# An efficient consolidation model for morphodynamic simulations in low SPM-environments

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# An efficient consolidation model for morphodynamic simulations in low SPM-environments

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## Abstract

This paper presents a fast consolidation model suitable for long-term morphodynamic simulations. This model is applicable for muddy systems where sedimentation rates are smaller than consolidation rates, assuming quasi-equilibrium of the consolidating bed. It compares to the consolidation model developed by Sanford (2008). However, in that model, a heuristic, exponential density profile was used. Instead, the current model is derived from the full consolidation (Gibson) equation. The model's material parameters (hydraulic conductivity, consolidation coefficient and strength) can therefore be derived from soil mechanical experiments in the laboratory.

This consolidation model has been implemented in Deltares' generic bed model (GBM), which contains a mixed Eulerian-Lagrangean discretization of the bed in multiple layers (Van Kessel et al., 2011). The choice for this approach was based on numerical considerations, guaranteeing stable and non-negative solutions, while numeric diffusion remains small. The most upper layer represents the so-called Fluffy Layer, which thickness is undefined. This layer communicates with the water column above. Below the Fluffy Layer, we find the Active Layer (AL) of variable thickness and variable dry density. This Lagrangean Active Layer is sub-divided into six (or more) sub-layers for the new consolidation model proposed. Below the (Lagrangean) Active Layers, a number of Eulerian Bed Layers are defined (maximum thickness and dry density of different sediment fractions are user-defined). However, thickness and sediment composition may vary over time. The sediment composition in the Active and Bed Layers may vary in response to mixing/bioturbation. If a Eulerian layer becomes too thick, it is split, creating a new Eulerian bed layer above that thickening layer. Similarly, bed layers may disappear when depleted through erosion. The model's density distribution is updated at a user-defined time step, which may differ from the time step of the sediment-hydrodynamic simulations. The total mass in the bed model is updated at this latter time step, accounting for erosion and deposition. The bed model is coupled to the Delft3D software of Deltares, but may be run in stand-alone mode as well.

The new consolidation model has been favorably tested against the results of one-dimensional consolidation experiments, and for virtual test cases in a straight tidal flume and a two-dimensional tidal basin. Fig. 1 shows the computed vertical density profile with the profile measured in a settling column. The model's material parameters were obtained from the measured settling curve of that consolidation experiment. The large peak in the measured density profile is attributed to a gas bubble in the bed, affecting the response of the acoustic measuring sensor. These material properties were also used in our other test cases.

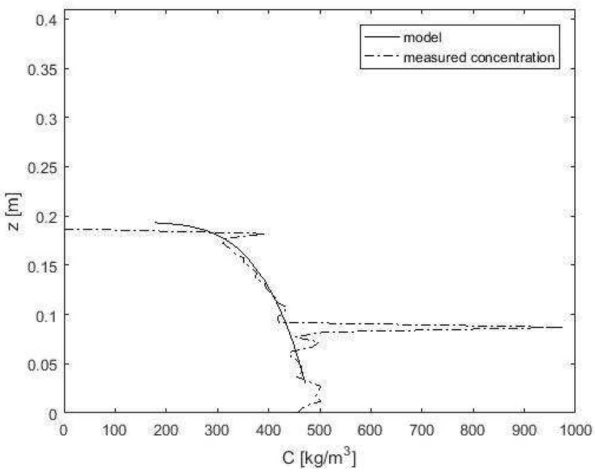


Fig. 1: Comparison computed and measured density profile at equilibrium for mud from Lake Markermeer. The large peak in measured concentration is caused by gas in the sample.

Next, we applied the model in a morphodynamic simulation of a hypothetical tidal inlet. An initial bathymetry was established by running Delft3D in morphodynamic mode for 100 years, with sand alone. Then the model is run another 25 years with mud alone (by prescribing a constant SPM value at the open model boundary), filling in the sandy channels and intertidal areas determined by the sandy morphology. An example of the computational results is given in Fig. 2, presenting the bathymetry for the cases with and without consolidation, showing that in the latter case, tidal channels fill in, whereas sediments do not reach the head of the basin.

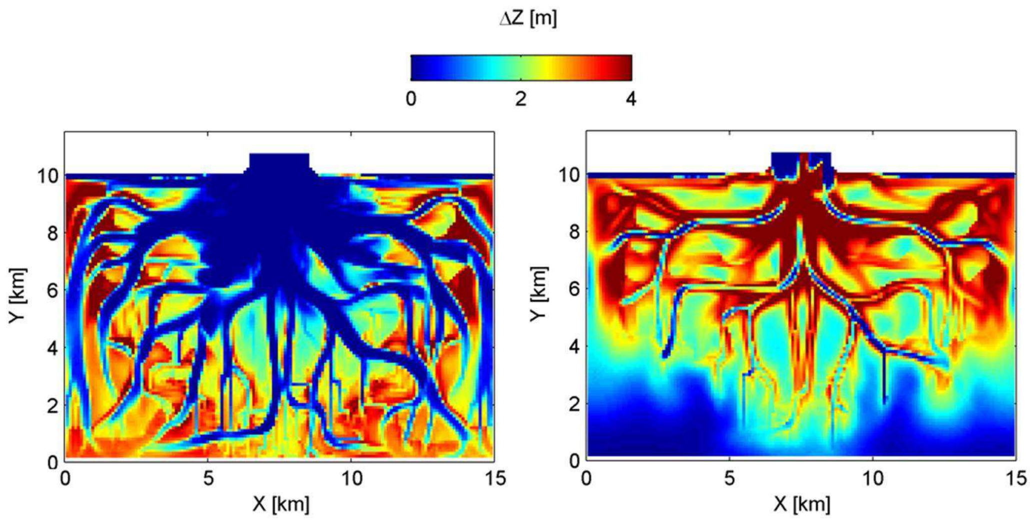


Fig. 2: Computed bed evolution after 25 years by mud w.r.t. to original sand bathymetry with (left panel) and without (right panel) consolidation.

The computational overhead of the new consolidation model is a few 100% (for the tidal inlet simulations above a factor two in case waves are included, and a factor five when waves are not included). However, because of its off-line coupling, the model can easily be vectorized.

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