US Army Corps of Engineers®

Adaptive Hydraulics (AdH) Version 4.5 Sediment Transport User Manual

A TWO-DIMENSIONAL MODELING SYSTEM DEVELOPED BY THE COASTAL AND HYDRAULICS LABORATORY

January 2015

Abstract: Guidelines are presented for using the US Army Corps of Engineers (USACE) AdH modeling software to model two-dimensional shallow water problems with sediment transport, (i.e. AdH linked to SEDLIB). AdH can be used in conjunction with the Department of Defense Groundwater Modeling System (GMS) or the Surface Water Modeling System (SMS); examples in this manual did use these systems. Other pre- and post-processors are available for grid generation and visualization and can be used with AdH with some modification of the files.

The SEDLIB sediment transport library is intended to be of general use and, as such, examples are given for basic sediment transport of cohesive, noncohesive, and mixed suspended sediment loads and bed loads.

Table of Contents

1 Introduction

The Adaptive Hydraulics (AdH) Model is a modeling package that can describe both saturated and unsaturated groundwater, overland flow, 3D Navier-Stokes and 3D shallow water problems, in addition to the 2D shallow water module described here.

It can be used in a serial or multiprocessor mode on personal computers, UNIX, Silicon Graphics and CRAY operating systems. The uniqueness of AdH is its ability to dynamically refine the domain mesh in areas where more resolution is needed at certain times due to changes in the flow conditions.

AdH can simulate the transport of conservative constituents, such as dye clouds, as well as sediment transport that is coupled to bed and hydrodynamic changes. The ability of AdH to allow the domain to wet and dry as flow conditions or tides change is suitable for shallow marsh environments, beach slopes, floodplains and the like.

AdH is set up such that supercritical and subcritical flows can be represented at the model boundaries as well as internal to the system. It has the ability to simulate vessel transport as well as bridge decks and culvert entrances as pressure field applications.

This tool is being developed at the Coastal and Hydraulics Laboratory (CHL) and has been used to model sediment transport in sections of the Mississippi River, tidal conditions in southern California, and vessel traffic in the Houston Ship Channel. The model is designed to work in conjunction with the DoD Surface Water Modeling System (SMS). The Surface Water Modeling System (SMS) and the Groundwater Modeling System (GMS) are modeling packages for building models, running simulations, and visualizing results.

For further information regarding the GMS or SMS, contact the USACE Research and Development Center, Coastal and Hydraulics Laboratory site or visit the website at http://chl.erdc.usace.army.mil and select the software link. Additional information on AdH can be obtained at the AdH site, http://adh.usace.army.mil.

1.1 Sediment Transport

AdH allows the user to calculate the transport of cohesionless sediment (sand), cohesive sediment (clay and silt), and mixed sediments (sand, clay, and silt). The model is capable of running multiple grain sizes in a single simulation. These computations are performed through a link with EDLIB..

SEDLIB is a sediment transport library. It is capable of solving problems consisting of multiple grain sizes, cohesive and cohesionless sediment types, and multiple layers. It calculates erosion and deposition processes simultaneously, and simulates such bed processes as armoring, consolidation, and discrete depositional strata evolution.

The SEDLIB library system is designed to link to any appropriate hydrodynamic code (e.g., AdH). The hydrodynamic code must be capable of performing advection diffusion calculations for a constituent. SEDLIB interacts with the parent code by providing sources and sinks to the advection diffusion solver in the parent code. The solver is then used to calculate both bedload and suspended load transport, for each grain class. The sources and sinks are passed to the parent code via a source/sink bed sediment flux, for both suspended load and bedload.

Sign Convention

The sign convention in AdH is the standard Cartesian coordinate system and flow into the control volume is positive.

A note on units

AdH is designed so that the user can specify the unit system to use. However, all parameters must be consistent in that they are all given in English units or SI units and not mixed.

The geometry file, boundary condition file, and hotstart file must all be given in the same unit system. There is no card that directly specifies the units being used. Rather, AdH uses the values given and calculates with them. If any equations internal to AdH are unit specific, the density or gravity terms are used to decipher which system is being used.

This manual will give unit specifications where necessary in dimensional form.

The exception to allowing the user to determine the unit system is when sediment transport is being simulated. These equations are based on empirical relationships of SI units and require all calculations to be made in SI units. This means that all of the input files must also be given in SI units. **Sediment transport must be in SI units.**

The sediment is transported separately as suspended load and bed load. Each grain class is transported as a moving constituent. So in making a sediment transport calculation, one must determine how many grain classes are going to be modeled. Sediment calculations also depend on the number of layers used to define the bed strata, as well as how the sediment is distributed within the bed. Sediment modeling requires much more site specific data for the model set up than does hydrodynamic moldeing alone. Also, small changes in these parameters can lead to large changes in the solutions, since morphologic change is the time-integrated result of everything that has happened before.

The AdH and SedLib developers recommend that anyone using AdH and SEDLIB to model sediment transport be familiar with sediment transport dynamics and numerical modeling principals. Large amountsv of observed data are often needed when attempting to develop and validate a sediment transport model of a field site with any numerical model and AdH is no different. Please take your time when setting up your model and make all necessary sensitivity simulations to ensure that you fully understand the dynamics of the system and the driving forces so as to not provide false information to your sponsors.

1.2 Files Needed to Run AdH

The same three files necessary to run AdH are also needed when when sediment is included. No additional files are required. The three files are the mesh file, the boundary conditions file and the hotstart file.

The **mesh file** must be constructed first and can be generated directly with GMS (2D or 3D) or SMS (2D).

Once a mesh file has been constructed, the **boundary conditions** for the problem and operating parameters for AdH must be specified in the boundary condition file.

The **hotstart** file is then generated to establish the initial conditions of the problem.

Once the three required files have been created, pre_AdH is run and it creates the necessary input file for AdH. Then the AdH model is run. The commands are:

pre_adh filename
adh filename

where *filename* is the root of the model's filenames, i.e. for a model named pl8_AdH the following three files would be required pl8_AdH.3dm, pl8_AdH.hot and pl8_AdH.bc. All three files must have the same *filename* as their root followed by one of three suffixes. After the model is run, GMS or SMS can be used to visualize the results.

1.3 Specifically for Sediment Modeling

When running AdH with sediment transport, there are a few required changes to some of the mandatory cards. Additional sediment specific cards are also required in order to model suspended and bed load sediment.

The mesh file can remain unchanged unless material designations need to be modified to match bed layer definitions. The hotstart file can also remain unchanged unless the initial conditions need to include concentrations or other sediment specific initial conditions, or unless one is hotstarting a sediment transport simulation, in which case all of the relevant sediment parameters must be include on the hotstart file. These will be discussed in the hotstarting section.

Most of the modifications for sediment transport modeling will occur in the boundary conditions files. This manual will describe the changes that must occur to a previously generated set of input files along with all of the options for modeling sediment in AdH using SEDLIB.

1.4 Control Card Categories

The sediment control cards listed here are in addition to those required to run hydrodynamics only. These cards include some that are necessary to run any constituent (each sediment grain is a separate constituent) and some that are necessary to run sediment. There are also several cards that are optional. The sediment control cards and their categories are:

Operation Parameters	
OP TRN	Transport Quantities

Constituent Properties	
CN CLA	Cohesive Sediment (Clay and/or Silt)

CN SND	Cohesionless Sediment (Sand)

Material Properties

MP DF	Turbulent Diffusion (Transport Constituent Property)
MP TRT	Transport Refinement Tolerance (Transport Constituent Property)
MP NBL	Number of Bed Layers
MP SBA	Bed layer applied to all nodes
MP SBN	Bed layer applied to selected nodes
MP SBM	Bed layer applied by material
MP CBA	Cohesive bed sediment applied by layer
MP CBN	Cohesive bed sediment applied to selected nodes
MP CBM	Cohesive bed sediment applied by material
MP NCP	Number of consolidated layers
MP CPA	Consolidation properties applied by layer
MP CPN	Consolidation properties applied to selected nodes
MP CPM	Consolidation properties applied by material

Sediment Process Controls

SP NSE	Noncohesive Suspended Sediment Entrainment
SP NBE	Noncohesive Bedload Sediment Entrainment
SP HID	Noncohesive Hiding Factor
SP CSV	Cohesive Settling Velocity
SP WWS	Bed Shear Stress due to Wind waves

Solution Controls

DB TRN	Dirichlet – Transport
NB TRN	Natural – Transport
EQ TRN	Equilibrium Sand Transport Boundary

2 Operation Parameters

The number of transported quantities is given on an OP TRN card. The OP TRN card is a required input card. If the problem does not involve transport (sediment or constituent), zero (0) quantities are specified on the OP TRN card. If 2 sediment classes and salinity are being modeled then three (3) will be specified on the OP TRN card.

In addition, if transport equations are not being modeled, no transport properties or boundary conditions may be specified. An error message will be displayed if transport properties are included in the input file but no transport quantities have been specified.

The following card specifies one transported quantity:

OP TRN 1

Operation parameter cards

OP TRN

TRANSPORT EQUATIONS

Field	Type	Value	Description
1	char	OP	Card type
2	char	TRN	Parameter
3	int	≥ 0	Total number of transported materials (includes all transport types: vorticity, temperature, salinity, sand, clay, etc.)

3 Material Properties

Material properties are used to define features and parameters associated with section of the model domain, as defined in the mesh file. Material property cards begin with **MP** and are followed by specific card indicators. Some **MP** cards are used for hydrodynamics and others are specific to sediment transport.

3.1 Mesh refinement

Mesh refinement is defined on the **MP ML** card for both hydrodynamic and sediment models. An **MP TRT** card is required to define the tolerance for the sediment adaption. A transport refinement tolerance is required for all transport (sediment and constituent) classes for all materials. Just as with hydrodynamics, if the transport solution error on an element exceeds the transport refinement error tolerance given on the **TRT** card, the element is split. This card is only a tolerance, however. The material must be set to allow refinement in order for any adaption to occur.

The error for transport calculations is:

$$coefficient = \int_e \left(h\frac{\partial c}{\partial t} + uh\frac{\partial c}{\partial x} + ch\frac{\partial u}{\partial x} + vh\frac{\partial c}{\partial y} + ch\frac{\partial v}{\partial y} \right)$$

$$Error = \sqrt{coefficient} * Area_{element}$$

In models with transport, the larger of the flow error or the transport error will determine each element's value in the *project_name_*err.dat file It is this value that is used to determine whether or not an element is refined or relaxed. However, for reference, the hydrodynamic and transport errors will be stored separately in files labeled as such: *project_name_*err_hydro.dat and *project_name_*err_con#.dat.

When including transport constituents, the error tolerance for hydrodynamics and sediment should be determined separately. The combined error file, *project_name_*err.dat, contains values that are normalized by the tolerance values and can be useful to determine how the refinement is adjusting the mesh. The individual error files for hydrodynamics and transport are not normalized but as the mesh is refined, these values should reduce in areas where refinement is occurring.

The unrefine tolerance is currently set within the code as 10 percent of the refine tolerance for both flow conditions and transport conditions. When the grid solution error improves, the elements are recombined, although no coarser than the original mesh. The solutions saved, although calculated on a finer mesh, are displayed on the original mesh.

```
MP ML   1 5
MP TRT  1 1 100
MP TRT  1 2 50
```

Different material types can have different levels of refinement. Some experimentation with the error tolerance is usually necessary to gain the desired level of refinement. The adapted meshes can be output during the simulation by including a **PC ADP** card. By including this card, the mesh and associated solution files will be saved at the time step intervals specified on the output control card. The output files will be named like so: "filename.3dm-timestep#.0", "filename.dep-timestep#.0", "filename.ovl-timestep#.0" which is a geometry file for each time step, the depths for each time step, and the velocities for each time step.

3.2 Turbulent Diffusion and Dispersion

Diffusion and dispersion are handled with the eddy viscosity cards and must be defined for every material with either an **EEV** or **EVS** card (see AdH Hydrodynamic User Manual). Turbulent diffusion of transport constituents is defined on the **MP DF** card. This diffusion rate must be specified for each material and constituent. This diffusion card is only required when using the **EVS** option. When using the **EEV** option the diffusion is computed based on the parameters provided on the **EEV** card. (Note that vorticity induced dispersion is always active when vorticity transport is active).

Material property cards

MP ML

REFINEMENT LEVELS

Field	**Type**	**Value**	**Description**
1	char	MP	Card type
2	char	ML	Parameter
3	int	≥ 1	Material type ID number
4	int	≥ 0	Maximum number of refinement levels

MP TRT

TRANSPORT CONSTITUENT REFINEMENT TOLERANCE

Field	Type	Value	Description
1	char	MP	Card type.
2	char	TRT	Parameter.
3	int	≥ 1	Material type ID number
4	int	≥ 1	Constituent ID number
5	real	≥ 0	Error tolerance for refinement terms

MP DF

TURBULENT DIFFUSION RATE

Field	**Type**	**Value**	**Description**
1	char	MP	Card type
2	char	DF	Parameter
3	int	≥ 1	Material type ID number
4	int	> 0	Constituent ID number
5	real	≥ 0.0	Turbulent diffusion rate

4 Sediment Transport Specific Properties

In addition to the transport properties that are provided above, many properties are required for the sediment definitions within the AdH input files. These properties include details to define the grain properties such as size and porosity, the bed layering such as layer thickness and grain distributions, and the sediment process such as the erosion equations.

4.1 Cohesionless sediment (Sand) and Cohesive Sediment (Silt and Clay)

Cohesionless sediment tends to erode grain by grain; hence the erosional and depositional properties of cohesionless sediment can be defined purely as grain properties. The characteristics of the cohesionless sediment are its grain diameter, its specific gravity, and its porosity. These are supplied via the **CN SND** cards. SND stands for sand. Here's an example:

```
CN SND    1  1.0  1.E-4  2.65  0.3
CN SND    2  1.0  5.E-4  2.65  0.3
CN SND    3  1.0  1.E-3  2.65  0.3
```

Beginning after the **CN SND** are the constituent number, the reference concentration for this grain class, grain diameter, the specific gravity, and the porosity. The reference concentration, like all sediment concentrations given in AdH, is in units of micromass per unit mass. AdH actually operates on the dimensionless units but the input/output is easier if multiplied by 1.E+6. AdH sediment transport is also based on metric units, so grain diameter must be given in meters.

Next, describe the bed layer structure. The number of bed layers is given with the **NB NBL** card. This card requires the number of layers and a protocol flag. The bed layer thickness assignment protocol can be 0 for bed layer thickness assigned directly on SB cards or 1 for bed layer thickness assigned by strata elevation horizon on SB cards. After the layer number, each layer must be described by beginning with the lowest layer (layer 1) and then working up to the bed surface. These can be given by individual node (**SBN**), by material type (**SBM**), or for all nodes at once (**SBA**). In fact, the model writes over any prior designation so one could specify all first, followed by a few material types, followed by individual nodes. As an example for two layers we might have the following:

MP NBL 2 0
MP SBA 1 0.5 0.0 0.4 0.6
MP SBA 2 0.5 0.4 0.3 0.3

The **MP NBL** card tells AdH to expect two bed layers to be defined with the **MP SBA** cards and thickness magnitude will be provided. **MP SBA** means that the sediment bed description will be used for all nodes. The next number is the layer number, followed by the layer thickness. Layer 1 is the deepest (or bottom) layer. The next three numbers are the fractions of each of the sediments shown in the **CN SND** cards. There are two layers shown here. Layer 2 is the top layer and its distribution is more weighted toward the smaller grain diameter sand. Material and/or node can now be designated and these nodes would be modified to reflect the difference. Note that it is often desirable to have several layers of zero thickness specified at the bed surface (i.e. the highest layer numbers). These are used by the model as depositional layers, each one storing information from discrete depositional events, and thereby generating new strata in the bed.

When using the strata elevation option, the bed layer thickness is computed based on the elevation of each node. If the bed elevation is above the bottom elevation of a given layer, then that layer thickness is zero. If the bed elevation is below the bottom elevation of a given layer and above the bottom elevation of the layer below, then the bed thickness is the difference between these two elevations.

The elevation horizon option functions as follows:

For layer n, the thickness of the layer is equal to:
$t_n = MAX\left[\left(MIN\left(\eta_{n+1}, \eta_{bed}\right) - \eta_n\right), 0\right]$ where η is elevation.

For example, the following layers are defined (with one grain for simplicity):

MP NBL 3 1
SBA -5 1.0
SBA 10 1.0
SBA 1000 1.0

The code will then look at the z coordinate for each node and assign layer thicknesses. If node 1 has a z coordinate of -10 this elevation is below the deepest defined elevation on the cards so all three layers will have zero thicknesses. For a z coordinate of 2, the layer thicknesses are 7, 0, and 0. For a z coordinate of 15, the layer thicknesses are 20, 5, and 0. Using a large number (such as 1000) is how to define zero thickness layers when using the elevation strata option since the number is chosen such that no elevation in the domain exceeds it.

Sediment boundary conditions can abe specified with **NB TRN** and **DB TRN** cards. These cards function much like the hydrodynamic and transport cards. The natural boundary condition will apply a suspended sediment concentration along a defined edge and the dirichlet boundary condition will apply a suspended sediment concentration at a list of nodes. These boundary conditions must be defined for each grain class . These boundary conditions define suspended load only: bedload flux at the budary is simply lumped into this applied suspended load, and then the model determines what mode the sediment should transport in as the transport computations proceed into the model domain.suspended load only.

An added boundary condition option is available for cohesionless sediment transport. aThis is the equilibrium transport boundary condition.. When this condition is specified, the concentration that is required for a state of equilibrium at that location is applied in suspension and in bedload (i.e. both suspeneded and bedload boundary conditions are specified). Since this boundary condition varies both in space and time, and is dependent on the local shear stress at each node, it can only be applied as a nodal boundary condition (i.e. it cannot be applied along an edge string). For anequilibrium condition, almost no sediment will erode or deposit along the boundary. This condition is specified with an **EQ TRN** card followed by the node string number where it is to be applied, and the constituent number for the grain being applied. Cohesive sediment (clay and/or silt)

Cohesive sediment behaves differently than cohesionless sediment. The cohesive properties of silts and clays result in erosion behavior that is more generally a property of the condition of the sediment bed than a property of the individual grains. Therefore, the user must specify the erosion characteristics of the cohesive bed. In AdH, these erosion characteristics are governed by the following equation:

$$F_E = M\left(\frac{\tau}{\tau_c} - 1\right)^n$$

Where F_E is the erosion flux, M is the erosion rate constant, n is the erosion rate exponent, and τ_c is the critical shear stress for erosion.

The erosional characteristics of *newly deposited* sediment are given in the **CN CLA** card (CLA stands for clay, although both clay and silt are specified with this card). This card also gives the grain properties and settling properties of the individual cohesive sediment grain classes.

The parameters given on the **CN CLA** card are:

- Grain diameter
- Specific gravity
- Bulk density
- Critical shear stress for erosion (τ_c)
- Erosion rate constant (M)
- Critical shear stress for deposition
- Settling velocity

Note that the erosion rate exponent (n) is assumed to be equal to 1 for newly deposited sediment (this is consistent with the observation of Parthenaides).

```
CN CLA 1 1.0 0.000001 2.65 1200.0 0.014 0.00016 0.01 0.00006
CN CLA 2 1.0 0.00001  2.65 1400.0 0.02  0.00018 0.015 0.00016
```

The reference concentration like all sediment concentrations given in AdH is in units of micromass per unit mass, *ppm*. The grain class distributions in the bed are defined in the same way as they are defined for the cohesionless case (i.e. with **MP NBL** and **MP SBA** cards). In addition to these, cohesive sediment beds require a **MP CBA** card for each bed layer to define the cohesive properties of the layers.

The inputs to the **MP CBA** cards include the following:

- Layer number
- Bulk density
- Critical shear stress for erosion (τ_c)
- Erosion rate constant (M)
- Erosion rate exponent (n).

Here's an example for 2 bed layers:

```
MP CBA  1  2200.0  0.1   0.00018   3.0
MP CBA  2  2000.0  0.08  0.00016   2.0
```

As with sand beds, the cohesive bed can be defined by all nodes (**CBA**), specific materials (**CBM**), or specific nodes (**CBN**). As with the previous bed definitions, the layer numbering begins with the bottom-most layer.

EQ TRN cards cannot be used for cohesive sediments. The concept of an equilibrium concentration has no physical meaning for cohesive sediments, since in general simultaneous erosion and deposition does not occur. The natural and dirichlet transport boundary condition options (**NB TRN** and **DB TRN**) are used when defining suspended sediment inflow for cohesive material.

4.2 Mixed sediments (sand, silt and clay)

Mixed sediment beds behave as either cohesive or cohesionless beds, depending on the total fraction of cohesive material in the bed. In AdH, this fraction has been set at 0.1 (i.e. 10%). So at each time step, the model calculates the fraction of cohesive sediment present in the bed surface at each node. If, at a given node, that fraction is greater than 0.1, then the bed at that node behaves as a cohesive bed for that time step. Below is an example of 2 sands, 1 clay, and 1 silt being given in the same file:

```
CN SND  1  1.0  0.0001    2.65  0.3
CN SND  2  1.0  0.001     2.65  0.3
CN CLA  3  1.0  0.000001  2.65  1200.0  0.01  0.00016326  0.01  0.00006
CN CLA  4  1.0  0.00001   2.65  1400.0  0.01  0.00016326  0.01  0.00016
```

The sediment bed properties and the cohesive bed properties would then be defined in the boundary condition file.

4.3 Bed consolidation

Cohesive beds will consolidate over time due to the weight of the grain particles and embedded water. Sediment models that include cohesive constituents can also include bed consolidation parameters. These parameters are defined over time and are specified similarly to the other bed properties, i.e. by all nodes, by materials, or by selected nodes. An **NP NCP** card is necessary to define the number of time values that will be used to define the consolidation. Then an **MP CPA** (or **CPM**, or **CPN**) card is given for each of the time values with the time in seconds that has elapsed since sediment was deposited, the bulk density of the material, the critical shear for erosion, the erosion rate constant, and the erosion rate exponent for the bed material at that time. The data on these cards provides a time history of how the sediment properties change over time.

4.4 No displacement by material

It is common to be uncertain of inflow sediment concentrations when modeling sediment and since extreme differences in results can results from slight changes in suspended concentration, it is easy to get unstable results near the model boundary. The **MP NDM** card was created in an effort to ease this frustration. This card requires a material number to be specified and no displacement will occur in this area. Material can be sourced from the bed or sunk to the bed but it will not appear on the bed. By using this feature, a section of the model domain can be used for adjustment of the suspended sediment without the trouble of the bed elevation changing to adjust to inaccurate suspended sediment loads.

4.5 Sediment output files

When running the transport functions in AdH, much more data are saved and output than when running just the hydrodynamics. In addition to the water depth, velocity, and residual error files, concentration files are provided for each transported quantity along with solution files for bed displacement, bedload vector, and bed shear stress. The bed layer thickness for each bed layer and the active layer as well as the grain distribution for each bed layer and active layer are saved. Cohesive bed properties are also saved for each bed layer. An additional file is saved containing the sediment mass residual information for use in mass balance computations.

Sediment Constituent cards

CN CLA

COHESIVE SEDIMENT (CLAY AND/OR SILT)

Field	Type	Value	Description
1	char	CN	Card type
2	char	CLA	Parameter

3	int	≥ 1	The constituent ID number
4	real	> 0	Characteristic concentration
5	real	> 0	Grain diameter
6	real	> 1	Specific gravity
7	real	> 0	Bulk density
8	real	> 0	Critical shear for erosion
9	real	> 0	Erosion rate constant
10	real	> 0	Critical shear for deposition
11	real	> 0	Free Settling velocity

CN SND

COHESIONLESS SEDIMENT (SAND)

Field	Type	Value	Description
1	char	CN	Card type
2	char	SND	Parameter
3	int	≥ 1	The constituent ID number
4	real	> 0	Characteristic concentration
5	real	> 0	Grain diameter
6	real	> 1	Specific gravity
7	real	> 0	Grain porosity

Sediment Material property cards

MP NBL

NUMBER OF SEDIMENT BED LAYERS

Field	Type	Value	Description
1	char	MP	Card type
2	char	NBL	Parameter
3	int	≥ 0	Number of bed layers for sediment transport (layer number begins with the bottom-most layer)
4	int	0 or 1	Bed layer thickness assignment protocol 0 = bed layer thickness assigned directly on SB cards 1 = bed layer thickness assigned by strata elevation horizon on SB cards

The elevation horizon option functions as follows:

For layer n, the thickness of the layer is equal to:

$$t_n = MAX\left[\left(MIN\left(\eta_{n+1}, \eta_{bed}\right) - \eta_n\right), 0\right]$$

Where η is elevation

MP SBN

SEDIMENT BED INITIALIZATION APPLIED TO SELECTED NODES

Field	Type	Value	Description
1	char	MP	Card type
2	char	SBN	Parameter
3	int	> 0	Bed layer ID number
4	int	> 0	The node number from which to start
5	int	> 0	The node number at which to end
6	real	≥ 0.0	The bed layer thickness or strata elevation horizon
7	real	≥ 0.0	The grain class fraction for the first sediment
8	real	≥ 0.0	The grain class fraction for the second sediment
#	real	≥ 0.0	The grain class fraction for the final sediment

MP SBA

SEDIMENT BED INITIALIZATION APPLIED TO ALL NODES

Field	Type	Value	Description
1	char	MP	Card type
2	char	SBA	Parameter
3	int	> 0	Bed layer ID number
4	real	≥ 0.0	The bed layer thickness or strata elevation horizon
5	real	≥ 0.0	The grain class fraction for the first sediment
6	real	≥ 0.0	The grain class fraction for the second sediment
#	real	≥ 0.0	The grain class fraction for the final sediment.

MP SBM

SEDIMENT BED INITIALIZATION APPLIED BY MATERIAL

Field	Type	Value	Description
1	char	MP	Card type
2	char	SBM	Parameter
3	int	> 0	Bed layer ID number
4	int	> 0	Material type ID number
5	real	≥ 0.0	The bed layer thickness or strata elevation horizon
6	real	≥ 0.0	The grain class fraction for the first sediment
7	real	≥ 0.0	The grain class fraction for the second sediment
#	real	≥ 0.0	The grain class fraction for the final sediment

MP CBN

COHESIVE BED SEDIMENT PROPERTIES APPLIED TO SELECTED NODES

Field	Type	Value	Description

1	char	MP	Card type
2	char	CBN	Parameter
3	int	> 0	Bed layer ID number
4	int	> 0	The node number from which to start
5	int	> 0	The node number at which to end
6	real	≥ 0.0	The bulk density
7	real	≥ 0.0	The critical shear stress for erosion
8	real	≥ 0.0	The erosion rate constant
9	real	≥ 0.0	The erosion rate exponent

MP CBM

COHESIVE BED SEDIMENT PROPERTIES APPLIED BY MATERIAL

Field	Type	Value	Description
1	char	MP	Card type
2	char	CBM	Parameter
3	int	> 0	Bed layer ID number
4	int	> 0	Material type ID number
5	real	≥ 0.0	The bulk density
6	real	≥ 0.0	The critical shear stress for erosion
7	real	≥ 0.0	The erosion rate constant
8	real	≥ 0.0	The erosion rate exponent

MP CBA

COHESIVE BED SEDIMENT PROPERTIES APPLIED TO ALL NODES

1	char	MP	Card type
2	char	CBA	Parameter
3	int	> 0	Bed layer ID number
4	real	≥ 0.0	The bulk density
5	real	≥ 0.0	The critical shear stress for erosion
6	real	≥ 0.0	The erosion rate constant
7	real	≥ 0.0	The erosion rate exponent

MP NCP

CONSOLIDATION TIME SERIES SPECIFICATION

1	char	MP	Card type
2	char	NCP	Parameter
3 for	int	≥ 0	Number of time values in the consolidation time series sediment transport

MP CPN

CONSOLIDATION TIME SERIES PROPERTIES APPLIED TO SELECTED NODES

1	char	MP	Card type

2	char	CPN	Parameter
3	int	> 0	The node number from which to start
4	int	> 0	The node number at which to end
5	int	> 0	Consolidation time value number
6	real	≥ 0.0	Elapsed time since sediment deposition (sec)
7	real	≥ 0.0	The bulk density
8	real	≥ 0.0	The critical shear stress for erosion
9	real	≥ 0.0	The erosion rate constant
10	real	≥ 0.0	The erosion rate exponent

MP CPM

CONSOLIDATION TIME SERIES PROPERTIES APPLIED BY MATERIAL

1	char	MP	Card type
2	char	CPM	Parameter
3	int	> 0	Material type ID number
4	int	> 0	Consolidation time value number
5	real	≥ 0.0	Elapsed time since sediment deposition (sec)
6	real	≥ 0.0	The bulk density
7	real	≥ 0.0	The critical shear stress for erosion
8	real	≥ 0.0	The erosion rate constant
9	real	≥ 0.0	The erosion rate exponent

MP CPA

CONSOLIDATION TIME SERIES PROPERTIES APPLIED BY LAYER

1	char	MP	Card type
2	char	CPA	Parameter
3	int	> 0	Consolidation time value number
4	real	≥ 0.0	Elapsed time since sediment deposiiton (sec)
5	real	≥ 0.0	The bulk density
6	real	≥ 0.0	The critical shear stress for erosion
7	real	≥ 0.0	The erosion rate constant
8	real	≥ 0.0	The erosion rate exponent

MP NDM

TURN OFF DISPLACEMENT BY MATERIAL TYPE

1	char	MP	Card type
2	char	NDM	Parameter
3	int	> 0	Material type ID number

Solution control cards

EQ TRN

EQUILIBRIUM SAND TRANSPORT BOUNDARY CONDITION

Field	Type	Value	Description
1	char	EQ	Card type
2	char	TRN	Parameter
3	int	≥ 1	String ID number (node)
4	int	≥ 1	Constituent ID number
5	int	≥ 0	placeholder

NB TRN

NATURAL BOUNDARY CONDITION - TRANSPORT

Field	Type	Value	Description
1	char	NB	Card type
2	char	TRN	Parameter
3	int	≥ 1	String ID number (edge)
4	int	≥ 1	Constituent ID number
5	int	≥ 1	Series ID number that contains the constituent concentration (units dependent of the transport type)

DB TRN

DIRICHLET - TRANSPORT

Field	Type	Value	Description
1	char	DB	Card type
2	char	TRN	Parameter
3	int	≥ 1	String ID number (node)
4	int	≥ 1	Constituent ID number
5	int	≥ 1	Series ID number that contains the constituent concentration (units depend on the transport type)

5 Sediment Processes

The sediment process cards are designed to allow the user to select among various methods of describing a specific process. SedLib has several process options available and intends to grow as additional options are necessary or requested. Processes include to date are:

- cohesive settling
- wind wave shear
- noncohesive suspended entrainment
- noncohesive bedload entrainment
- noncohesive hiding factor

These process cards all begin with **SP** and are followed by a three letter descriptor of the specific process being specified. The third field is a flag indicating which process algorithm to use. Since some methods require additional parameters, the fields 4 and above are reserved for any parameter that may be required for a specific method.

Sediment Process cards

SP CSV

SEDIMENT PROCESS: COHESIVE SETTLING VELOCITY

Field	Type	Value	Description
1	char	SP	Card type
2	char	CSV	Parameter
3	int	= 0	0 - Free Settling
		= 1	1 - Hwang and Mehta
4…	real	≥ 0	Process specific parameter(s)

SP WWS

SEDIMENT PROCESS: WIND WAVE SHEAR

Field	Type	Value	Description
1	char	SP	Card type
2	char	WWS	Parameter
3	int	= 0	0 – No applied wind-wave stress
		= 1	1 - Grant and Madsen

		= 2	2 - Teeter
4…	real	≥ 0.0	Process specific parameter(s)

SP NSE

SEDIMENT PROCESS: NONCOHESIVE SUSPENDED ENTRAINMENT

Field	Type	Value	Description
1	char	SP	Card type
2	char	NSE	Parameter
3	int	= 0	0 - Garcia-Parker
		= 1	1 - Wright-Parker
		= 2	2 – Van Rijn
4…	real	≥ 0.0	Process specific parameter(s)

SP NBE

SEDIMENT PROCESS: NONCOHESIVE BEDLOAD ENTRAINMENT

Field	Type	Value	Description
1	char	SP	Card type
2	char	NSE	Parameter
3	int	= 0	0 – Van Rijn
		= 1	1 – Meyer Peter Mueller
		= 2	2 – Meyer Peter Mueller with Wong Parker Correction
4…	real	≥ 0.0	Process specific parameter(s)

SP HID

SEDIMENT PROCESS: NONCOHESIVE HIDING FACTOR

Field	Type	Value	Description
1	char	SP	Card type
2	char	NSE	Parameter
3	int	= 0	0 – Karim Holly Yang
		= 1	1 – Egiazaroff
		=2	2 – Wu Wang Jia
4…	real	≥ 0.0	Process specific parameter(s)

6 Running AdH

Running AdH for sediment is no different that running it for hydrodynamics. Once the three required files have been created, pre_AdH is run and it creates the necessary input file for AdH. Then the AdH model is run. The commands are:

pre_adh filename
adh filename

where *filename* is the root of the model's filenames, i.e. for a model named pl8_AdH the following three files would be required pl8_AdH.3dm, pl8_AdH.hot and pl8_AdH.bc. All three files must have the same *filename* as their root followed by one of three suffixes.

The standard output for AdH is in a tab delimited format so that it can be manipulated by the user in many different ways. The first column of data gives the physics being solved for that iteration. For hydrodynamics the physics is listed as **HYD** and for transport it is listed as **TRN**. When modeling sediment each suspended load and bed load iteration is listed as **SLT** and **BLT**, respectively. The order of the data in the short column tabular form (**PC LVL** 0) from left to right is physics being solved time, time step size, percent completion progress, nonlinear iteration number, linear iteration count, node number giving the maximum residual, node number giving the maximum increment norm, node count after adaption, failure flag. The order of the data in the long column tabular form (**PC LVL** 1) from left to right is physics, time, time step size, percent completion progress, nonlinear iteration number, linear iteration count, maximum residual norm, node number giving the maximum residual, x, y, and z-coordinates of this worst node, maximum increment norm, node number giving this maximum increment, x, y, and z-coordinates of this worst node, node count after adaption, failure flag. All time values in the screen output are in seconds. The maximum residual norm is used to determine convergence against the **NTL** value. The maximum increment norm is used to determine convergence against the **ITL** value, if included in the boundary conditions file. If no adaption is taking place, the node count after adaption will not change throughout the run. The failure flag is the # symbol and indicates that convergence did not occur and the time step will be cut to ¼ the previous value. This column is left empty in all other instances. For transport iterations, the same information is provided but preceded by a line indicating that the data to follow is from the transport computations.

After the model is run, GMS or SMS can be used to visualize the results. The depth, velocity, and error files are the minimum output files that will be produced in any simulation. Sediment simulations will include concentration output, bed layer output, and bed displacement output. Other output files will be generated depending on the options requested in the boundary conditions file.

Output filename conventions (*.dat)

*_con#.dat	constituent concentration, # = constituent number (scalar, parts per million for sediment), rouse profile factor+, bedload mass per unit area
*err_con#.dat	non-normalized residual error for the transport constituent (scalar)
*_bed_dpl.dat	sediment bed displacement (scalar, meters)
*_alt.dat	active layer thickness (scalar, meters)
*_ald.dat	active layer distribution (scalar, one column for each grain class)
*_blt#.dat	bed layer thickness, # = layer number (scalar, meters, 1 is the bottom-most layer)
*_bld#.dat	bed layer distribution, # = layer number (scalar, 1 is the bottom-most layer, one column for each grain class)
*_cbp#.dat	cohesive bed property, # = layer number (scalar, 1 is the bottom-most layer, one column for each grain class)
*_bsh.dat	bed shear stress magnitude (scalar, Pa)
*_smr.dat	sediment mass residual (kg/m^2)
*_bedload.dat	bedload (vector, kg/m/s)
*_susload.dat	suspended load (vector, kg/m/s)
*_belev.dat	breach bed elevation (scalar, length)
*_conflx	concentration flux across a string for each constituent is included when the FLX card is used followed by the string number…this is NOT an SMS file
*_tflx	hydrodynamic flux across a string is included when the FLX card is used followed by the string number…this is NOT an SMS file

For a 3-constituent simulation (1 non-sediment constituent and 2 sediment constituents) of 2 grains and 3 bed layers, the sediments are constituent 2 and 3, the output files would be: (information in parenthesis gives names for the hotstart file)

*_dep.dat (ioh)	Depth value
*_ovl.dat (iov)	X_vel, Y_vel, Z_vel (Z_vel = 0 for 2D)
*_err.dat	Residual error
*_err_hydro.dat	Hydro residual error
*_con1.dat (icon 1)	Concentration 1
*_con2.dat (icon 2)	Concentration 2, Rouse factor+, bedload mass per unit area
*_con3.dat (icon 3)	Concentration 3, Rouse factor+, bedload mass per unit area
*_err_con1.dat	Transport residual error for transport 1
*_err_con2.dat	Transport residual error for transport 2
*_err_con3.dat	Transport residual error for transport 3
*_bed_dpl.dat (ibd)	Sediment bed displacement
*_alt.dat (ialt)	Active layer thickness
*_ald.dat (iald)	Ald-grain1, Ald-grain2
*_blt1.dat (iblt 1)	Bed layer thickness
*_blt2.dat (iblt 2)	Bed layer thickness
*_blt3.dat (iblt 3)	Bed layer thickness
*_bld1.dat (ibld 1)	Bld-grain1, Bld-grain2
*_bld2.dat (ibld 2)	Bld-grain1, Bld-grain2
*_bld3.dat (ibld 3)	Bld-grain1, Bld-grain2
*_bsh.dat	Bed shear magnitude
*_smr.dat	Sediment mass residual grain 1, grain 2
*_bedload.dat	Bedload_X, Bedload_Y
*_susload.dat	Suspended load X, Suspended load Y

+Rouse factor is the ratio of the near-bed concentration to the depth averaged concentration.

7 References

Teeter, Allen Michael (2002) "Sediment Transport in Wind-Exposed Shallow, Vegetated Aquatic Systems" A Dissertation. Louisiana State University.

Wu, Jin (1982). "Wind-Stress Coefficients Over Sea Surface From Breeze to Hurricane" *Journal of Geophysical Research,* Vol 87, No. C12, November 1982, pp 9704-9706.