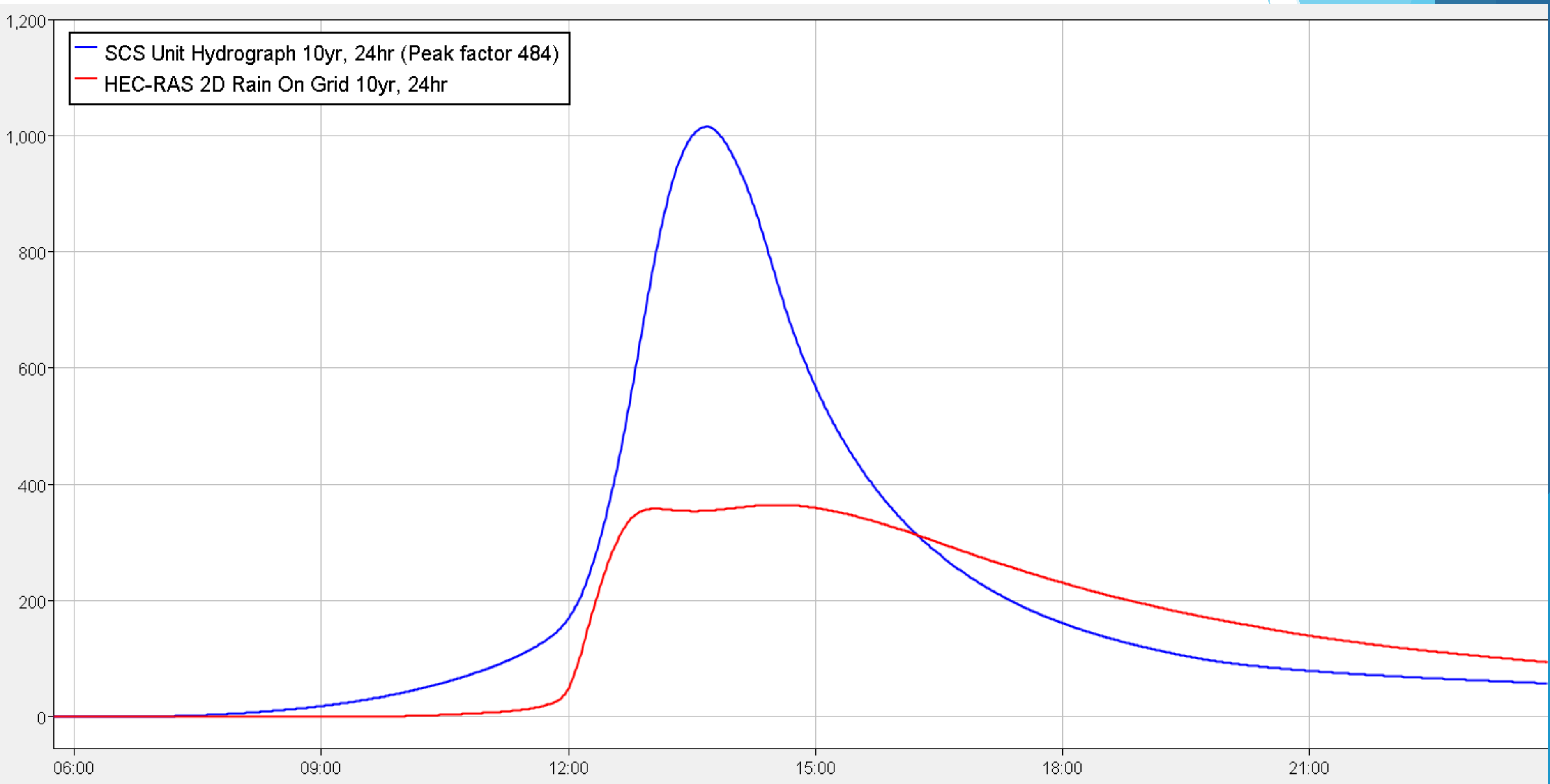
Coastal Plain Watershed



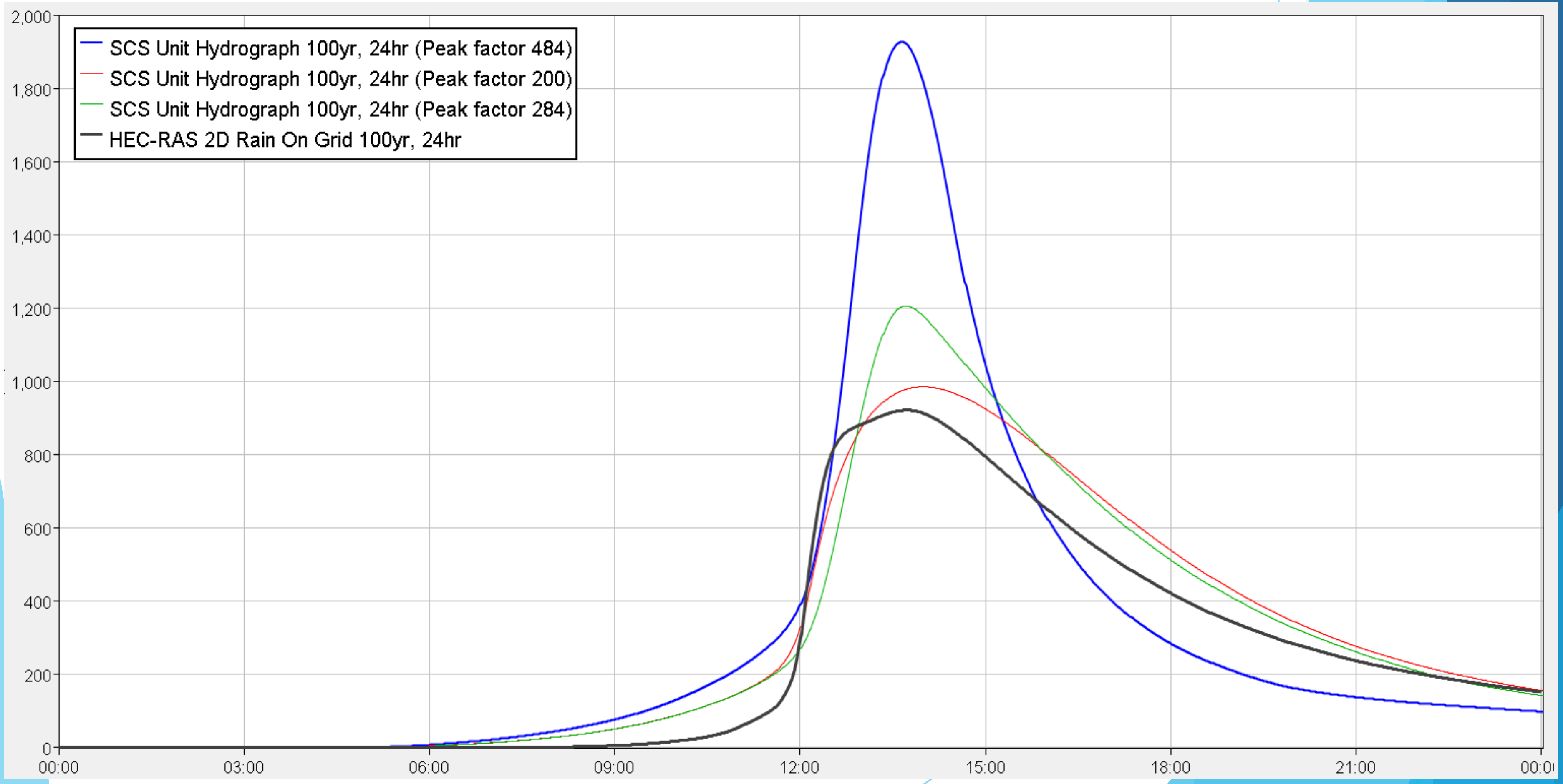
Coastal Plain Watershed



Coastal Plain Watershed
10-year, 24 hour Results – Peak Rate Factor



Coastal Plain Watershed
100-year, 24 hour Results – Peak Rate Factor



Initial Comparison Conclusions

- 2D rain on grid runoff results match well with SCS runoff hydrographs if the right Peak Rate Factor is used
- The standard SCS Peak Rate Factor (484), likely under predicts peak flows in mountainous terrain and over predicts peak flows in flat terrains like coastal Virginia
- Peak rate factors may vary by storm frequency

But does the hypothetical match reality?...

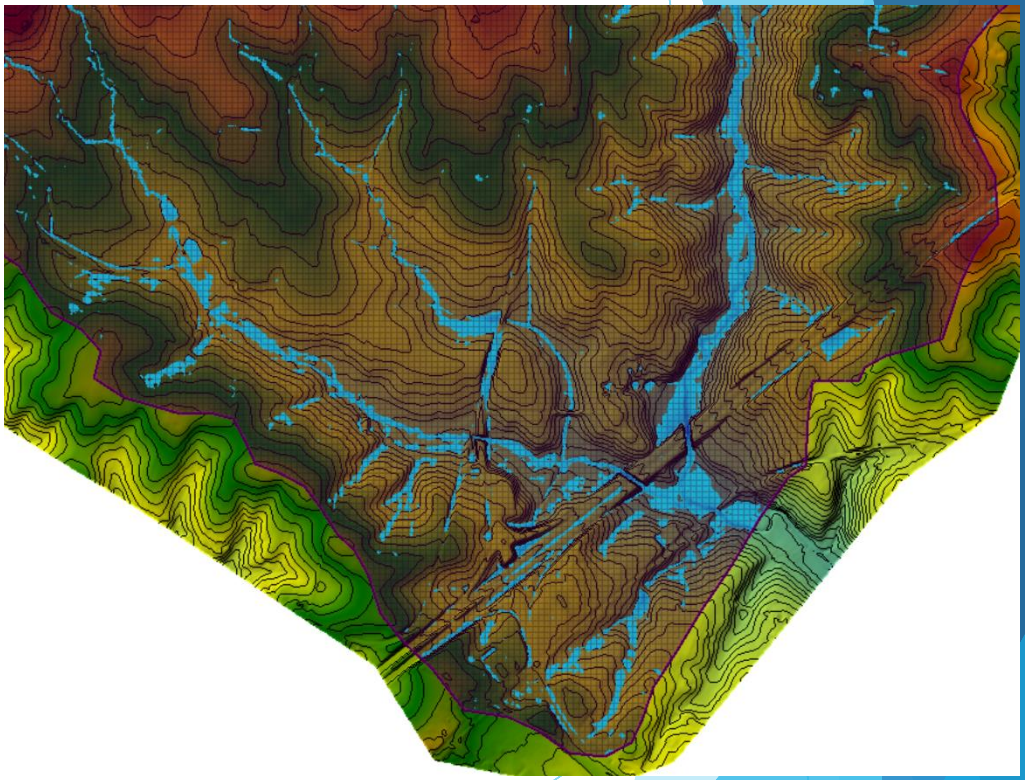
Rain on Grid Storm Calibration

Primary Goal

Show that a simple rain on grid model can accurately replicate the rainfall-runoff response of a watershed.

If the rain on grid model is accurate for hydrology, watershed parameters such as the peak rate factor can be derived from the model results…

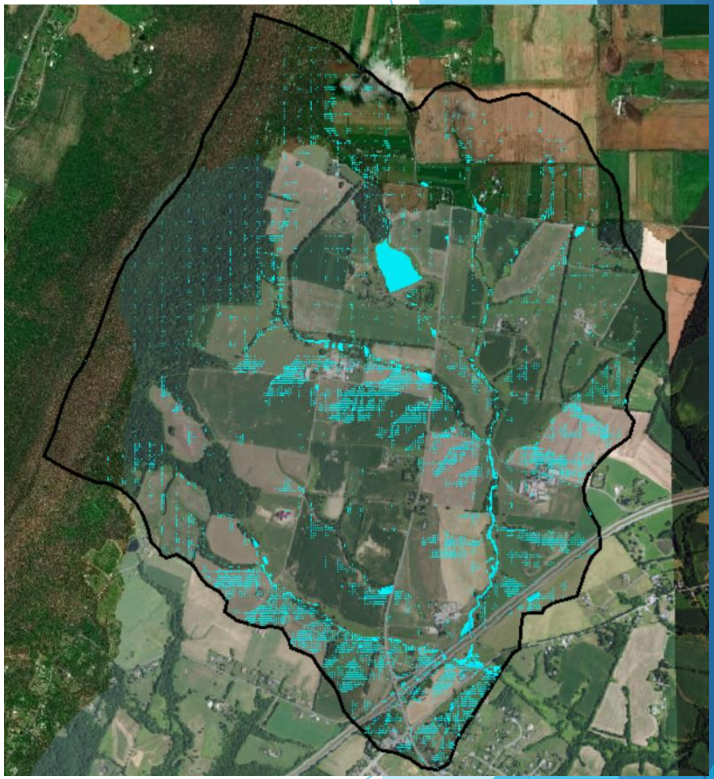
This opens up the opportunity for more tailored peak rate factors that are watershed specific.



Rain on Grid Storm Calibration

Critical Factors for this Exercise

- Watershed with an accurate stream gage and a **nearby rain gage**
- Need to produce an accurate model of watershed runoff with respect to time
- Smaller watersheds are preferred to reduce sources of error and computational load
- Larger the storm, the better



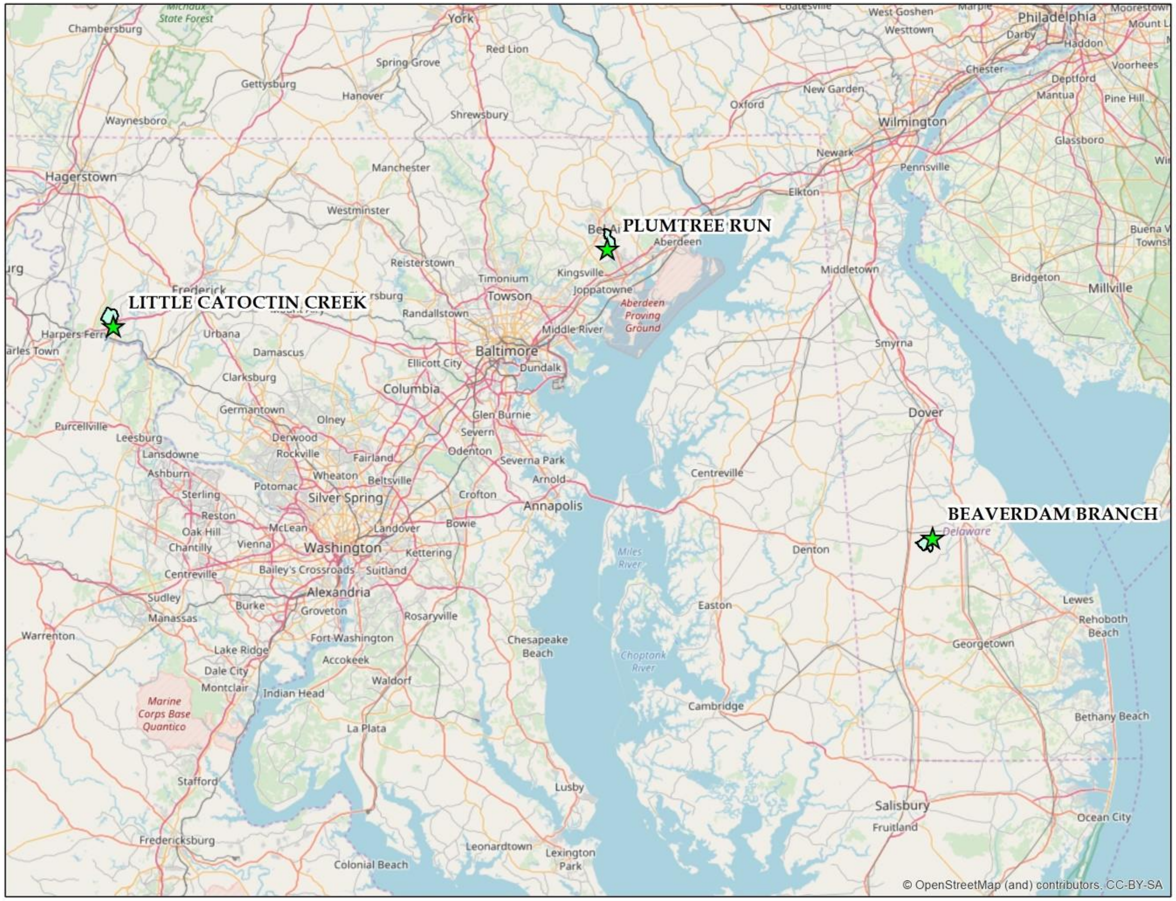
Shortcomings

- When analyzing historic storms, rainfall is assumed to be uniform across watershed based on nearby rain gage
- Runoff at each time step is uniformly applied – single curve number for watershed
- Assumes Hortonian overfland flow… doesn't simulate runoff from groundwater or interflow

Rain on Grid Storm Calibration

After scouring USGS stream gage records and lots of empty searches for nearby rain gages…

Found three watersheds in different geographic regions that met criteria.



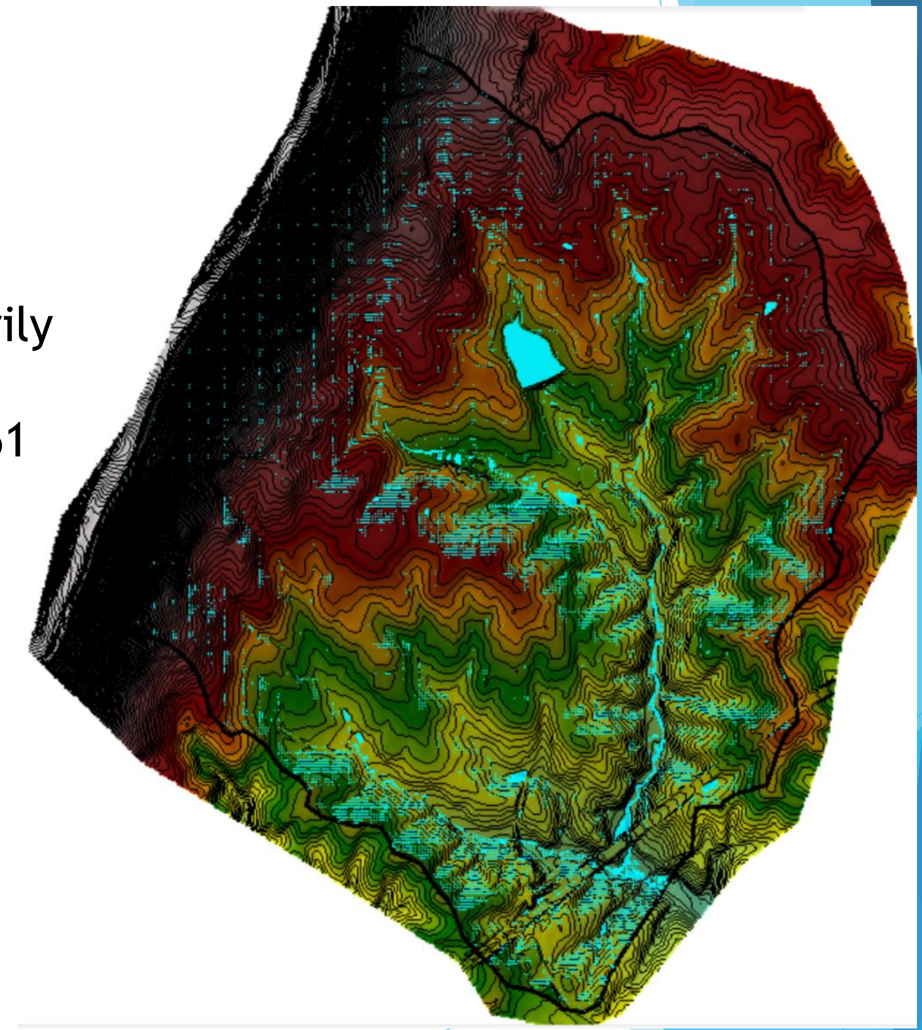
2D Calibration Steps for Each Watershed

Similar steps as initial comparison with a twist…

1. Create a HEC-HMS model and run the specific historic storm
2. Adjust the CN value to get the same runoff volume as the gage records. Adjust other parameters to match gage hydrograph
3. Use the subbasin runoff loss in inches over each time step from the historic storm, and input it into a HEC-RAS 2D model
4. Compare the results between the 2D model outfall, gage record and SCS runoff hydrograph

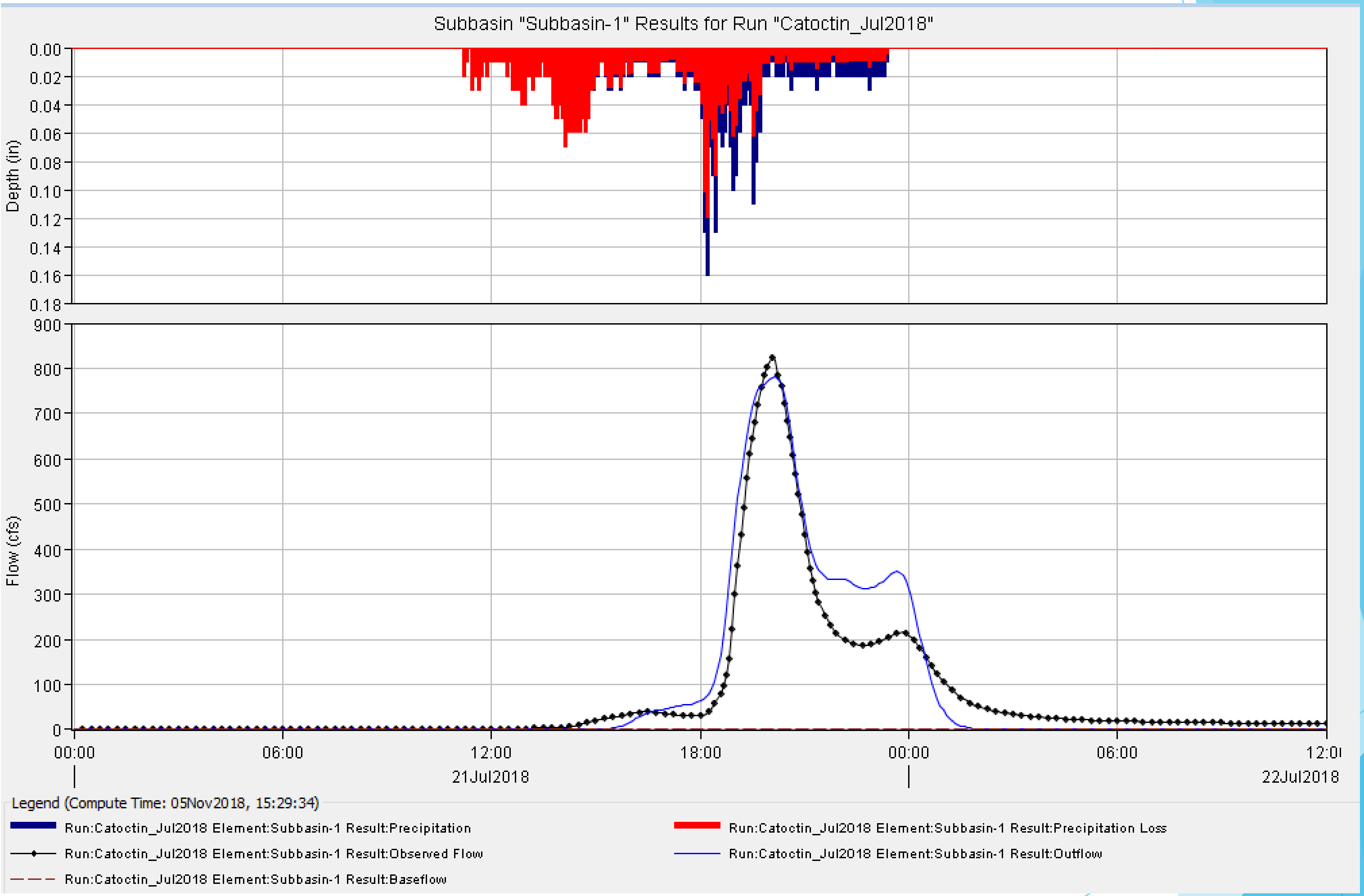
Little Catoctin Creek Watershed

Drainage Area = 4.2 mi2
Land Use - Upland Forest with primarily Agricultural land
Curve Number from Gage Analysis = 61
Longest Flow Path Avg. Slope = 4.3%



Little Catoctin Creek Watershed

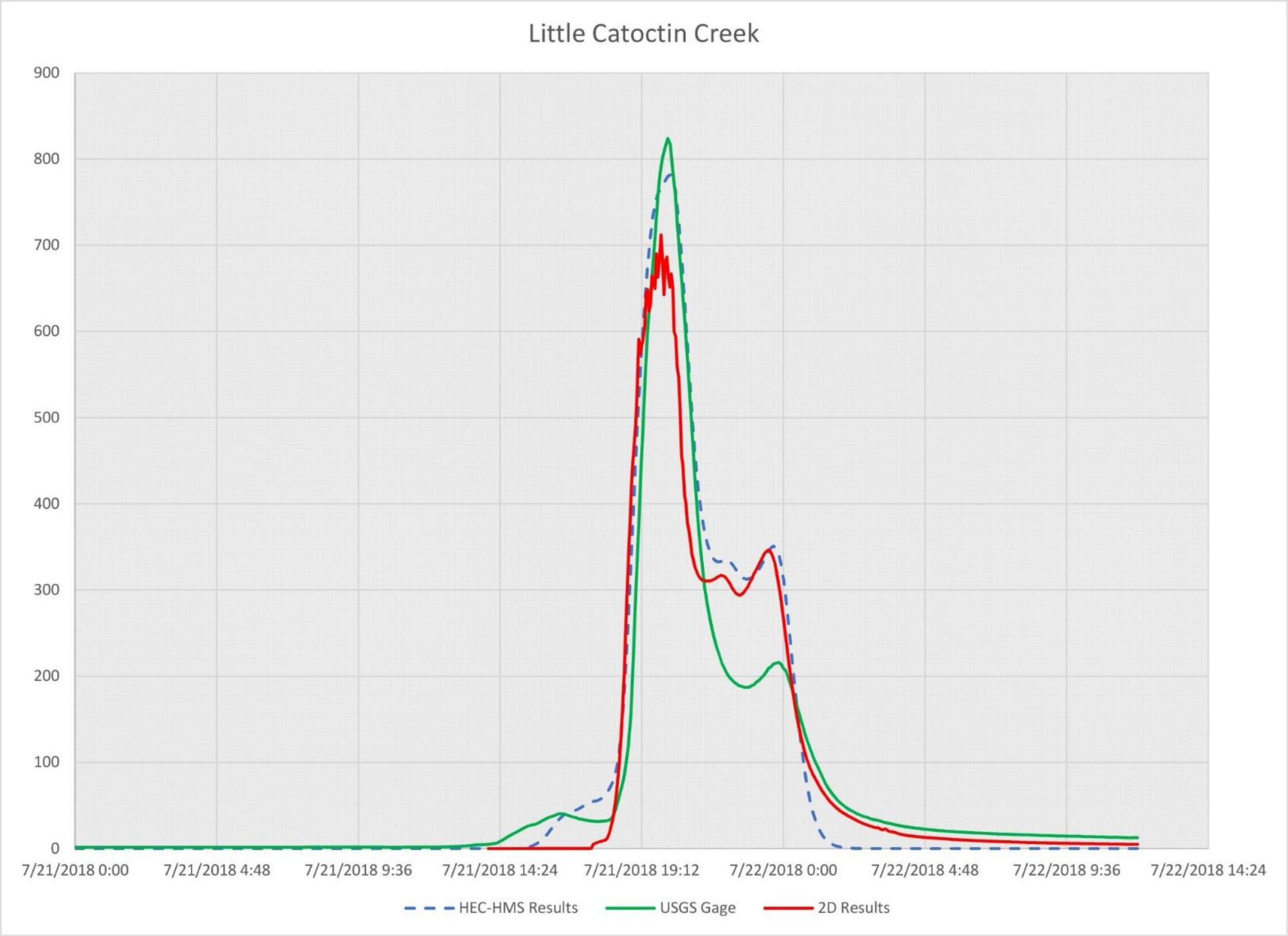
July 21-22, 2018 Event - HMS Results



Total Rainfall = 4.44 in
Stream gage runoff = 0.98 in
HMS Basin Runoff = 1.05 in

Little Catoctin Creek Watershed

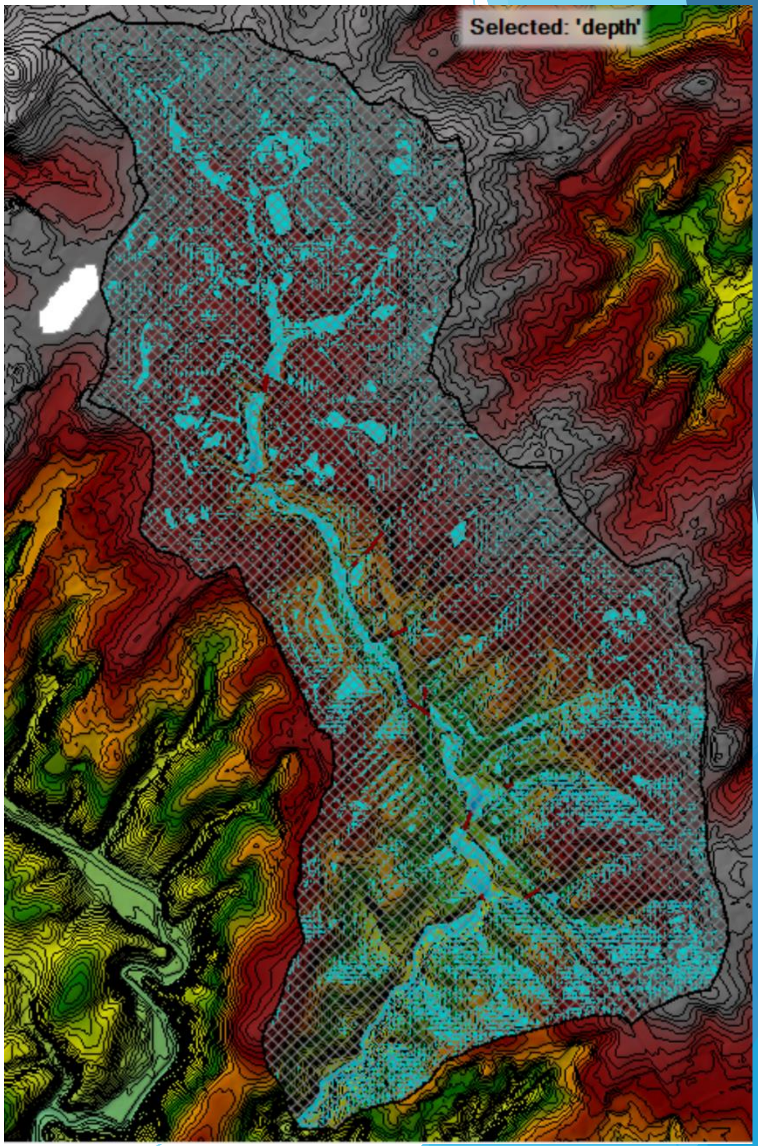
July 21-22, 2018 Event, 2D Results



Basin Peak Rate Factor = 600

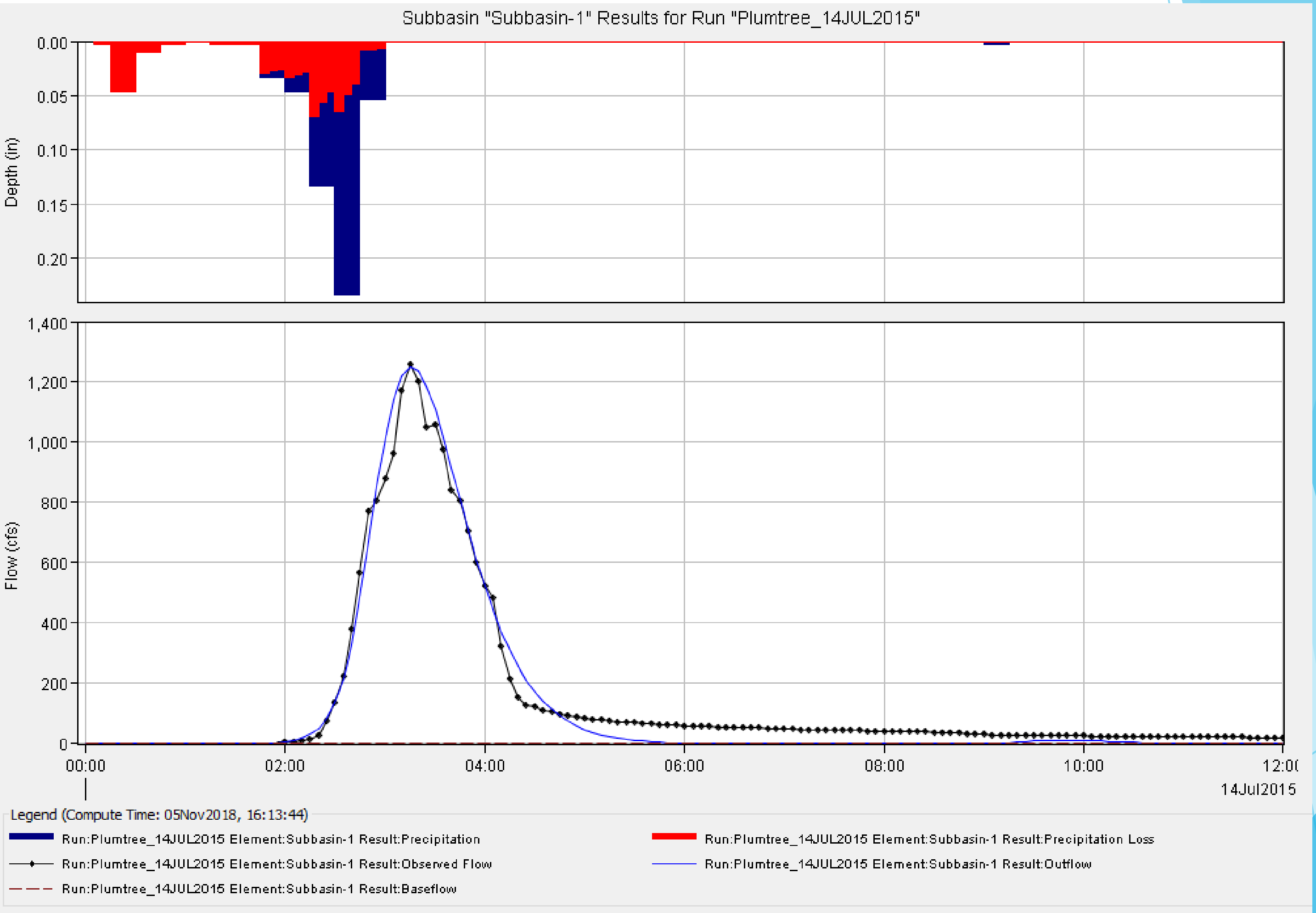
Plumtree Lane Watershed

Drainage Area = 2.4 mi2
Land Use – Primarily Urban
Curve Number from Gage Analysis = 92
Longest Flow Path Avg. Slope = 1.2%



Plumtree Lane Watershed

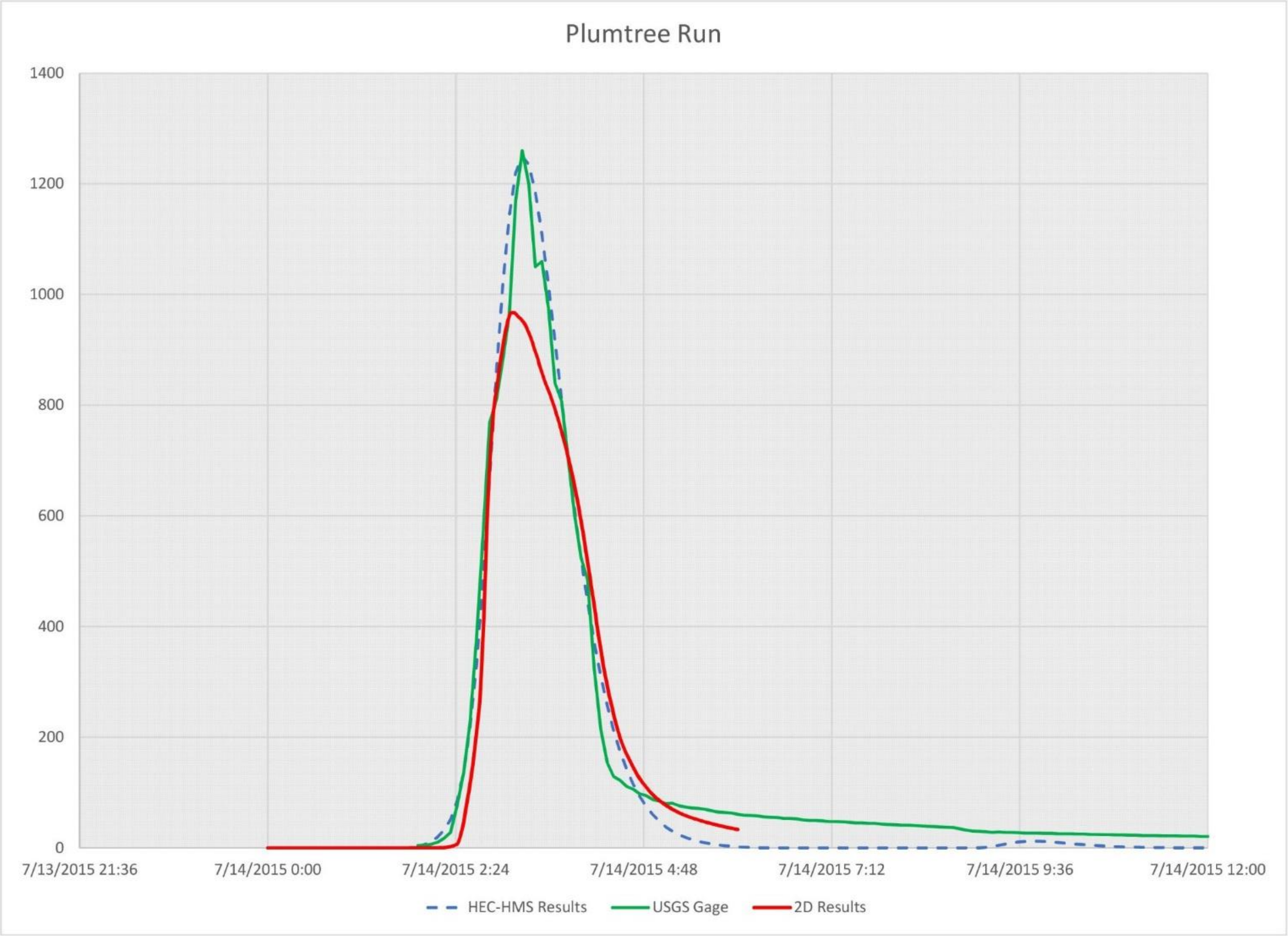
July 14, 2015 Event - HMS Results



Total Rainfall = 1.72 in
Stream gage runoff = 1.11 in
HMS Basin Runoff = 0.99 in

Plumtree Lane Watershed

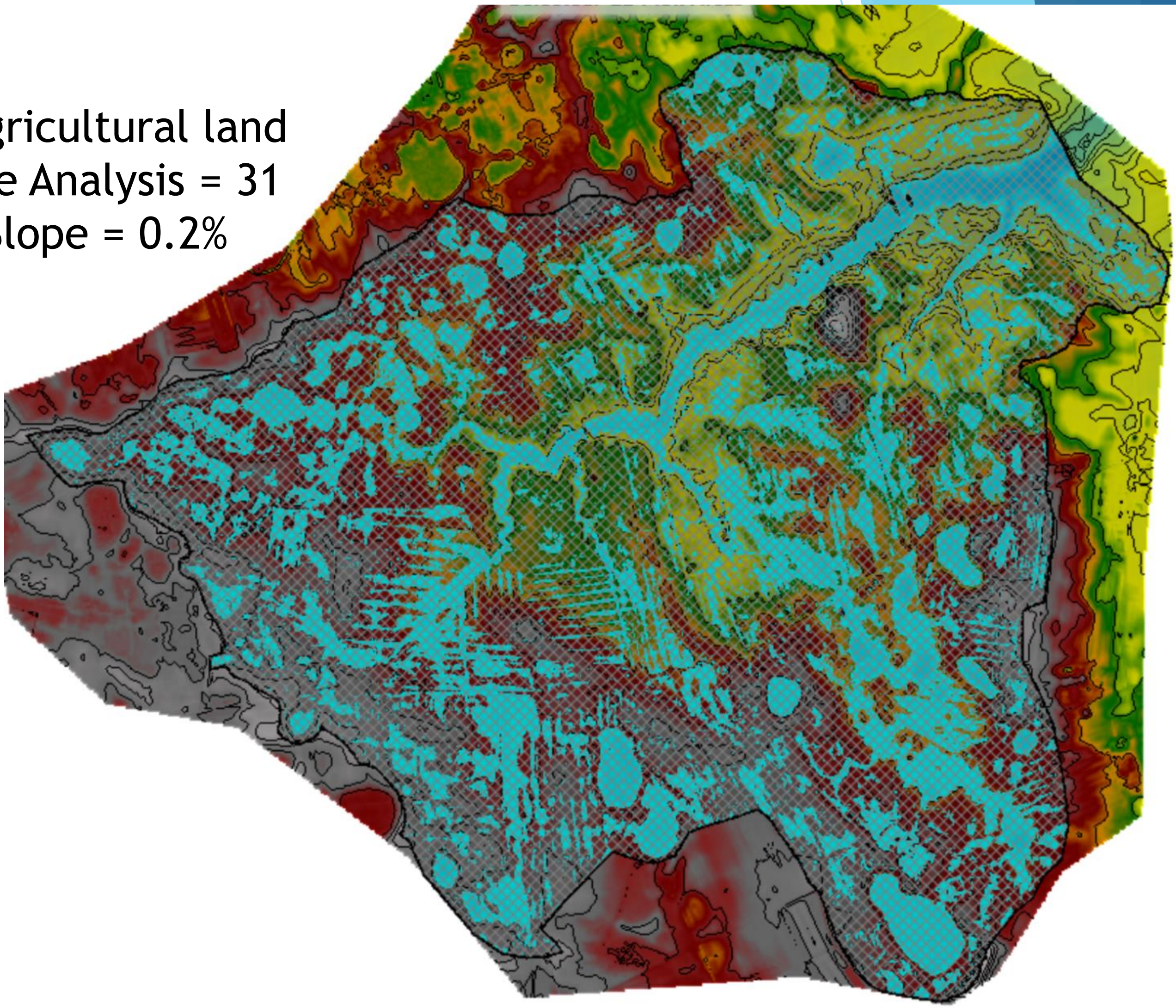
July 14, 2015 Event, 2D Outfall Results



Basin Peak Rate Factor = 400

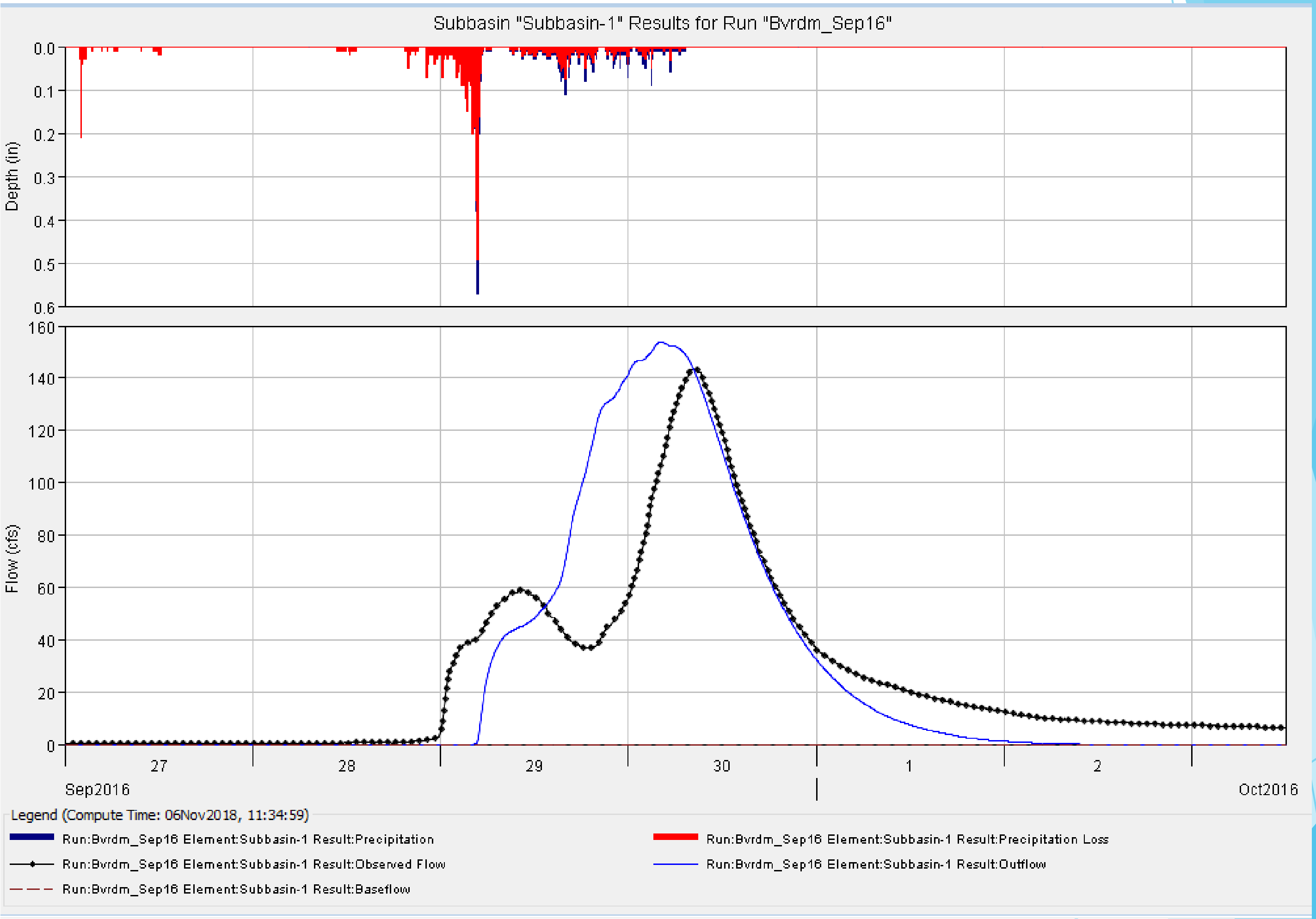
Beaverdam Branch Watershed

Drainage Area = 3.3 mi2
Land Use – Forest and Agricultural land
Curve Number from Gage Analysis = 31
Longest Flow Path Avg. Slope = 0.2%



Beaverdam Branch Watershed

September 28 - October 3, 2018 Event - HMS Results

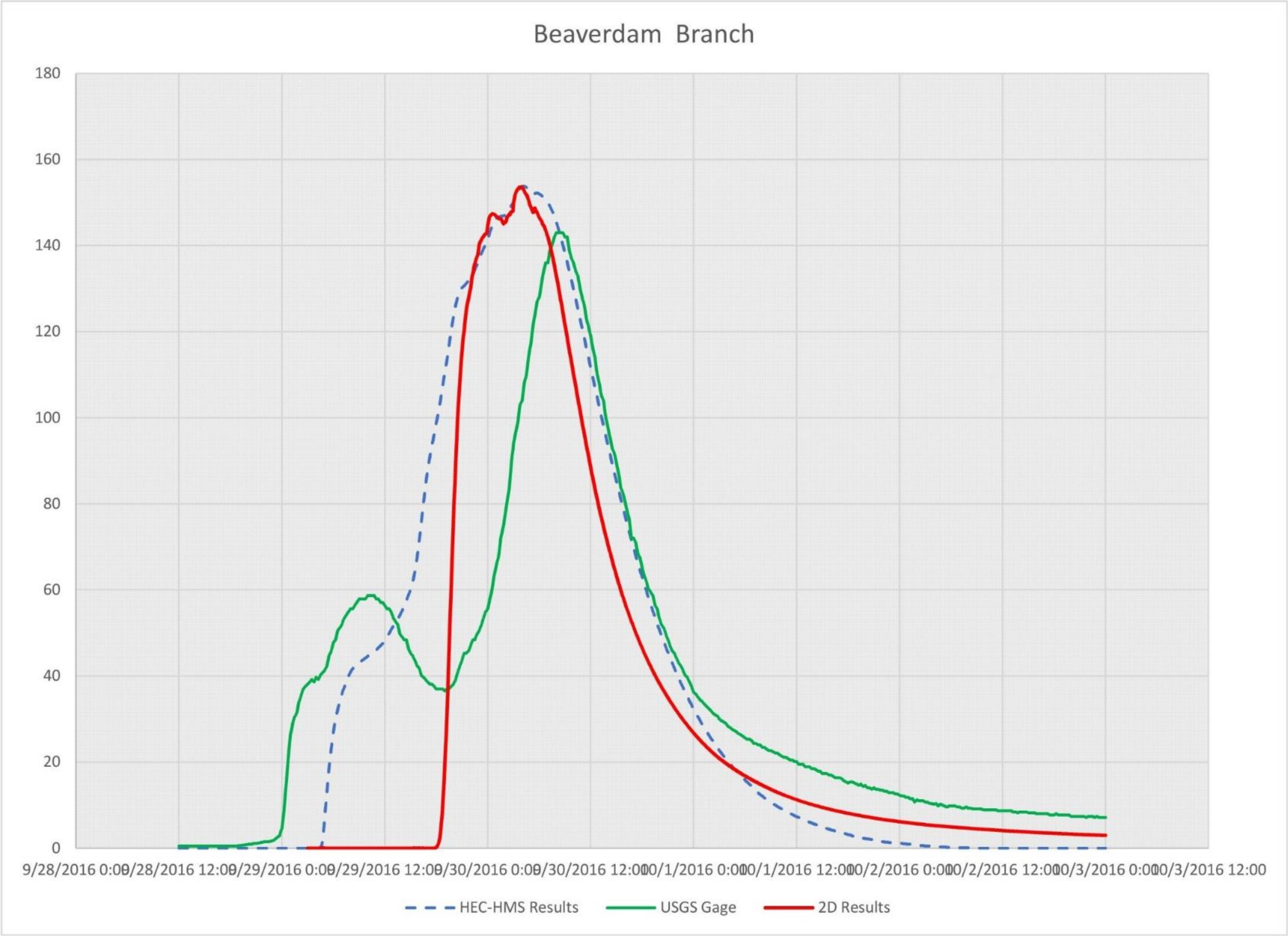


Total Rainfall = 11.8 in

Stream gage runoff = 1.95 in

HMS Basin Runoff = 1.98 in

Beaverdam Branch Watershed
September 28 – October 3, 2018 Event – 2D Results



Basin Peak Rate Factor = 200

What do the results mean?
Was the primary goal achieved?

Hydrograph shape matched well with the gage data, but didn't match the peak of the observed hydrograph in most cases.

Possible Reasons

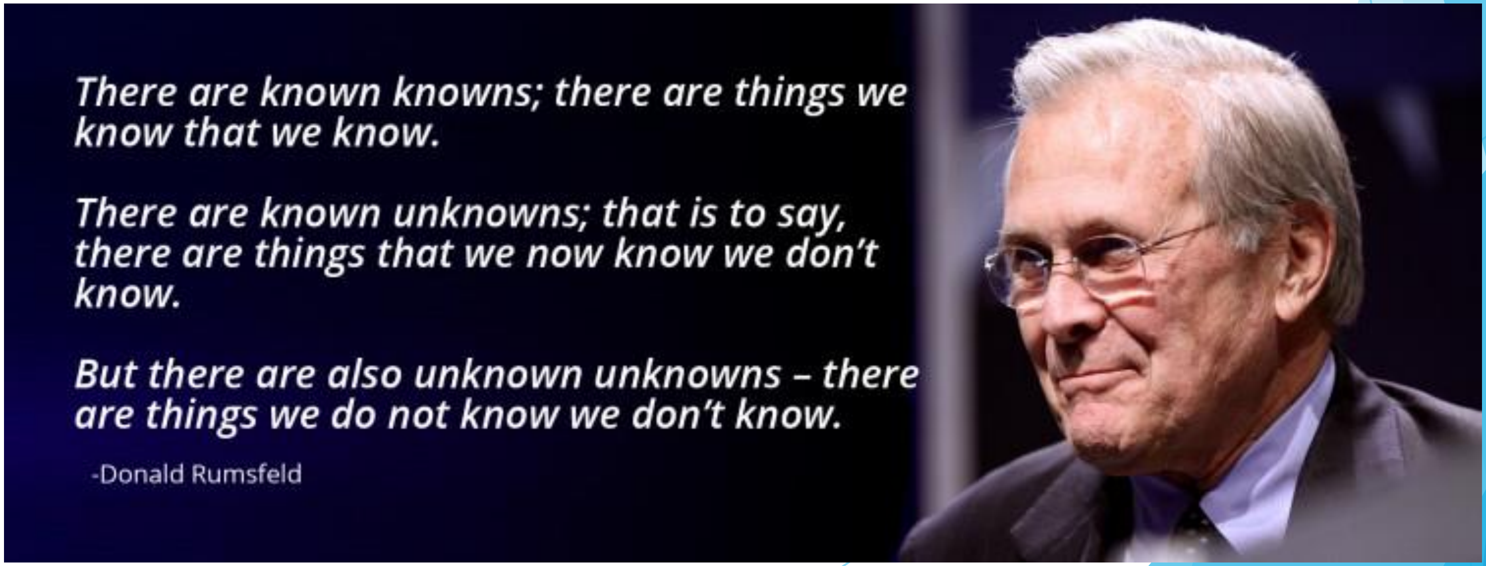
- Rainfall was variable across the watershed and/or it didn't match the rain gage
- Distribution of actual runoff across the watershed was not uniform
- Attenuation behind roadways and other embankments affected 2D results
- Smaller (<10-year) storms are difficult to calibrate

Taking it further…

- Collect more gaged watersheds to analyze
- Try to find gaged watersheds with large (10-year or greater) storm events that fit criteria

Conclusions

- The unit hydrograph approach still shines after all these years… there is value in simplicity!
- Detailed 2D models are now easy to produce and free to run… let's continue to advance our understanding of ways to better use the new tools.
- We need further study of appropriate regional Peak Rate Factors, particularly for coastal and mountainous watersheds
- Respect that there are still many unknowns when it comes to hydrology… be conservative in the face of unknowns



Questions?

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