Troubleshooting and Calibrating a 2D HEC-RAS Model

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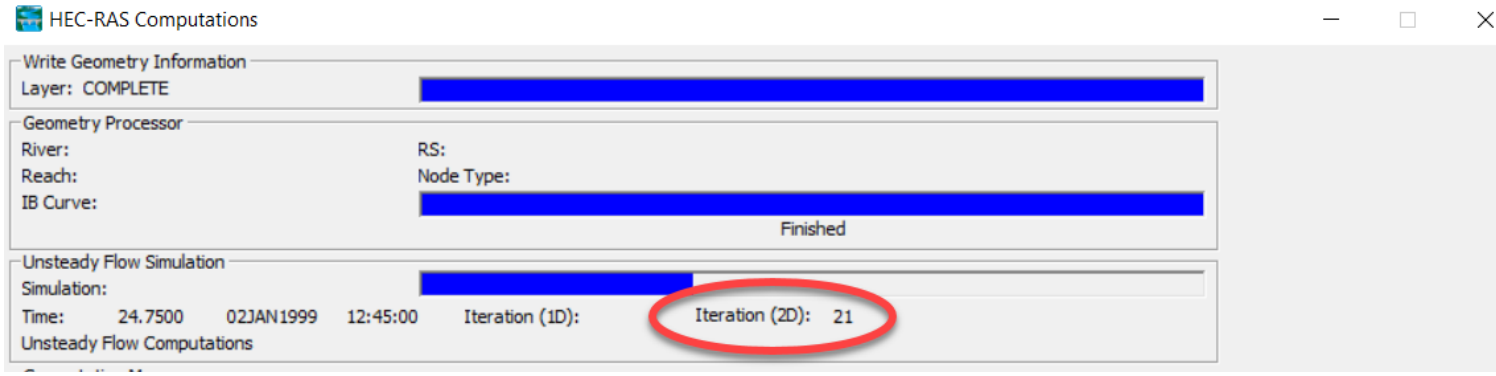
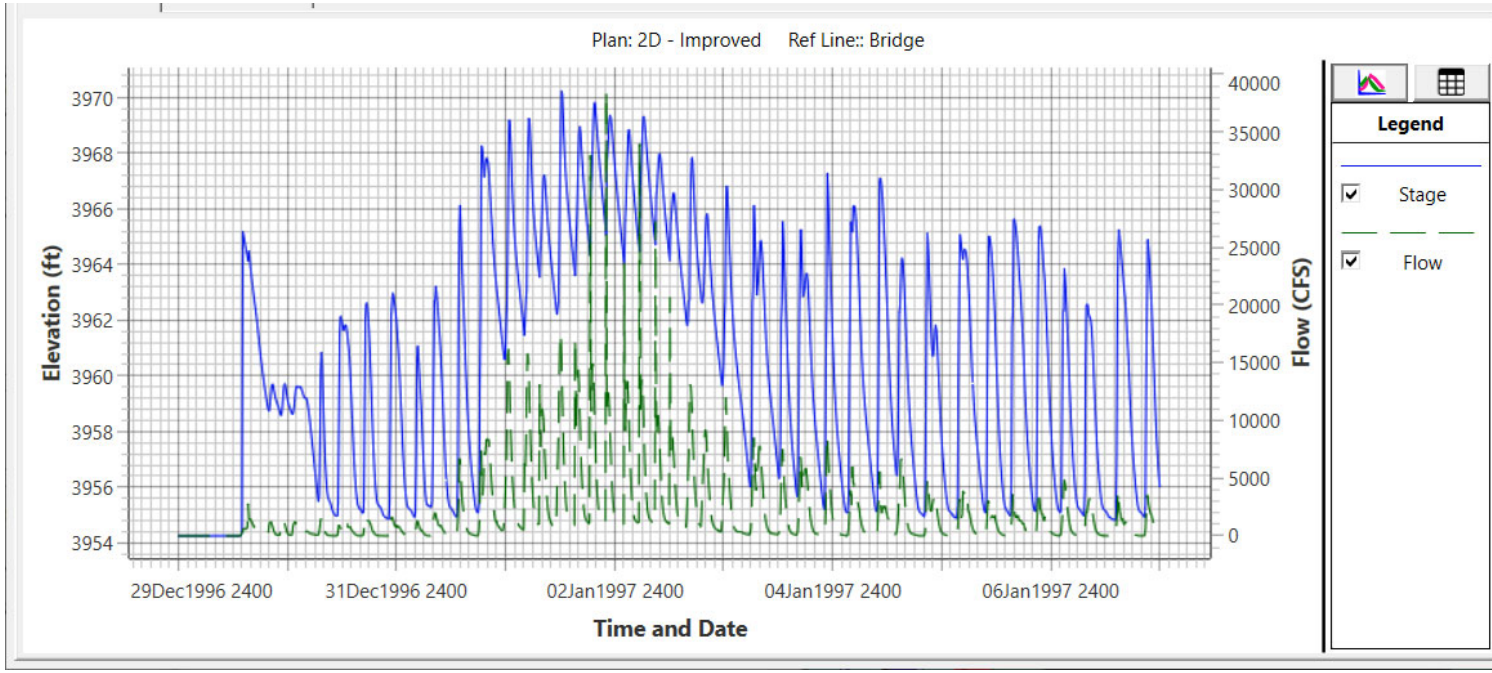
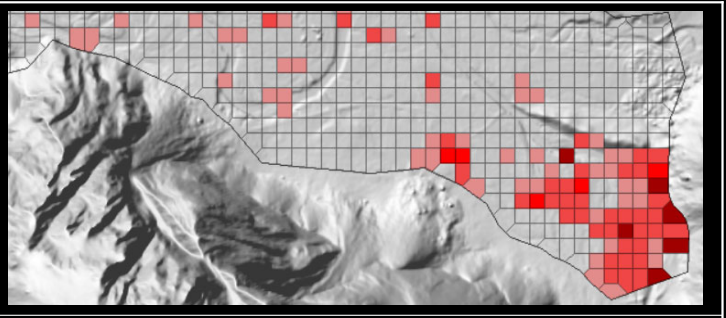
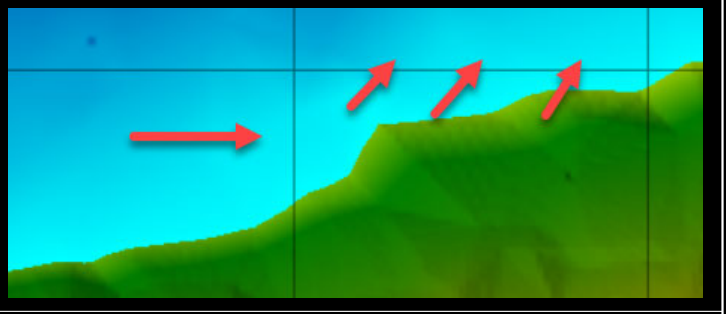
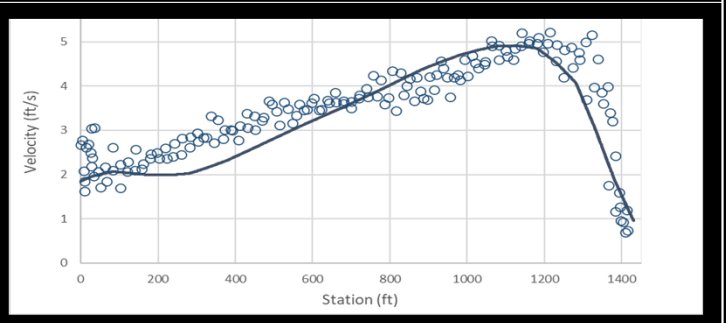
Iterations

- Iteration doesn't just degrade your model quality, it can increase your run time by >an order of magnitude

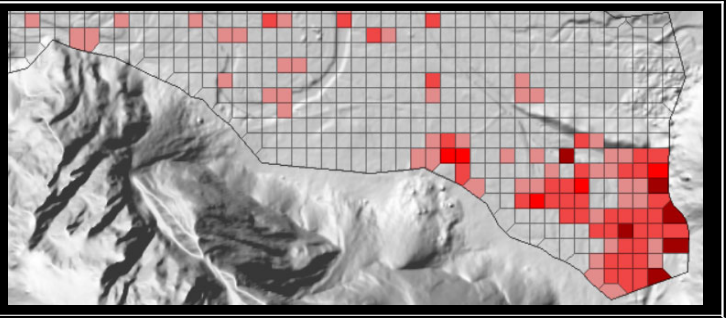
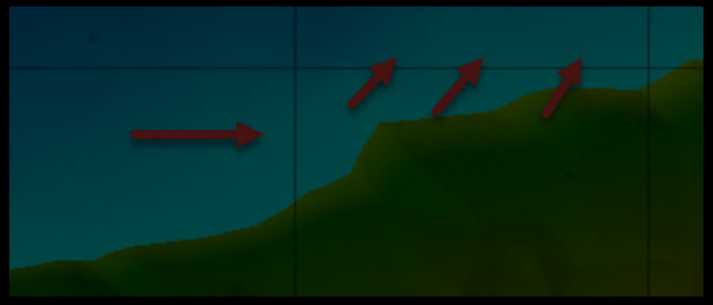
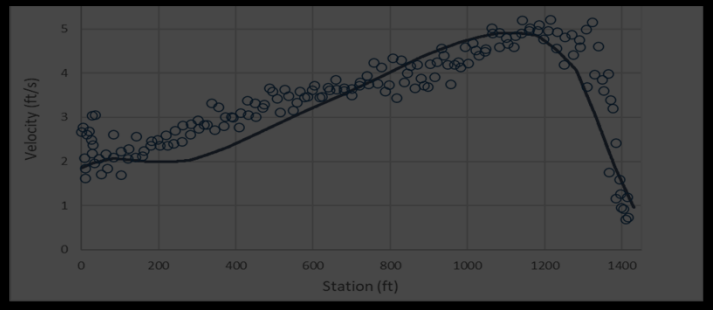




2D Hydraulic Stability Issues

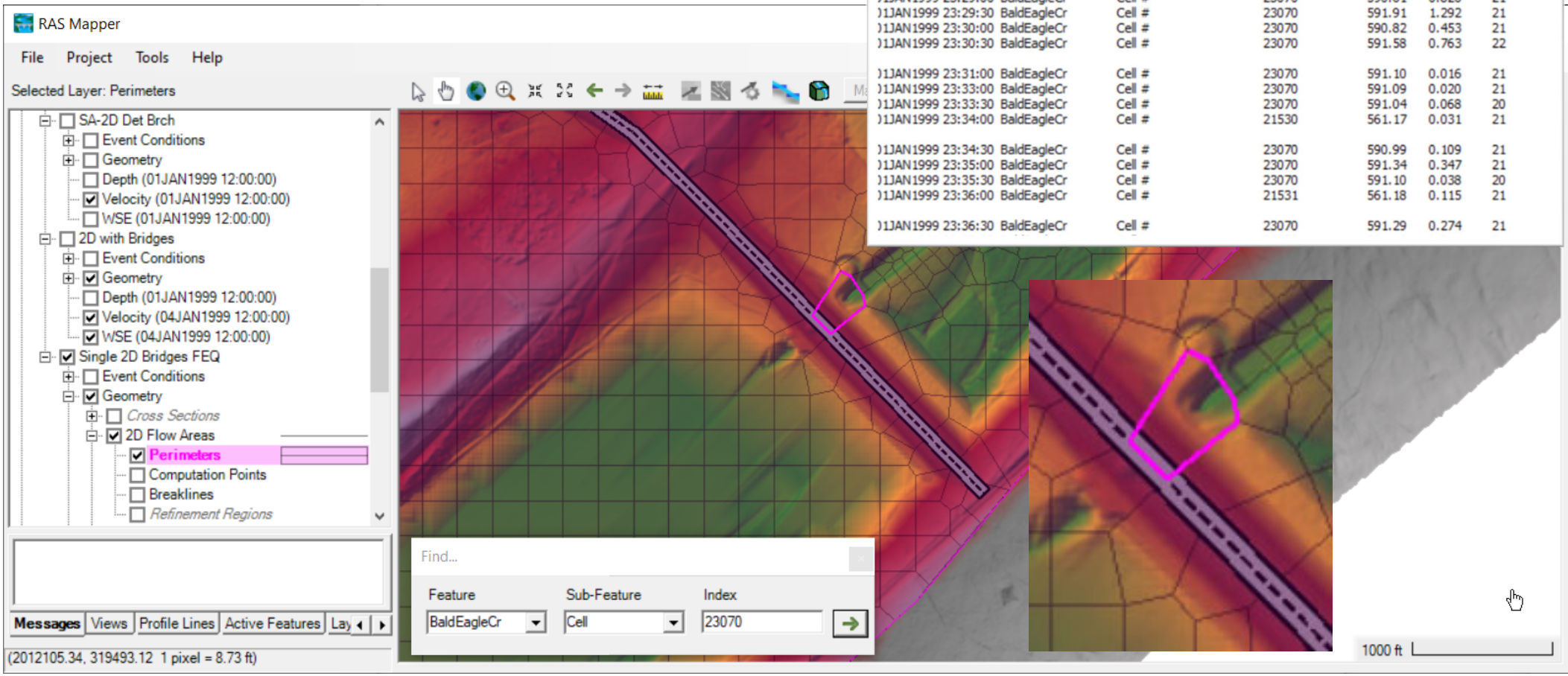
Diagnostic Tools	
Common Errors	
2D Calibration	

2D Hydraulic Stability Issues

Diagnostic Tools	
Common Errors	
2D Calibration	

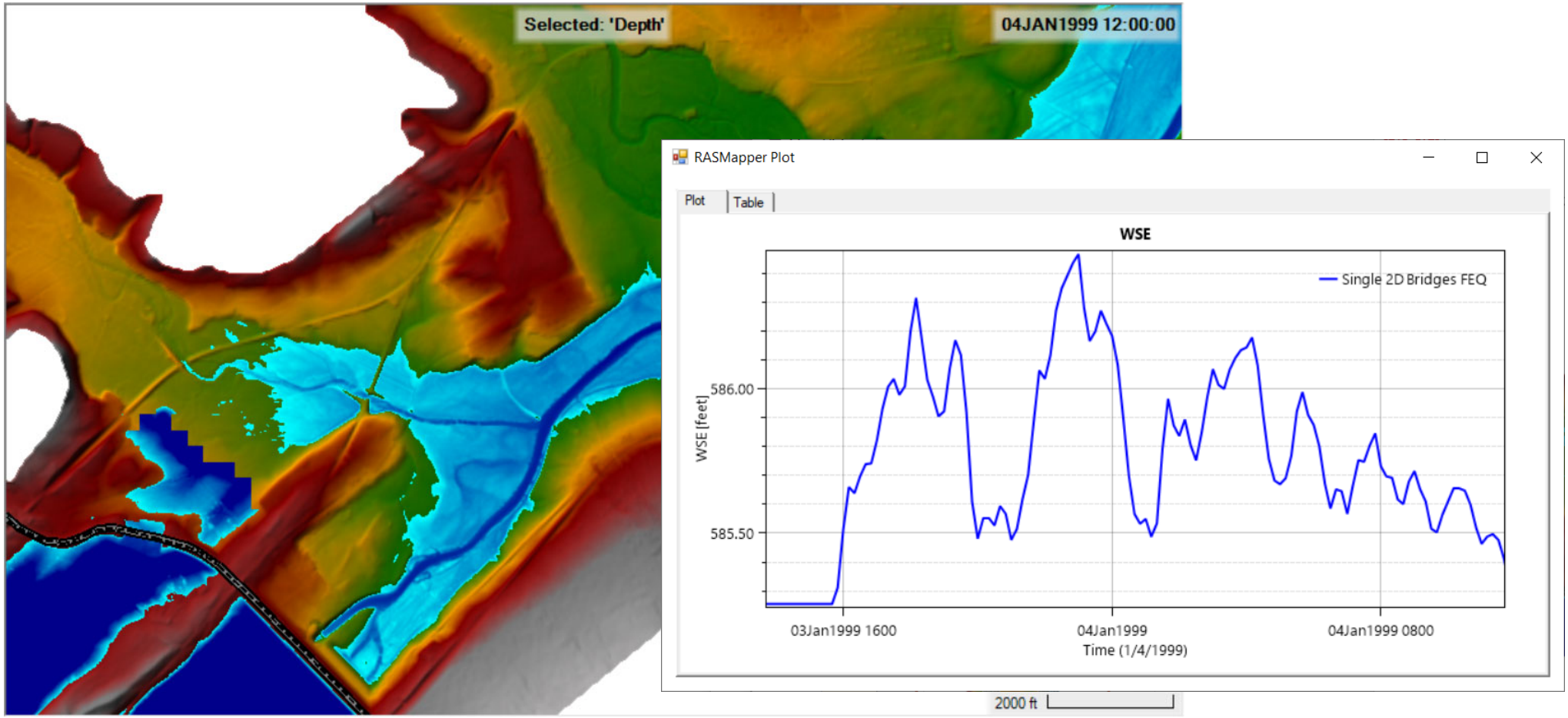
Iterations….Investigation

- Ctrl+F (Find a Cell)

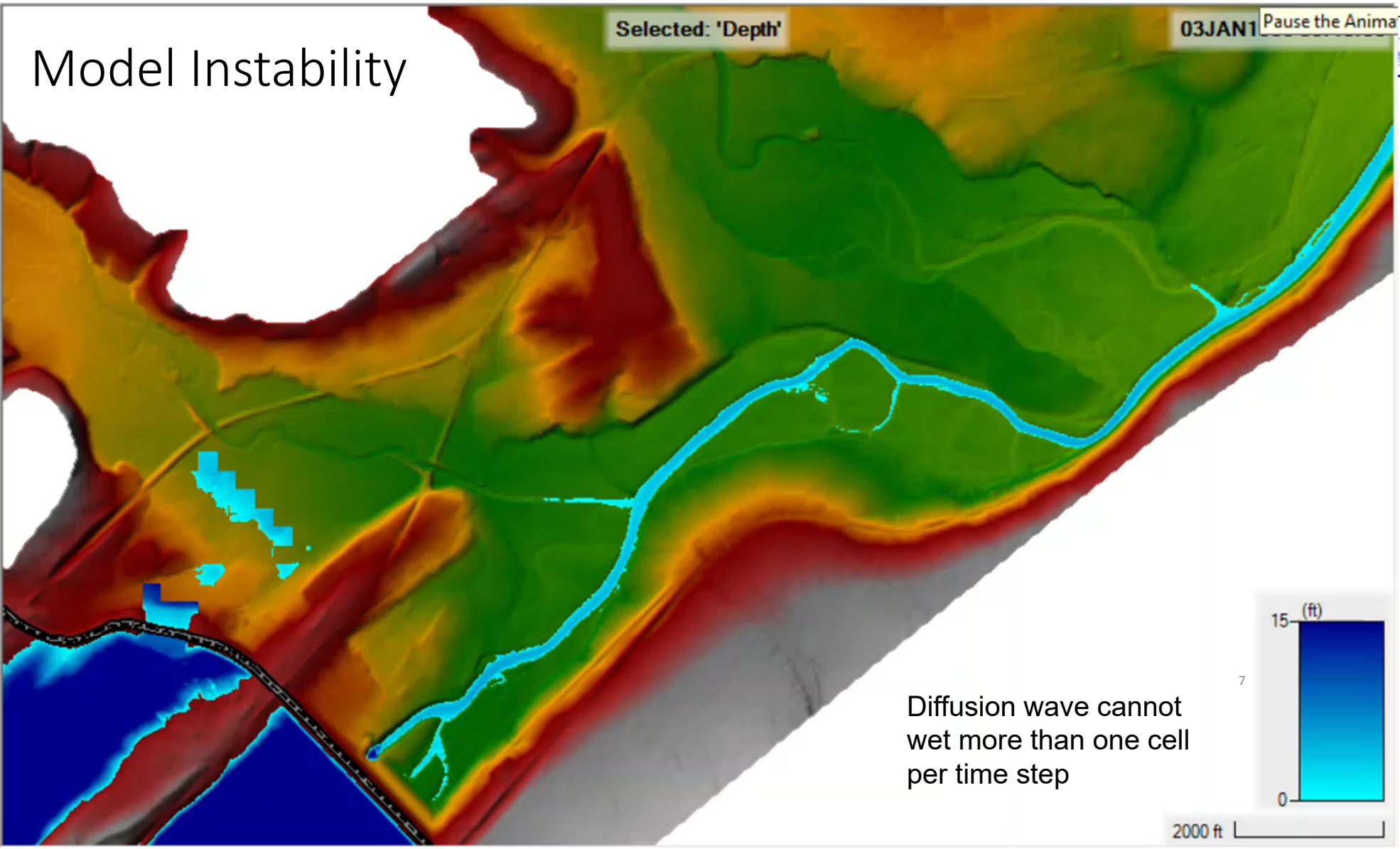


01JAN1999 23:24:30	BaldEagleCr	Cell #	23070	591.23	0.222	21
01JAN1999 23:25:00	BaldEagleCr	Cell #	23070	590.53	0.703	22
01JAN1999 23:25:30	BaldEagleCr	Cell #	23070	590.80	0.667	20
01JAN1999 23:26:00	BaldEagleCr	Cell #	23070	591.77	0.972	20
01JAN1999 23:26:30	BaldEagleCr	Cell #	23070	589.20	2.566	22
01JAN1999 23:27:00	BaldEagleCr	Cell #	23070	589.27	3.414	22
01JAN1999 23:27:30	BaldEagleCr	Cell #	23070	592.73	3.288	20
01JAN1999 23:28:00	BaldEagleCr	Cell #	23070	590.16	1.100	21
01JAN1999 23:28:30	BaldEagleCr	Cell #	23070	592.53	2.369	22
01JAN1999 23:29:00	BaldEagleCr	Cell #	23070	590.61	0.826	21
01JAN1999 23:29:30	BaldEagleCr	Cell #	23070	591.91	1.292	21
01JAN1999 23:30:00	BaldEagleCr	Cell #	23070	590.82	0.453	21
01JAN1999 23:30:30	BaldEagleCr	Cell #	23070	591.58	0.763	22
01JAN1999 23:31:00	BaldEagleCr	Cell #	23070	591.10	0.016	21
01JAN1999 23:33:00	BaldEagleCr	Cell #	23070	591.09	0.020	21
01JAN1999 23:33:30	BaldEagleCr	Cell #	23070	591.04	0.068	20
01JAN1999 23:34:00	BaldEagleCr	Cell #	21530	561.17	0.031	21
01JAN1999 23:34:30	BaldEagleCr	Cell #	23070	590.99	0.109	21
01JAN1999 23:35:00	BaldEagleCr	Cell #	23070	591.34	0.347	21
01JAN1999 23:35:30	BaldEagleCr	Cell #	23070	591.10	0.038	20
01JAN1999 23:36:00	BaldEagleCr	Cell #	21531	561.18	0.115	21
01JAN1999 23:36:30	BaldEagleCr	Cell #	23070	591.29	0.274	21

RAS Mapper Visualization



Model Instability

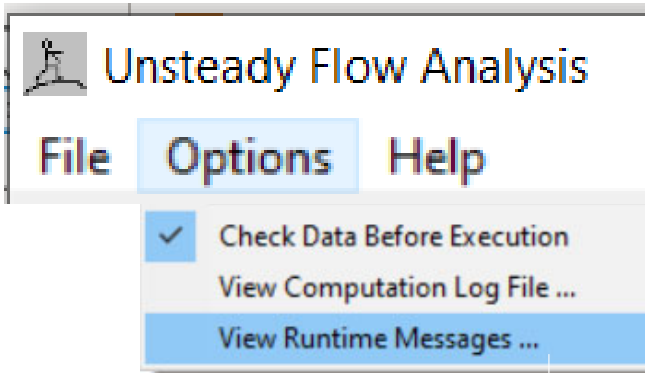


Diffusion wave cannot wet more than one cell per time step

Volume Accounting Check

Runtime Messages

```
07JAN1997 15:14:00  2DArea    Cell #    1085    4003.97    0.010    20
07JAN1997 15:37:00  2DArea    Cell #    1085    4003.97    0.010    20
07JAN1997 15:39:00  2DArea    Cell #    1085    4003.97    0.012    20

07JAN1997 16:06:00  2DArea    Cell #    1085    4003.96    0.010    20
07JAN1997 16:22:00  2DArea    Cell #    1085    4003.96    0.010    20
07JAN1997 16:24:00  2DArea    Cell #    1085    4003.96    0.011    20
07JAN1997 16:39:00  2DArea    Cell #    1085    4003.96    0.010    20

07JAN1997 16:52:00  2DArea    Cell #    1085    4003.96    0.011    20
07JAN1997 16:54:00  2DArea    Cell #    1085    4003.96    0.012    20
07JAN1997 17:28:00  2DArea    Cell #    1085    4003.96    0.010    20
07JAN1997 17:45:00  2DArea    Cell #    1085    4003.96    0.011    20

Overall Volume Accounting Error in Acre Feet:        0.3240
Overall Volume Accounting Error as percentage:       0.000662
Please review "Computational Log File" output for volume accounting details

Writing Results to DSS

Finished Unsteady Flow Simulation

1D Post Process Skipped (simulation is all 2D)

Computations Summary

Computation Task                          Time(hh:mm:ss)
```



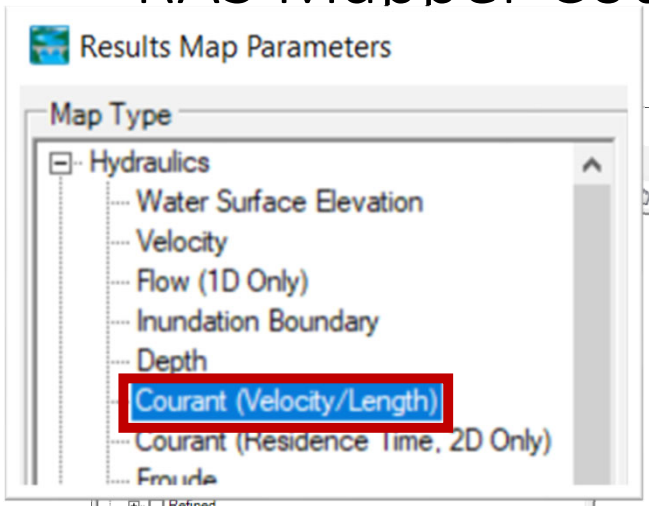
Computation Log File

```
***   Volume Accounting for 2D Flow Area in Acre Feet   ***

2D Area     Starting Vol     Ending Vol     Cum Inflow     Cum Outflow          Error    Percent Error
*******     ************     **********     **********     ***********          *****    *************

2DArea                          401.4          48924.         48523.         0.3240         0.000662


***   Total Volume Accounting (for the entire model) in Acre Feet   ***

Total Boundary Flux of Water In          48924.
Total Boundary Flux of Water Out         48523.

Starting Volume                      0.000000
Ending Volume                           401.4

                                Error    Percent Error
                                *****    *************
                               0.3240         0.000662
```

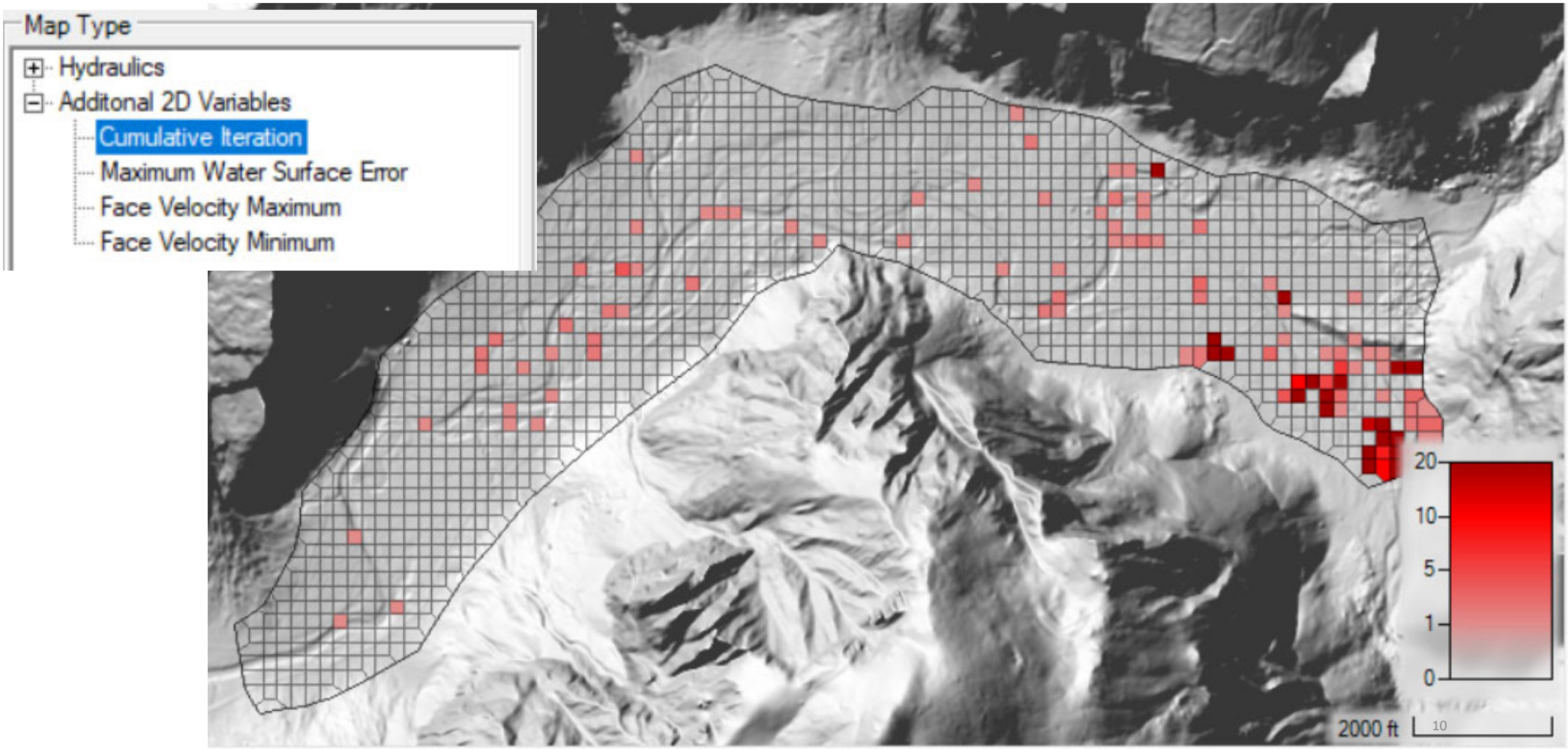
<<1% for 2D

1D-2D will have more error

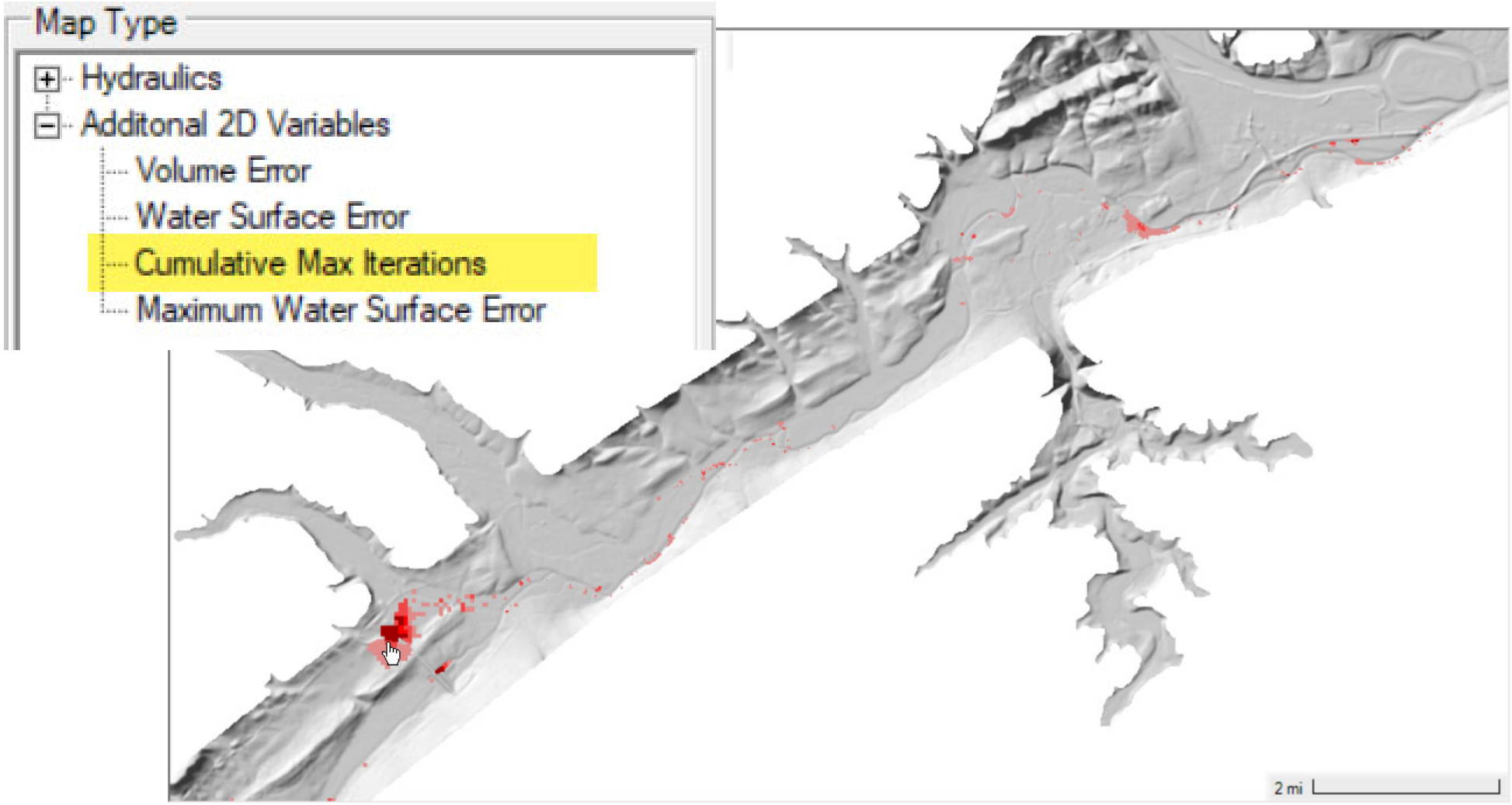
RAS Mapper Courant Number Map



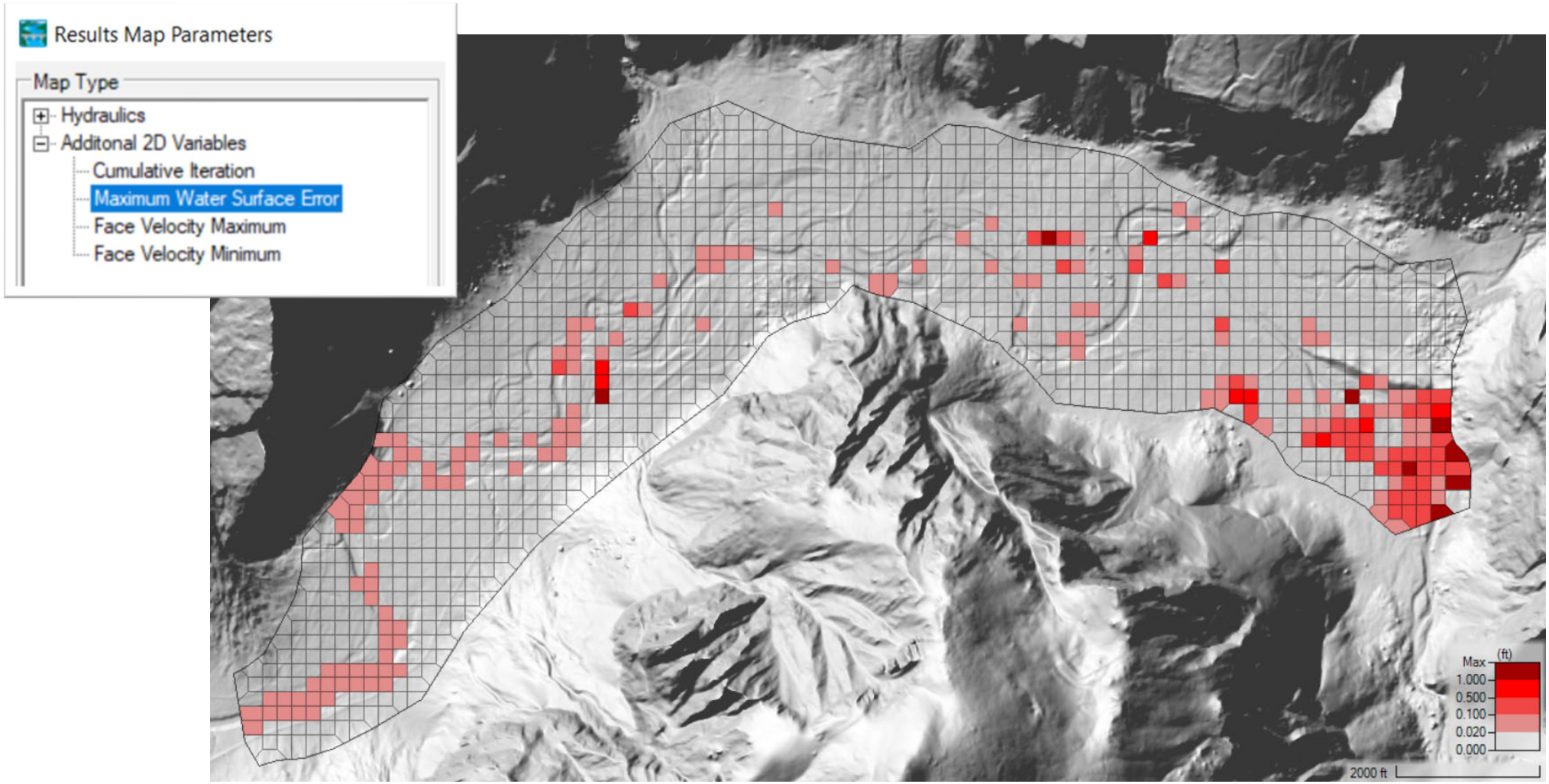
Cumulative Iterations

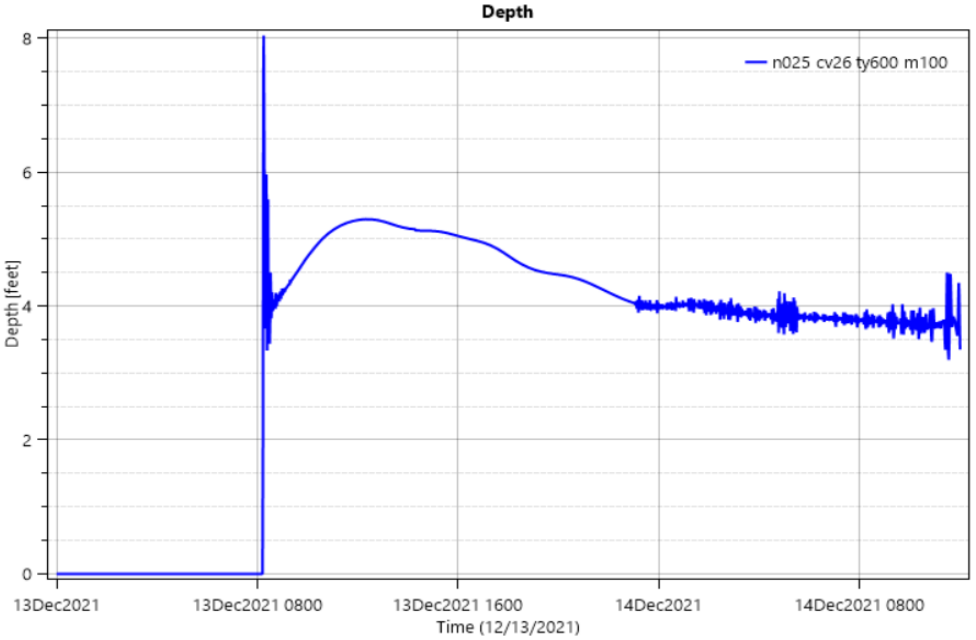


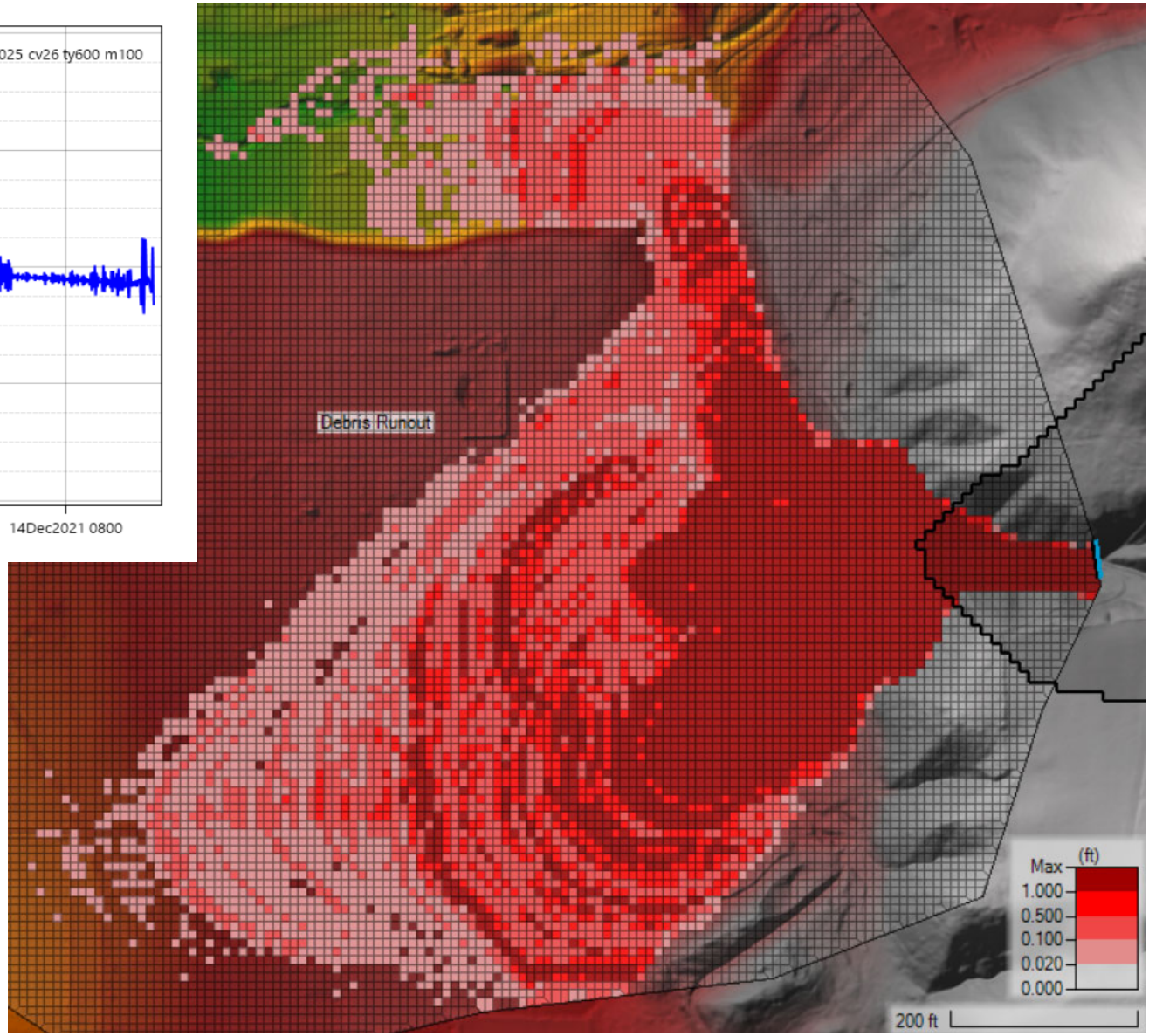
Cumulative Iterations



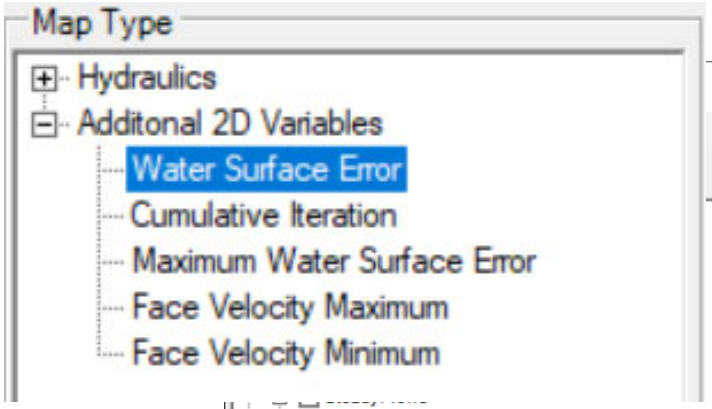
Maximum Water Surface Error

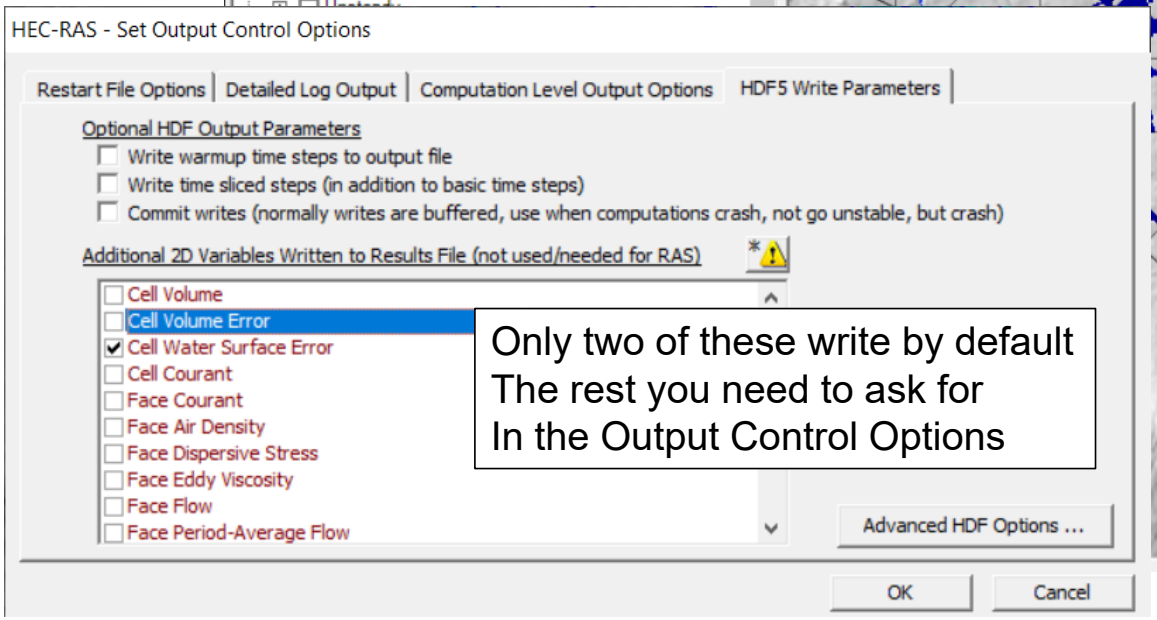



Depth
n025 cv26 ty600 m100
Depth [feet]
8
6
4
2
0
13Dec2021
13Dec2021 0800
13Dec2021 1600
14Dec2021
14Dec2021 0800
Time (12/13/2021)

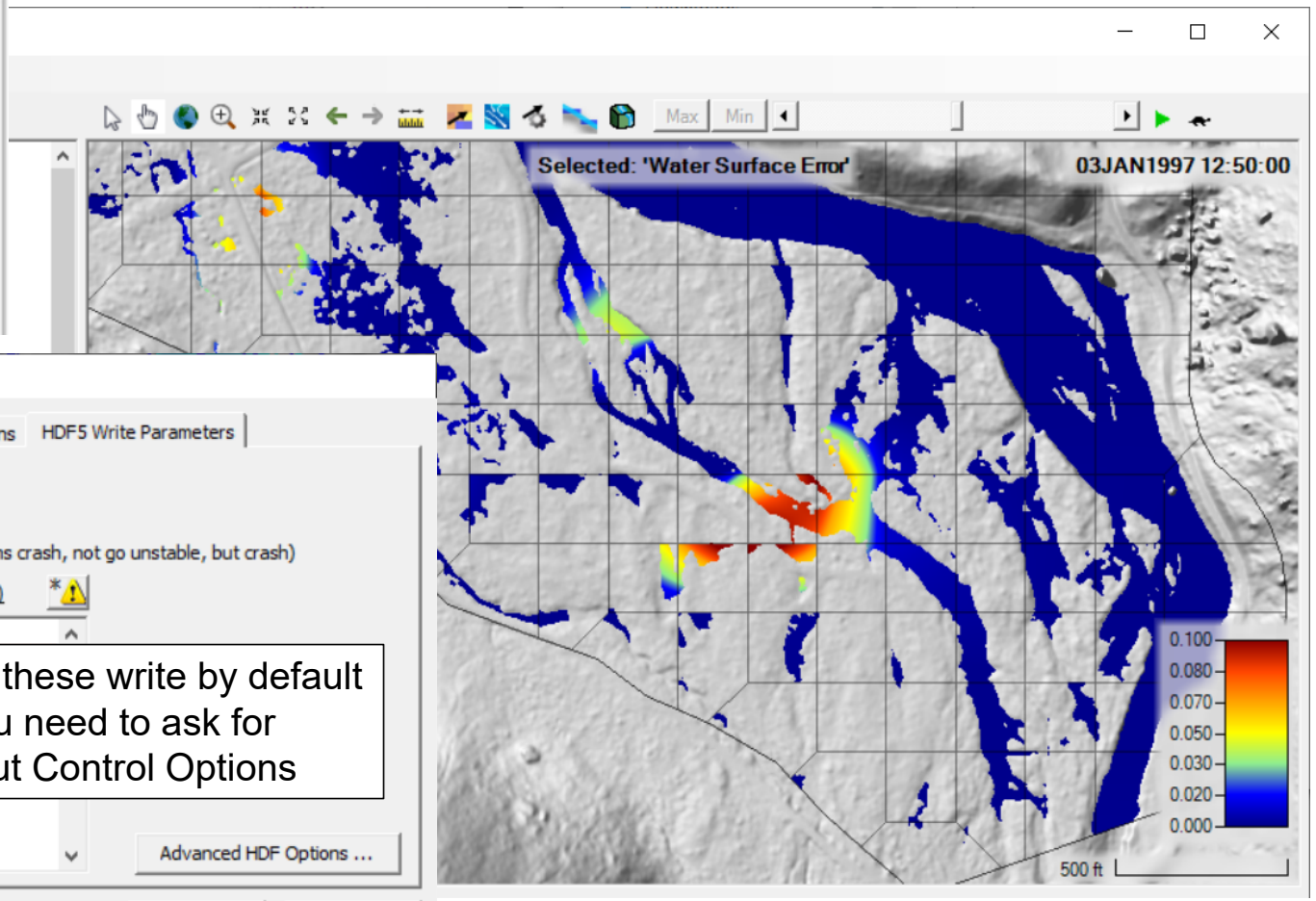

Debris Runout
Max
(ft)
1.000
0.500
0.100
0.020
0.000
200 ft

Cell Water Surface Error (For each time step)





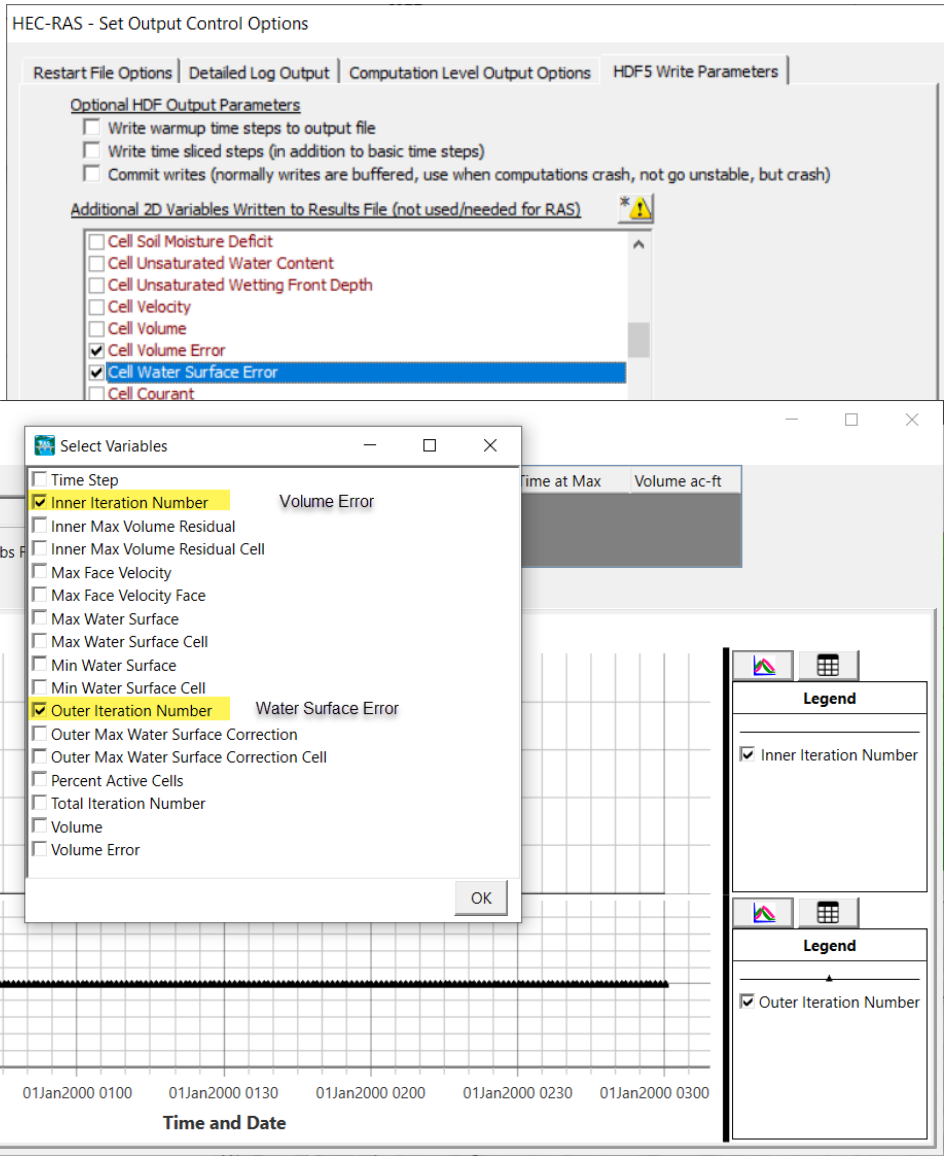
Only two of these write by default
The rest you need to ask for
In the Output Control Options



WS Elevation Tolerance - Diagnostics

- Output reports Cell with largest Error

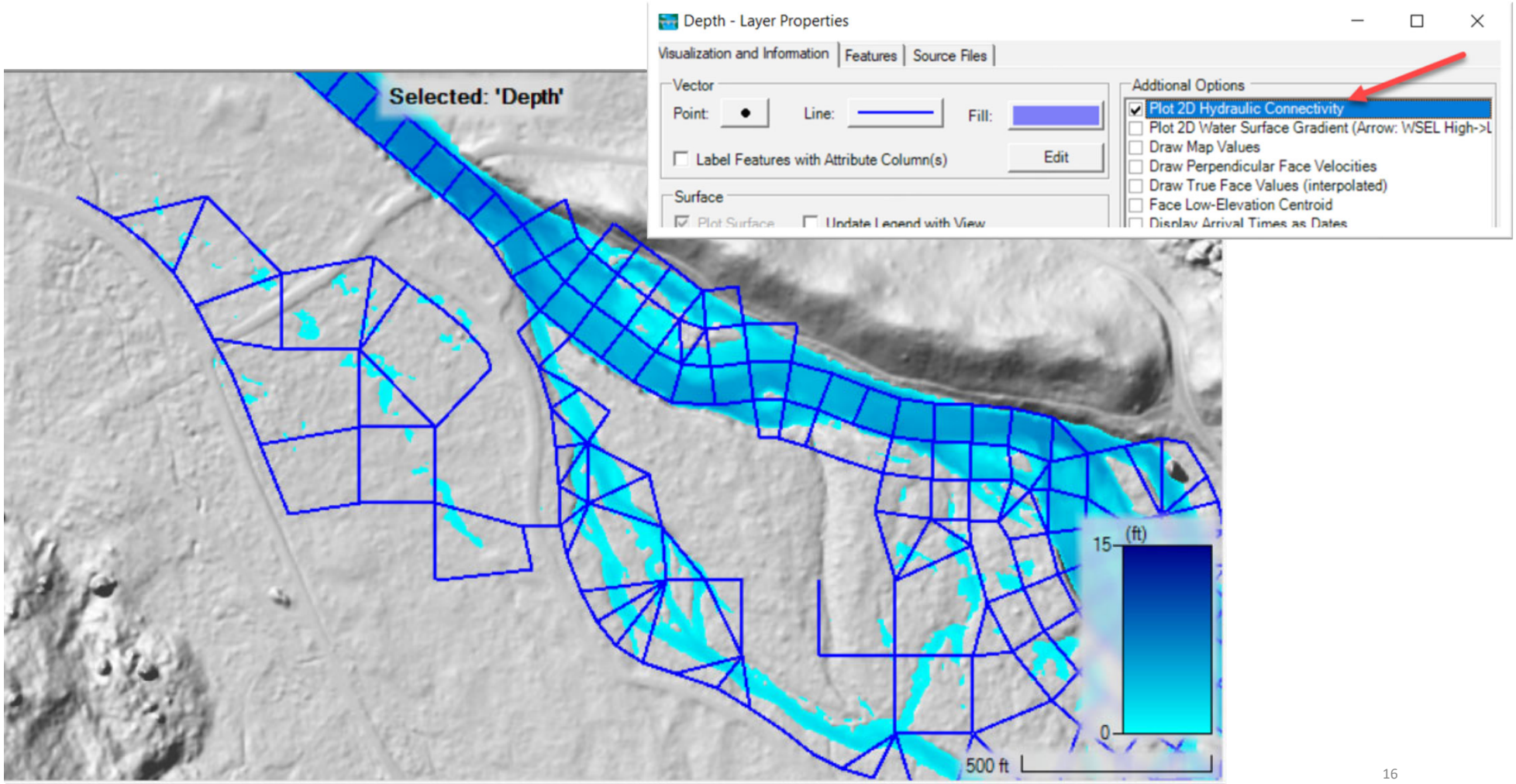
01JAN2000 00:00:30	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:00:40	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:00:50	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:01:00	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:01:10	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:01:20	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:01:30	2DFlowArea	Cell #	2022			
01JAN2000 00:01:40	2DFlowArea	Cell #	2022			
01JAN2000 00:01:50	2DFlowArea	Cell #	2022			
01JAN2000 00:02:00	2DFlowArea	Cell #	2022			
01JAN2000 00:02:10	2DFlowArea	Cell #	2022			
01JAN2000 00:02:20	2DFlowArea	Cell #	2022			
01JAN2000 00:02:30	2DFlowArea	Cell #	2022			
01JAN2000 00:02:40	2DFlowArea	Cell #	2022			
01JAN2000 00:02:50	2DFlowArea	Cell #	2022			
01JAN2000 00:03:00	2DFlowArea	Cell #	2022			
01JAN2000 00:03:10	2DFlowArea	Cell #	2022			
01JAN2000 00:03:20	2DFlowArea	Cell #	2022			
01JAN2000 00:03:30	2DFlowArea	Cell #	2022			
01JAN2000 00:03:40	2DFlowArea	Cell #	2022			
01JAN2000 00:03:50	2DFlowArea	Cell #	2022			
01JAN2000 00:04:00	2DFlowArea	Cell #	2022			

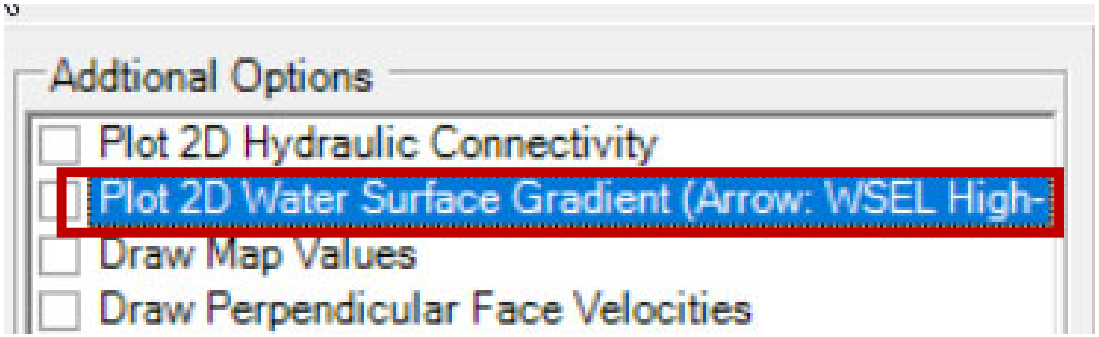


- Error due to volume or water surface?

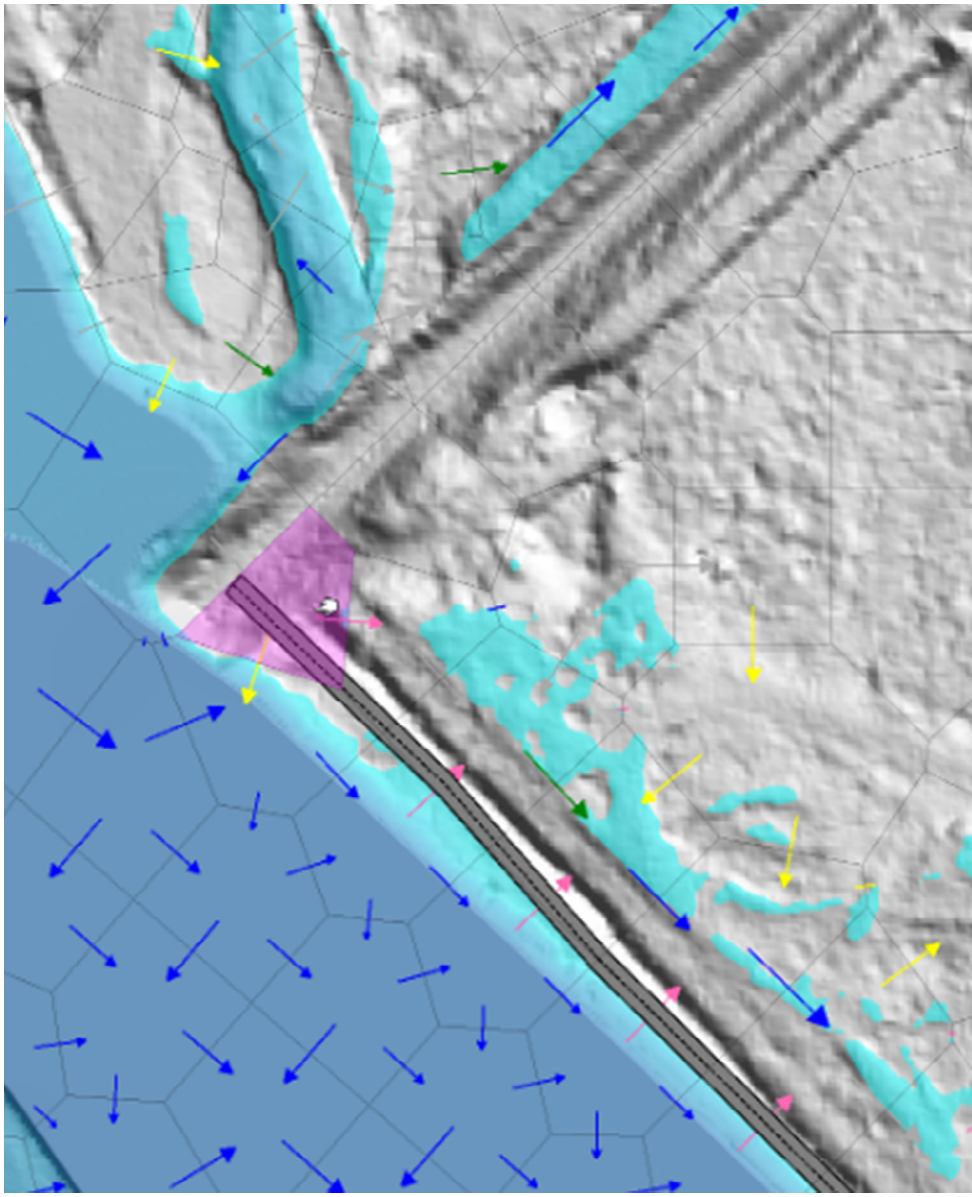
Inner iteration Volume
Outer iteration WSE

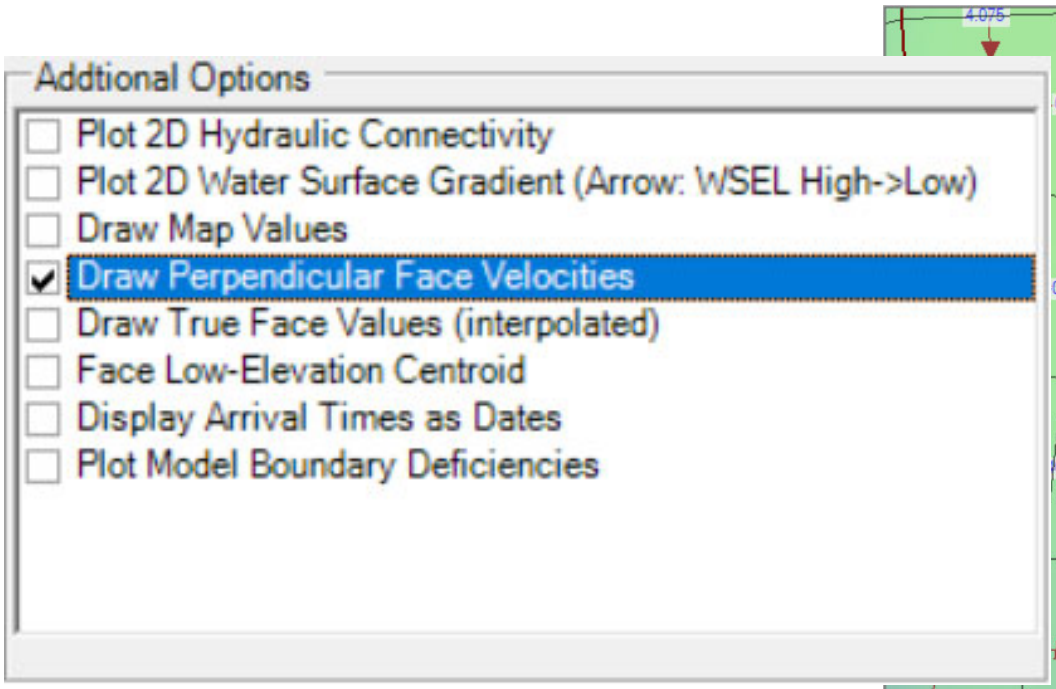
Hydraulic Connectivity

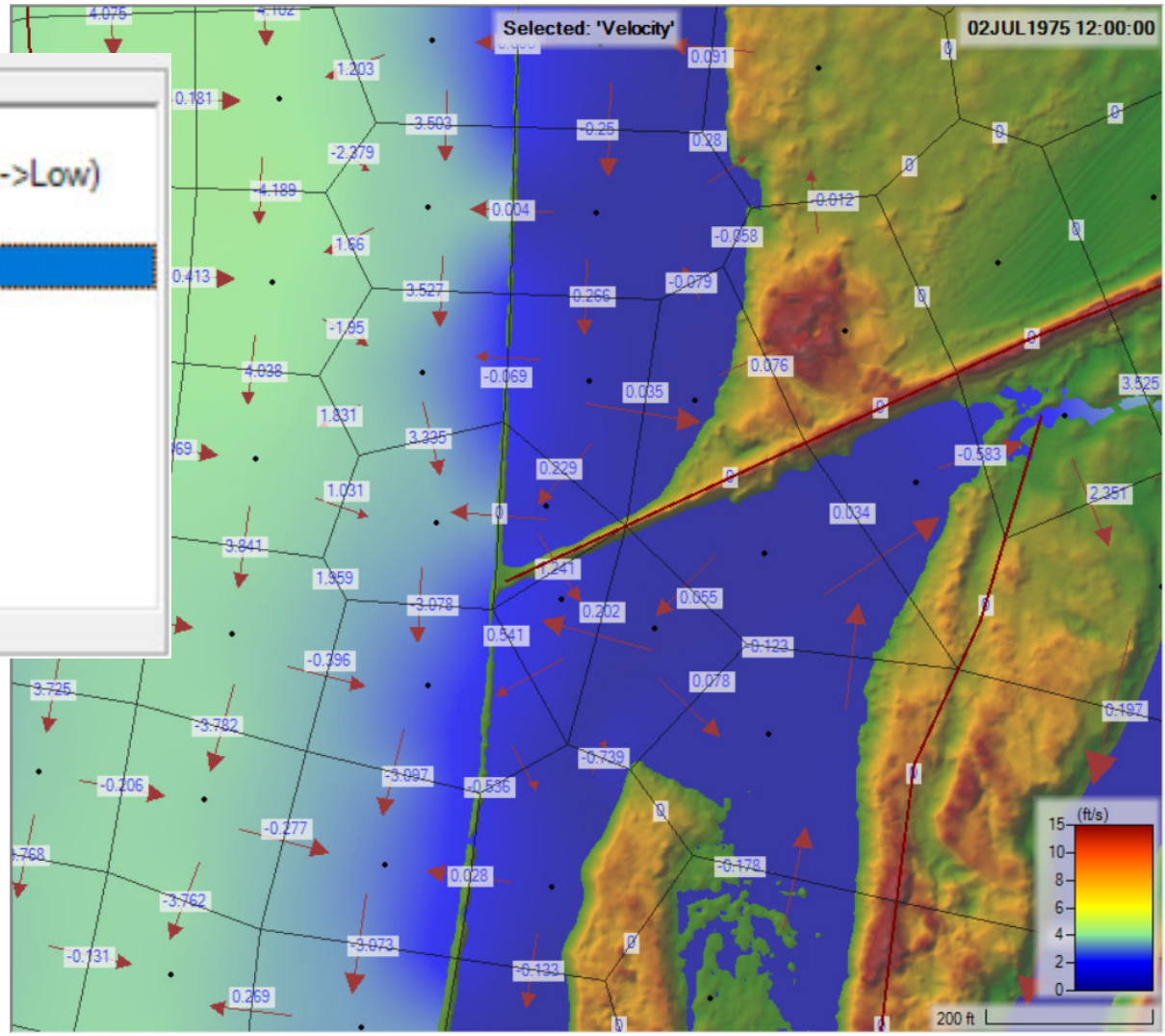


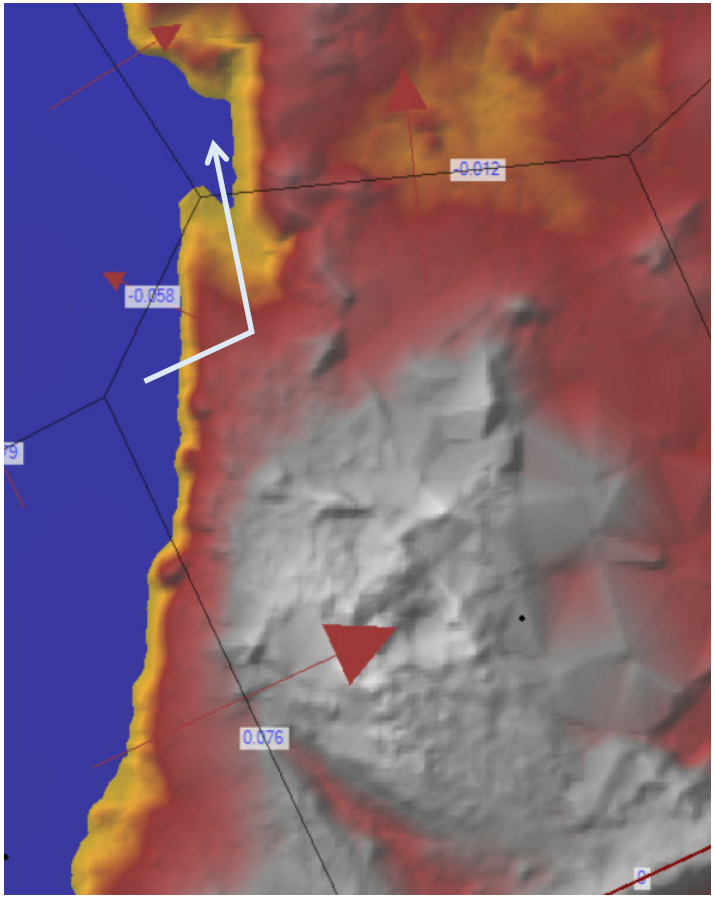


Blue →	Normal flow. Upstream WSE > downstream WSE and flow is with the predominant velocity.
Yellow →	Shallow depth of flow. Water is moving from high ground to low ground. Flow is not of significant depth over the cell face; however, it is expected to be hydraulically connected.
Green →	Intermediate depth of flow. While not deep, flow is expected over the adjacent cell face.
Gray →	Backwater. Downstream WSE > upstream WSE. Cell with the higher water surface elevation usually has lower terrain elevation.
Pink →	Critical. Flow most likely passes through critical depth over a cell face.



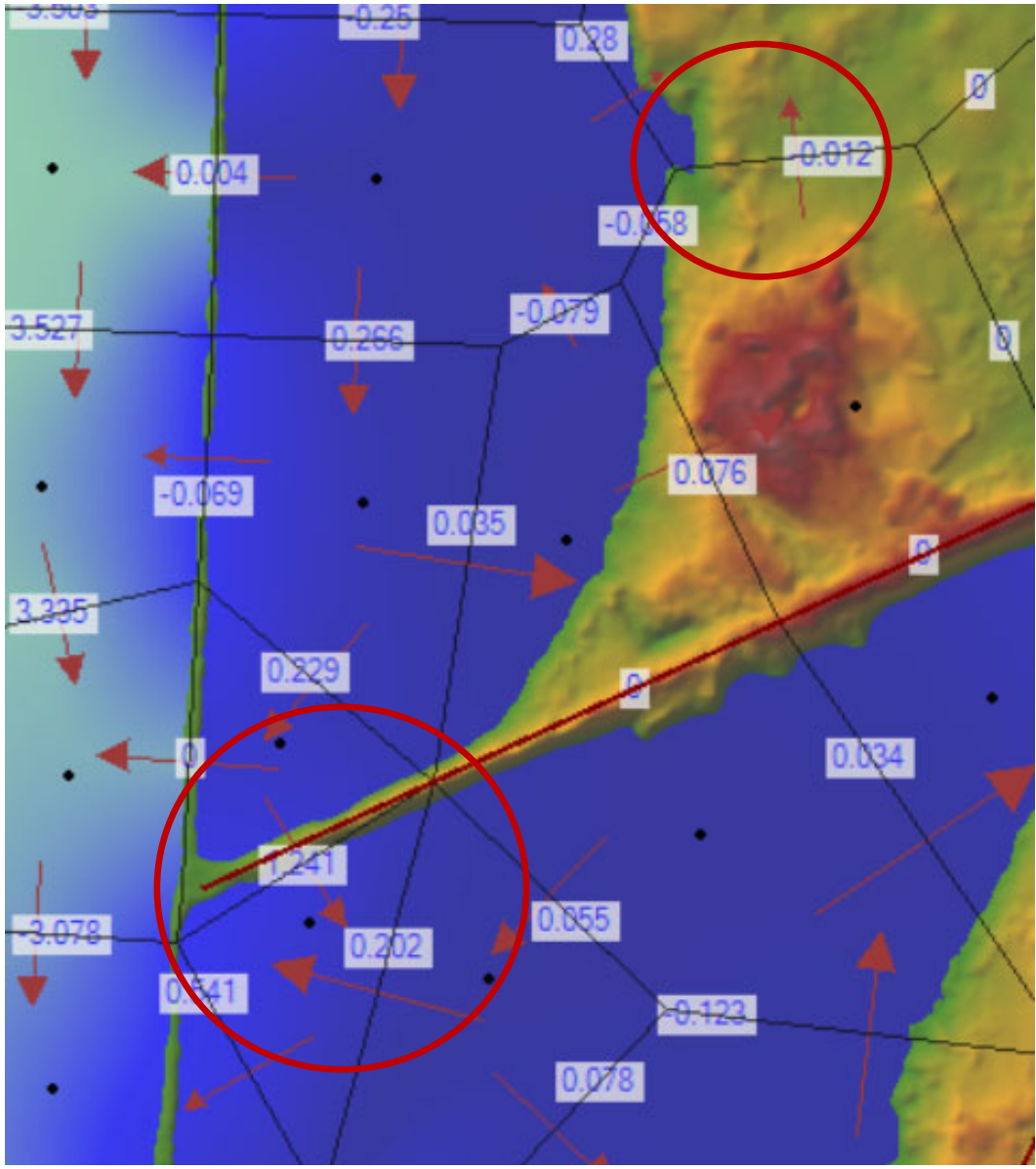

Addtional Options
Plot 2D Hydraulic Connectivity
Plot 2D Water Surface Gradient (Arrow: WSEL High->Low)
Draw Map Values
Draw Perpendicular Face Velocities
Draw True Face Values (interpolated)
Face Low-Elevation Centroid
Display Arrival Times as Dates
Plot Model Boundary Deficiencies


Selected: 'Velocity'
02JUL1975 12:00:00
(ft/s)
15
10
8
6
4
2
0
200 ft

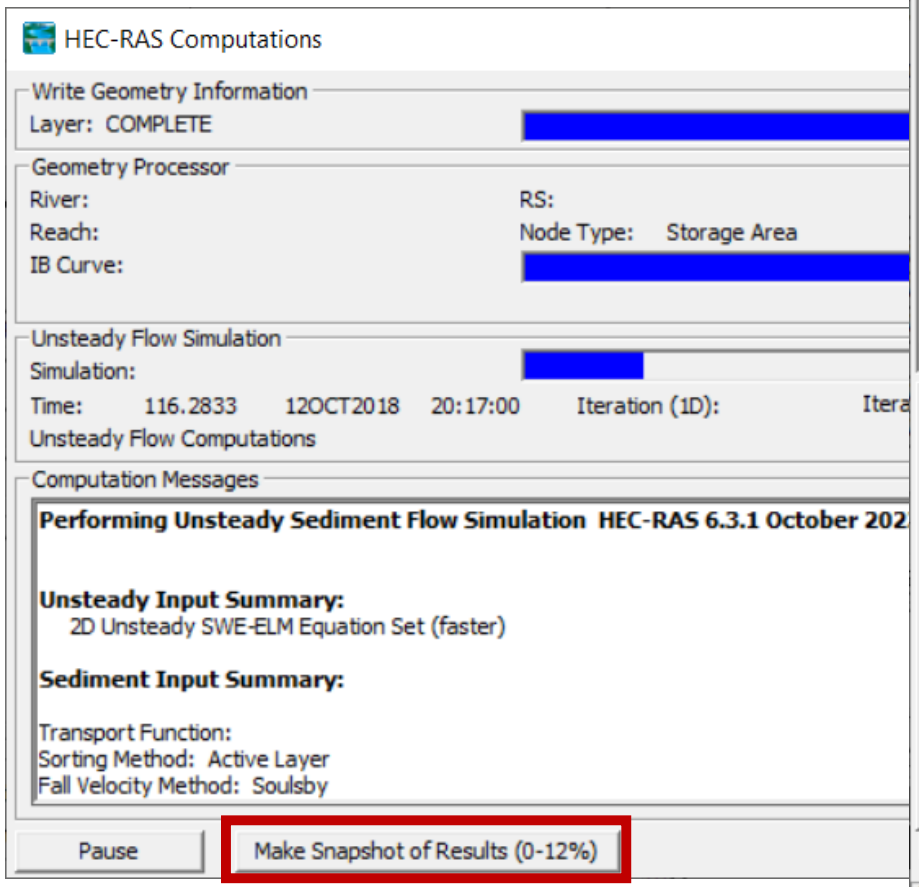


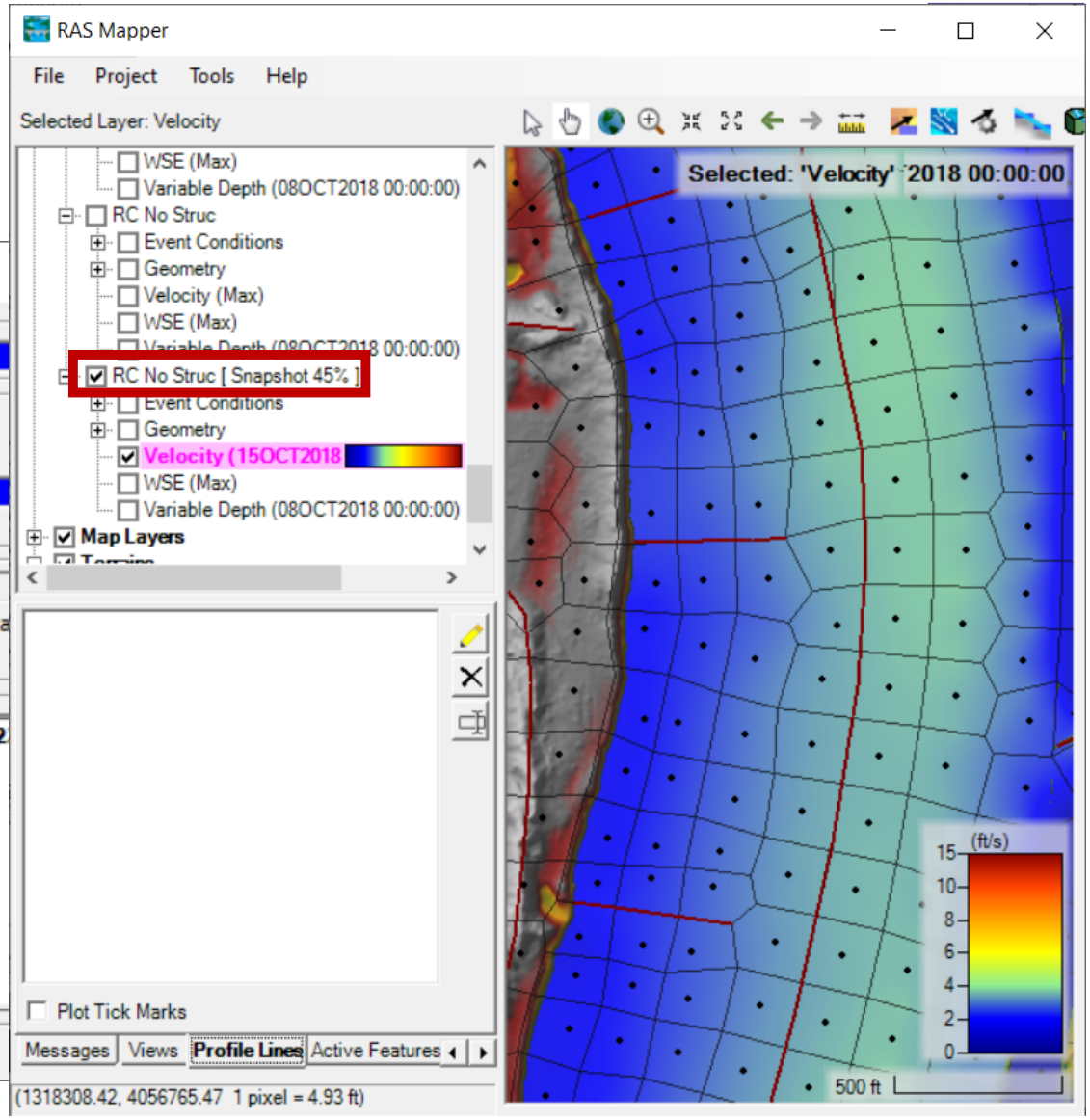
Addtional Options

- [ ] Plot 2D Hydraulic Connectivity
- [ ] Plot 2D Water Surface Gradient (Arrow: WSI
- [ ] Draw Map Values
- [x] Draw Perpendicular Face Velocities

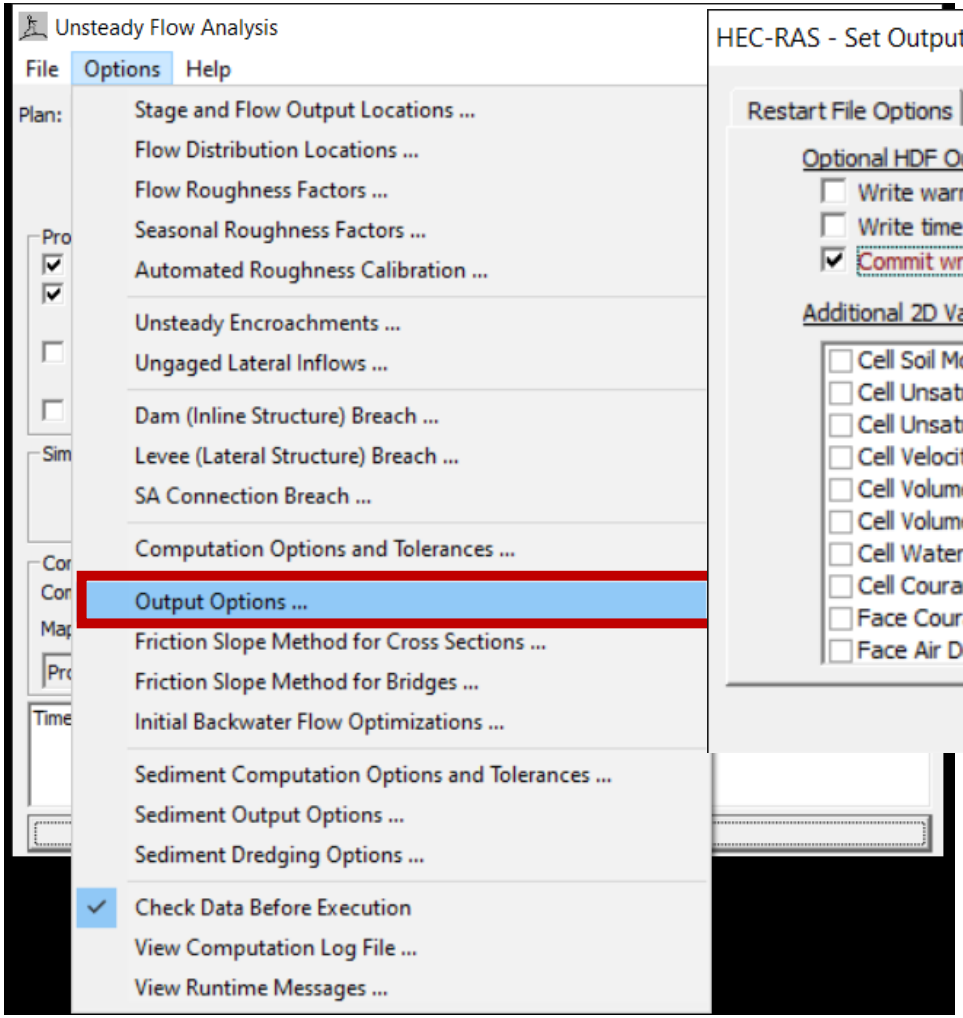


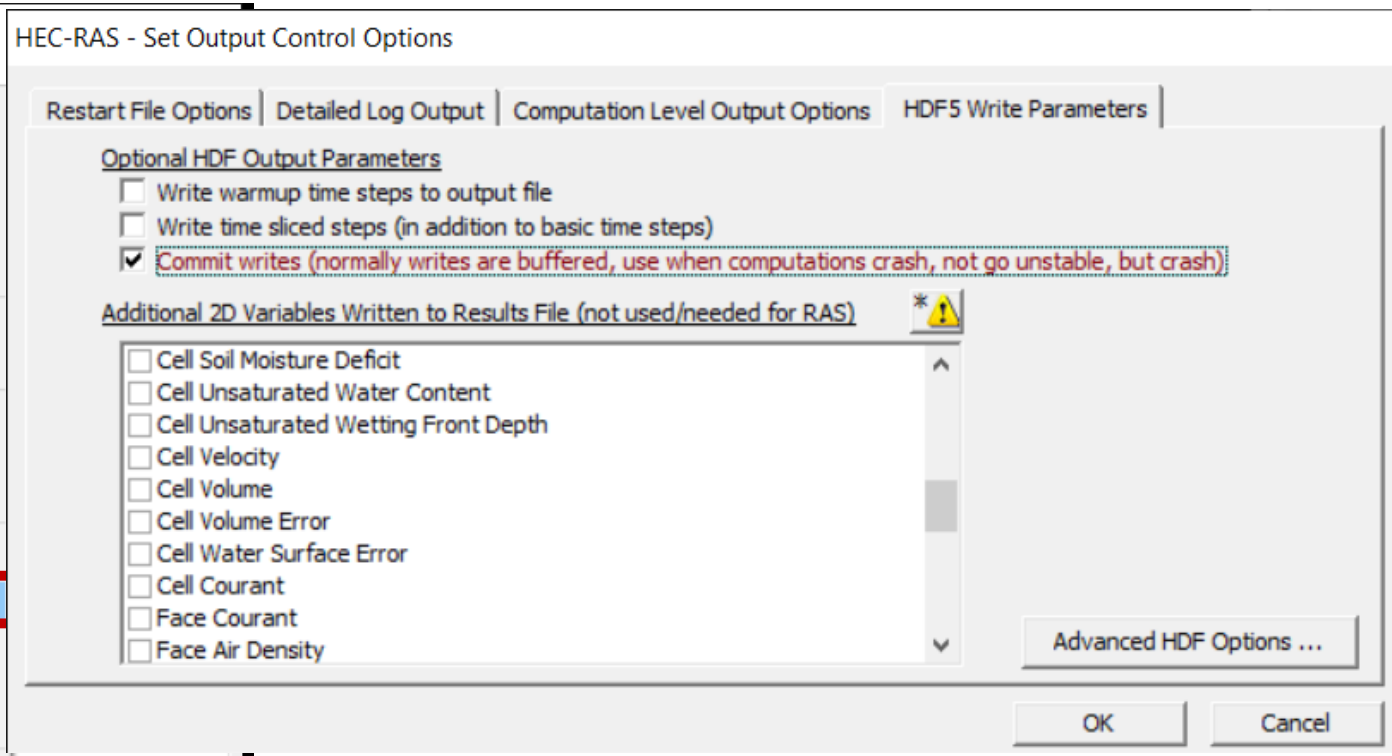
Snapshots


HEC-RAS Computations
Write Geometry Information
Layer: COMPLETE
Geometry Processor
River:
RS:
Reach:
Node Type: Storage Area
IB Curve:
Unsteady Flow Simulation
Simulation:
Time: 116.2833 12OCT2018 20:17:00 Iteration (1D):
Unsteady Flow Computations
Computation Messages
Performing Unsteady Sediment Flow Simulation HEC-RAS 6.3.1 October 202
Unsteady Input Summary:
2D Unsteady SWE-ELM Equation Set (faster)
Sediment Input Summary:
Transport Function:
Sorting Method: Active Layer
Fall Velocity Method: Soulsby
Pause
Make Snapshot of Results (0-12%)


RAS Mapper
File
Project
Tools
Help
Selected Layer: Velocity
WSE (Max)
Variable Depth (08OCT2018 00:00:00)
RC No Struc
Event Conditions
Geometry
Velocity (Max)
WSE (Max)
RC No Struc [Snapshot 45%]
Event Conditions
Geometry
Velocity (15OCT2018
WSE (Max)
Variable Depth (08OCT2018 00:00:00)
Map Layers
Plot Tick Marks
Messages
Views
Profile Lines
Active Features
(1318308.42, 4056765.47 1 pixel = 4.93 ft)
Selected: 'Velocity' 2018 00:00:00
(ft/s)
15
10
8
6
4
2
0
500 ft

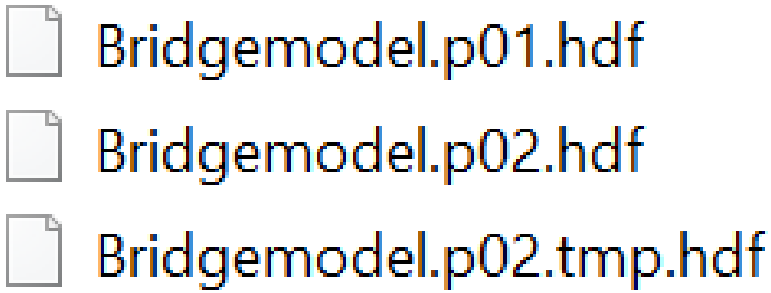
Commit Writes Before Crashes





- Writes results to disk throughout the simulation
- Increases run time

Harvesting Temporary Output File



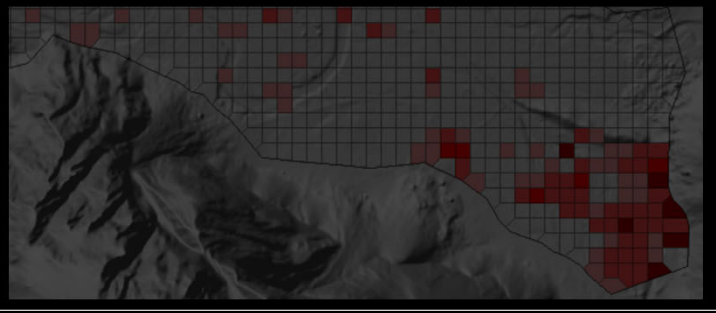
HEC-RAS keeps the old result file until the new one is complete.

The new file has a .tmp. In the Extension.

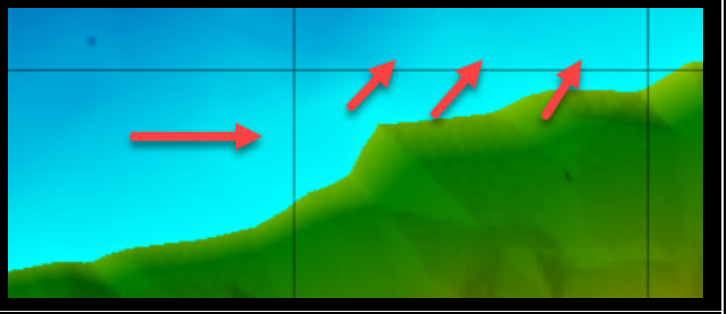
If the run crashes, you can often remove the old file and delete the ".tmp" to try to open the crashed result.

2D Hydraulic Stability Issues

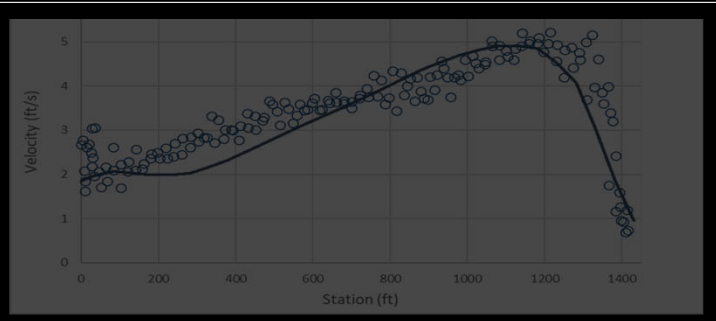
Diagnostic Tools



Common Errors



2D Calibration



Cell Size and Time Step

- Too large a time step for the cell size/velocity can cause model instability.
- Diffusion Wave is more forgiving than Shallow Water eqns. But full St. Venant more accurate.
- Use Courant condition pick the best time step.
- The time step you use will also depend on how fast the hydrograph rises:
  - Fast rising = Lower time step/Courant number
  - Slow rising = Higher time step/Courant number

Courant Condition Guidelines

- Shallow Water Equations
  - Experience shows, max C = 3.0

$$C = \frac{V * \Delta T}{\Delta X} \leq 1.0$$

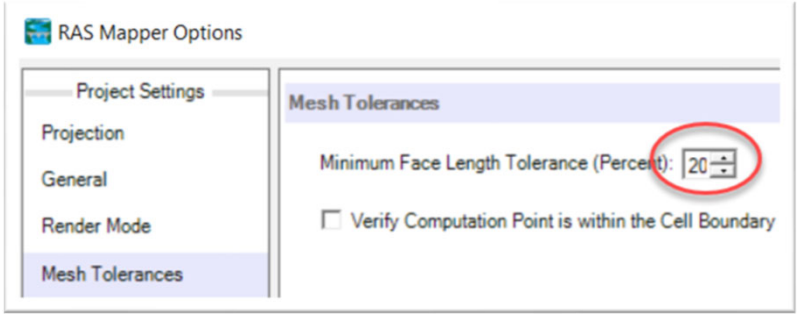
- Diffusion Wave Approximation
  - Experience shows, max C = 5.0

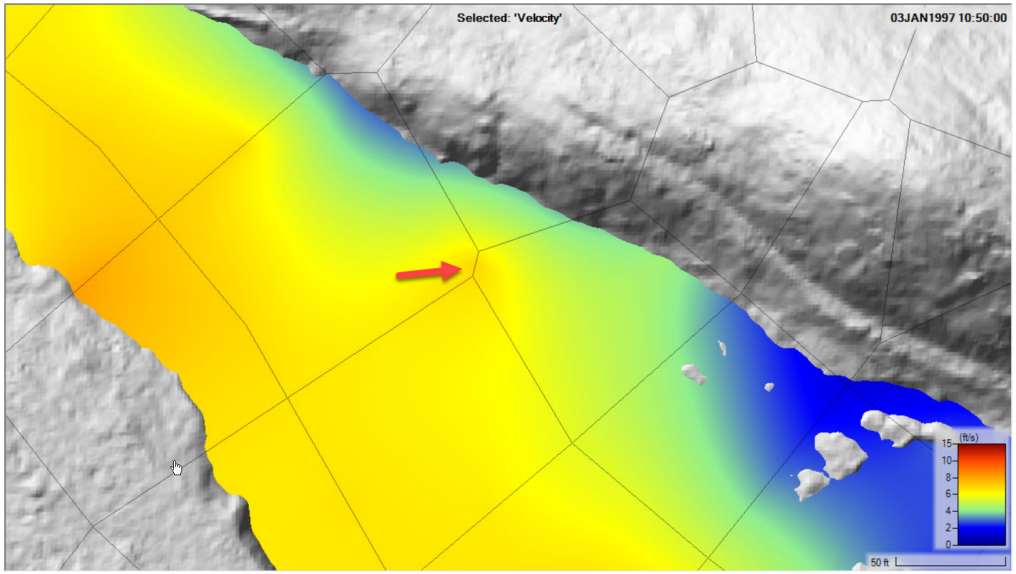
$$C = \frac{V * \Delta T}{\Delta X} \leq 2.0$$

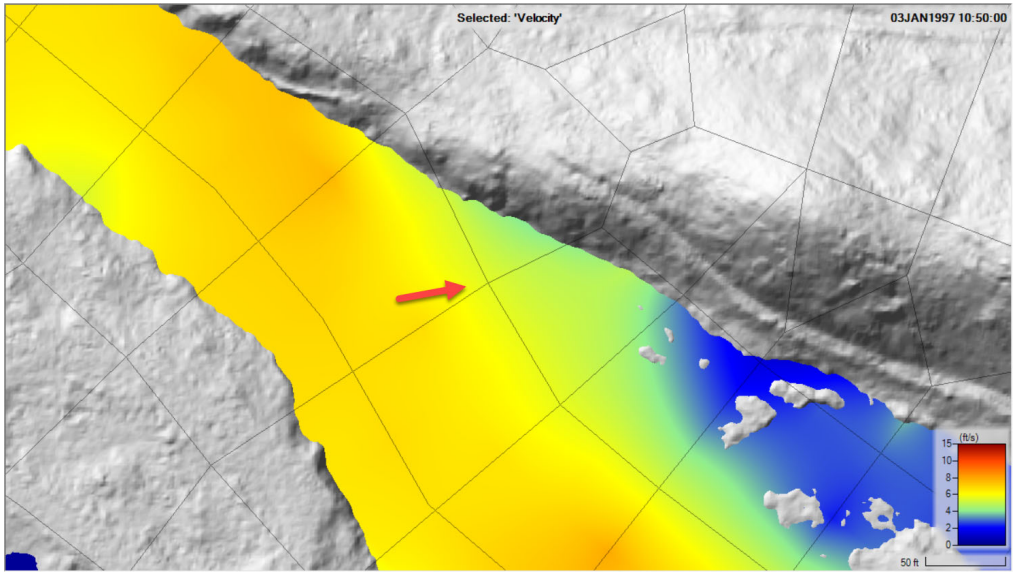
C	=	Courant Number
V	=	Velocity of the Flood Wave (ft/s)
ΔT	=	Computational Time Step (seconds)
ΔX	=	The average Cell size (ft)

Weird Shaped Cells/Small Faces

- Cells need to transition in size slowly
  - No more than 50% change in size
- Small cells and short faces compared to other cells and cells – this may cause excessive model iterations.

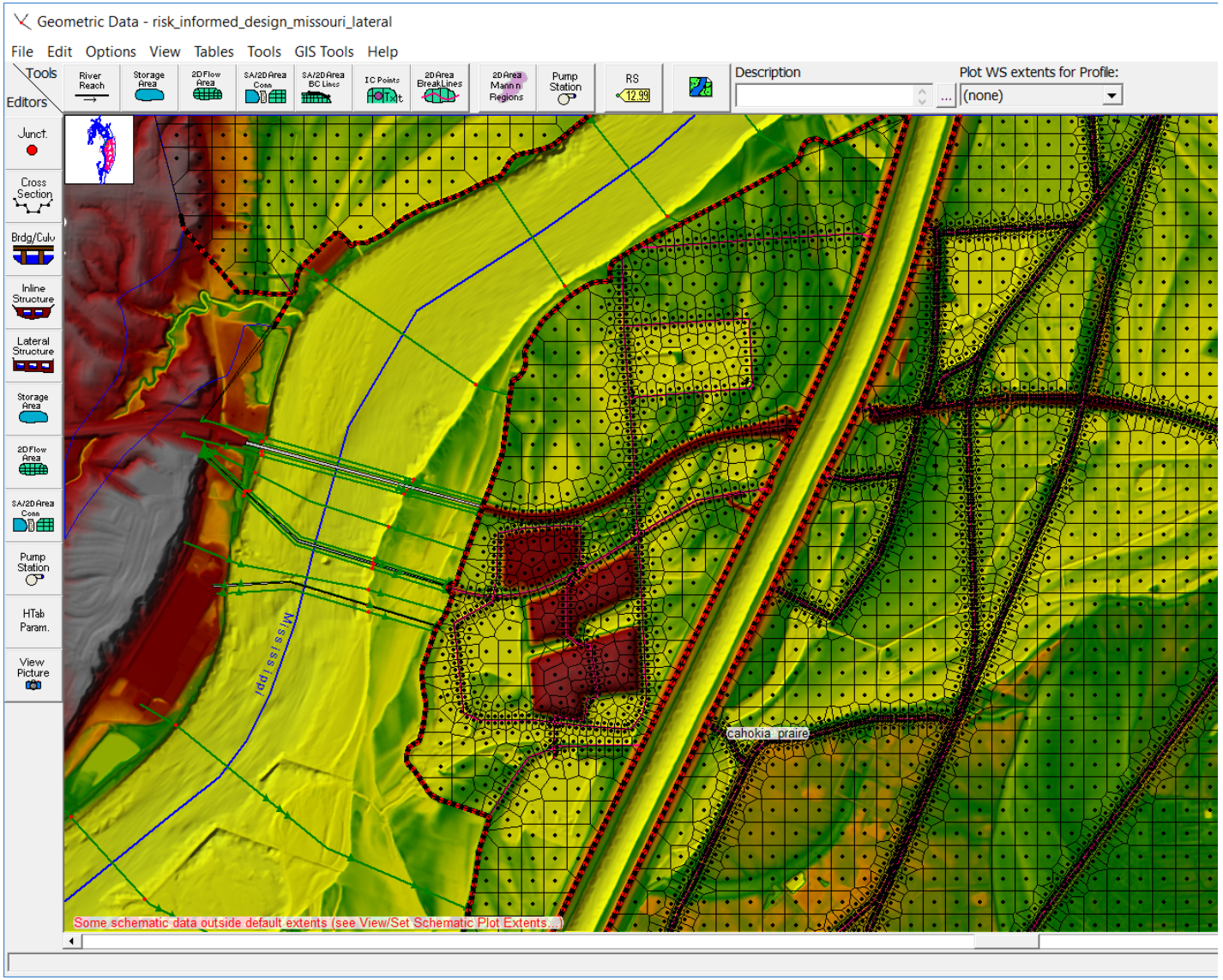






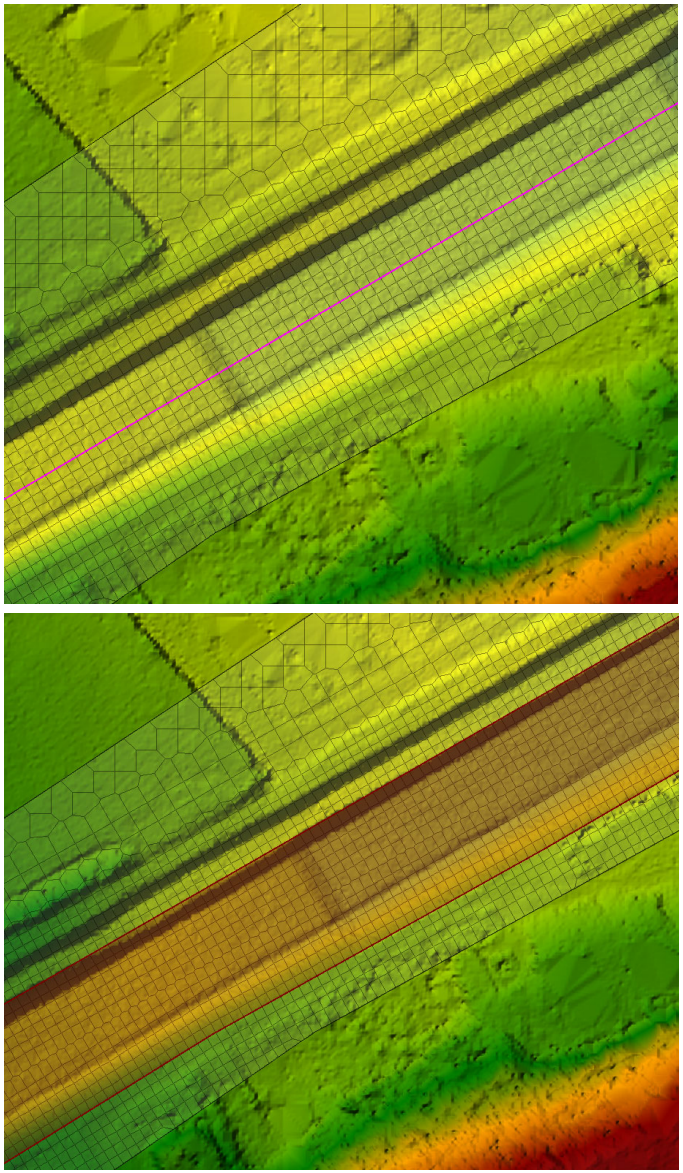
Breaklines

- In general people do not use enough breaklines
- Use breaklines along high ground barriers to flow in order to align faces
  - This will improve accuracy
  - This will improve model stability

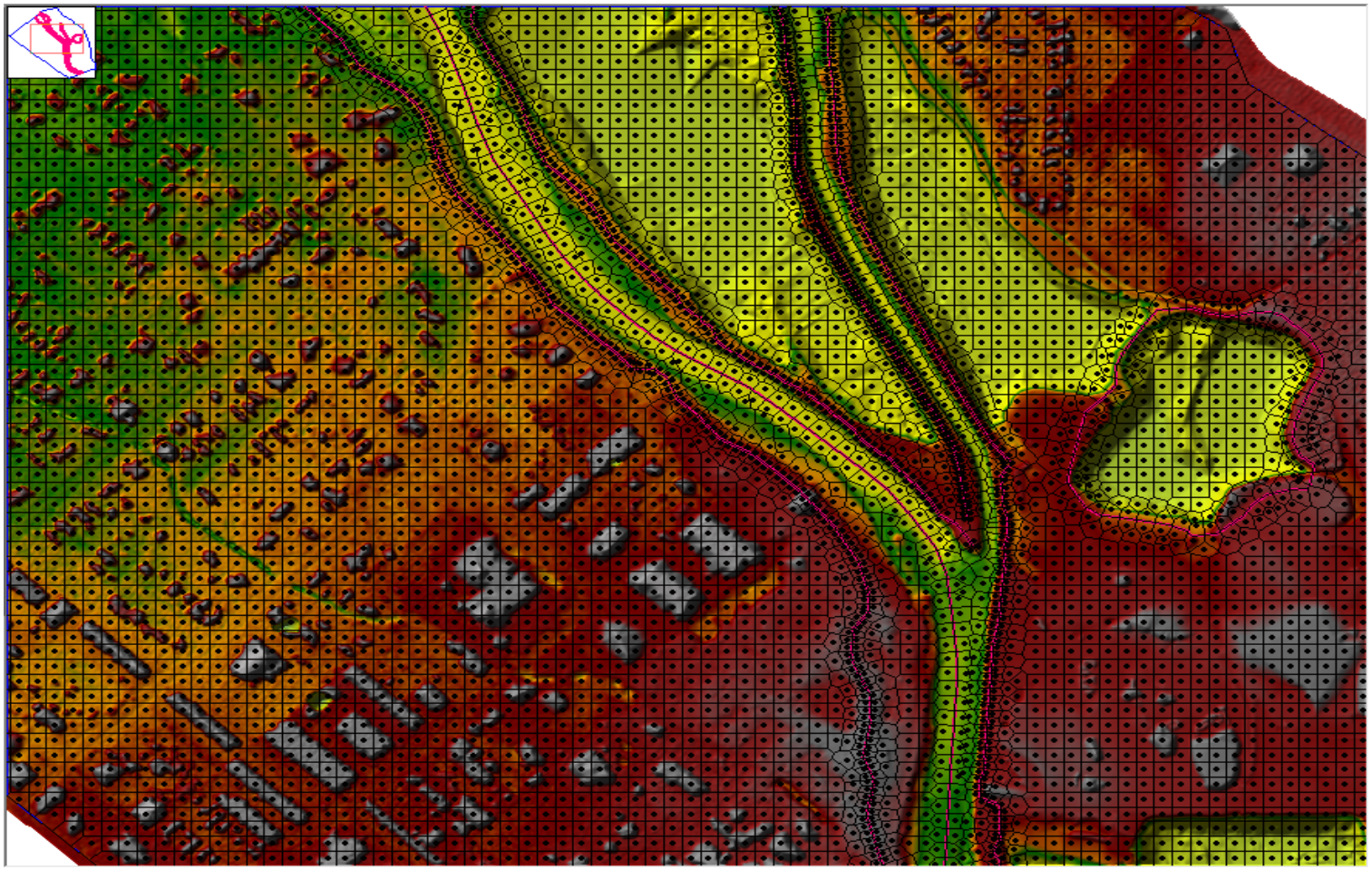


Channel Alignment and Cell Size

- Need to define the channel portion of the 2D mesh appropriately
- 2D Faces need to be aligned with high ground separating channel from floodplain
- Channel needs to have enough cells across the channel in order to get a good velocity profile. Recommend at least 7 to 10 cells across channel
- Fewer cells ok for water surface only
- Use Breaklines/Refinement Regions to accomplish this



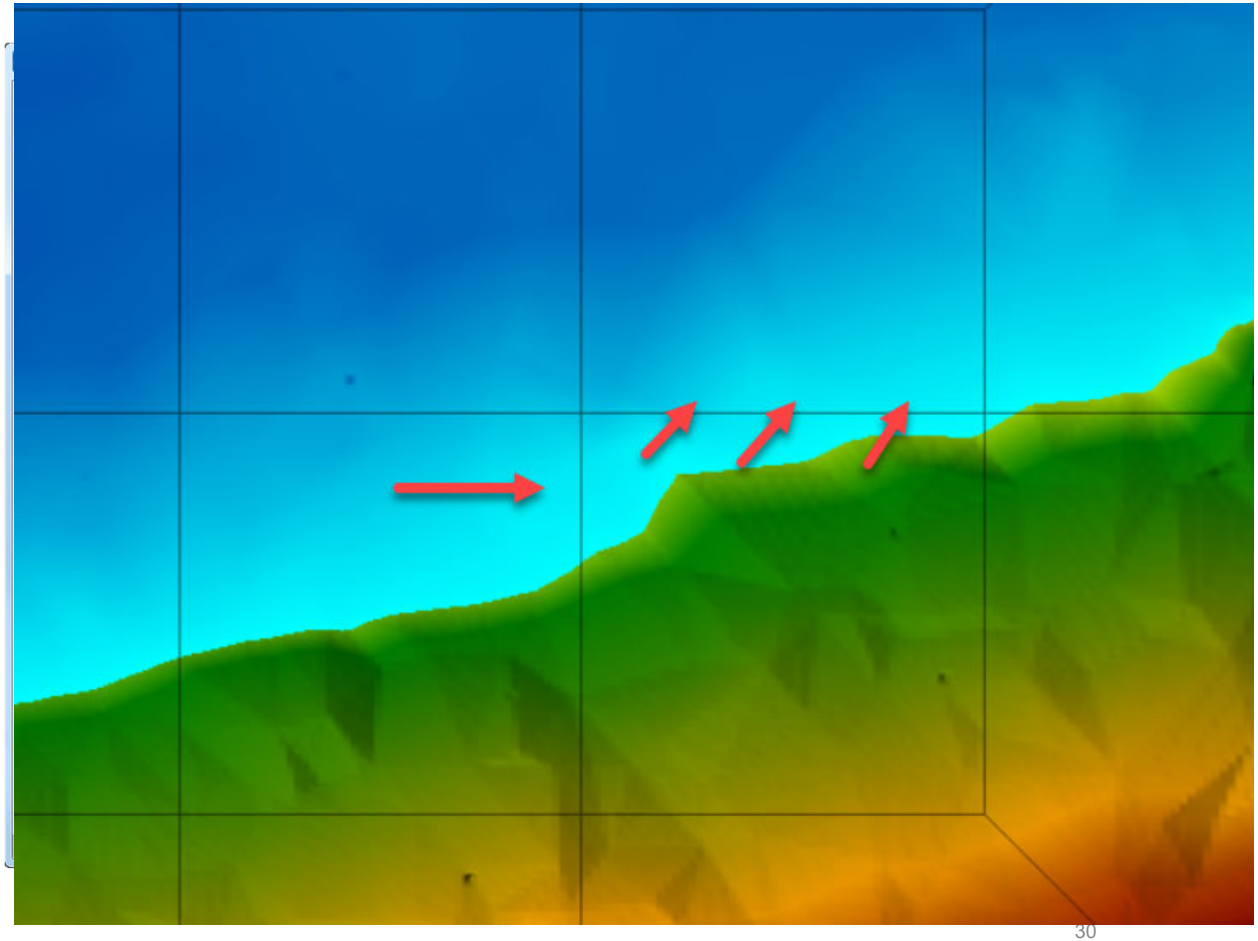
Polygon Refinement for Main Channel



Partial Cell Wetting Issue

- Excessive model iteration can occur when just a corner of a cell has flow and the velocity is high.
- This will be even more unstable when flow comes into a cell through a small portion of a face but can leave over a much larger portion of another face
- Adjust cell sizes, use breaklines and polygon refinement tool to fix

Why does cell alignment matter?



Floodwave Wetting Front

- 2D Models can often go unstable at the wetting front of the floodwave
  - Can cause model iterations
  - Can also cause bad max velocity plots
- Ways to improve this:
  - Reduce Time Step
  - Poor Cell Size – use polygon refinement tool
  - To large of an elevation change across a single cell – make cells smaller or larger
  - Breaklines for high ground barriers

WS Elevation Tolerance

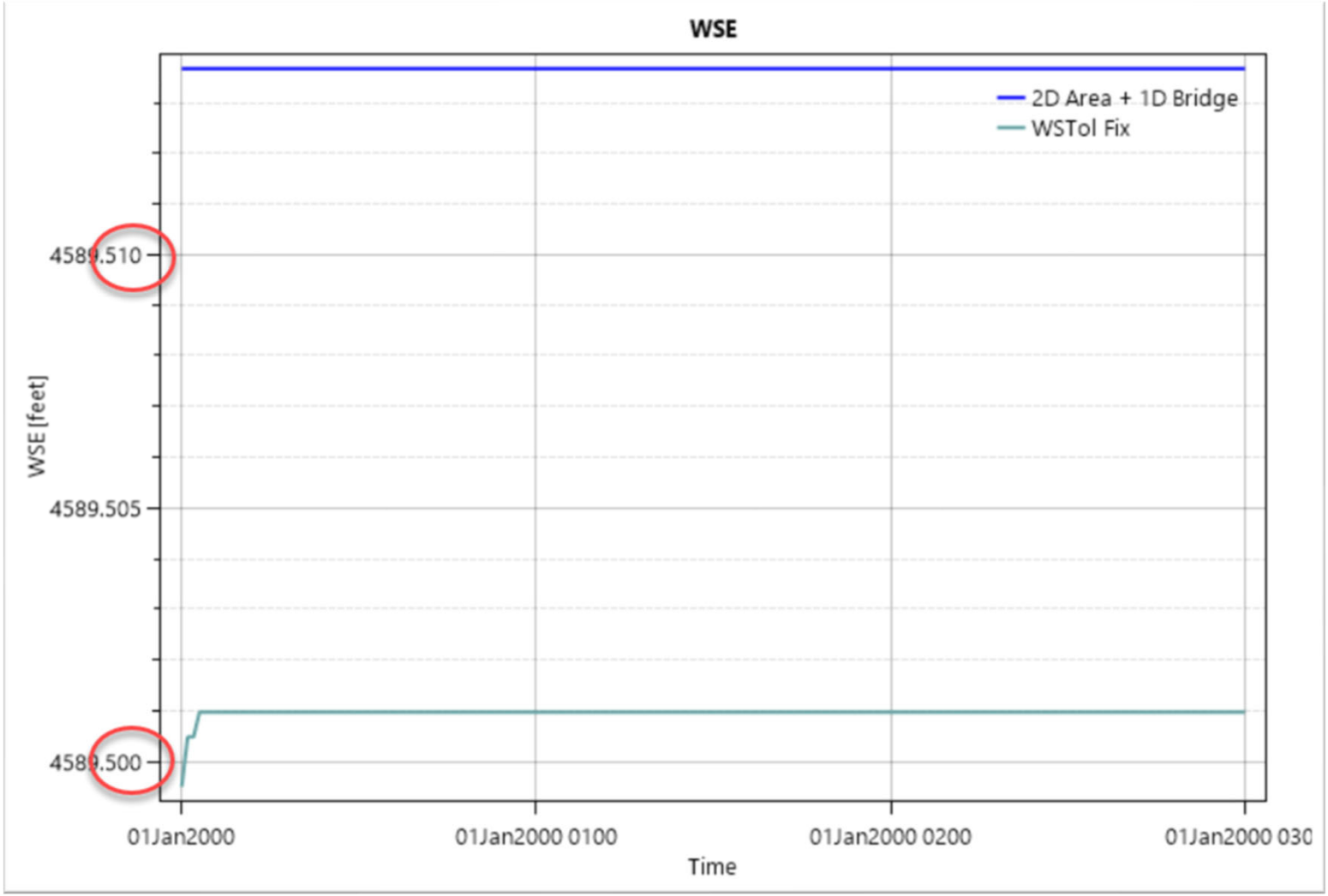
01JAN2000 00:00:30	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:00:40	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:00:50	2DFlowArea	Cell #	2022	4589.43	0.105	20

	Parameter	(Default)	2DFlowArea
1	Theta (0.5-1.0)	1	1
2	Theta Warmup (0.5-1.0)	1	1
3	Water Surface Tolerance [max=0.2](ft)	0.01	0.11
4	Volume Tolerance (ft)	0.01	0.01
5	Maximum Iterations	20	20
6	Equation Set	Diffusion Wave	SWE-ELM (original/faster)

01JAN2000 00:02:00	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:02:10	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:02:20	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:02:30	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:02:40	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:02:50	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:03:00	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:03:10	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:03:20	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:03:30	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:03:40	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:03:50	2DFlowArea	Cell #	2022	4589.43	0.105	20
01JAN2000 00:04:00	2DFlowArea	Cell #	2022	4589.43	0.105	20

- Take care!

WS Elevation Tolerance – Evaluate Results



Internal Hydraulic Structures

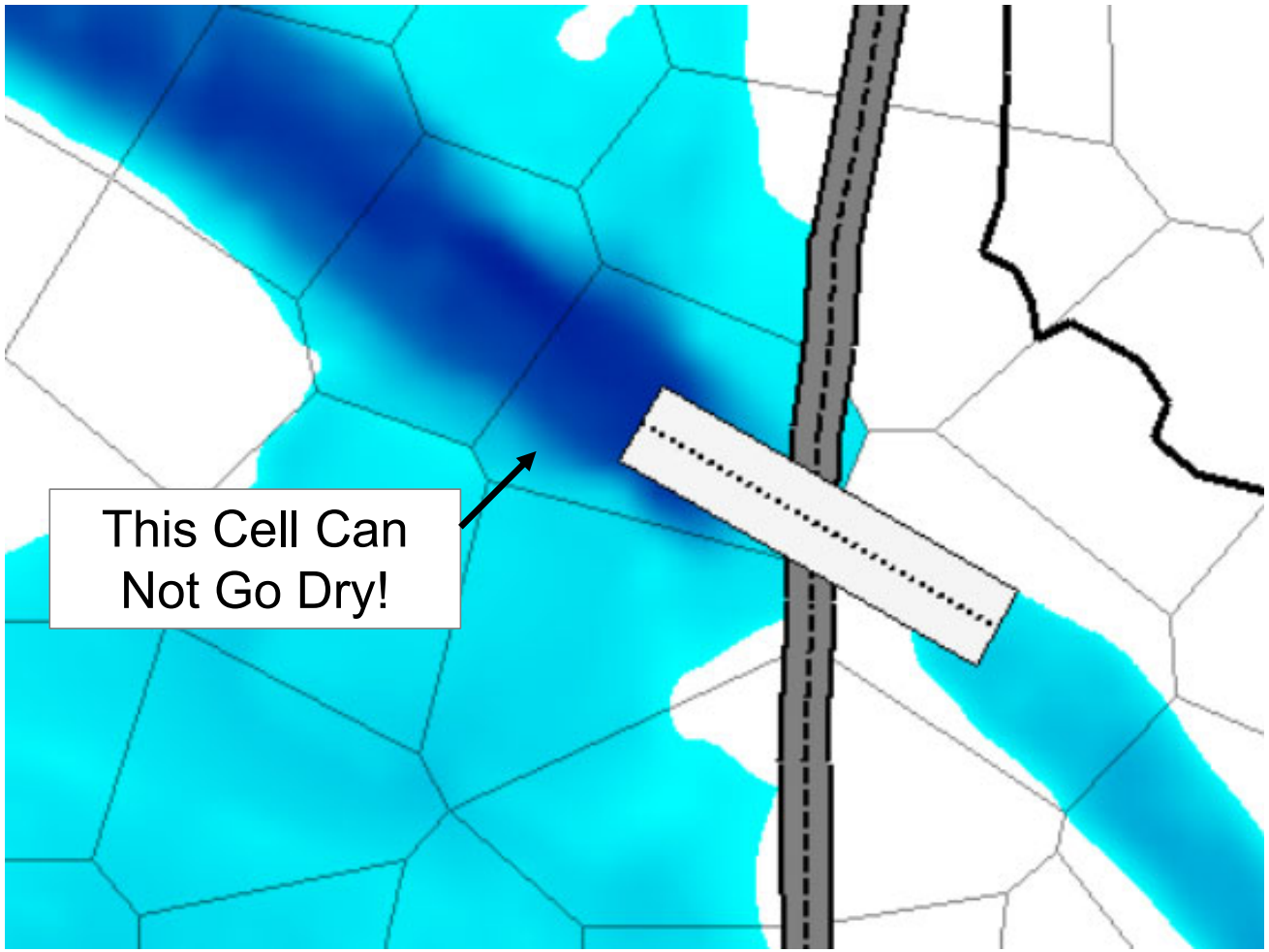
- Too small of cell sizes at invert of culvert or gate.
  - Small cells have less volume
  - Flow/volume for the culvert is computed over the time step as V = Q x DT
- Highly submerged weirs with culverts and gates can have stability issues. “Weir and Gate Flow Submergence decay exponents”
- Flow over the embankment can be computed as weir flow or 2D Flow Equations
  - Use Weir options when the is a high embankment
  - Use 2D flow option for non-weir flow situations

Culverts Modeling Failure Mode

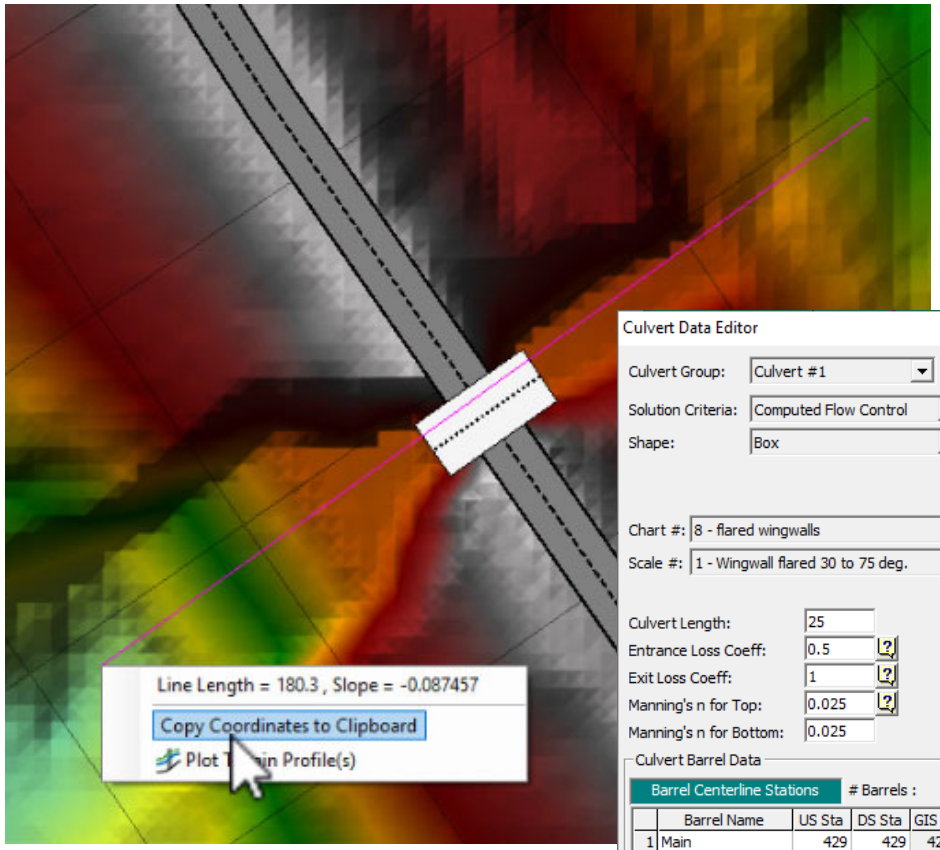
The cell that intersects with the upstream culvert location must be large enough that it will not empty during the time step.

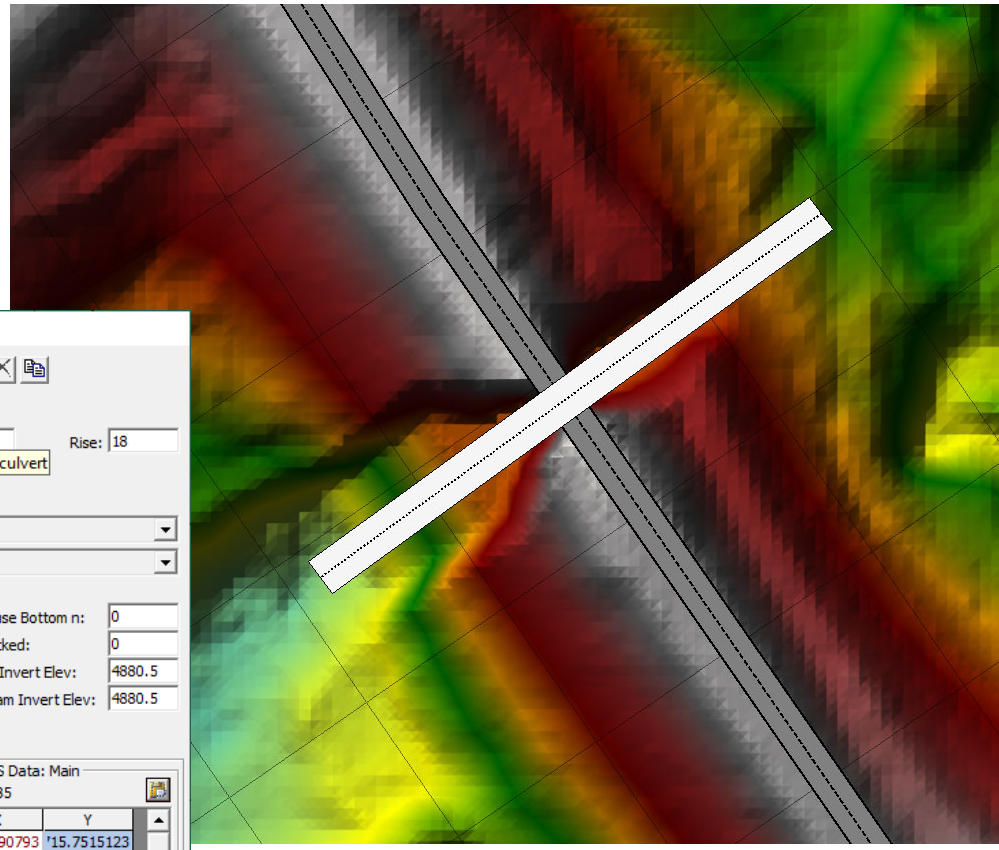
$$Vol_{Cell} > Q_{culvert} * \Delta t$$

Note: Source Cell does not need to be first cell upstream of culvert



Georeference Culvert Inlet/Outlet





Culvert Data Editor

Culvert Group: Culvert #1

Solution Criteria: Computed Flow Control

Shape: Box Span: 12 Rise: 18

span of the culvert

Chart #: 8 - flared wingwalls

Scale #: 1 - Wingwall flared 30 to 75 deg.

Culvert Length:	25	Depth to use Bottom n:	0
Entrance Loss Coeff:	0.5	Depth Blocked:	0
Exit Loss Coeff:	1	Upstream Invert Elev:	4880.5
Manning's n for Top:	0.025	Downstream Invert Elev:	4880.5
Manning's n for Bottom:	0.025		

Culvert Barrel Data

Barrel Centerline Stations # Barrels: 1

	Barrel Name	US Sta	DS Sta	GIS Sta
1	Main	429	429	429.8
2				
3				
4				
5				

Barrel GIS Data: Main

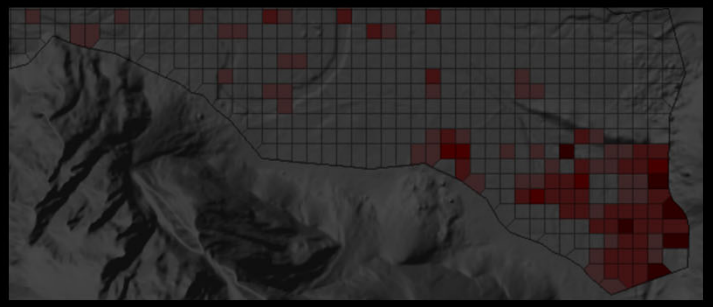
Length: 185

	X	Y
1	9.00490793	15.7515123
2	69.3127226	06.9931182
3		
4		
5		

Individual Barrel Centerlines ... Show on Map OK Cancel Help

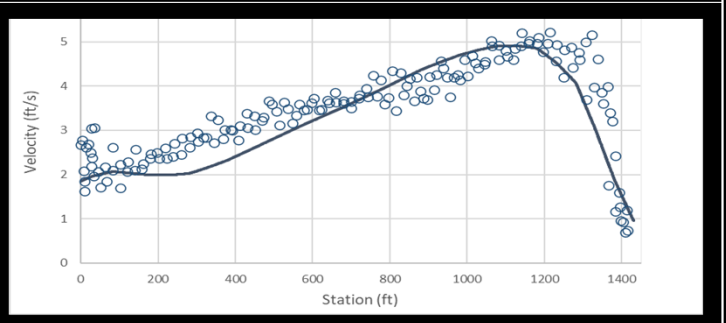
2D Hydraulic Stability Issues

Diagnostic Tools

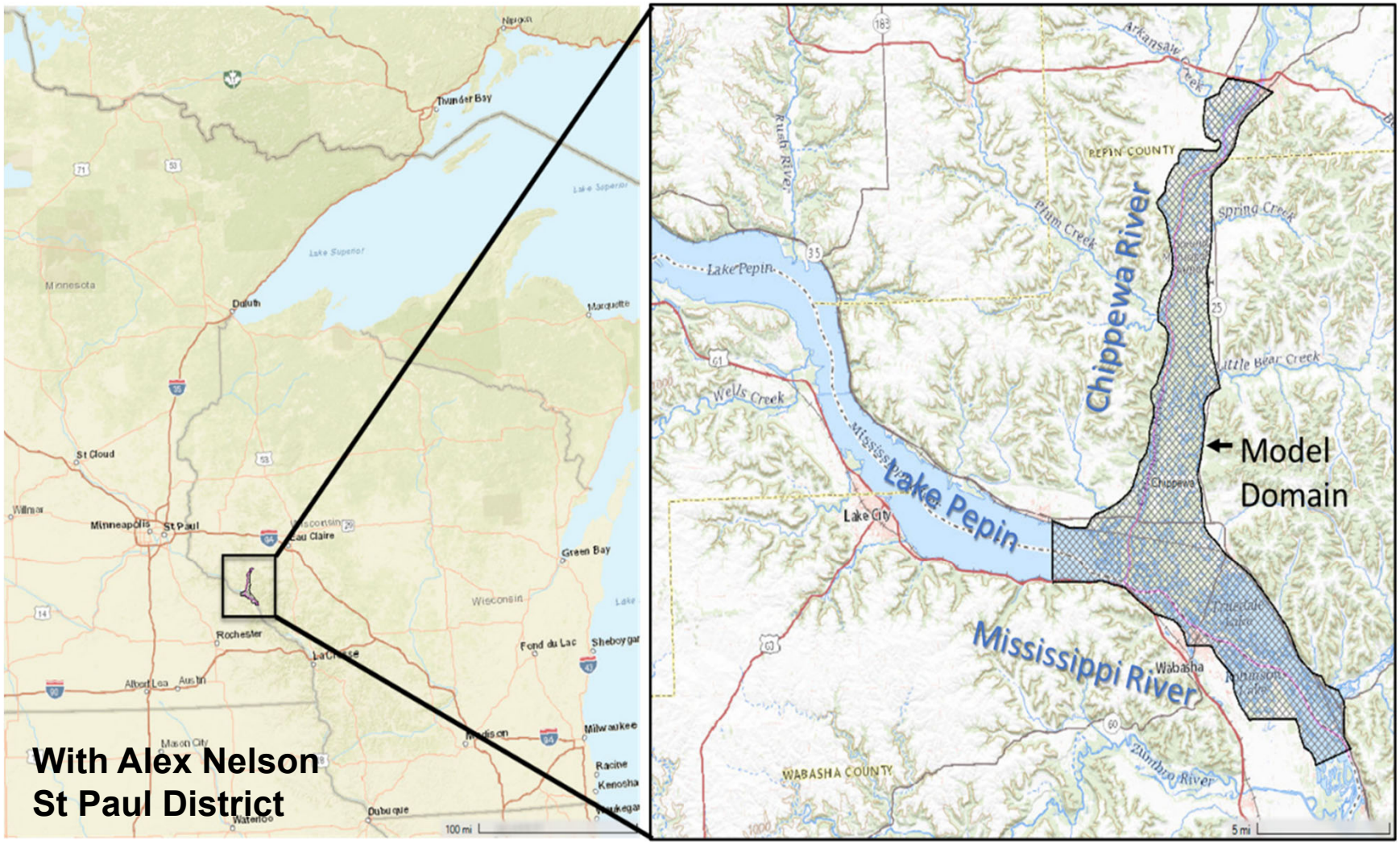


Common Errors

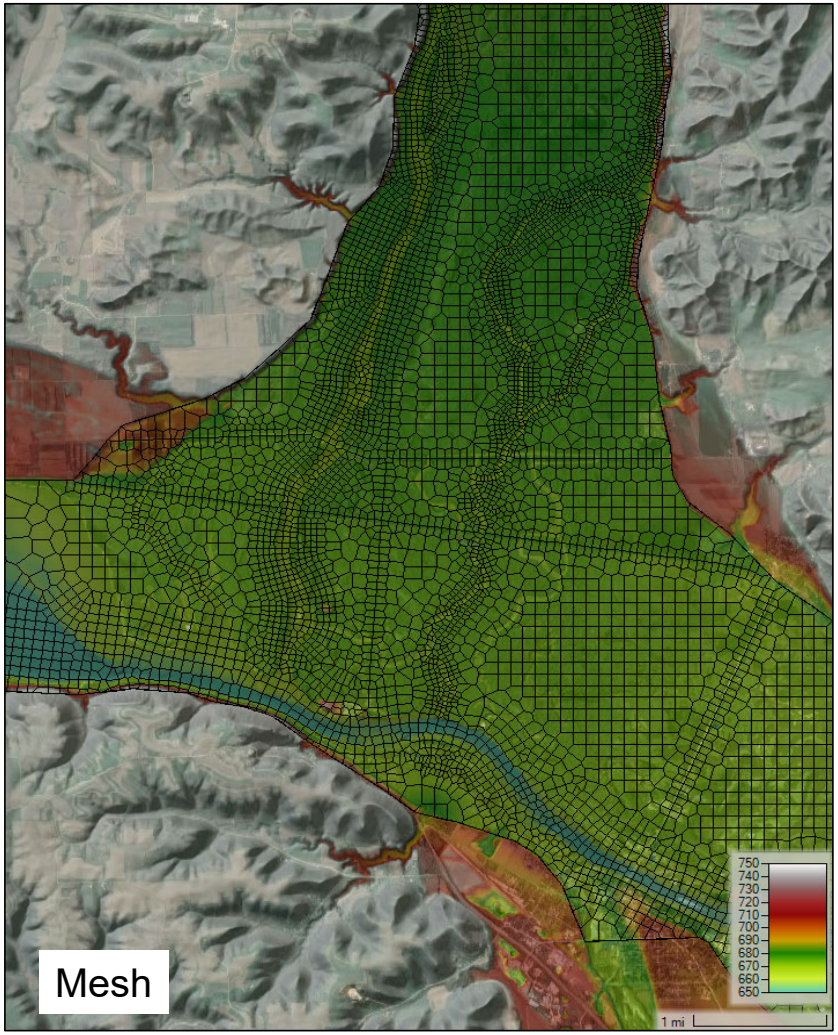
2D Calibration

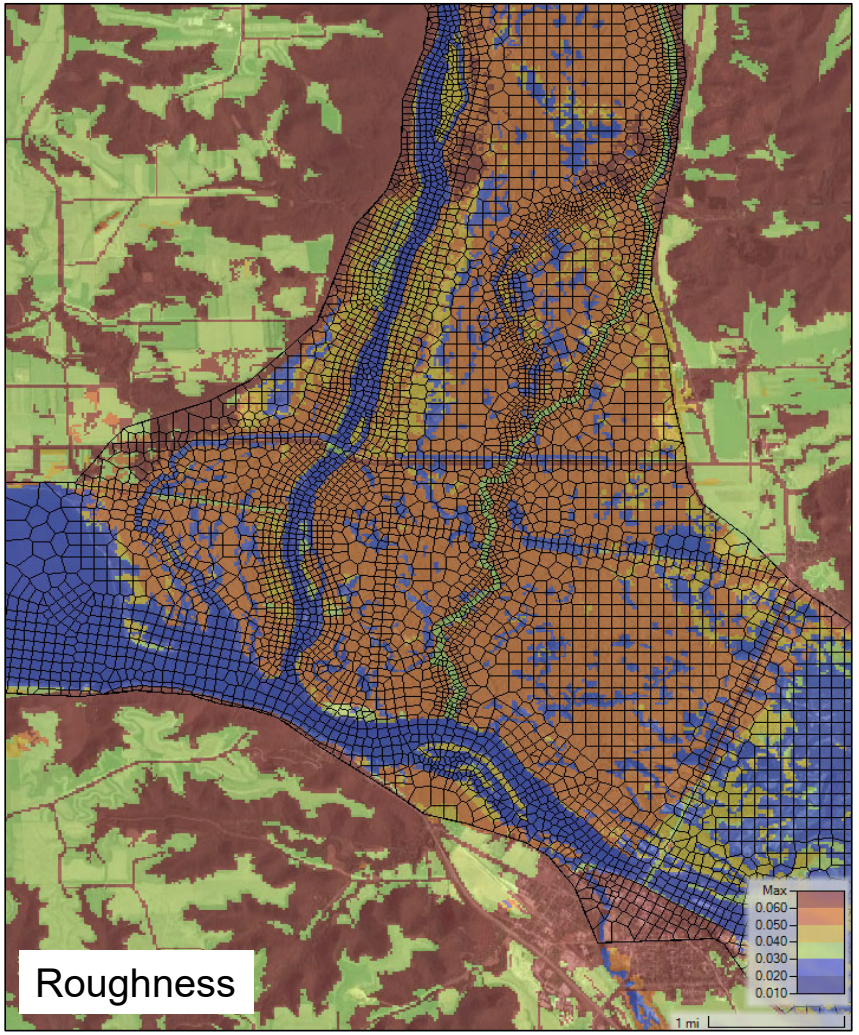


Chippewa River, Wisconsin

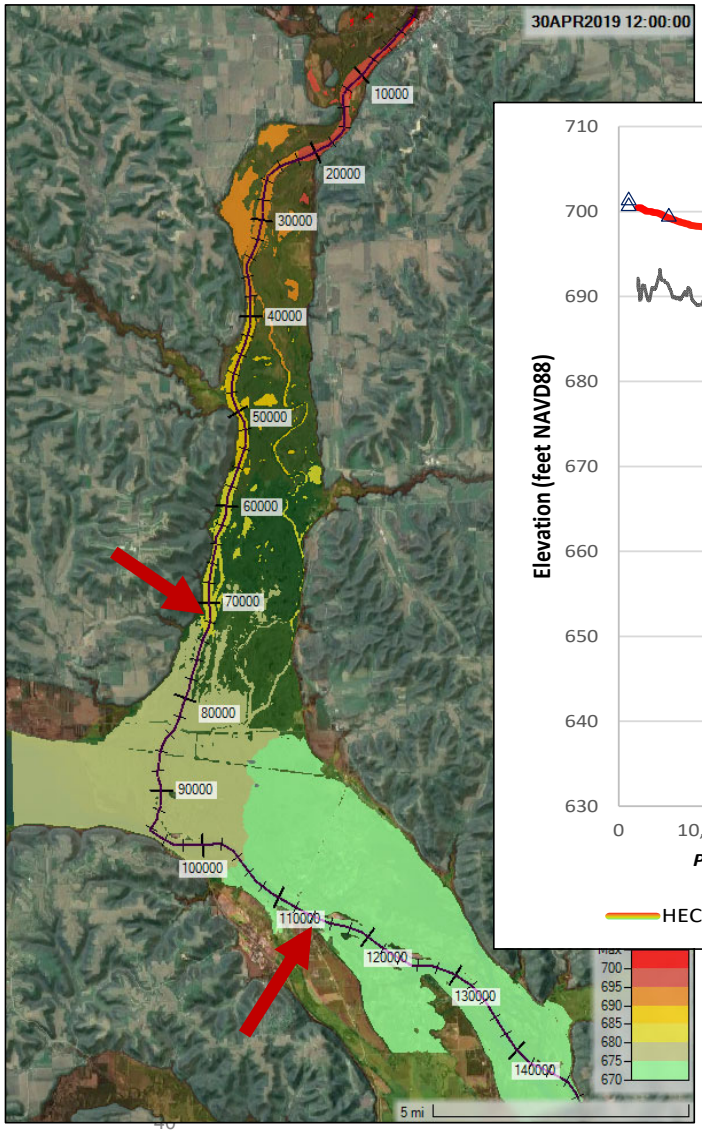


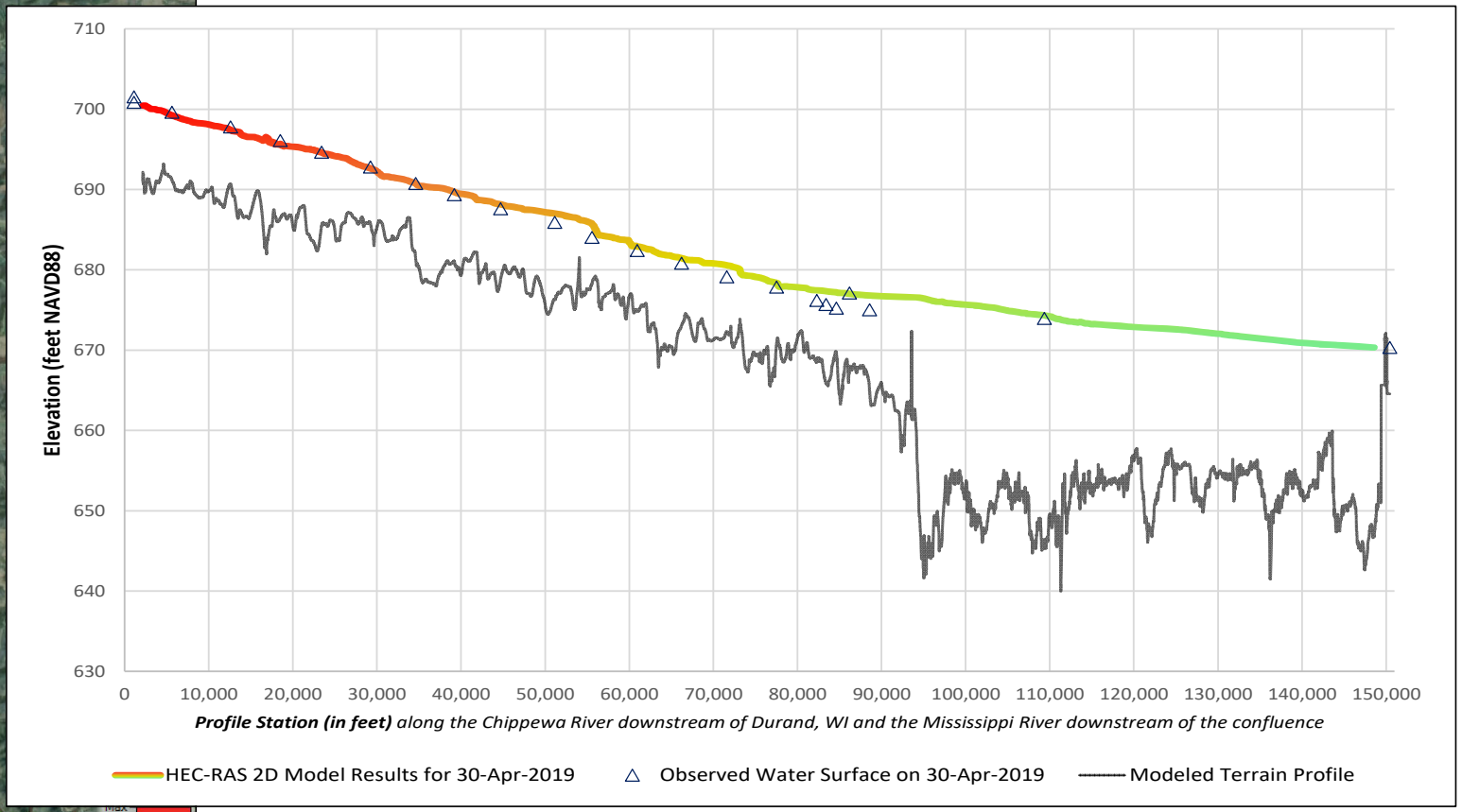
Chippewa River, Wisconsin





One-Dimensionalized Calibration

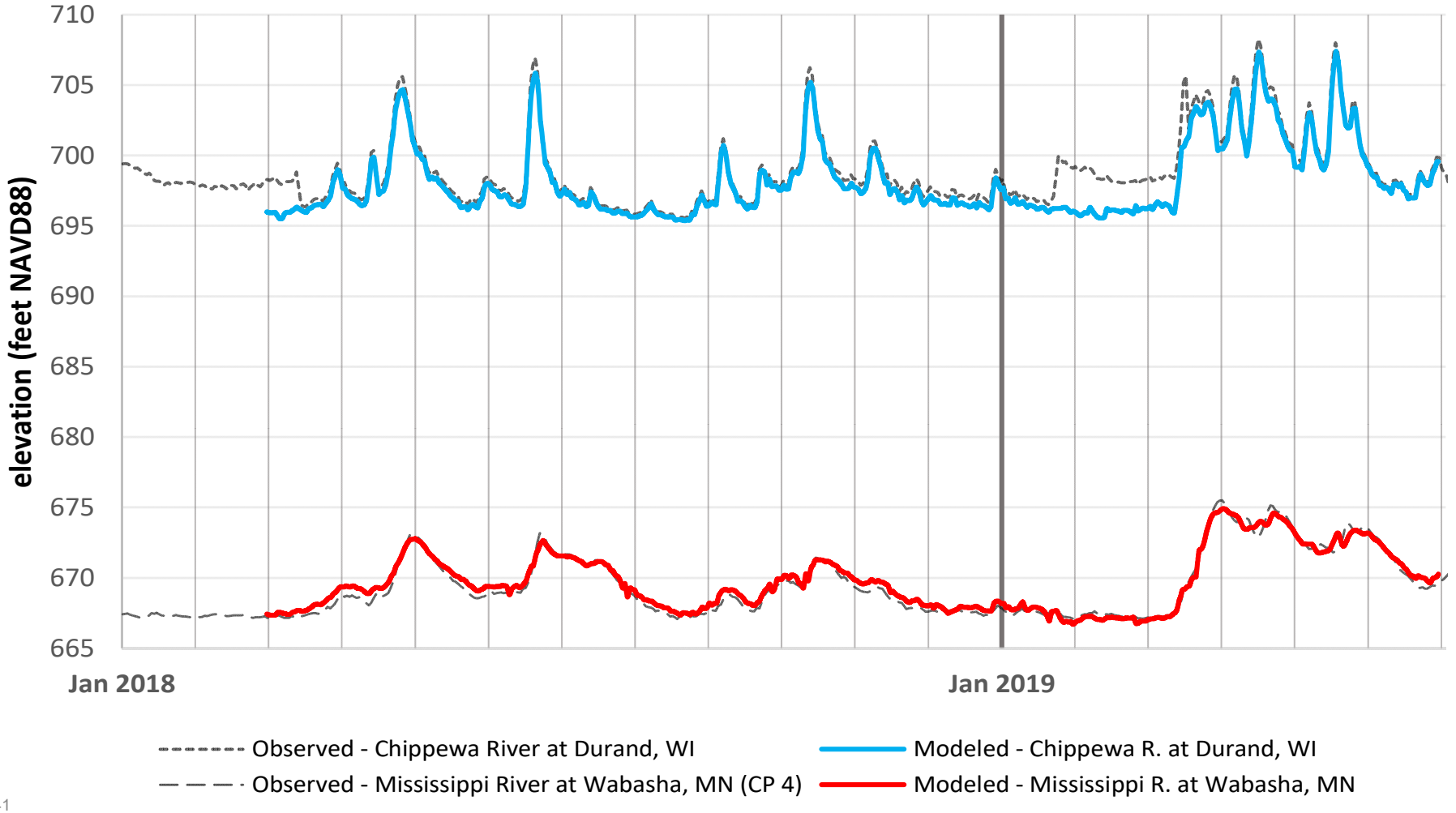




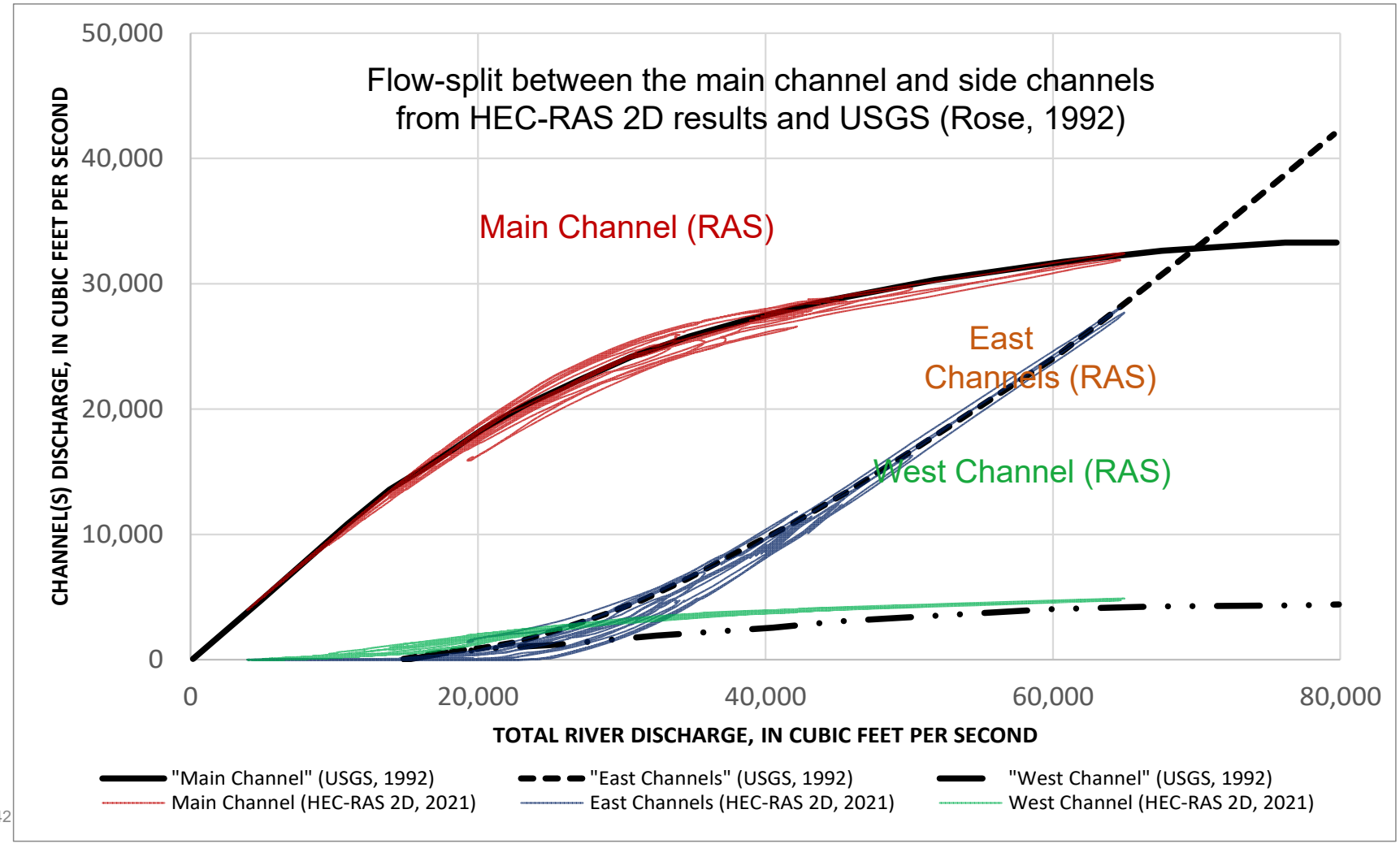
Hydraulic calibration by Alex Nelson (MVP)

Hydraulic calibration by
Alex Nelson (MVP)

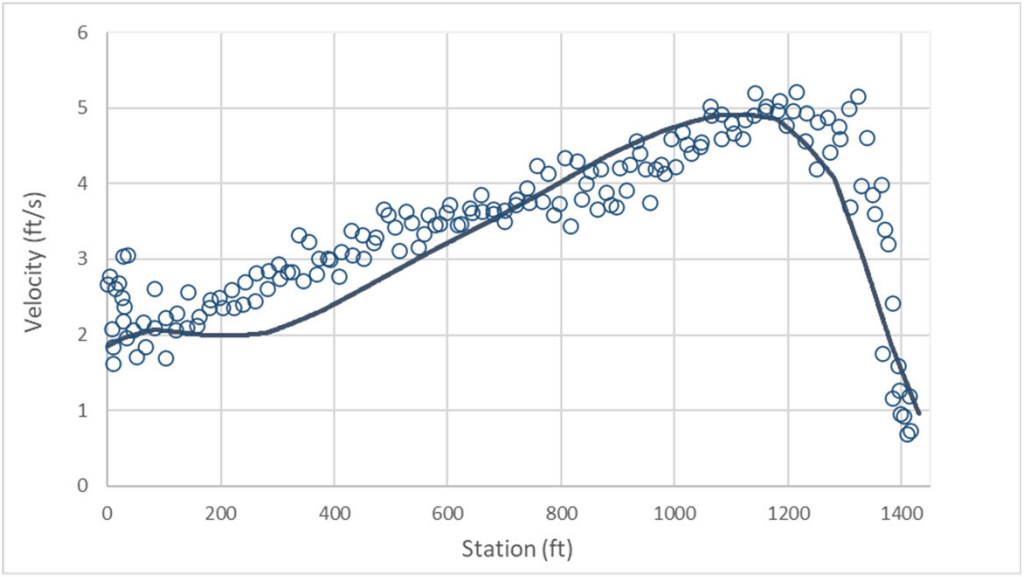
2D Calibration Cont…

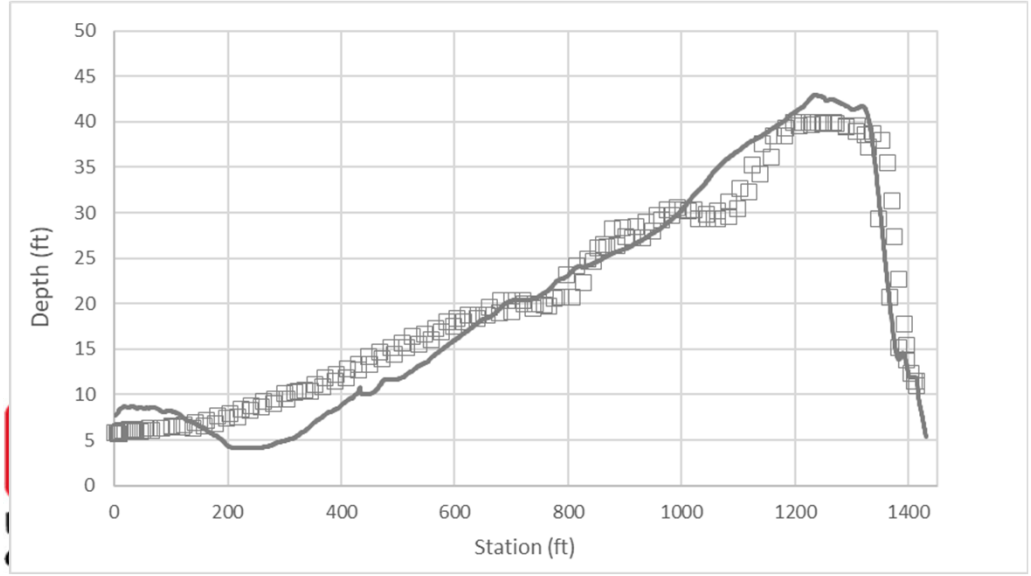


2D Hydraulic Calibration Cont…



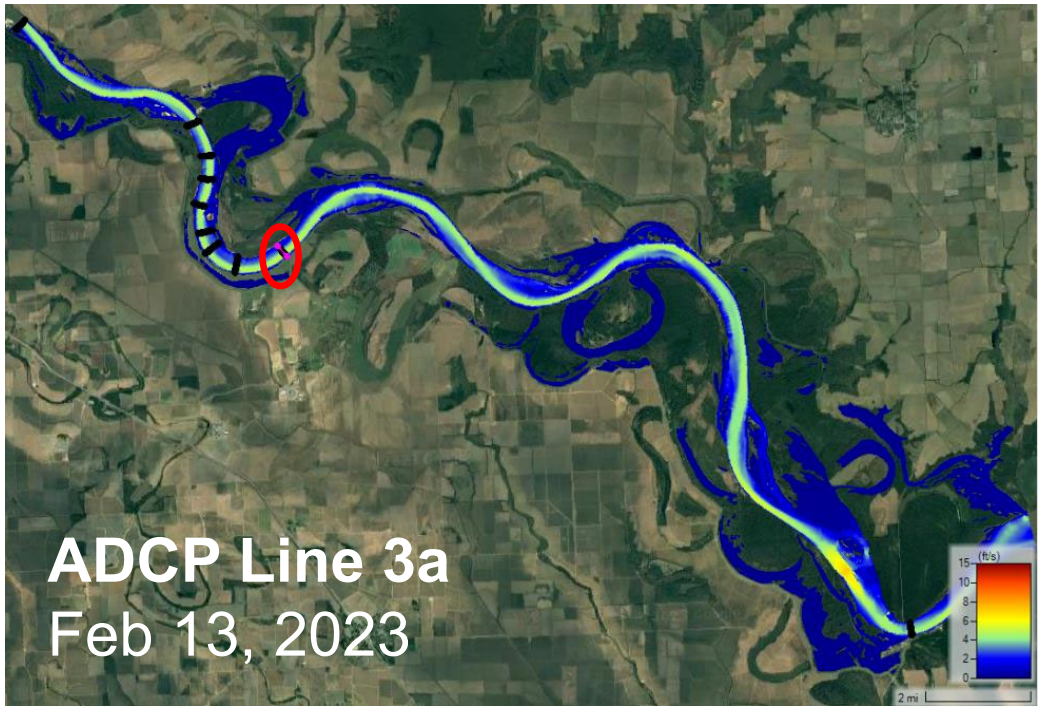
Hydraulic Calibration by Alex Nelson (MVP)





But a Lateral Depth and Velocity Calibration Can Improve Your 2D Model Performance Substantially

ID	Date	GMT	CMT	Flow (cfs)
P_2010	2\13\2023	18:12:53	13:12:53	115835
P_2011	2\13\2023	18:16:58	13:16:58	115237.2



2D Hydraulic Calibration

New tools in HEC-RAS 6.6 – **Reference Locations**

Documentation in **Mapper Users Manual > Geometry Data > Reference Locations**

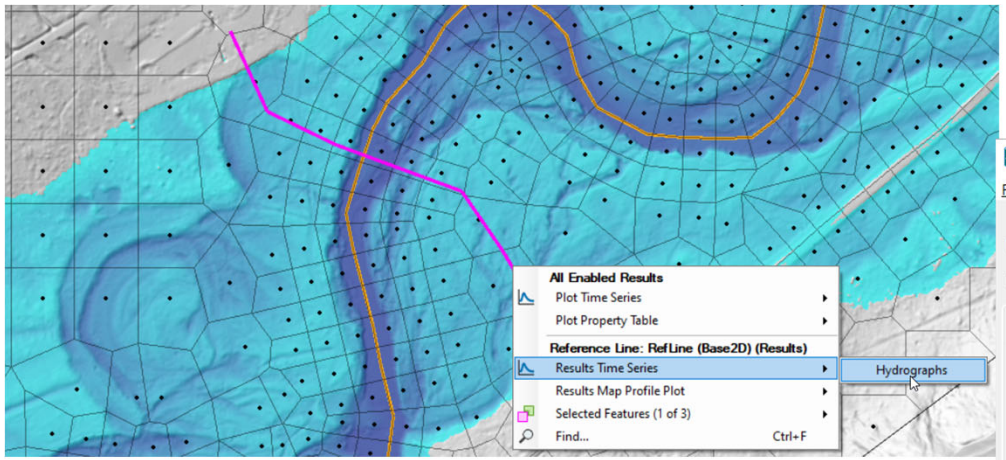
- **Reference Points** Observed Stage and High Water Mark Data
- **Reference Lines** Observed Stage, Observed Flow, Rating Curve, and High Water Mark Data
- **Reference Areas** Can be used to evaluate Flow In, Flow Out, and Volume for the specified area.

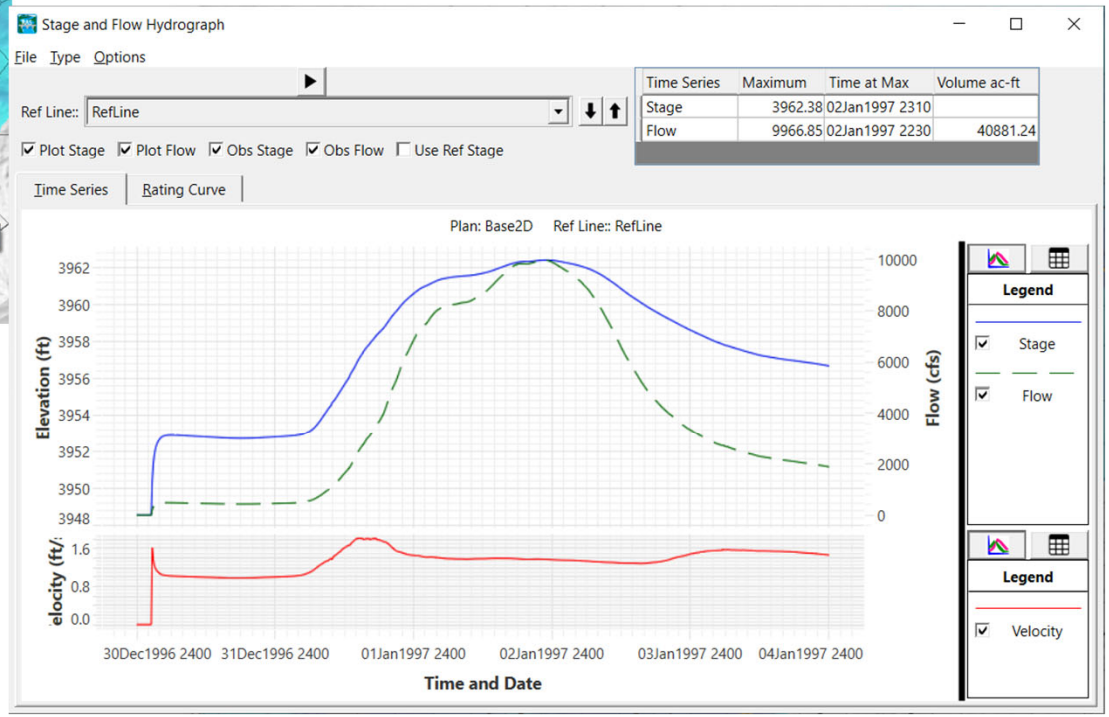
Reference Points, Lines, and Areas must be created in RAS Mapper prior to simulation. Results are computed during run-time based on the cells and cell faces contained within the Reference Points, Lines, and Areas.

Currently, Reference Points, Lines, and Areas are only supported for single 2D Flow Areas or 1D area - they can NOT overlap multiple areas

2D Hydraulic Calibration

Once data has been created in RAS Mapper, reference locations can be used to specify **Observed Data** tab from the **Unsteady Flow Data editor**





2D Hydraulic Calibration

Note: Calibrate to your final equation. Don't calibrate to DW if you will need SWE