

Common 2D Model Stability Problems Troubleshooting Strategies

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2D Flow Area Stability Issues

- Cell size and time step
- Diagnostic Tools
- Flood wave wetting front
- Weird shaped/small cells
- Channel Alignment/cell size
- Partial cell wetting
- Internal hydraulic structures



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)



Iterations



HEC-RAS Computations

Write Geometry Information
Layer: COMPLETE

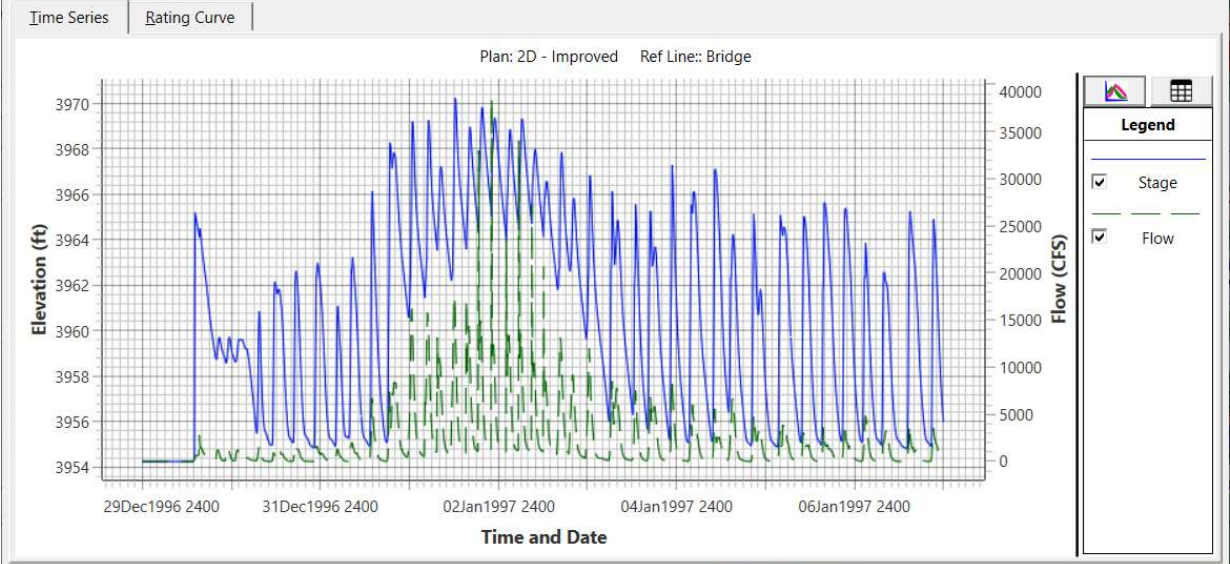
Geometry Processor
River: RS:
Reach: Node Type:
IB Curve: Finished

Unsteady Flow Simulation
Simulation:
Time: 24.7500 02JAN1999 12:45:00 Iteration (1D): Iteration (2D): 21
Unsteady Flow Computations



| | Time at Max | Volume ac-ft |
|------|-------------------------|--------------|
| Flow | 7 02Jan1997 1220 | |
| | 38618.02 02Jan1997 2210 | 37090.87 |

Plot Stage Plot Flow Obs Stage: Obs Flow Use Ref Stage





Iterations.... Investigation

- Ctrl+F (Find a Cell)

| | | | | | | |
|-------------------|-------------|--------|-------|--------|-------|----|
| 1JAN1999 23:24:30 | BaldEagleCr | Cell # | 23070 | 591.23 | 0.222 | 21 |
| 1JAN1999 23:25:00 | BaldEagleCr | Cell # | 23070 | 590.53 | 0.703 | 22 |
| 1JAN1999 23:25:30 | BaldEagleCr | Cell # | 23070 | 590.80 | 0.667 | 20 |
| 1JAN1999 23:26:00 | BaldEagleCr | Cell # | 23070 | 591.77 | 0.972 | 20 |
| 1JAN1999 23:26:30 | BaldEagleCr | Cell # | 23070 | 589.20 | 2.566 | 22 |
| 1JAN1999 23:27:00 | BaldEagleCr | Cell # | 23070 | 589.27 | 3.414 | 22 |
| 1JAN1999 23:27:30 | BaldEagleCr | Cell # | 23070 | 592.73 | 3.288 | 20 |
| 1JAN1999 23:28:00 | BaldEagleCr | Cell # | 23070 | 590.16 | 1.100 | 21 |
| 1JAN1999 23:28:30 | BaldEagleCr | Cell # | 23070 | 592.53 | 2.369 | 22 |
| 1JAN1999 23:29:00 | BaldEagleCr | Cell # | 23070 | 590.61 | 0.826 | 21 |
| 1JAN1999 23:29:30 | BaldEagleCr | Cell # | 23070 | 591.91 | 1.292 | 21 |
| 1JAN1999 23:30:00 | BaldEagleCr | Cell # | 23070 | 590.82 | 0.453 | 21 |
| 1JAN1999 23:30:30 | BaldEagleCr | Cell # | 23070 | 591.58 | 0.763 | 22 |
| 1JAN1999 23:31:00 | BaldEagleCr | Cell # | 23070 | 591.10 | 0.016 | 21 |
| 1JAN1999 23:33:00 | BaldEagleCr | Cell # | 23070 | 591.09 | 0.020 | 21 |
| 1JAN1999 23:33:30 | BaldEagleCr | Cell # | 23070 | 591.04 | 0.068 | 20 |
| 1JAN1999 23:34:00 | BaldEagleCr | Cell # | 21530 | 561.17 | 0.031 | 21 |
| 1JAN1999 23:34:30 | BaldEagleCr | Cell # | 23070 | 590.99 | 0.109 | 21 |
| 1JAN1999 23:35:00 | BaldEagleCr | Cell # | 23070 | 591.34 | 0.347 | 21 |
| 1JAN1999 23:35:30 | BaldEagleCr | Cell # | 23070 | 591.10 | 0.038 | 20 |
| 1JAN1999 23:36:00 | BaldEagleCr | Cell # | 21531 | 561.18 | 0.115 | 21 |
| 1JAN1999 23:36:30 | BaldEagleCr | Cell # | 23070 | 591.29 | 0.274 | 21 |

RAS Mapper

File Project Tools Help

Selected Layer: Perimeters

- SA-2D Det Brch
 - Event Conditions
 - Geometry
 - Depth (01JAN1999 12:00:00)
 - Velocity (01JAN1999 12:00:00)
 - WSE (01JAN1999 12:00:00)
- 2D with Bridges
 - Event Conditions
 - Geometry
 - Depth (01JAN1999 12:00:00)
 - Velocity (04JAN1999 12:00:00)
 - WSE (04JAN1999 12:00:00)
- Single 2D Bridges FEQ
 - Event Conditions
 - Geometry
 - Cross Sections
 - 2D Flow Areas
 - Perimeters
 - Computation Points
 - Breaklines
 - Refinement Regions

Find...

Feature: BaldEagleCr Sub-Feature: Cell Index: 23070

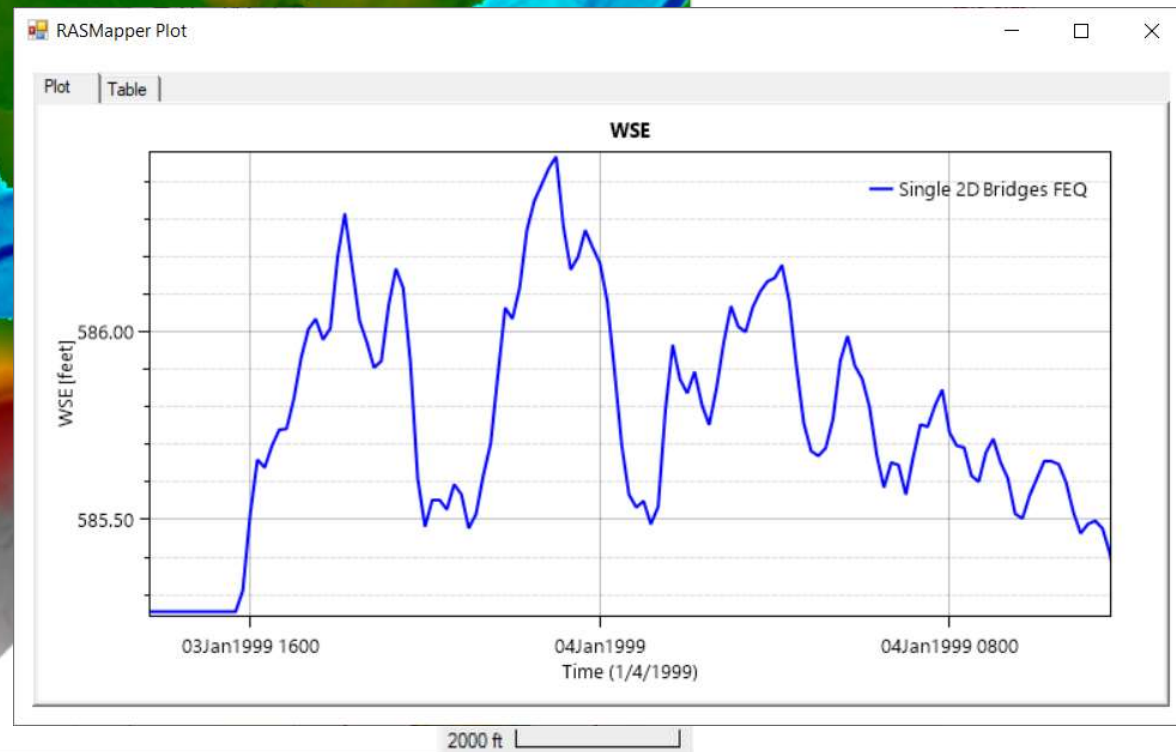
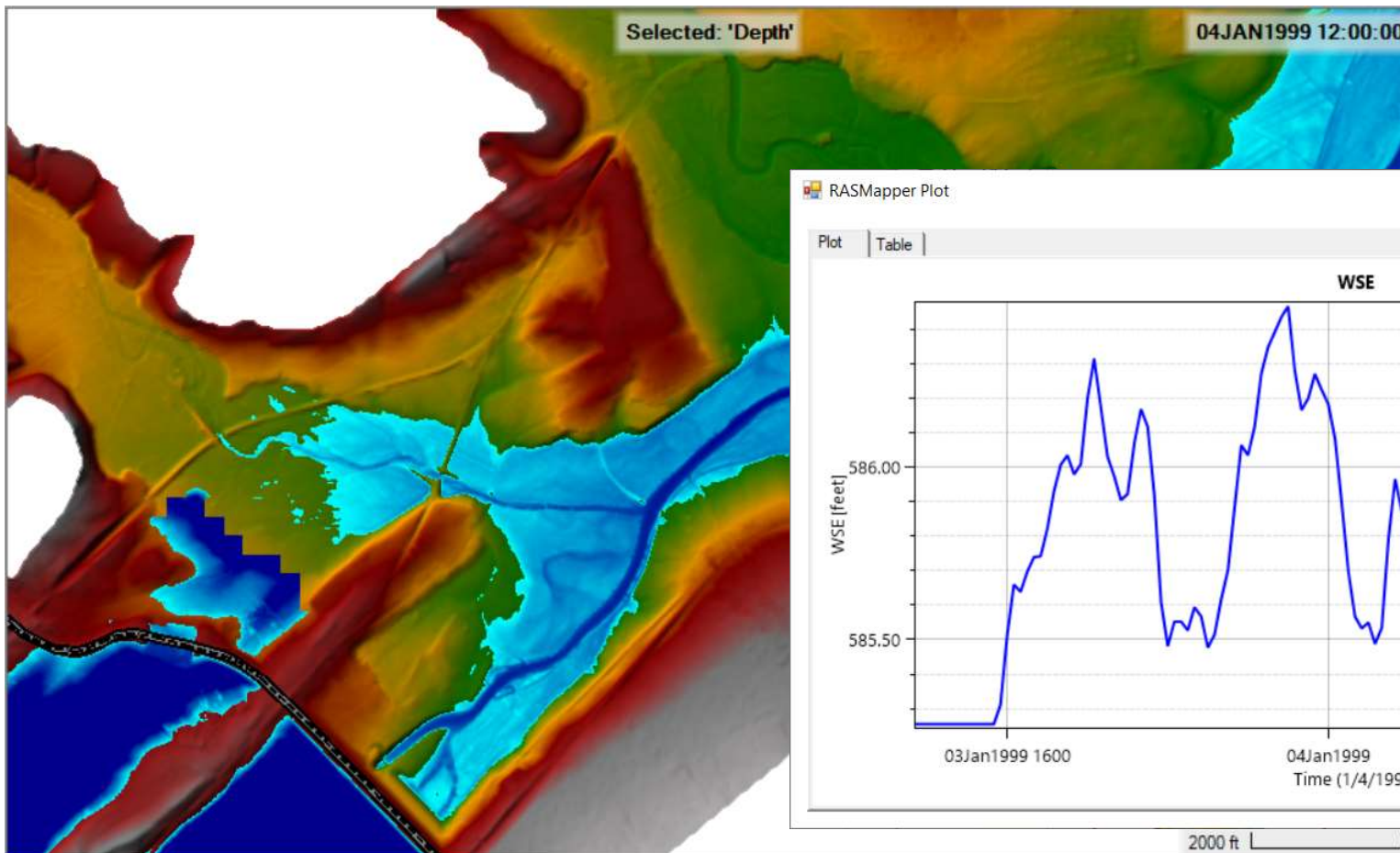
Messages Views Profile Lines Active Features Lay

(2012105.34, 319493.12 1 pixel = 8.73 ft)

1000 ft

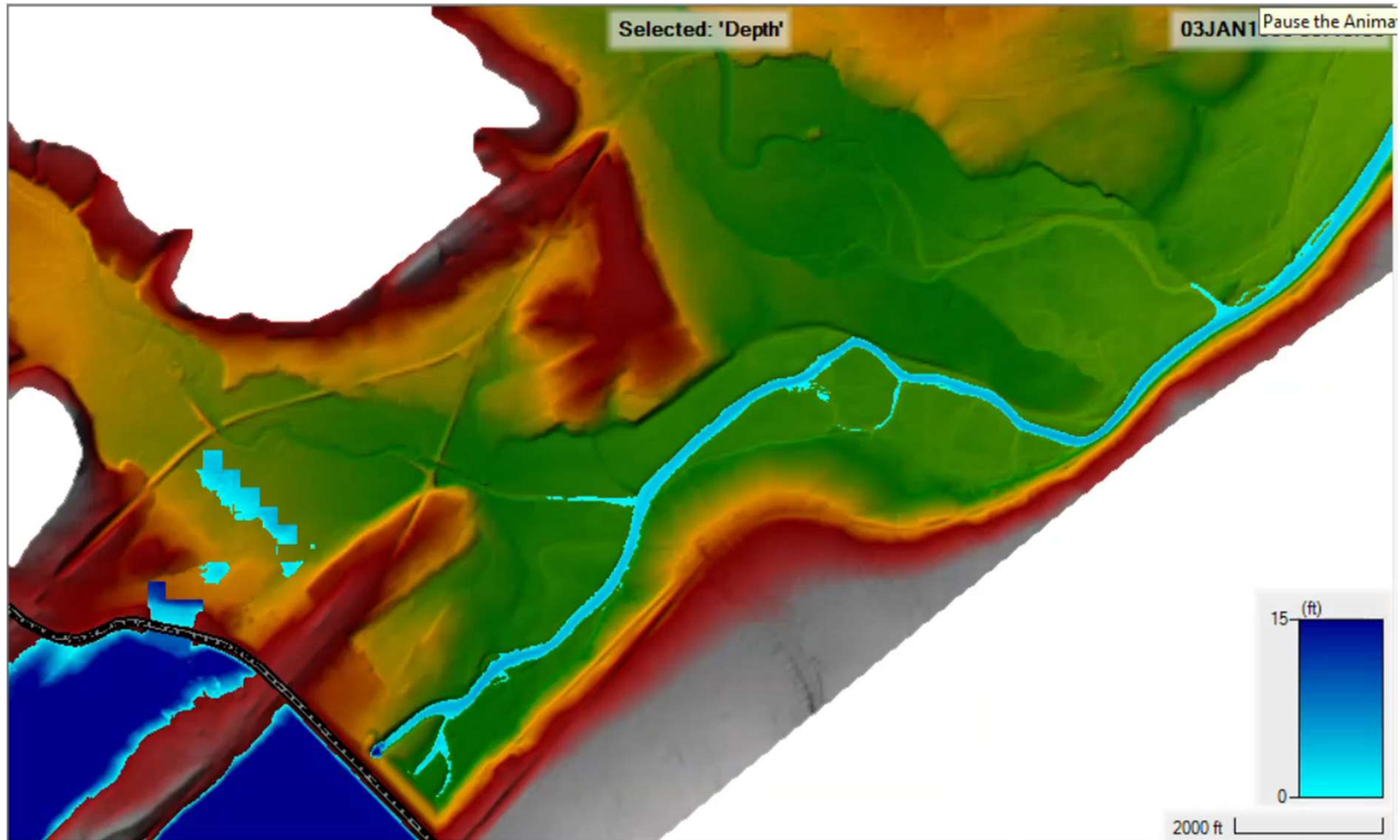


RAS Mapper Visualization



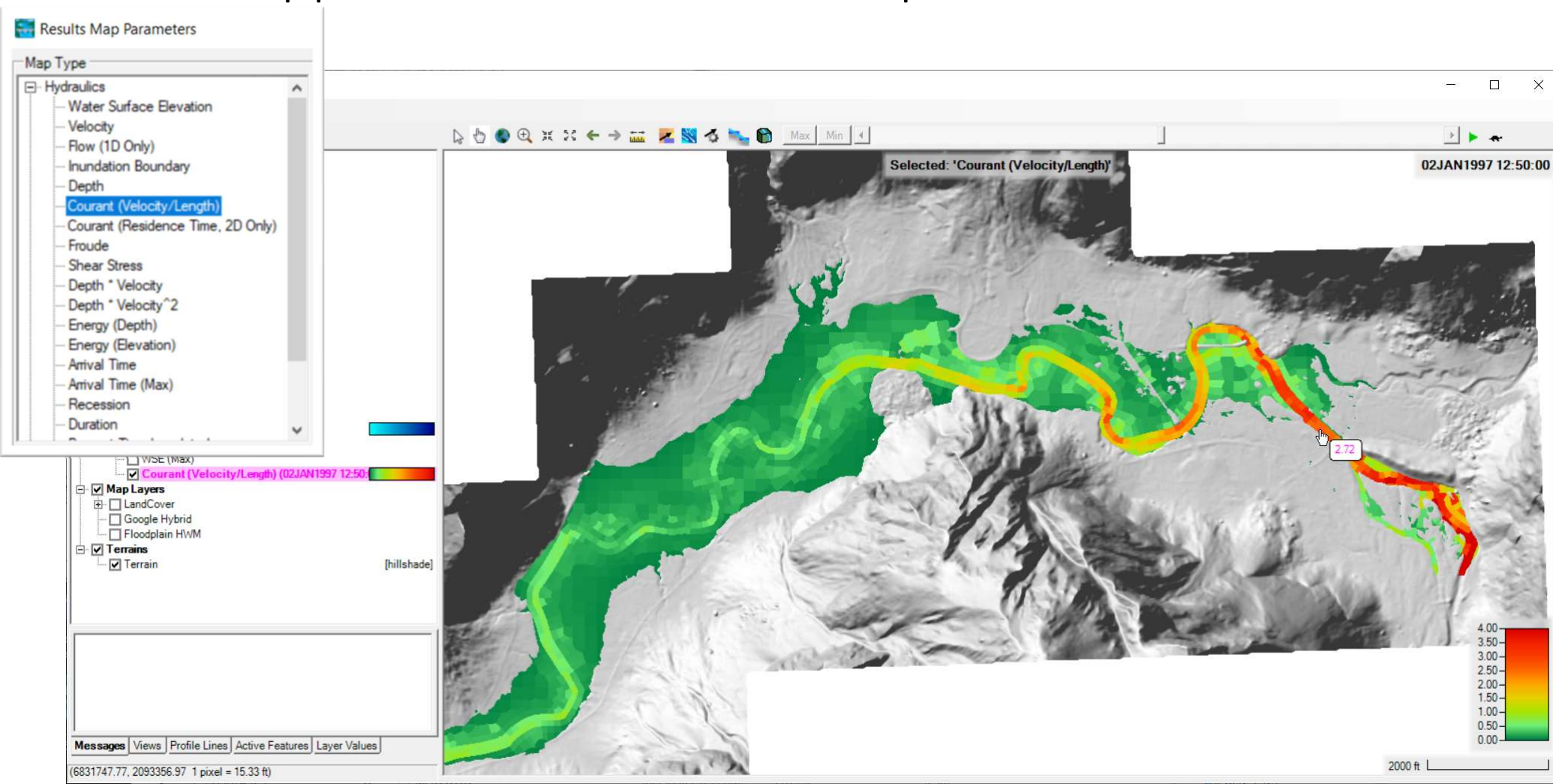


Model Instability





RAS Mapper Courant Number Map





Volume Accounting Check



Runtime Messages

```

J7JAN1997 15:14:00 2DArea      Cell #      1085      4003.97  0.010  20
J7JAN1997 15:37:00 2DArea      Cell #      1085      4003.97  0.010  20
J7JAN1997 15:39:00 2DArea      Cell #      1085      4003.97  0.012  20

J7JAN1997 16:06:00 2DArea      Cell #      1085      4003.96  0.010  20
J7JAN1997 16:22:00 2DArea      Cell #      1085      4003.96  0.010  20
J7JAN1997 16:24:00 2DArea      Cell #      1085      4003.96  0.011  20
J7JAN1997 16:39:00 2DArea      Cell #      1085      4003.96  0.010  20

J7JAN1997 16:52:00 2DArea      Cell #      1085      4003.96  0.011  20
J7JAN1997 16:54:00 2DArea      Cell #      1085      4003.96  0.012  20
J7JAN1997 17:28:00 2DArea      Cell #      1085      4003.96  0.010  20
J7JAN1997 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

```



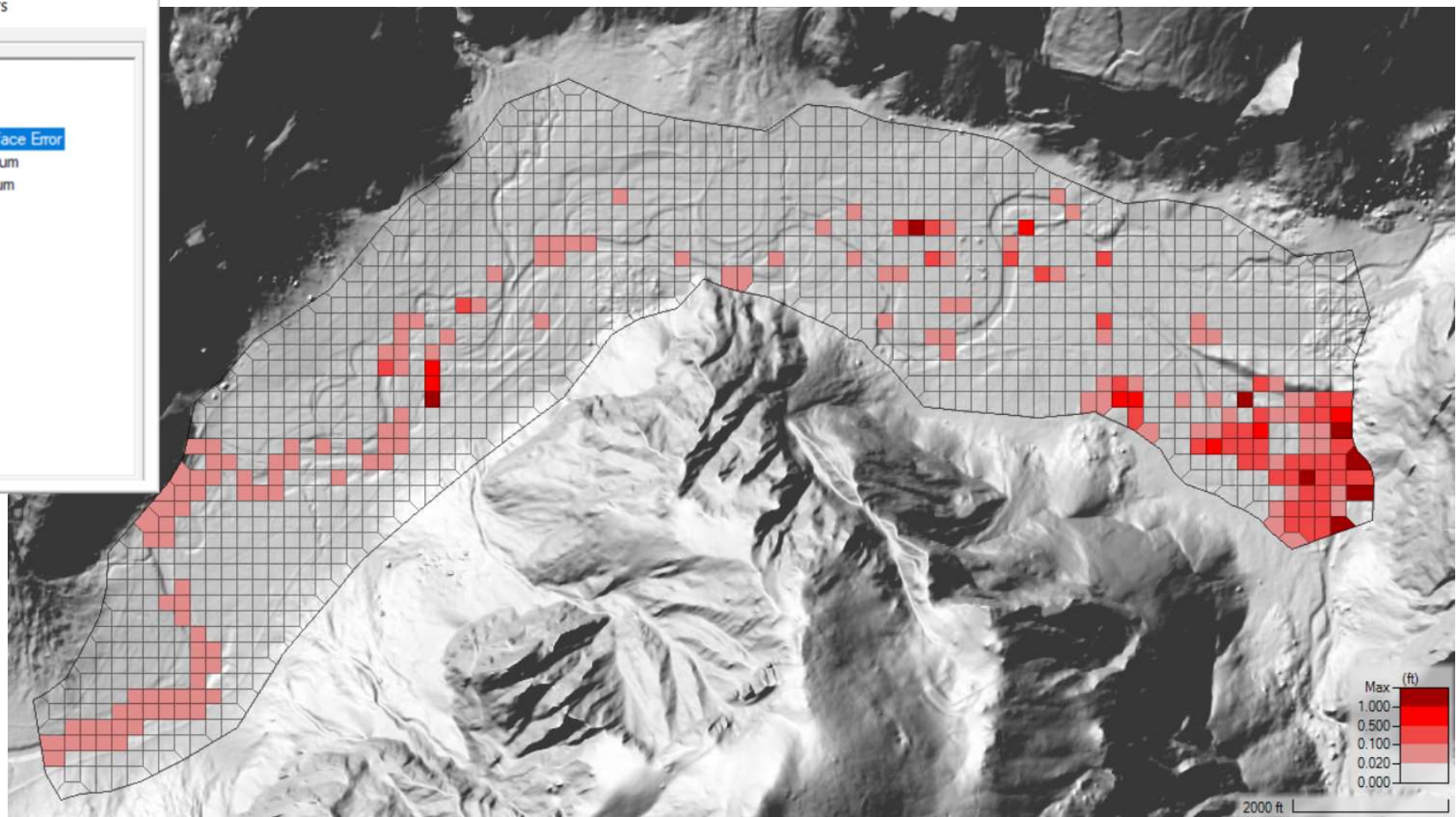
Maximum Water Surface Error



Results Map Parameters

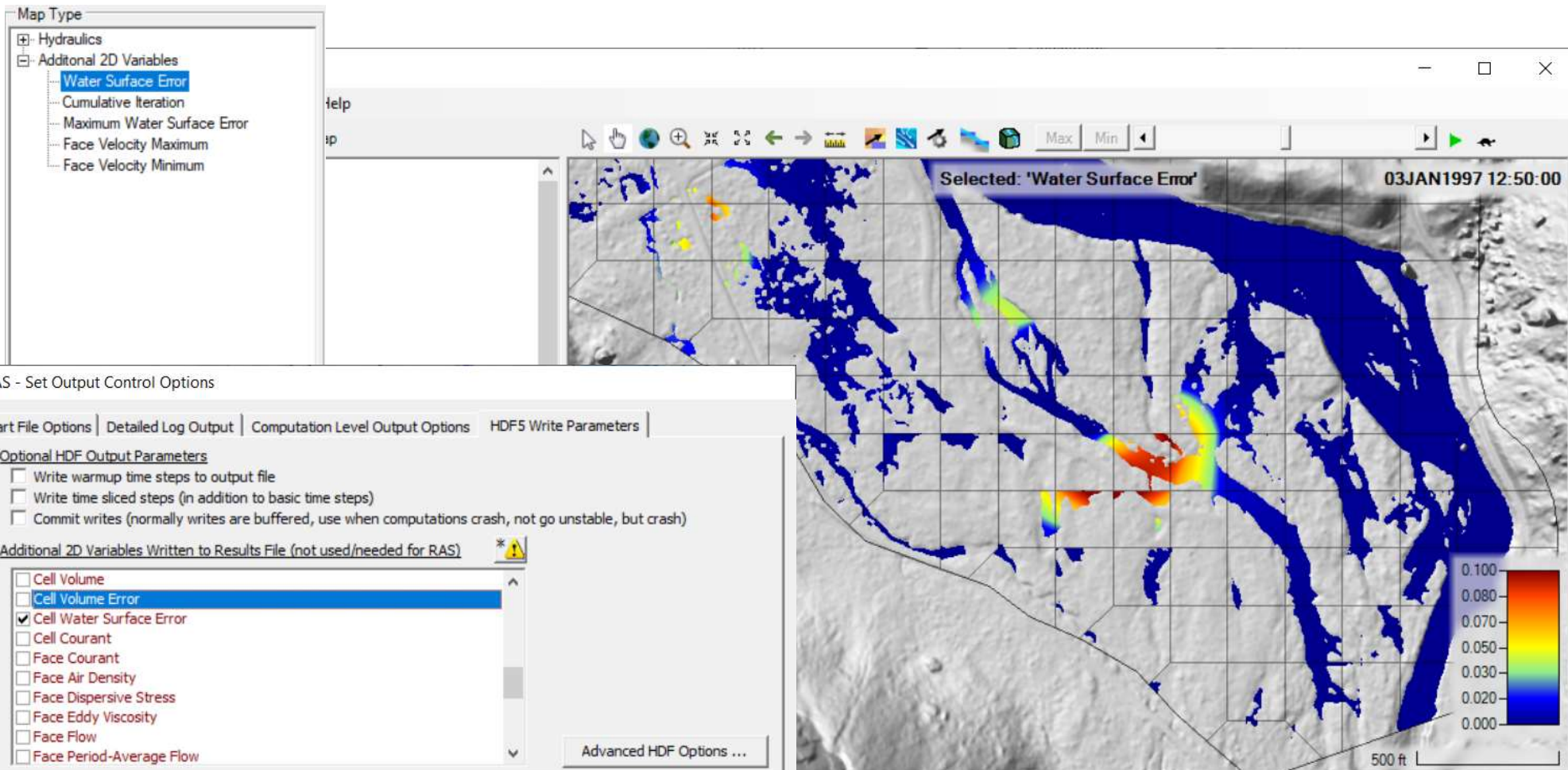
Map Type

- Hydraulics
- Additional 2D Variables
 - Cumulative Iteration
 - Maximum Water Surface Error
 - Face Velocity Maximum
 - Face Velocity Minimum





Cell Water Surface Error (For each time step)



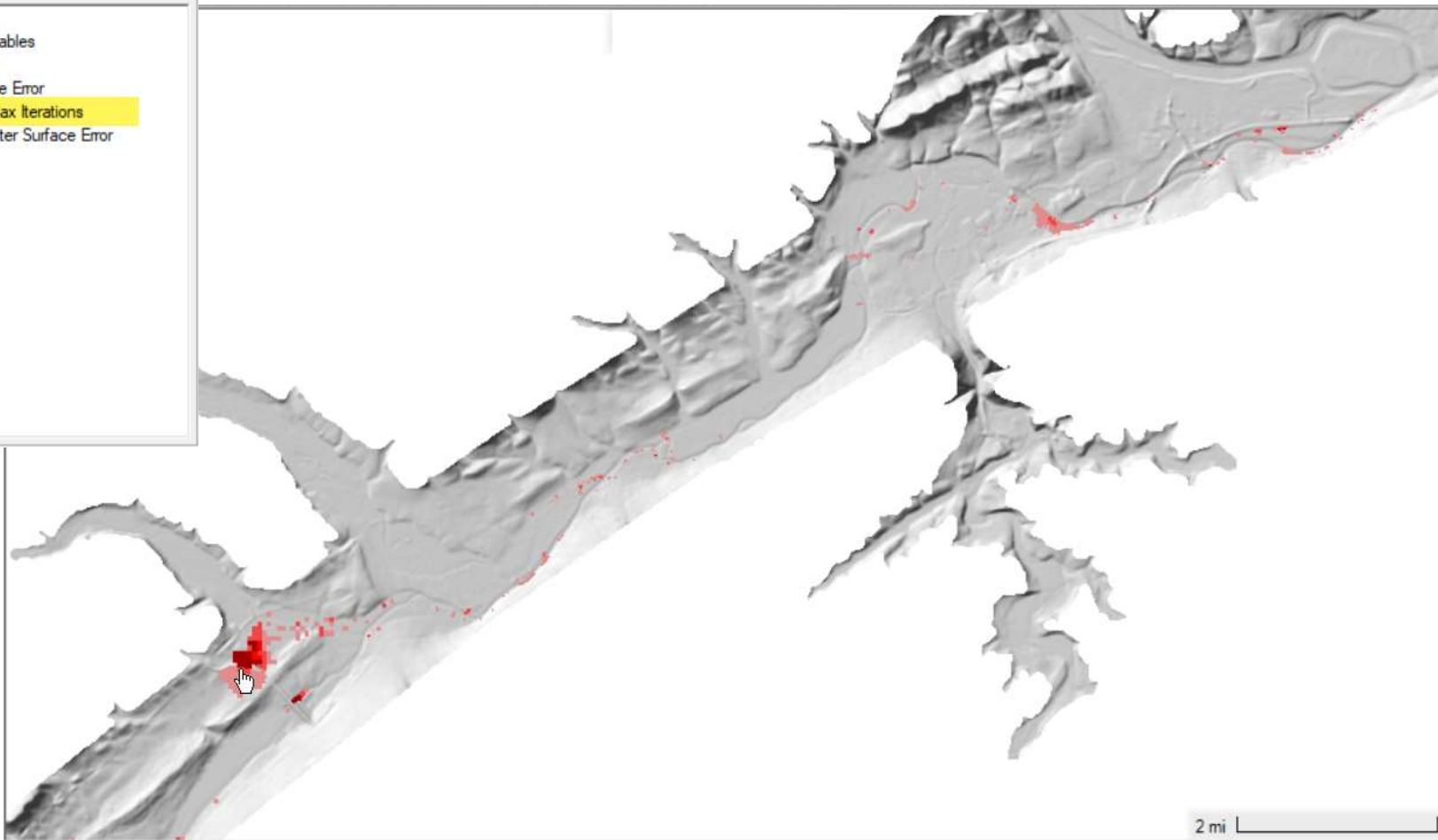


Cumulative Iterations



Map Type

- Hydraulics
- Additional 2D Variables
 - Volume Error
 - Water Surface Error
 - Cumulative Max Iterations
 - Maximum Water Surface Error



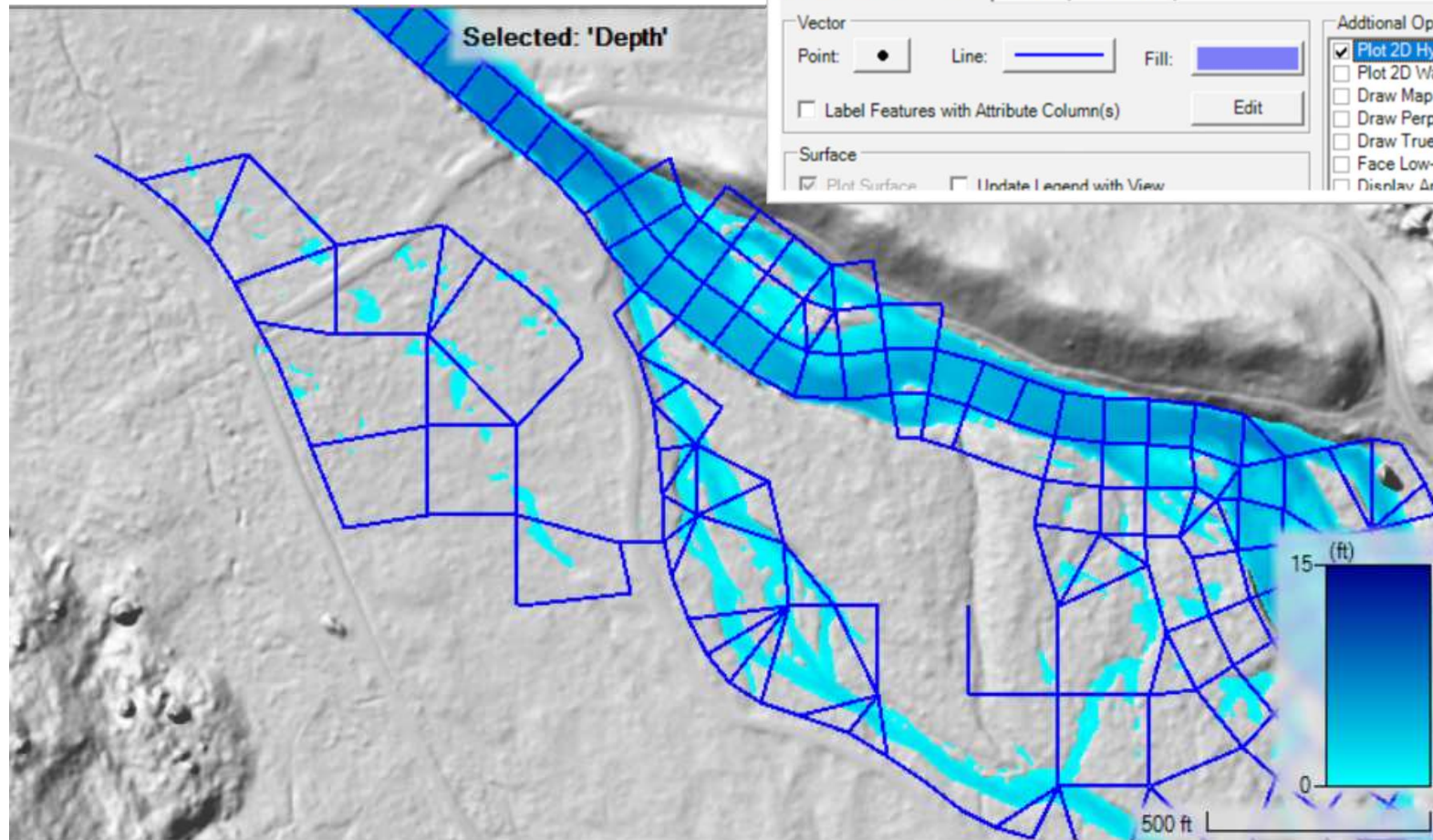


Floodwave Wetting Front

- 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
 - Too large of an elevation change across a single cell – make cells smaller or larger
 - Breaklines for high ground barriers



Hydraulic Connectivity



Depth - Layer Properties

Visualization and Information | Features | Source Files

Vector

Point: Line: Fill:

Label Features with Attribute Column(s)

Surface

Plot Surface Update Legend with View

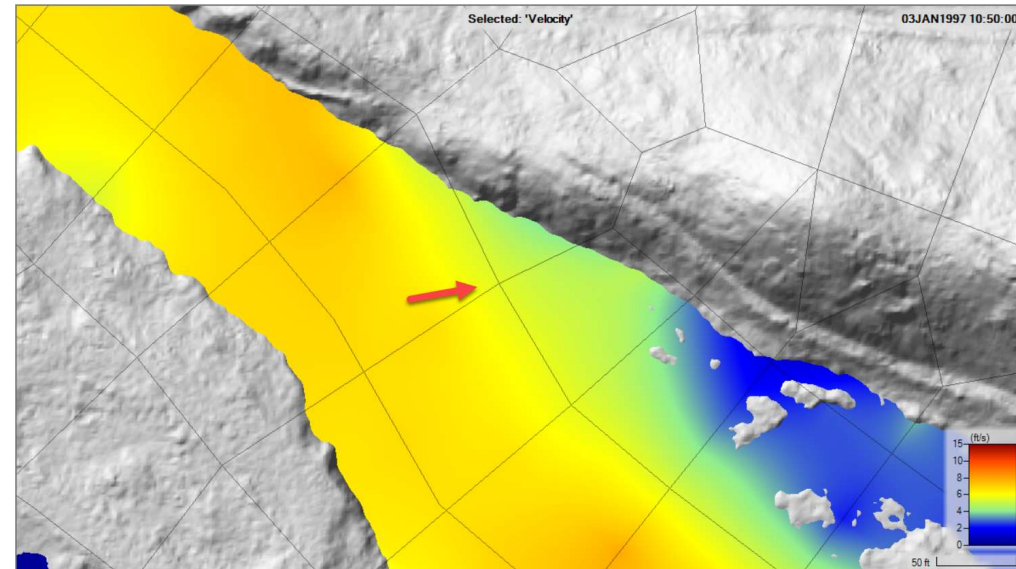
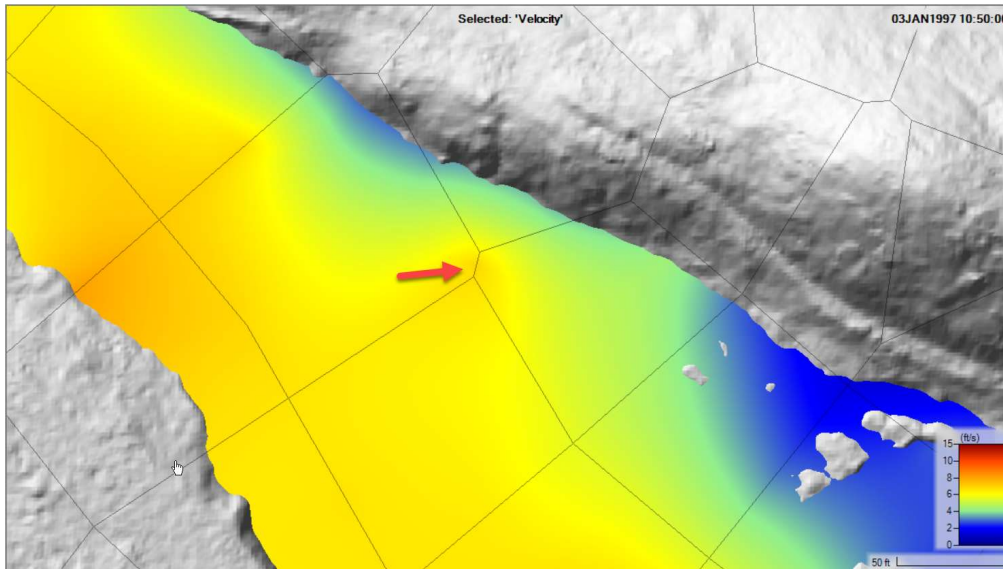
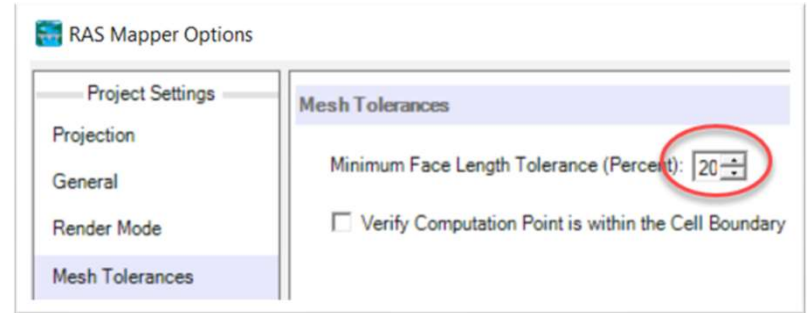
Additional Options

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



Weird Shaped Cells/Small Faces

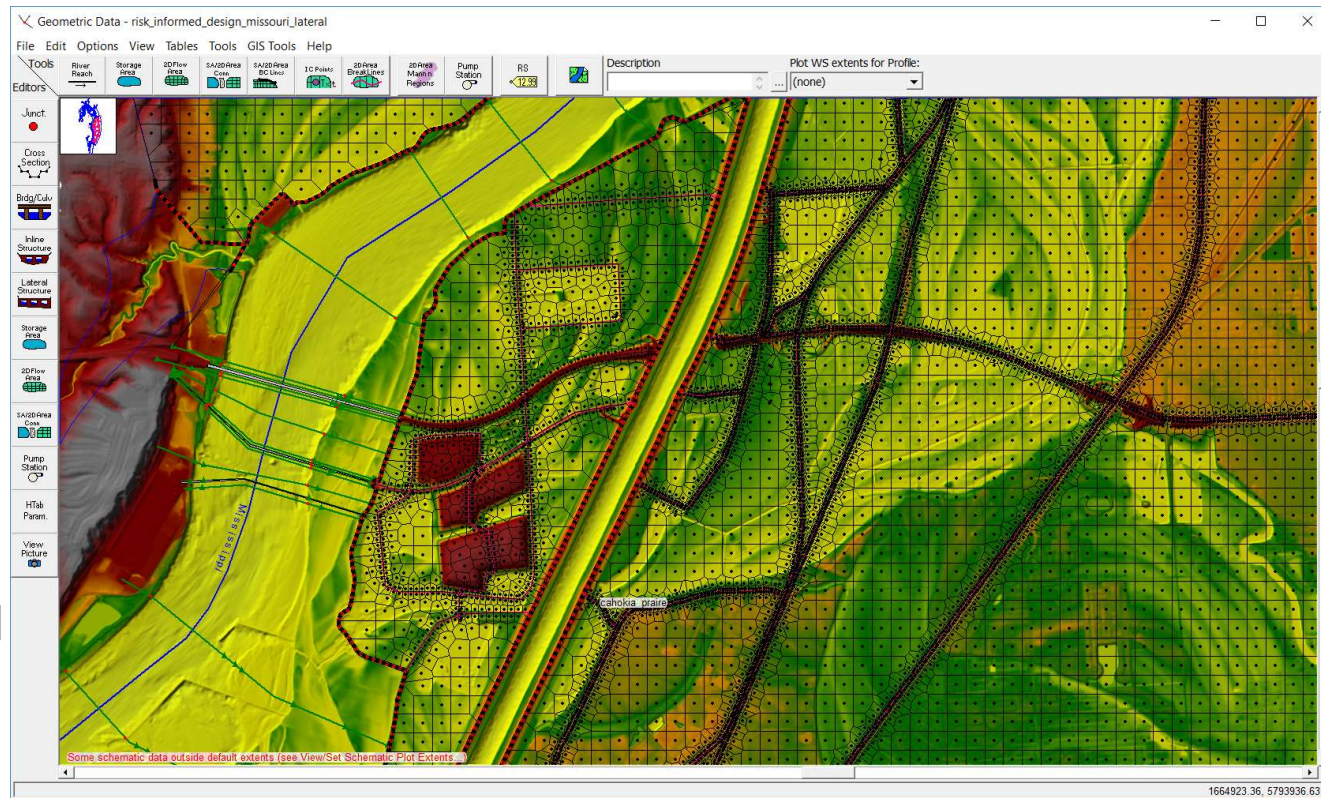
- Cells need to transition in size slowly
 - No more than 50% change in size
- Small cells and short faces compared to other cells and cells – this may cause excessive model iterations.





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



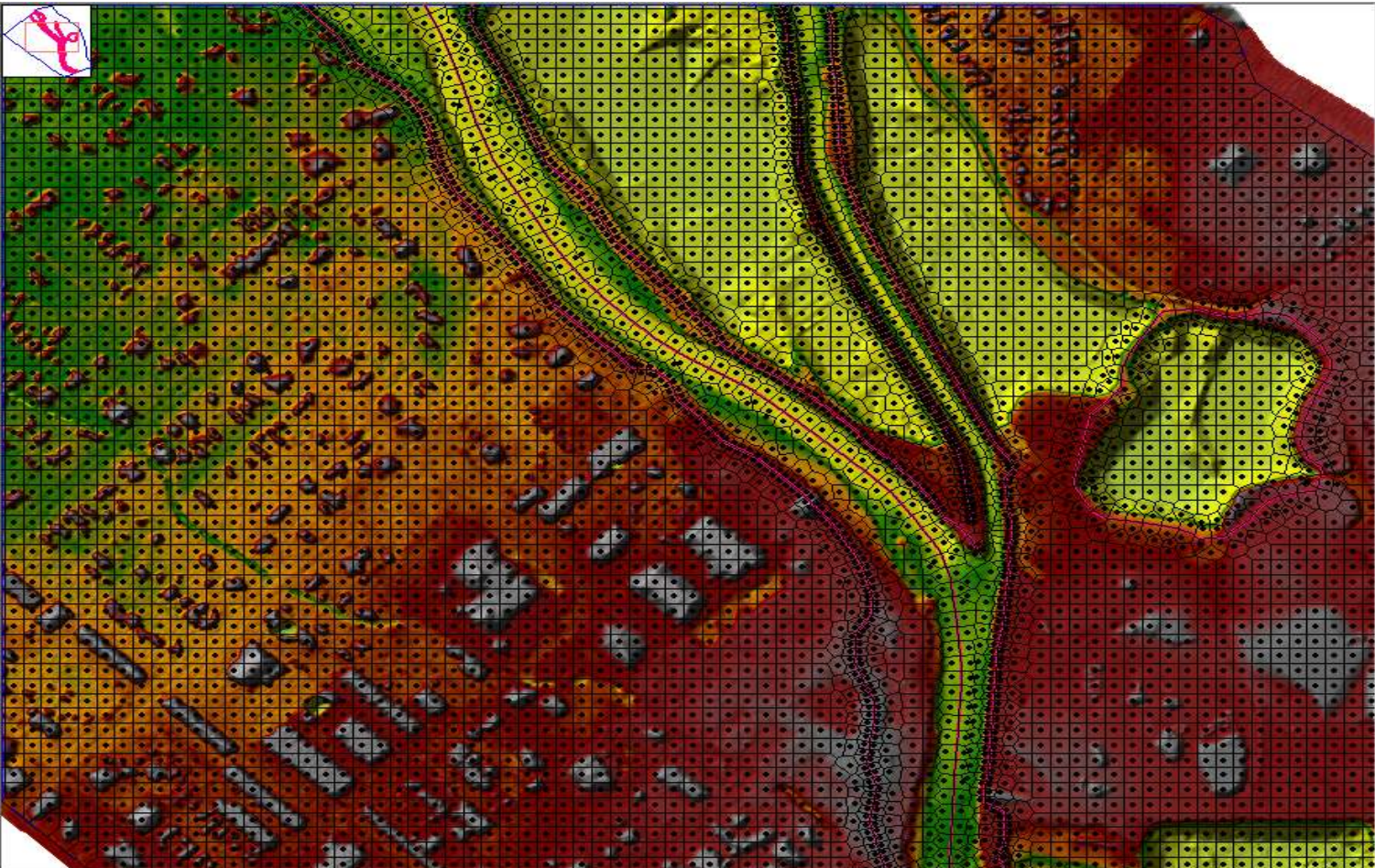


Channel Alignment and Cell Size

- 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



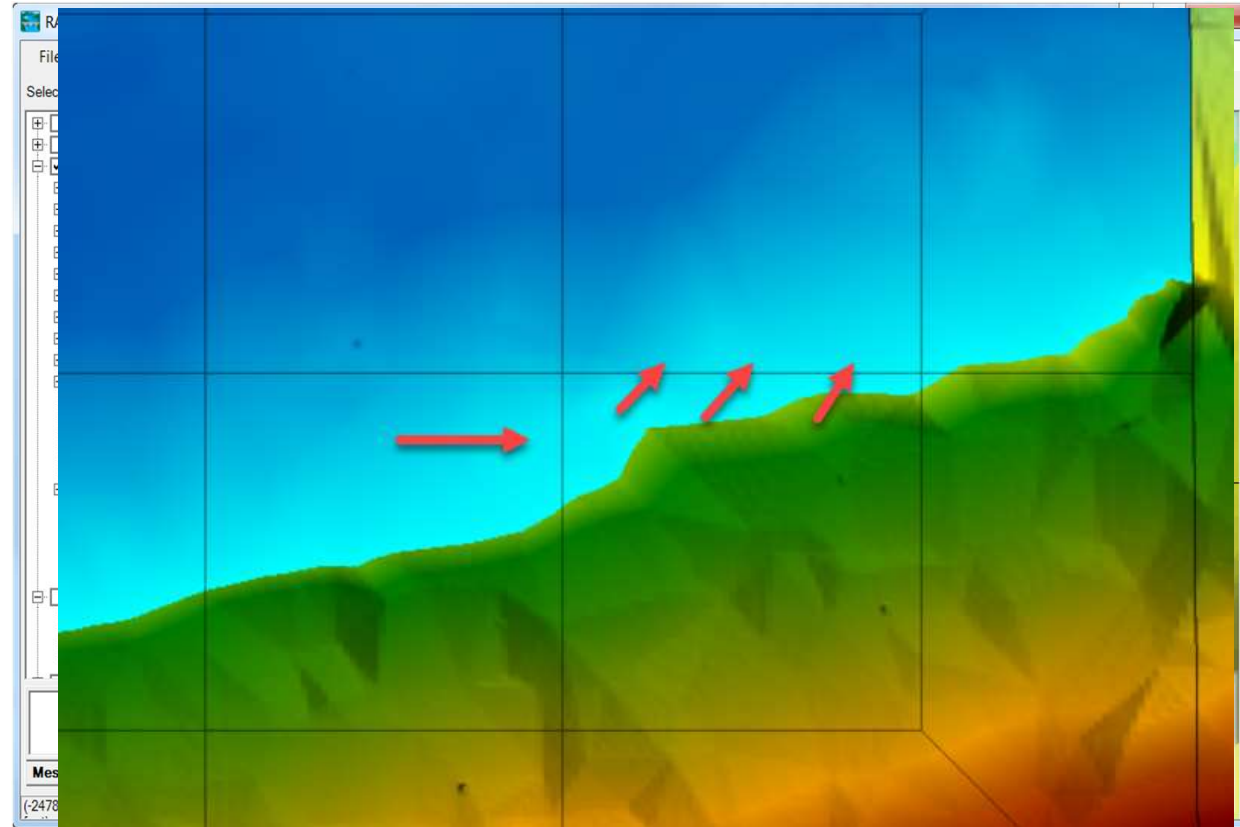
Polygon Refinement for Main Channel





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





WS Elevation Tolerance - Diagnostics



- Output reports Cell with largest Error

| | | | | | | |
|-------------------|------------|--------|------|---------|-------|----|
| 1JAN2000 00:00:30 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:00:40 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:00:50 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:01:00 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:01:10 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:01:20 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:01:30 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:01:40 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:01:50 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:02:00 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:02:10 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:02:20 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:02:30 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:02:40 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:02:50 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:03:00 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:03:10 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:03:20 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:03:30 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:03:40 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:03:50 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |
| 1JAN2000 00:04:00 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 2C |

- Error due to volume or water surface?

HEC-RAS - Set Output Control Options

Restart File Options | Detailed Log Output | Computation Level Output Options | HDF5 Write Parameters

Optional HDF Output Parameters

- Write warmup time steps to output file
- Write time sliced steps (in addition to basic time steps)
- Commit writes (normally writes are buffered, use when computations crash, not go unstable, but crash)

Additional 2D Variables Written to Results File (not used/needed for RAS) *

- Cell Soil Moisture Deficit
- Cell Unsaturated Water Content
- Cell Unsaturated Wetting Front Depth
- Cell Velocity
- Cell Volume
- Cell Volume Error
- Cell Water Surface Error
- Cell Courant

Stage and Flow Hydrograph

File Type Options

2D Area: 2DFlowArea

Plot Stage Plot Flow Obs Stage Obs Flow

Time Series | Rating Curve

Inner Iteration Number

Outer Iteration Number

Volume Error

Water Surface Error

Time and Date

Select Variables

- Time Step
- Inner Iteration Number
- Inner Max Volume Residual
- Inner Max Volume Residual Cell
- Max Face Velocity
- Max Face Velocity Face
- Max Water Surface
- Max Water Surface Cell
- Min Water Surface
- Min Water Surface Cell
- Outer Iteration Number
- Outer Max Water Surface Correction
- Outer Max Water Surface Correction Cell
- Percent Active Cells
- Total Iteration Number
- Volume
- Volume Error

Legend

- Inner Iteration Number
- Outer Iteration Number



WS Elevation Tolerance

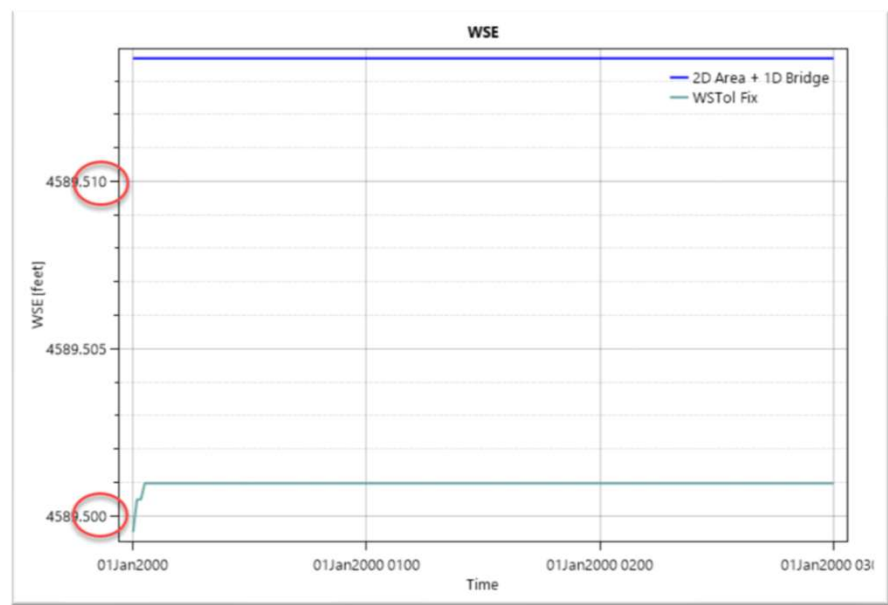


| | | | | | | |
|--------------------|------------|--------|------|---------|-------|----|
| 01JAN2000 00:00:30 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 20 |
| 01JAN2000 00:00:40 | 2DFlowArea | Cell # | 2022 | 4589.43 | 0.105 | 20 |
| 01JAN2000 00:00:50 | 2DFlowArea | Cell # | 2022 | 4589.43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

| Parameter | (Default) | 2DFlowArea |
|---|----------------|---------------------------|
| 1 Theta (0.5-1.0) | | 1 |
| 2 Theta Warmup (0.5-1.0) | | 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) |

• 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 $V = Q \times DT$
- 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 there is a high embankment
 - Use 2D flow option for non-weir flow situations

Questions?

