QUESTIONS FOR THE STM TAC 1-13-10

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We have prepared a list of questions for the STM TAC members. We would be very pleased to have insights from the members regarding the following points; we have classified the questions according to three main categories:

A. Questions of physical nature

B. Questions of user point of view

C. Questions of numerical nature

A. Physical - Effective Bed Roughness

Background:

There are two main types of flow resistance which are skin friction and form drag. Skin friction is given by the shear stress that the bed particle experiences as the reaction to the shear stress exerted to the flow by the boundary. Form drag is the flow resistance from the separation of flow due to bed-forms. Flow resistance is represented as:

$K_s = K_s' + K_s''$

where,
Ks is the total roughness height due to flow resistance
Ks' denotes the roughness height which is associated with skin friction forces
Ks" is the equivalent form roughness height which is generated by pressure forces acting on the bed-forms.

It could also be represented by a similar relation regarding Manning's *n* resistance coefficient. A calibrated Manning's *n* value in the Delta accounts for both types of friction, as well as other effects like bathymetry representation, three dimensional effects which are not included in the 1D approach, etc. However, sediment particles only move due to skin friction. Thus the Manning's *n*, as currently used in the Delta, isn't appropriate to employ in the STM model to represent the effects of friction on movement of sediment particles.

Questions:

How should movement of particles due to skin friction be characterized in the STM model?

Do you prefer to have a method based on Manning's *n* or the roughness height?

Options:

Basically, two approaches can be found in the literature to estimate the bed roughness height:

1) Methods based on bed-forms and grain-related parameters such as bed-form length, height, steepness, and bed-material size; these methods are more universal and can also

be used to determine the roughness of a movable bed in non-steady conditions, provided that the bed-form characteristics are known. One such method is van Rijn (1993):

$K'_{s\,min} = 0.01$ m

$K's = 3\ d_{90}$ for $\theta < 1$ (lower regime)

$K's = 3\ \theta\ d_{90}$ for $\theta > 1$ (upper regime)

$\theta = \tau_b / ((\rho_s - \rho) g d_{50})$ = mobility parameter

τ_b= bed shear stress

The lower regime is the condition of the river that contains dunes, and the upper regime is the situation in which anti-dunes appear (García 1999). If this method is adopted, estimations of d_{50} and d_{90} (i.e., the grain sizes for which the 50% and 90% are finer, respectively) in the entire Delta are needed. How much field information on grain size distribution is available in the Delta to support this type of approach?

2) Methods based on integral parameters such as mean depth, mean velocity, and bed material size, namely the methods based on partition of the shear stress, such as that by Einstein (1950), Nelson and Smith etc. As an example, the Smith and McLean method uses the following expression:

$$k_{s,c} = d_{50}[1 + 700(\theta - \theta_{cr})]$$

in which:

$k_{s,c}$ = effective current-related bed roughness

θ = mobility parameter

θ_{cr} = critical mobility parameter

d_{50} = median particle diameter of bed material

The above equation is valid in the lower regime ($\theta < 0.7$) with dunes; it yields $k_{s,c}=d_{50}$ for $\theta \leq \theta_{cr}$. Is there any information on location and size of dunes in the Delta? (We know that there is some data on the USGS website).

A. Physical – Distribution of Sediment in Junctions

Background:

By definition a 1D sediment transport model can not predict the split of sediment transport in a junction; therefore various models for split of sediment load as a function of discharge have been proposed. One of the available methods is as follows (taken from MIKE 11, Danish Hydraulic Institute, see figure below):

$$S_3 = \frac{K_3 Q_3^{n3}}{K_3 Q_3^{n3} + K_4 Q_4^{n4}} (S_1 + S_2)$$

where K_3, K_4, n_3, and n_4 are calibration coefficients; S_i is the sediment load and Q is discharge.

Option:

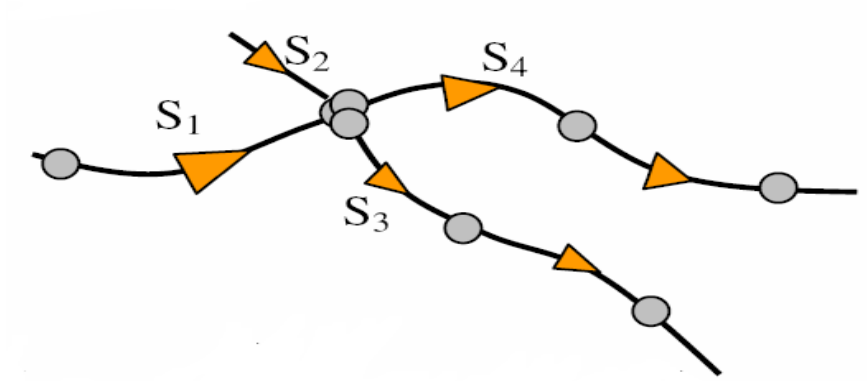
To use the method presented above to represent the split, extrapolating the approach of the model MIKE 11.

Questions:

Do you know of any studies of sediment transport at junctions in the Delta or in other systems?

Do you have any experience on how sediment behaves in the Delta at junctions?

Do you have any major objections to adopting the MIKE 11 method for dealing with sediment flow splits at junctions? Please keep in mind that if this method is to be adopted, the coefficients will have to be calibrated at each junction or one value for them could in principle assumed to be valid for the entire Delta?



Source: Mike11, DHI

A. Physical – Treatment of Bed-load

Background:

There are two methods to implement the computation of bed-load transport. The first method is to use an empirical formula for computing bed-load, and add this to the transport of sediment in suspension (this method separates the treatment of both modes of transport). The second method is to solve an advection-diffusion-reaction equation including *both* the bed-load and the suspended load, following the proposal by Greimann et al. (2008, Journal of Hydraulic Engineering). The proposed formulation is as follows, for a 2D case:

$$\frac{\partial hC}{\partial t}+\frac{\partial \cos(\alpha)\beta V_t hC}{\partial x}+\frac{\partial \sin(\alpha)\beta V_t hC}{\partial y}=\frac{\partial}{\partial x}(hfD_x\frac{\partial C}{\partial x})+\frac{\partial}{\partial y}(hfD_y\frac{\partial C}{\partial y})+S_e$$

where:

S_e = Erosion source term

f = Transport load parameter, fraction of suspended load to total load

h = Flow depth

α = Angle of sediment transport

β = Ratio of sediment velocity to flow velocity

V_t = Total flow velocity

C = Sediment concentration.

Question:

Do you prefer that STM use an empirical representation of the bed-load or incorporate the bed load into the advection-diffusion-reaction equation?

If you prefer the former, do you know of any tested expression for bed-load in the Delta?

Option:

We would be very interested in using the approach by Greimann et al. (2008). The question is whether the regressions employed by Greimann et al. are valid for the Delta.

A. Physical - Deposition and Entrainment of Sediments in the Delta

Background:

Krone (1962) characterized the settling conditions in the San Francisco Bay, providing insight into the time dependence of the phenomenon.

Questions:

In the Delta, is there any tested method for representation of settling velocity (or deposition) for cohesive sediment particles beyond Krone's (1962) work?

In the Delta, is there any tested expression for entrainment of cohesive sediment particles beyond the work by Krone (1962)?

Options:

a) There are many cases in which a constant settling velocity (W_s) for cohesive sediment has been used in the literature in diverse systems; for example 0.5 mms^{-1}.

b) One step further, a power-law relation has been used as a function of concentration, such as $W_{s,m} = W_s\,(1 - a\,c)^b$ or $W_{s,m} = K\,c^m$ where a, b, and m involve calibration parameters. The relations could be calibrated based on existing data to be more representative. Krone has reported data from the Delta which may be useful.

Regarding entrainment formulas, we propose to use $E = \alpha \left[\frac{\tau_b - \tau_{cr}}{\tau_{cr}} \right]^{\beta}$ where α and β denote calibration parameters, τ_b= bed shear stress, and τ_{cr}=critical bed shear stress for incipient motion.

A. Physical - Description of Cohesive Sediment in General

Background:

Many parameters need to be determined in order to fully describe cohesive sediment in the model. It is practically impossible to include more than a few variables in a model.

Question:

To reduce the number of variables, which are the most important variables for the Delta?

Options:

If convenient, for the settling velocity, we could use other variables from the following group of variables. Including more variables will mean that a spatial and temporal description for them is needed.

$W_s = W_s$ *(salinity, concentration, potential additional variables)*

Potential additional variables: Maximum current velocity; maximum wave height; dry sediment density; water column temperature; pH chemical composition; percentage of clay, silt and sand; percentage of organic content; etc.

B. User Needs/Requests

Questions:

- What units for sediment/constituent concentration would you like to see in DSM2-STM? Volume per volume, or mass per volume?

- Is it desirable for STM to have a feature that allows the user to select the numerical scheme to be used to solve the advection part? e.g. higher order vs second order (initial implementation is second order), various versions of second order, etc.

- Initial non-cohesive implementation has four options for entrainment functions which are:

  1) Garcia and Parker (1991); it works well for fine-grained non-cohesive sediments.

  2) van Rijn (1984), whose formula has been used extensively in the numerical treatment of suspended sediment transport.

  3) Smith and McLean (1977); this equation is based on Yalin early works (1963).

  4) Zyserman and Fredsoe (1994) analyzed different entrainment formulations; they proposed an empirical relation using the Fort Collins experimental data.

Are there any other formulations you would like to have in DSM2-STM?

- What kinds of analytical tests and comparisons to data (field and laboratory) would you like to see as part of the STM project validation? We have included and plan to include the following:

  1- Error convergence test on L_∞ (absolute value of largest error in the domain).

  2- Comparison with analytical solutions of advection-diffusion-reaction equations with different boundary conditions, including:

  a) diffusion of a spike of a mass at the center of coordinate system;
  b) diffusion of a symmetric triangle;
  c) diffusion of a harmonic distribution of concentration with a Diritchlet boundary condition on one side, and a Neumann boundary condition on the other;
  d) advection of a Gaussian curve;
  e) advection of a square of concentration.

  3- Comparison with flume data from the literature (not yet done). Test to include: Newton (1951), Soni (1981), Cui (1996).

C. Numerical

- What order, in the splitting procedure, should we solve the advection-diffusion-reaction equations? Our initial thought is to solve advection first, then reaction and finally diffusion. Advection is always the dominant term and it should come first.

- Do you know of any reliable second order methods for updating boundary conditions for advection-diffusion-reaction equations with operator splitting?