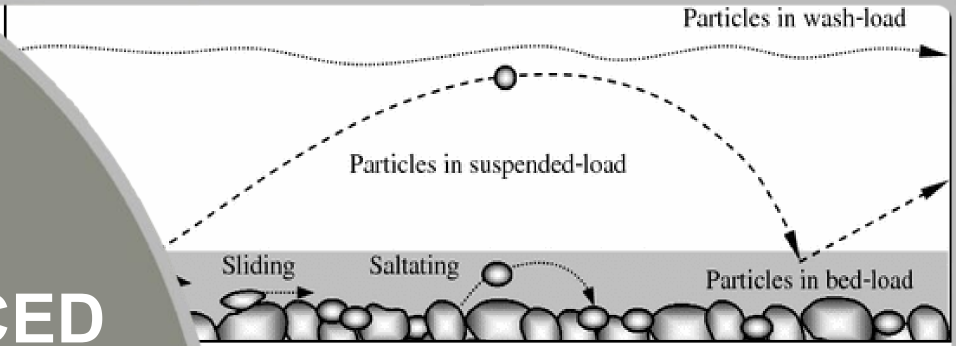
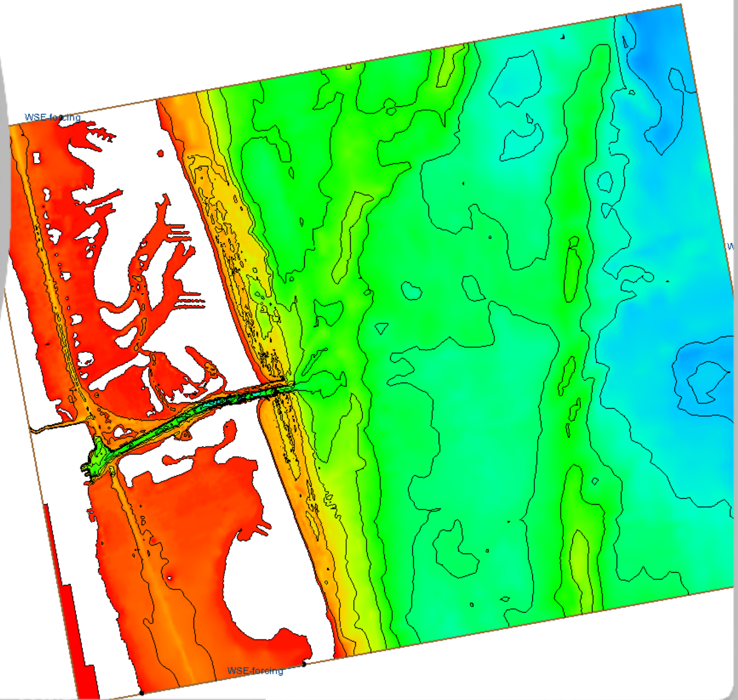
Coastal Modeling System: Advanced Topics using CMS 5.3 and SMS 13.1

Multiple-sized Sediment Transport





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Outline

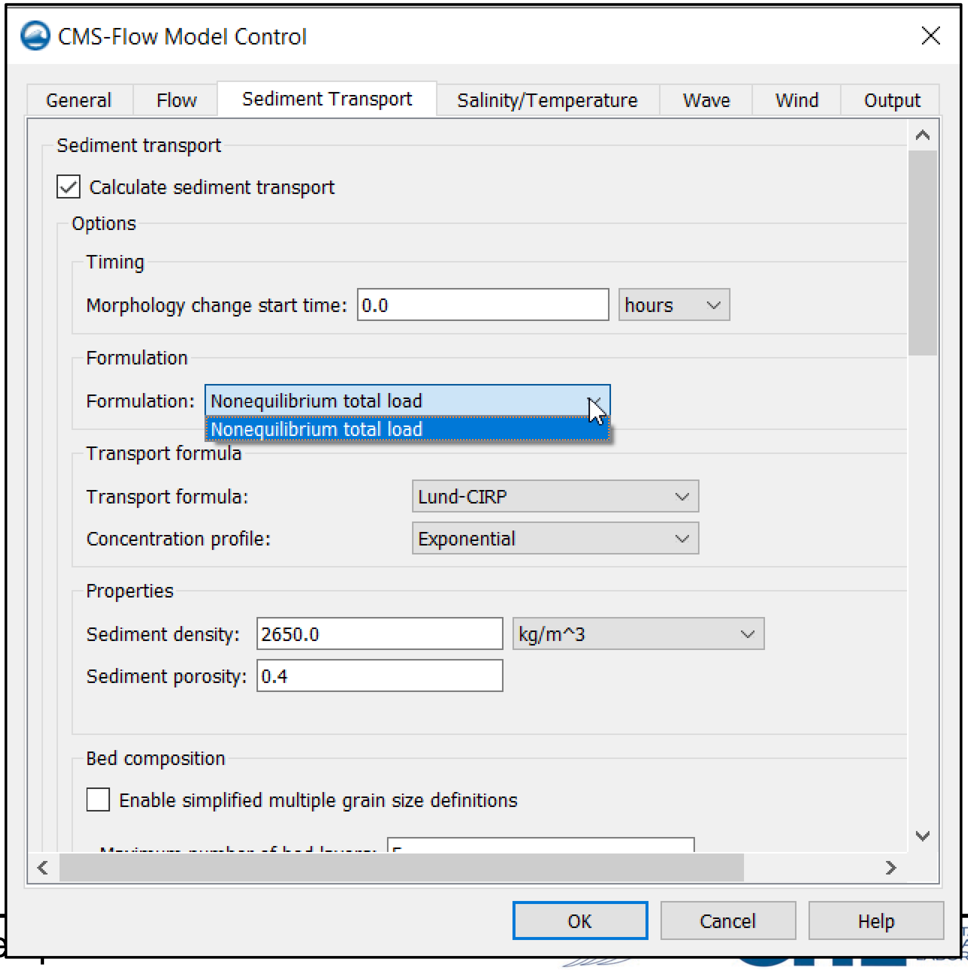
- Sediment transport in CMS
  - Equations
  - Parameters
- Multiple-sized sediment transport calculation
  - Site
  - Transport grain sizes
  - Bed layering
  - Bed composition
- Export CMS files

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**

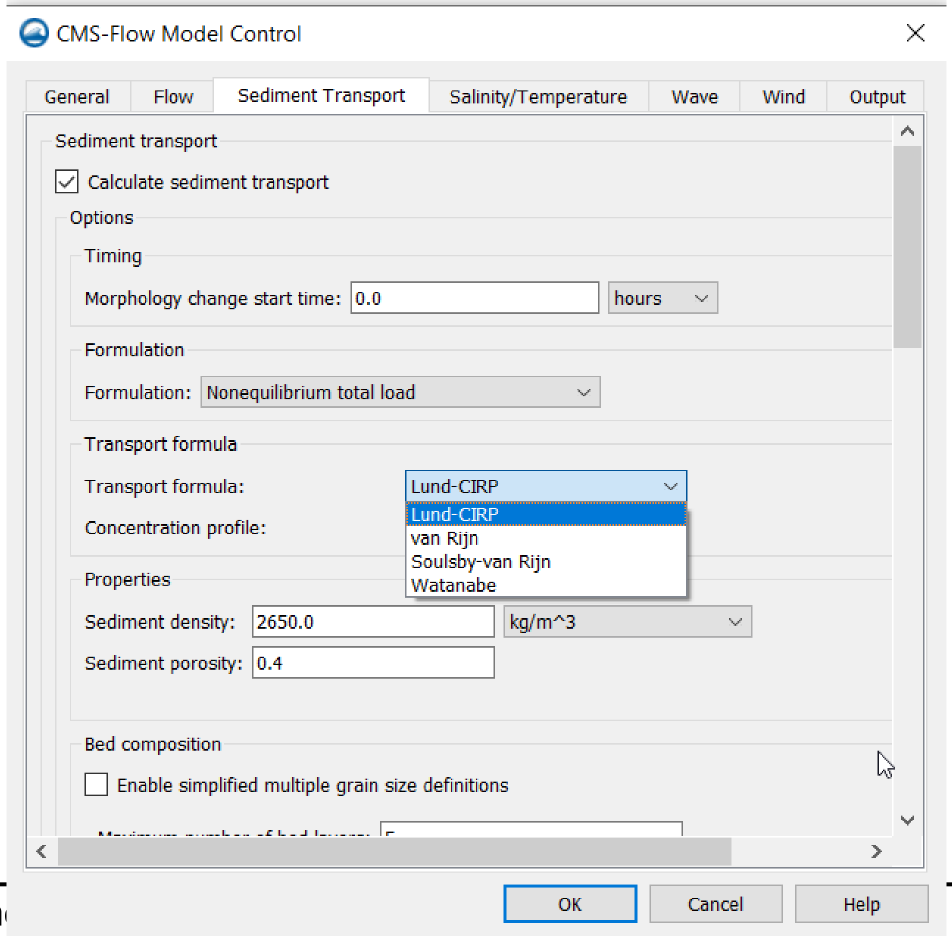


Sediment Transport Formulas
(Non-equilibrium Transport, NET)

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

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

Sediment Transport Calculation
(Parameters)

Activate sediment transport calculation

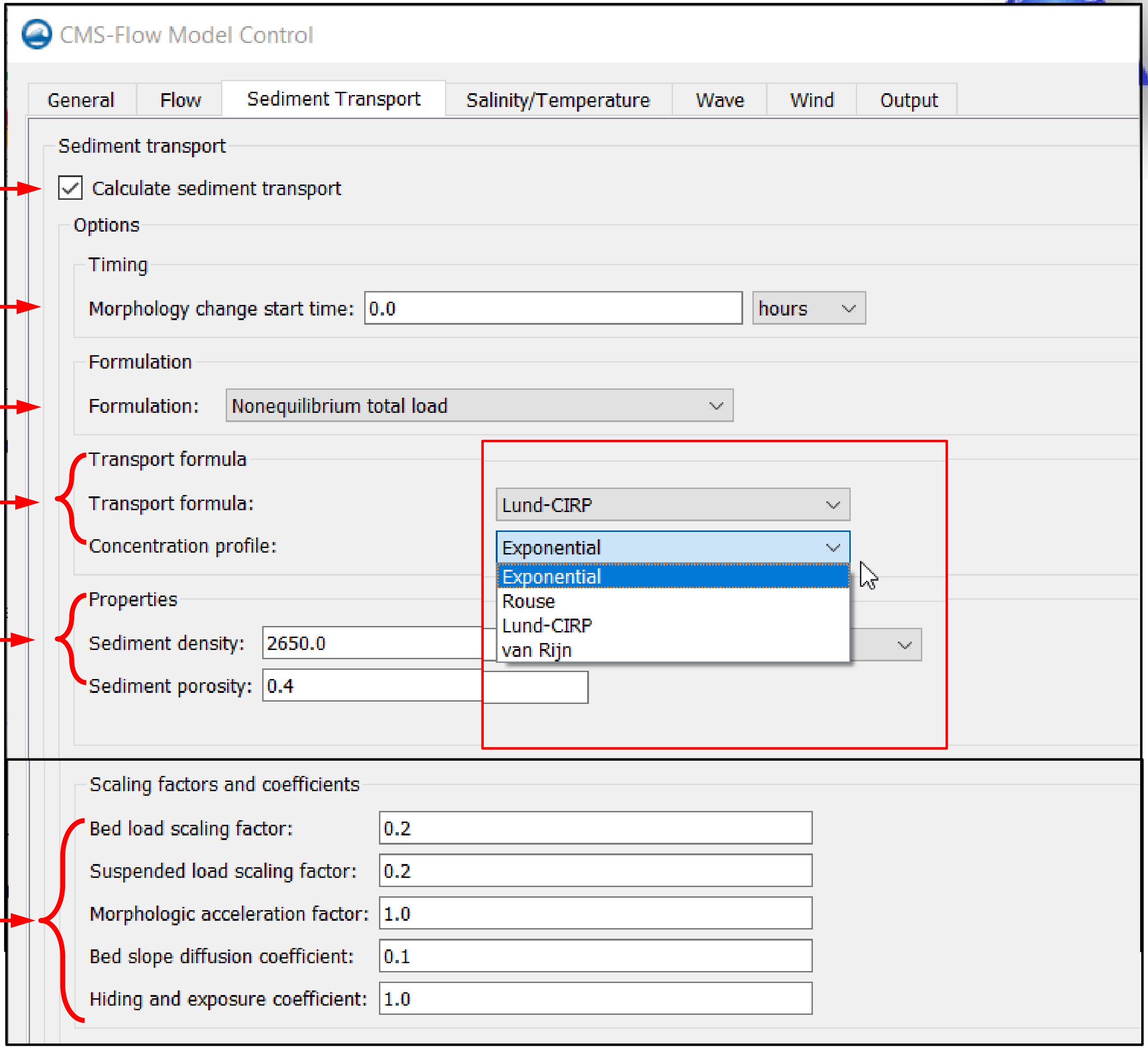
Time to start the calculation of morphology change

Sediment transport models: non-equilibrium total load

Sediment transport formulas and concentration profile

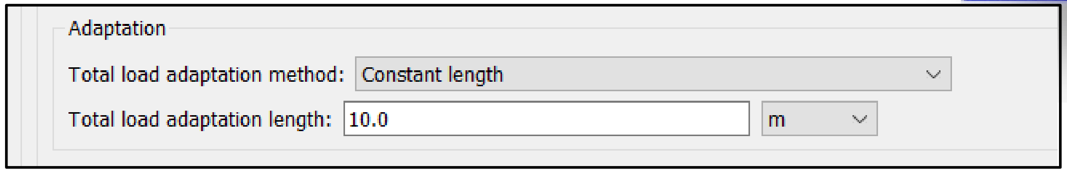
Sediment density and porosity

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

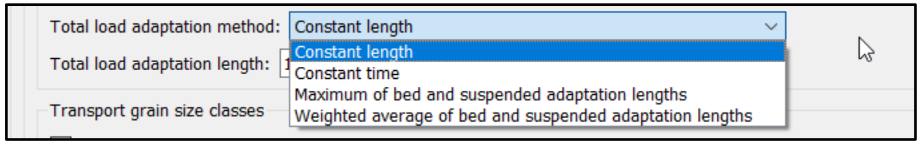


Sediment Transport Calculation
(Adaptation Coefficient)

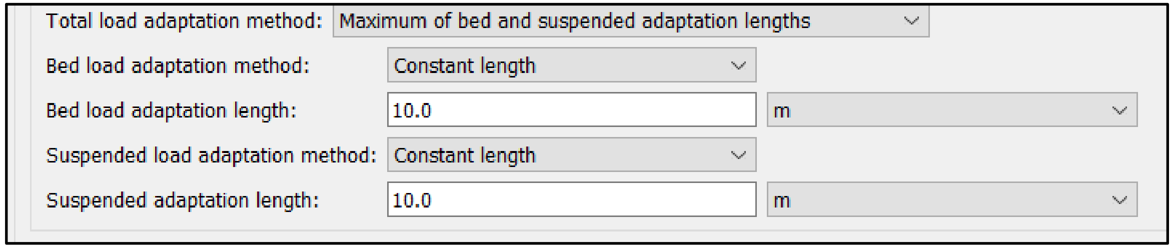
Adaptation coefficient (method and length)



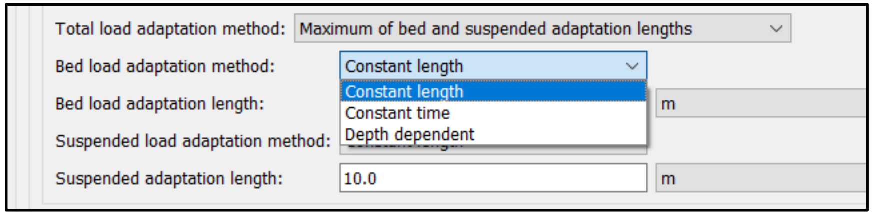
Adaptation method



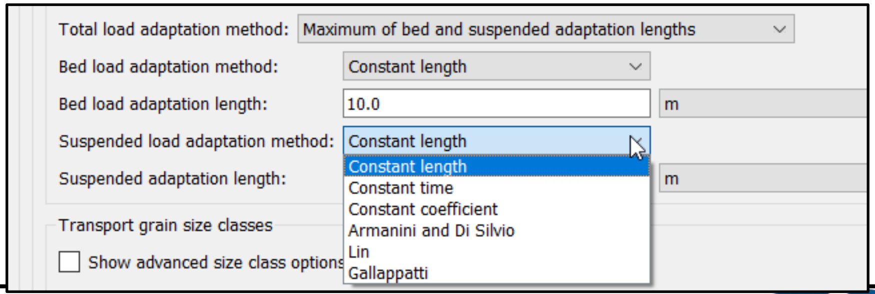
Bed and suspended adaptation lengths



Bed load adaptation method



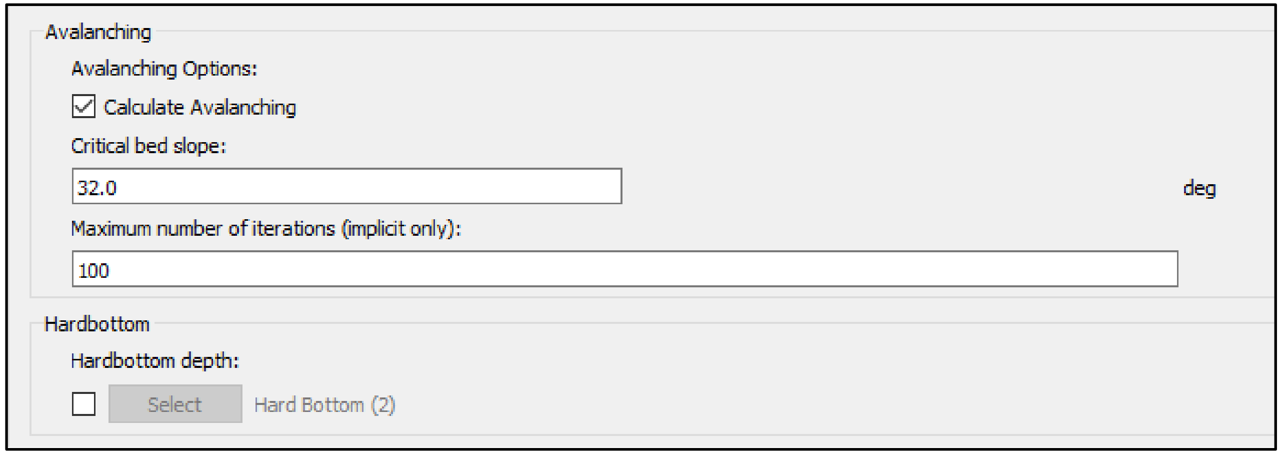
Suspended load adaptation method



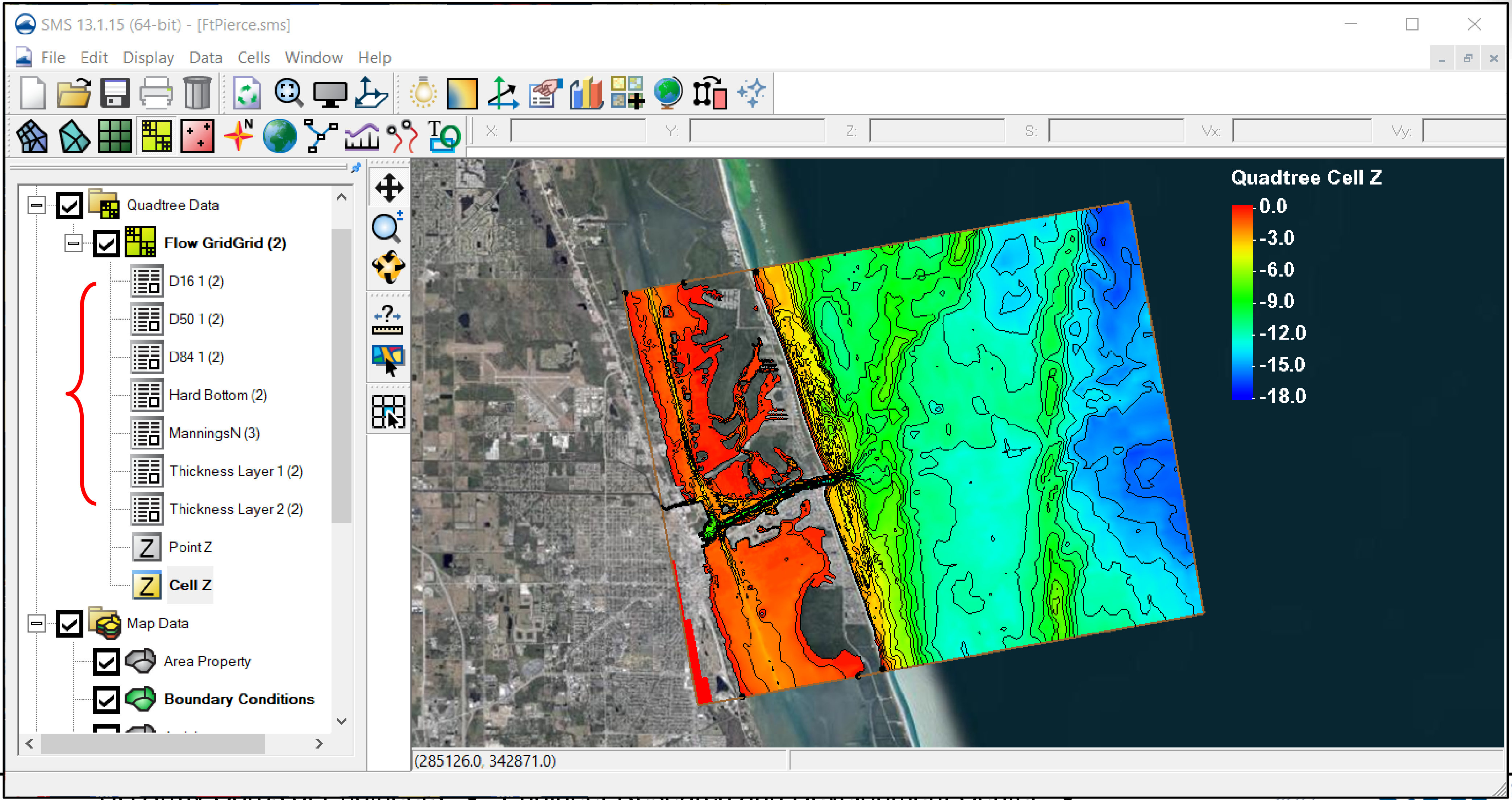
Sediment Transport Calculation
(Avalanching and Hard Bottom)

Avalanching

Angle of repose



Multiple-sized Sediment Transport Calculation
(Ft. Pierce, Florida)



Multiple-sized Sediment Transport Calculation

Geometric Standard Deviation

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

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

$$d_g = exp\left(\sum p_k ln(d_k)\right)$$

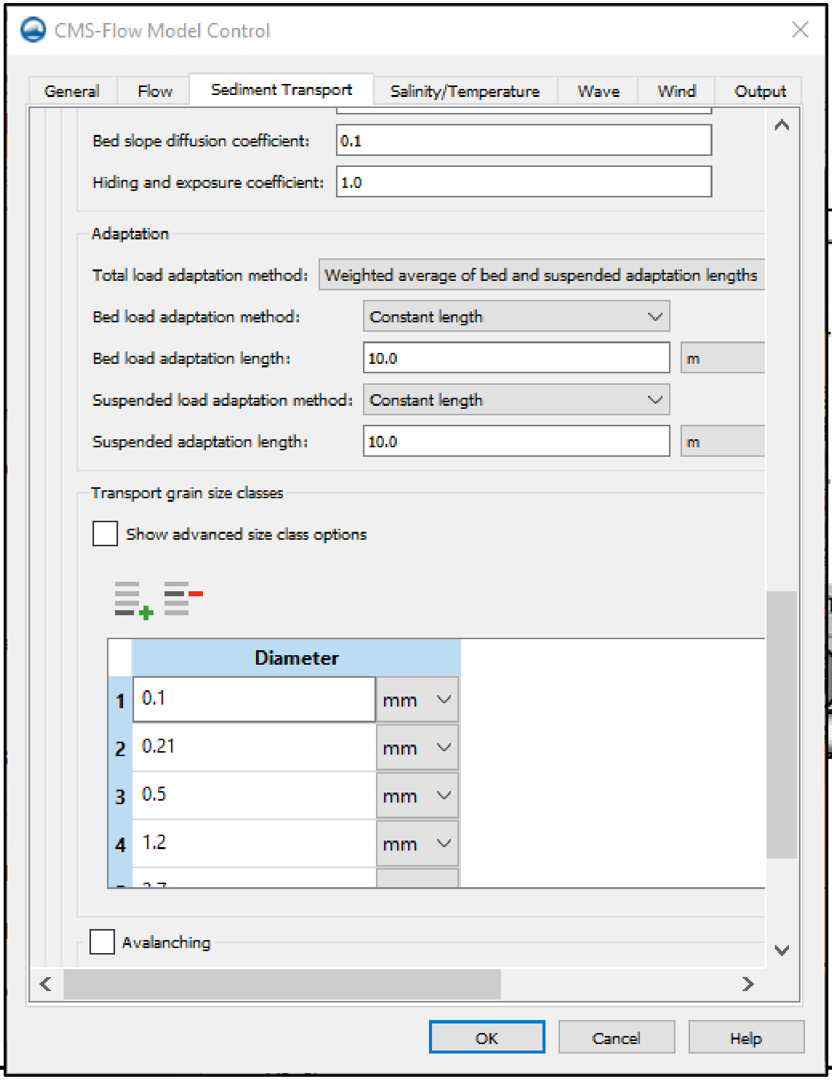
Geometric Standard Deviation	Sorting Classification
<1.27	Very well sorted
1.27-1.41	Well sorted
1.41-1.62	Moderately well sorted
1.62-2.00	Moderately sorted
2.00-4.00	Poorly sorted
4.00-16.00	Very poorly sorted
>16.00	Extremely poorly sorted

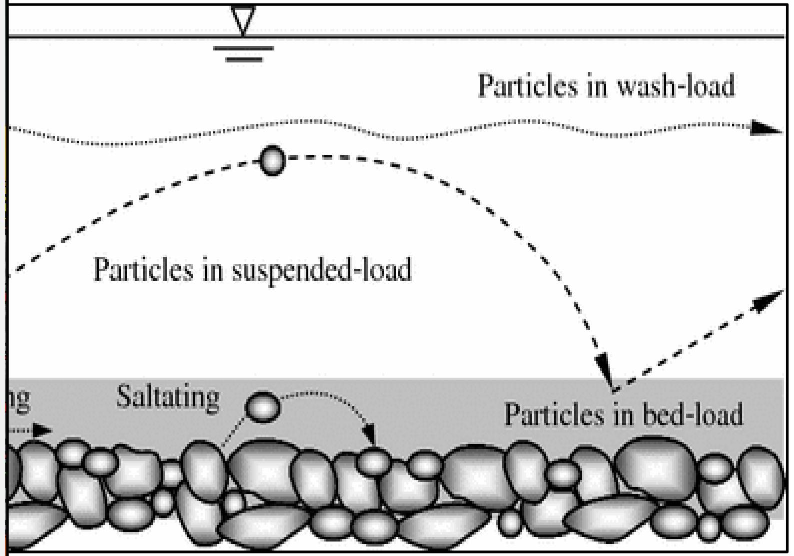
Geometric Standard Deviation greater than approximate 1.41 should be simulated with multiple grain sizes

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

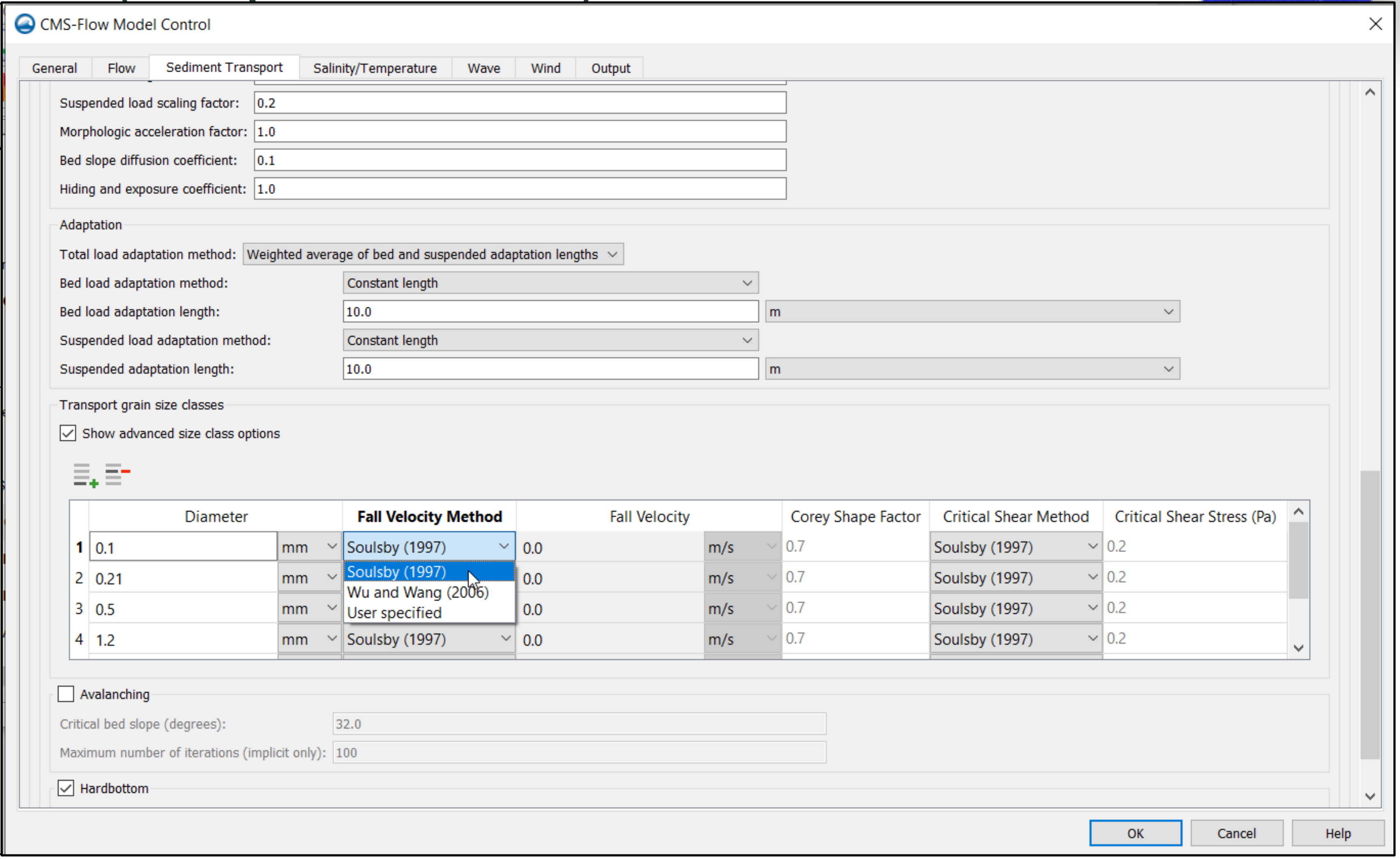
- Characteristic diameter
  - Related to the lower $d_{k-1/2}$ and u

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

  - Estimate the grain size classes b of the distribution

$$d_k = exp\left[lnd_1 + ln(d_N/d_1\right.$$

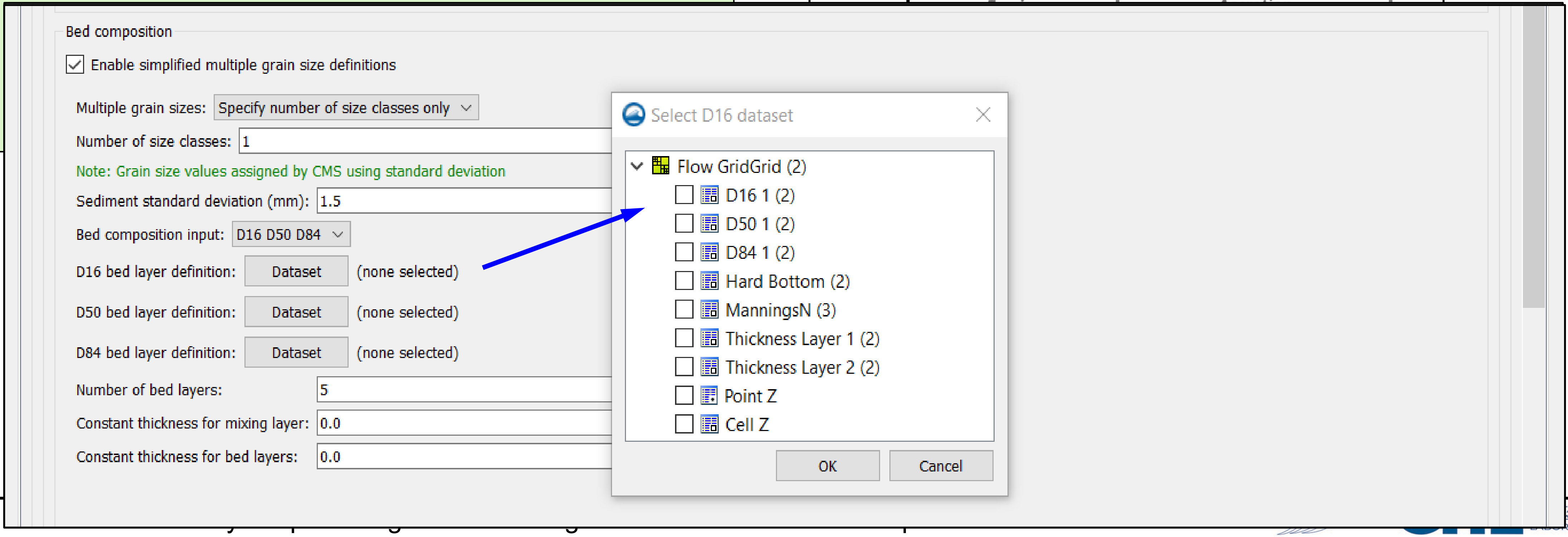
- Fall velocity
  - Soulsby (1997)
  - Wu and Wang (2006)
  - User-specified
- Corey shape factor
  - Used in Wu and Wang (2006)
- Critical shear stress
  - Soulsby (1997)
  - Wu and Wang (1999)
  - User-specified



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

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

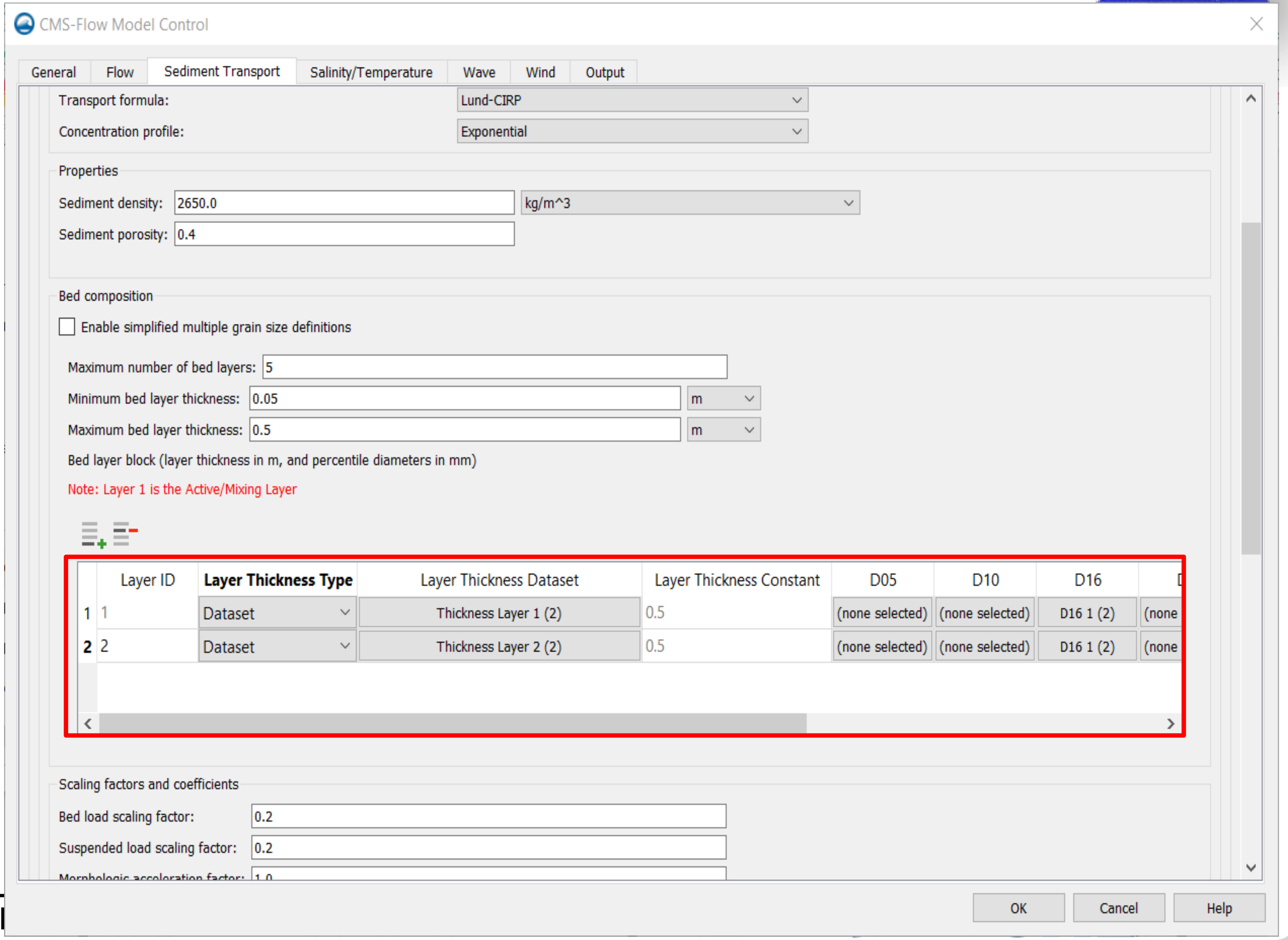


Multiple-sized Sediment Transport Calculation
(Bed Composition)

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



References

Coastal Modeling System: Mathematical Formulations and Numerical Methods
https://apps.dtic.mil/dtic/tr/fulltext/u2/a598297.pdf

Coastal Modeling System User Manual
(Draft Tech Report)

A Revisit and Update on the Verification and Validation of the Coastal Modeling System
(Draft Tech Report)