

Common 2D Model Stability Problems Troubleshooting Strategies

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2D Flow Area Stability Issues



- Iterations and Instabilities
- 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



Iterations



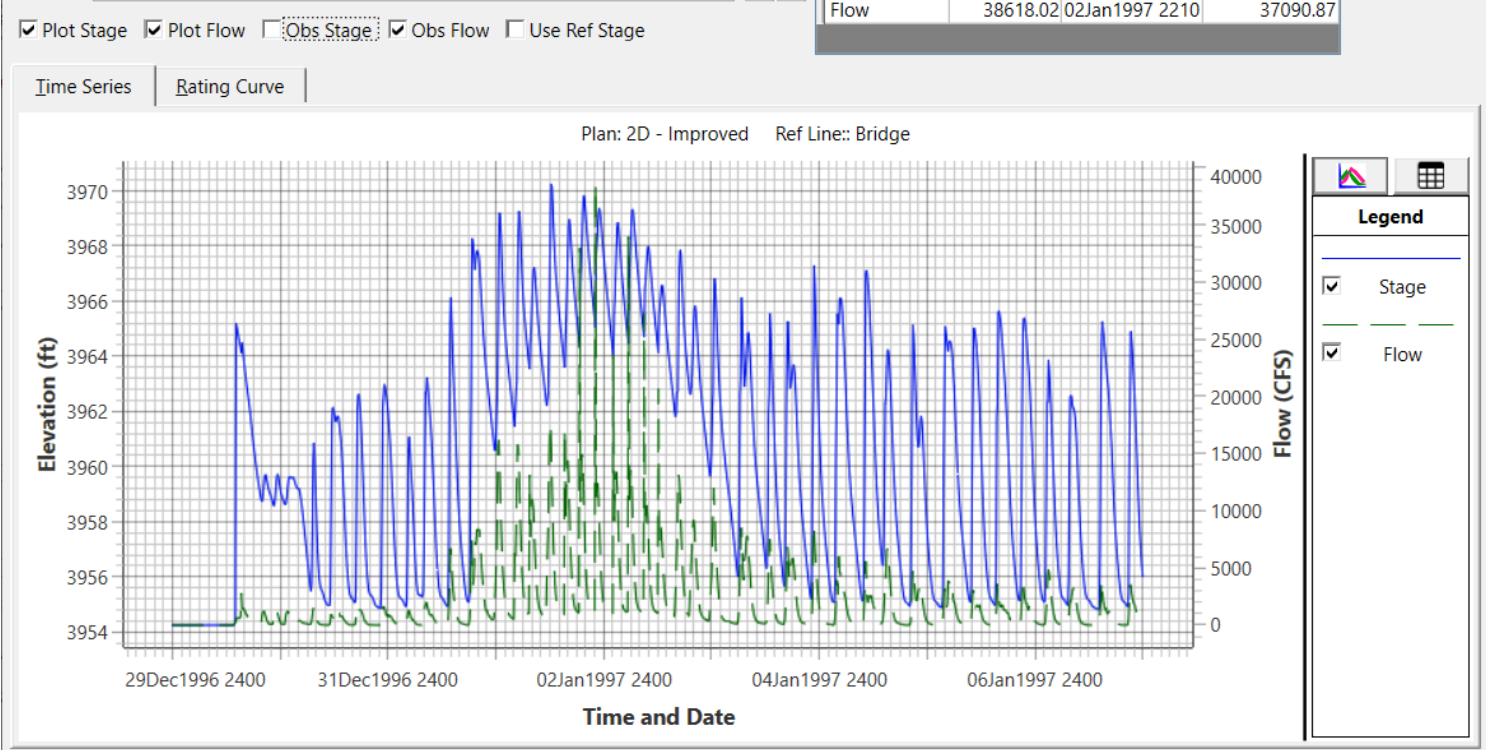
HEC-RAS Computations

Write Geometry Information
Layer: COMPLETE

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

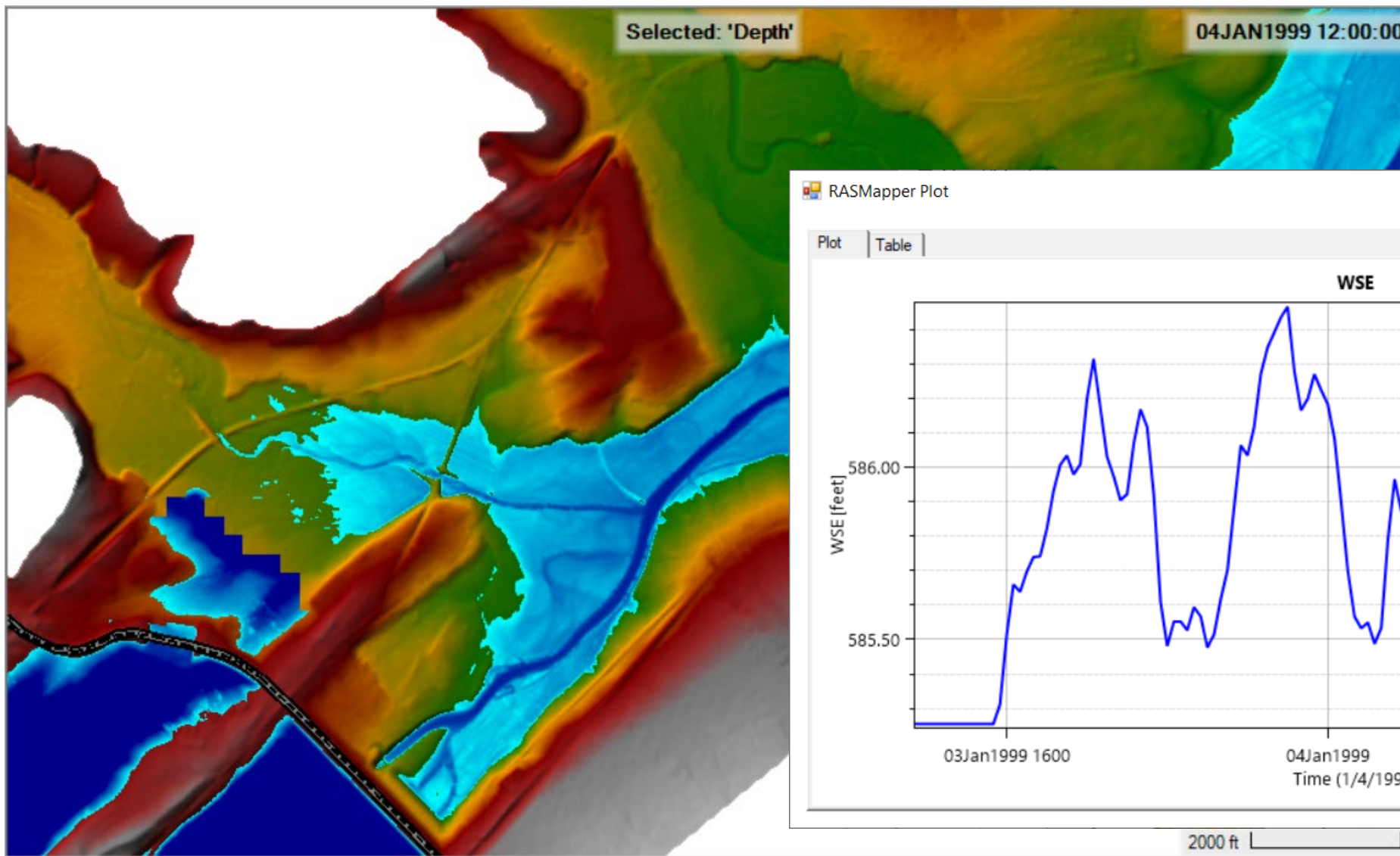
Unsteady Flow Simulation
Simulation:
Time: 24.7500 02JAN1999 12:45:00 Iteration (1D):
Unsteady Flow Computations **Iteration (2D): 21**

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



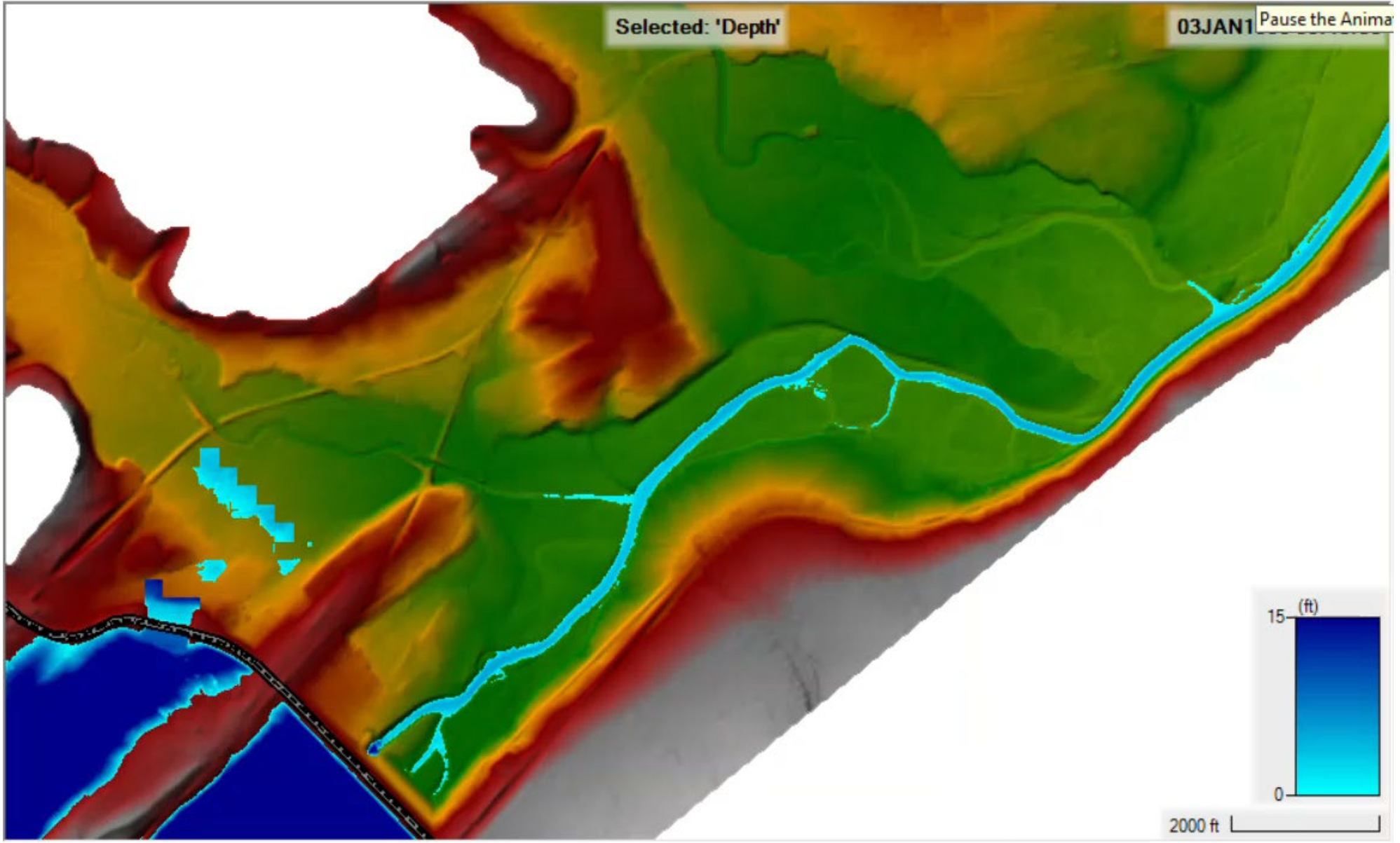


RAS Mapper Visualization





Model Instability





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

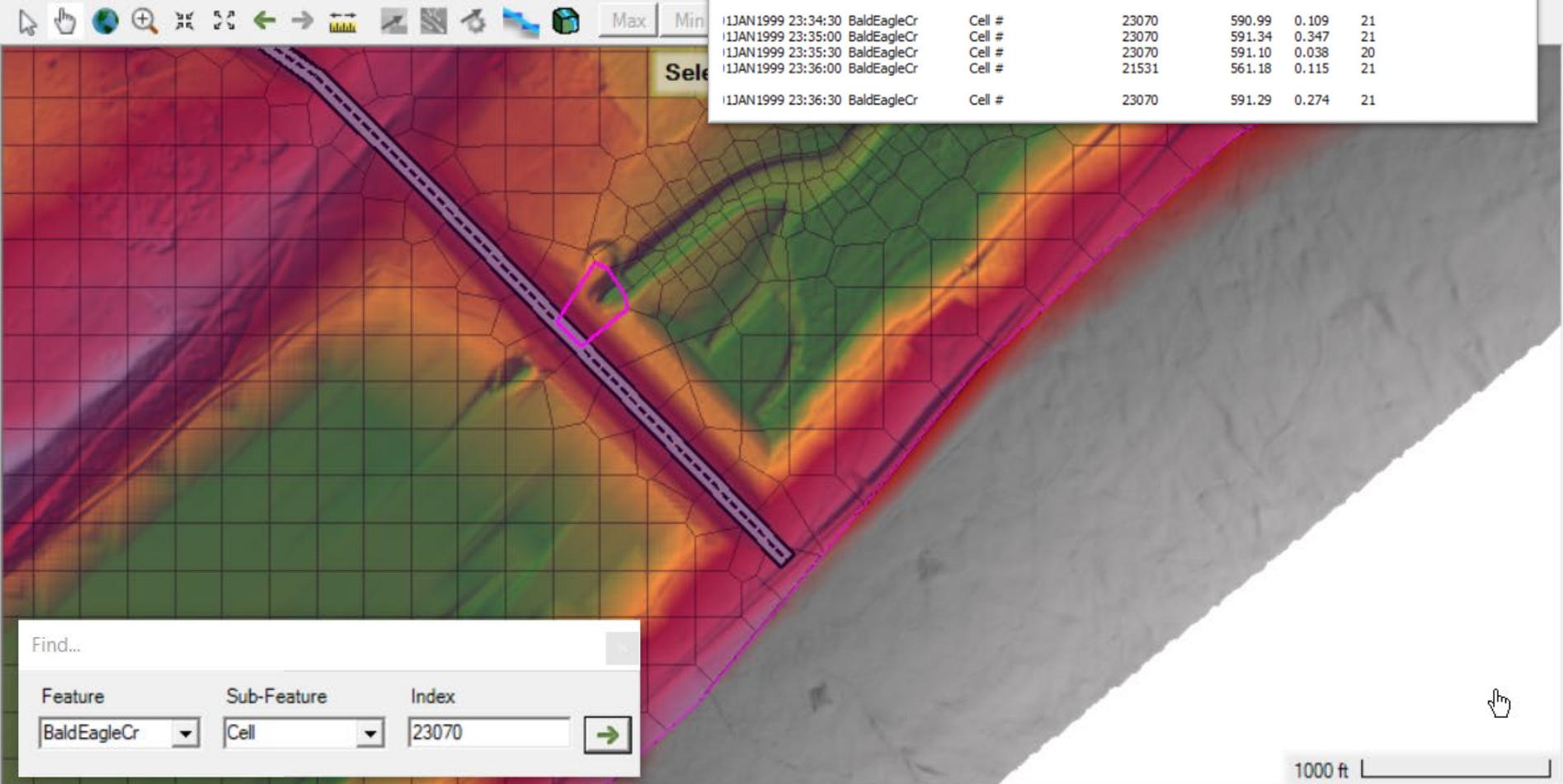
File Project Tools Help

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

Messages Views Profile Lines Active Features Lay

(2012105.34, 319493.12 1 pixel = 8.73 ft)



Find...

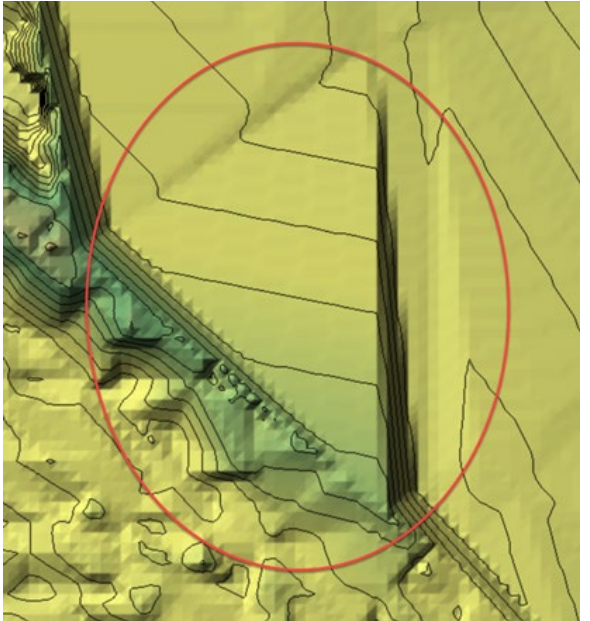
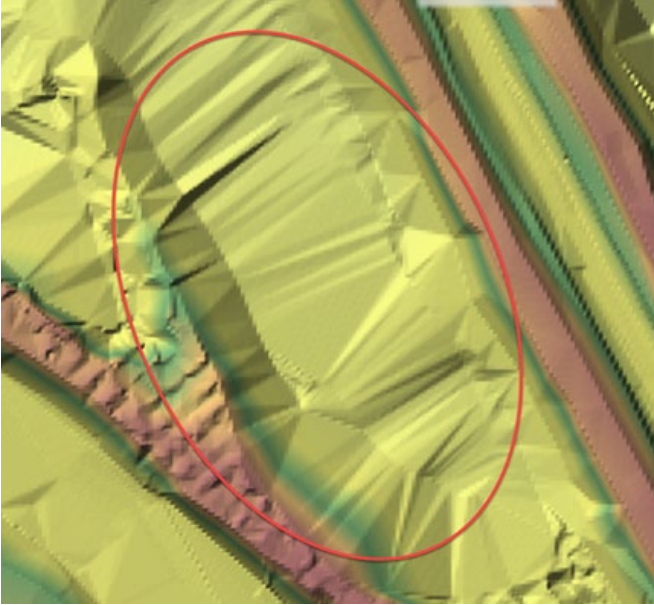
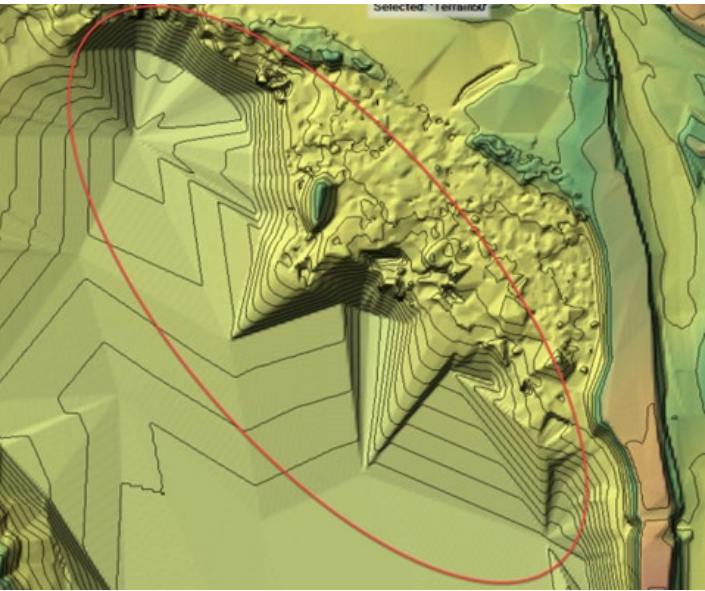
Feature	Sub-Feature	Index
BaldEagleCr	Cell	23070

→

1000 ft



Terrain Issues





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)



RAS Mapper Courant Number Map



Results Map Parameters

Map Type

- Hydraulics
 - Water Surface Elevation
 - Velocity
 - Flow (1D Only)
 - Inundation Boundary
 - Depth
 - Courant (Velocity/Length)**
 - Courant (Residence Time, 2D Only)
 - Froude
 - Shear Stress
 - Depth * Velocity
 - Depth * Velocity²
 - Energy (Depth)
 - Energy (Elevation)
 - Arrival Time
 - Arrival Time (Max)
 - Recession
 - Duration

WSE (Max)

Courant (Velocity/Length) (02.JAN1997 12:50:00)

Map Layers

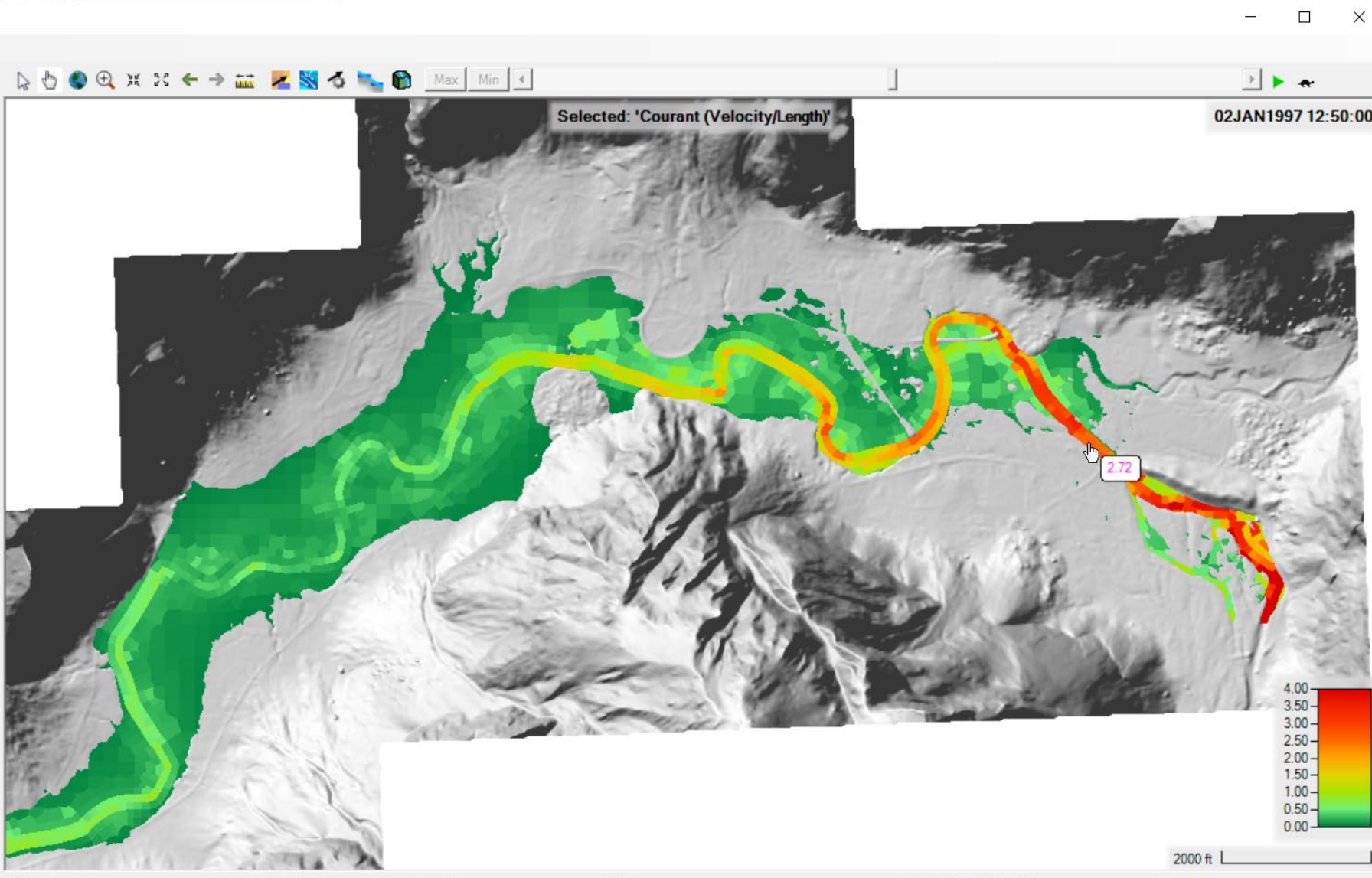
- LandCover
- Google Hybrid
- Floodplain HWM

Terrains

- Terrain [hillshade]

Messages | Views | Profile Lines | Active Features | Layer Values

(6831747.77, 2093356.97 1 pixel = 15.33 ft)





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
```



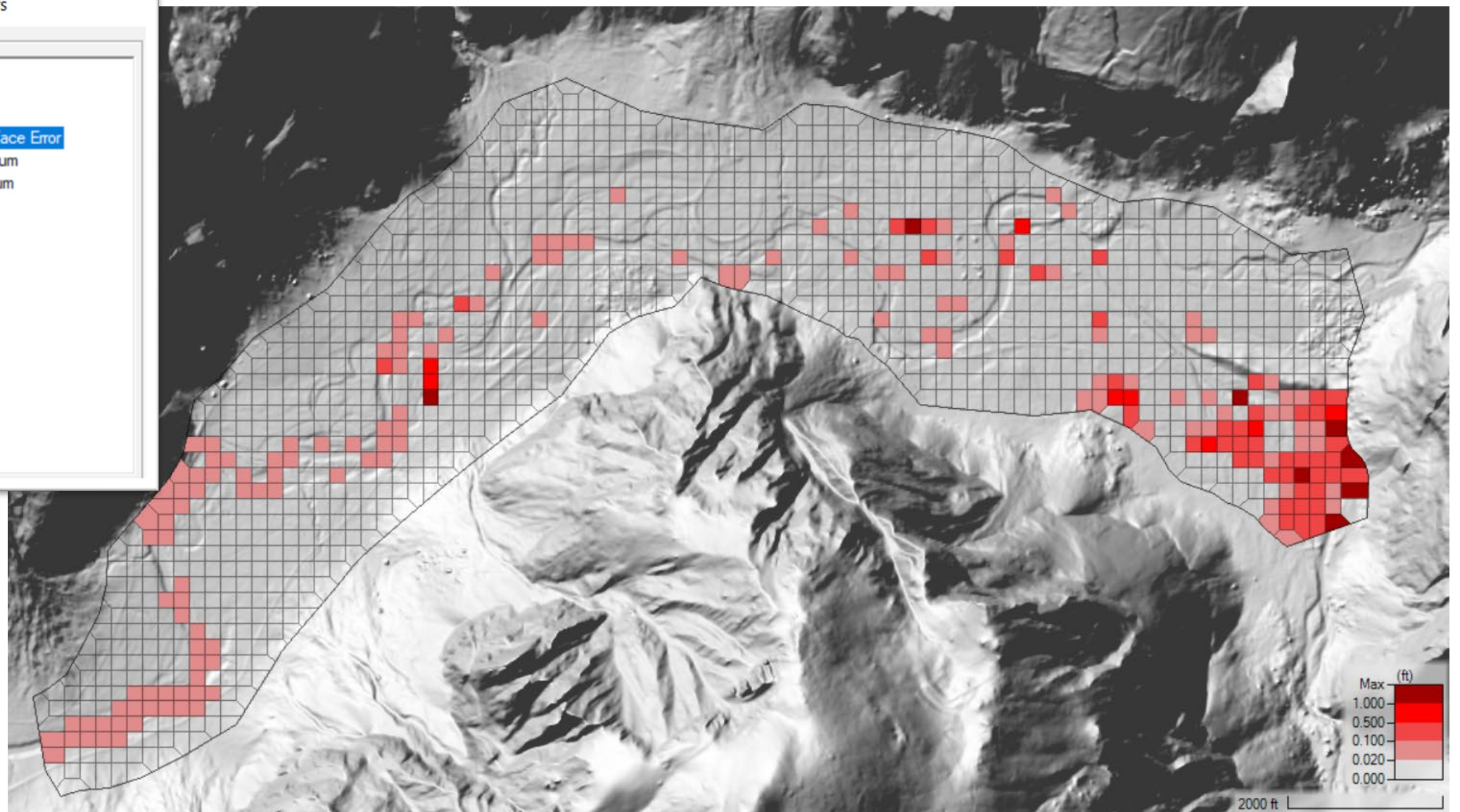
Maximum Water Surface Error



Results Map Parameters

Map Type

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



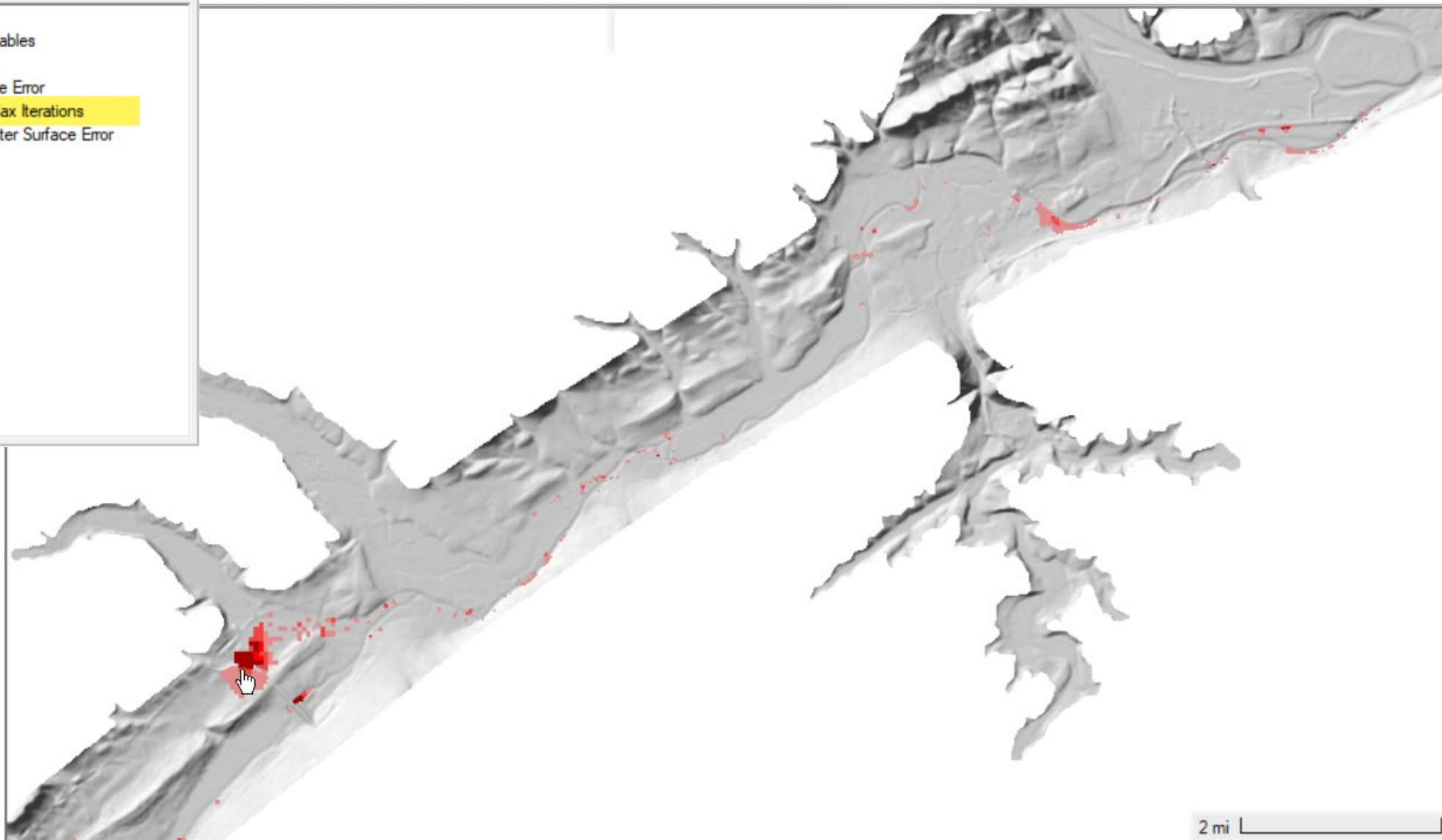


Cumulative Max Iterations



Map Type

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

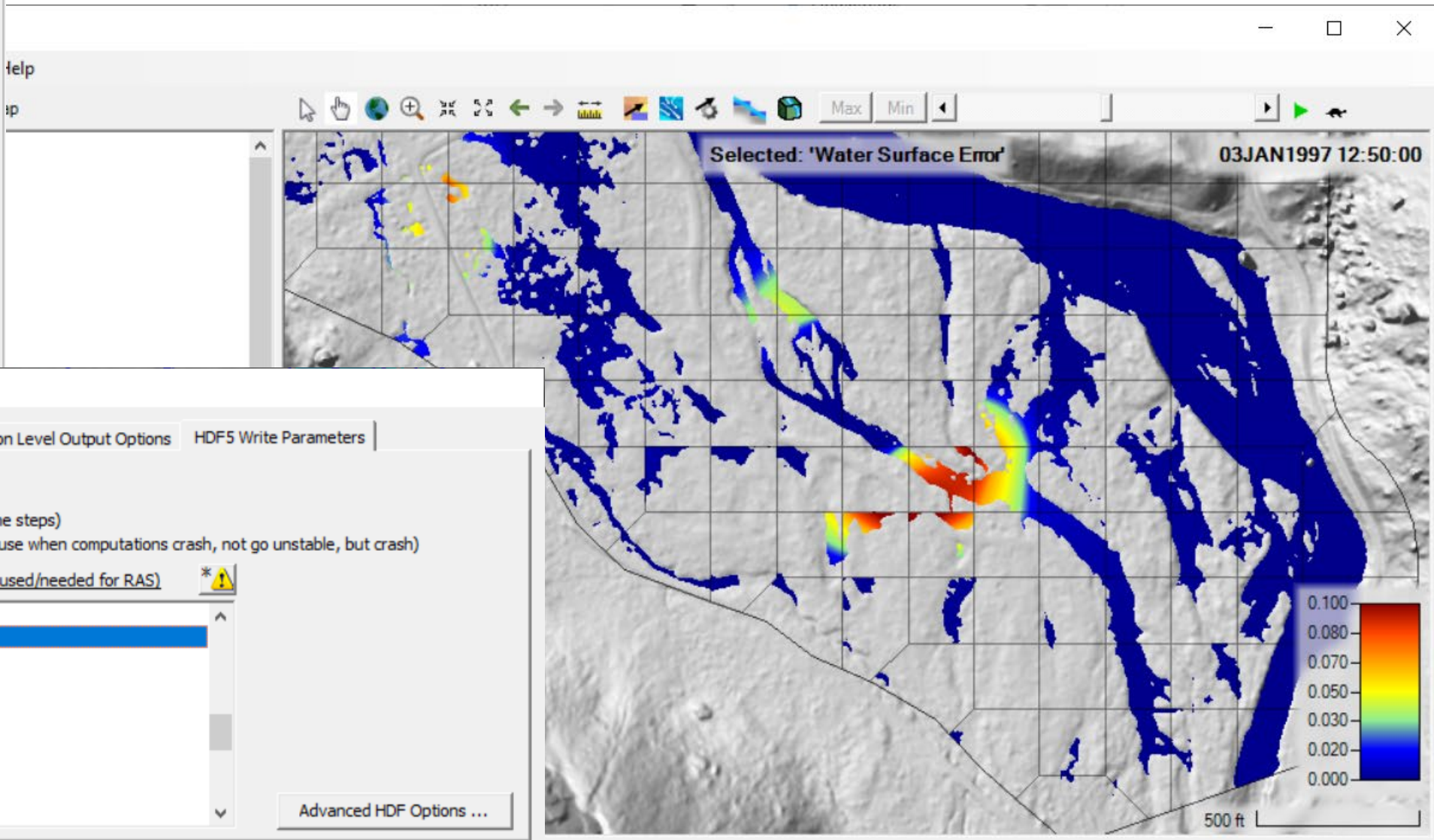




Cell Water Surface Error (For each time step)

Map Type

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



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 Volume
- Cell Volume Error
- Cell Water Surface Error**
- Cell Courant
- Face Courant
- Face Air Density
- Face Dispersive Stress
- Face Eddy Viscosity
- Face Flow
- Face Period-Average Flow

Advanced HDF Options ...

OK Cancel



Reduce Output Intervals



Unsteady Flow Analysis

File Options Help

Plan: ROM - Demo - Infiltration Short ID: ROM - Demo - Infiltration

Geometry File: PascaUpperToEnterprise - Demo - Infil

Unsteady Flow File: 600_Baseflow_Precip

Programs to Run

- Geometry Preprocessor
- Unsteady Flow Simulation
- Sediment
- Post Processor
- Floodplain Mapping

Simulation Time Window

Starting Date: 11APR2020 Starting Time: 2400

Ending Date: 14Apr2020 Ending Time: 1200

Computation Settings

Computation Interval: 1 Minute

Mapping Output Interval: 1 Hour

Hydrograph Output Interval: 1 Hour

Detailed Output Interval: 1 Hour

Project DSS Filename: ...

debug parameters

compute

RAS Mapper

File Project Tools Help Debug

Selected Layer: Velocity

- Velocity (Max)
- WSE (Max)
- Cumulative Precipitation Depth (13APR2020 09:00:00)
- Maximum Water Surface Error
- ROM - Demo - Infiltration
 - Event Conditions
 - Geometry
 - Plan
 - Depth (13APR2020 11:00:00)
 - Velocity (13APR2020 21:00:00)
 - WSE (Max)
 - Cumulative Infiltration Depth (14APR2020 08:00:00)
- ROM - Demo - Infiltration [Snapshot 51%]
 - Event Conditions
 - Geometry

Selected: 'Velocity' 13APR2020 21:00:00

15 (ft/s)

10

8

6

4

2

0

1 mi

Messages Views Profile Lines Active Features Layer Values

(2185921.51, 3454789.45 1 pixel = 33.20 ft)



Snapshot of Results



HEC-RAS Computations

Write Geometry Information
Layer: COMPLETE

Geometry Processor
River: BoiseRiver RS: 5012
Reach: Upper Node Type: Inline Weir
IB Curve: Finished

Unsteady Flow Simulation
Simulation: Finished
Time: 35.5000 18APR2014 14:30:00 Iteration (1D): 0 Iteration (2D): 0

Unsteady Post Processor
Date/Time:

Computation Messages

Maximum 1D/2D iterations			
18APR2014 13:04:32	1D/2D Flow error	1.0770	BoiseRiver Lower 3749
18APR2014 13:04:36	1D/2D Flow error	1.2262	Tributary Split 3774
18APR2014 13:04:52	1D/2D Flow error	-1.3702	Tributary Split 3774
18APR2014 13:04:56	1D/2D Flow error	2.	Tributary Split 3774
18APR2014 13:05:00	1D/2D Flow error	1.1835	BoiseRiver Lower 3749
18APR2014 13:05:08	1D/2D Flow error	1.6173	Tributary Split 3774
18APR2014 13:05:16	1D/2D Flow error	1.1859	BoiseRiver Lower 3749
18APR2014 13:05:20	1D/2D Flow error	-1.0872	BoiseRiver Lower 3749
18APR2014 13:05:24	1D/2D Flow error	1.1193	BoiseRiver Lower 3749
18APR2014 13:05:32	1D/2D Flow error	-1.1789	BoiseRiver Lower 3749
18APR2014 13:05:40	1D/2D Flow error	1.0666	BoiseRiver Lower 3749
18APR2014 13:05:48	1D/2D Flow error	1.2239	BoiseRiver Lower 3749
18APR2014 13:06:08	1D/2D Flow error	3.	Tributary Split 3774
18APR2014 13:06:48	1D/2D Flow error	1.3832	BoiseRiver Lower 3749
18APR2014 14:00:36	1D/2D Flow error	1.0778	BoiseRiver Upper 7099
18APR2014 14:01:44	1D/2D Flow error	1.0277	BoiseRiver Upper 7099
18APR2014 14:11:48	1D/2D Flow error	-1.5405	Tributary Split 3774
18APR2014 14:20:20	1D/2D Flow error	1.0940	BoiseRiver Upper 7099
18APR2014 14:29:24	1D/2D Flow error	1.1574	BoiseRiver Upper 7099

Pause Make Snapshot of Results (0-62%) Stop

Results

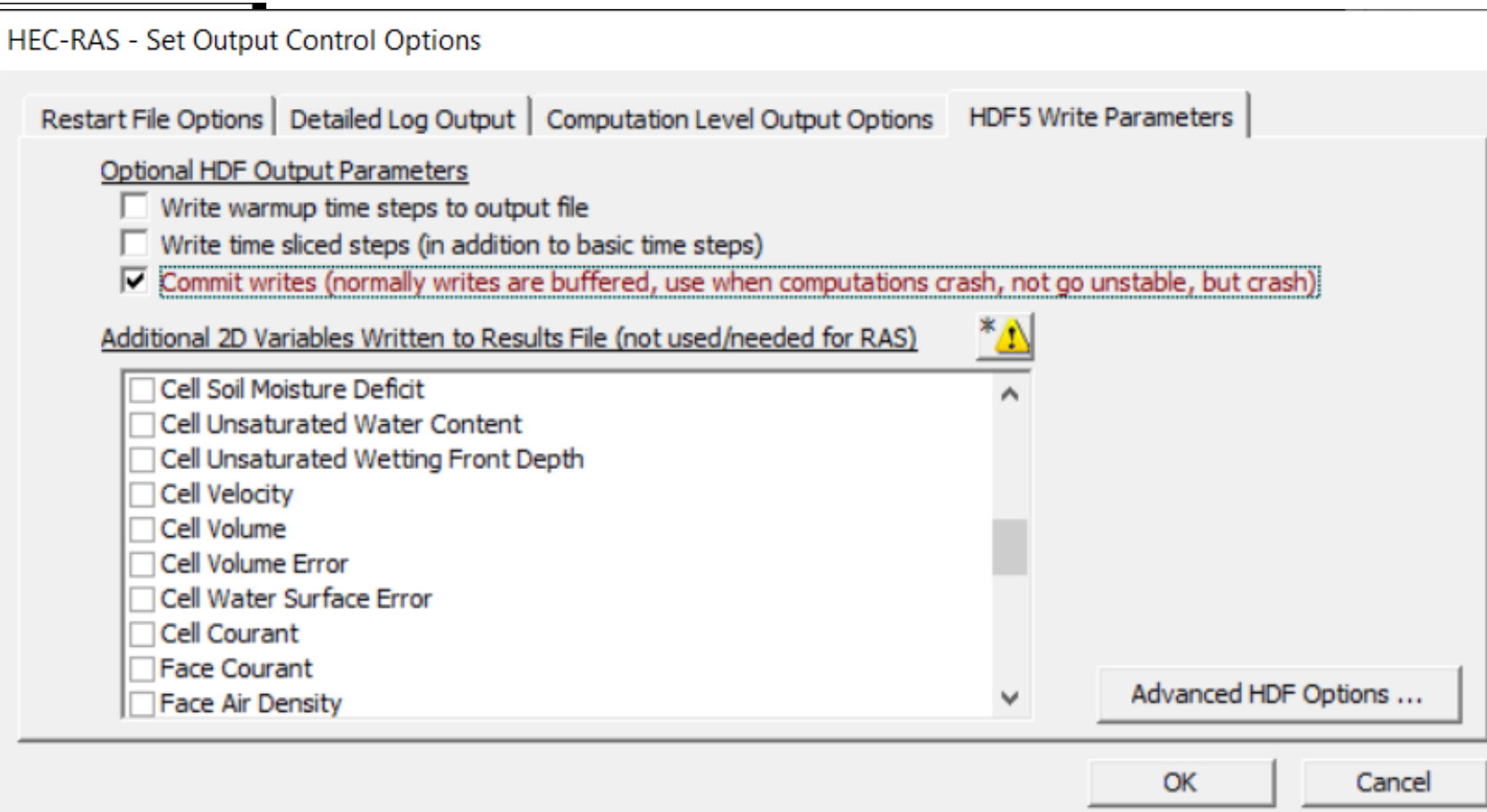
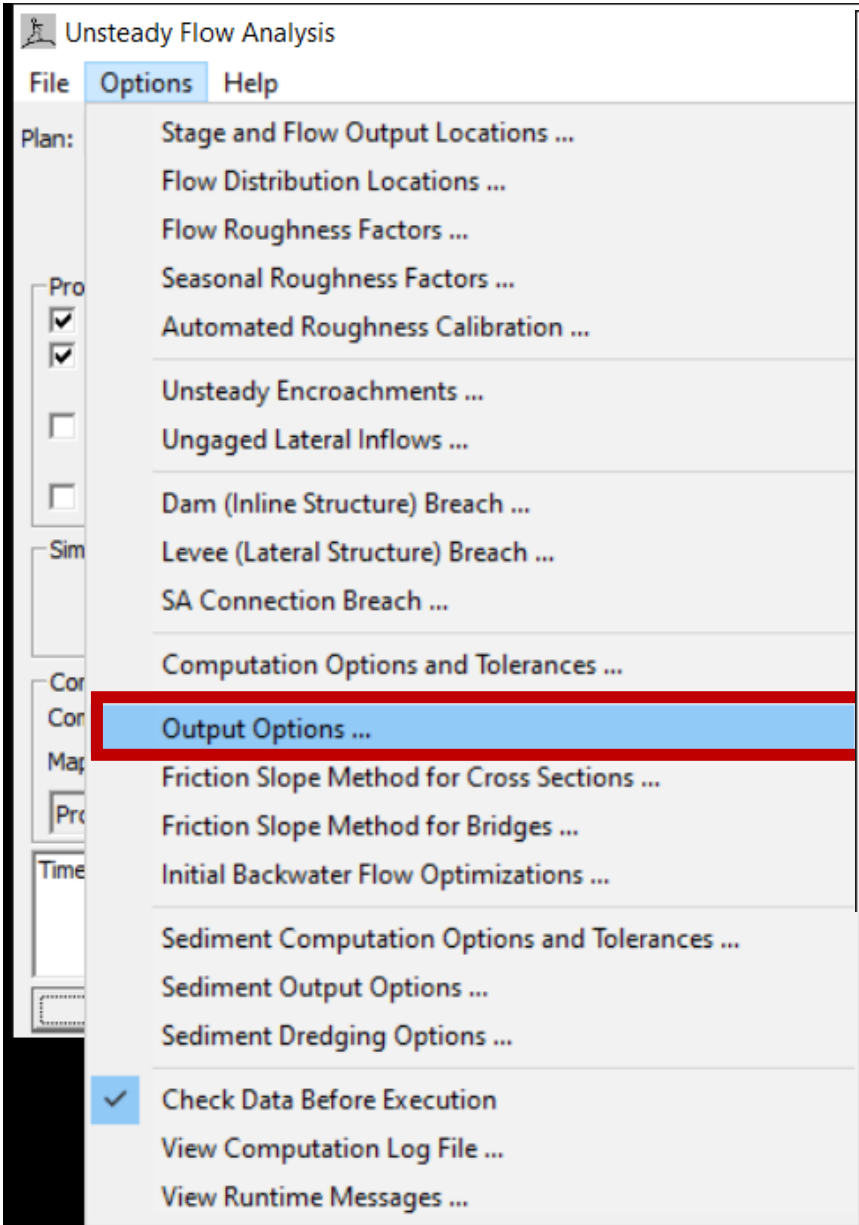
Layer Values

- l.p07.snapsho
- rrPark2D.p06.
- rrPark2D.p10.
- rrPark2D.p03.
- rrPark2D.p09.

500 ft



Commit Writes Before Crashes



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



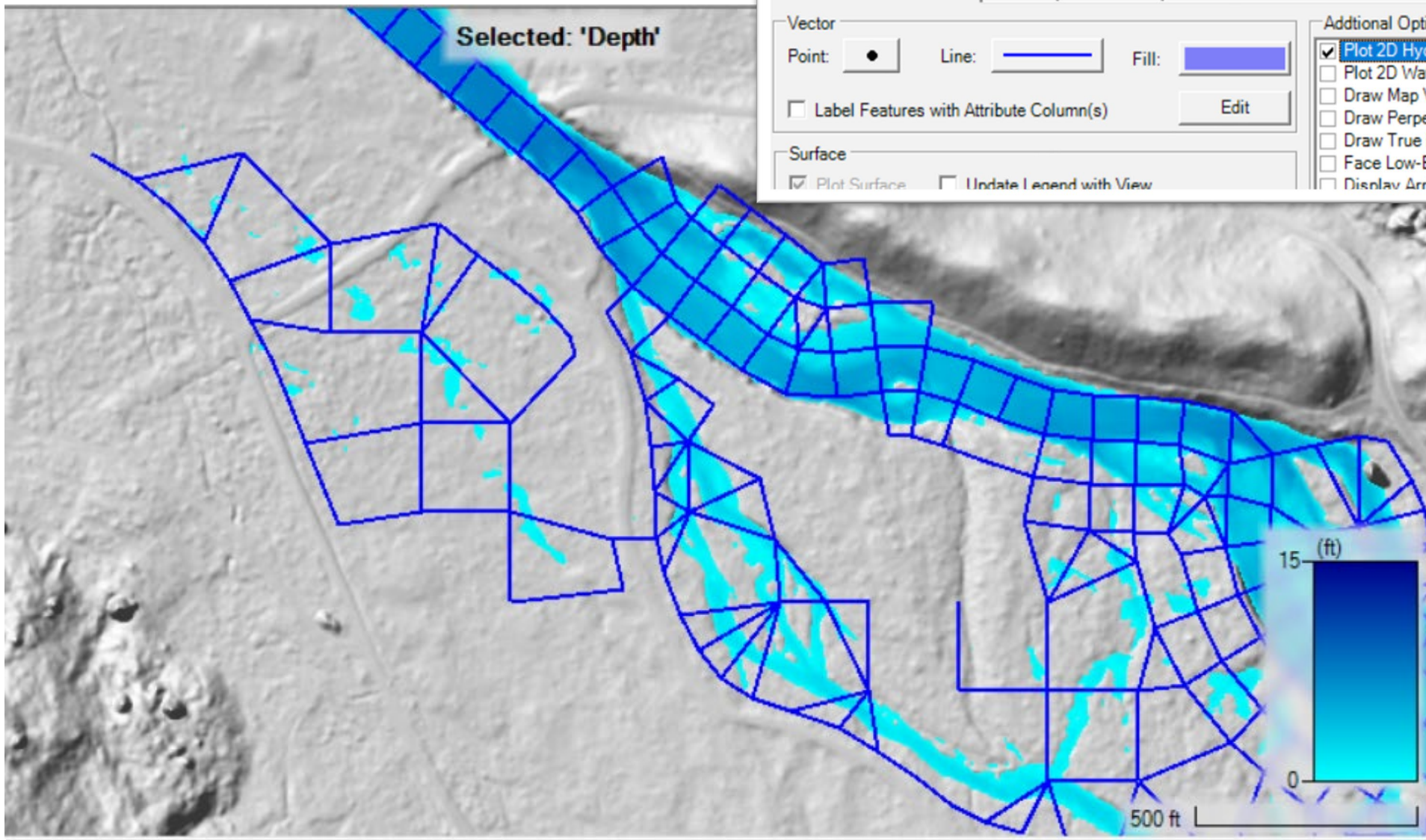
Floodwave Wetting Front



- 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
 - Increase 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

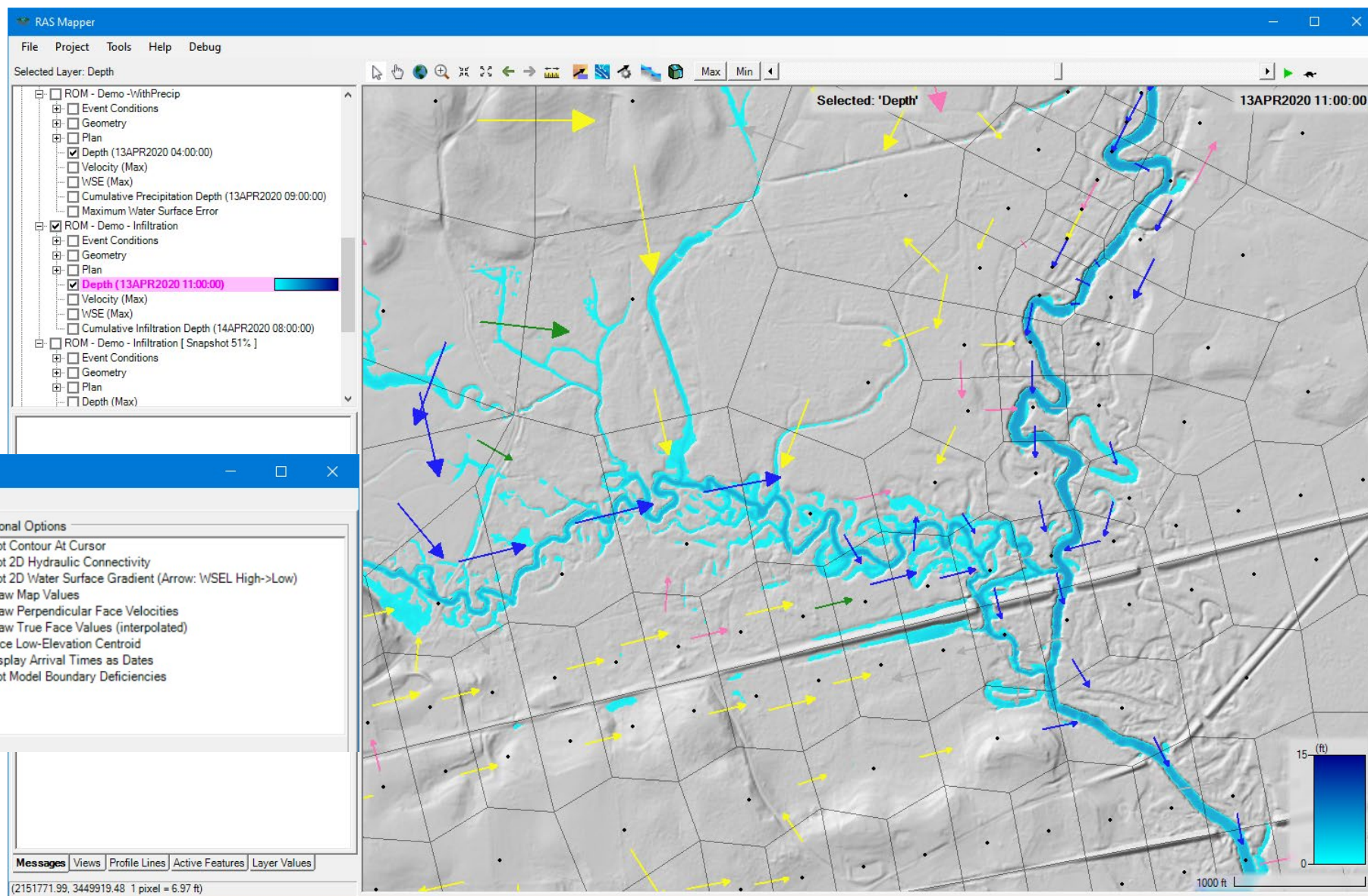
Plot Surface Update Legend with View

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



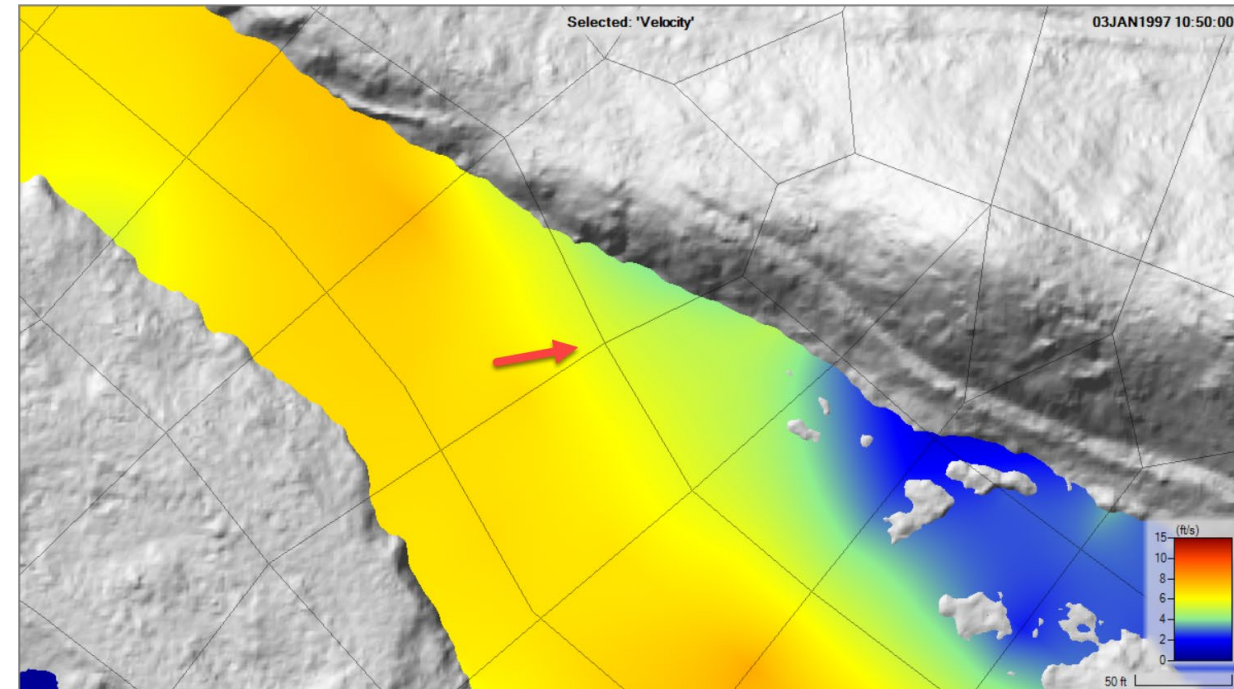
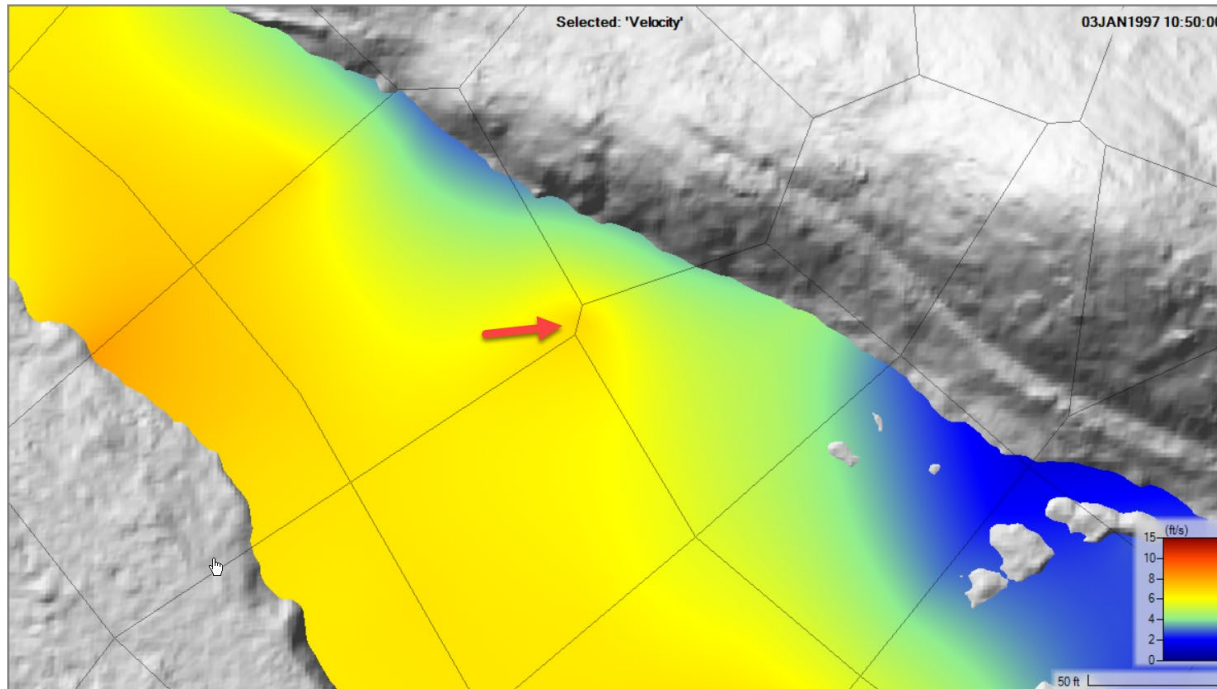
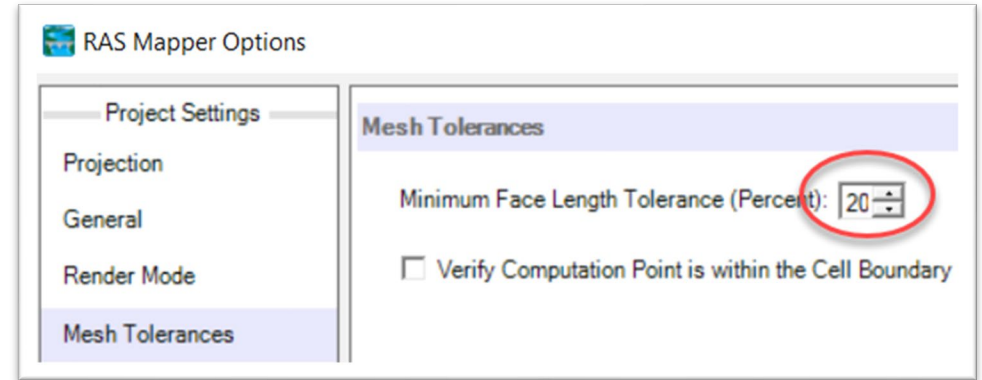
2D Water Surface Gradient





Weird Shaped Cells/Small Faces

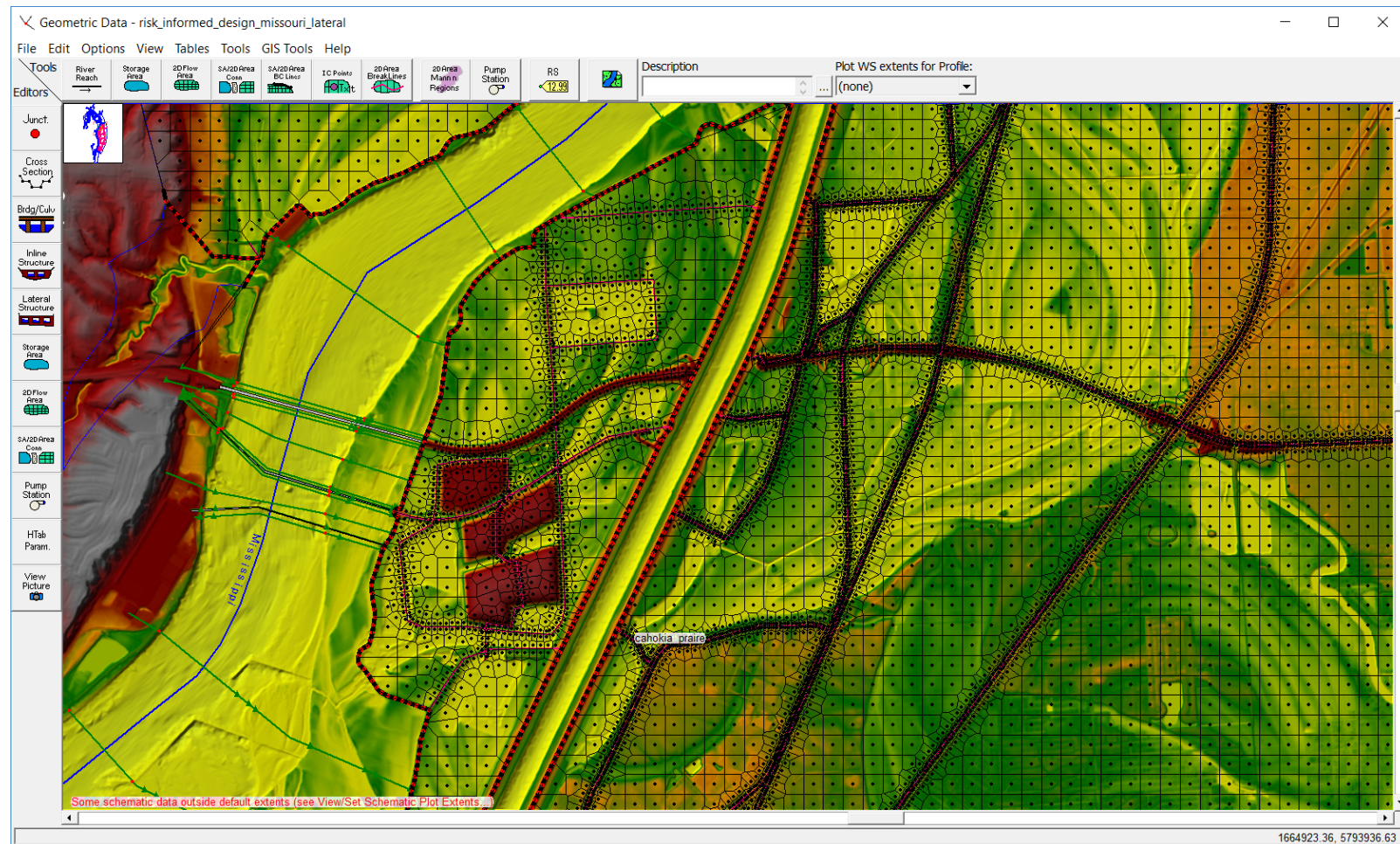
- Cells need to transition in size slowly
 - No more than 50% change in size
- Small cells and short faces compared to other cells and cells – this may cause excessive model iterations.





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



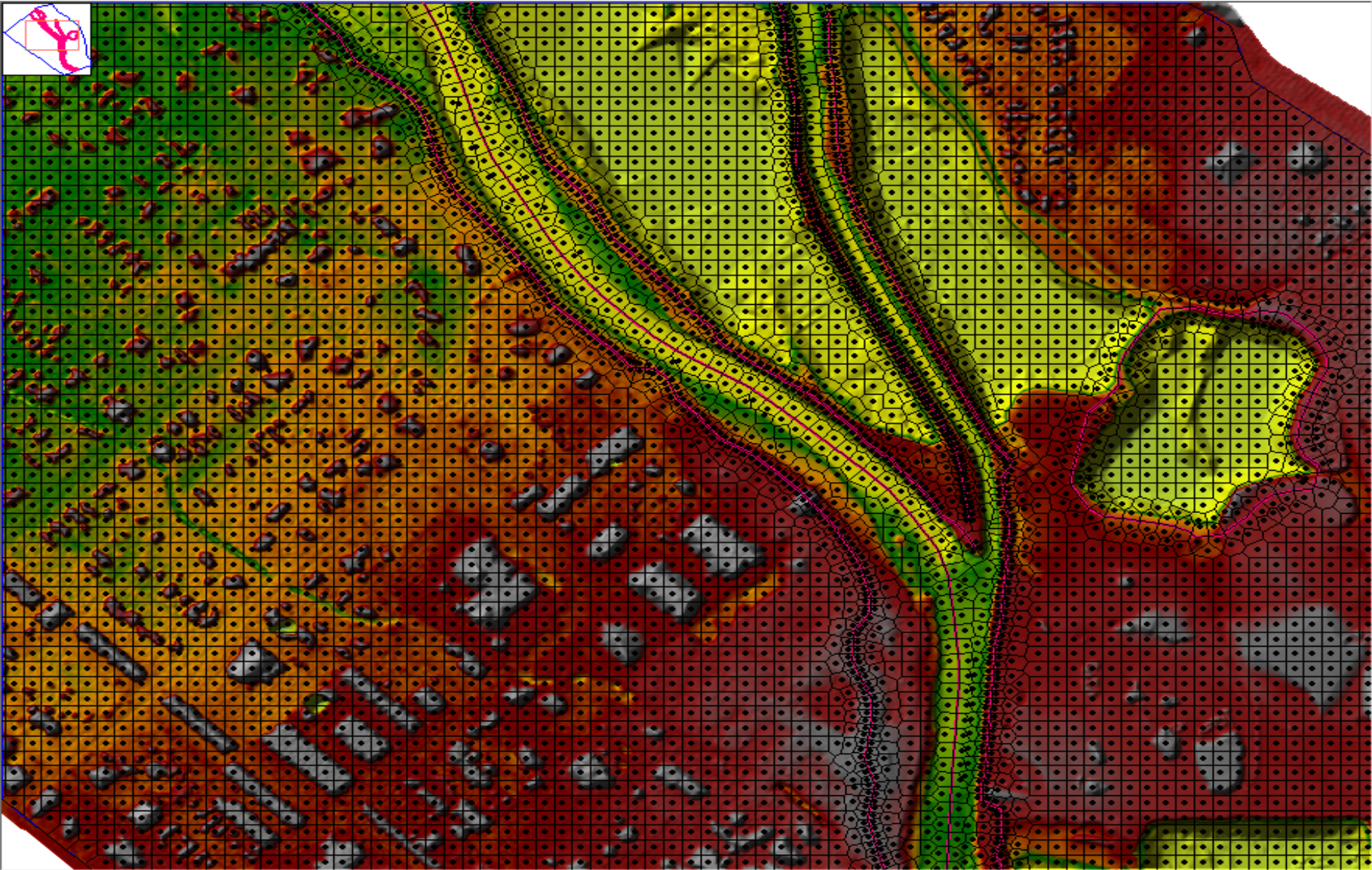


Channel Alignment and Cell Size

- 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



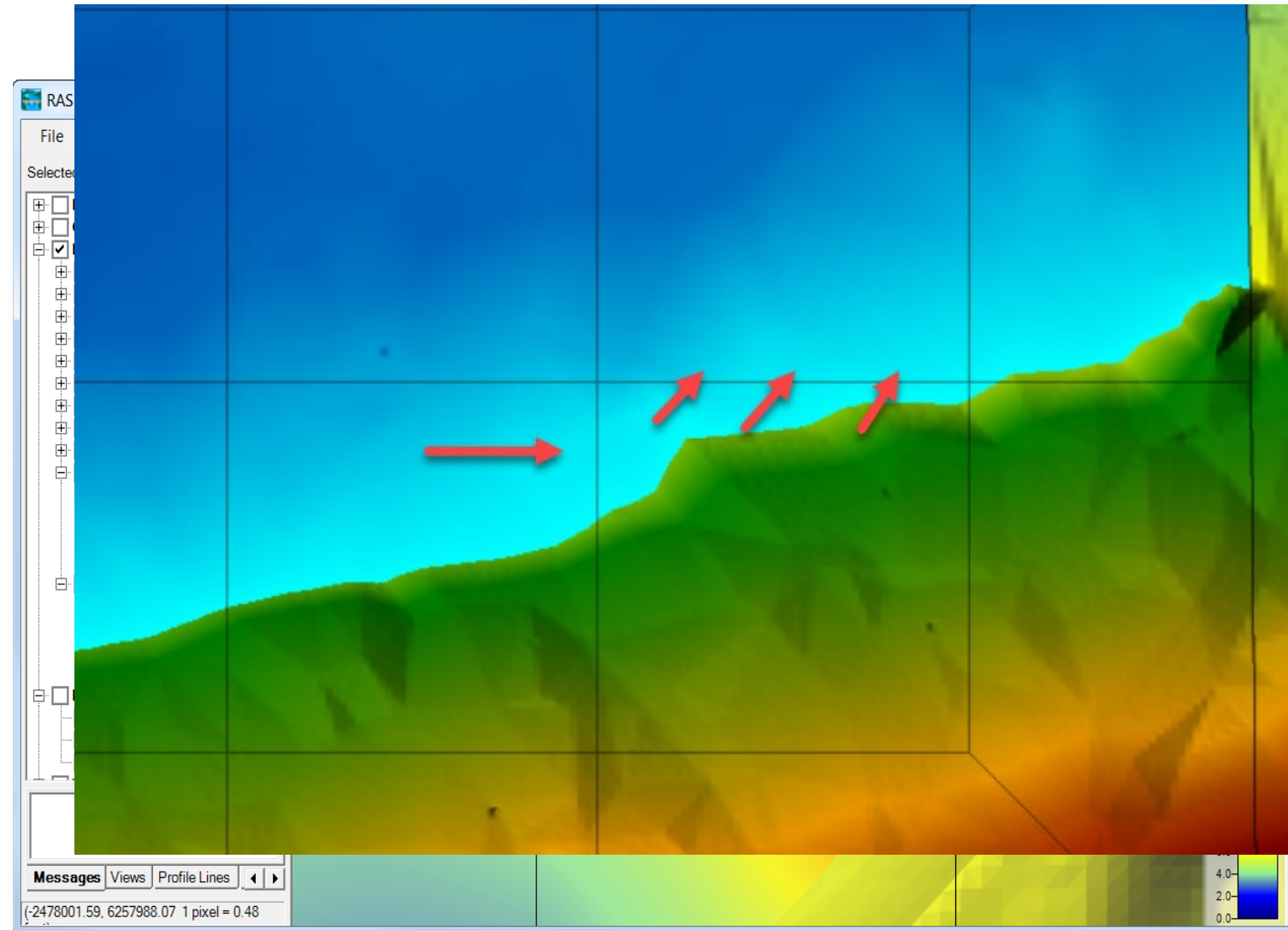
Polygon Refinement for Main Channel





Partial Cell Wetting Issue

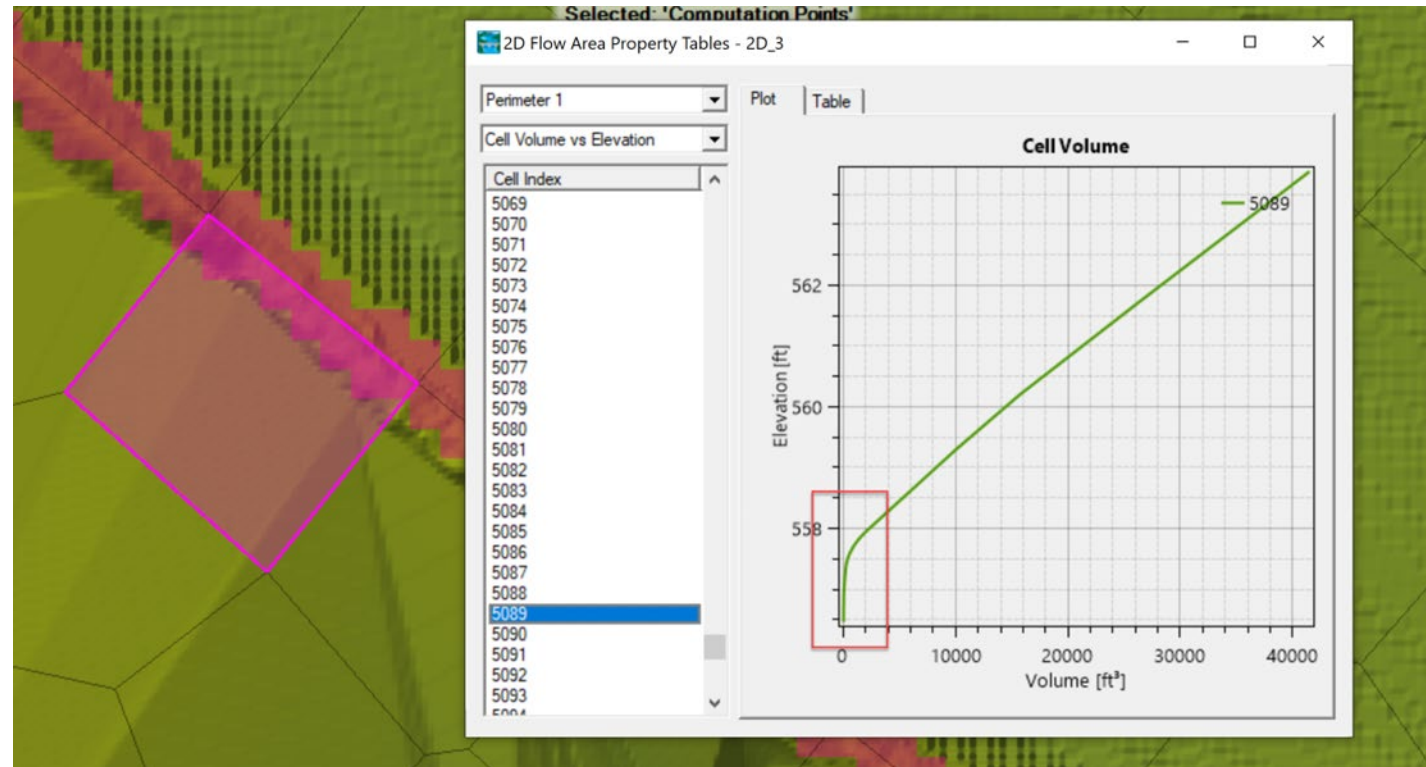
- Excessive model iteration can occur when just a corner of a cell has flow and the velocity is high.
- This will be even more unstable when flow comes into a cell through a small portion of a face but can leave over a much larger portion of another face
- Adjust cell sizes, use breaklines and polygon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





Steep Volume Elevation

- When the lower portion of the cell volume-elevation is steep,
- Small changes in volume produce large changes in water surface
- Excessive iterations have a hard time converging
- Large water surface errors represent small volume errors





WS Elevation Tolerance - Diagnostics



- Output reports Cell with largest Error

Time	2DFlowArea	Cell #	Volume	U. Vol	W. Error
11JAN2000 00:00:30	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:00:40	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:00:50	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:01:00	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:01:10	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:01:20	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:01:30	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:01:40	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:01:50	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:02:00	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:02:10	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:02:20	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:02:30	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:02:40	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:02:50	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:03:00	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:03:10	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:03:20	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:03:30	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:03:40	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:03:50	2DFlowArea	Cell #	4589.43	0.105	20
11JAN2000 00:04:00	2DFlowArea	Cell #	4589.43	0.105	20

- 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

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

Legend

- Inner Iteration Number
- Outer Iteration Number



WS Elevation Tolerance

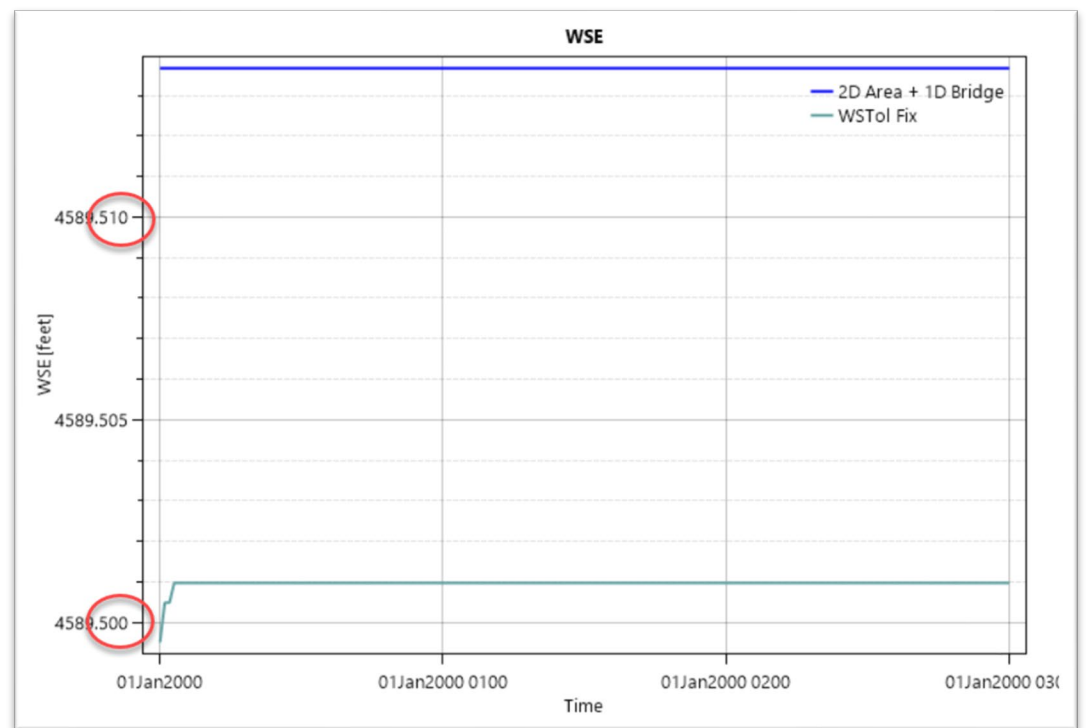


11JAN2000 00:00:30	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:00:40	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:00:50	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:01:00	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:01:10	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:02:10	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:02:20	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:02:30	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:02:40	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:02:50	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:03:00	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:03:10	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:03:20	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:03:30	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:03:40	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 00:03:50	2DFlowArea	Cell #	2022	4589.43	0.105	20
11JAN2000 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?