HEC-RAS 2D Sediment Computation Options and Tolerances

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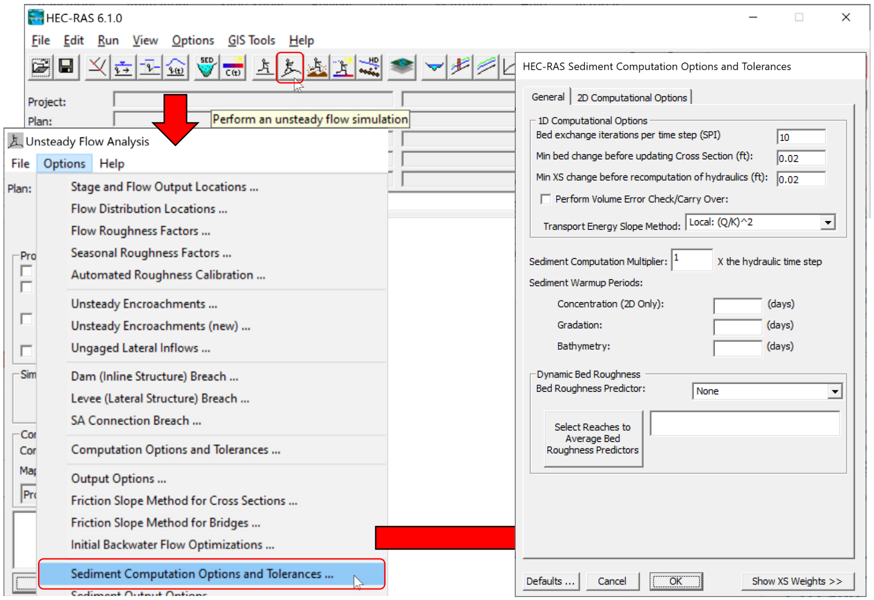
Sediment Computation Options and Tolerances



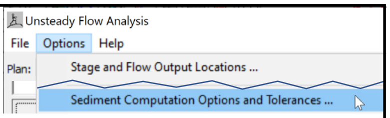
HEC-RAS Sediment Computation Options and Tolerances

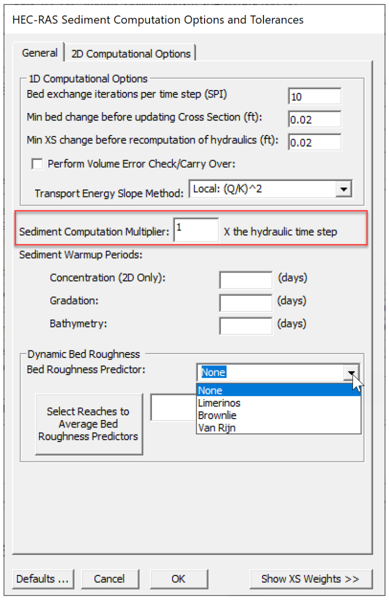
1D Computational Options
Bed exchange iterations per time step (SPI): 10
Min bed change before updating Cross Section (ft): 0.02
Min XS change before recomputation of hydraulics (ft): 0.02
☐ Perform Volume Error Check/Carry Over:
Transport Energy Slope Method: Local: (Q/K)^2

Sediment Computation Multiplier: 1 X the hydraulic time step
Sediment Warmup Periods:
Concentration (2D Only): (days)
Gradation: (days)
Bathymetry: (days)

Dynamic Bed Roughness
Bed Roughness Predictor: None

Sediment Computation Multiplier

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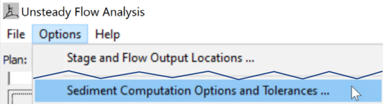
Dynamic Bed Roughness
Bed Roughness Predictor: None

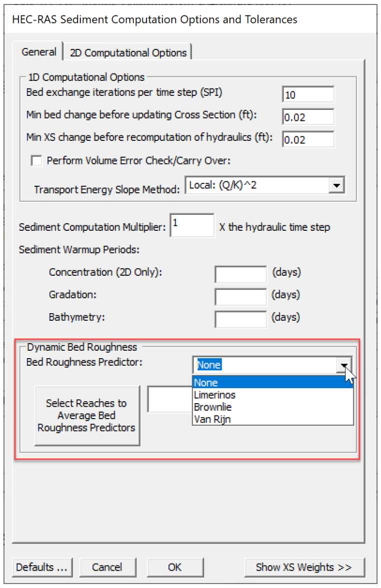
- Number of hydraulic time steps within a sediment time step

$$\Delta t_{Sed} = m\Delta t_{Hyd}$$

- Multiplier used in adaptive time stepping
- Uses time-average (conservative) fluxes and instantaneous hydraulics
- Output Mapping Interval enforced
- Reduces computational time
- Maximum value
  - Depends on application
  - Typically ranges from 2 to 20
  - Needs validation
- Adaptive scheme coming

Bed Roughness Predictor

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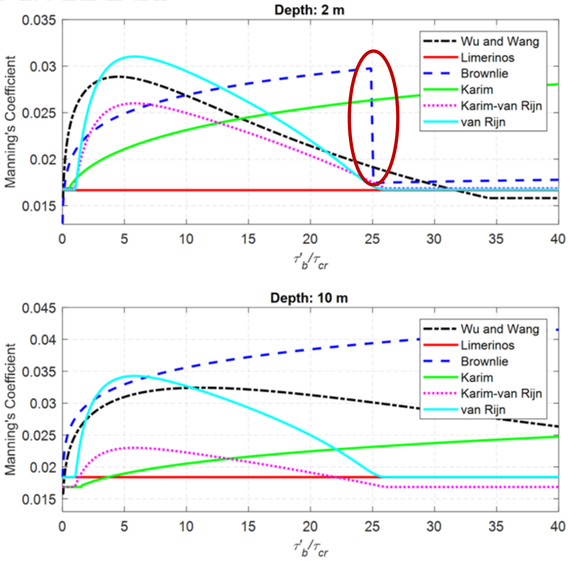
Bed Roughness Predictor: None

- Limerinos (1970)
  - Based only on R and d_{84}
  - Applicable to gravel and cobbles streams
- Brownlie (1983)
  - Grain size and distribution
  - Large sand rivers
  - Captures lower roughness in upper flow regimes
- Van Rijn
  - Based on bed form predictor
  - Captures higher roughness in lower regime and lower roughness in upper flow regimes

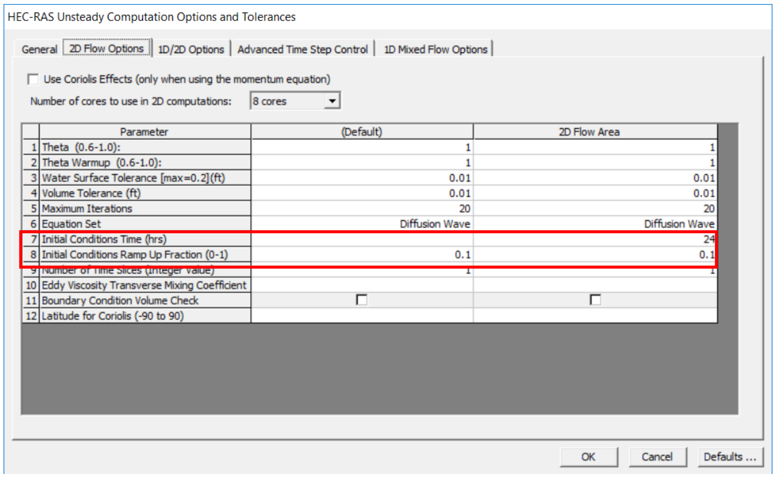
Bed Roughness Pre

- Brownlie
  - Discontinuity at flow regime change at shallow depths
  - No flow regime change for deeper depths
- Limerinos
  - Mostly underestimates
- Van Rijn
  - Good agreement with other formulas
  - Recommended formula for 2D



Computation Options (2D)

- Initial Conditions (Warm Up)


HEC-RAS Unsteady Computation Options and Tolerances

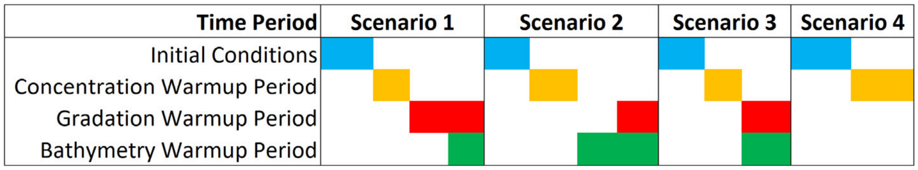
☐ Use Coriolis Effects (only when using the momentum equation)

Number of cores to use in 2D computations: 8 cores

	Parameter	(Default)	2D Flow Area
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	Diffusion Wave	Diffusion Wave
7	Initial Conditions Time (hrs)		24
8	Initial Conditions Ramp Up Fraction (0-1)	0.1	0.1
9	Number of Time Slices (Integer Value)	1	1
10	Eddy Viscosity Transverse Mixing Coefficient		
11	Boundary Condition Volume Check	☐	☐
12	Latitude for Coriolis (-90 to 90)		

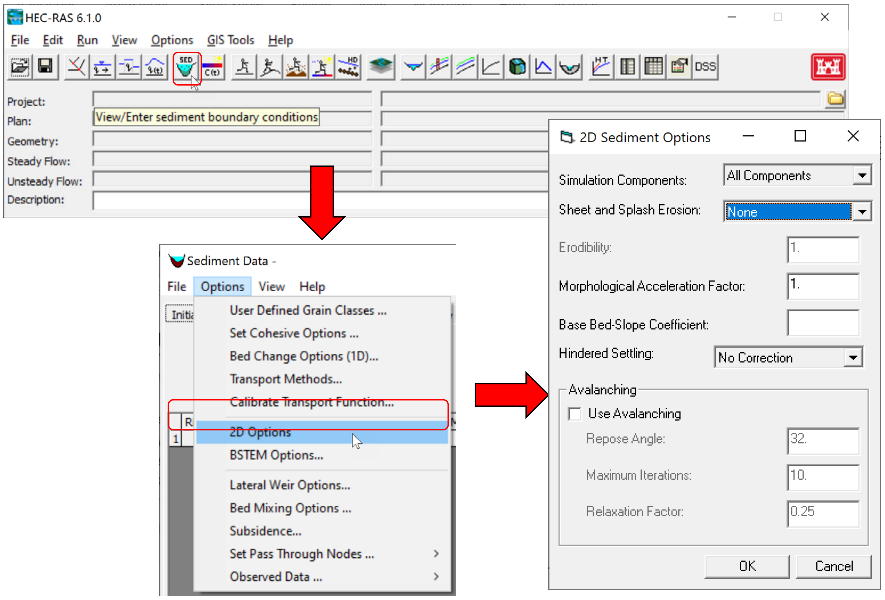
Sediment Warmup Periods

- Three types of Sediment Warmup Periods
  - Concentration
  - Gradation
  - Bathymetry
- Mostly there for backwards compatibility
- No output during this time period



Time Period	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Initial Conditions	🟦	🟦	🟦	🟦
Concentration Warmup Period	🟧	🟧	🟧	🟧
Gradation Warmup Period	🟥	🟥	🟥	
Bathymetry Warmup Period	🟩	🟩	🟩	

2D Options



Simulation Components: All Components

Sheet and Splash Erosion: None

Erodibility: 1.

Morphological Acceleration Factor: 1.

Base Bed-Slope Coefficient:

Hindered Settling: No Correction

Avalanching

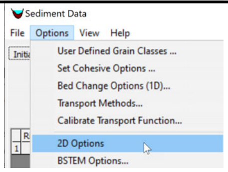
☐ Use Avalanching

Repose Angle: 32.

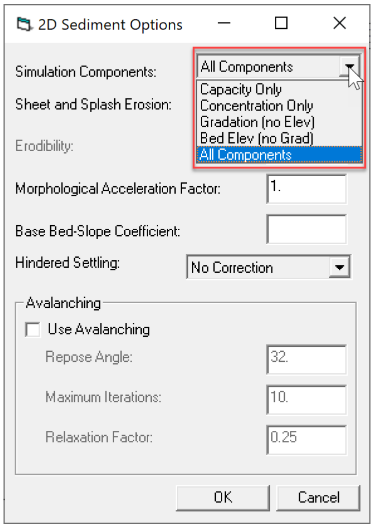
Maximum Iterations: 10.

Relaxation Factor: 0.25

Simulation Components



- Capacity Only
  - Extremely Fast
  - Only computed at output interval
  - Non-mobile bed Equilibrium model
- Concentration Only
  - Useful for preliminary runs or assessments
- Bed Gradations Only (No Bed Elevations)
  - Useful for bed "preconditioning"
- Bed Elevation Only (No Bed Gradations)
  - Useful for bed "preconditioning"
- All Components



Simulation Components: All Components

Sheet and Splash Erosion:

Erodibility:

Morphological Acceleration Factor: 1.

Base Bed-Slope Coefficient:

Hindered Settling: No Correction

☐ Use Avalanching

Repose Angle: 32.

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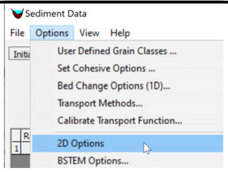
Splash and Sheet Erosion



- Wei et al. (2009)

$$E_{tk}^{*SS} = \psi_{E,k} K_{SS} r^{1.052} v^{0.592}$$

$\psi_{E,k}$: Grain size function

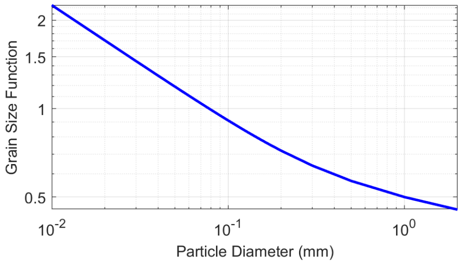
K_{SS} : Erodibility coefficient

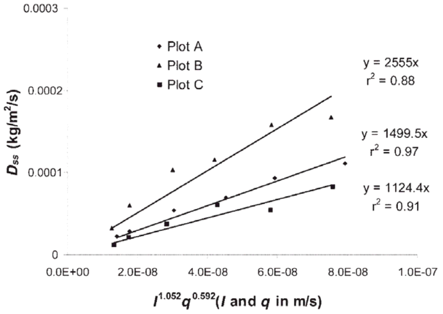
r : Precipitation rate [L/T]

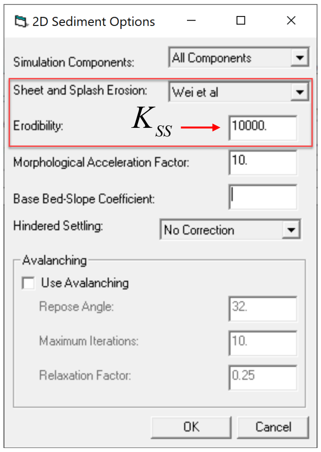
v : Excess rate [L/T]

- Limiter

$$\hat{E}_{tk}^{*SS} = \min(E_{tk}^{*SS}, r\rho_{d1})$$







Simulation Components: All Components

Sheet and Splash Erosion: Wei et al

Erodibility: 10000.

Morphological Acceleration Factor: 10.

Base Bed-Slope Coefficient:

Hindered Settling: No Correction

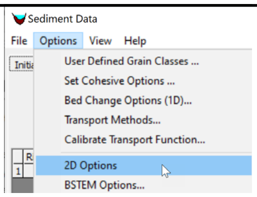
☐ Use Avalanching

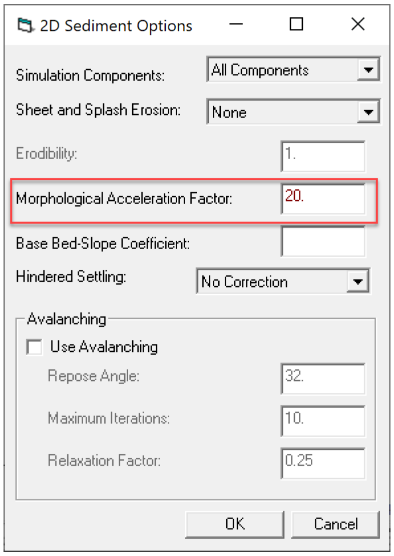
Repose Angle: 32.

Maximum Iterations: 10.

Relaxation Factor: 0.25

Morphologic Acceleration Factor





Simulation Components: All Components

Sheet and Splash Erosion: None

Erodibility: 1.

Morphological Acceleration Factor: 20.

Base Bed-Slope Coefficient:

Hindered Settling: No Correction

Avalanching

☐ Use Avalanching

Repose Angle: 32.

Maximum Iterations: 10.

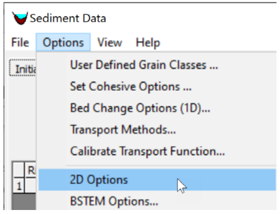
Relaxation Factor: 0.25

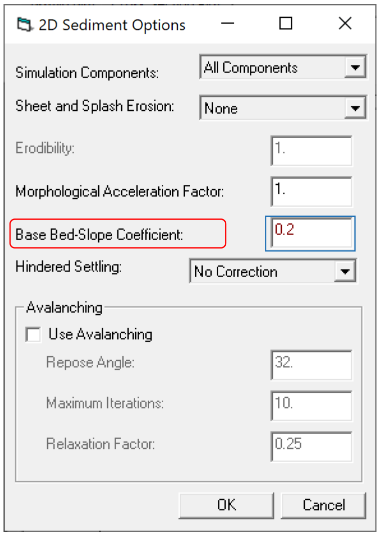
- Useful and under-utilized parameter
- Multiplies by bed change every time step

Approaches

1. Turn off bed change
2. Scale bed change
3. Scale time

Base Bed Slope Coefficient





Simulation Components: All Components

Sheet and Splash Erosion: None

Erodibility: 1.

Morphological Acceleration Factor: 1.

Base Bed-Slope Coefficient: 0.2

Hindered Settling: No Correction

Avalanching

☐ Use Avalanching

Repose Angle: 32.

Maximum Iterations: 10.

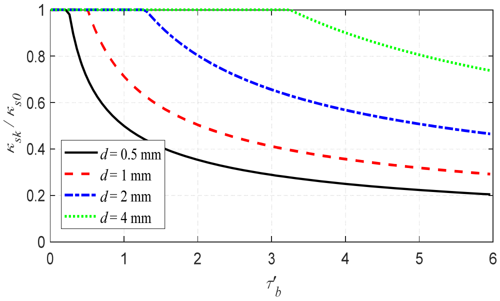
Relaxation Factor: 0.25

Bed Change Equation

$$\rho_{db}\left(\frac{\partial z_b}{\partial t}\right)_k = D_{tk} - E_{tk} + \nabla \cdot \left(\boxed{\kappa_{bk}}\left|q_{bk}\right|\nabla z_b\right)$$

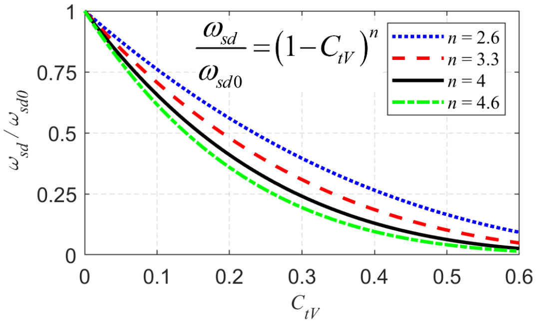
$$\boxed{\kappa_{bk}} = \boxed{\kappa_{b0}}\sqrt{\frac{\tau_{crk}}{\max(\tau_b', \tau_{crk})}}$$

$$\boxed{\kappa_{b0} = 0.1 - 0.5}$$



Hindered Settling

- Concentrations > 3,000 mg/L
- Only for noncohesives (Cohesives treated separately)
- Richardson and Zaki (1952)
  - HEC-RAS assumes n = 4

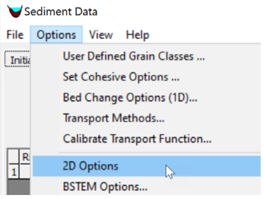


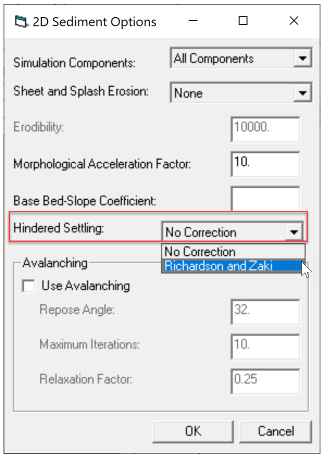
ω_{sd0}: Clear water settling velocity [L/T]

ω_{sd}: Hindered water settling velocity [L/T]

C_{tV}: Total sediment concentration by volume [-]

n: Calibration exponent [-]





Simulation Components: All Components

Sheet and Splash Erosion: None

Erodibility: 10000.

Morphological Acceleration Factor: 10.

Base Bed-Slope Coefficient:

Hindered Settling: No Correction

☐ Use Avalanching

Repose Angle: 32.

Maximum Iterations: 10.

Relaxation Factor: 0.25

Non-Erodible Beds

- Erosion is limited over non-erodible bed

$$E_{tk}^{'} = \min\left(E_{tk,hb}, E_{tk}\right)$$

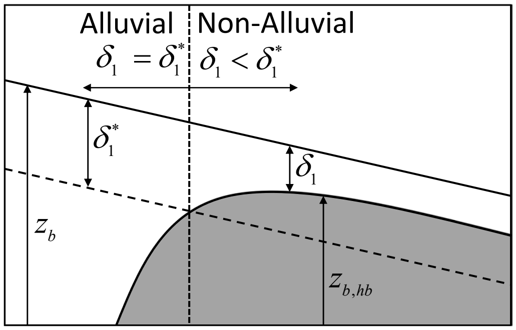
- Maximum erosion rate

$$E_{tk,hb} = D_{tk} + \psi_{na} \frac{f_{1k}\rho_{d1}}{f_M \Delta t}\left(z_b^n - z_{b,hb}\right)$$

  - with

$$\psi_{na} = \frac{\delta_1}{\delta_1^*}$$

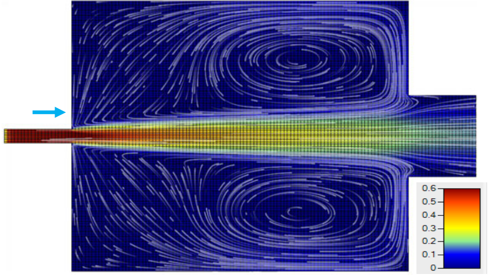
$\therefore$ if $z_b = z_{b,hb}$ then $E_{tk} = D_{tk}$ and $\Delta z_b = 0$



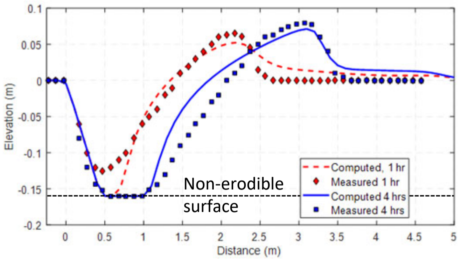
Validation: Clear-water Scour

- Lab Experiment:
  - Thuc (1991)
- 16-cm layer of medium sand

Initial Current Velocity in m/s



Transects along centerline



Mesh and 4-hr Bed Change in m

Avalanching

- Limits bed slope to critical value

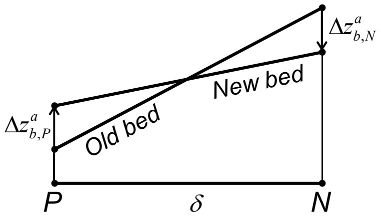
$$\frac{(z_{bN}+\Delta z_{bN}^{a})-(z_{bP}+\Delta z_{bP}^{a})}{\delta}=\operatorname{sgn}\phi_b \tan\phi_r$$

Δz_b^a : Avalanching bed change

δ : Distance between cells

ϕ_b : Bed slope

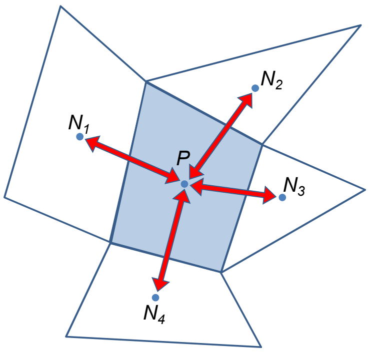
ϕ_r : Repose angle

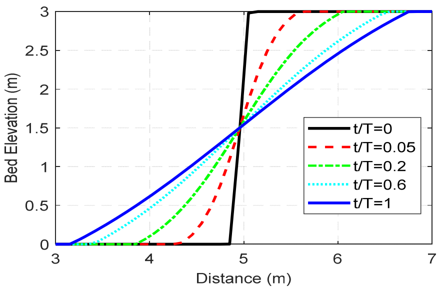


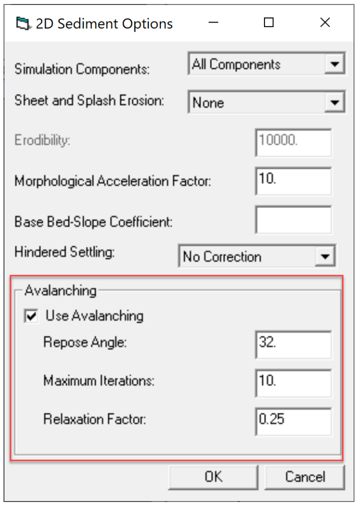
Avalanching

- Iterative relaxation approach

$$\Delta z_{b,P}^{a} = \alpha_a \sum_{N} \frac{A_N \delta}{A_P + A_N} \left(\tan \phi_b - \operatorname{sgn} \phi_b \tan \phi_R \right) \mathrm{H}\left(\left| \phi_b \right| - \phi_R \right)$$







2D Sediment Options

Simulation Components: All Components

Sheet and Splash Erosion: None

Erodibility: 10000.

Morphological Acceleration Factor: 10.

Base Bed-Slope Coefficient:

Hindered Settling: No Correction

Avalanching

☑ Use Avalanching

Repose Angle: 32.

Maximum Iterations: 10.

Relaxation Factor: 0.25

Bed Layering

- Active Layer

$$\delta_{1i}^{n+1} = \min\left[\max\left(f_{1,90} d_{90,i}, 0.5\Delta, \Delta z_{bi}, \delta_{1,\min} \right), \delta_{1,\max} \right]$$

$$\Delta z_{bi} = z_{bi}^{n+1} - z_{bi}^{n}$$

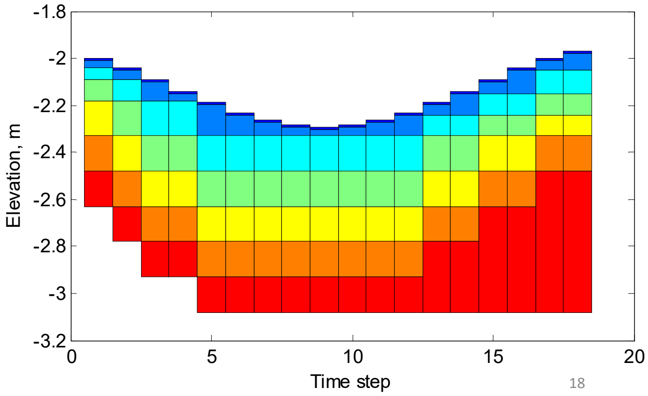
Δ : Bedform height

- Second Layer

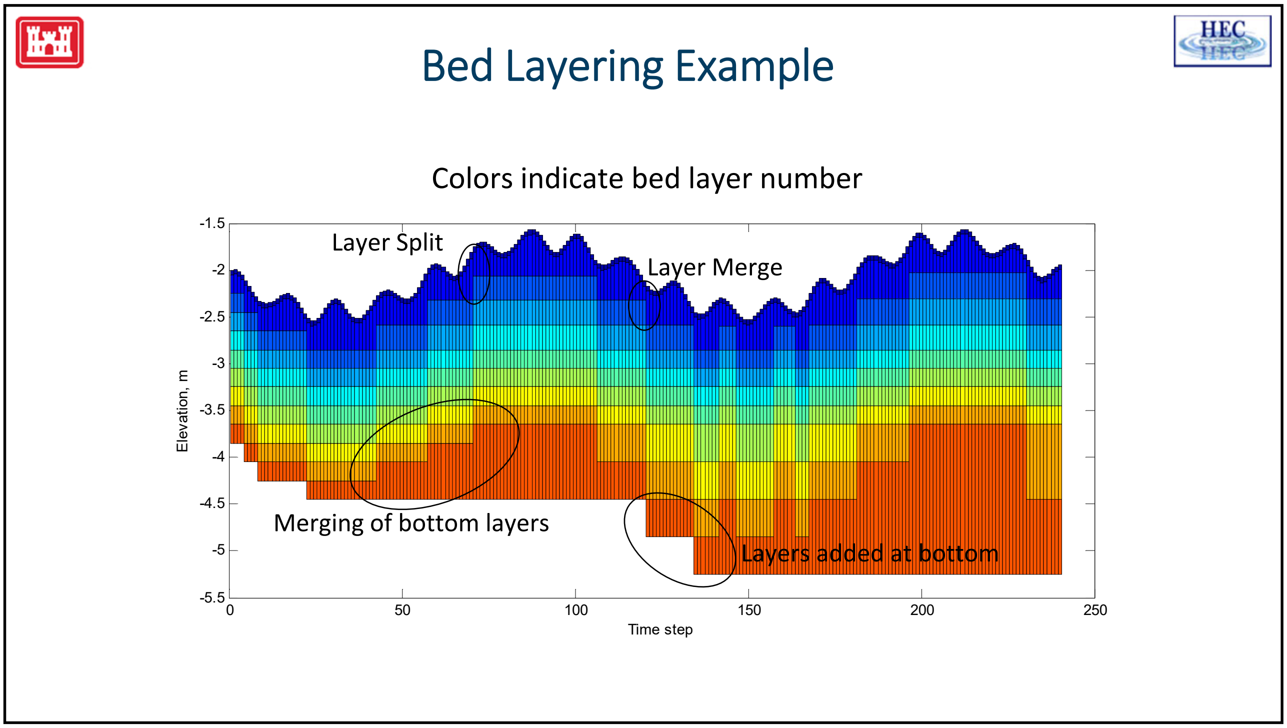
$$\delta_{2i}^{n+1} = \delta_{2i}^{n} + \Delta\delta_{2i}$$

$$\Delta\delta_{2i} = \Delta z_{bi} - \Delta\delta_{1i}$$

$$\Delta\delta_{1i} = \delta_{1i}^{n+1} - \delta_{1i}^{n}$$



Bed Layering Example



Colors indicate bed layer number

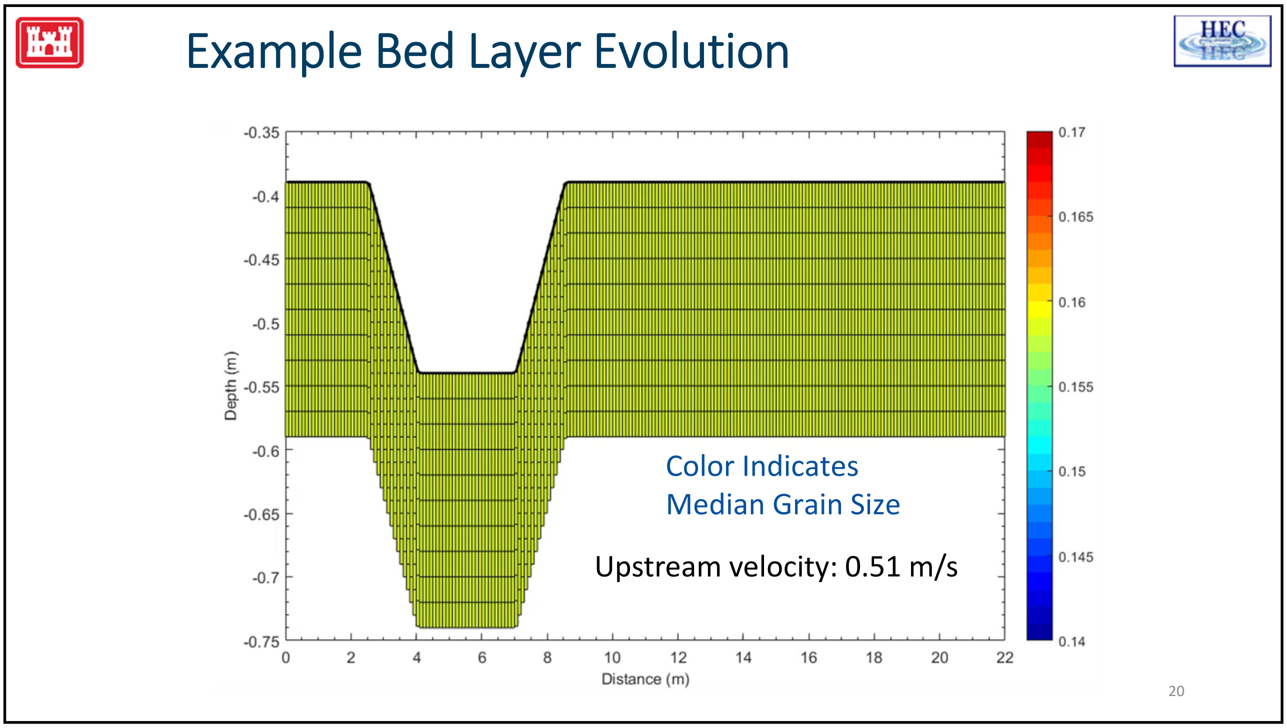
Layer Split

Layer Merge

Merging of bottom layers

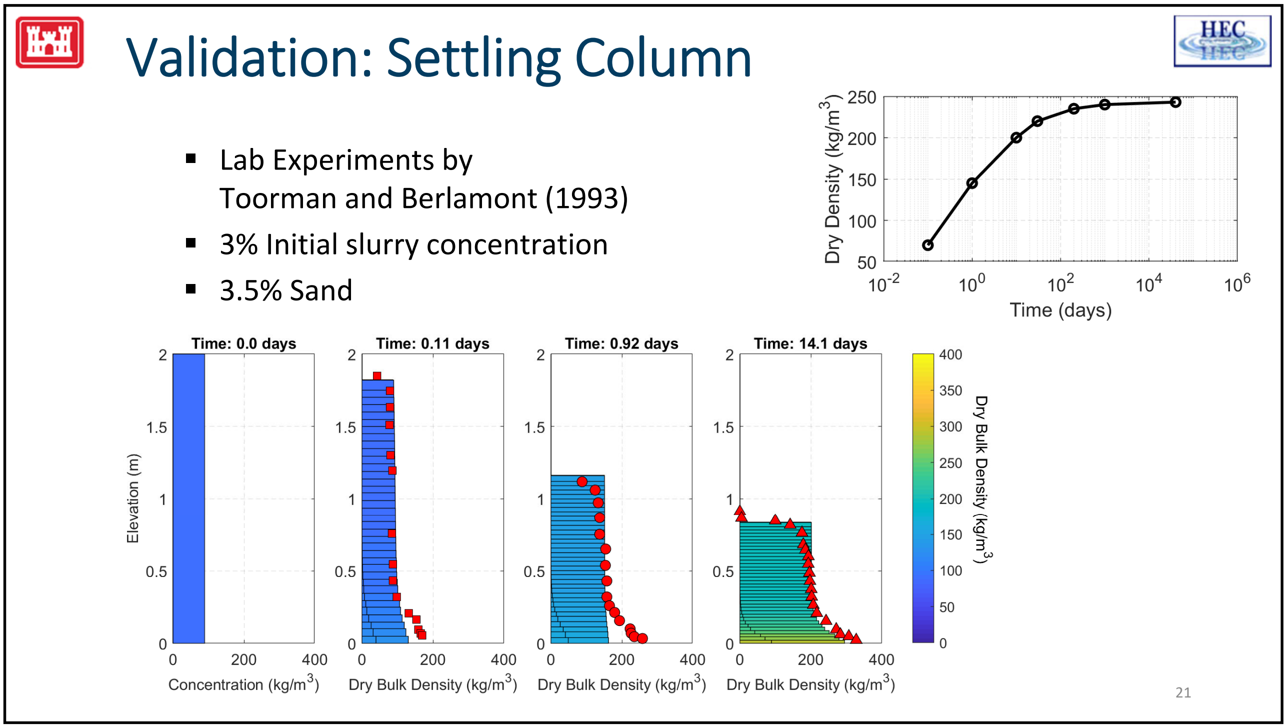
Layers added at bottom

Example Bed Layer Evolution



Color Indicates
Median Grain Size

Upstream velocity: 0.51 m/s



Validation: Settling Column

- Lab Experiments by Toorman and Berlamont (1993)
- 3% Initial slurry concentration
- 3.5% Sand

Variable Density Bed Sorting Model

1. Mass Exchange Rates $$\Delta M_{bk} = f_M \Delta t \left(D_{tk} - E_{tk} + S_{bk} \right)$$
2. Bed Change $$\Delta z_{bk} = \frac{\Delta M_{bk}}{(1-\phi_b)\rho_{sk}} \qquad \Delta z_b = \sum_k \Delta z_{bk} \qquad \Delta z^D_{bk} = -\frac{f_M \Delta t E^{SS}_{tk}}{(1-\phi_b)\rho_{sk}} \qquad \Delta z^W_{bk} = \Delta z_{bk} - \Delta z^D_{bk}$$
3. Grain Mass Concentrations $$m^{n+1}_{1k} = \frac{\Delta M_{bk} + m^n_{1k}\delta^n_1 - m^n_{*k}\Delta\delta_2}{\delta^{n+1}_1} \qquad m^{n+1}_{2k} = \frac{m^n_{2k}\delta^n_2 + m^n_{*ki}\Delta\delta_2}{\delta^{n+1}_2}$$
4. Bulk Densities $$\rho^{n+1}_{dj} = \sum_k m^{n+1}_{jk} \text{ for } j = 1,2 \qquad m_{*k} = \begin{cases} m_{1k} & \text{for } \Delta\delta_2 \ge 0 \\ m_{2k} & \text{otherwise} \end{cases}$$
5. Grain Mass Fractions $$f^{n+1}_{jk} = \frac{m^{n+1}_{jk}}{\rho^{n+1}_{dj}} \qquad \phi_b = \begin{cases} \phi_0 & \text{for } \Delta z_b > 0 \\ \phi_1 & \text{for } \Delta z_b \le 0 \end{cases}$$

Computation Procedure

1. Solver Transport Equations
2. Compute Bed Change and Mass Exchange

$$\Delta M_{bk} = f_M \Delta t \left(D_{tk} - E_{tk} + S_{bk} \right) \qquad \Delta z_b = \frac{1}{1-\phi_b} \sum_k \frac{\Delta M_{bk}}{\rho_{sk}}$$

3. Fractions and Dry Density

$$m_{1k}^{n+1} = \frac{\Delta M_{bk} + m_{1k}^n \delta_1^n - m_{*k}^n \Delta\delta_2}{\delta_1^{n+1}} \qquad \rho_{d1} = \sum_k m_{1k} \qquad f_{1k} = \frac{m_{1k}}{\rho_{d1}}$$

4. Check convergence and repeat
5. Compute second layer

$$m_{2k}^{n+1} = \frac{m_{2k}^n \delta_2^n + m_{*k}^n \Delta\delta_2}{\delta_2^{n+1}} \qquad \rho_{d2} = \sum_k m_{2k}$$

Implicit Weighting Factor

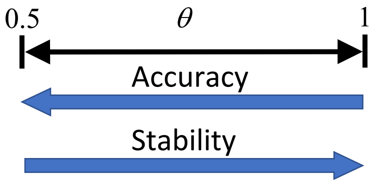
- Temporal Weighting $\quad C_{tk}^{n+\theta} = (1-\theta) C_{tk}^n + \theta C_{tk}^{n+1}$

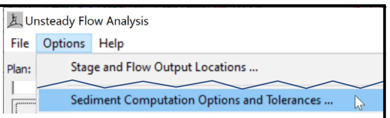
θ : Implicit weighting factor $0.5 \le \theta \le 1$

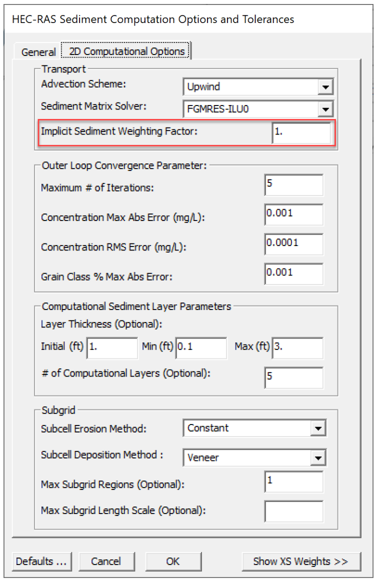
$\theta = 1$: Fully implicit

$\theta = 0.5$: Fully implicit

- Advection-Diffusion Terms Only
- Erosion and Deposition Fully Implicit






HEC-RAS Sediment Computation Options and Tolerances

Transport

Advection Scheme: Upwind

Sediment Matrix Solver: FGMRES-ILU0

Implicit Sediment Weighting Factor: 1.

Outer Loop Convergence Parameter:

Maximum # of Iterations: 5

Concentration Max Abs Error (mg/L): 0.001

Concentration RMS Error (mg/L): 0.0001

Grain Class % Max Abs Error: 0.001

Computational Sediment Layer Parameters

Layer Thickness (Optional):

Initial (ft) 1. Min (ft) 0.1 Max (ft) 3.

# of Computational Layers (Optional): 5

Subgrid

Subcell Erosion Method: Constant

Subcell Deposition Method : Veneer

Max Subgrid Regions (Optional): 1

Max Subgrid Length Scale (Optional):

Convergence Parameters

- Maximum number of iterations

  $m:$ Iteration number $\qquad m \le M_{\max} = [0,20]$

- Concentration Max Abs Error

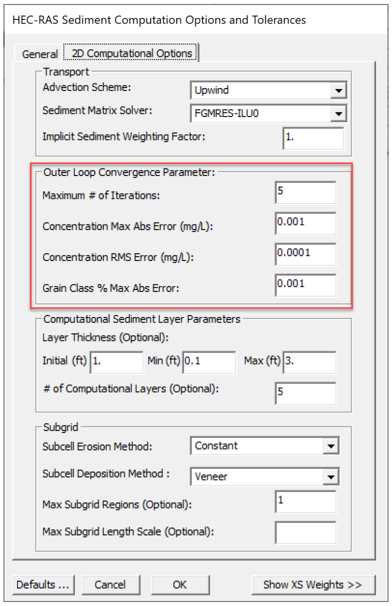
$$E^{C}_{\text{MAE}} = \max\left|C^{m+1}_{tk,i} - C^{m}_{tk,i}\right| < T^{C}_{\text{MAE}} = [0.0001, 0.01]\ \text{mg/L}$$

- Concentration Root Mean Squared Error

$$E^{C}_{\text{RMSE}} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(C^{m+1}_{tk,i} - C^{m}_{tk,i}\right)^{2}} < T^{C}_{\text{RMSE}} = [0.00001, 0.001]\ \text{mg/L}$$

- Grain Class % Max Absolute Error

$$E^{D}_{\text{MAE}} = \max\left|f^{m+1}_{1k,i} - f^{m}_{1k,i}\right| < T^{D}_{\text{MAE}} = [0.001, 0.01]\ \%$$


HEC-RAS Sediment Computation Options and Tolerances

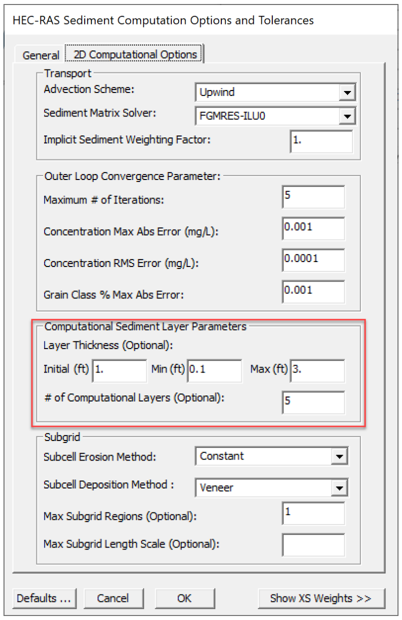
Transport
Advection Scheme: Upwind
Sediment Matrix Solver: FGMRES-ILU0
Implicit Sediment Weighting Factor: 1.

Outer Loop Convergence Parameter:
Maximum # of Iterations: 5
Concentration Max Abs Error (mg/L): 0.001
Concentration RMS Error (mg/L): 0.0001
Grain Class % Max Abs Error: 0.001

Computational Sediment Layer Parameters
Layer Thickness (Optional):
Initial (ft) 1. Min (ft) 0.1 Max (ft) 3.
# of Computational Layers (Optional): 5

Subgrid
Subcell Erosion Method: Constant
Subcell Deposition Method : Veneer
Max Subgrid Regions (Optional): 1
Max Subgrid Length Scale (Optional):

Computational Sediment Bed Layers


HEC-RAS Sediment Computation Options and Tolerances

Transport
Advection Scheme: Upwind
Sediment Matrix Solver: FGMRES-ILU0
Implicit Sediment Weighting Factor: 1.

Outer Loop Convergence Parameter:
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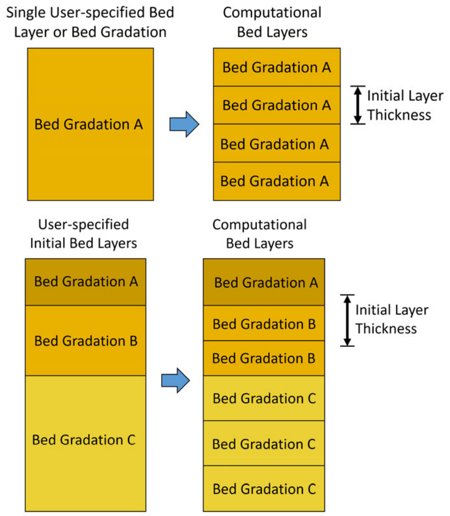
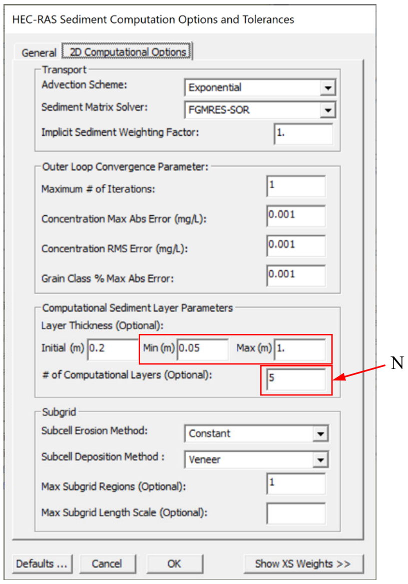
Computational Sediment Layer Parameters
Layer Thickness (Optional):
Initial (ft) 1. Min (ft) 0.1 Max (ft) 3.
# of Computational Layers (Optional): 5

Subgrid
Subcell Erosion Method: Constant
Subcell Deposition Method : Veneer
Max Subgrid Regions (Optional): 1
Max Subgrid Length Scale (Optional):

Initial Bed Layer Thickness



Computational Sediment Bed Layers



HEC-RAS Sediment Computation Options and Tolerances

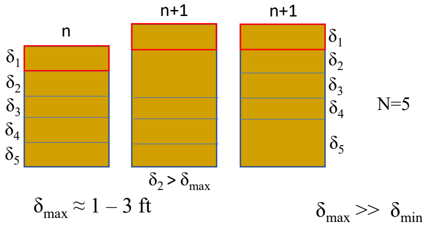
Transport
Advection Scheme: Exponential
Sediment Matrix Solver: FGMRES-SOR
Implicit Sediment Weighting Factor: 1.

Outer Loop Convergence Parameter:
Maximum # of Iterations: 1
Concentration Max Abs Error (mg/L): 0.001
Concentration RMS Error (mg/L): 0.001
Grain Class % Max Abs Error: 0.001

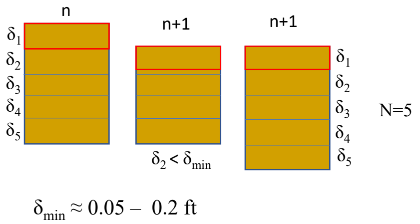
Computational Sediment Layer Parameters
Layer Thickness (Optional):
Initial (m) 0.2 Min (m) 0.05 Max (m) 1.
# of Computational Layers (Optional): 5

Subgrid
Subcell Erosion Method: Constant
Subcell Deposition Method : Veneer
Max Subgrid Regions (Optional): 1
Max Subgrid Length Scale (Optional):

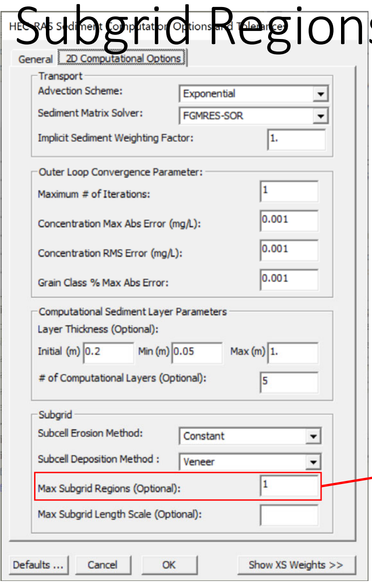
Maximum Thickness



Minimum Thickness



Max Subgrid Regions



HEC-RAS Sediment Computation Options and Tolerances

Transport
Advection Scheme: Exponential
Sediment Matrix Solver: FGMRES-SOR
Implicit Sediment Weighting Factor: 1.

Outer Loop Convergence Parameter:
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Computational Sediment Layer Parameters
Layer Thickness (Optional):
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# of Computational Layers (Optional): 5

Subgrid
Subcell Erosion Method: Constant
Subcell Deposition Method : Veneer
Max Subgrid Regions (Optional): 1
Max Subgrid Length Scale (Optional):

Hydrodynamic property tables can have a lot of sub regions per cell (e.g. 30)

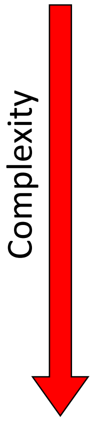
Way more than you need for sediment

N=1 → standard 2D model (no subgrid) – but still sub-grid hydrodynamics, and still tracks partially wet and dry (e.g. sheet and splash erosion on dry hydraulic on wet)

Subdivides larger cells more

Non-Newtonian Modeling

- Goal: Provide users with different modelling approaches with different levels of complexity



1. Constant user-specified total-load concentration
2. Total-load concentration time-series (spatially constant) (Not implemented yet)
3. Representative grain class, spatially variable concentration, and fixed bed
4. Representative grain class, spatially variable concentration, and movable bed
5. Multiple grain classes, spatially variable concentration, and movable bed

Non-Newtonian Flow Equation

Continuity Equation

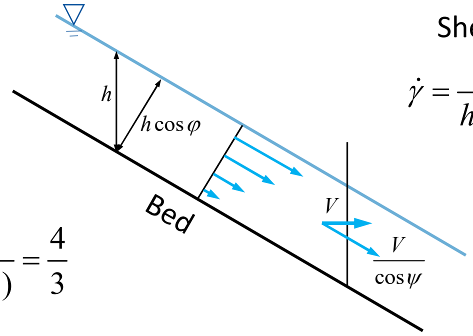
$$\frac{\partial h}{\partial t}+\nabla\cdot(h\mathbf{U})=q-\frac{\partial z_b}{\partial t}$$

Momentum Equation:

$$\underbrace{\frac{\partial \mathbf{U}}{\partial t}}_{\text{Temporal}}+\underbrace{(\mathbf{U}\cdot\nabla)\mathbf{U}}_{\text{Advection}}+\underbrace{f_c\mathbf{k}\times\mathbf{U}}_{\text{Coriolis}}=\underbrace{-g\cos^2\varphi\Big(\nabla z_s}_{\text{Pressure gradient}}\underbrace{+\frac{h}{2\rho}\nabla\rho\Big)}_{\text{Density gradient}}+\underbrace{\frac{1}{h}\nabla\cdot(\mathbf{v}_t h\nabla\mathbf{U})}_{\text{Diffusion}}-\underbrace{\frac{\boldsymbol{\tau}_b}{\rho R}\frac{\cos\psi}{\cos\varphi}}_{\text{Bottom Stress}}+\underbrace{\frac{\boldsymbol{\tau}_s}{\rho h}}_{\text{Wind Stress}}+\underbrace{\frac{\rho_0-\rho}{\rho h}\frac{\partial z_b}{\partial t}\mathbf{U}}_{\text{Bed change}}$$

$$\tan\varphi=|\nabla z_s| \qquad \tan\psi=\frac{\mathbf{V}\cdot\nabla z_s}{|\mathbf{V}|}$$

Slope Corrections



Shear Rate

$$\dot{\gamma} = \frac{B|V|}{h\cos\varphi\cos\psi}$$

$$1 \le B \le 3$$

$$\frac{1}{\cos^2(30^o)} = \frac{4}{3}$$

Model limitation:

- Hydraulic property tables computed with flat water surface

Slope Corrections

- Flow direction not always follows water surface slope
- Hegarten and Robl (2015) propose using surface or bed slope
- A more robust method is implemented with a slope limiter:

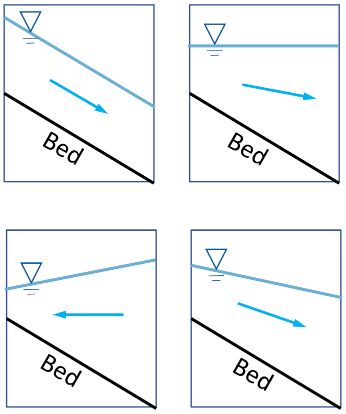
$$\tan\varphi = \left|\phi\left(\nabla z_b, \nabla\eta\right)\right|$$

$$\tan\psi = \frac{V\cdot\phi\left(\nabla z_b, \nabla\eta\right)}{|V|}$$

$$\phi\left(a,b\right) = \text{slope limiter}$$

Tests show that the Minmod Slope Limiter works well

Possible Conditions



Formulations

- Mixture density $\rho = C_{tV}\left(\bar{\rho}_s - \rho_w\right) + \rho_w$
- Volume concentrations $C_{tkV}\rho_{sk} = C_{tk}$ $C_{tV}\bar{\rho}_s = C_t$
- Volume fractions $\hat{f}_{0k} = C_{tkV} / C_{tV}$
- Volume-average grain density $\bar{\rho}_s = \sum_k \hat{f}_{0k}\rho_{sk}$
- Volume-average grain diameter $\bar{d} = \sum_k \hat{f}_{0k} d_k$

Transport Limiters

- Total-load

$$\hat{q}^*_{tk} = q^*_{tk} \min\left(\frac{C_{t,\max}}{C_{t*}}, 1\right) \qquad C_{t*} = \frac{1}{Uh}\sum_k f_{1k} q^*_{tk}$$

$$q_{tk*} = UhC_{tk*}$$

- Suspended-load

$$\hat{q}^*_{sk} = q^*_{sk} \min\left(\frac{C_{s,\max}}{C_{s*}}, 1\right) \qquad C_{s*} = \frac{1}{Uh}\sum_k f_{1k} q^*_{sk}$$

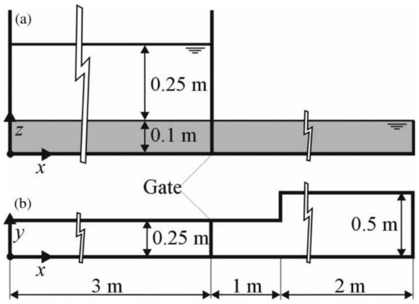
$$q_{sk*} = UhC_{sk*}$$

- Bed-load

$$\hat{q}^*_{bk} = q^*_{bk} \min\left(\frac{c_{b,\max}}{c_{b*}}, 1\right) \qquad c_{bk*} = \frac{q_{bk*}}{u_{bk}\delta_{bk}} \qquad c_{b*} = \sum_k c_{bk*}$$

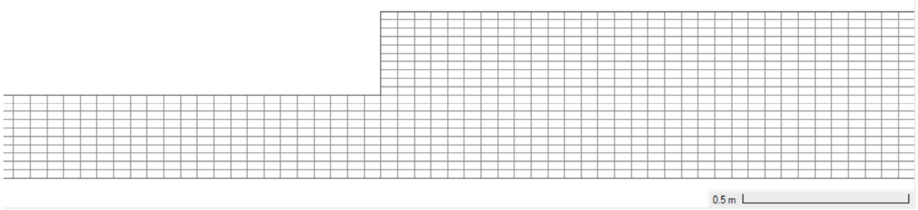
Validation

- Lab dam break experiment at Université Catholique de Louvain (UCL)
- Gate opening: <0.1 s
- Median diameter: 1.72 mm
- Bed layer thickness: 10 cm
- Froude number: <3.8

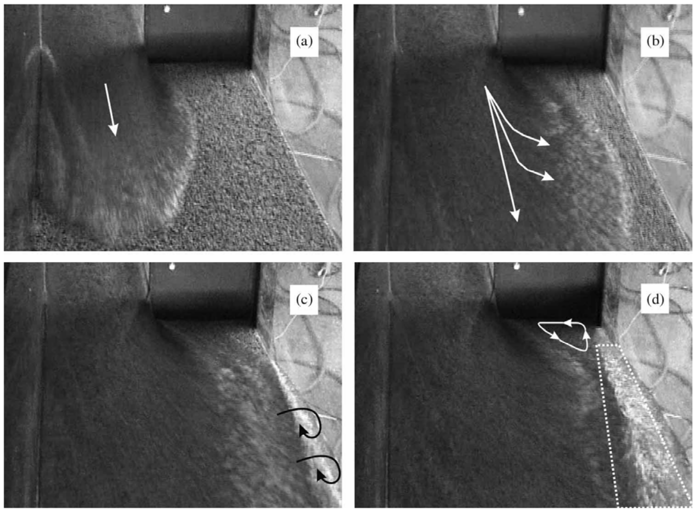


Model Setup

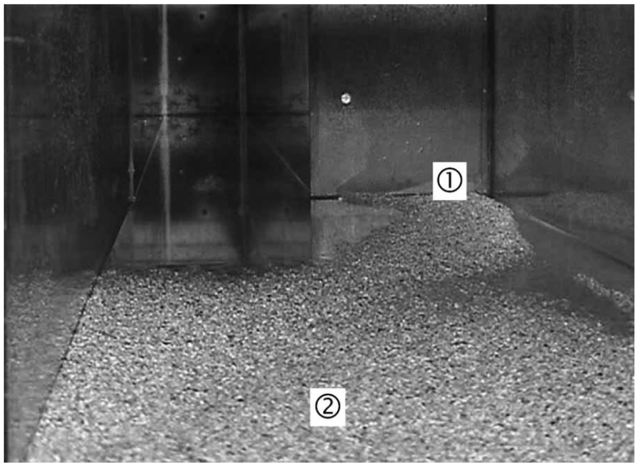
- Resolution: 5 x 2.5 cm
- Manning's n: 0.02 s/m$^{1/3}$
- Single grain class
- Diameter: 1.72 mm
- Transport potential: Wu et al.
- Fall velocity: Soulsby
- Hindered settling: Richardson and Zaki

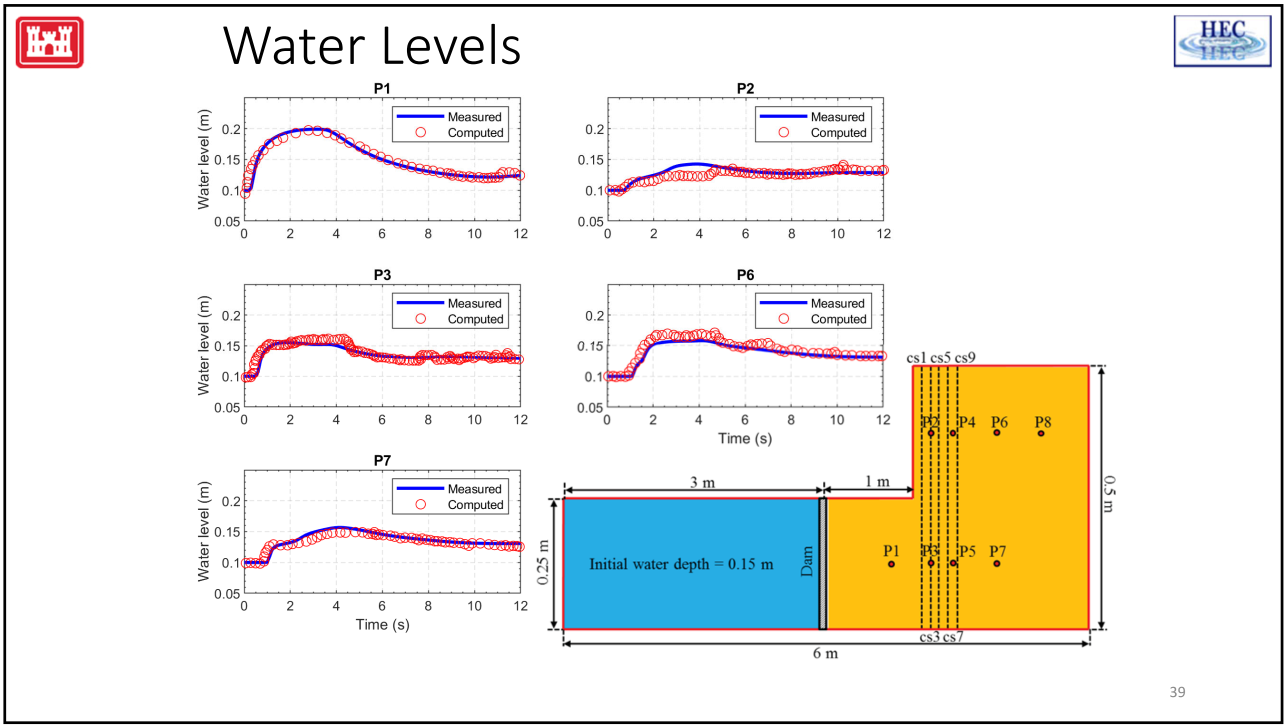


Results

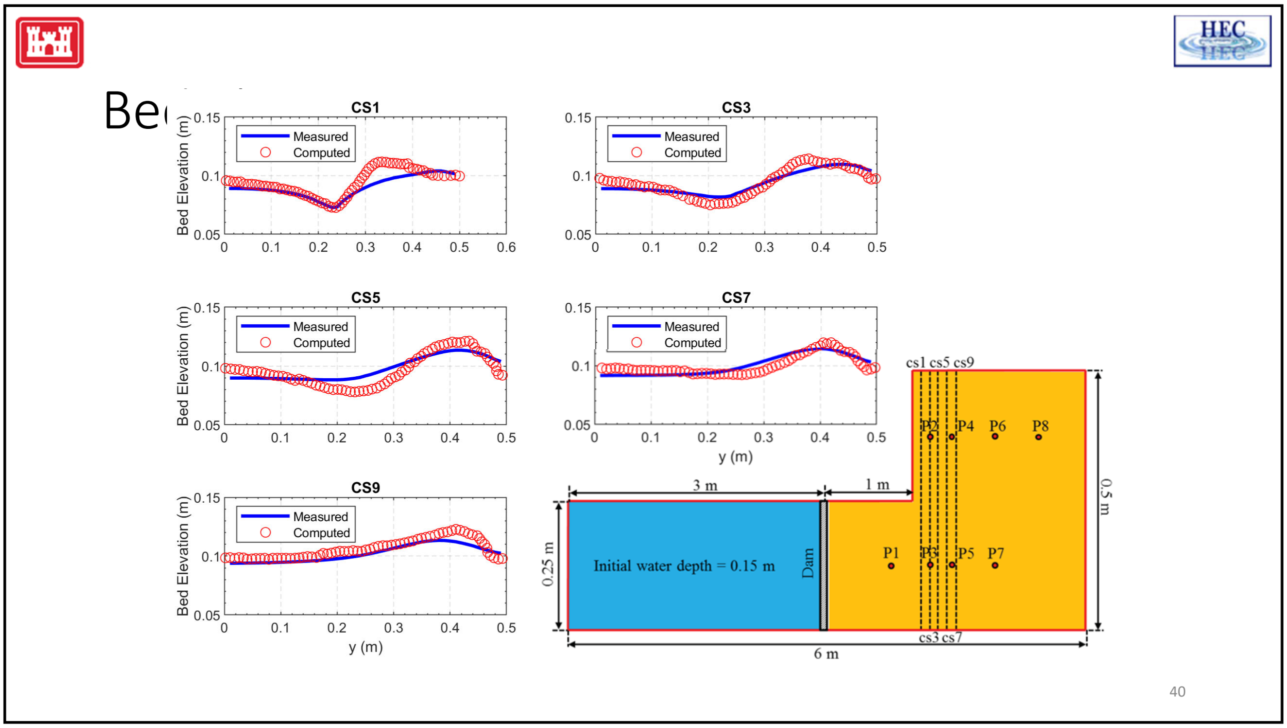


Lab Result





Water Levels



Be

Thank You!

HEC-RAS Website:
https://www.hec.usace.army.mil/software/hec-ras/

Online Documentation:
https://www.hec.usace.army.mil/confluence/rasdocs

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