Coastal Modeling System: Advanced Topics using CMS 5.1 and SMS 13.0

Day 3: Multiple-sized Sediment Transport

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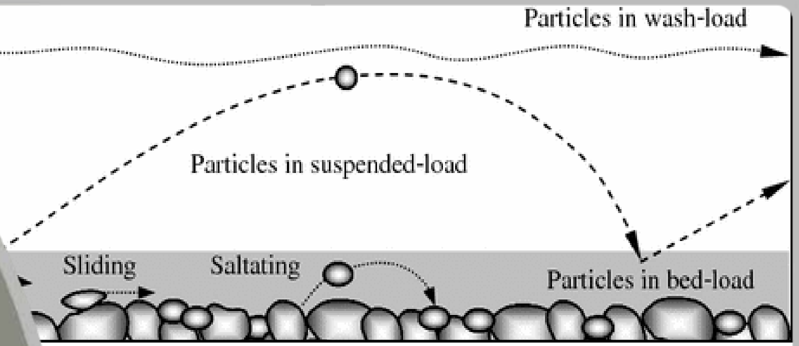

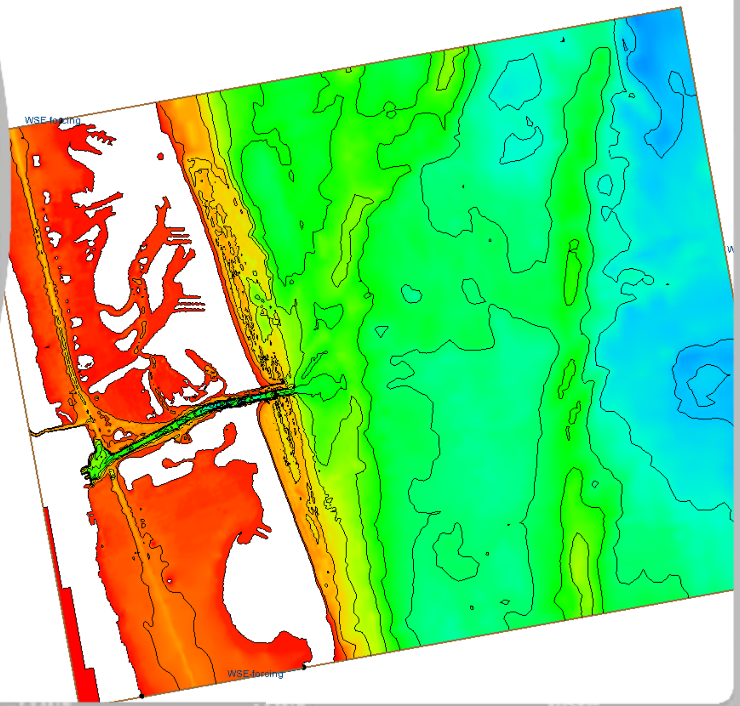

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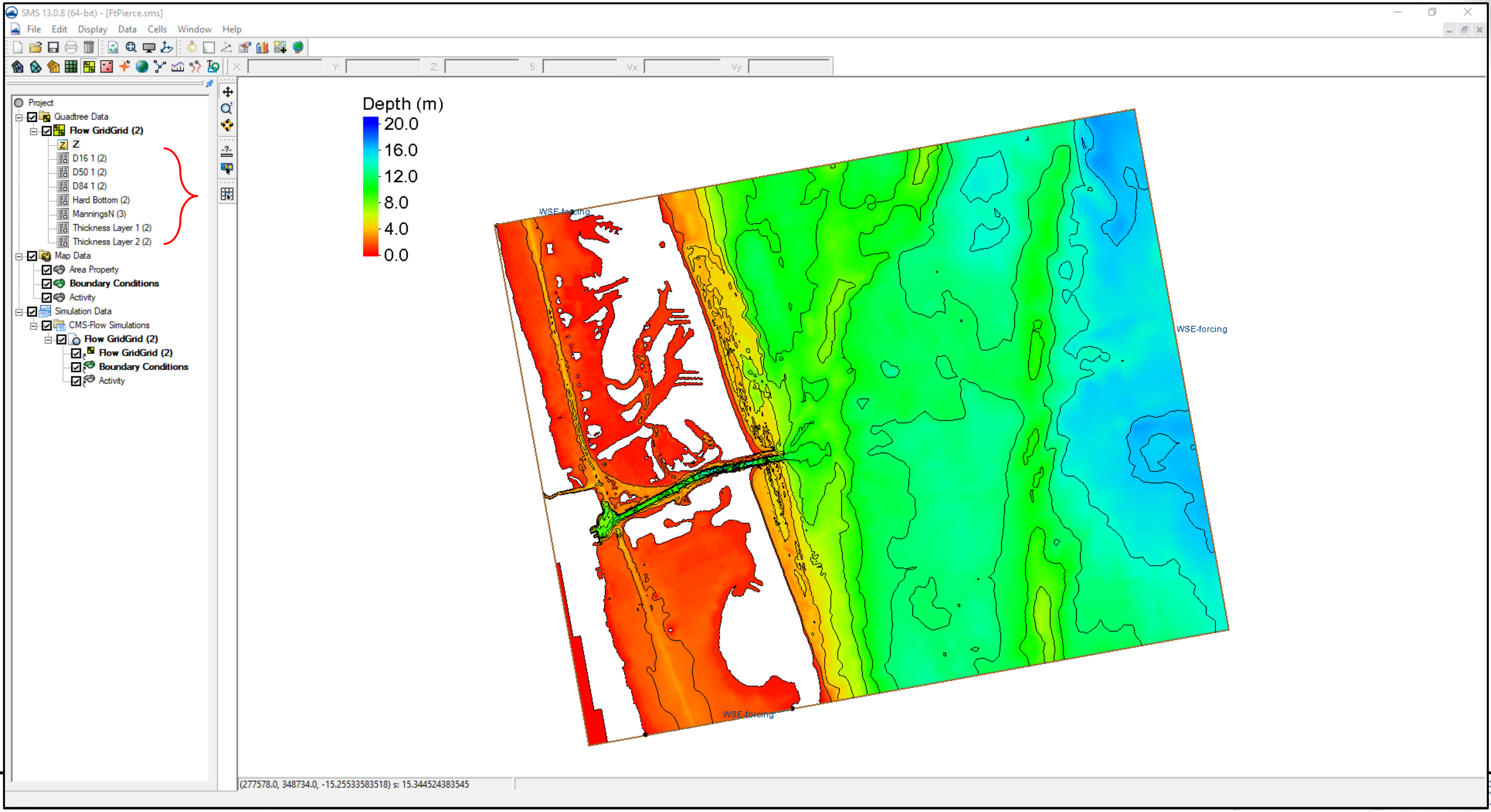
Outline

- Sediment transport in CMS
- Multiple-sized sediment transport calculation
  - Transport grain sizes
  - Bed layering
  - Bed composition
  - Other parameters
- Export CMS files

Multiple-sized Sediment Transport Calculation

(Ft. Pierce, Florida)



Sediment Transport in CMS

(Non-equilibrium Transport, NET)

$$\frac{\partial}{\partial t}\left[\frac{DC_{tk}}{\beta_{tk}}\right]+\frac{\partial(DuC_{tk})}{\partial x}+\frac{\partial(DvC_{tk})}{\partial y}=\frac{\partial}{\partial x}\left[\varepsilon_s D\frac{\partial(r_{sk}C_{tk})}{\partial x}\right]+\frac{\partial}{\partial y}\left[\varepsilon_s D\frac{\partial(r_{sk}C_{tk})}{\partial y}\right]+\frac{U_c D}{L_t}(C_{t^*k}-C_{tk})$$

c_{tk}: **depth-averaged sediment concentration**

k: **sediment size class**

c_{t^*k}: **depth-averaged total load concentration at the equilibrium state**

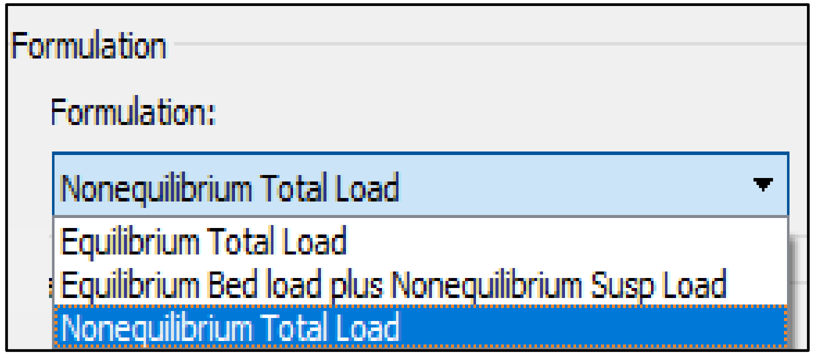
β_{tk}: **correction factor as the ratio of depth-averaged sediment and flow velocities**

U_c: **resultant velocity of current**

ε_s: **sediment diffusion coefficient**

r_{sk}: **ratio of suspended load to total load**

L_t: **total load adaptation length**



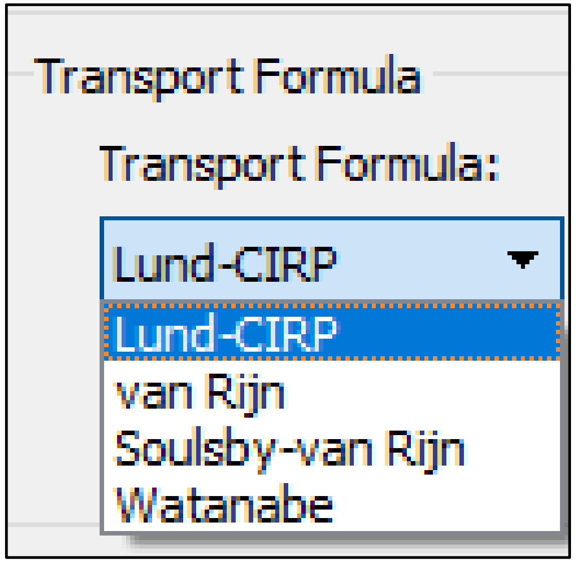
Sediment Transport Formulas

(Non-equilibrium Transport, NET)

$$\frac{\partial}{\partial t}\left[\frac{DC_{tk}}{\beta_{tk}}\right]+\frac{\partial(DuC_{tk})}{\partial x}+\frac{\partial(DvC_{tk})}{\partial y}=\frac{\partial}{\partial x}\left[\varepsilon_s D\frac{\partial(r_{sk}C_{tk})}{\partial x}\right]+\frac{\partial}{\partial y}\left[\varepsilon_s D\frac{\partial(r_{sk}C_{tk})}{\partial y}\right]+\frac{U_c D}{L_t}(C_{t^*k}-C_{tk})$$

Sediment concentration and concentration capacity:

LUND-CIRP
VAN RIJN
SOULSBY-VAN RIJN
WATANABE
***CSHORE**



Bed Change

Bed change due to the *k*th class of sediment:

$$(1-p_m')\left(\frac{\partial z_b}{\partial t}\right)_k$$
$$=\frac{U_c D}{L_t}(C_{tk}-C_{t^*k})+\frac{\partial}{\partial x}\left[d_s U_c D(1-r_{sk})C_{tk}\frac{\partial z_b}{\partial x}\right]+\frac{\partial}{\partial y}\left[d_s U_c D(1-r_{sk})C_{tk}\frac{\partial z_b}{\partial y}\right]+\frac{\partial q_{twx}}{\partial x}+\frac{\partial q_{twy}}{\partial y}$$

p_m': porosity of bed material

d_s: coefficient for bed slope effect

q_{twx}: sediment transport rate due to wave asymmetry and undertow in x-direction

q_{twy}: sediment transport rate due to wave asymmetry and undertow in y-direction

Multiple-sized Sediment Transport Calculation

Geometric Standard Deviation

$$\boldsymbol{\sigma_g = exp\sqrt{\sum p_k\left(lnd_k - lnd_g\right)^k}}$$

p_k: **fraction**
d_k: **size class diameter**
d_g: **geometric mean**

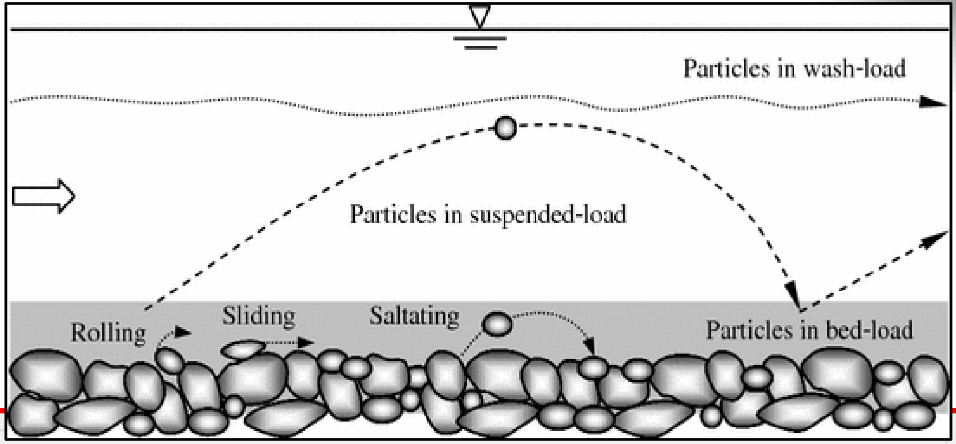
Geometric Standard Deviation	Sorting Classification
<1.27	Very well sorted
1.27-1.41	Well sorted
1.41-1.62	Moderately well sorted
1.62-2.00	Moderately sorted
2.00-4.00	Poorly sorted
4.00-16.00	Very poorly sorted
>16.00	Extremely poorly sorted

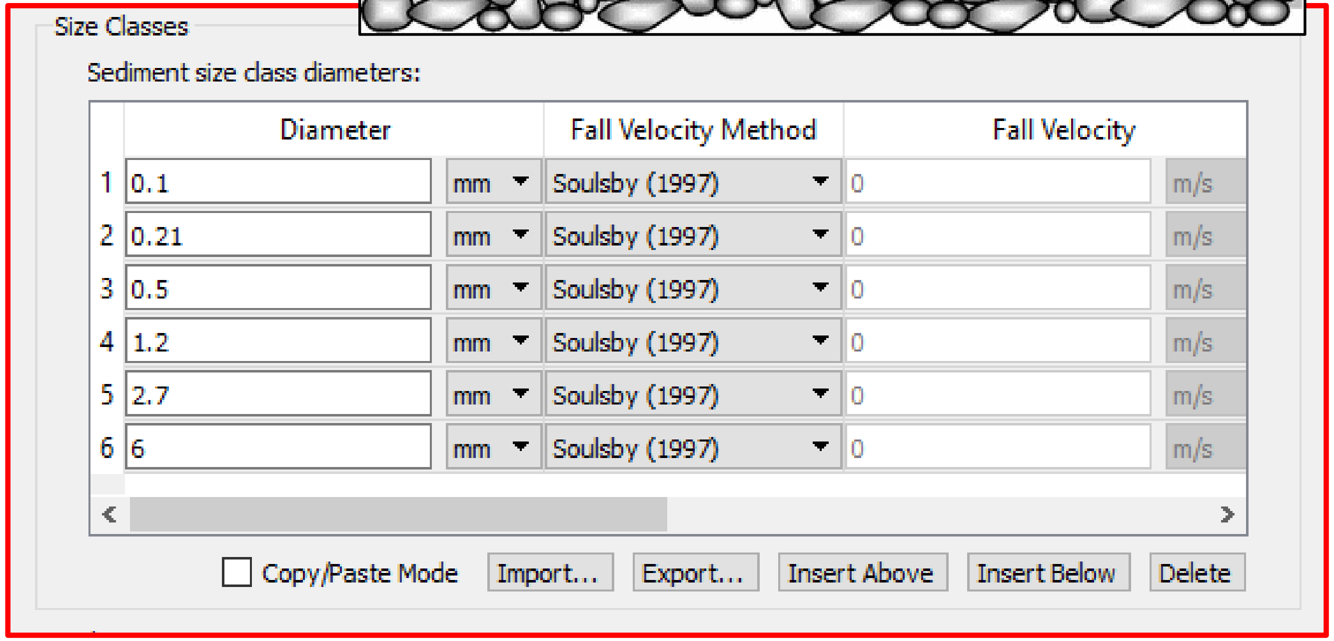
Geometric Standard Deviation greater than approximate 1.41 should be simulated with multiple grain sizes

Multiple-sized Sediment Transport Calculation
(Transport Grain Sizes)

Transport Grain Sizes

- Transported sediment material is discretized into different groups each representing the sediments within a specific size range
- These groups are referred to as sediment size classes and have the following properties
  - Characteristic diameter
  - Fall velocity
  - Corey shape factor
  - Critical shear stress





Multiple-sized Sediment Transport Calculation
(Transport Grain Sizes)

Transport Grain Sizes

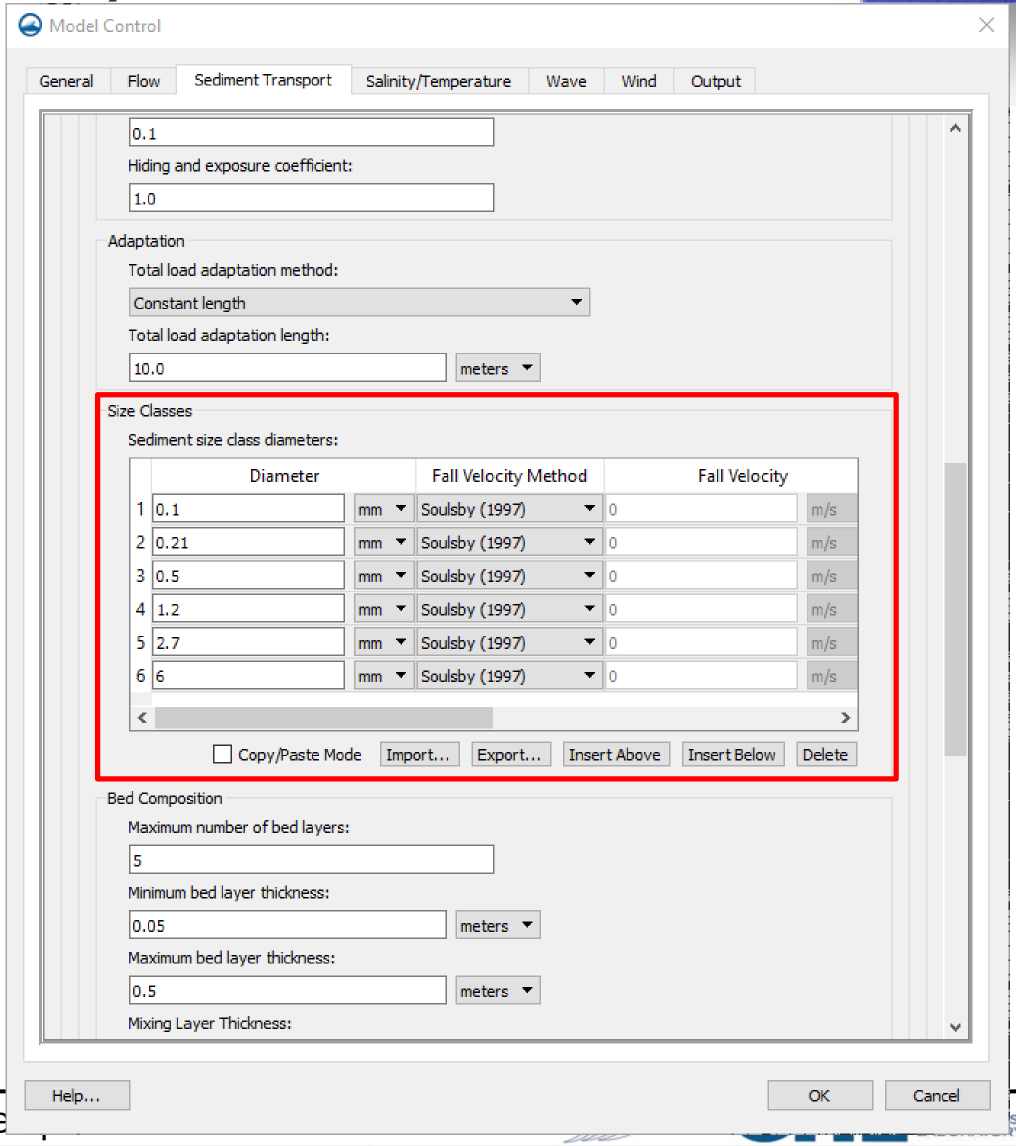
- Characteristic diameter
  - Related to the lower $d_{k-1/2}$ and upper $d_{k+1/2}$ bin limits by

$$d_k = \sqrt{d_{k-1/2} d_{k+1/2}}$$

  - Estimate the grain size classes based only on the size limits of the distribution

$$d_k = exp\left[lnd_1 + ln(d_N/d_1)\frac{k-1}{N-1}\right]$$

- Fall velocity
  - Soulsby (1997)
  - Wu and Wang (2006)
  - User-specified
- Corey shape factor
  - Used in Wu and Wang (2006)
- Critical shear stress
  - Soulsby (1997)
  - Wu and Wang (1999)
  - User-specified



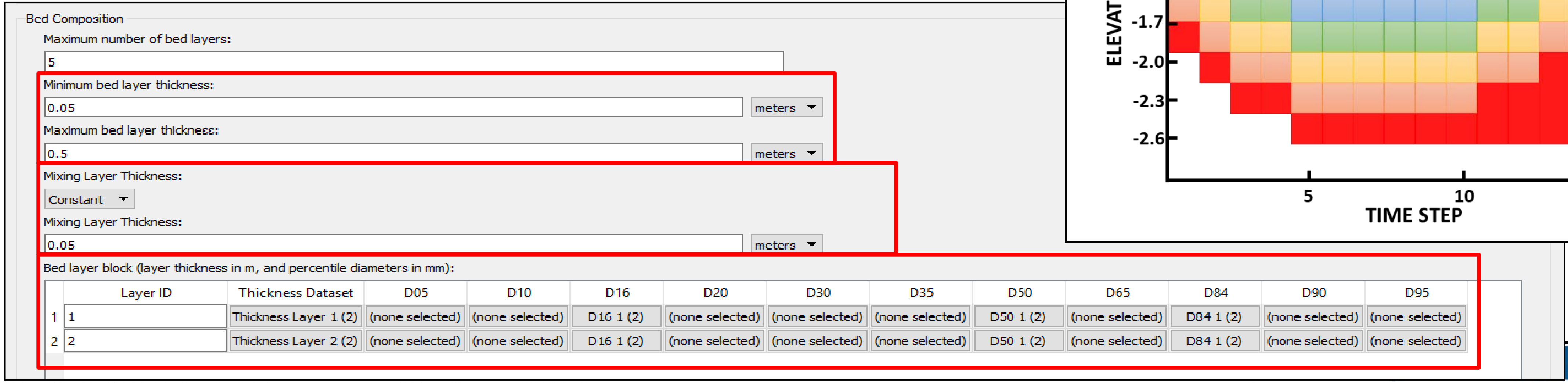
Multiple-sized Sediment Transport Calculation
(Bed Discretization)

- **Mixed Layer Thickness**
  - Sediment exchange
  - Constant, Default: 0.05 m
    Typical range: 0.001 – 0.2 m
  - Automatic (calculated)
    Median grain size
    Bed form size

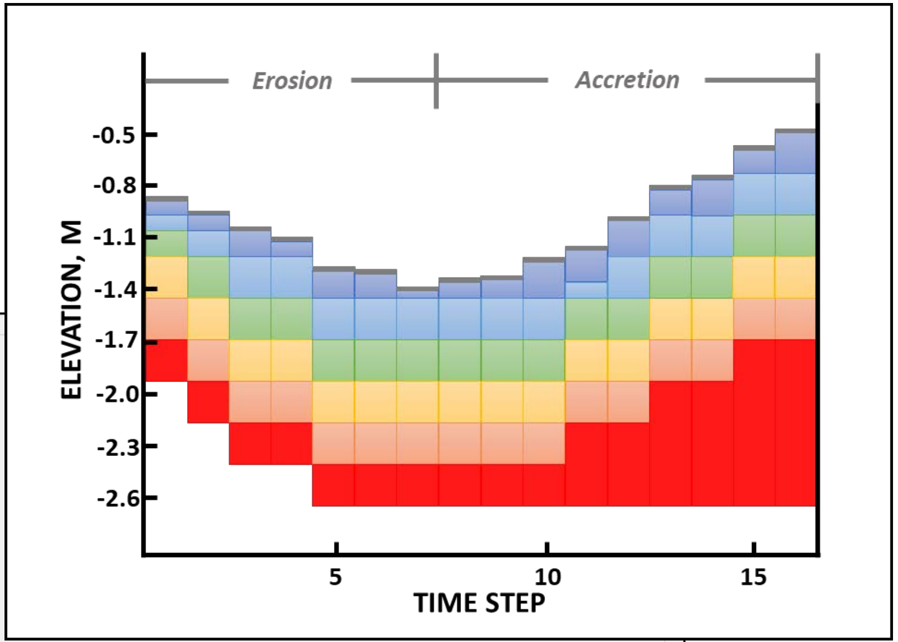
$$\delta_1 = min[max(\delta_{min}, 2d_{50}, 0.5H_r), \delta_{max}]$$

δ_1: thickness of the first layer
H_r: ripple height

- **Lower Layers**
  - Specified
  - Copied from the layer above
  - Constant
  - Spatially varying (dataset)


Bed Composition
Maximum number of bed layers:
5
Minimum bed layer thickness:
0.05 meters
Maximum bed layer thickness:
0.5 meters
Mixing Layer Thickness:
Constant
Mixing Layer Thickness:
0.05 meters
Bed layer block (layer thickness in m, and percentile diameters in mm):

	Layer ID	Thickness Dataset	D05	D10	D16	D20	D30	D35	D50	D65	D84	D90	D95
1	1	Thickness Layer 1 (2)	(none selected)	(none selected)	D16 1 (2)	(none selected)	(none selected)	(none selected)	D50 1 (2)	(none selected)	D84 1 (2)	(none selected)	(none selected)
2	2	Thickness Layer 2 (2)	(none selected)	(none selected)	D16 1 (2)	(none selected)	(none selected)	(none selected)	D50 1 (2)	(none selected)	D84 1 (2)	(none selected)	(none selected)

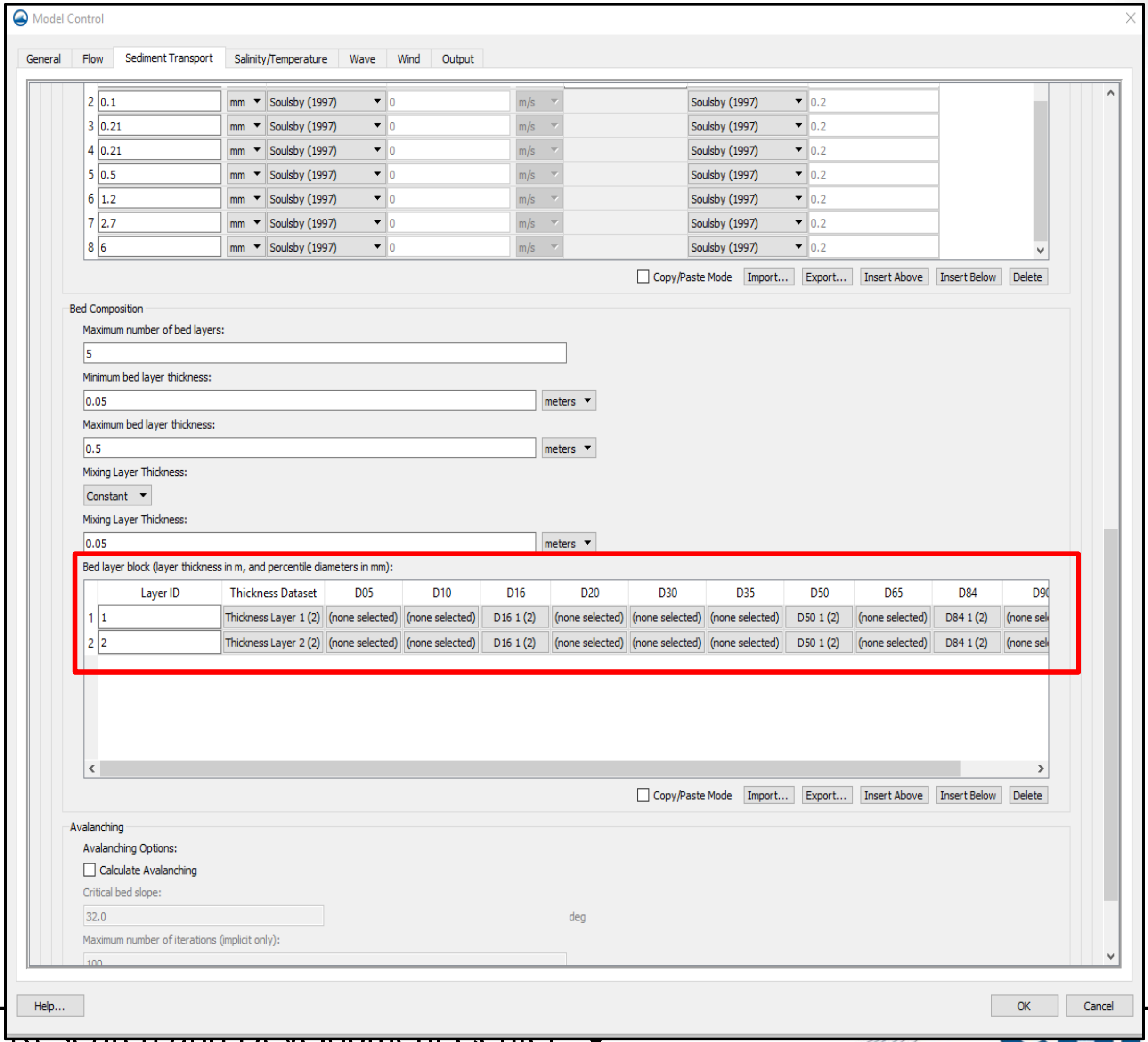


Multiple-sized Sediment Transport Calculation
(Bed Composition)

Bed Composition:

- d_{16}, d_{50}, d_{84} datasets
- d_{35}, d_{50}, d_{90} datasets
- Accumulative grain size distribution

  Percentile diameters allowed in SMS are: 5, 10, 16, 20, 30, 35, 50, 65, 84, 90, and 95.
- D50 dataset and constant geometric standard deviation
- Size class fractions



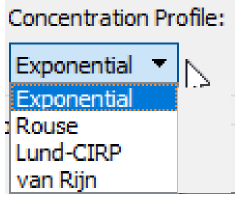
Multiple-sized Sediment Transport Calculation
(Other Parameters)

Activate sediment transport calculation

Sediment transport and morphologic time steps, and time to start the morphology change

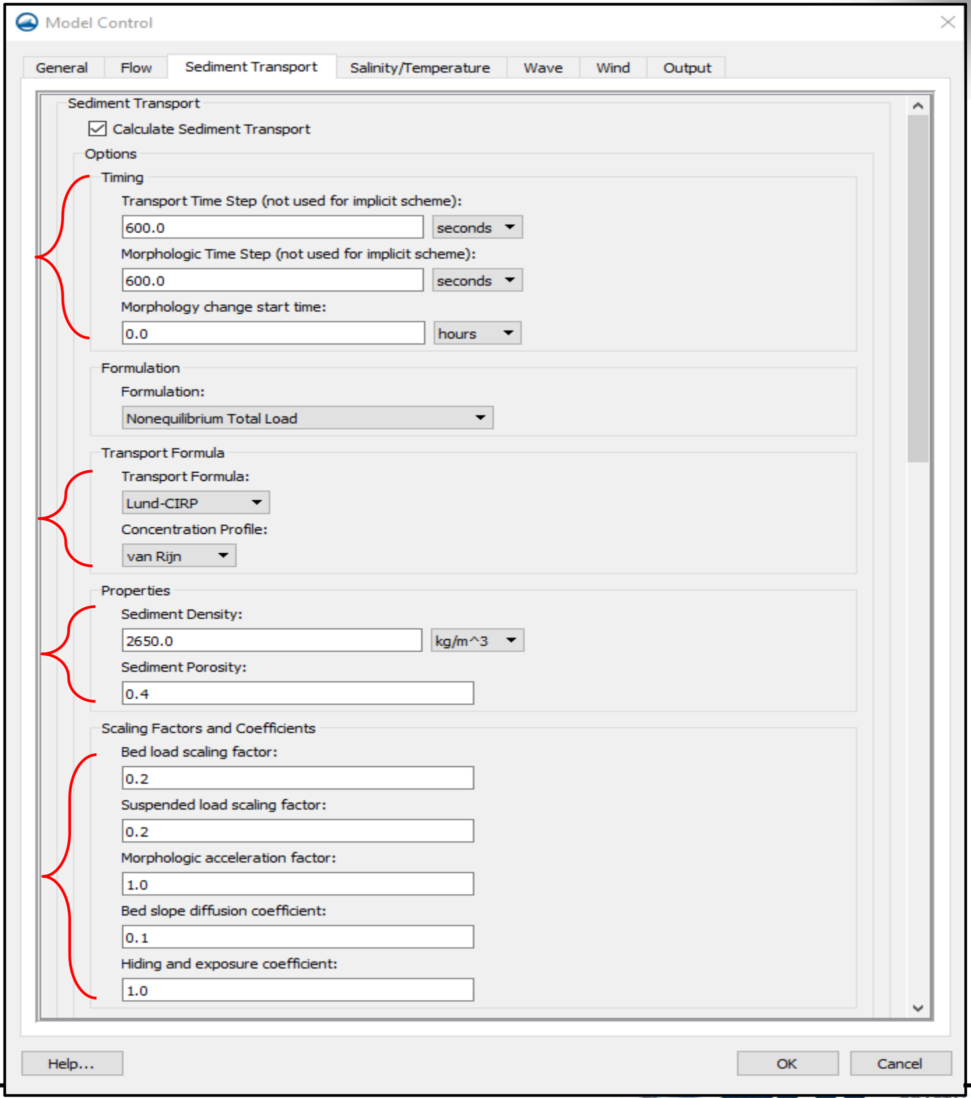
Sediment transport models: equilibrium total load, equilibrium bed load plus advection-diffusion for suspended load, and non-equilibrium total load

Sediment transport formulas and concentration profile



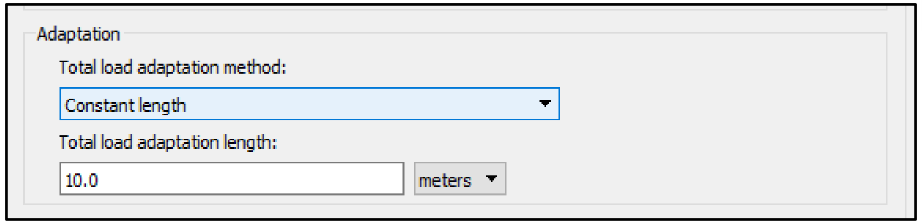
Sediment density and porosity

Transport scaling factors, morphologic acceleration factor, bed slope coefficient (0-5), and hiding and exposure coefficient (0.1-1)

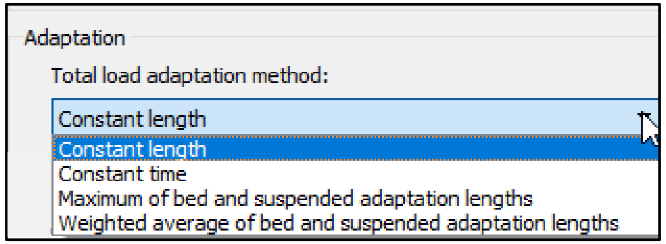


Multiple-sized Sediment Transport Calculation
(Adaptation Coefficient)

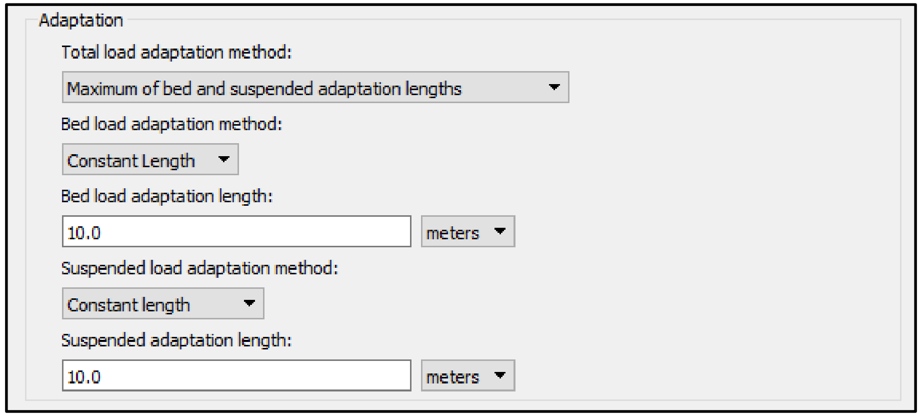
Adaptation coefficient (method and length)



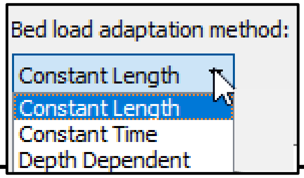
Adaptation method

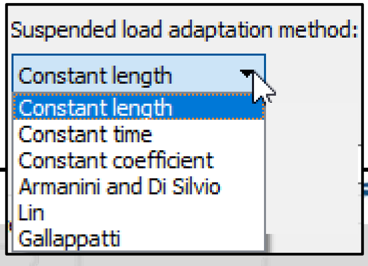


Bed and suspended adaptation lengths



Bed and suspended adaptation methods

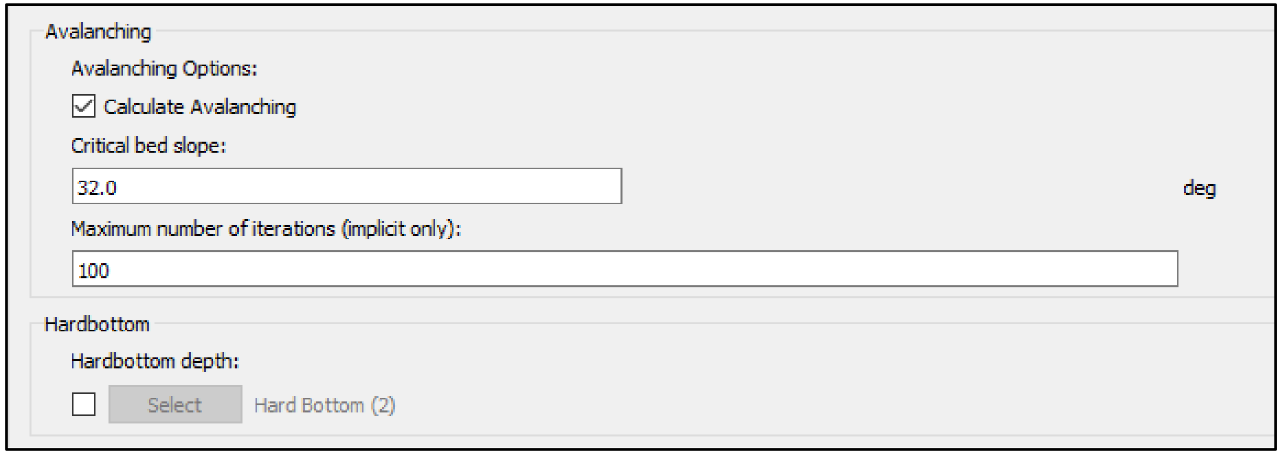




Multiple-sized Sediment Transport Calculation
(Avalanching and Hard Bottom)

Avalanching

Angle of repose



References

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Sanchez, A., Wu, W., Li, H., Brown, M., Reed, C., Rosati, J., Demirbilek, Z. (2014)
https://apps.dtic.mil/dtic/tr/fulltext/u2/a598297.pdf