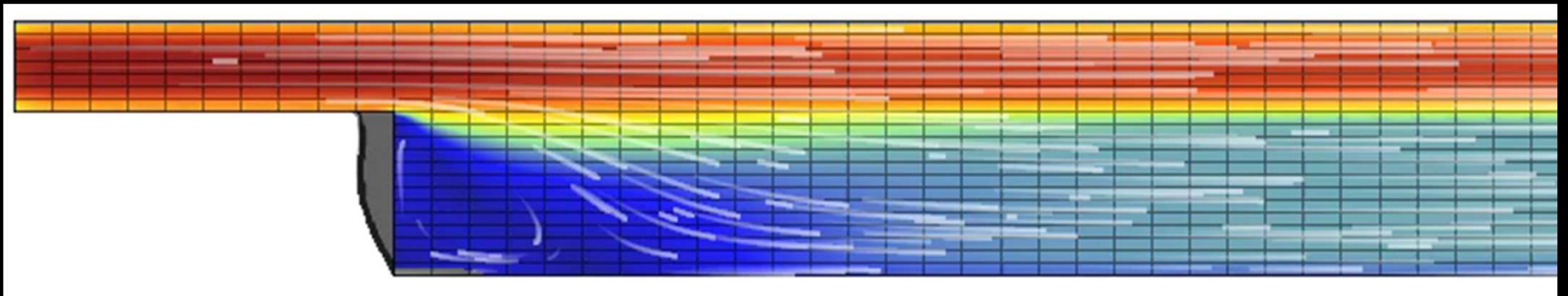
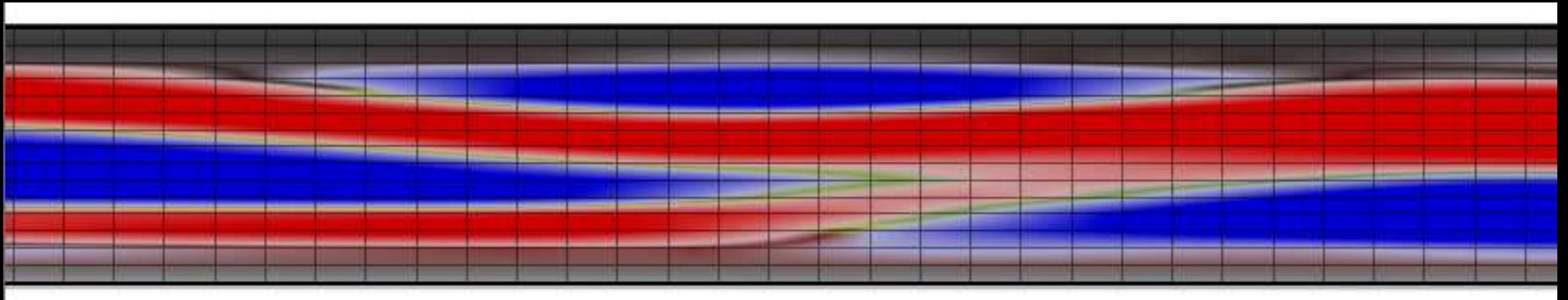


Mesh and Hydraulic Best Practices for HEC-RAS 2D Sediment Models



Stanford Gibson, PhD
Alex Sanchez, PhD



Big Ideas

- Sediment transport amplifies hydraulic modeling errors (in 1D and 2D)
- Calibrate and refine your hydraulic model before you add sediment.

Big Ideas

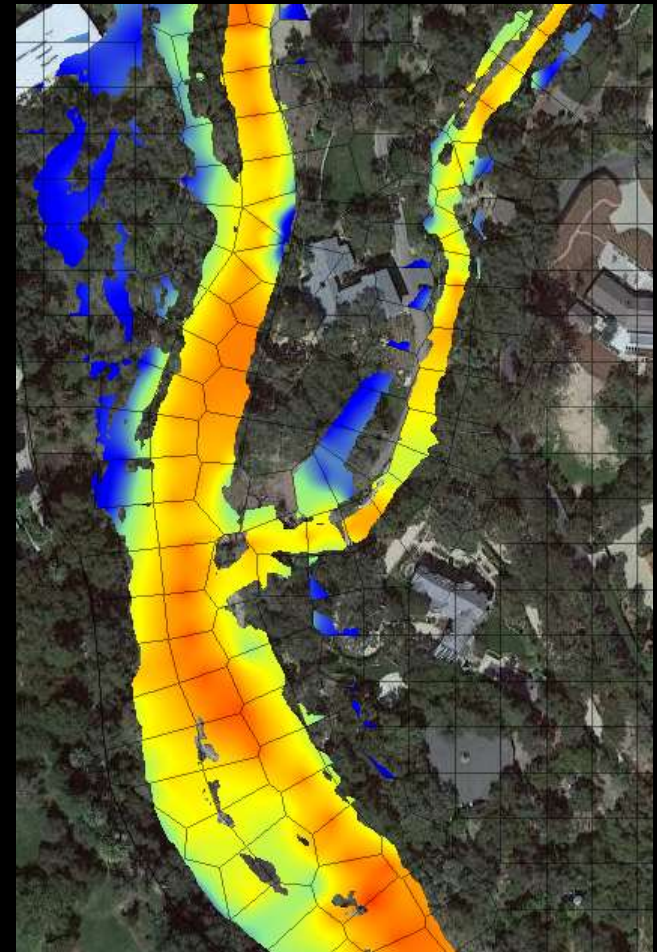
- Calibrate and refine your hydraulic model before you add sediment.

Stages of Sediment Calibration

	Flow	Bed Elevation
Stage 1: Hydraulic Calibration	Variable	Fixed
Stage 2: Steady Flow Mobile Bed Analysis	Fixed	Variable
Stage 3: Dynamic Calibration	Variable	Variable
If Possible:		
Stage 4: "Validation" (Multiple Time Series Analysis)	Variable	Variable

Hydraulic Best Practices for 2D Sediment Modeling

1. Top Two Issues
2. Mesh Best Practices
3. Computational Best Practices



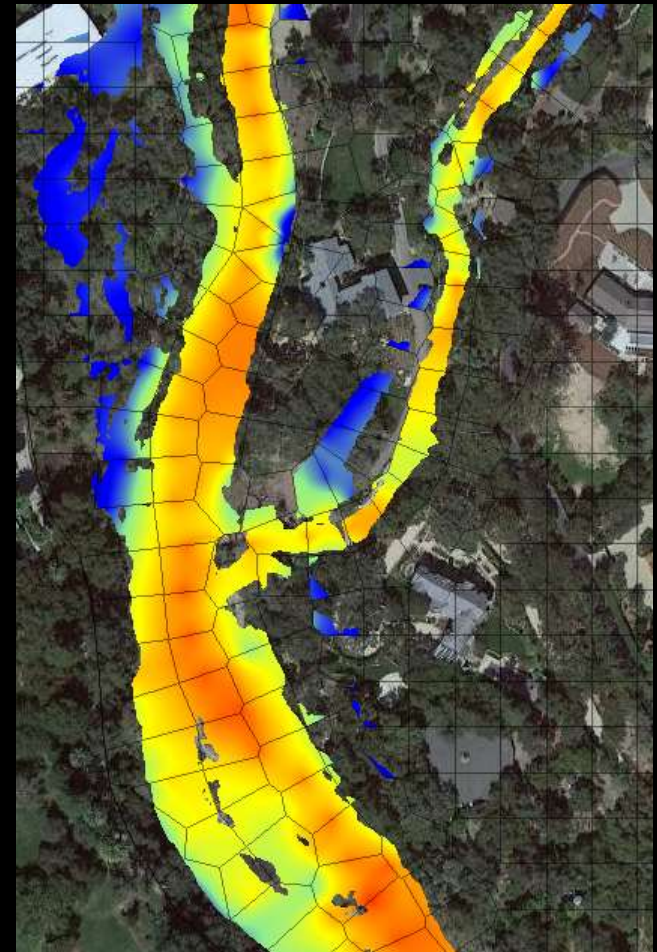
Hydraulic Best Practices for 2D Sediment Modeling

1. Top Two Issues

- Time Step
- Cell Faces and High Ground

2. Mesh Best Practices

3. Computational Best Practices



Your Time Step

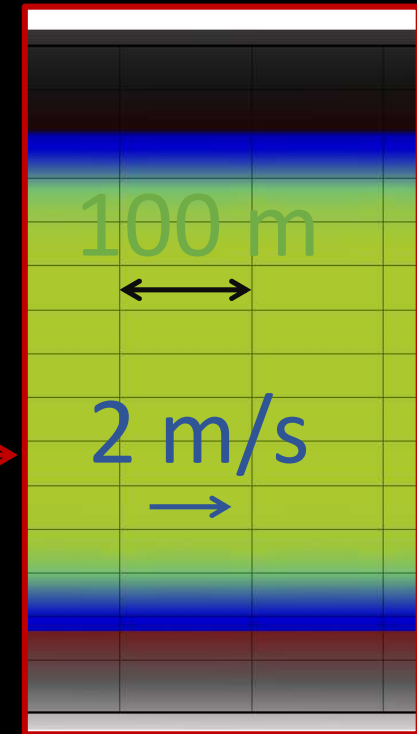
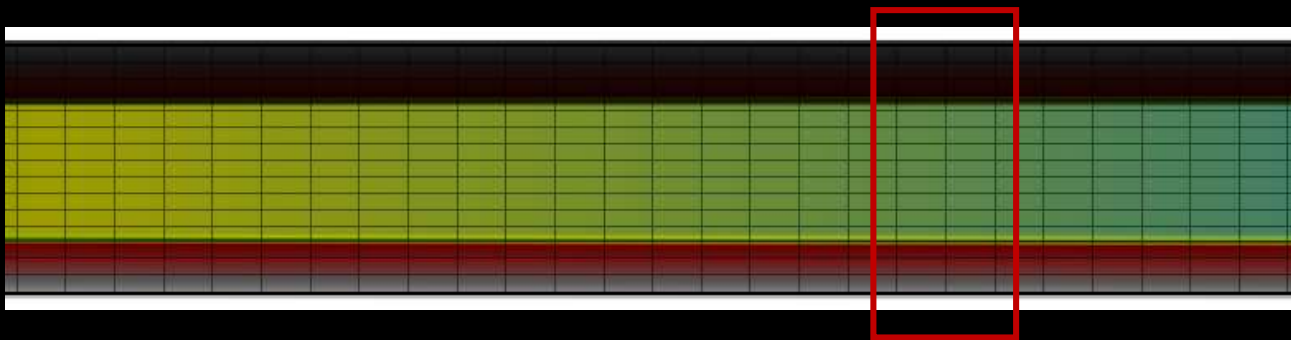


Is Too (Darn) High

A 2D model has:
a regular cell size of 100m and
an average velocity of 2 m/s.

Hint:

$$C = \frac{V \Delta t}{\Delta x}$$



What is a good
starting time step?

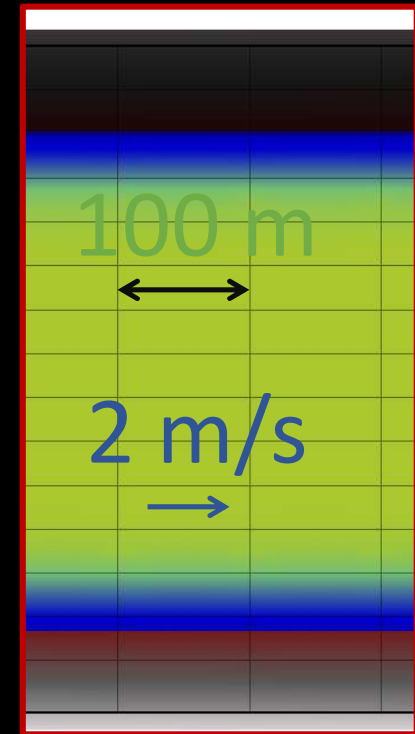
A 2D model has:
a regular cell size of 100m and
an average velocity of 2 m/s.

Hint:

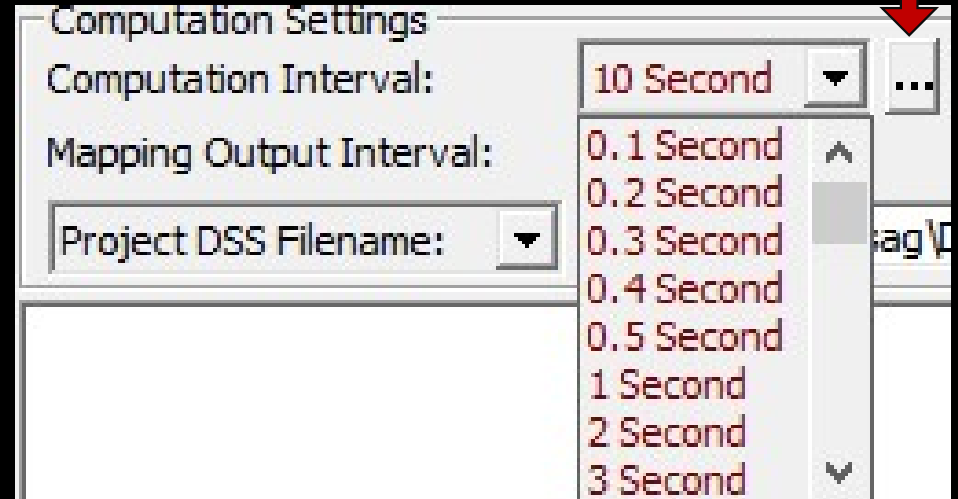
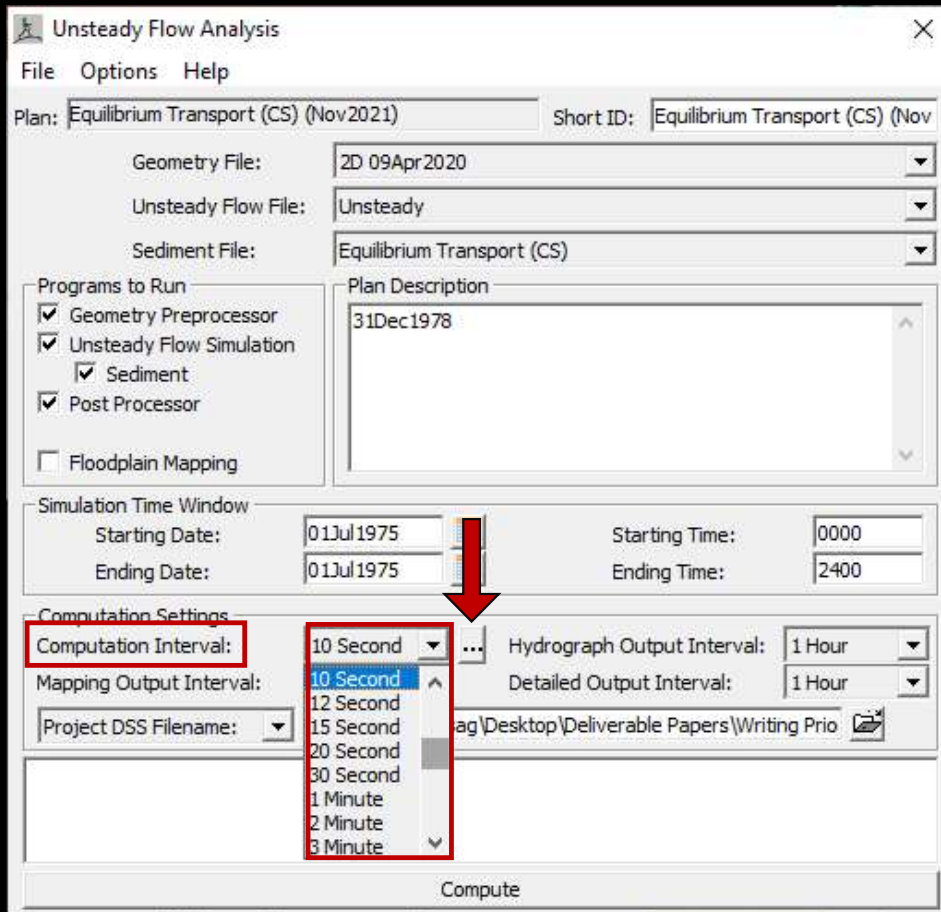
$$C = \frac{V \Delta t}{\Delta x}$$

$$\Delta t = \frac{\Delta x C}{V}$$

$$\Delta t = \frac{100m (1)}{2 m/s} = 50s$$

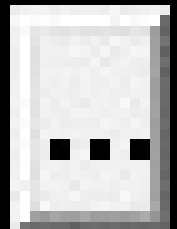


Selecting an Appropriate Timestep



Or....

...let RAS compute it



Selecting an Appropriate Timestep...

...Let RAS Do It

Adjust Time Step Based on Courant

Maximum Courant: 2

Minimum Courant: 0.9

Number of steps below Minimum before doubling: 4

Maximum number of doubling base time step: 4 32.00 min

Maximum number of halving base time step: 4 7.50 sec

Courant Methodology

Velocity/Length (face velocity * dt / cell to cell distance)

Residence Time (cell outflow * dt / cell volume)

1,2,4

Just < Max/2

2-8

- Based on the “critical cell” – smallest or fastest
- Works best if cell size is relatively regular
- Can reach time steps <0.1s

Adaptive Time Step Video Tutorial

The screenshot displays the HEC-RAS software interface. The main window shows the 'Unsteady Flow Analysis' dialog box with the following settings:

- Plan: Coarse 2D
- Geometry File: Geometry Copy (Coarse Grid)
- Unsteady Flow File: Unsteady_for_v7
- Simulation Time Window: Starting Date: 03JAN3000, Ending Date: 03JAN3000
- Starting Time: 0000, Ending Time: 0000
- Computation Settings: Computation Interval: 6 Minute, Hydrograph Output Interval: 6 Minute, Mapping Output Interval: 6 Minute, Detailed Output Interval: 6 Minute
- Project DSS Filename: C:\Users\j\hecsag\Desktop\Bugs and Support\Ponca_Creek\...

The dialog box also includes a 'Compute' button and a note: 'Time Step is controlled by courant condition.' In the background, a 2D flow area map is visible, and a video inset shows a man wearing a headset, likely the presenter of the tutorial.

Variable Time Steps and Time Slicing in HEC-RAS

506 views • Nov 5, 2021

👍 39 🗑 DISLIKE ➦ SHARE ≡+ SAVE ...

<https://youtu.be/kcBrOML3iS0>

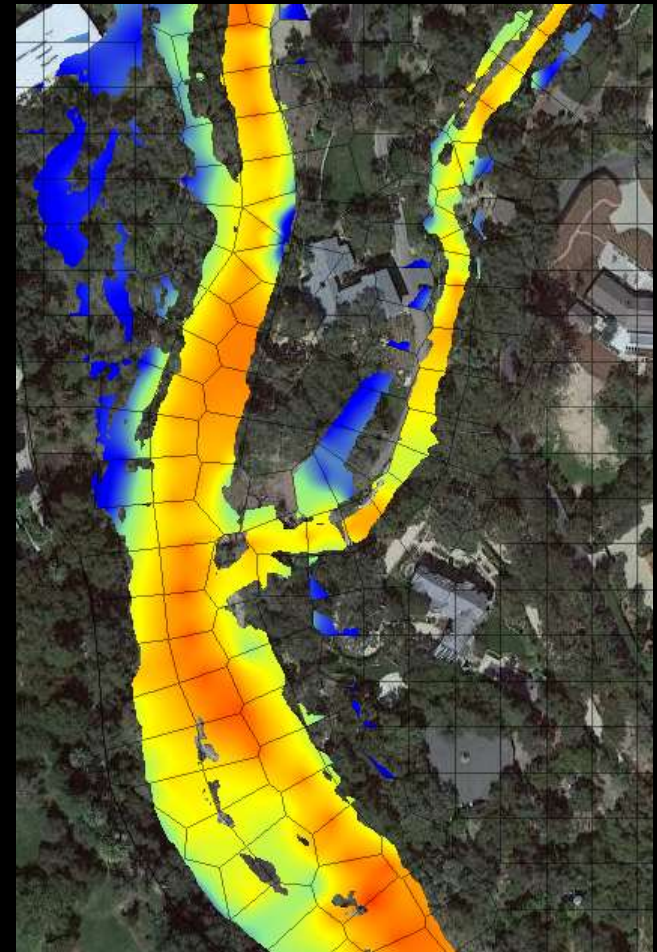
Hydraulic Best Practices for 2D Sediment Modeling

1. Top Two Issues

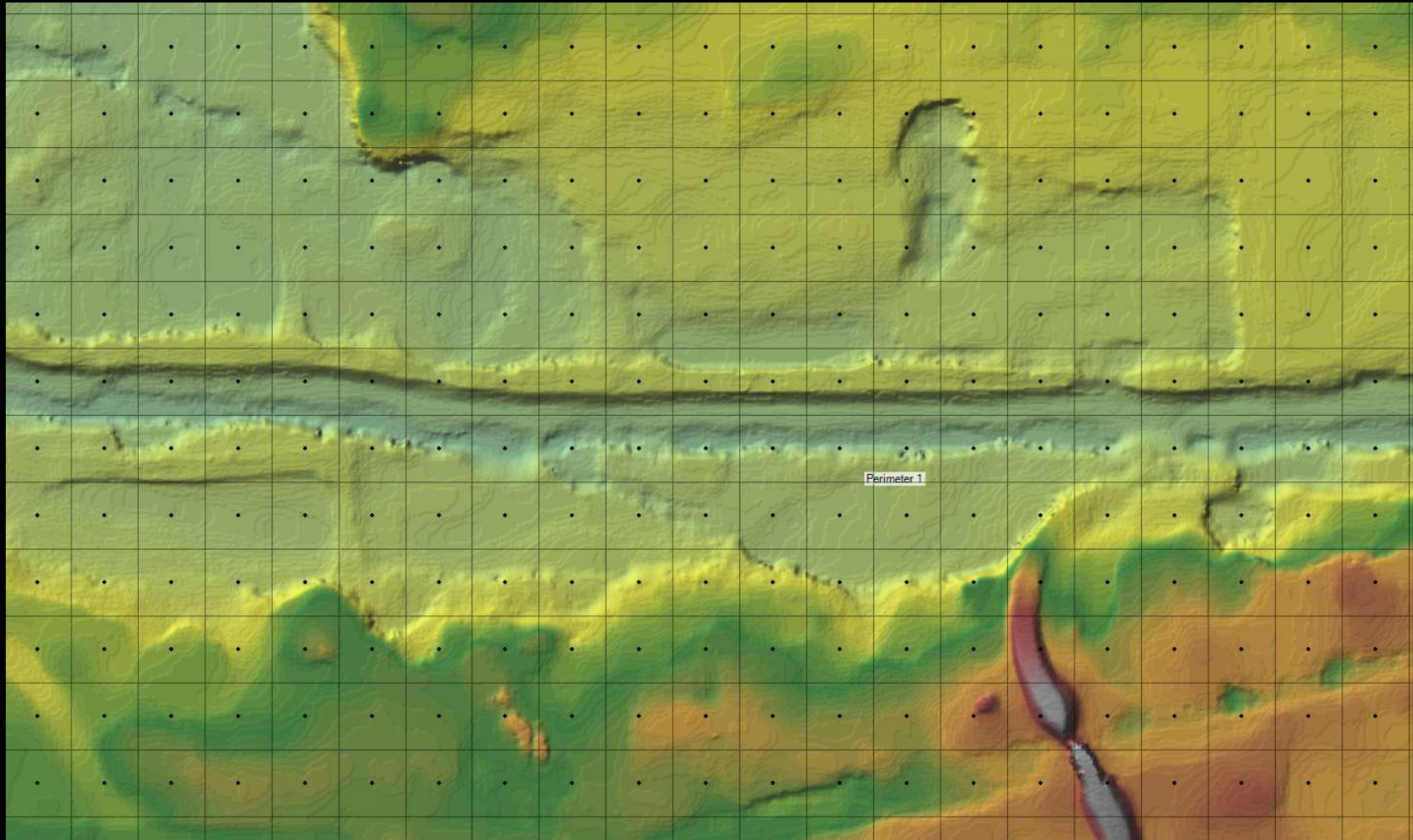
- Time Step
- Cell Faces and High Ground

2. Mesh Best Practices

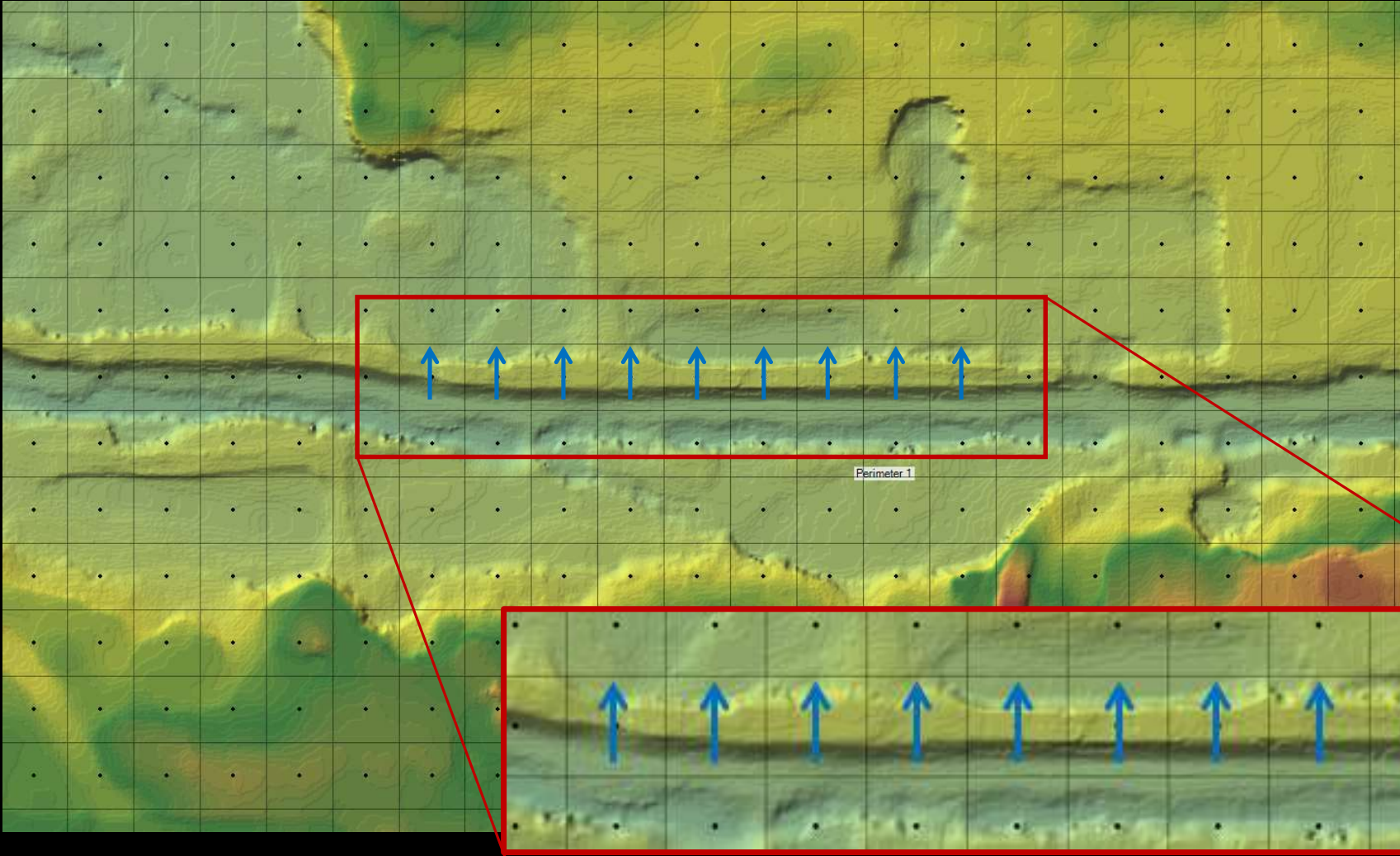
3. Computational Best Practices



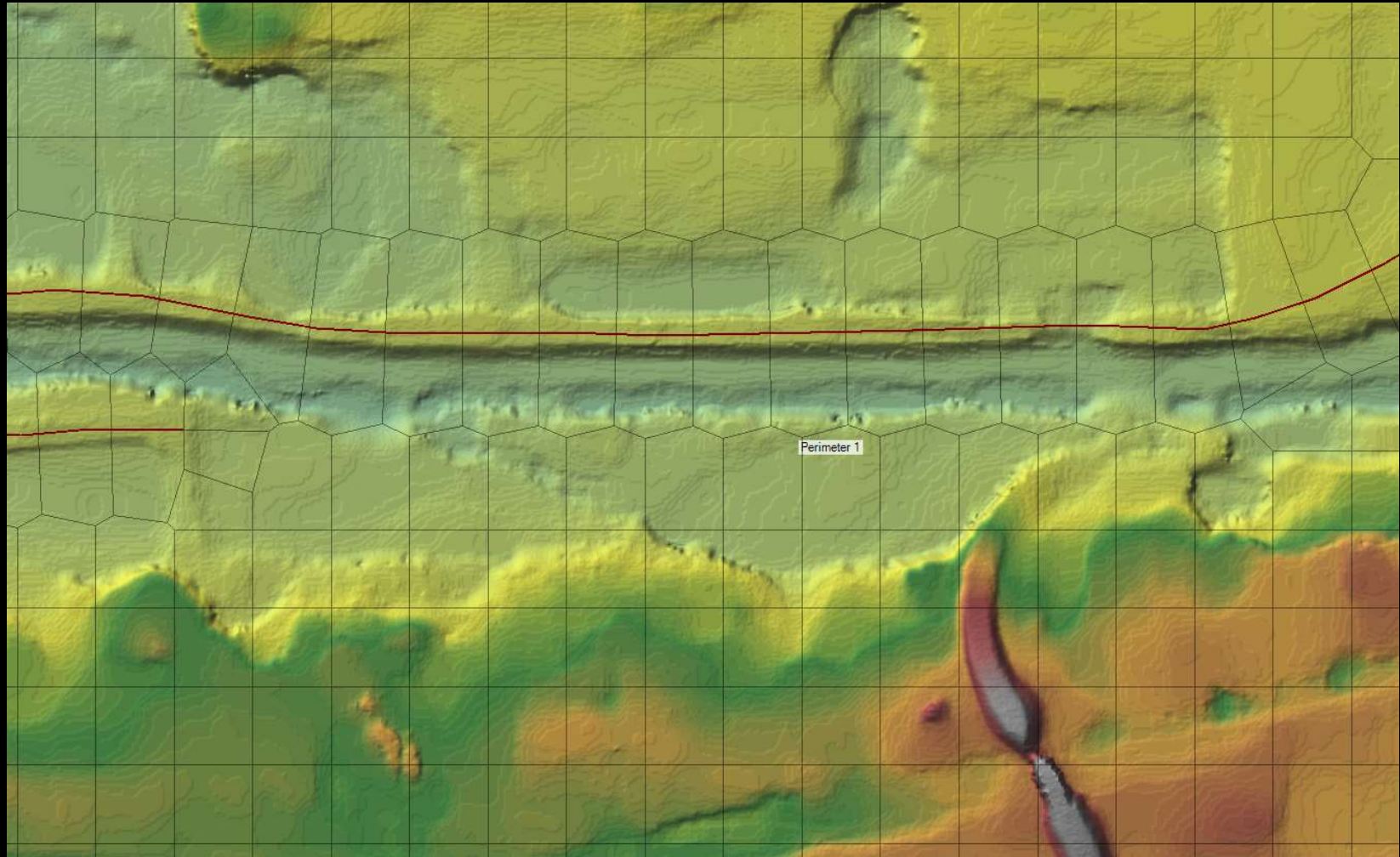
What is the biggest problem with this mesh?



Cell Edges Do Not Follow High Ground



Add a Breakline (or a bunch)

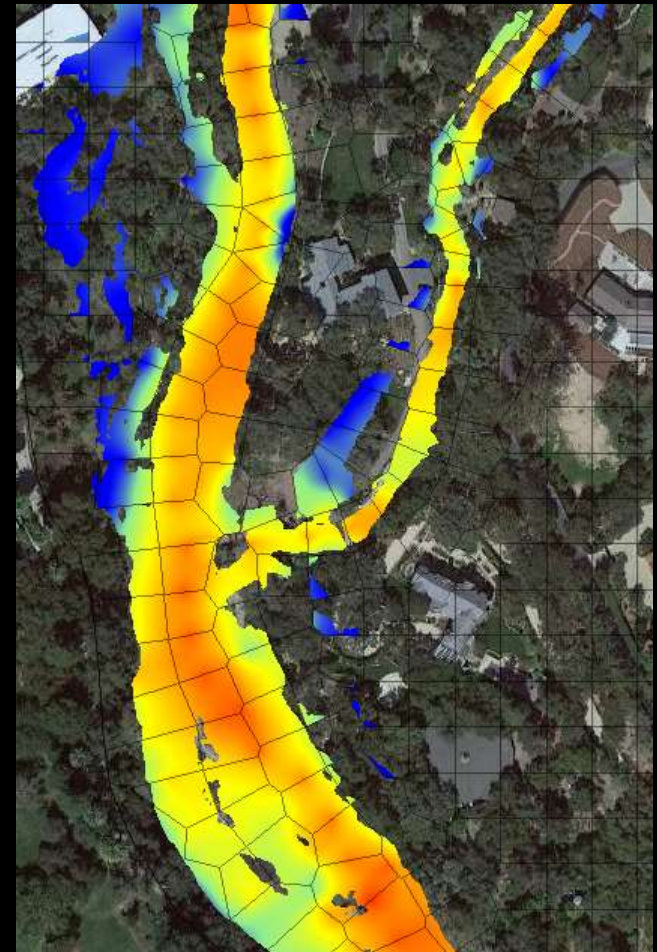


Take Away – Take Control of the High Ground

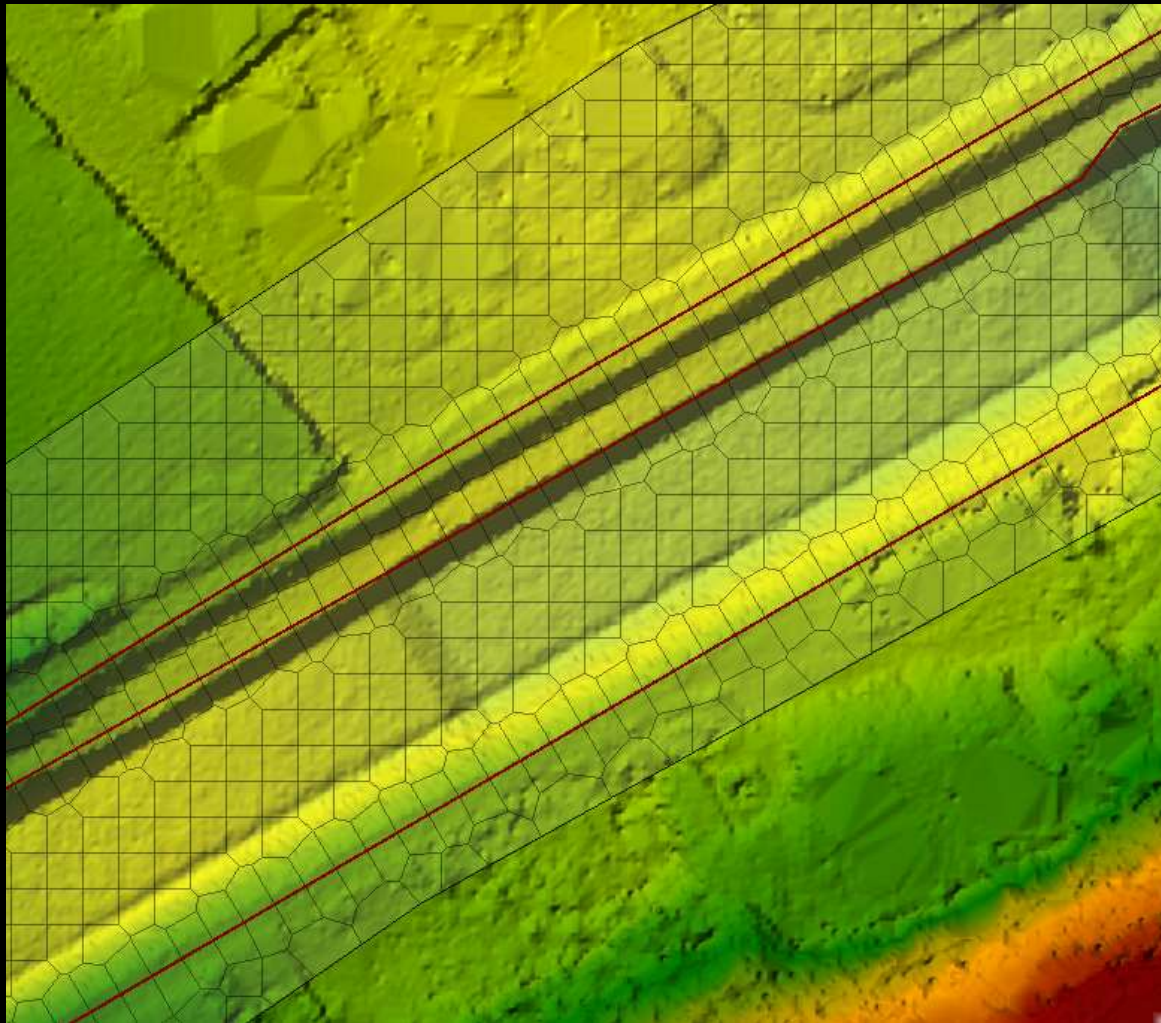


Hydraulic Best Practices for 2D Sediment Modeling

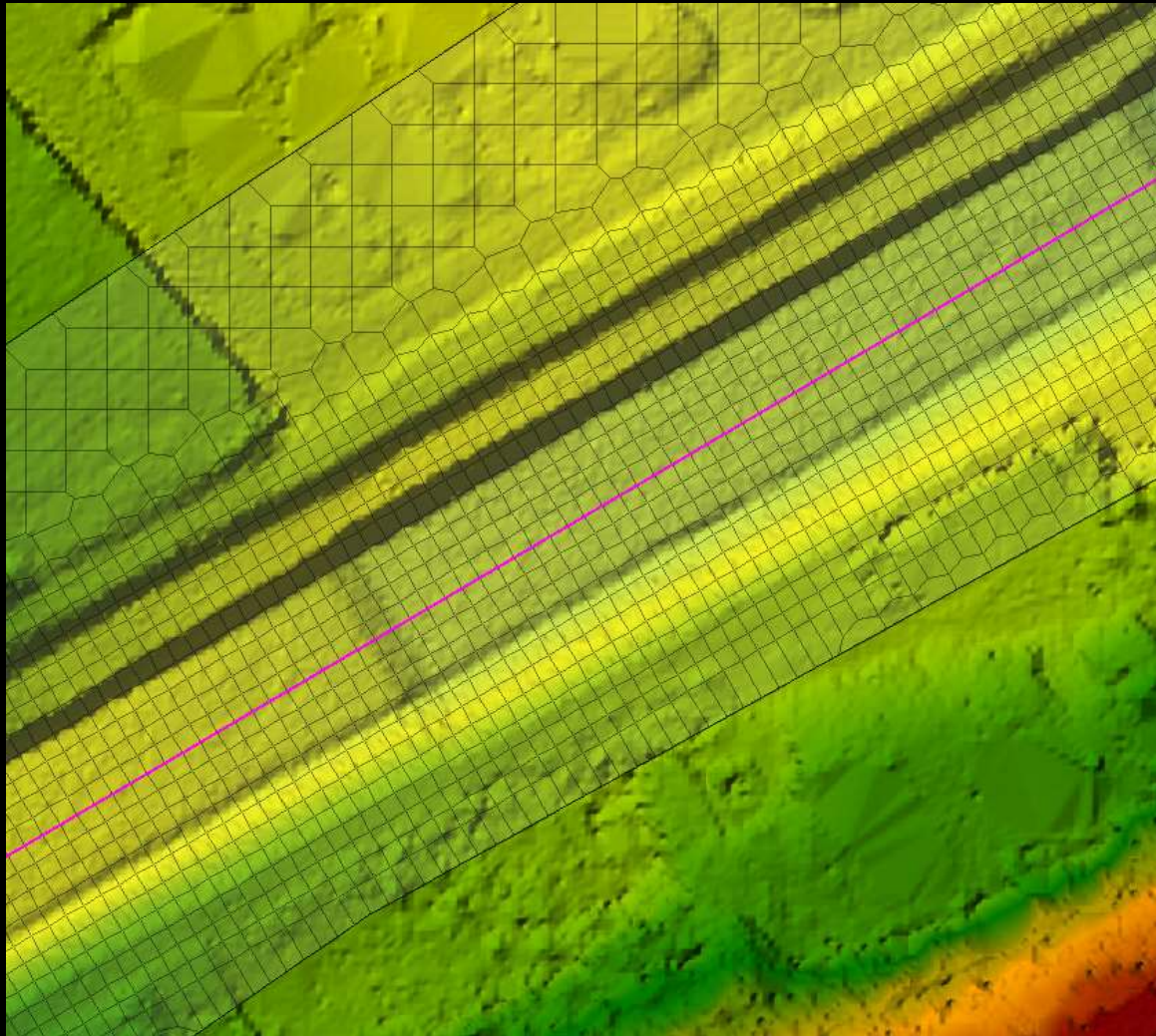
1. Top Two Issues
2. Mesh Best Practices
3. Computational Best Practices



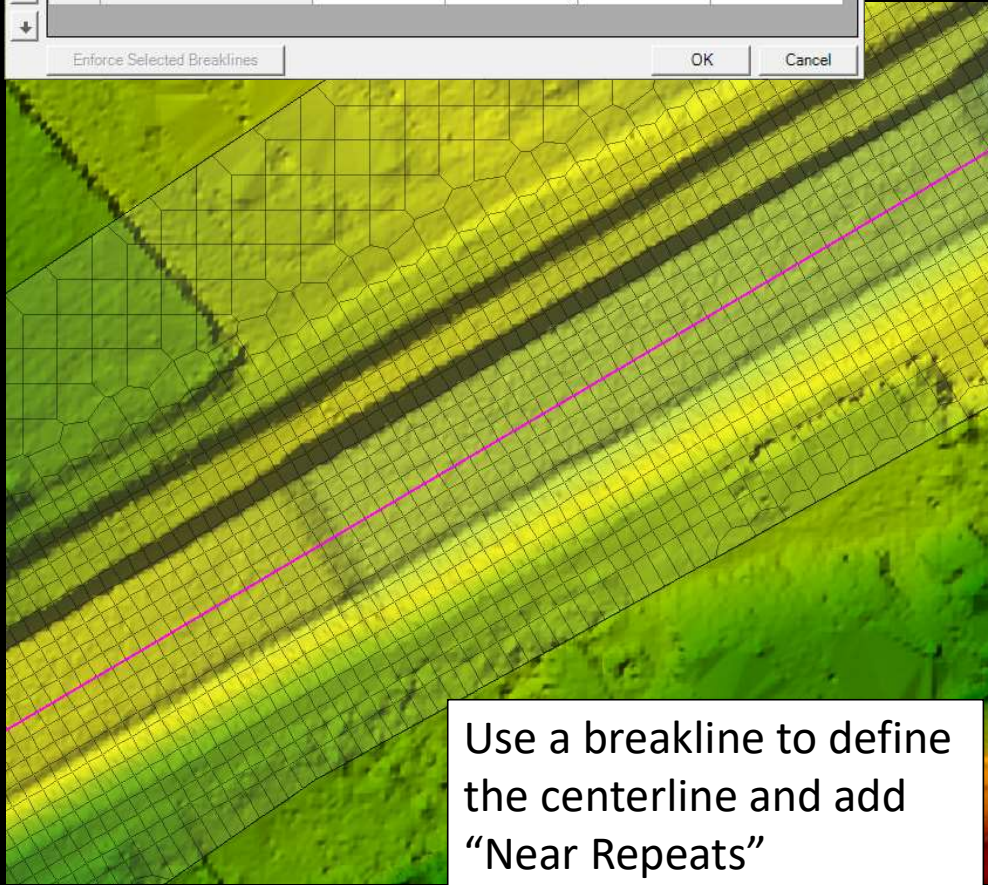
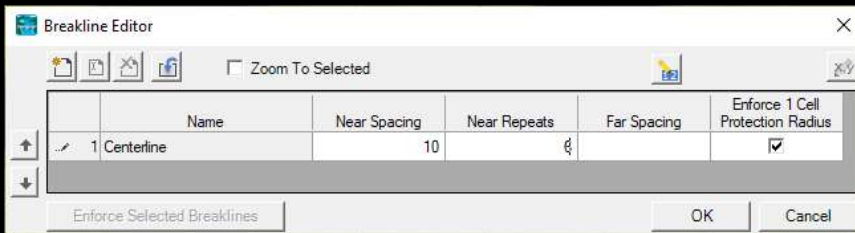
How Could We Improve This Mesh?



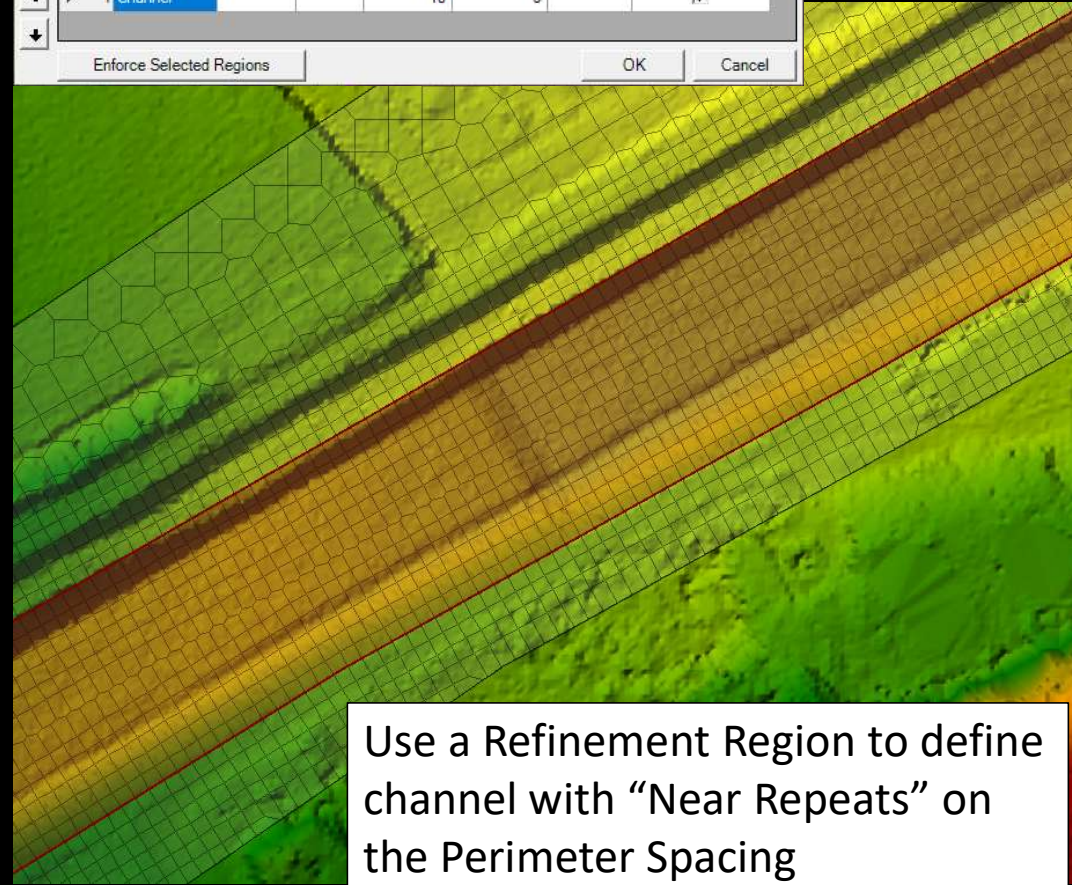
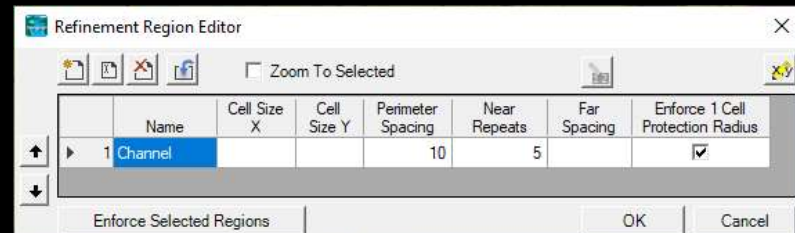
Align the Mesh with the Flow



Two Methods to Align Cells with Flow

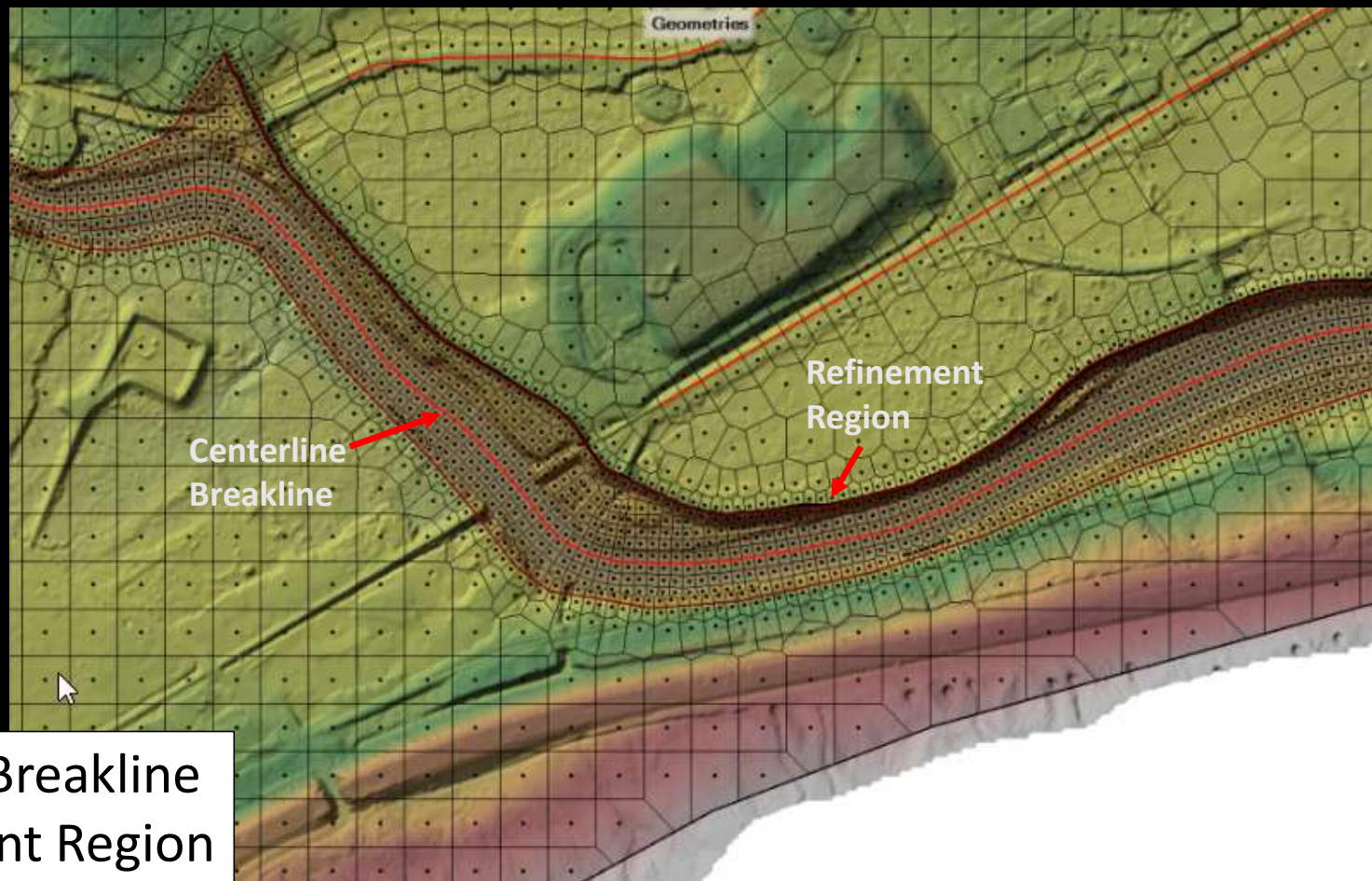


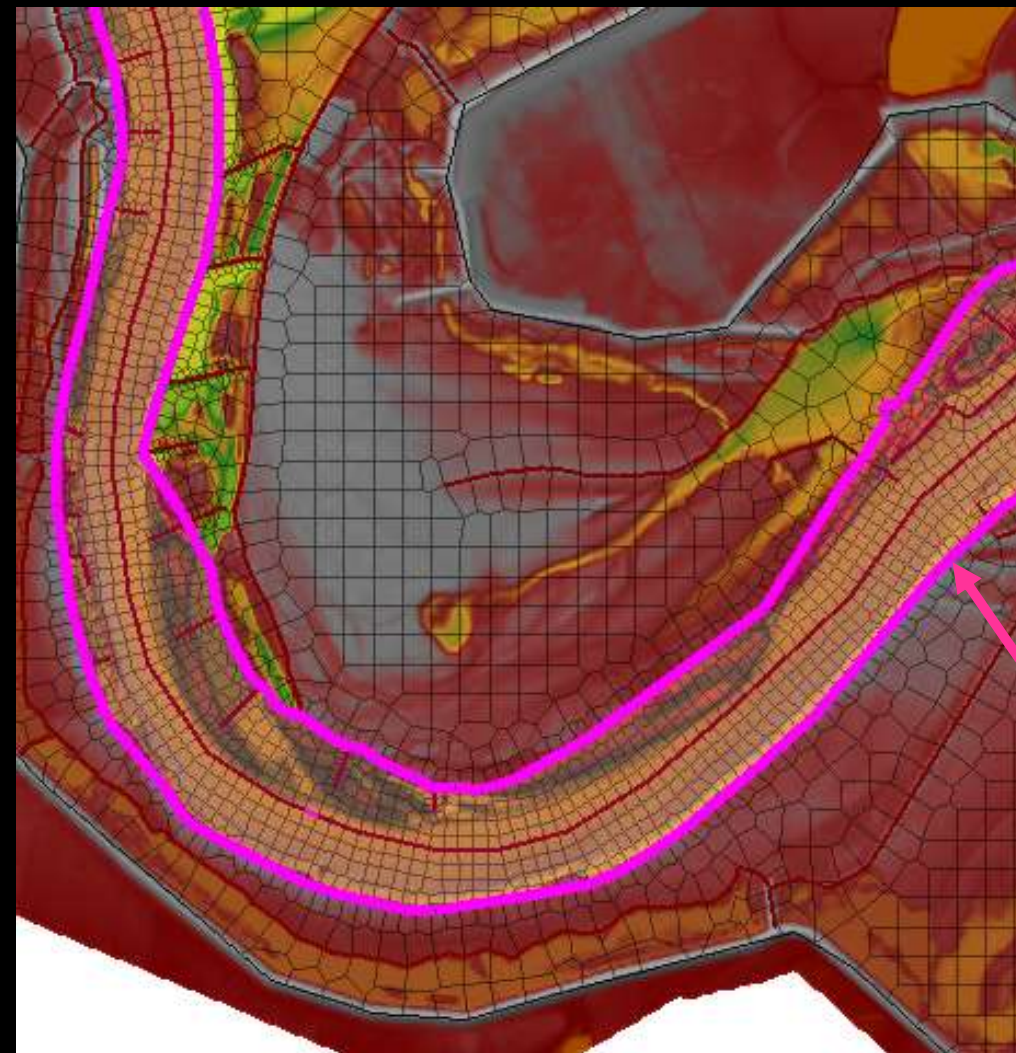
Use a breakline to define the centerline and add "Near Repeats"



Use a Refinement Region to define channel with "Near Repeats" on the Perimeter Spacing

Best Practice – Use Them Together





Centerline breakline

Near Repeats with Near Spacing

Breakline Editor

Zoom To Selected

Name	Near Spacing	Near Repeats	Far Spacing	Enforce 1 Cell Protection Radius
1 Center Line	200	4		<input checked="" type="checkbox"/>

Enforce Selected Breaklines (When 2 overlap, last row is considered on top) OK Cancel

Refinement Region

Only Meant to Snap the Outside Cell Faces to Banks
Perimeter Spacing and Enforce Cell Protection Only

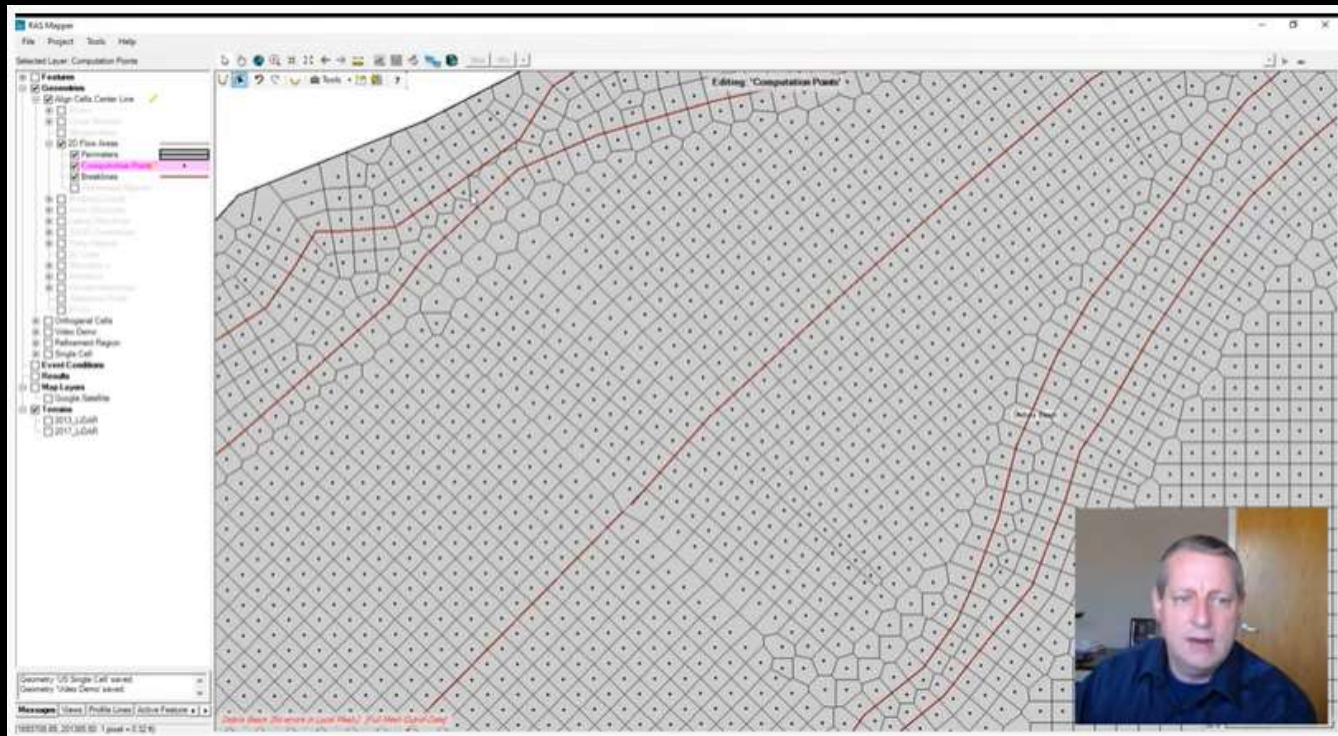
Refinement Region Editor

Zoom To Selected

Name	Cell Size X	Cell Size Y	Perimeter Spacing	Near Repeats	Far Spacing	Enforce 1 Cell Protection Radius
1 Channel			200	0		<input checked="" type="checkbox"/>

Enforce Selected Regions (When 2 overlap, last row is considered on top) OK Cancel

Alignment Video Tutorial



Align Cells with Flow Direction: HEC-RAS 2D Mesh

2,475 views...

73

DISLIKE

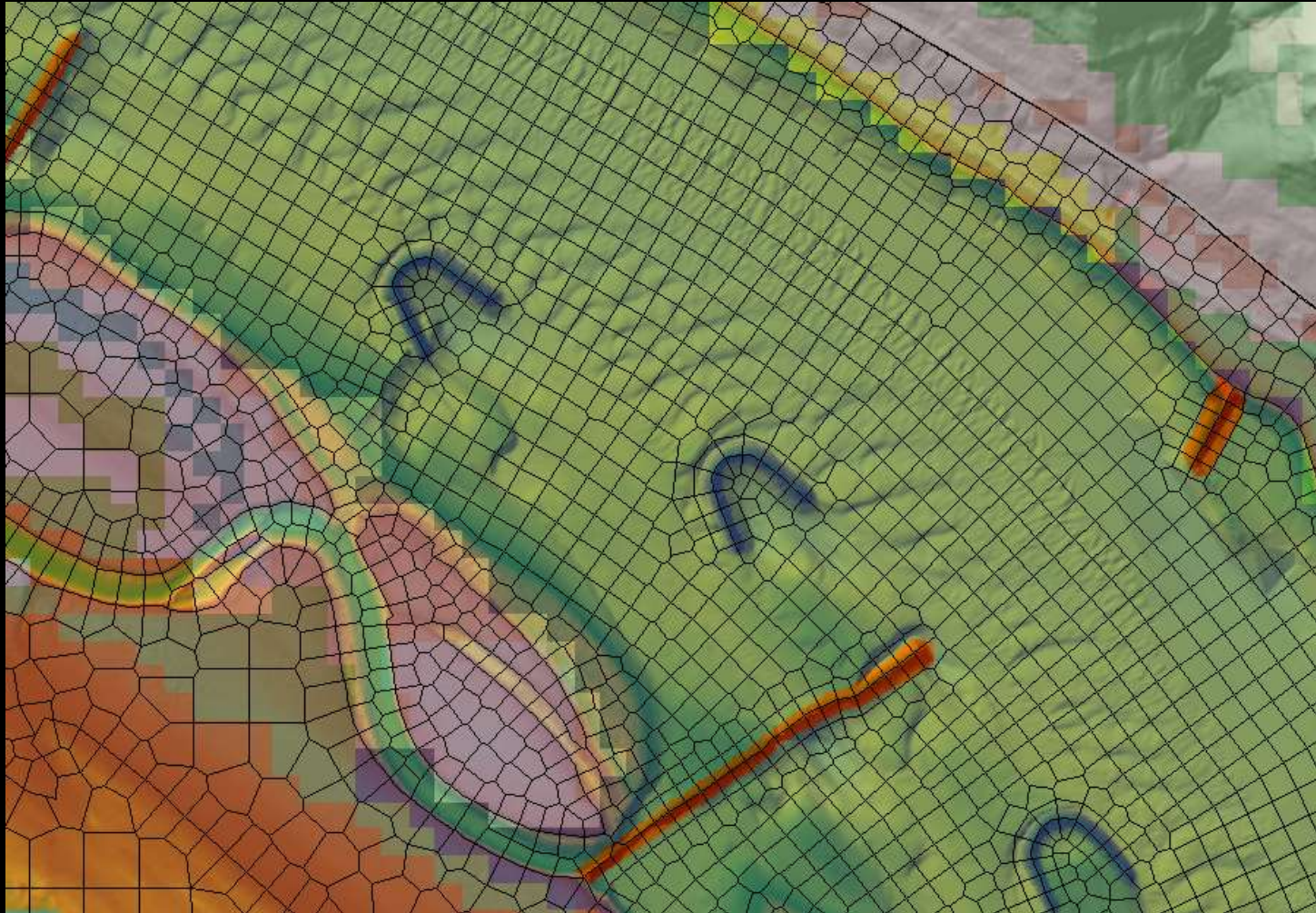
SHARE

SAVE

...

<https://youtu.be/oTfFdSmXbYQ>

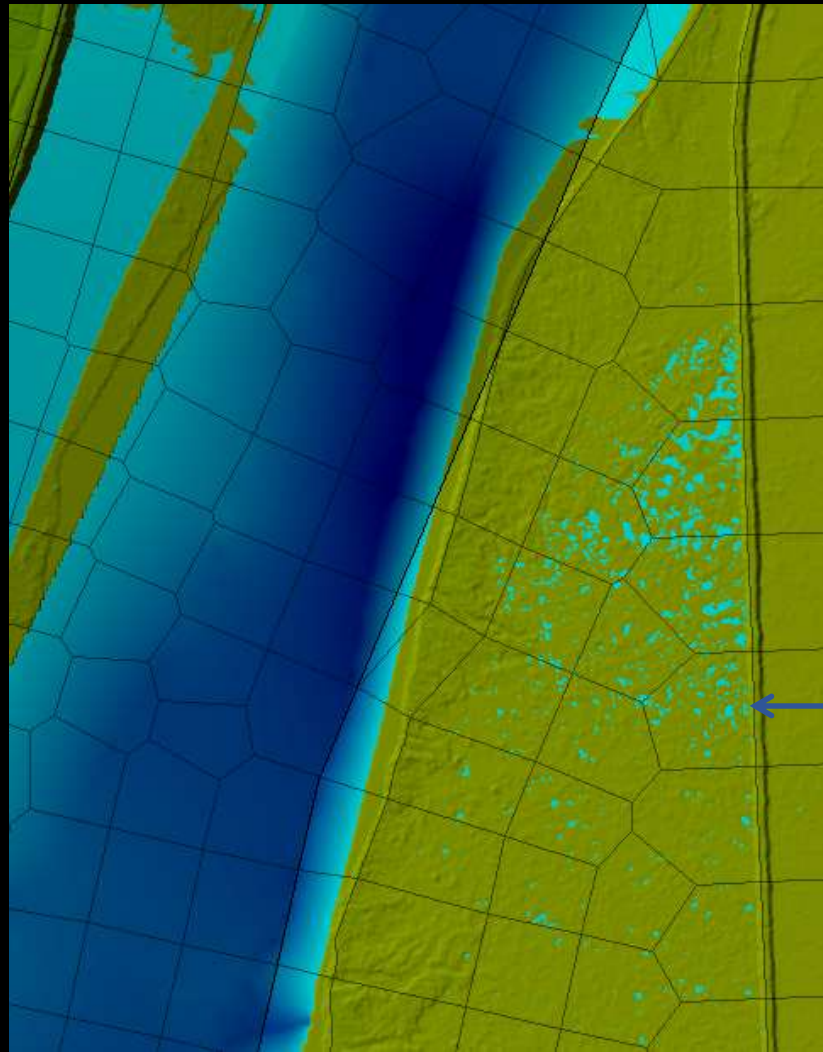
Use Breaklines for Linear Structures



Developing a Quality, Aligned, Mesh Takes Time



Evaluating Connectivity



Where does this floodplain water come from?

Evaluating Connectivity

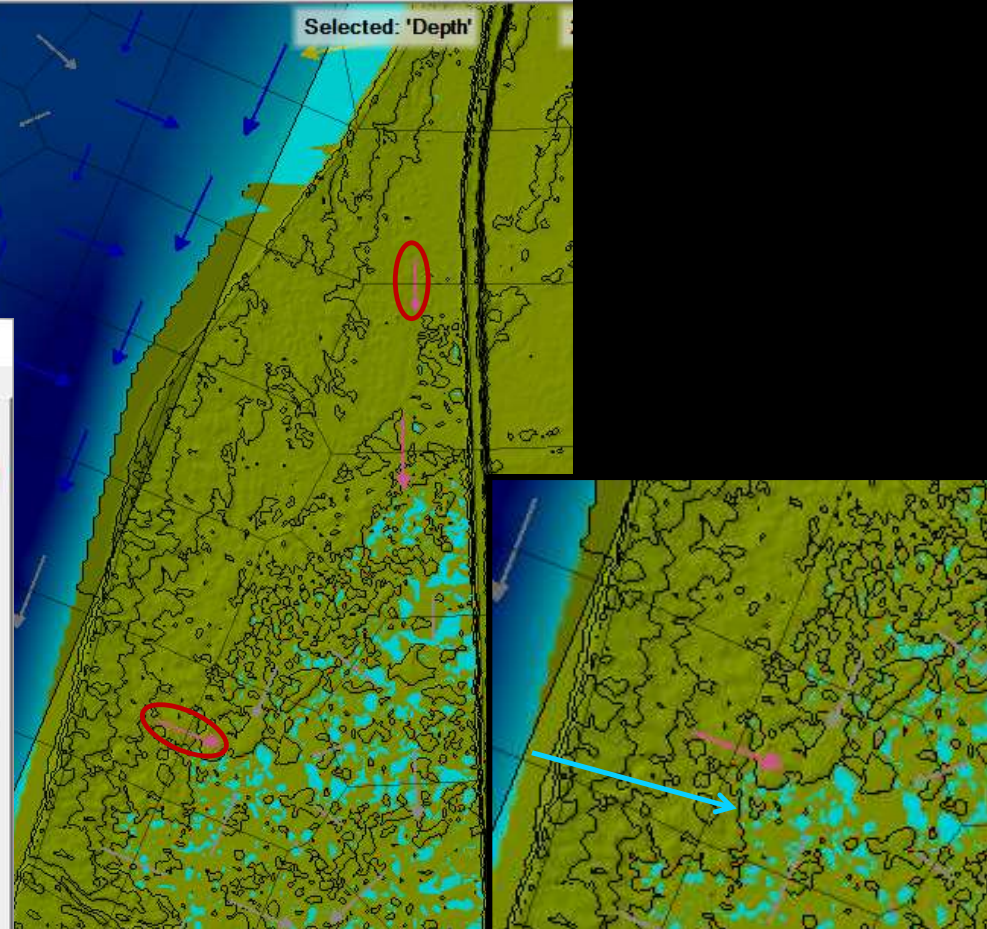
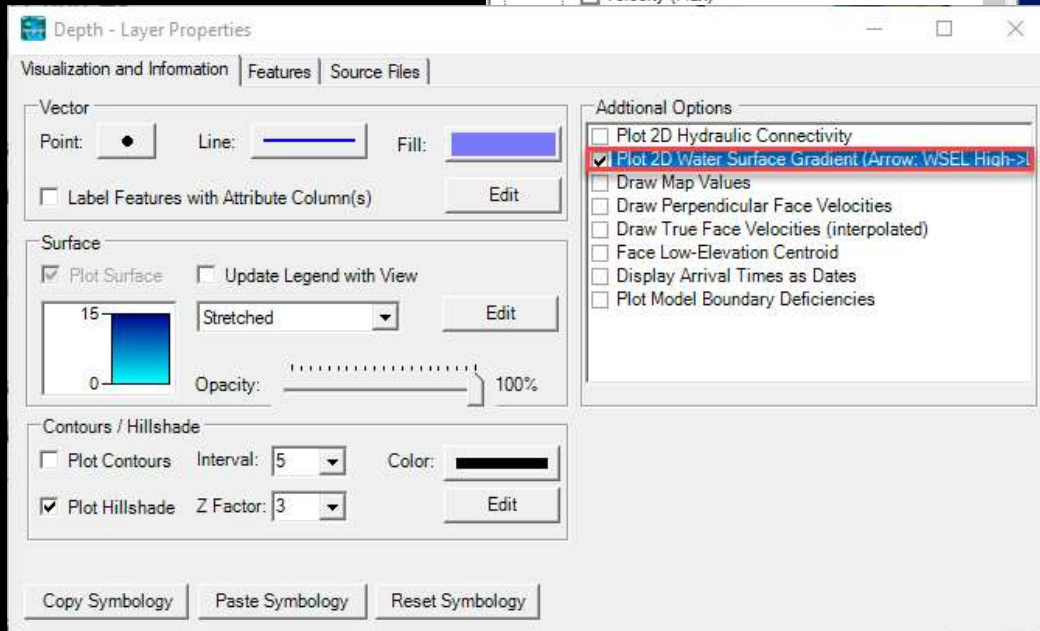
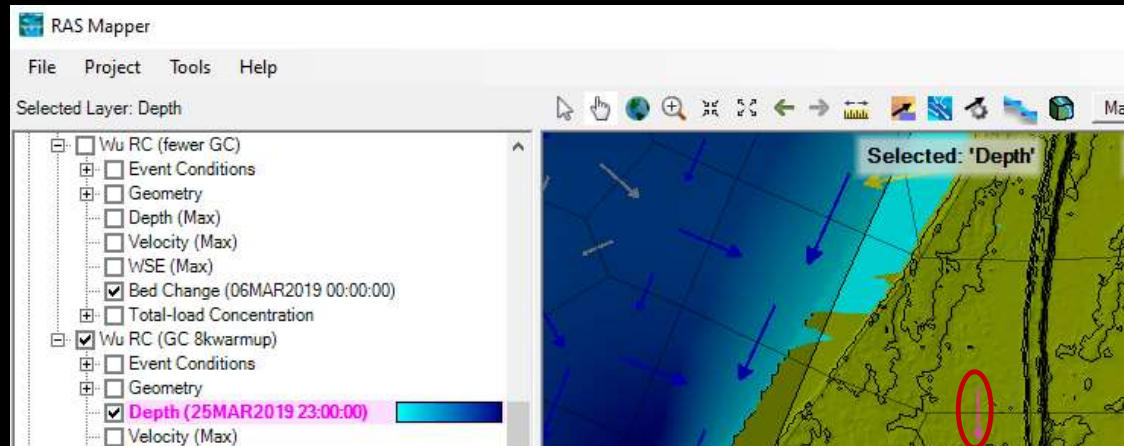
Turn on Contours
At a Helpful Interval

The screenshot displays a GIS application interface. On the left, a legend shows various layers, with 'Terrain' selected and highlighted in pink. A red arrow points from the 'Terrain' layer to the 'Terrain - Layer Properties' dialog box. The dialog box is open to the 'Visualization and Information' tab. In the 'Contours / Hillshade' section, the 'Plot Contours' checkbox is checked, and the 'Interval' is set to 1. The 'Plot Hillshade' checkbox is also checked, and the 'Z Factor' is set to 3. The background map shows a terrain surface with a color gradient from blue (low elevation) to green (high elevation). A red box highlights the 'Contours / Hillshade' section of the dialog box.

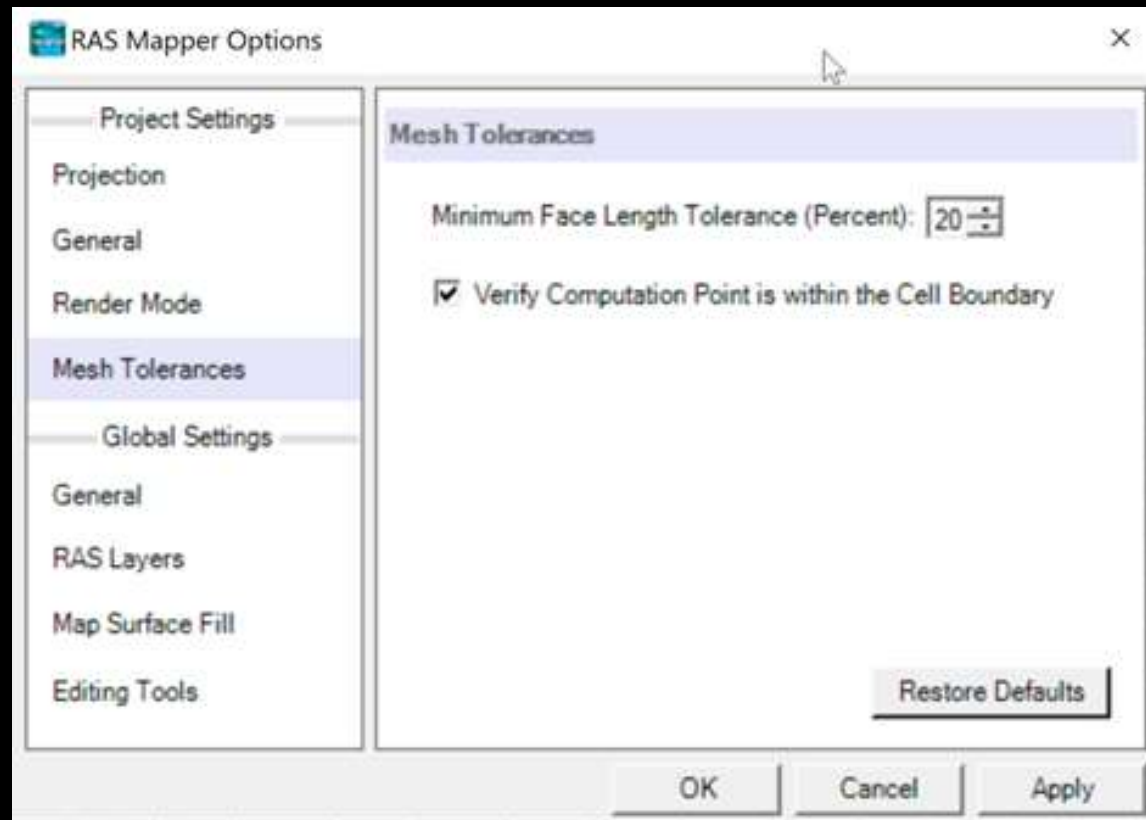
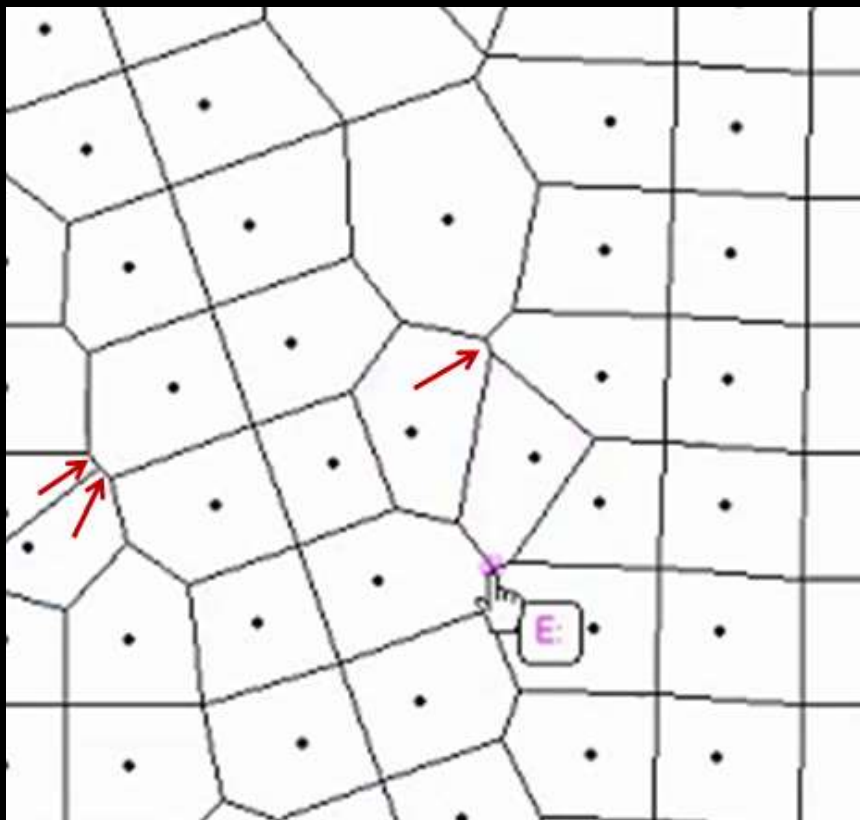
Messages Views Profile Lin

Copy Symbology Paste Symbology Reset Symbology

Evaluating Connectivity

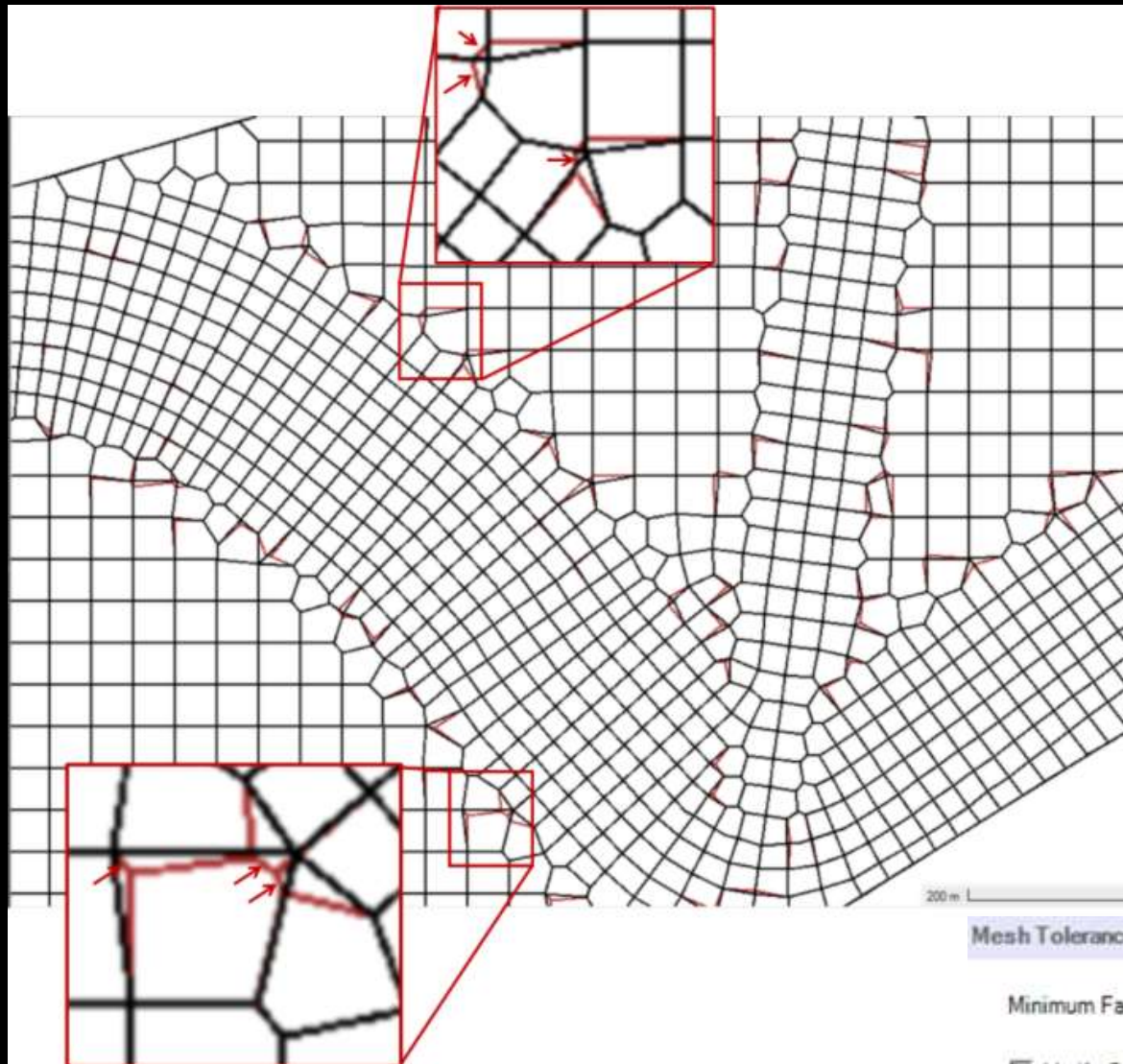


Avoid Tiny Cell Faces



This is much easier to fix in recent versions.
Use the Mesh Tolerances in Mapper Options

Avoid Tiny Cell Faces



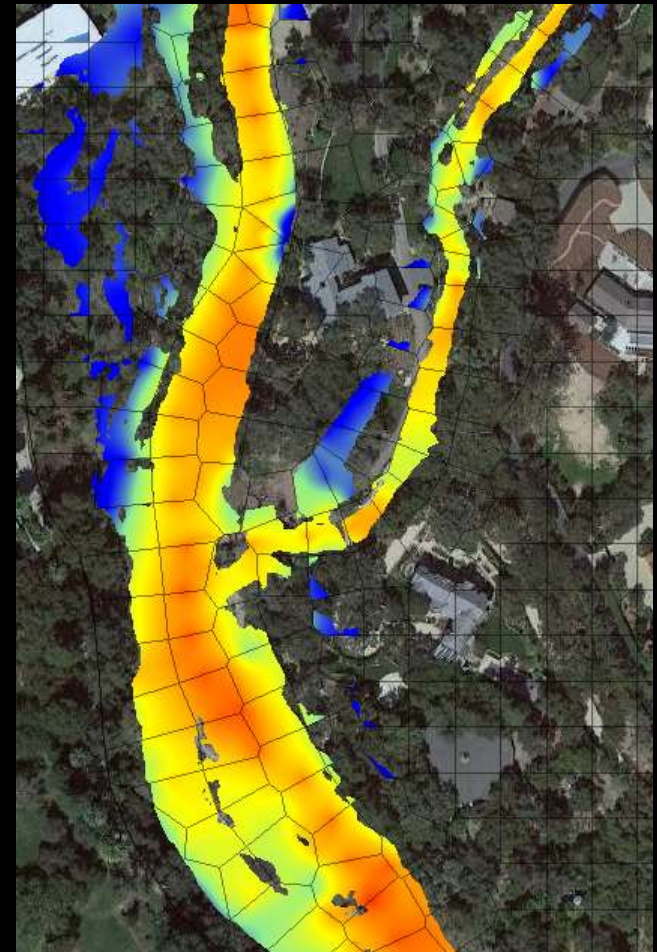
Mesh Tolerances

Minimum Face Length Tolerance (Percent):

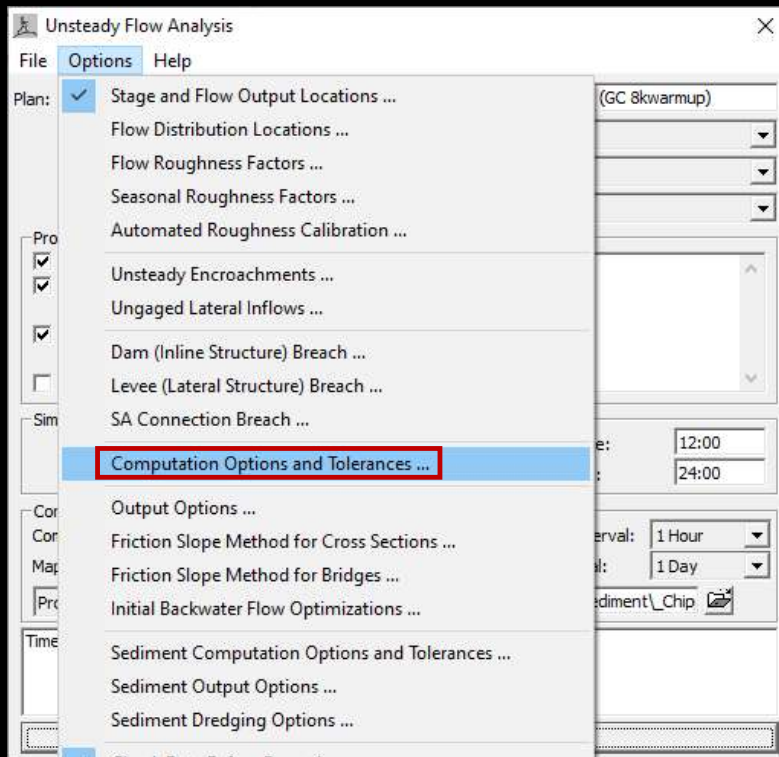
Verify Computation Point is within the Cell Boundary

Hydraulic Best Practices for 2D Sediment Modeling

1. Top Two Issues
2. Mesh Best Practices
3. Computational Best Practices
 - Hydraulic Warmup
 - Hydrodynamic Equations
 - Turbulence and Mixing
 - Other Tips and Tricks



Initial Conditions: Hydraulic Warm Up/Ramp Up

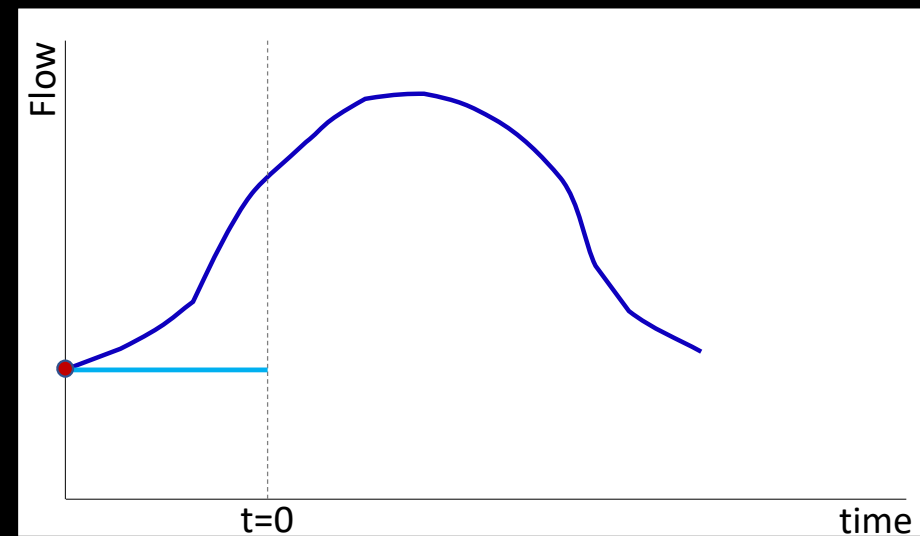


HEC-RAS Unsteady Computation Options and Tolerances

General | 2D Flow Options | 1D/2D Options | Advanced Time Step Control | 1D Mixed Flow Options

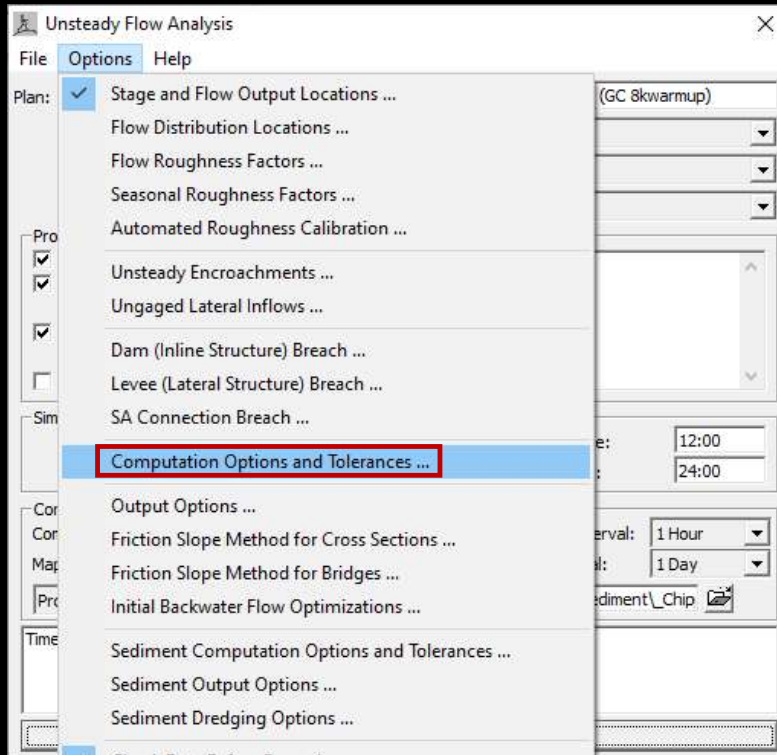
Use Coriolis Effects (not used with Diffusion Wave equation)

	Parameter	(Default)	Chippewa
1	Theta (0.6-1.0)	1	1
2	Theta Warmup (0.6-1.0)	1	1
3	Water Surface Tolerance [max=0.2](ft)	0.01	0.01
4	Volume Tolerance (ft)	0.01	0.01
5	Maximum Iterations	20	20
6	Equation Set	SWE-ELM (original/faster)	SWE-ELM (original/faster)
7	Initial Conditions Time (hrs)	12	12
8	Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1



- 1D Unsteady Starts with a Steady Flow Run For Initial Conditions
- 2D Hydraulics Starts Dry: There is no “Steady Flow 2D”
- The “Ramp Up” Allows you to Reach “Dynamic Steady State”
- Giving a Model Enough Time to Reach Hydraulic Steady State is Critical for a Sediment Simulation

Initial Conditions: Hydraulic Warm Up/Ramp Up



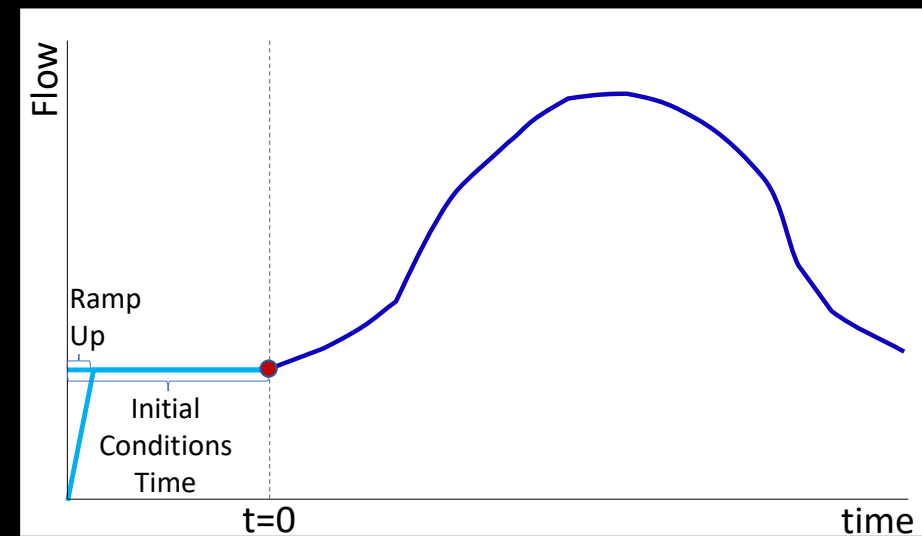
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6	Equation Set	SWE-ELM (original/faster)	SWE-ELM (original/faster)
7	Initial Conditions Time (hrs)	12	12
8	Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1

- Note: The Initial Conditions Time Does not Use the Adaptive Time Step



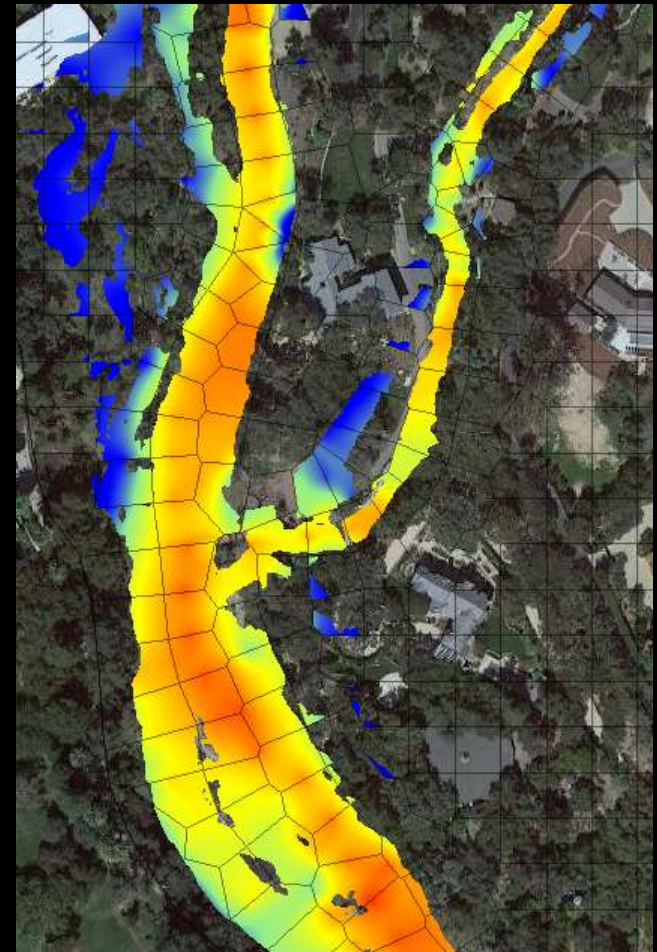
Hydraulic Best Practices for 2D Sediment Modeling

1. Top Two Issues

2. Mesh Best Practices

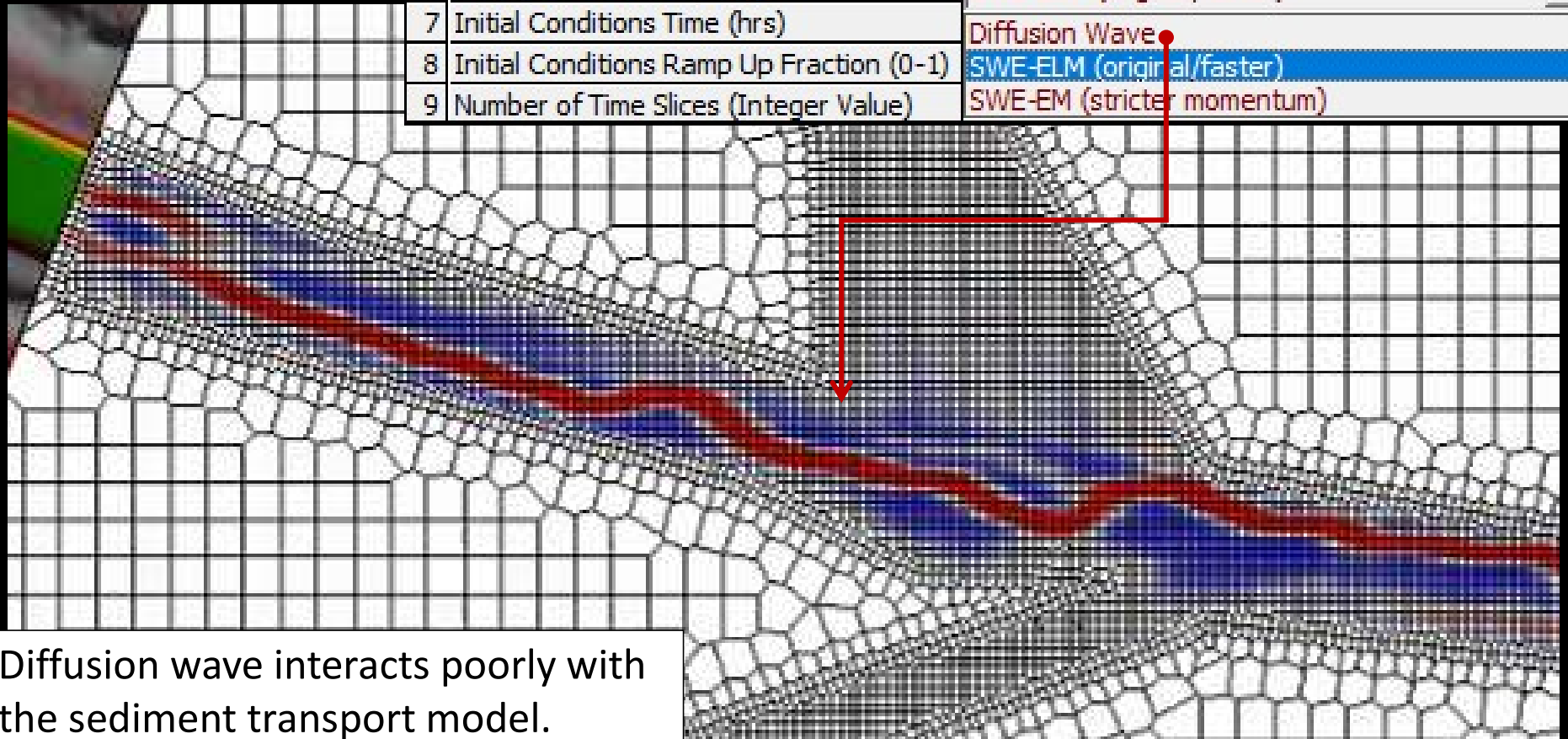
3. Computational Best Practices

- Hydraulic Warmup
- Hydrodynamic Equations
- Turbulence and Mixing
- Other Tips and Tricks



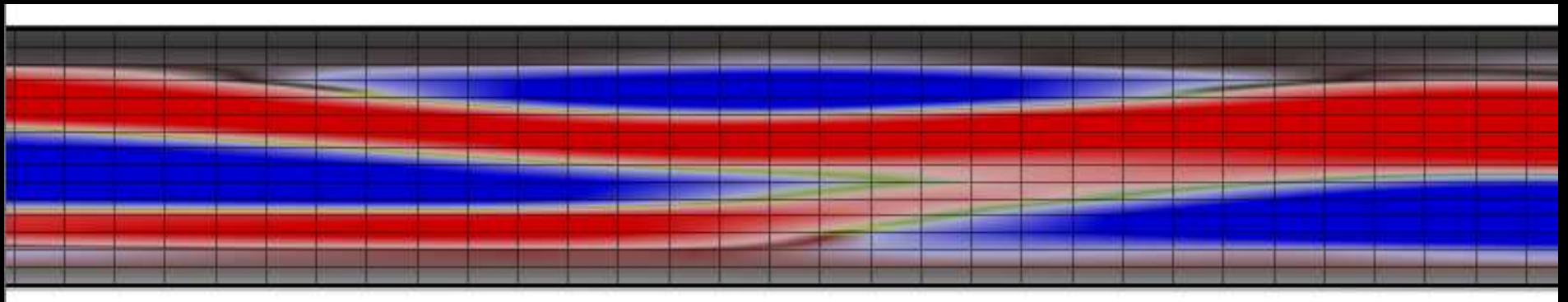
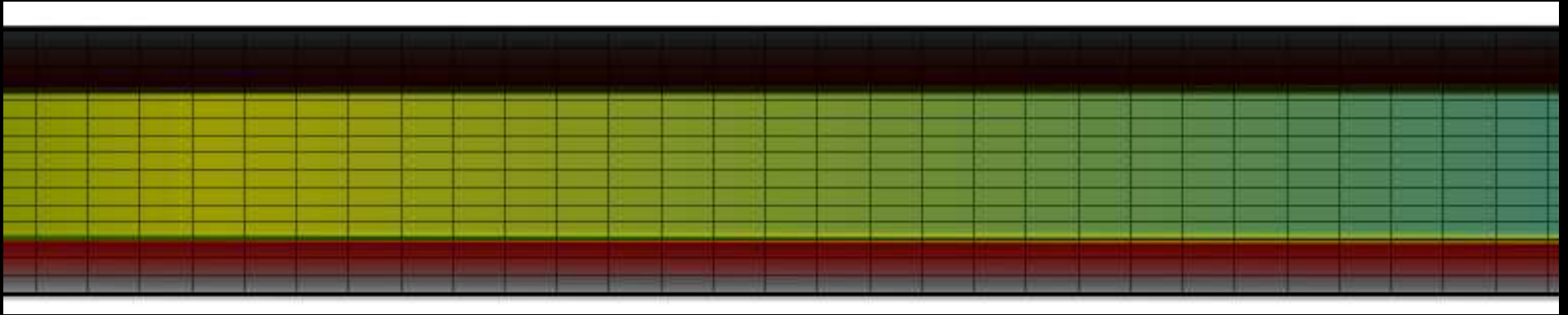
Always Use the Full Momentum Equations

6	Equation Set	SWE-ELM (original/faster)
7	Initial Conditions Time (hrs)	Diffusion Wave
8	Initial Conditions Ramp Up Fraction (0-1)	SWE-ELM (original/faster)
9	Number of Time Slices (Integer Value)	SWE-EM (stricter momentum)



Diffusion wave interacts poorly with the sediment transport model.

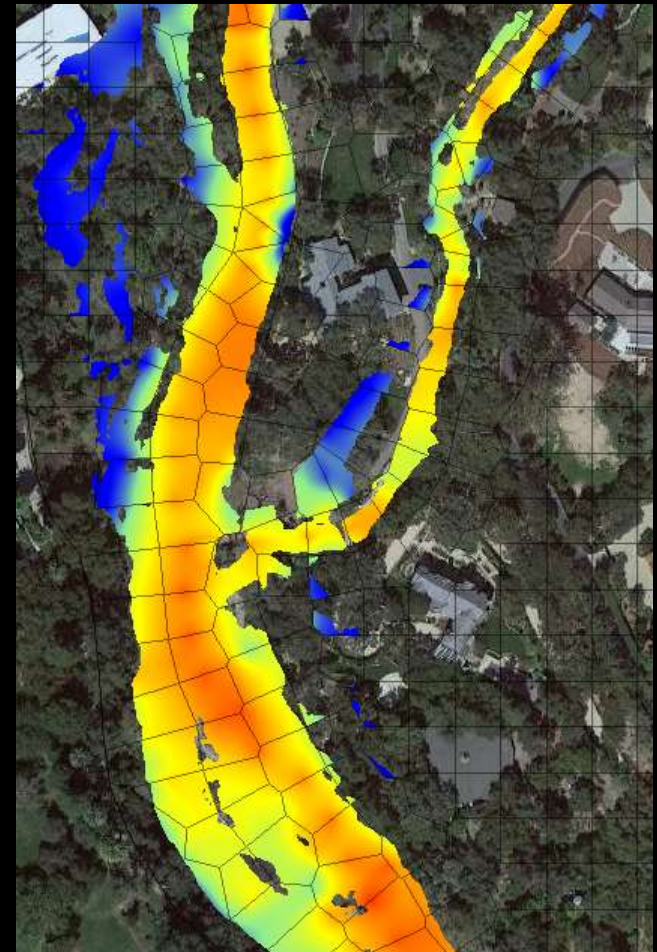
Always Use the Full Momentum Equations



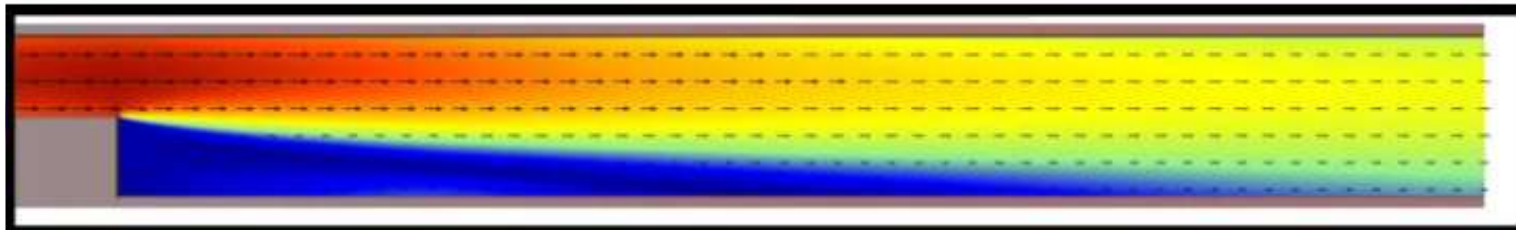
Diffusion Wave Result

Hydraulic Best Practices for 2D Sediment Modeling

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How does sediment transport laterally in RAS?
(Choose all that apply)

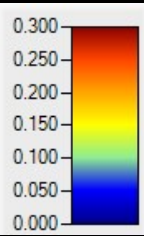
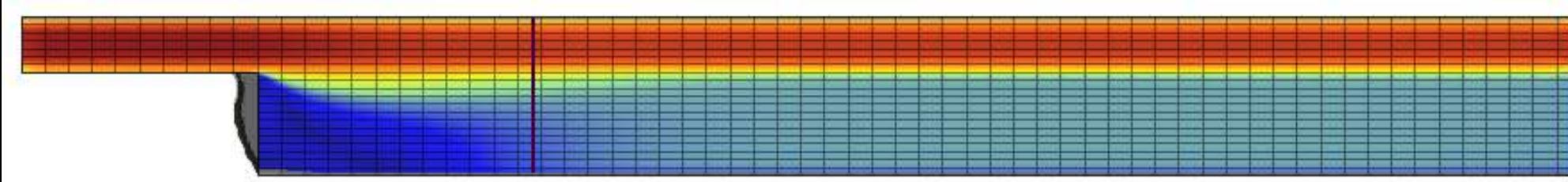
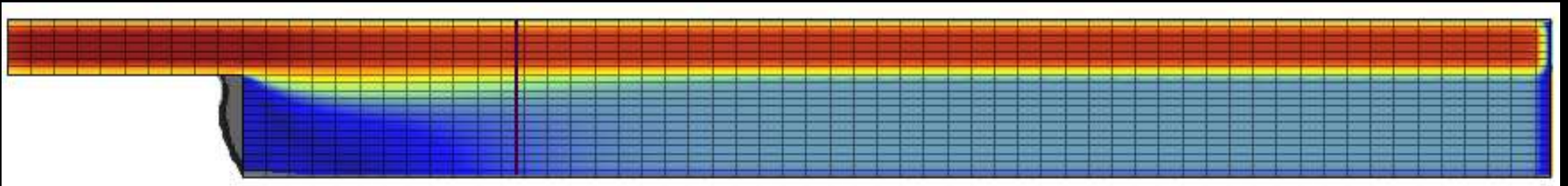


▲ Turbulence and mixing

◆ Numerical Dispersion

● Sediment Diffusion

■ Muskrat Metabolism



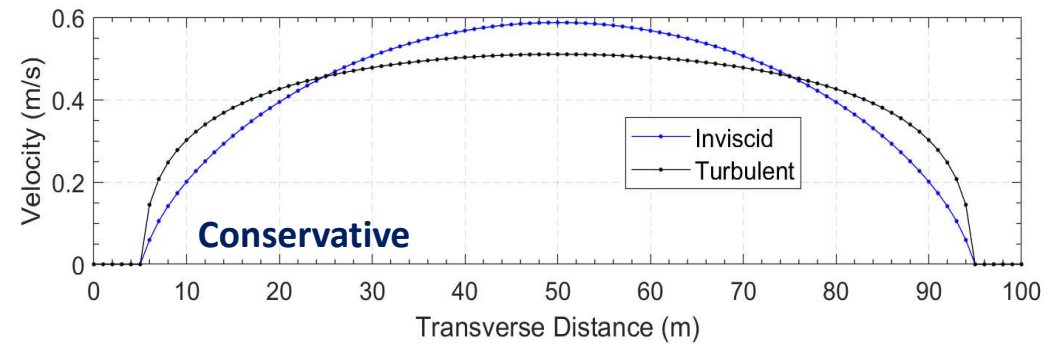
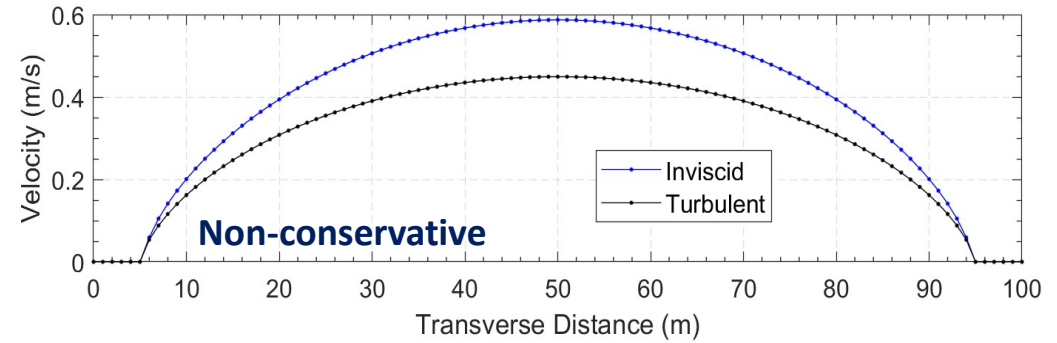
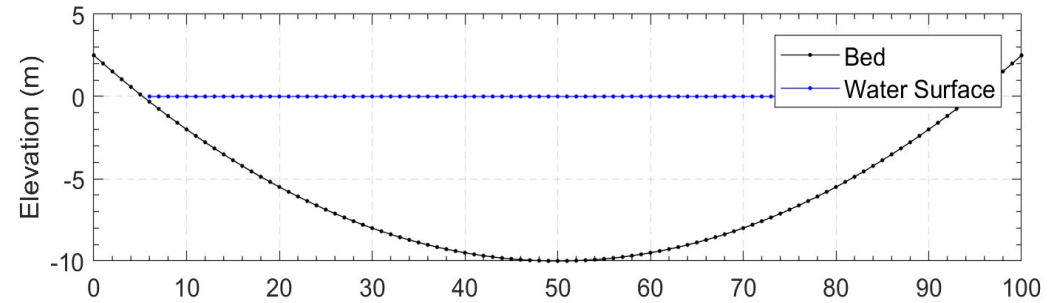
Turbulence Equations

HEC-RAS Unsteady Computation Options and Tolerances

General | 2D Flow Options | 1D/2D Options | Advanced Time Step Control | 1D Mixed Flow Options

Use Coriolis Effects (not used with Diffusion Wave equation)

Parameter	(Default)	2D Area
1 Theta (0.6-1.0)	1	1
2 Theta Warmup (0.6-1.0)	1	1
3 Water Surface Tolerance [max=0.06](m)	0.01	0.01
4 Volume Tolerance (m)	0.01	0.01
5 Maximum Iterations	20	20
6 Equation Set	SWE-EM (stricter momentum)	SWE-EM (stricter momentum)
7 Initial Conditions Time (hrs)	0.5	0.5
8 Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1
9 Number of Time Slices (Integer Value)	1	1
10 Turbulence Model	None	None
11 Longitudinal Mixing Coefficient		None
12 Transverse Mixing Coefficient		Conservative
13 Smagorinsky Coefficient		Non-Conservative (original)
14 Boundary Condition Volume Check	<input type="checkbox"/>	<input type="checkbox"/>



Turbulence Equations

Turbulence and mixing are essentially diffusion terms.

Non-Conservative

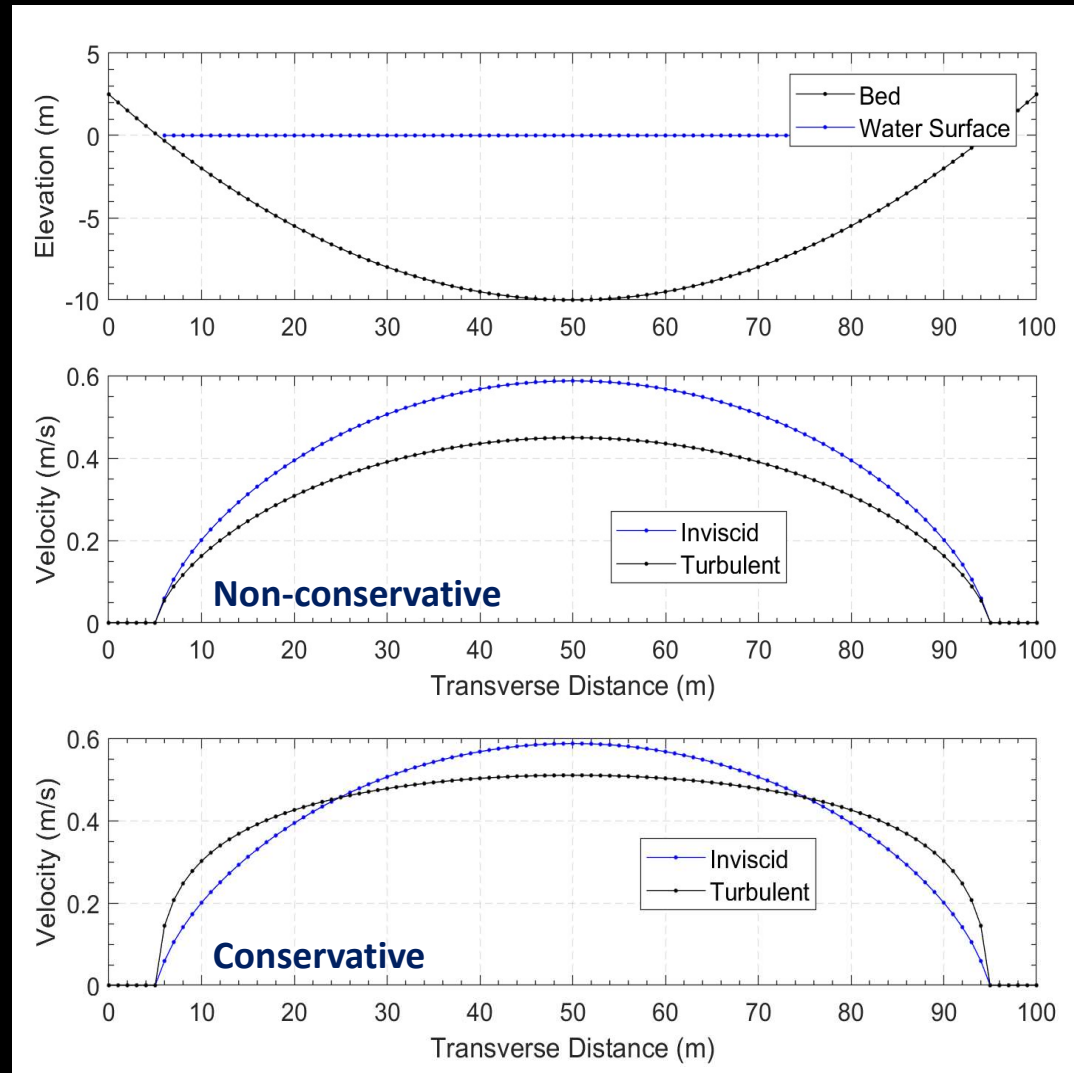
Assumes smoothly varying velocities (changes are gradual)
 The eddy viscosity can come outside the derivative
 But the spatial average drop – so this becomes a dissipation term not just a mixing term

$$\frac{\partial u}{\partial t} + v \frac{\partial u}{\partial y} - fv = -g \frac{\partial H}{\partial x} + v_t \left(\frac{\partial^2 u}{\partial y^2} \right) - c_f u$$

Conservative

Transforms the mixing term into the diffusive flux by moving the coefficient inside the derivative and multiplying by h/h
 This is a finite volume approach and yields a conservative formulation

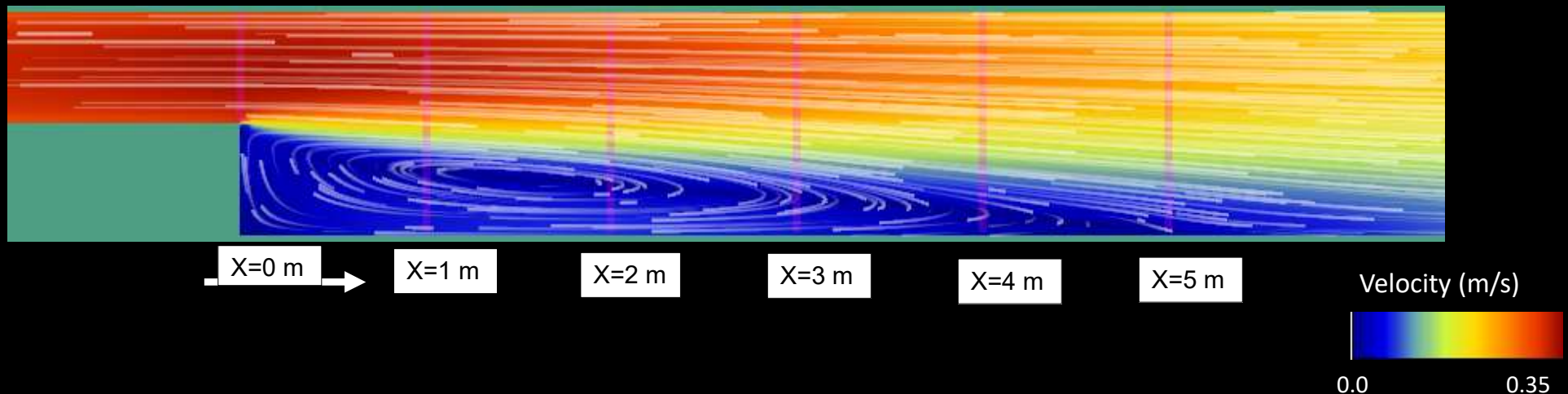
$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + fv = -g \frac{\partial H}{\partial x} + \frac{1}{h} \frac{\partial}{\partial x} \left(v_{t,xx} h \frac{\partial u}{\partial x} \right) - c_f u$$



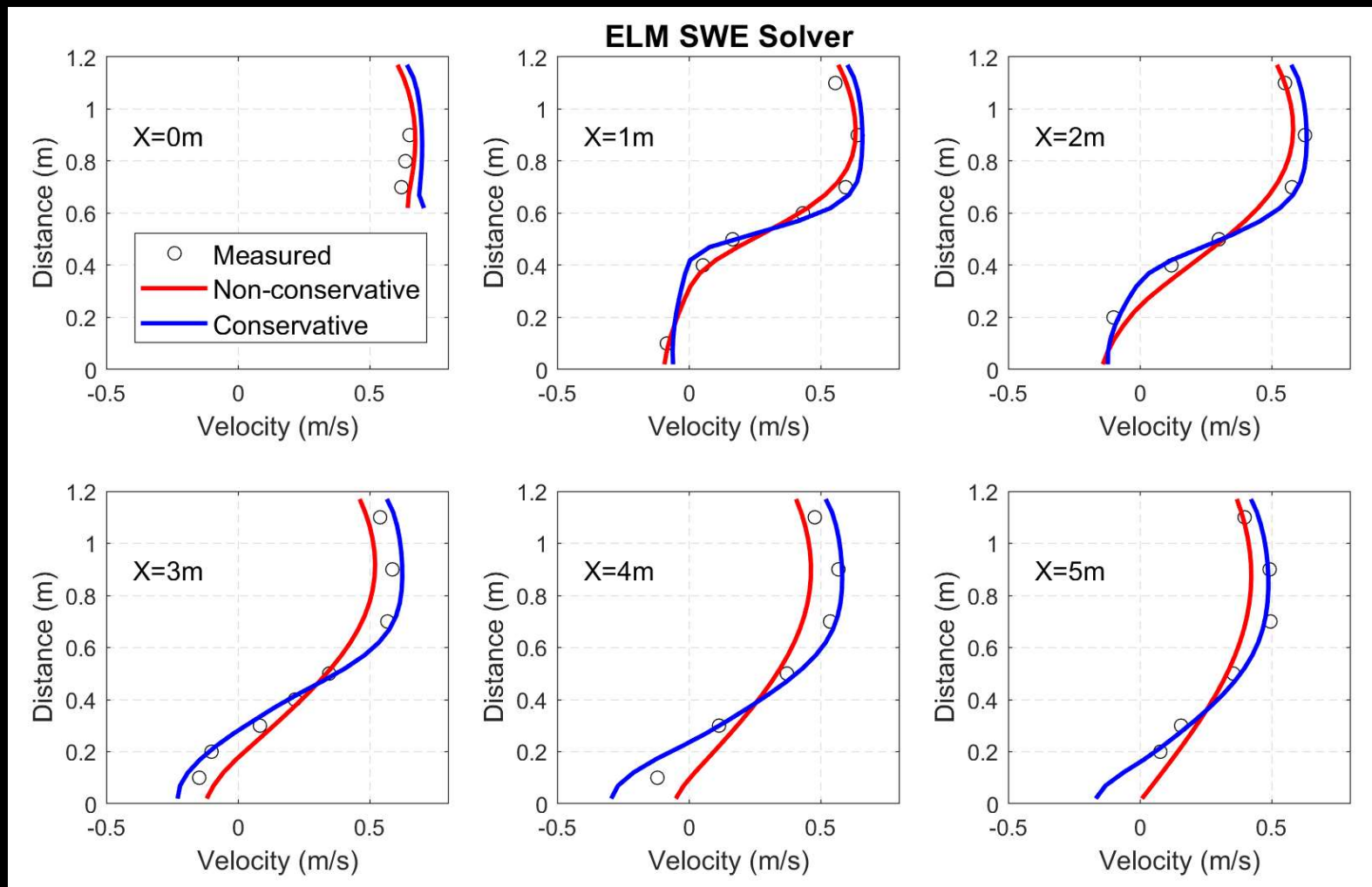
(Note: Equations one-dimensionalized for simplicity)

Example: Sudden Expansion Lab Experiment

- Inflow: $0.039 \text{ m}^3/\text{s}$
- Downstream depth: 11 cm
- Slope: 0.0001
- Grid Resolution: 2.5 cm
- Time step: 0.02 and 0.0333 s
- Manning's n: $0.015 \text{ s}/\text{m}^{1/3}$



Results: Sudden Expansion Lab Experiment



New Turbulence Approach in 6.0+

Old Method: Parabolic

Isotropic ($D_L = D_T$)

Sensitive to Roughness

Not sensitive to cell size

$$v_t = Du_*h$$

New Method: Parabolic-Smagorinsky

Anisotropic ($D_L \neq D_T$)

Sensitive to Roughness

Sensitive to cell size (Δ)

(As cell size decreases more of the sub-cell dispersion is accounted for explicitly, and the Smagorinsky term drops out)

$$v_{txx} = D_{xx}u_*h + (C_s\Delta)^2|\bar{S}|$$

$$v_{ty} = D_{yy}u_*h + (C_s\Delta)^2|\bar{S}|$$

u_* : Shear velocity

h : Water depth

D : Mixing coefficient

D_L : Longitudinal mixing coefficient

D_T : Transverse mixing coefficient

C_s : Smagorinsky coefficient

$$|\bar{S}| = \sqrt{2\left(\frac{\partial u}{\partial x}\right)^2 + 2\left(\frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)^2}$$

New Turbulence Approach in 6.0+

$$\begin{aligned}v_{tx} &= D_{xx}u_*h + (C_s\Delta)^2|\bar{S}| \\v_{tyy} &= D_{yy}u_*h + (C_s\Delta)^2|\bar{S}|\end{aligned}$$

“Vertical Stuff”

Bottom Friction

Dispersion From the Vertical
Velocity Distribution

“Horizontal Stuff”

Dispersion across
gradients in the horizontal
plane

HEC made these changes with 2D sediment in mind.

Turbulence Coefficients

HEC-RAS Unsteady Computation Options and Tolerances

General **2D Flow Options** 1D/2D Options | Advanced Time Step Control | 1D

Use Coriolis Effects (not used with Diffusion Wave equation)



Parameter	2D Area
1 Theta (0.6-1.0)	1
2 Theta Warmup (0.6-1.0)	1
3 Water Surface Tolerance [max=0.06](m)	0.01
4 Volume Tolerance (m)	0.01
5 Maximum Iterations	20
6 Equation Set	SWE-EM (stricter momentum)
7 Initial Conditions Time (hrs)	0.5
8 Initial Conditions Ramp Up Fraction (0-1)	0.1
9 Number of Time Slices (Integer Value)	1
10 Turbulence Model	Conservative
11 Longitudinal Mixing Coefficient	0.3
12 Transverse Mixing Coefficient	0.1
13 Smagorinsky Coefficient	0.05

Mixing Intensity	Geometry and Surface	D_L	D_T
Weak	Straight channel Smooth Surface	0.1 to 0.3	0.04 to 0.1
Moderate	Gentle meanders Moderately irregular	0.3 to 1	0.1 to 0.3
Strong	Strong meanders Rough surface	1 to 3	0.3 to 1

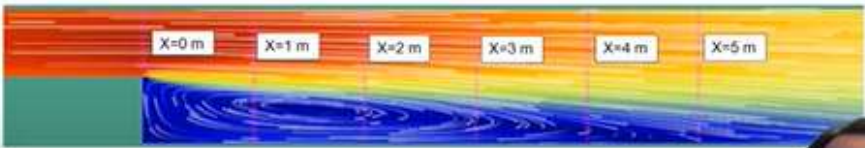
Smagorinsky Coefficient: 0.05 to 0.2

- $D_L \sim 2-4 D_T$
- If $D_L = D_T$ (isotropic) the model will overpredict floodplain deposition
- Non-conservative formulation generally requires larger values (2x) compared to the conservative formulation
- Calibrating to WSE without turbulence can get stages right but be wrong about how the water moves. Sediment will reveal that error. Calibrate hydraulics with reasonable turbulence and mixing.

Turbulence Method


 Example: Sudden Expansion Lab Experiment 

- Inflow: $0.039 \text{ m}^3/\text{s}$
- Downstream depth: 11 cm
- Slope: 0.0001
- Grid Resolution: 2.5 cm
- Time step: 0.02 and 0.0333 s
- Manning's n: $0.015 \text{ s/m}^{1/3}$



Velocity (m/s)

0.0 0.35



HEC-RAS 2D Class: 2.10 - Advanced
Computation Options

<https://www.youtube.com/watch?v=nEr87YpHnzA>

Fixed Bed Capacity Calculation

HEC-RAS Sediment Computation Options and Tolerances

General | 2D Computational Options |

Computational Options

Bed exchange iterations per time step (SPI):

Min bed change before updating Cross Section (ft):

Min XS change before recomputation of hydraulics (ft):

Perform Volume Error Check/Carry Over:

Bed Roughness Predictor:

Select Reaches to Average Bed Roughness Predictors

Sediment Computation Multiplier: X the hydraulic time step

Sediment Warmup Periods:

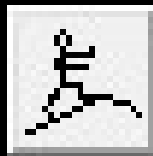
Concentration (2D Only): (days)

Gradation: (days)

Bathymetry: (days)

Defaults ... Cancel OK Show XS Weights >>

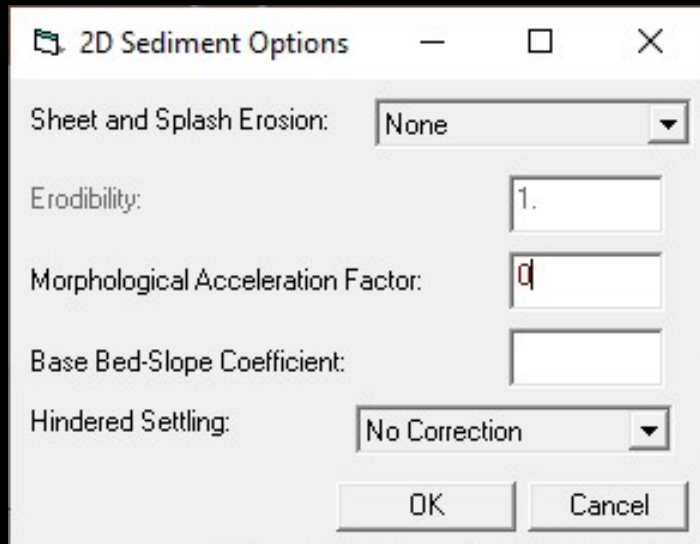
- Sediment transport does ~ and order of magnitude calculations than hydraulics.
- Carefully manage time step, cell size, and number of grain classes.
- HEC added a computational multiplier to help manage run times because rivers tend to erode and deposits on different time scale.



- Sediment Computation Options and Tolerances ...
- Sediment Output Options ...
- Sediment Dredging Options ...

Sediment Computation Multiplier: X the hydraulic time step

Fixed Bed Capacity Calculation



2D Sediment Options

Sheet and Splash Erosion:

Erodibility:

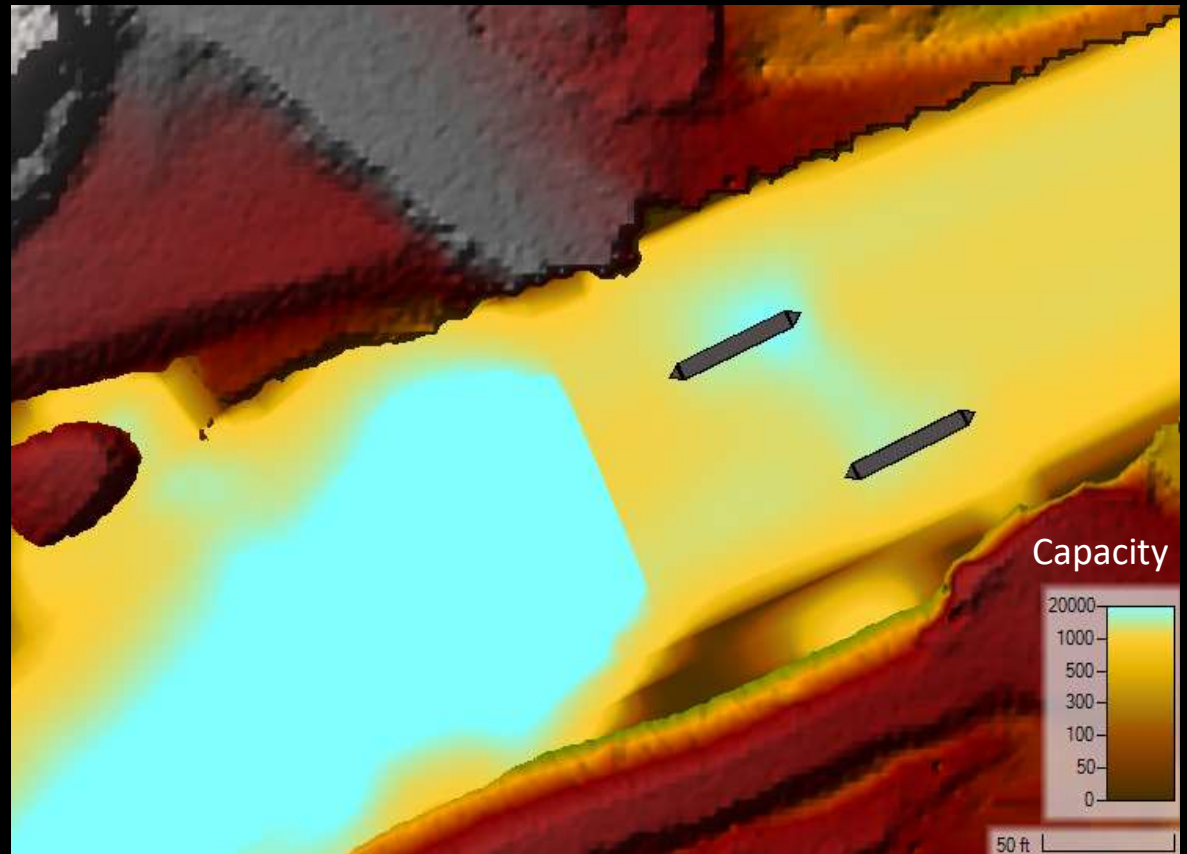
Morphological Acceleration Factor:

Base Bed-Slope Coefficient:

Hindered Settling:

OK Cancel

You can run 2D RAS as a fixed-bed capacity model by setting the morphological acceleration factor to zero



Making a Channel Mesh

Another use for the refinement region is around the main channel of a stream. Shown in Figure 3-10 is an example where a single refinement region was created for the entire main channel. By doing this, the user can control the cell size inside of the channel and ensure that cell faces are aligned with the high ground at the main channel banks. This approach ensures that flow does not spill out of the channel until the water is high enough to cross over the outer cell faces representing the high ground of the main channel bank lines. In addition to the refinement region, a break line was placed right down the center of the refinement region, following the path of the flow. The break line is used to align the cells in the middle of the channel with the direction of the flow. For the breakline in the example below, the number of near repeats was set to 4. For the refinement region, the near repeats was set to zero. Additionally, the option to "Enforce a 1 cell protection radius" was turned on for both the refinement region and the break line. Also, the break line was enforced after the refinement region. This combination of a refinement region and a break line down the center of the channel makes for a very nice channel mesh (Figure 3-10).



<https://www.hec.usace.army.mil/confluence/rasdocs/r2dum/latest/development-of-a-2d-or-combined-1d-2d-model/development-of-the-2d-computational-mesh#id-.Developmentofthe2DComputationalMeshv6.0-MakingaChannelMesh>