1 1D Upstream bedload sediment boundary condition (bcm)

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
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Purpose

The purpose of these tests is to assess model behaviour for different options of upstream sediment boundary conditions that are available in Delft3D-FM 1D. Following are the options for boundary conditions, which can be imposed at upstream open boundary:

(i) 'bed level fixed', default or can be specified in morphological input file (no need to have boundary condition file)

(ii) 'depth', which implies specifying constant or varying bed level change in *.bcm file

(iii) 'depth change', which implies constant or time varying rate of bed level change (i.e. bed level acceleration) in $*.bcm$ file, and

(iv) 'transport including pores', which implies sediment transport rate including pores in *.bcm file.

The test cases numbers are e02-f22-c21,c23,c25,c26 and c28.

Linked claims

Claims that are related to the test case are:

- The imposed upstream sediment transport conditions work in a proper way
- The results are consistent and comparable

Approach

Three different grids are designed and combined with similar bathymetry. Each of the grids models a straight channel but the first grid has a width of 20 cells, the second a width of 1 cell and the third is a 1D grid, see Figure **??**. The bathymetries are a flat channel with bed level of $-5m$. These schematisations are combined to verify the claims.

The grids used to build a simple model with downstream water level boundary of $0.17m$ and upstream discharge boundary condition as follows:

- Discharge, of the 2D grid with 20 cells and total width of 1.6 m and length of 16 m, is $Q = 1.6m3/s$. This grid will be called in this document "full 2D model or grid".
- Discharge, of the 2D model with 1 cell and total width of 0.08 m and length of 16 m, is $Q = 0.08m3/s$. This grid will be called in this document "quasi 2D model or grid".
- Discharge, of the 1D model and total width of 0.08 m and length of 15.68 m, is $Q = 0.08m3/s$. This grid will be called in this document "1D model or grid".

The model with three grids is used to test different options of upstream boundary condition of 1D-FM compared to 2D-FM. Four options are considered as mentioned above. Firstly, basic model behaviour is checked by imposing the conditions for 'Depth' and 'Depth change' at the boundary, and also 'transport incl pores' option.The simulations are made by imposing certain values for these options to assess whether the changes at the boundary are consistent. Some tests are made with multiple sediment fractions (two in current tests) under similar condition as for single fraction.

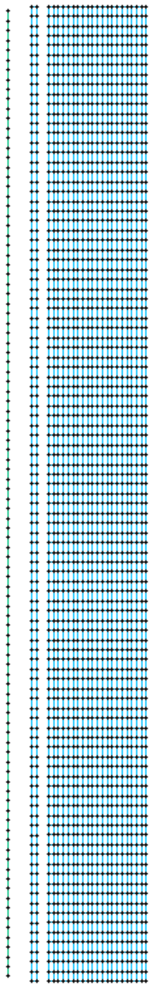

Figure 1: Figure of the different grids. The figure (from left to right) shows the 2D grid with 20 cell in the width,the 2D grid with 1 cell (a quasi-2D grid) in the width and 1D grid.

Conclusion

The results show that the bed load upstream boundary conditions in 1D gives similar results as in the 2D case for the case of depth (iBedcond2), depth change (iBedcond3) and bed-load transport rate (iBedcond4). However, the different change in morphology and bed level between 1D and 2D models leading to some discrepancies and issues. These discrepancies and issues cannot be fully attributed to the morphological boundary condition only. And it ia recommended to be investigated further. The following has to be considered to improve the testing in future:

- Investigate of why during the Spin-up time (MorStt), the model is calculating the sediment transport and where this has influence in the bed update directly after the spin-up time. It seems that the spin-up time is not well recognized by the 1D model.
- Investigate why the observation points do not record data at the ghost or the dummy cell at the boundary.

- Find a method to record the bed composition change at the ghost cell in order to verify that the model is reading the imposed boundaries correctly.

There are some discrepancies for the computational scenarios with inclined channel bed. Although this is expected given the fact that inclined bed causes transverse gradients. Imposing uniform sediment (or bed change) condition along the inclined boundary appears to be leading to some discrepancies and issues. This is evident even for fixed bed condition, so this issue cannot be fully attributed to the morphological boundary condition only.

Model description

A simple model of 16 m long, 1.6 m wide with a flat bed at a constant level of -0.5 is used. A discharge of 2000 l/s is imposed. At the downstream boundary a water level of 0.17 m is imposed. A Chézy coefficient of 60 m$^0.5$/s is used for the channel roughness.

In these test cases, we use a network composed of 3 straight channels in a single schematisation. The schematisation consists of or 3 flat channels . Each channel as a length of 16 m except 1D channel is a bit less. Because the sediment transport results are interpolated in the cell center, while the 1D results are interpolated at the note. Therefore, the first note of the 1D model has to be parallel to the first cell center of of the 2D model.

In this test-cases the sediment grain size $D_{50} = 5.0 \cdot 10^{-4} m$ is used.

The default parameters in the morphological setup are mainly used. Nevertheless, in the following section important related setup of morphology and sediment files used are described as follows:

- Sediment file $< *.sed >$:

```
[Sediment]
Name              = #Sediment_sand#               Name of sediment fraction
SedTyp            = sand                          Must be "sand", "mud" or "bedload"
RhoSol            =  2.6500000e+003     [kg/m3]   Specific density
SedDia            =  5.0000000e-004     [m]       Median sediment diameter (D50)
CDryB             =  1.6000000e+003     [kg/m3]   Dry bed density
IniSedThick       =  5.0000000e-001     [m]       Initial sediment thickness layer-bed
FacDSS            =  1.0000000e+000     [-]       FacDss * SedDia = Initial SS dia
TraFrm            = 1
ACAL              = 1.0
```

Sediment transport equation is the transport relation by **EngelundH67**

- Morphology file $< *.mor >$:

```
IopKCW           = 1      Flag for determining Rc and Rw
RDC              = 0.01   [m] Current related roughness (IopKCW = 2)
RDW              = 0.02   [m] Wave related roughness (IopKCW = 2)
MorFac           = 1      [-] Morphological scale factor
MorStt           = 300    [TUnits] Spin-up interval
BedUpd           = true   Update bathymetry during flow run
```

```
CmpUpd           = true
EqmBc            = false     Equilibrium concentration at inflow boundaries
BcFil            = str2.bcm
[Boundary]
Name      = #up2dmulti#
IBedCond = 2     0 no bed level constraint
                 1 bed level fixed
                 2 depth specified as function of time
                 3 depth change specified as function of time
                 4 bedload transport rate prescribed (volume rate of bed material)
                 5 bedload transport rate prescribed (volume rate of stone)

ICmpCond = 2     0 no bed composition constraint
                 1 composition constant
                 2 mass fractions specified as function of time
                 3 volume fractions specified as function of time.
[Boundary]
Name      = #downstream#
IBedCond = 0
ICmpCond = 0
[Boundary]
Name      = #up2dsingle#
IBedCond = 2
ICmpCond = 2
[Boundary]
Name      = #uponedimen#
IBedCond = 2
ICmpCond = 2
```

The morphological update $MorUpd$ and bed composition update $CmpUpd$ are switched on to check the bed level change. The bedload upstream boundary condition is checked as follows for every test case:

- c21 with iBedcond = 2 and icmpcond = 2, using uniform sediment.
- c23 with iBedcond = 3 and icmpcond = 2, using uniform sediment.
- c25 with iBedcond = 4 and icmpcond = 2, using uniform sediment.
- c26 with iBedcond = 4 and icmpcond = 0, using graded sediment.
- c28 with iBedcond = 2 and icmpcond = 2, using graded sediment.

An example of bcm File used in c21 is shown below. In the bcm file we can specify the conditions of the boundary selected for the bed load.

- Morphology file $< *.mor >$:

```
table-name          'Boundary Section : 1'
contents            'Uniform'
location            'up2dmulti'
time-function       'non-equidistant'
reference-time      20151101
time-unit           'minutes'
interpolation       'linear'
parameter           'time' unit '[min]'
parameter           'depth'  unit  '[m]'
```

```
parameter             'mass fraction Sediment_sand'  unit  '[-]'
records-in-table       3
0.00000000            0.5   1
0.00000000            0.5   1
20                    1.0   1
 Note: Similar set up has beed imposed for the other 3 boundaries.
 Deltails can be found in the bcm file of the test case "c21".
 However, the bcm file parameters and parameters values are changed
 based on the requirement of every test case.
```

Results

The results will discussed for every test case separately as follows:

c21 iBedcond2 and icmpcond2 (Uniform sediment)

In this test case , we enforce the model to change the upstream bed level from -0.5 to -1. The comparison between water level and bed level simulated by 2D-model and 1D-model of FM after 20 minutes is shown in Figure **??** and Figure **??** respectively. These figures shows the change in a typical longitudinal section from both models.

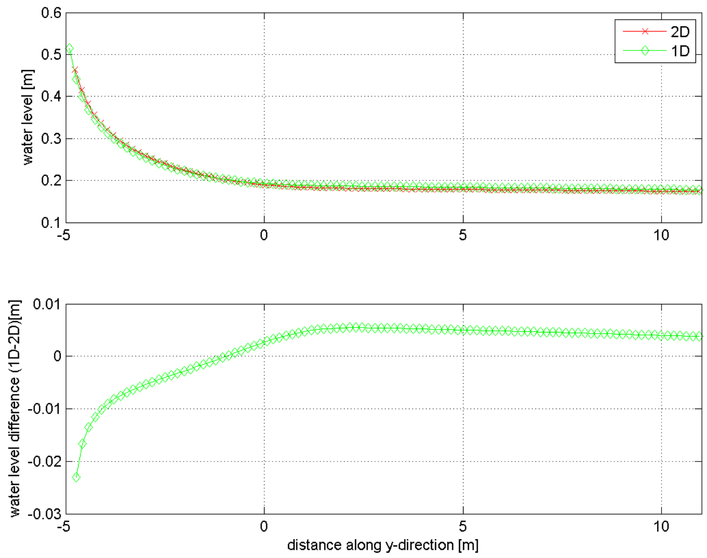

Figure 2: c21:Comparison of water levels (iBedcond2).

In order to see that the model is reading the imposed boundary at the upstream correctly (at the ghost cell), we plotted the bed level change at the zero time and after 10 minutes and after 20 mintutes in Figure **??**. More clear veiw of the longitudinal section and the gohost cell bed level can be seen in Figure **??**.

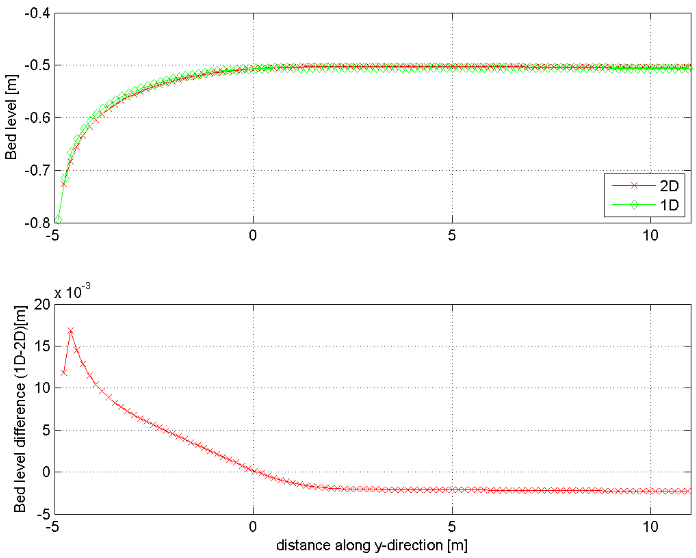

Figure 3: c21:Comparison of bed levels (iBedcond2).

c23 iBedcond3 and icmpcond2 (Uniform sediment)

Similar comparisons for other imposed conditions, namely 'Depth change' (from 0 to -0.5 m in 20 min of simulation time) are depicted in Figure **??** for water level and Figure **??** for the bed level. The result shows a difference between the results of ID and 2D bed level. This also can be seen in the velocity comparison plot in Figure **??**. This might need to be investigated further. The change rate of the depth creates a bed level at the upstream boundary of -300 m, which means the models read imposed bed load boundary correctly at the ghost cell as shown in Figure **??**.

c25 iBedcond4 and icmpcond2 (Uniform sediment)

In c25 test case, we impose bedload sediment fluxes at the upstream boundary 'transport incl pores' of (0.0002 m^2/s). The model results are depicted in Figure **??** for water level, and Figure **??** for the velocity and Figure **??** for the bed level. The result shows a small difference between the results of ID and 2D bed level. In order to investigate the change of bed level and sediment transport at the boundary Figure **??** and **??** are plotted. In Figure **??**, the bed level at the ghost cell goes down from -0.5 to 0.56 in the first 10 minutes and then from -0.56 to 0.57 in the last 10 minutes. Figure **??** indicates that there is sediment transport fluxes during the spin-up time of 300 second (Morstt). This has to be investigated whether the sediment transport has to be on during the spin-up time or not . However, after the spin-up time sediment transport recorded in the cross-sections show that the model read correct amount of bed load fluxes imposed by the bcm file to the models.

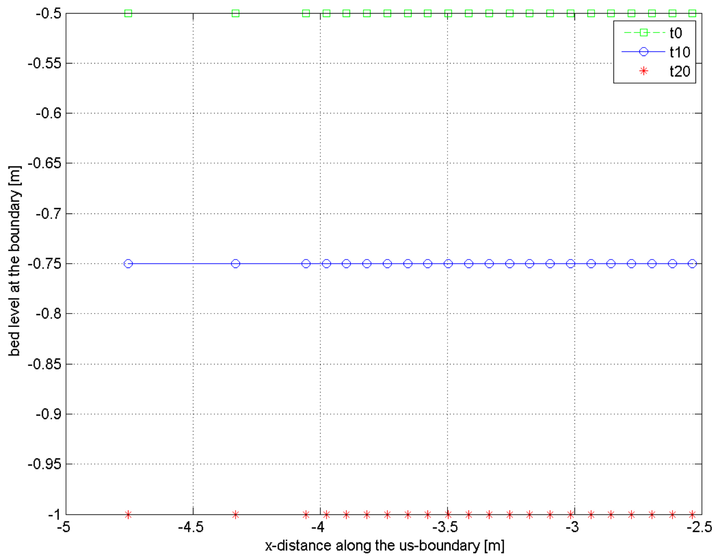

Figure 4: c21:The bed level change at the upstream ghost cell(iBedcond2).

c26 iBedcond4 and icmpcond0 (graded sediment)

For computations with multiple fractions,two similar fractions are used for the sake of simplicity. The boundary condition 'transport incl pores' is tested to ensure correctness based on output results, namely imposing same amount (0.0002 m^2/s) for both fractions,but the initial layer of the model contains only one fraction to see if the second fraction gets into the model composition. Under layer approach ('IUnderLyr=2' and 'ThTrLyr = 0.5') has been used in this test case in the mor file. However, it is not yet clear how that could be seen from the model results. Results of this test are shown in Figure**??** for water level comparison,Figure**??** for bed level and Figure**??** for velocity magnitude comparison. the results shows that there a different of 1.5 cm in the water level at the upstream boundary. This difference start to decrease after 2.5 m far from the boundary. a difference is also can be seen in the velocity plot and the bed level.

By looking to the bed level at the upstream ghost cell in Figure **??** , it can be seen that the bed is going up which is logical as we are imposing sediment. However, Figure **??** shows that there is bed load sediment transport recorded during the spin-up time (the first 5 minutes) after that the amount of sediment transport recorded is similar to the sediment input fluxes.

c28 iBedcond2 and icmpcond2 (graded sediment)

For computations with multiple fractions, We change c21 to test the graded sediment.Two similar fractions are used for the sake of simplicity. The boundary condition 'depth' and 'mass fractions specified as function of time' are tested to ensure correctness based on output results. The parameters setup used in the bcm file is shown below.Under layer approach ('IUnderLyr=2' and 'ThTrLyr = 0.5') has been also used in this test case in the mor file.

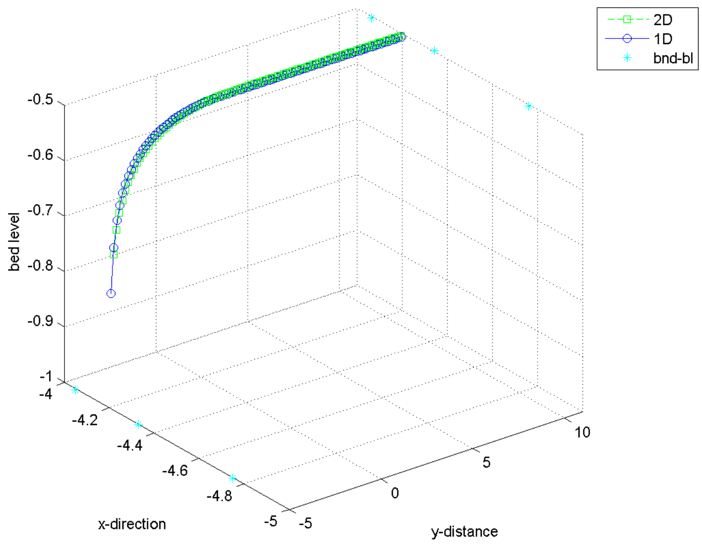

Figure 5: c21:3D-view of the longitudinal section and the bed level at the ghost cell (iBedcond2).

- bed load boundary file $< *.bcm >$ for c28:

```
parameter            'time' unit '[min]'
parameter            'depth'  unit  '[m]'
parameter            'mass fraction Sediment_sand'  unit  '[-]'
parameter            'mass fraction Sediment_tracer'  unit  '[-]'
records-in-table      2
0.00000000           0.5   1   0
20.0000000           1.0   0   1
```

The results show that the water level and bed-level comparisons have some differences as shown in Figure **??** and Figure **??**. The model read the depth imposed at the upstream boundary correctly as shown in Figure **??**. However, the change in bed composition at the boundary (ghost or dummy cell) can not be seen. No change is recorded inside the model. This might be because the computation time is not enough to propagate the bed composition change.

There are some discrepancies for the computational scenarios with inclined channel bed. Although this is expected given the fact that inclined bed causes transverse gradients. Imposing uniform sediment (or bed change) condition along the inclined boundary appears to be leading to some discrepancies and issues. This is evident even for fixed bed condition (as depicted in Figure **??**), so this issue cannot be fully attributed to the morphological boundary condition only.

Analysis of results

The results shows that the ID model is able to read the boundary condition correctly. However,

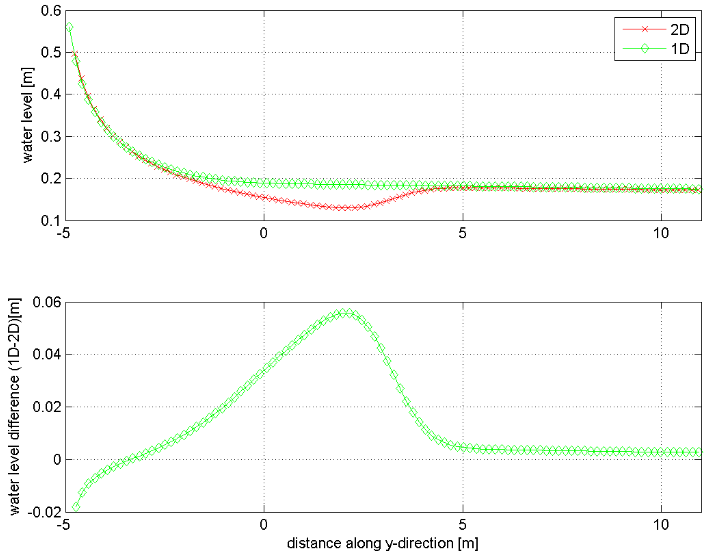

Figure 6: c23:Comparison of water levels (iBedcond3).

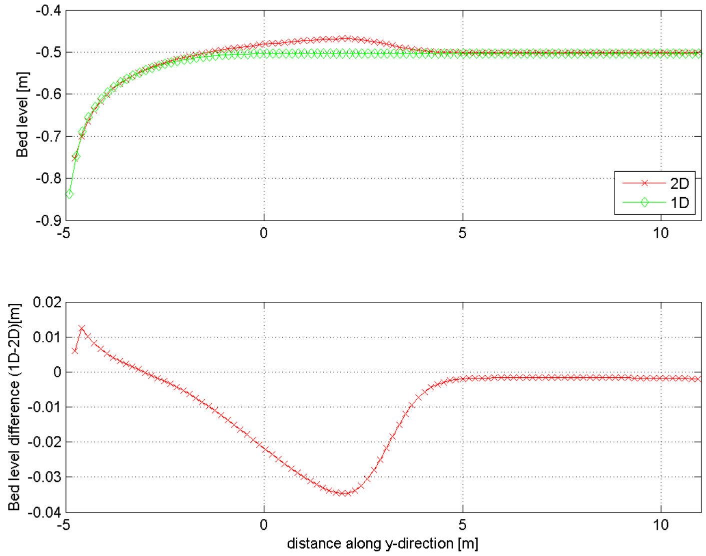

Figure 7: c23:Comparison of bed levels (iBedcond3).

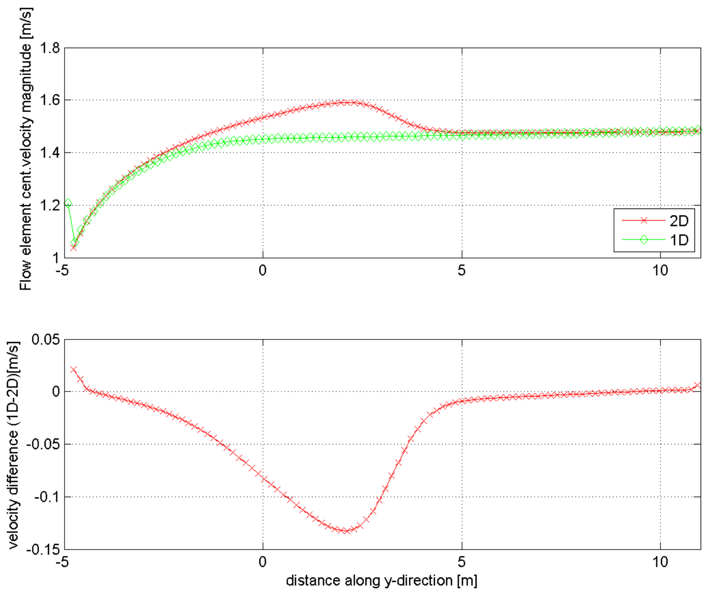

Figure 8: c23:Averaged velocity magnitude a long the 1D and 2D models (iBedcond3).

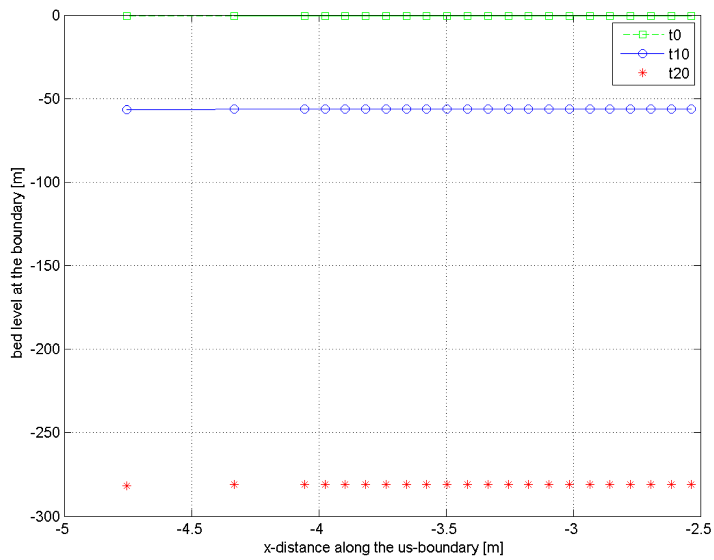

Figure 9: c23:The bed level change at the upstream ghost cell (iBedcond3).

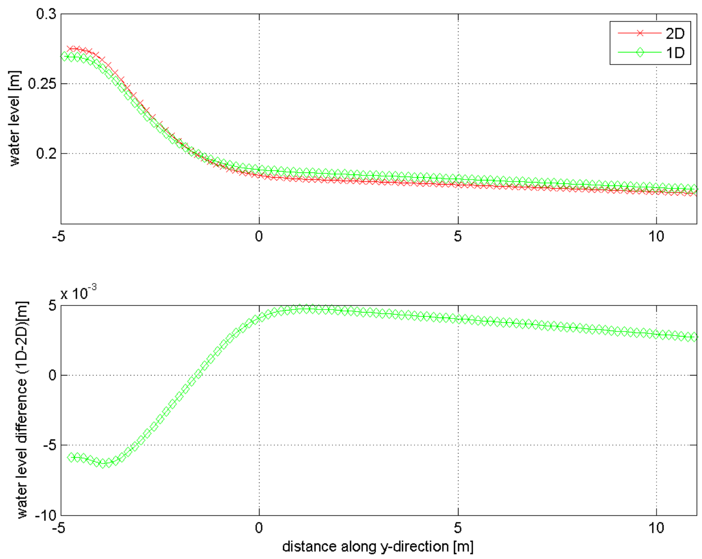

Figure 10: c25:Comparison of water levels (iBedcond4).

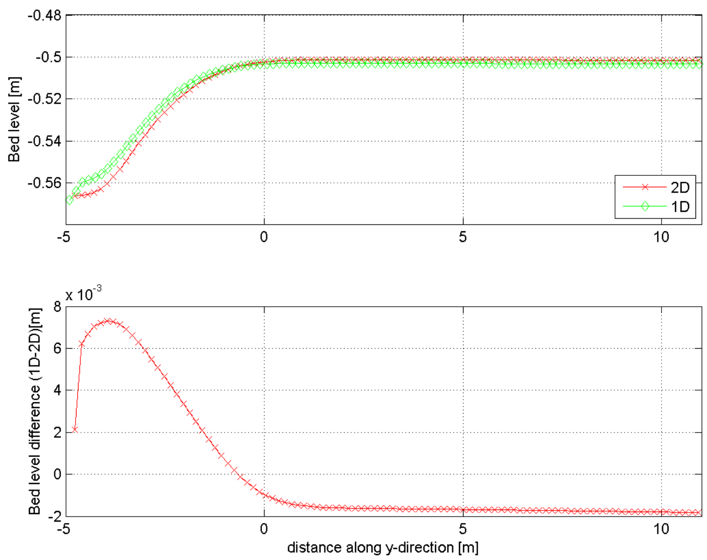

Figure 11: c25:Comparison of bed levels (iBedcond4).

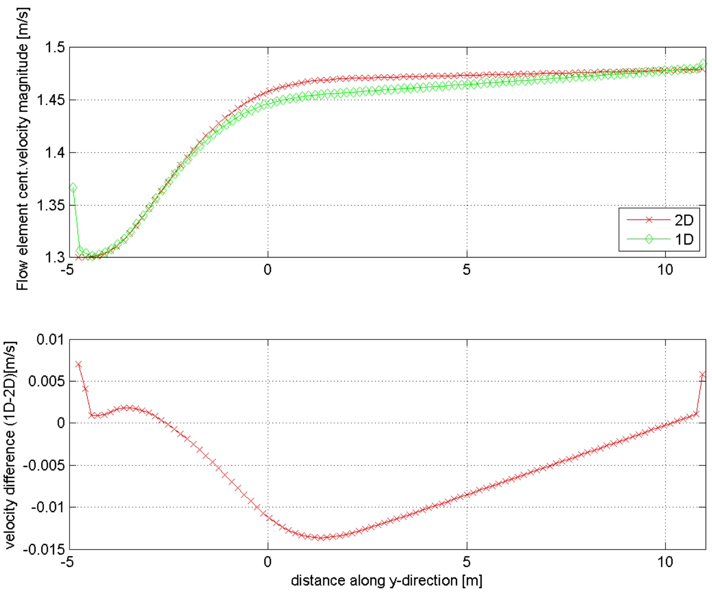

Figure 12: c25:Averaged velocity magnitude a long the 1D and 2D models (iBedcond4).

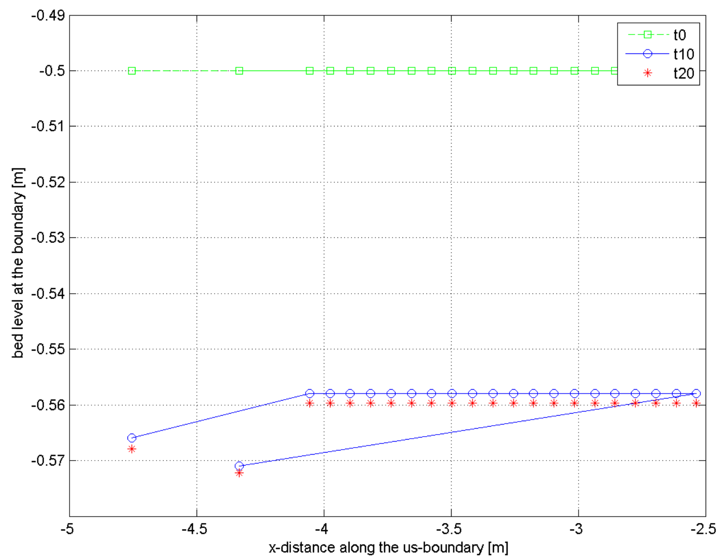

Figure 13: c25:The bed level change at the upstream ghost cell (iBedcond4).

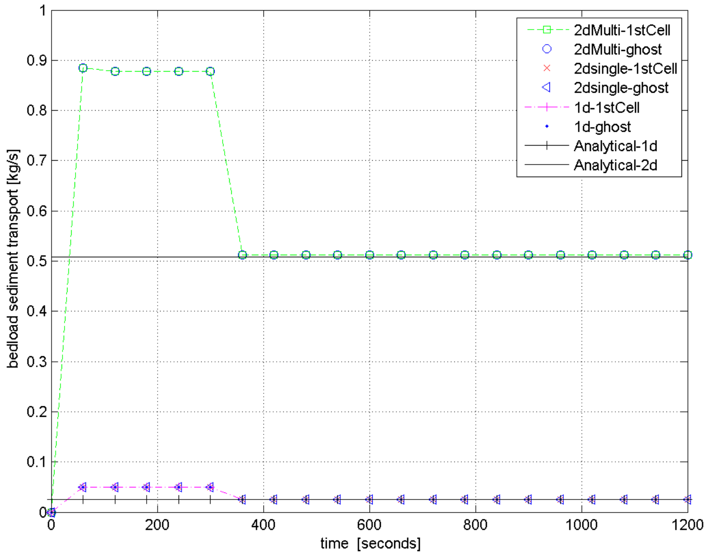

Figure 14: c25:bed load sediment transport flues recorded at the ghost cell and the 1st cell of every model(iBedcond4).

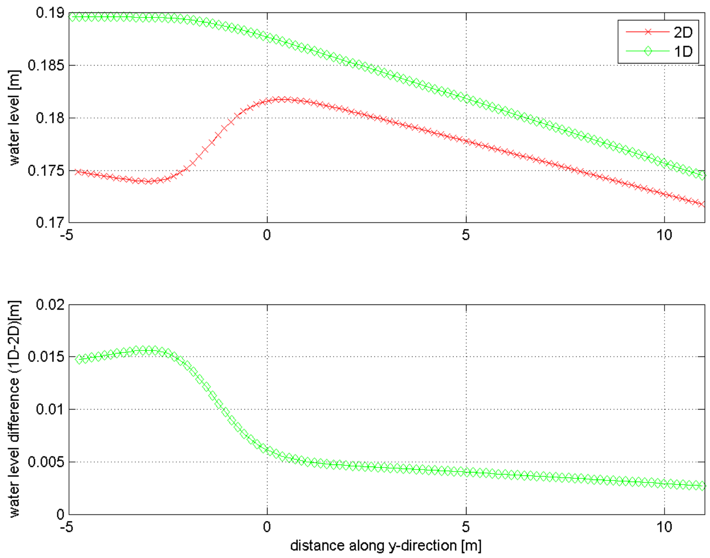

Figure 15: c26:Comparison of water levels (iBedcond4).

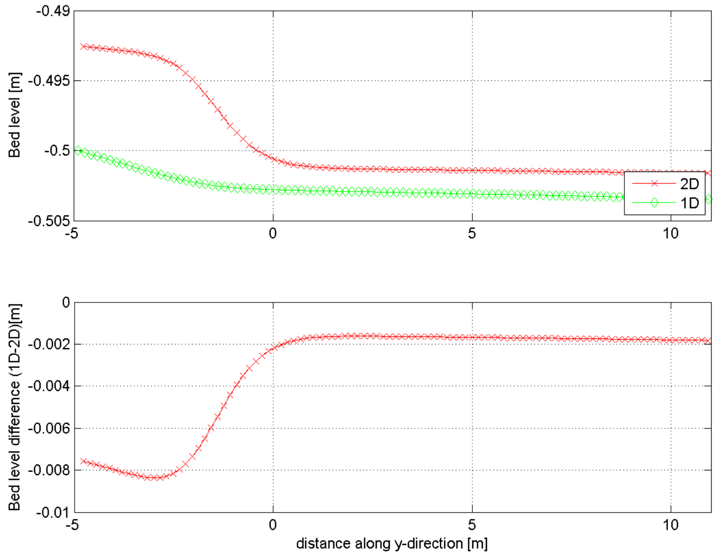

Figure 16: c26:Comparison of bed levels (iBedcond4).

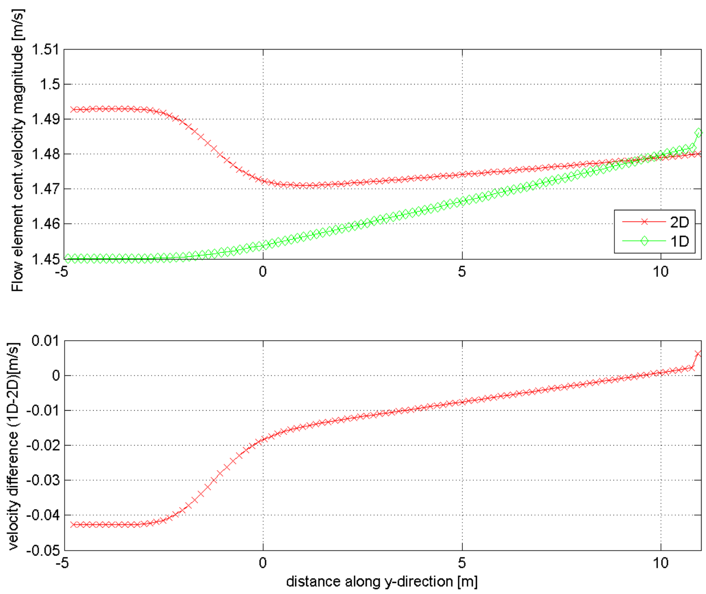

Figure 17: c26:Averaged velocity magnitude a long the 1D and 2D models (iBedcond4).

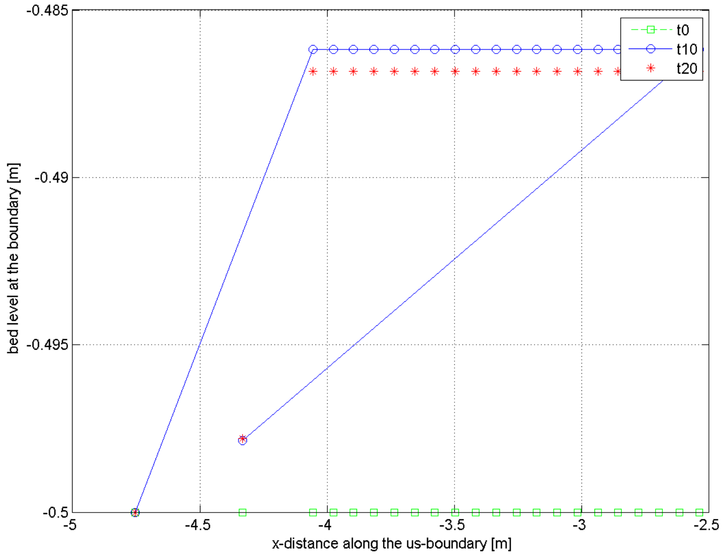

Figure 18: c26:The bed level change at the upstream ghost cell (iBedcond4).

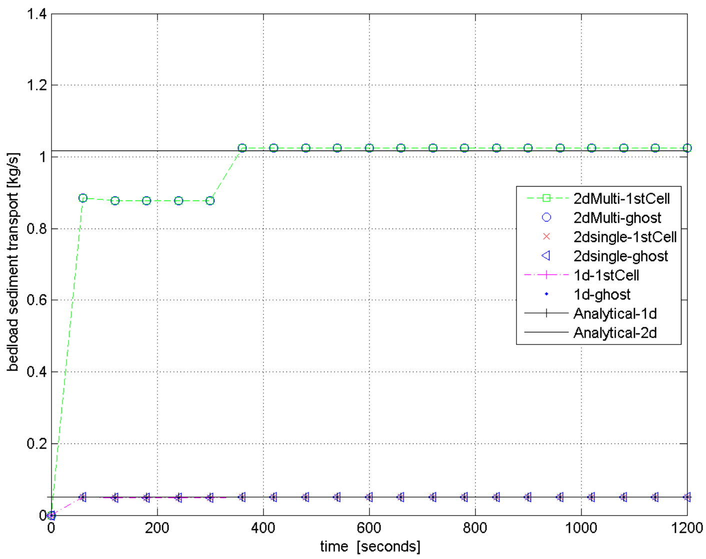

Figure 19: c26:bed load sediment transport flues recorded at the ghost cell and the 1st cell of every model(iBedcond4).

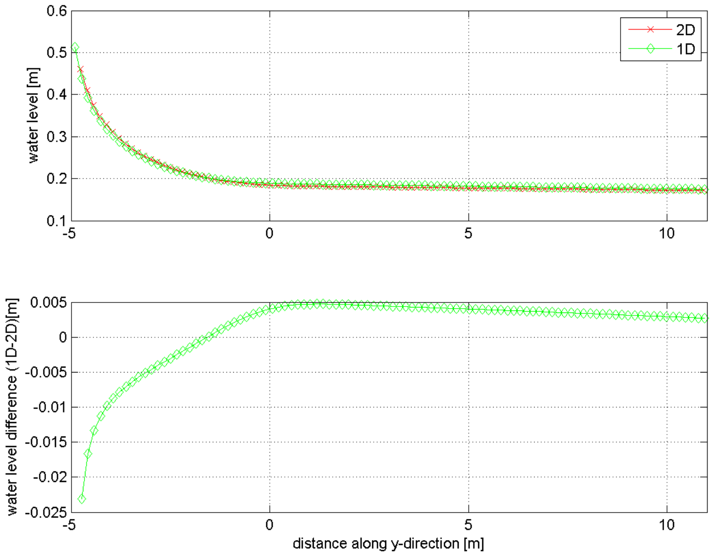

Figure 20: c28:Comparison of water levels (iBedcond2).

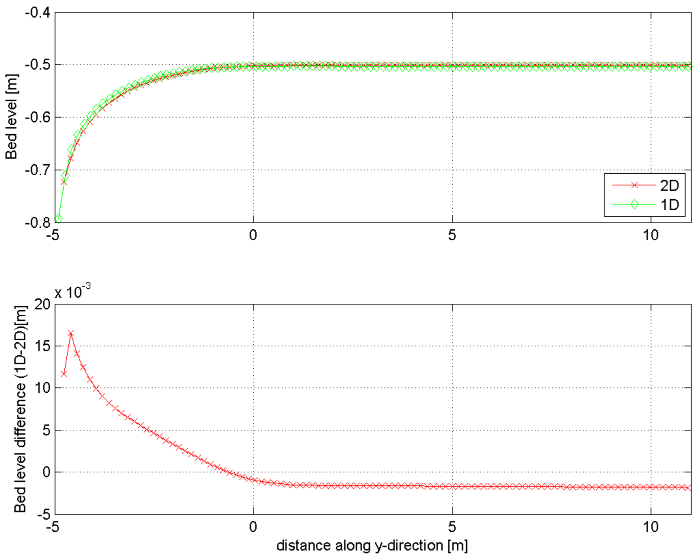

Figure 21: c28:Comparison of bed levels (iBedcond2).

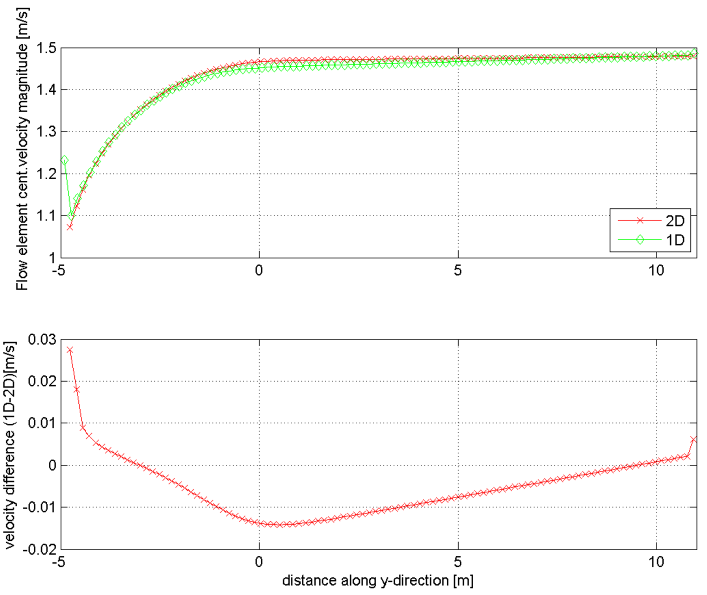

Figure 22: c28:Averaged velocity magnitude a long the 1D and 2D models (iBedcond4).

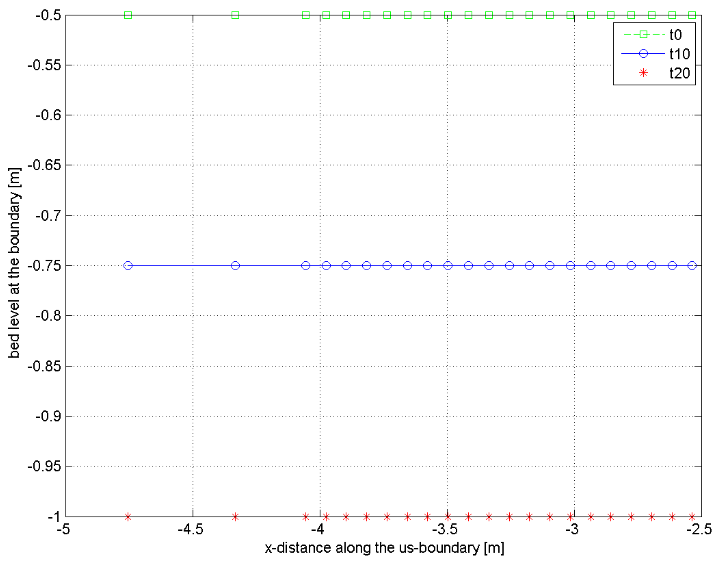

Figure 23: c26:The bed level change at the upstream ghost cell (iBedcond2).