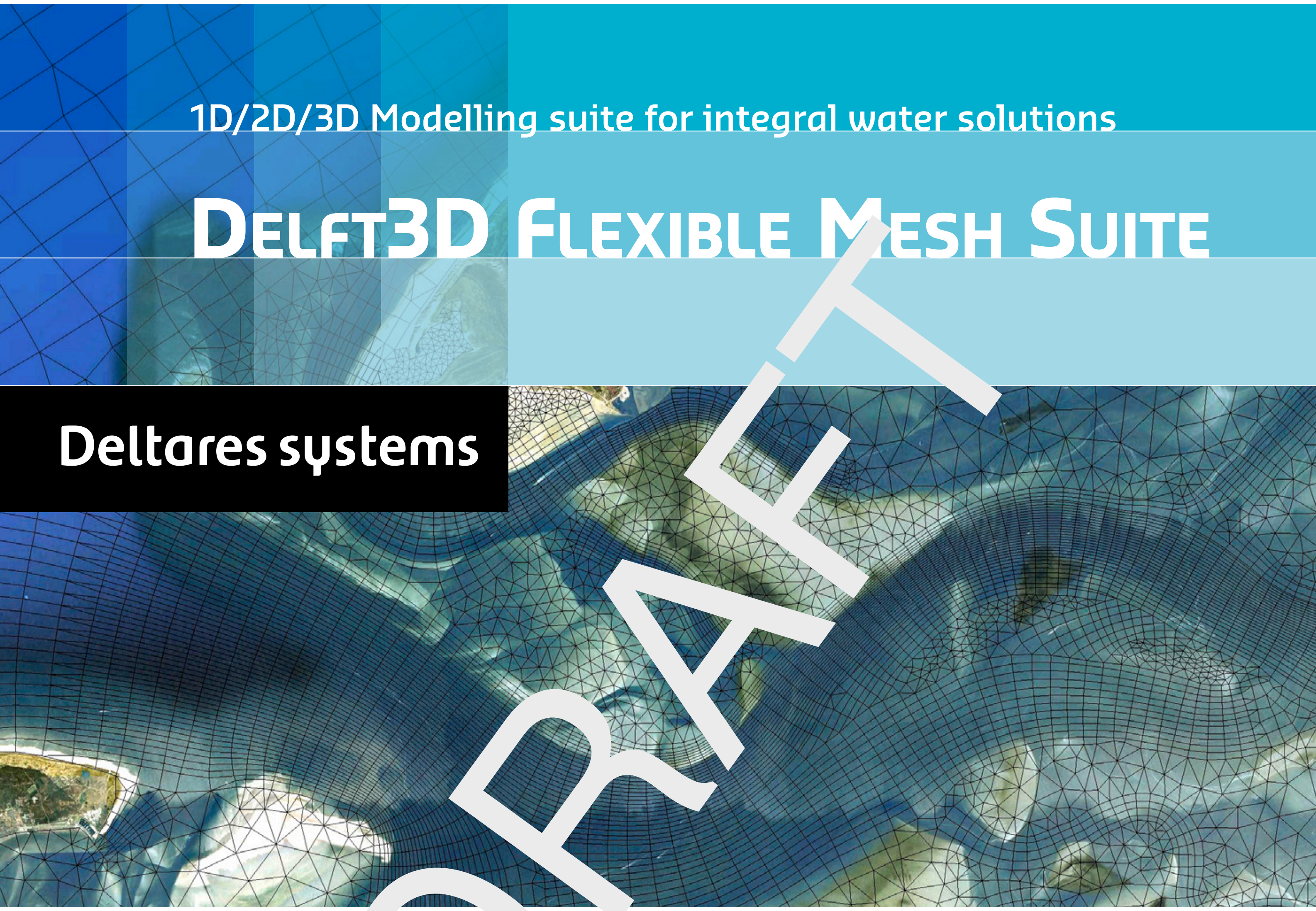
1D/2D/3D Modelling suite for integral water solutions

Delft3D Flexible Mesh Suite



Deltares systems

D-Flow Flexible Mesh

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Enabling Delta Life

Validation Document

D-Flow Flexible Mesh

Validation Document

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1.1 Bélanger surface profile with zero bed slope

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
08 Dec 2017	Andries Paarlberg		Arthur van Dam		Aukje Spruyt	

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Purpose

The purpose of this validation case is to examine the performance of D-Flow FM for a schematized channel flow simulation. For stationary flow through a river with a rectangular cross-section, the Bélanger surface profile equation can be utilized to compare the numerical solution with.
In the D-Flow FM test bench, a case is available where a numerical approximation of the surface profile based on the Bélanger equation is implemented. For use in further test cases we test a Matlab-version of this implementation for bed slope $i_b \geq 0$ The case for flat bed slope ($i_b = 0$) is of specific interest, since for a number of test cases, it is convenient to use a flat bed (without a bed slope).

Linked claims

Claims that are related to the current test case are:

- ◇ Water levels in 1D-model are identical to Quasi2D-model for flat bed.
- ◇ Water levels are identical to semi-analytical solution.
- ◇ Matlab implementation of Bélanger approximation is equal to that in D-Flow FM.

Approach

Base case: `/DSCTestbench/cases/e02_dflowfm/f03_advection/c010_belanger/`
This case is set-up for arbitrary bed slopes ($i_b \geq 0$). Here we investigate how the Matlab code performs w.r.t. the D-Flow FM code for the case with a horizontal flat bed ($i_b = 0$) and a bed slope of $i_b = 4\text{x}10^{-4}$ m/m.

A straight channel with a rectangular cross-section is defined. Given an inflow discharge Q, a channel width B, a bottom slope i_b and a Chézy friction factor C, the distance between the free surface profile and the bed profile can be described by the Bélanger equation for d as the water depth:

$$\frac{\mathrm{d}d}{\mathrm{d}x} = i_b \frac{d^3 - d_e^3}{d^3 - d_g^3} \tag{1.1}$$

with d_e the equilibrium depth and d_g the limit depth (associated with $\mathrm{Fr} = 1$) following:

$$d_e = \left(\frac{Q^2}{B^2 g}\right)^{1/3} \qquad \text{and} \qquad d_g = \left(\frac{Q^2}{B^2 C^2 i_b}\right)^{1/3}. \tag{1.2}$$

Given a certain inflow discharge Q_{in} and a certain outflow water level condition h_{out}, the surface profile can hence numerically be estimated in the most simple way as:

$$\frac{d_i - d_{i-1}}{\Delta x} = i_b \frac{d_i^3 - d_e^3}{d_i^3 - d_g^3}, \tag{1.3}$$

having $d_i = h_{out} + i_b L$ at the outflow boundary. This, in fact *semi-analytical*, solution can be used for comparison.

For zero bed slope we use a slightly different formula for the estimation of the surface profile, which is independent of the equilibrium depth:

$$\frac{d_i - d_{i-1}}{\Delta x} = -\frac{c_f d_g^3}{d_i^3 - d_g^3}, \tag{1.4}$$

where:

$$c_f = \frac{g}{C^2} \tag{1.5}$$

Model description

Relevant files for the case with zero bed slope are:

- ◇ MDU-file: belangerflat1d2d_rst.mdu
- ◇ Grid-file: 5001d2dflat_net.nc
- ◇ External forcings file: flat.ext

For the case of non-zero bed slope, the bed levels are set *inside* D-Flow FM (only implemented for 2D) by using a 2D-grid file with NaN-values and specifying the bed slope directly in the

- ◇ MDU-file: belanger_AP_rst.mdu
- ◇ Grid-file: 5002dmis_net.nc

The 1D and 2D channels have equal length, see figure below.

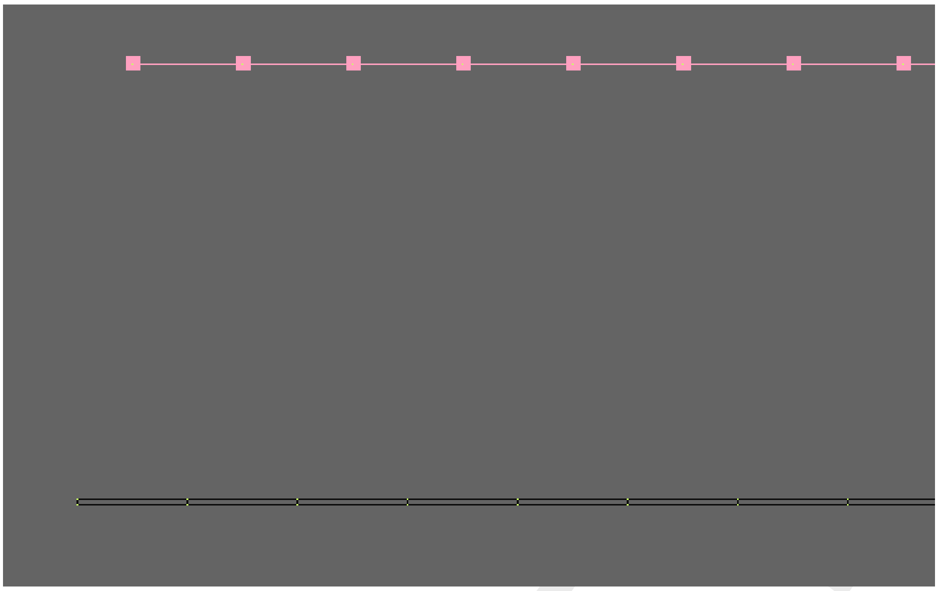

Figure 1.1: *Figure of the layout of the model*

The 2D computational domain has the sizes $L \times B = 100$ km $\times$ 20 m. The grid consists of 200×1 cells. The cell size is 500×20 m^2 everywhere. The bed slope i_b is 0. The inflow discharge is $Q = 600$ m^3/s. The Chézy coefficient is $C = 60$ m$^{1/2}$/s. The outflow water *level* is set equal to -0.12600 m (w.r.t. reference); the water *depth* at the downstream boundary is approximately 10 meters (differs per bed slope). Recall that the water depth is computed as the difference between the upstream water level (computed at the *cell center*) and the bed level at the velocity point (computed at the *cell face*), invoking a $\Delta x/2$ spatial shift. In the computational model, the bed level at the outflow boundary is equal to -10 m+NAP. Therefore, the specified water level holds at a distance $\Delta x/2$ outside the grid (mirrored location).

The case is run for 1 day, starting from a restart-file, to ensure a numerically converged solution.

Results

In D-Flow FM, the semi-analytical solution is implemented. When running the model in the interactive GUI, the deviations from the semi-analytical solution are shown on the screen, which are, for the case of a zero bed slope, approximately:

- 2D @upstream: 0.0157 m = 1.57 cm
- 1D @upstream: 0.0220 m = 2.22 cm
- 2D @ 80 km: 0.0224 m = 2.24 cm
- 1D @ 80 km: 0.0296 m = 2.96 cm

For the case of non-zero bed slope, the difference are sligthly larger, with a maximum of approximately 5 cm at the upstream boundary. In all cases, D-Flow FM is slightly lower than the analytical solution.

The result from D-Flow FM for the water *depth* is shown in the figures below in combination with its semi-analytical equivalent (here found with a Matlab code). The semi-analytical solution is based on the equation for the Bélanger surface profile.
Note!: to correctly reproduce the semi-analytical solution, Δx should be chosen small enough (here 1 m).

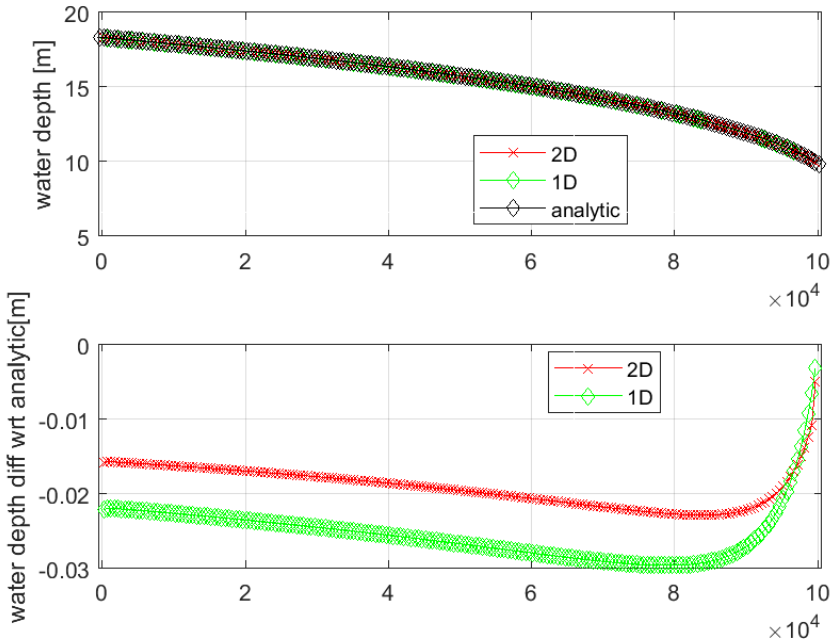

Figure 1.2: *Comparison of the numerical solution and the semi-analytical solution for the water depth for zero bed slope ($i_b = 0$).*

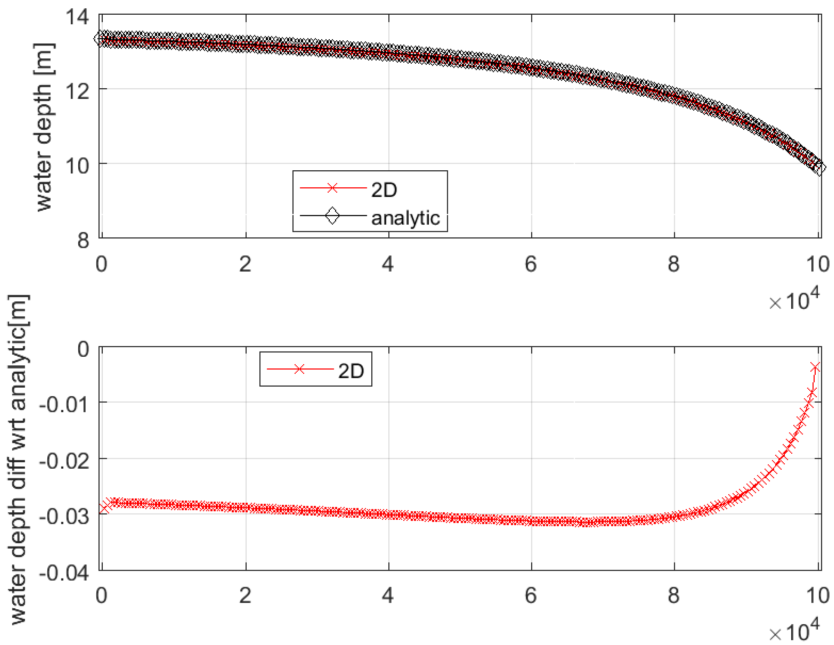

Figure 1.3: *Comparison of the numerical solution and the semi-analytical solution for the water depth for $i_b = 4\text{x}10^{-4}$ m/m.*

The difference in water depth compared to the analytical solution are equal to the difference computed in D-Flow FM. From validation document: root-mean-square difference between the numerical outcome from D-Flow FM and the semi-analytical solution is in the order of 10^{-3} m (for a channel of 100 km).

Conclusion

Water levels in the 1D-model are identical to those in the Quasi2D-model for the case of zero bed slope. For non-zero bed slope ($i_b = 4\text{x}10^{-4}$) the surface profiles found with D-Flow FM and Matlab are nearly identical.
This gives confidence to use the Matlab-code for $i_b \geq 0$ for further test cases.

1.2 Straight channel with zero bed slope (hydraulics)

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
08 Dec 2017	Andries Paarlberg		Arthur van Dam		Aukje Spruyt	

Version information

Date of study : 08 Dec 2017
Executable : Deltares, D-Flow FM Version 1.1.261.53235M, Nov 15 2017, 09:54:18
Location : https://repos.deltares.nl/repos/DSCTestbench/trunk/cases/e02_dflowfm/f28_mor1d_bakprof_hydraulics/c10_straight_channel_1Dvs2D_zero_bedslope
SVN revision : -

Purpose

The purpose of this test case is to test hydraulics for simple rectangular channel (so not-tabulated) with a zero bed slope. This is needed for correct interpretation of 1D-simulations including sediment transport and morphology. Computed water levels in 1D are compared with 2D (which is already validated) and a semi-analytical solution for the surface profile. By comparing flow velocities between 1D and 2D, we gain insight whether roughness and bed shear stress are modeled correctly in 1D.

Linked claims

- ◇ Water levels in 1D-model are identical to 2D-model for zero bed slope.
- ◇ Water levels are identical to semi-analytical solution of the surface profile.
- ◇ Flow velocity (and thus bed shear stress) in 1D-model are identical to Quasi2D-model for zero bed slope.

Approach

We start from an existing 2D test case which included sediment transport (switched off morphological changes). In D-Flow FM various options are available to specify the bed level, using so-called bedleveltypes. For morphology we use option 1, but for testing purposes also other zk-types are included. We test for three bedlevtypes: 1 (faces), 3 (zk) and 6 (faces via zk). For the 2D-grids we use the centerline values to compare with the 1D-results.

Model description

The figure below shows the computational domain, containing both the 1D and the 2D grid. The 2D channel (3 cells wide, cell edges 0.1 m long, aspect ratio = 1) and 1D channel (0.3 m wide) are of equal length (30 m). Pressure points are at identical locations for the centerlines of the models. The bed level is set 0 for the entire domain.

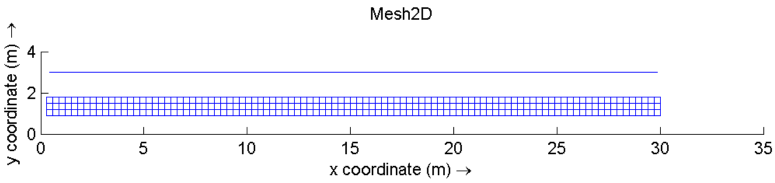

Figure 1.4: *Figure of the layout of the model.*

The model is forced with a constant discharge at the upstream boundary, and a constant water level at the downstream boundary. The discharge is 0.08 m^3/s for the 1D channel and 0.24 m^3/s for the 2D channel (since it has a width of 3 cells). The water level at the downstream boundary (and because of the zero bed level also the water depth) is 0.35 m.

For the semi-analytical solution of the water surface profile with zero bed slope (and validation of it), see 'c99_belangerflat1d2d' (Bélanger-equation).

Results

Below are the results for water depth (Bedlevtypes: 1 (faces), 3 (zk) and 6 (faces via zk)) and flow velocity (only bedlevtypes: 1 (faces)).

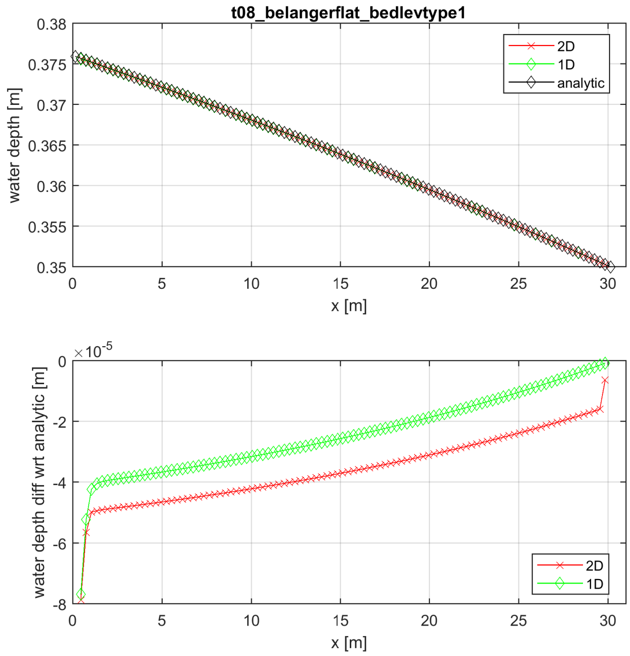

Figure 1.5: Water depth (top) and difference with semi-analytical solution (bottom) for bedlevtype=1.

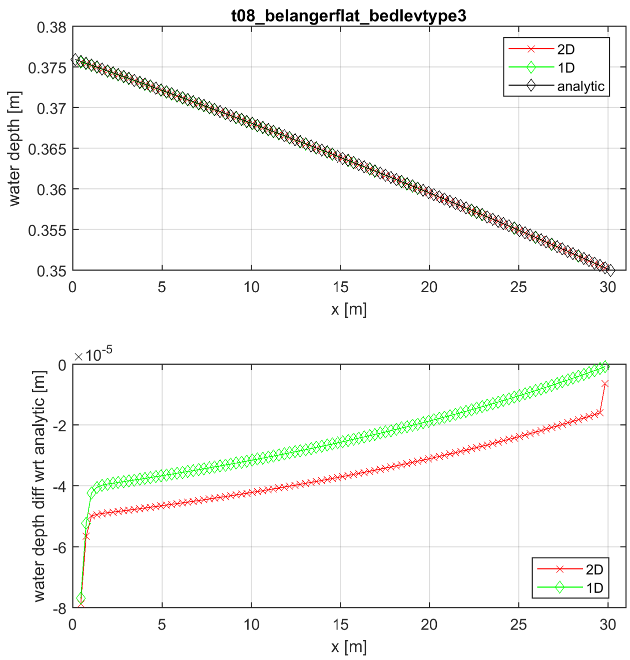

Figure 1.6: Water depth (top) and difference with semi-analytical solution (bottom) for bedlevtype=3.

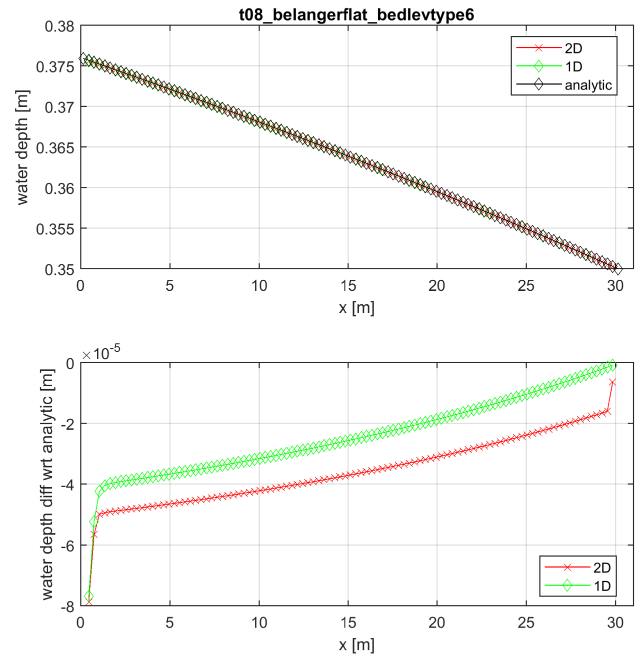

Figure 1.7: *Water depth (top) and difference with semi-analytical solution (bottom) for bedlevtype=6.*

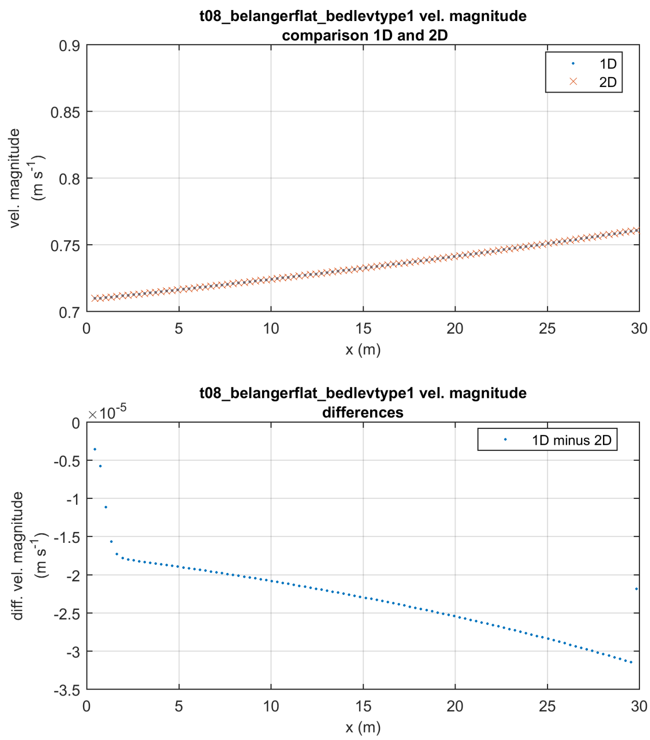

Figure 1.8: *Flow velocity comparison in 1D and 2D for bedlevtype=1.*

Analysis of results

◇ Water level: 1D is closer to analytical solution than 2D.

- ◇ Differences with analytical solution are small.
- ◇ Identical results for the considered bedlevtypes.
- ◇ Very small differences in flow velocity between 1D and 2D.

Conclusion

Differences in water level and flow velocities are small enough to use for test cases including morphology.
The water surface profile near the upstream boundary is different between 1D and 2D; this might need some attention in the future.

1.3 Straight channel with sloping bed (hydraulics)

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
08 Dec 2017	Andries Paarlberg		Stef Boersen		Aukje Spruyt	

Version information

Date of study : 08 Dec 2017
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SVN revision : -

Purpose

The purpose of this test case is to test hydraulics for simple rectangular channel (so non-tabulated) with a non-zero bed slope ($i_b > 0$). This is needed for correct interpretation of 1D-simulations including sediment transport and morphology. Computed water levels in 1D are compared with 2D (which is already validated) and a semi-analytical solution for the surface profile. By comparing flow velocities between 1D and 2D, we gain insight whether roughness and bed shear stress are modelled correctly in 1D. For 2D, we also test the effect of aspect ratio.

Linked claims

- ◇ Water levels in 1D-model are identical to 2D and Quasi2D-model for non-zero bed slope.
- ◇ Water levels are identical to semi-analytical solution of the surface profile.
- ◇ Flow velocity (and thus bed shear stress) in 1D-model are identical to 2D and Quasi2D-model for non-zero bed slope.
- ◇ Claims above are independent of aspect ratio (in 2D).

Approach

We start from an existing 2D test case which included sediment transport (switched off morphological changes). In D-Flow FM various options are available to specify the bed level, using so-called bedleveltypes. For morphology we use option 1, but for testing purposes also other zk-types are included. In this test case we consider two bedlevtypes: 1 (faces) and 3 (zk). For zero bed slope (REF), we showed that bedlevtype 6 gives identical results to 3. For the 2D-grids we use the centerline values to compare with the 1D-results and the semi-analytical solution. For certain cases there appear to be deviations from the analytical solution; this might be to using an aspect ratio $>> 1$, therefore we also test for aspect ratio $= 1$.

Model description

The figure below shows the computational domain, containing the considered grids. All channels have a constant bed slope of $4\text{x}10^{-4}\text{m/m}$ (dz 0.01188 on L = 29.7 m = $4\text{x}10^{-4}\text{m/m}$). Pressure points are at identical locations for the centerlines of the models. The effective length of the channels is 30 m (xleft=0.3m, xright=30m, considering the Δx/2 boundary location gives an effective length of 30 m).

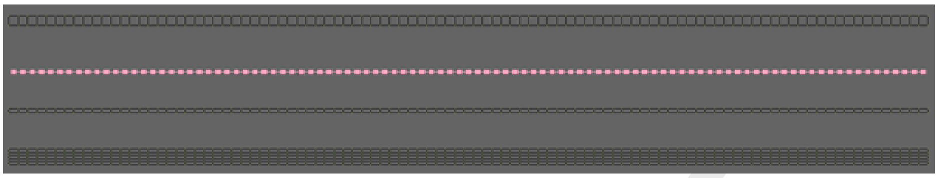

Figure 1.9: *Figure of the layout of the model.*

Explanation of different channels (counting from bottom to top):

1 2D grid, 3 cells wide, 0.3 m long x 0.1 m wide, so aspect ratio = 3 (“2D”)
2 2D grid, 1 cell wide, 0.3 m long x 0.1 m wide, so aspect ratio = 3 (“Quasi2D_ar3”)
3 1D channel, 0.1 m wide (so width equal to grid 2), 30 m long (“1D”)
4 2D grid, 1 cell wide, cells 0.3 m long x 0.3 m wide, so aspect ratio = 1 (“Quasi2D_ar1”)

To create sample xyz-files for the bed levels including the required bed slope, we used Matlab/createbedslope.m. For bedlevtype=3, the samples have to be interpolated to the zk-nodes in the network-file. For bedlevtype=1 (tiles), the xyz-file has to be added to the MDU-input file, as well, where it is important to have samples are each grid point. Another important aspect is that for bedlevtype=1 (so bed levels specified in pressure points), the velocities are still calculated at the (upwind) u-points (h_u). To be able to compare results for both bedlevtypes, the input bed level has to be shifted half a grid cell, because for the bed level in the u-point the maximum depth of the surrounding tiles is used. This is taken into account in the aforementioned Matlab-script (for straight 2D channels with constant bed slope).

In D-Flow FM the boundary conditions can be specified in different ways. For river models, it is a common choice to use a discharge upstream and a water level downstream. This is our first test. We use a constant bed roughness Chezy coefficient $C = 45$. The downstream water level is chosen 0 m (w.r.t. an arbitrary reference level). This boundary condition holds half a grid cell *outside* the grid, so the water level we need to specify is $0 - (dx/2) * ib = 0 - (0.3/2) * 4\text{x}10^{-4} = -6\text{x}10^{-4}\text{m}$. The bed level at the downstream boundary = -0.40188 (netnode), so the water depth (h) is 0.40188 m. The discharge is estimated such that in equilibrium for steady uniform flow, the water surface slope (i_w) should be equal to the bed slope (i_b). For this case we have (with discharge Q and constant channel width B): $Q = BhC\sqrt{(hi)}$, or the specific discharge (q): $q = hC\sqrt{(hi_b)}$ = 0.2293 m^2/s.

During testing, it turned out to be difficult to ensure perfectly steady uniform flow using an upstream discharge. Since we use Chézy for bed friction, theoretically, there should be an equilibrium between the pressure gradient and bed friction. Therefore, we also considered tests where we force the model with two water level boundaries, such that the pressure gradient is identical to the bed slope, i.e. $i_w = i_b$. To determine the upstream water level boundary condition, we also need to take into account the shift of half a grid cell at the boundary: $(L) * ib + (dx/2) * ib = 29.7 * 4\text{x}10^{-4} + (0.3/2) * 4\text{x}10^{-4} = 0.01188 + 6\text{x}10^{-5} = 0.01194\text{m}$.

Results - upstream discharge

The following figures show the water level and flow velocity (the latter only for bedlevtype=1). For this case we only considered aspect ratio = 3. Since the discharge is chosen such that the water depth should be equal to the downstream water depth in the domain, we use that as approximation for the "analytical solution".

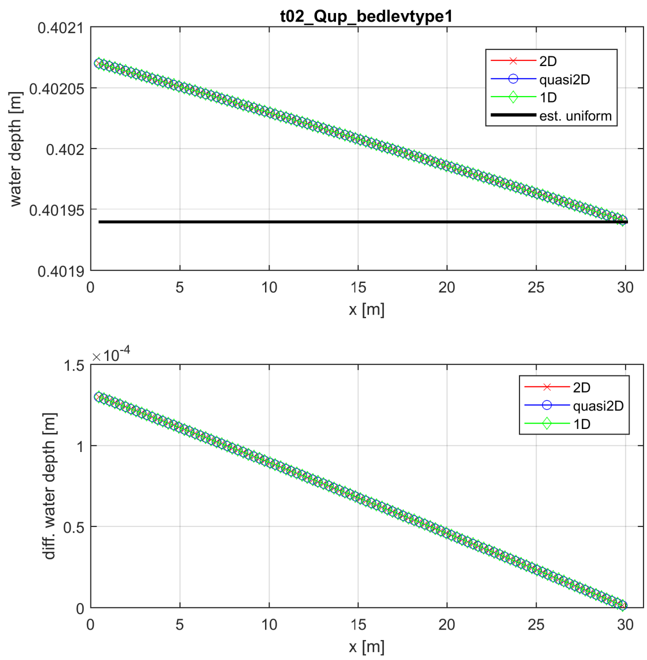

Figure 1.10: *Water depth (top) and difference with "uniform depth assumption" (bottom) for bedlevtype=1, upstream forcing: discharge.*

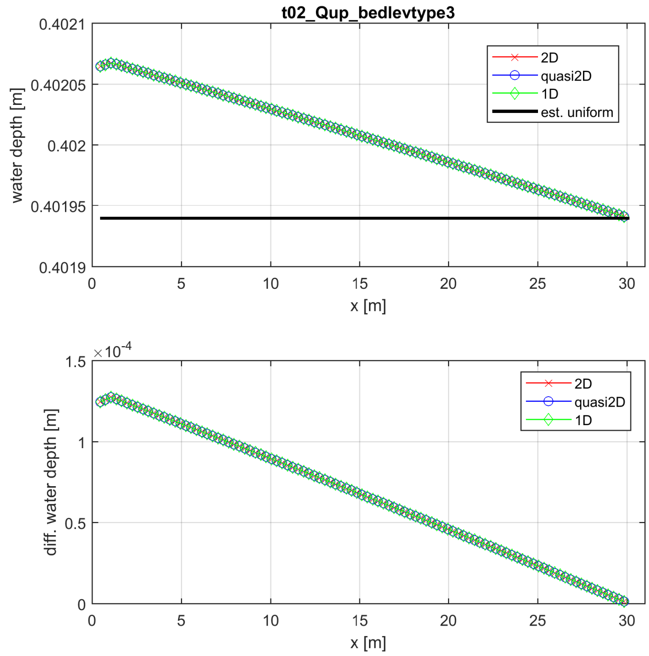

Figure 1.11: *Water depth (top) and difference with "uniform depth assumption" (bottom) for bedlevtype=3, upstream forcing: discharge.*

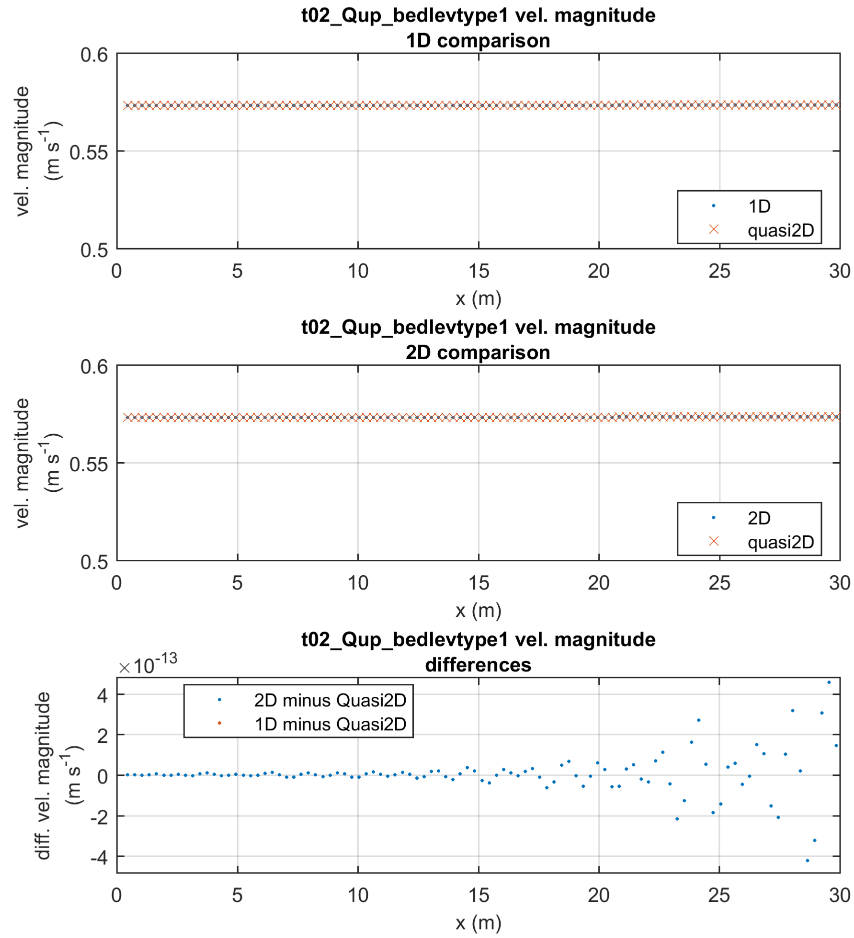

Figure 1.12: *Flow velocity comparison in 1D and 2D for bedlevtype=1, upstream forcing: discharge.*

Analysis:

◇ No difference in water level for 1D and 2D (for 2D centerlines).
◇ No difference for bedlevtype=1 and 3.
◇ The water level on the downstream boundary is correct.
◇ There appears to be a (small) backwater effect (“opstuwing”) towards the upstream boundary of the model. It is not entirely clear where this difference originates from, since the dicharge is chosen such that the water depth upstream should be equal to downstream. Possible reasons are related to the fact that the discharge is not calculated with sufficient accuracy (decimals), or with the fact that in D-Flow FM, a discharge boundary is internally recalculated to a velocity, which might introduce some (rounding?) error?
◇ There is a "jump" in 1D at the upstream boundary in the first 3 computational cells in the domain. The difference is small, and not further considered herein.
◇ Differences in flow velocity between 1D and 2D are very small, with maximum differences at the inflow boundary, where the water levels also deviates from the semi-analytical solution.

Results - Pressure gradient (including aspect ratio)

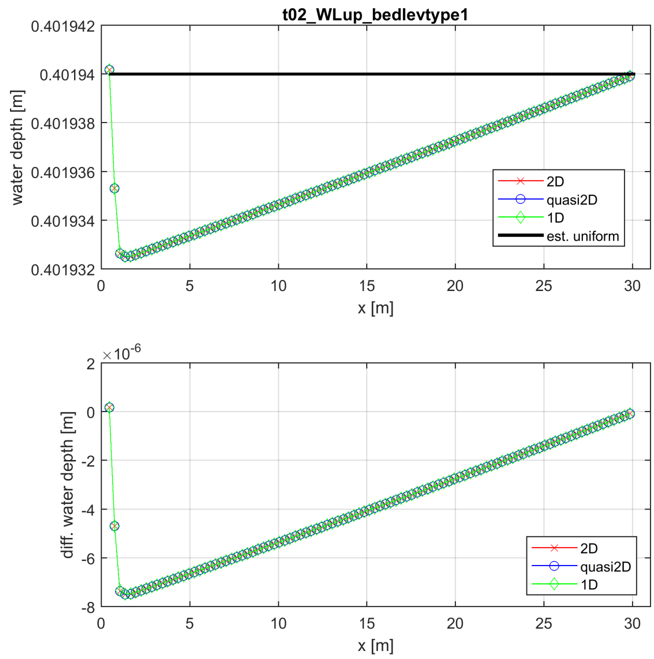

__Figure 1.13:__ Water depth (top) and difference with "uniform depth assumption" (bottom) for bedlevtype=1, upstream forcing: water level (pressure gradient).

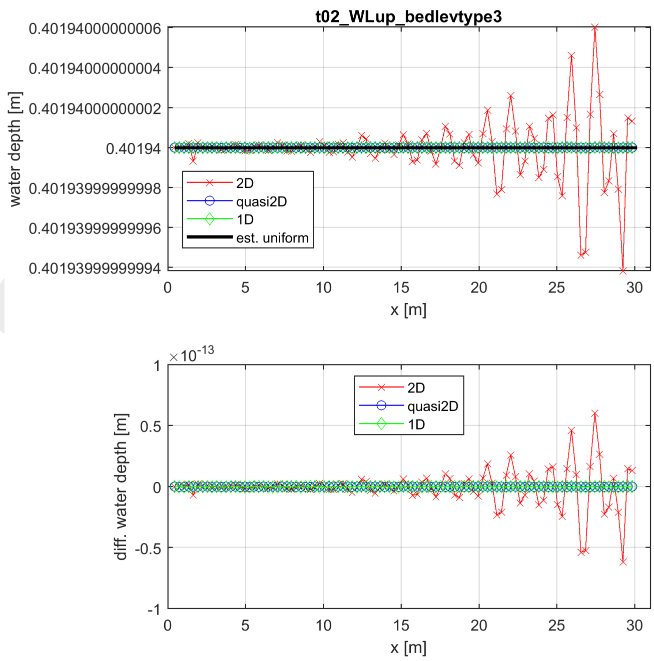

__Figure 1.14:__ Water depth (top) and difference with "uniform depth assumption" (bottom) for bedlevtype=3, upstream forcing: water level (pressure gradient).

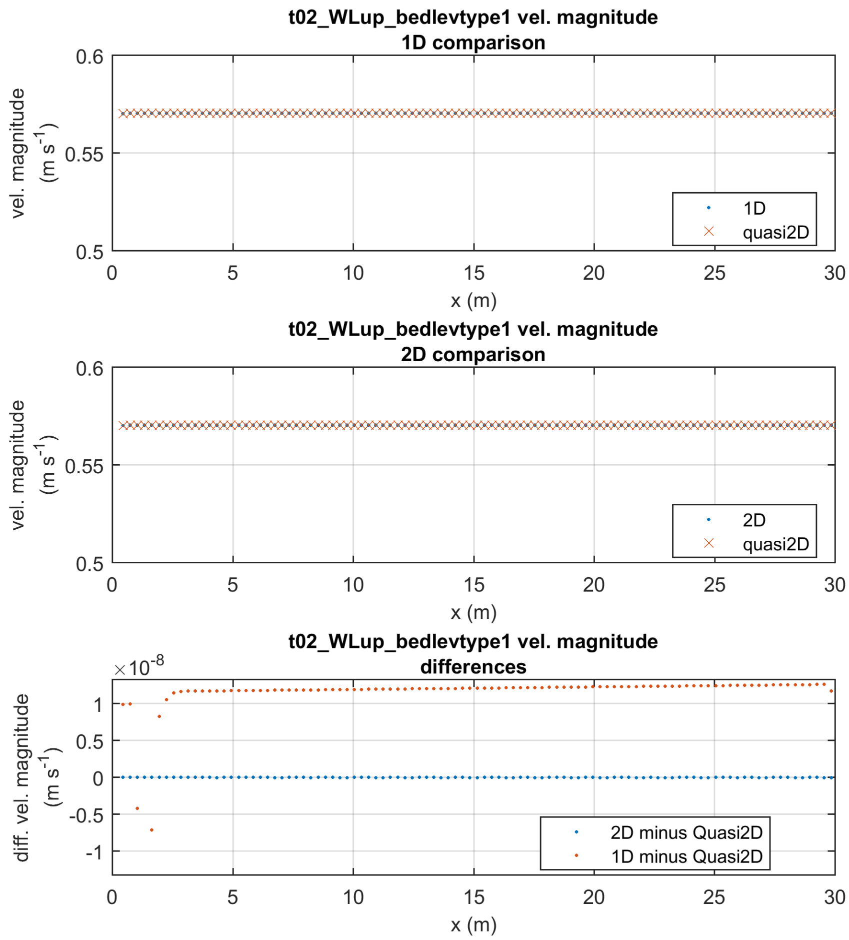

Figure 1.15: *Flow velocity comparison in 1D and 2D for* bedlevtype=1*, upstream forcing: water level (pressure gradient).*

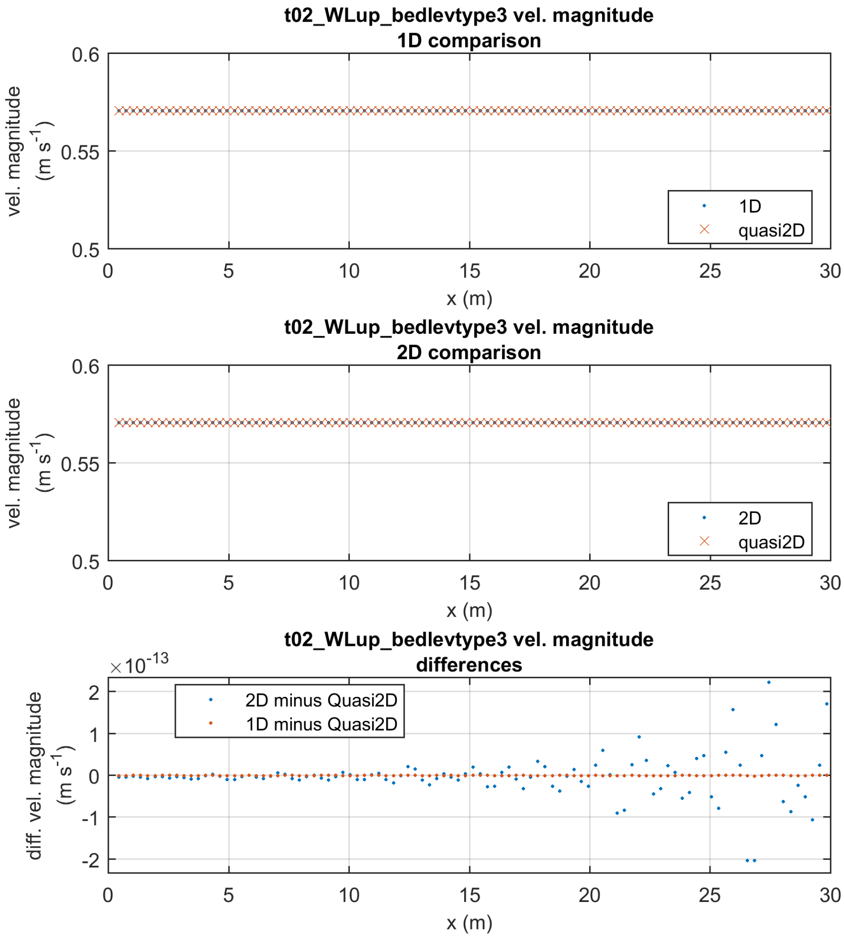

Figure 1.16: Flow velocity comparison in 1D and 2D for bedlevtype=3*, upstream forcing: water level (pressure gradient).*

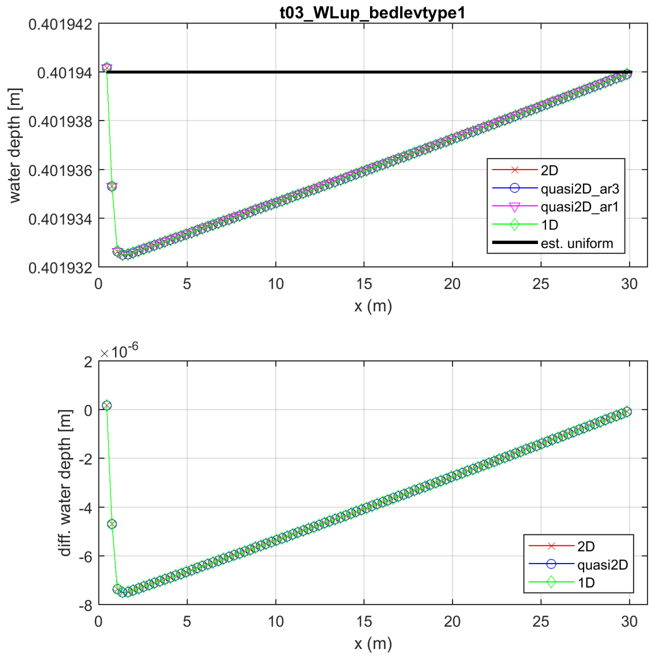

Figure 1.17: *Water depth (top) and difference with "uniform depth assumption" (bottom) for bedlevtype=1, upstream forcing: water level (pressure gradient). This includes aspect ratio = 1 for the 2D grid.*

Analysis:

- ◇ The water level on the downstream boundary is correct.
- ◇ For bedlevtype=3 the computed water levels are identical and as expected (constant water depth along the channel). Note that the fluctuations in the figure are in the orde of 10^{-13}.
- ◇ For bedlevtype=1, the above results only hold for the 1D channel.
- ◇ For 2D also with a pressure gradient as forcing, there is a striking difference for the first three grid points in the domain. It should be noted that for an upstream discharge, this was the other way around.
- ◇ The boundary effects (e.g. at the first 3 cells) is still present for an aspect ratio of 1 (see last figure).
- ◇ The are no differences in flow velocity for this case between 1D and 2D for bedlevtype=3. For bedlevtype=1 (which is relevant for morphology), there is expected to be no differences for 1D, but for 2D there are differences near the upstream boundary of the model, perhaps related to the treatments of the upstream boundary condition in 2D? (in the figure, it appears there is a difference for 1D, but this is because we compare velocities in 1D to velocity computed in 2D, what causes the differences here.)

Conclusion

For bedlevtype=3 and a pressure gradient as model forcing, the results in 1D and 2D are equal to each other and the surface profile is virtually indentical to a semi-analytical solution of the surface profile. However, for bedlevtype=1, which is used for morphological simulation, the are differences in water level and flow velocity, especially near the upstream boundary of the model. The differences are small though, and knowing these (small) differences, we can continue with the morphological validation cases.

1.4 Straight channels in 1D and 2D: including 90 degree bends

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
08 Dec 2017	Andries Paarlberg		Arthur van Dam		Aukje Spruyt	

Version information

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Executable : Deltares, D-Flow FM Version 1.1.261.53235M, Nov 15 2017, 09:54:18
Location : https://repos.deltares.nl/repos/DSCTestbench/trunk/cases/e02_dflowfm/f28_mor1d_bakprof_hydraulics/c11_Channels_1D_zigzag_zero_bedslope
SVN revision : -

Purpose

There is an important difference between SOBEK3 and D-Flow FM. In SOBEK3, the flow equations are solved in 1D: although the user can introduce geographical "bends" in a model, the equations are still solved as if the river is a straight line. Since D-Flow FM is set-up as a model-code for 1D-2D-3D, this is not the case for D-Flow FM. Also in 1D, the equations are solved in a vectorized way. This means that if there is a bend between computational nodes, the computed velocity can be very different from the velocity computed in SOBEK3. This test case is set-up to gain some insight in the effects of "bends" on water levels (backwater effects).

Linked claims

- ◇ "Bend effects" are treated differently in D-Flow FM and SOBEK3.
- ◇ For one single 90^o bend, the results are identical in 1D and 2D.

Approach

We start from an earlier test cases with straight channels in 1D and 2D: 'c10_straight_channel_1Dvs2D_zero_bedslope' (REF). In that test case we used a zero bed slope and bed level of 0 in the entire domain, which is convenient for modelling the channels with bends. In this test case we add various channels containing "bend lay-outs", and compare the water levels with those computed for straight channels of the same length. We consider two bedlevtypes: 1 (faces) and 3 (zk). For one bend lay-out, we compare 1D and 2D results.

Model description

The figure below shows the computational domain, containing both the straight 1D and 2D channels (bottom two) and the channels with bends (top three).

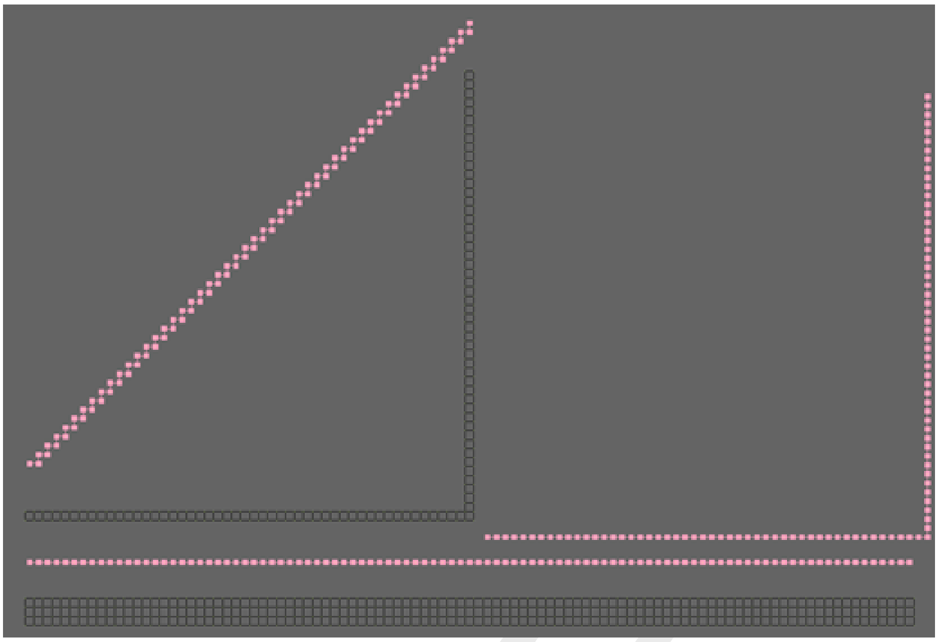

Figure 1.18: *Figure of the layout of the model.*

The 2D channel (3 cells wide, cell edges 0.1 m long, aspect ratio = 1) and 1D channel (0.3 m wide) are of equal length (30 m). Pressure points are at identical locations for the centerlines of the models. The bed level is 0 for the entire domain.

The model is forced with a constant discharge at the upstream boundary, and a constant water level at the downstream boundary. The discharge is 0.08 m^3/s for the 1D channel and 0.24 m^3/s for the 2D channel (since it is three cells wide). The water level at the downstream boundary (and because of the 0 bed level also the water depth) is 0.35 m.

For this test case we add the following grids to test the backwater effects due to bends:

◇ Two channels with a single 90^o bend, both in 1D and 2D (1 cell wide). The length of these channels is identical to the straight channels.
◇ One 1D channel with a 90^o bend between each node ("zigzag" per node, so each channel segment is 0.3 m long). Also for this case the total length of the channel is equal to the straight channel.

We use Bedlevtype = 1 and 3, which should be identical because of the uniform bed level in the computational domain. For the straight channel, the water levels are compared to a semi-analytical approximation of the surface profile.

Results

The results are shown in the figures below.

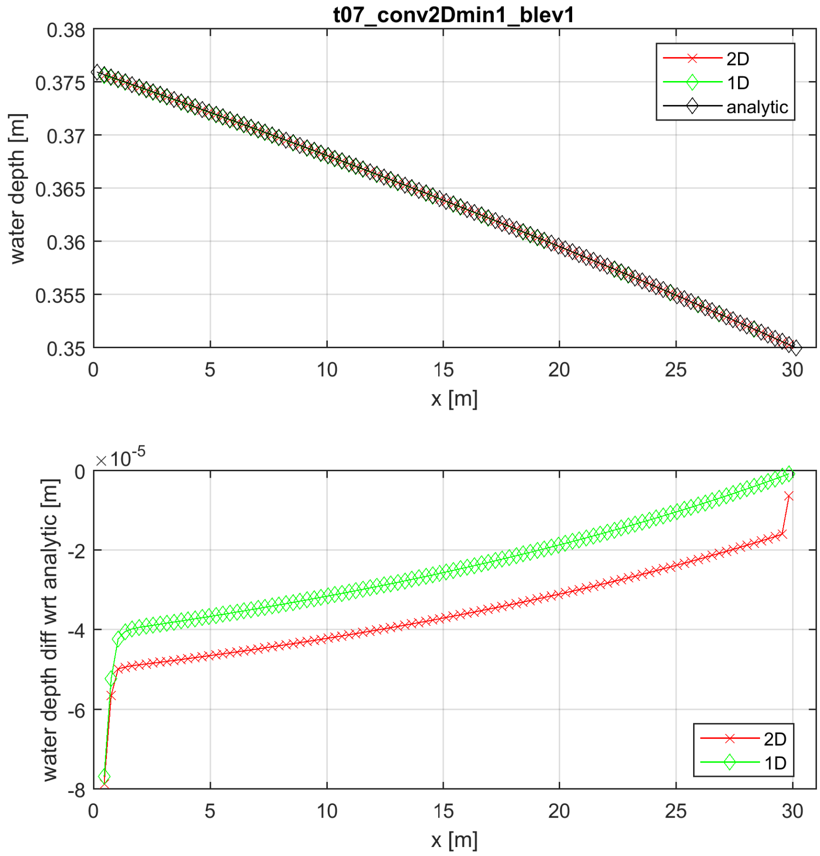

Figure 1.19: *Comparison water levels in the straight channels for 1D and 2D with semi-analytical solution, bedlevtype=1.*

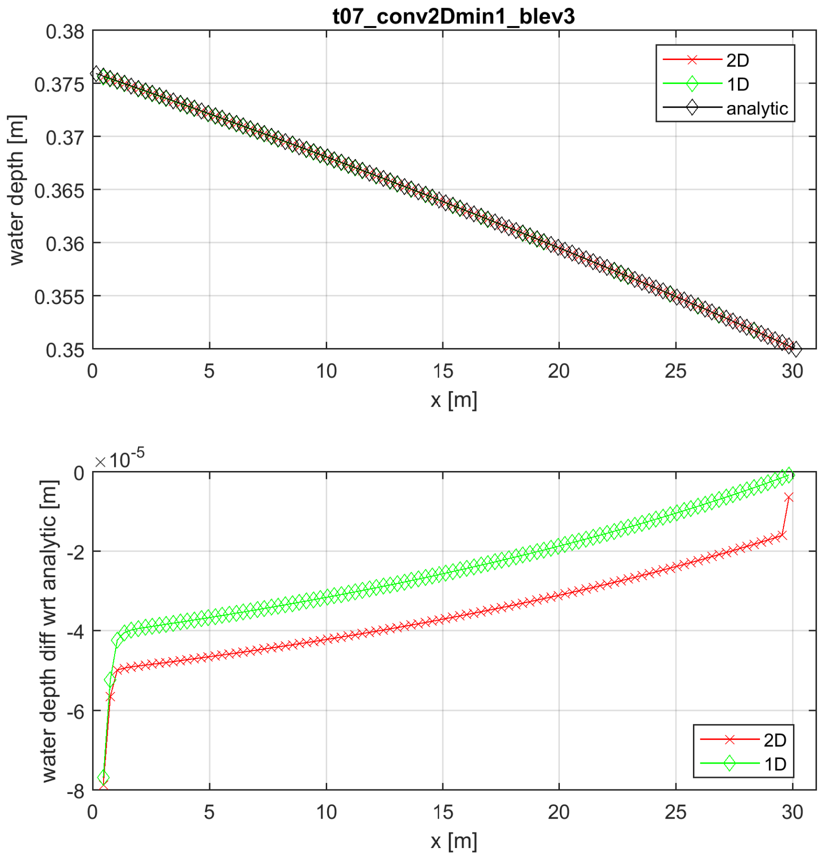

__Figure 1.20:__ Comparison water levels in the straight channels for 1D and 2D with semi-analytical solution, bedlevtype=3.

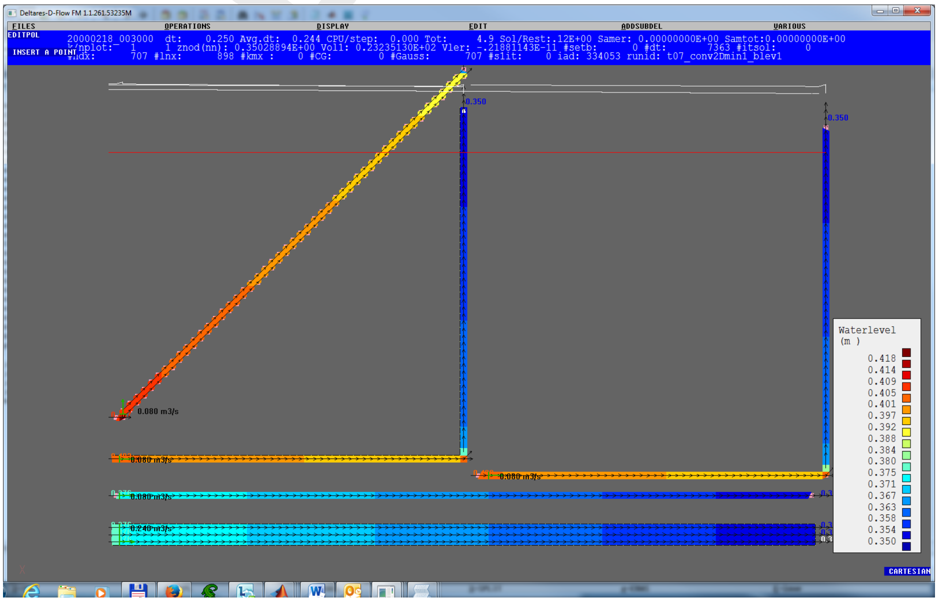

__Figure 1.21:__ Impression of water levels including bends, bedlevtype=1.

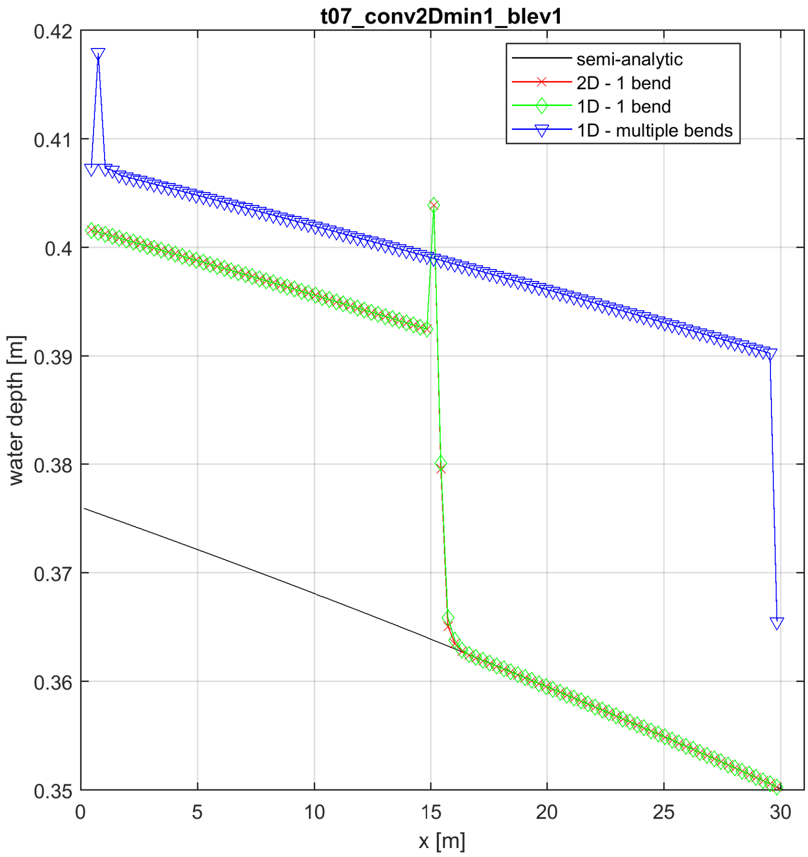

Figure 1.22: *Comparison of water levels in channels with bends compared to semi-analytical solution of surface profile for straight channel, bedlevtype=1.*

Analysis of results

From the figures above we can conclude:

- ◇ For straight channels: see previous test cases.
- ◇ Results independent of bedlevtype, so bend effects only analyzed for bedlevtype=1.
- ◇ Effect of one single 90^o bend is equal for 1D and 2D. For the considered geometry, the backwater effect is approximately 2.5 cm, which remains equal towards the upstream boundary of each model.
- ◇ For the case with multiple bends, the backwater effect originates at the downstream boundary. The effect is larger than considering one bend halfway a channel of equal length. In upstream direction, there appears to be no effect. Perhaps this is because we have schematized a 90^o bend at *each* node, making the channel virtually straight? At the upstream node, a backwater effect is visible due to the first downstream bend in the geometry.

Conclusion

"Bend-effects" are significant. It should be investigated how to treat this in D-Flow FM when considering 1D-models.
Another recommendation is to consider a “real world“ example for future test cases. Flow velocities in the channels with bends likely also deviate from those in the straight channel.

1.5 Straight channels in 1D and 2D: including 90 degree bend and effect of resolution

Quality Assurance

Date	Author	Initials	Review	Initials	Approval	Initials
08 Dec 2017	Andries Paarlberg		Arthur van Dam		Aukje Spruyt	

Version information

Date of study : 08 Dec 2017
Executable : Deltares, D-Flow FM Version 1.1.261.53235M, Nov 15 2017, 09:54:18
Location : https://repos.deltares.nl/repos/DSCTestbench/trunk/cases/e02_dflowfm/f28_mor1d_bakprof_hydraulics/c11_Channels_1D_zigzag_1D_zero_bedslope_resolution
SVN revision : -

Purpose

There is an important difference between SOBEK3 and D-Flow FM. In SOBEK3, the flow equations are solved in 1D: although the user can introduce geographical "bends" in a model, the equations are still solved as if the river is a straight line. Since D-Flow FM is set-up as a model-code for 1D-2D-3D, this is not the case. Also in 1D, the equations are solved in a vectorized way. This means that if there is a bend between computational nodes, the computed velocity can be very different from that computed in SOBEK3. The previous case gave insight in the effect of bends on water levels: backwater effects (opstuwing) at each bend. The question has risen whether this is physical or numerical. Therefore, in this test case we study whether the results from the previous case depend on the resolution of the grid.

Linked claims

◇ Bend effect independent of grid resolution.

Approach

In this case we compare a 1D straight channel with channels with a single 90^o bend with different horizontal resulotion (different dx).

Model description

See the figure below for the used grids in this case.

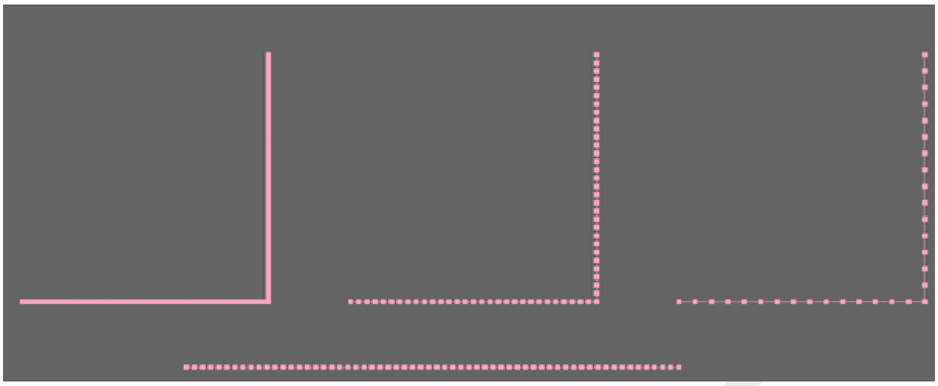

Figure 1.23: *Figure of the layout of the model.*

Properties of the considered cases:

- ◇ All channels are 30 m in length. Width of channel is 0.3 m.
- ◇ Straight 1D-channel: dx=0.5 m.
- ◇ 1D-channels with a single 90^o bend: from left to right dx=0.25 m, 0.50m, 1.00 m.
- ◇ Water depth downstream boundary: 0.35 m.
- ◇ Discharge at upstream boundary: 0.08 m^3/s.

Results

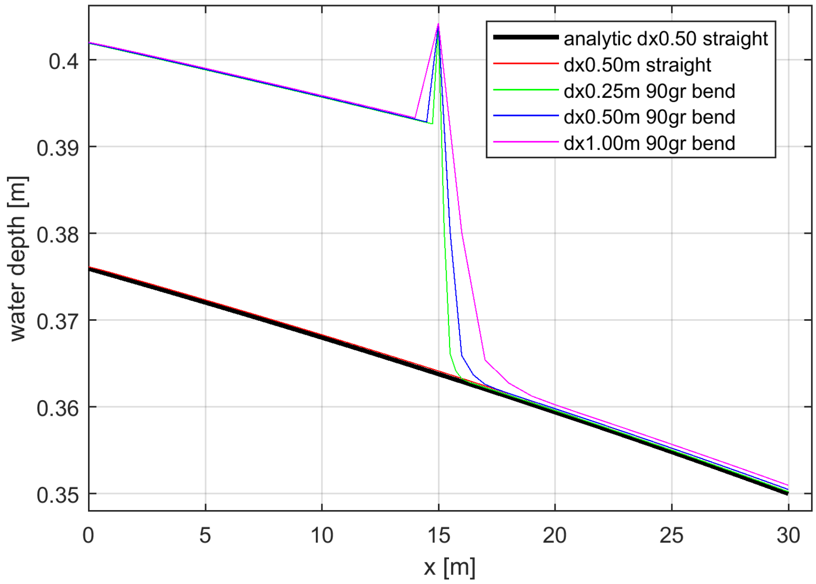

Figure 1.24: *Comparison of water depth for straight channels and channels with a single bend with various grid resolution.*

The backwater effect is independent of grid resolution (the apparent differences are only due to the relatively coarse grids). On hindsight, this result is probably logical. Two opposing effects "cancel out": the effect of a coarser grid and related numerical diffusion.

Conclusion

"Bend-effects" are independent of grid resolution. This gives reason to form a conceptual framework how to treat "bends" in 1D D-Flow FM applications.

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