



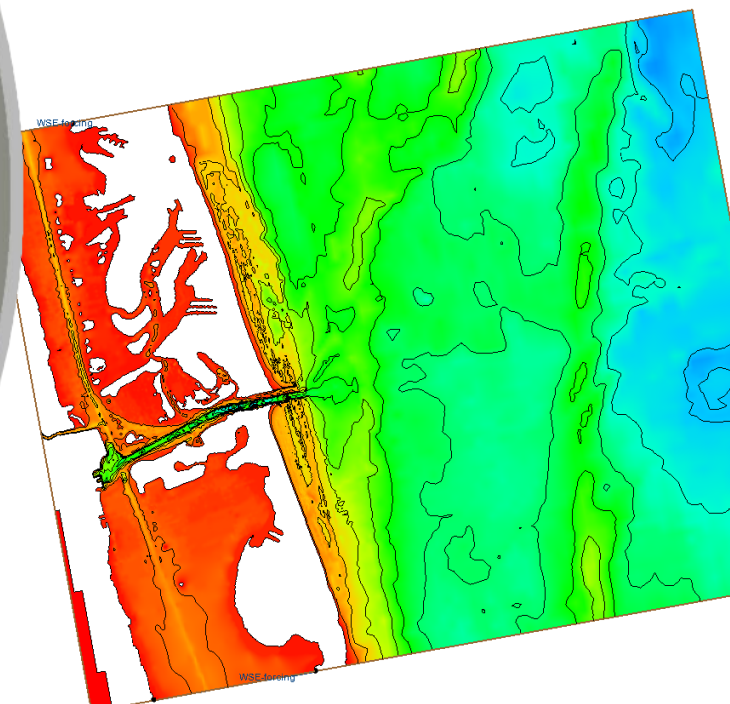
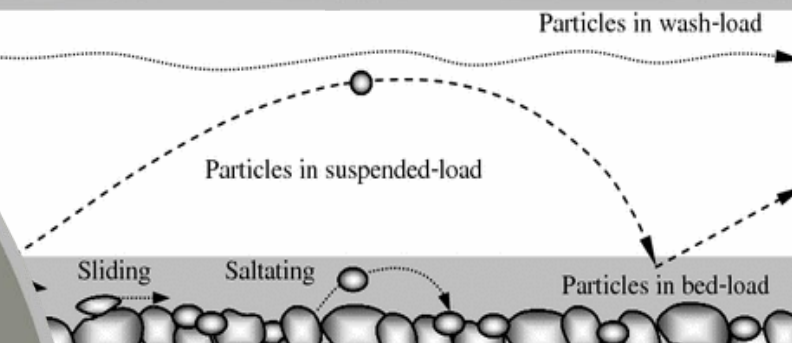
U.S.ARMY®



COASTAL MODELING SYSTEM: ADVANCED TOPICS USING CMS 5.3 AND SMS 13.1

MULTIPLE-SIZED SEDIMENT TRANSPORT

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of Engineers®

**CHL**

COASTAL &
HYDRAULICS
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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

The screenshot shows the 'CMS-Flow Model Control' dialog box with the 'Sediment Transport' tab selected. The 'Calculate sediment transport' checkbox is checked. Under 'Options', the 'Timing' section has 'Morphology change start time' set to 0.0 hours. The 'Formulation' section has a dropdown menu open showing 'Nonequilibrium total load' selected. The 'Transport formula' section has 'Lund-CIRP' selected for the transport formula and 'Exponential' for the concentration profile. The 'Properties' section has 'Sediment density' set to 2650.0 kg/m³ and 'Sediment porosity' set to 0.4. The 'Bed composition' section has 'Enable simplified multiple grain size definitions' unchecked. At the bottom, there are 'OK', 'Cancel', and 'Help' buttons.



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:

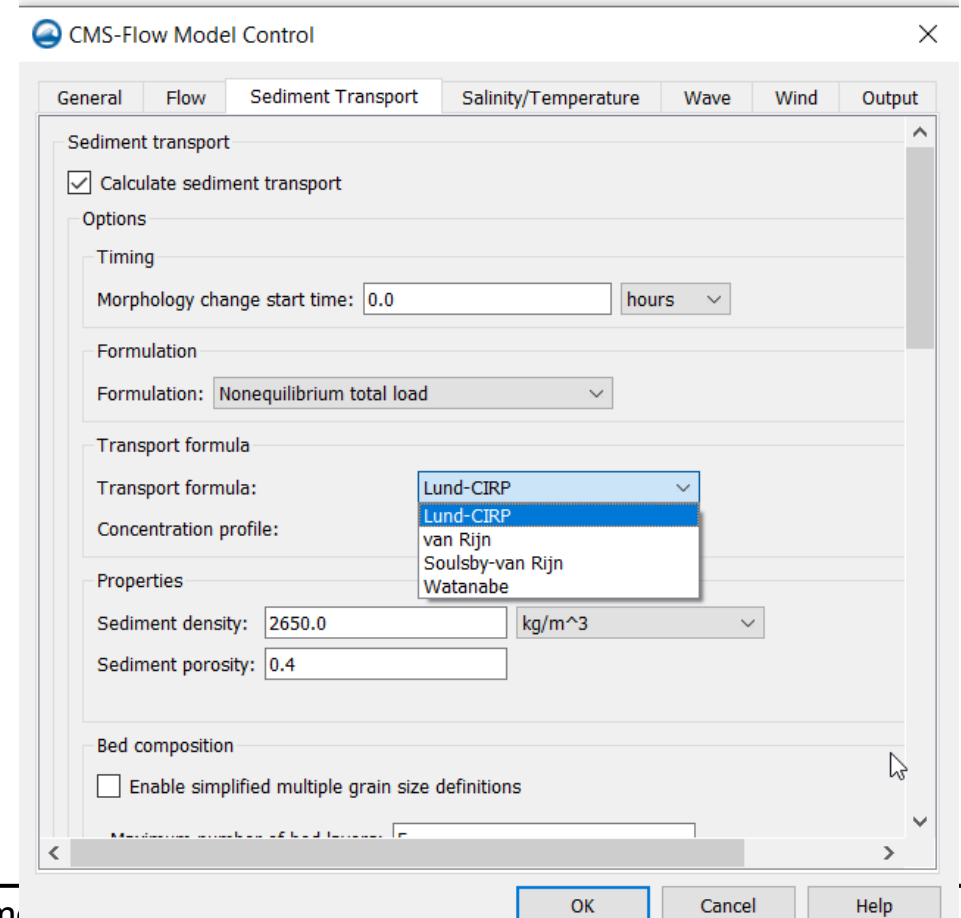
LUND-CIRP

VAN RIJN

SOULSBY-VAN RIJN

WATANABE

CSHORE





Bed Change

Bed change due to the k^{th} class of sediment:

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

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)

CMS-Flow Model Control

General | Flow | **Sediment Transport** | Salinity/Temperature | Wave | Wind | Output

Sediment transport

☒ Calculate sediment transport

Options

Timing

Morphology change start time: 0.0 hours

Formulation

Formulation: Nonequilibrium total load

Transport formula

Transport formula: Lund-CIRP

Concentration profile

Concentration profile: Exponential

Properties

Sediment density: 2650.0

Sediment porosity: 0.4

Scaling factors and coefficients

Bed load scaling factor: 0.2

Suspended load scaling factor: 0.2

Morphologic acceleration factor: 1.0

Bed slope diffusion coefficient: 0.1

Hiding and exposure coefficient: 1.0



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

Adaptation

Total load adaptation method: Constant length

Total load adaptation length: 10.0 m

Total load adaptation method: Constant length

Total load adaptation length: Constant length

Transport grain size classes: Maximum of bed and suspended adaptation lengths

Total load adaptation method: Maximum of bed and suspended adaptation lengths

Bed load adaptation method: Constant length

Bed load adaptation length: 10.0 m

Suspended load adaptation method: Constant length

Suspended adaptation length: 10.0 m

Total load adaptation method: Maximum of bed and suspended adaptation lengths

Bed load adaptation method: Constant length

Bed load adaptation length: Constant length

Suspended load adaptation method: Depth dependent

Suspended adaptation length: 10.0 m

Total load adaptation method: Maximum of bed and suspended adaptation lengths

Bed load adaptation method: Constant length

Bed load adaptation length: 10.0 m

Suspended load adaptation method: Constant length

Suspended adaptation length: Constant length

Transport grain size classes: Armanini and Di Silvio

☐ Show advanced size class options



Sediment Transport Calculation (Avalanching and Hard Bottom)

Avalanching

Angle of repose



Avalanching

Avalanching Options:

☒ Calculate Avalanching

Critical bed slope:

deg

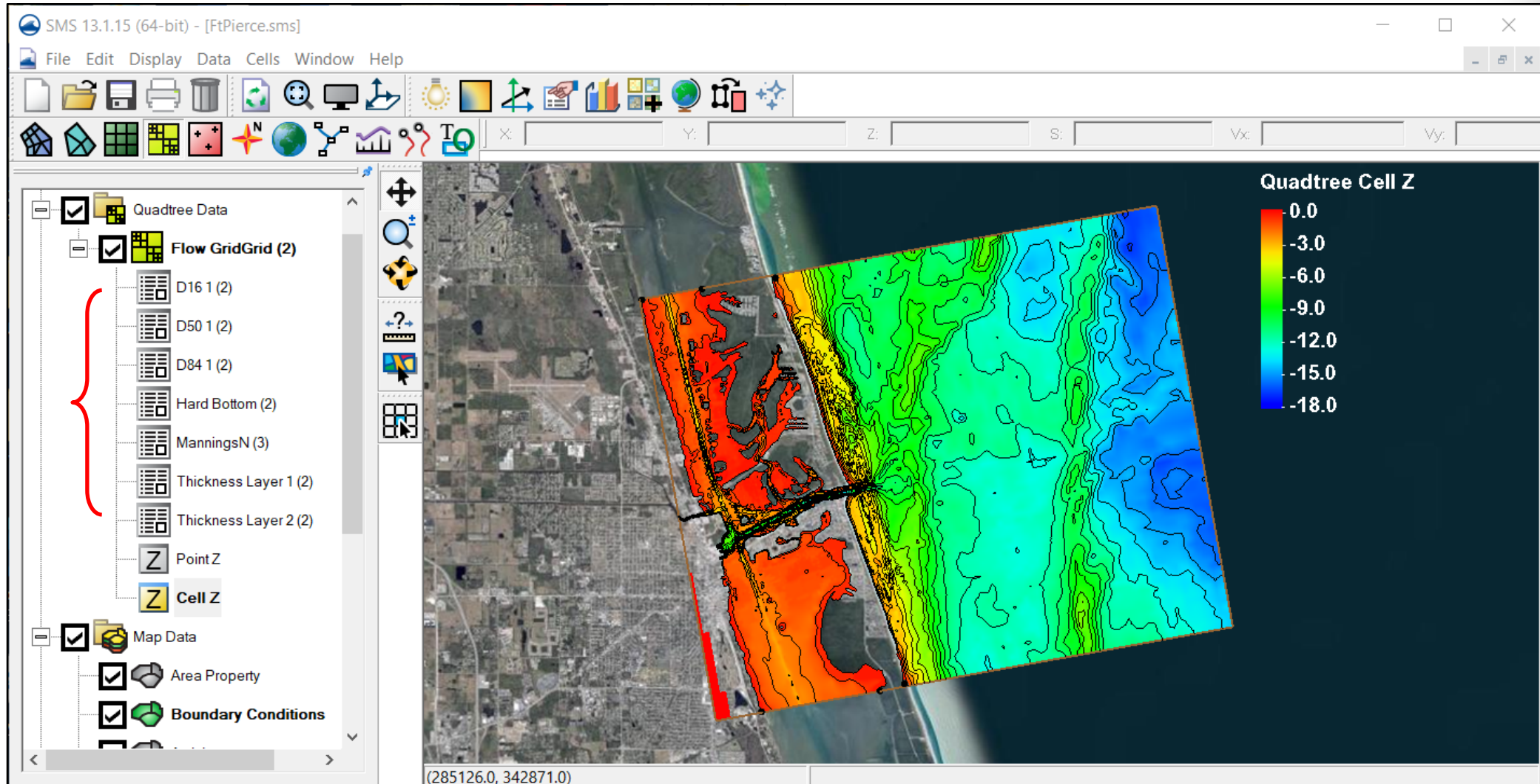
Maximum number of iterations (implicit only):

Hardbottom

Hardbottom depth:

☐ Hard Bottom (2)

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





Multiple-sized Sediment Transport Calculation

Geometric Standard Deviation

$$\sigma_g = \exp \sqrt{\sum p_k (\ln d_k - \ln d_g)^2}$$

p_k : fraction

d_k : size class diameter

d_g : geometric mean

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

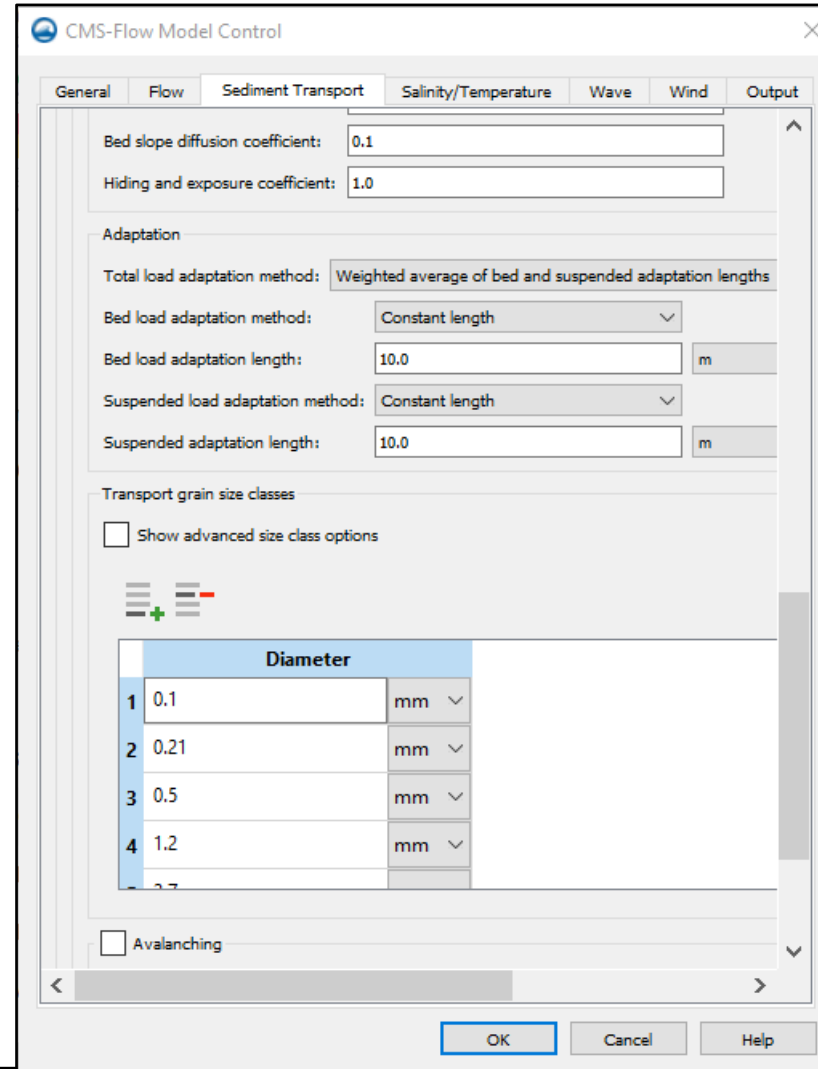
Geometric Standard Deviation	Sorting Classification
<1.27	Very well sorted
1.27-1.41	Well sorted
1.41-1.62	Moderately well sorted
1.62-2.00	Moderately sorted
2.00-4.00	Poorly sorted
4.00-16.00	Very poorly sorted
>16.00	Extremely poorly sorted

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



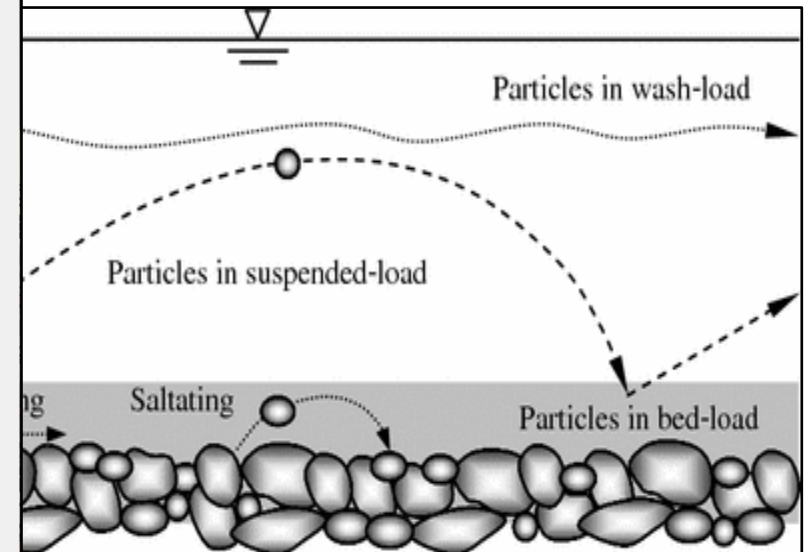
The screenshot shows the 'CMS-Flow Model Control' dialog box with the 'Sediment Transport' tab selected. The 'General' tab is also visible. The 'Sediment Transport' tab contains the following settings:

- Bed slope diffusion coefficient: 0.1
- Hiding and exposure coefficient: 1.0
- Adaptation:
 - Total load adaptation method: Weighted average of bed and suspended adaptation lengths
 - Bed load adaptation method: Constant length
 - Bed load adaptation length: 10.0 m
 - Suspended load adaptation method: Constant length
 - Suspended adaptation length: 10.0 m
- Transport grain size classes:
 - ☐ Show advanced size class options
 - Table with 4 columns: Index, Diameter, Unit, and a dropdown menu.
- ☐ Avalanching

The table for 'Transport grain size classes' is as follows:

	Diameter	
1	0.1	mm
2	0.21	mm
3	0.5	mm
4	1.2	mm

Buttons at the bottom: OK, Cancel, Help.



Multiple-sized Sediment Transport Calculation (Transport Grain Sizes)

Transport Grain Sizes

- Characteristic diameter

- Related to the lower $d_{k-1/2}$ and upper $d_{k+1/2}$

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

- Estimate the grain size classes based on the distribution

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

- 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

CMS-Flow Model Control

General Flow Sediment Transport Salinity/Temperature Wave Wind Output

Suspended load scaling factor: 0.2

Morphologic acceleration factor: 1.0

Bed slope diffusion coefficient: 0.1

Hiding and exposure coefficient: 1.0

Adaptation

Total load adaptation method: Weighted average of bed and suspended adaptation lengths

Bed load adaptation method: Constant length

Bed load adaptation length: 10.0 m

Suspended load adaptation method: Constant length

Suspended adaptation length: 10.0 m

Transport grain size classes

☒ Show advanced size class options

	Diameter	Fall Velocity Method	Fall Velocity	Corey Shape Factor	Critical Shear Method	Critical Shear Stress (Pa)
1	0.1 mm	Soulsby (1997)	0.0 m/s	0.7	Soulsby (1997)	0.2
2	0.21 mm	Soulsby (1997)	0.0 m/s	0.7	Soulsby (1997)	0.2
3	0.5 mm	Wu and Wang (2006)	0.0 m/s	0.7	Soulsby (1997)	0.2
4	1.2 mm	User specified	0.0 m/s	0.7	Soulsby (1997)	0.2

☐ Avalanching

Critical bed slope (degrees): 32.0

Maximum number of iterations (implicit only): 100

☒ Hardbottom

OK Cancel Help

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)

Bed composition

☒ Enable simplified multiple grain size definitions

Multiple grain sizes: Specify number of size classes only ▾

Number of size classes: 1

Note: Grain size values assigned by CMS using standard deviation

Sediment standard deviation (mm): 1.5

Bed composition input: D16 D50 D84 ▾

D16 bed layer definition: Dataset (none selected)

D50 bed layer definition: Dataset (none selected)

D84 bed layer definition: Dataset (none selected)

Number of bed layers: 5

Constant thickness for mixing layer: 0.0

Constant thickness for bed layers: 0.0

Select D16 dataset

- ▾ Flow GridGrid (2)
 - ☐ D16 1 (2)
 - ☐ D50 1 (2)
 - ☐ D84 1 (2)
 - ☐ Hard Bottom (2)
 - ☐ ManningsN (3)
 - ☐ Thickness Layer 1 (2)
 - ☐ Thickness Layer 2 (2)
 - ☐ Point Z
 - ☐ Cell Z

OK Cancel

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

CMS-Flow Model Control

General Flow Sediment Transport Salinity/Temperature Wave Wind Output

Transport formula: Lund-CIRP

Concentration profile: Exponential

Properties

Sediment density: 2650.0 kg/m³

Sediment porosity: 0.4

Bed composition

☐ Enable simplified multiple grain size definitions

Maximum number of bed layers: 5

Minimum bed layer thickness: 0.05 m

Maximum bed layer thickness: 0.5 m

Bed layer block (layer thickness in m, and percentile diameters in mm)

Note: Layer 1 is the Active/Mixing Layer

Layer ID	Layer Thickness Type	Layer Thickness Dataset	Layer Thickness Constant	D05	D10	D16	D35	D50	D65	D84	D90	D95
1 1	Dataset	Thickness Layer 1 (2)	0.5	(none selected)	(none selected)	D16 1 (2)	(none selected)	(none selected)	(none selected)	(none selected)	(none selected)	(none selected)
2 2	Dataset	Thickness Layer 2 (2)	0.5	(none selected)	(none selected)	D16 1 (2)	(none selected)	(none selected)	(none selected)	(none selected)	(none selected)	(none selected)

Scaling factors and coefficients

Bed load scaling factor: 0.2

Suspended load scaling factor: 0.2

Morphologic acceleration factor: 1.0

OK Cancel Help

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)

