1 Bifurcations

Quality Assurance

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Purpose

At bifurcations the sediment from the upstream branch is divided over two separate downstream branches. D-Flow FM can calculate the sediment distribution over the separate branches based on several nodal relations. The purpose of this validation case is te prove that SOBEK correctly distributes sediment at bifurcations given a certain nodal relation.

Linked claims

- D-Flow FM accurately redistributes sediment transport at nodes.

Approach

Given a typical bifurcation with one inflowing branch and two out flowing branches D-Flow FM offers two options to determine the distribution of sediment over the tow out flowing branches: (1) a power formula and (2) a table relation.

The power formula is in fact a form of Wang's formula. The formula of Wang et al. 1995 is usually defined as follows:

$$\frac{S_2}{S_3} = \left(\frac{Q_2}{Q_3}\right)^k \left(\frac{B_2}{B_3}\right)^m . \tag{1}$$

With indexes 2 and 3 denoting the two outflowing branches. Q_2 is the discharge in branch 2, B_2 is sediment transport width of branch 2 and k and m are calibration parameters. The sediment transport width is defined as the width of the 'main' section in a cross-section.

Alternatively, the table method directly relates two branches to each other. It consist of a lookuptable that determines S_2/S_3 based on Q_2/Q_3.

This test compares four different cases with the exact solution:

- c11: Default sediment distribution (Formula with k=1, m=0)
- c12: Sediment distribution according to Formula with k=5 and m=1
- c13: Sediment distribution according to Table

The table relation for case c13 is given as:

```
* Bifurcation relationship
* column 1 = QBranch1/QBranch2
* column 2 = SBranch1/SBranch2
TABL0
4 2
0.1   0.5
0.5   2.0
1.0   3.0
2.0   4.0
```

Model description

The bifurcation model network is set-up as in figure 1 with rectangular cross-sections. For each cross-section the total width is equal to the flow width.

Branch 1 has a length of 50 km, branch 2 and 3 have a length of approximately 49.7 km. The boundary conditions consist of an upstream constant discharge of 2500 m^3s^{-1} and downstream constant waterlevels of 0 m.

The slopes of the branches are based on the equilibrium slopes and dimensions of c11 and the Engelund-Hansen formula is used to calculate sediment transport. Table 1 gives an overview of the general model settings for all testcases.

Results

Bed development for each test case the bed level differences in time and the final bed are plotted (see Figure 3, Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8)

The distribution of the discharge and the sediment transport at the node is shown in Figure 9, Figure 10 and Figure 11

The comparison between calculated values of the sediment distribution over the branches with the theoretical values (c11,c12) is shown in Table 2

Table 1: Model settings

Input description	Symbol	Value	Unit
Flow			
gravitational acceleration	g	9.81	m/s2
width main channel branch 1	B1	300	m
width main channel branch 2	B2	150 (T1, T2, T3), 120 (T4)	m
width main channel branch 3	B3	100	m
upstream discharge boundary	Q	2500	m3/s
downstream water level boundary	h	0.00	m
Chézy roughness coefficient	C	50	m1/2/s
initial water depth	h_{ini}	6.62	m
water density	ρ_w	1000	kg/m3
Morphology parameters			
sediment diameter	D_50	0.0003	m
sediment density	ρ_s	2650	kg/m3
relative density	Δ	1.65	
porosity	ϵ_p	0.4	
engelund-hansen calibration parameter	n	1	
model parameters			
computational grid size	Δx	500	m
computational time step	Δy	300	s
output time step		1	h

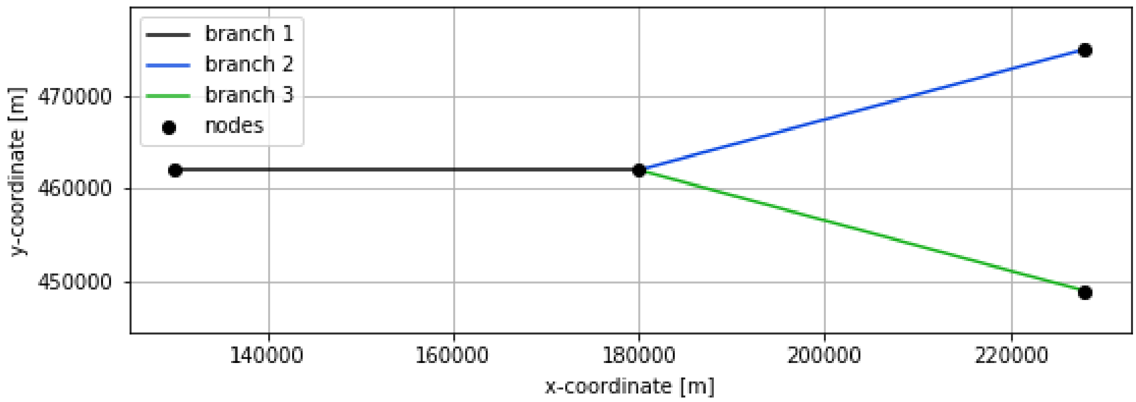

Figure 1: Bifurcation network

Table 2: Comparison between the modeled sediment distribution over the bifurcation and the distribution based on Equation (1) or the imposed table

	Q2/Q3	B2/B3	S2/S3	S2/S3 theory
c11	0.8767461631637189	1.5	0.8767461631637189	0.8767461631637189
c12	0.8783953846090898	1.5	0.7844070439328339	0.7844070439328339

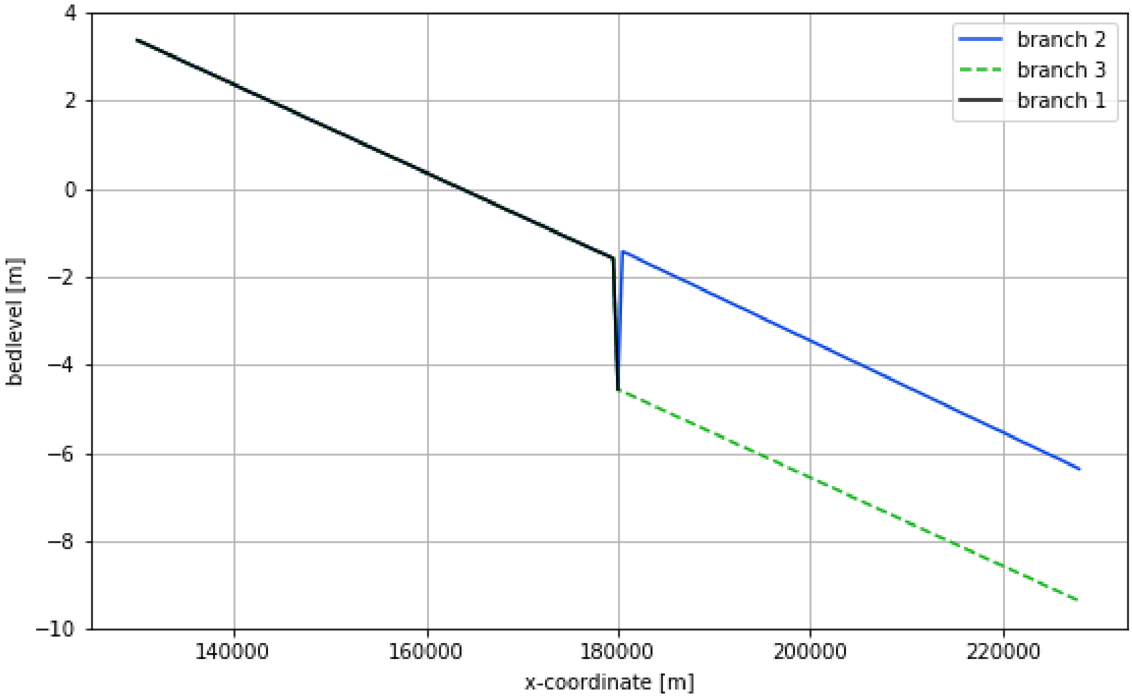

Figure 2: Initial bed level

For case c13 a table relating the sediment transport ratio to the discharge ratio of the two lower branches. The result is shown in Figure 12 indicating that the prescribed ratio is imposed.

Conclusion

The results indicate that the sediment distribution follows the imposed relation, through either a power relation or a lookup table.

Due to an underestimation of the sediment transport in the node, sedimentation occurs in the node. This is related to the computation of velocity in for flow passing through a bend.

The long term bed development remains to be investigated.

References

Wang, Z.B., R.J. Fokkink, M. de Vries, and A. Langerak (1995). “Stability of river bifurcations in 1D morphodynamic models”. In: *Journal of Hydraulic Research* 33.6.

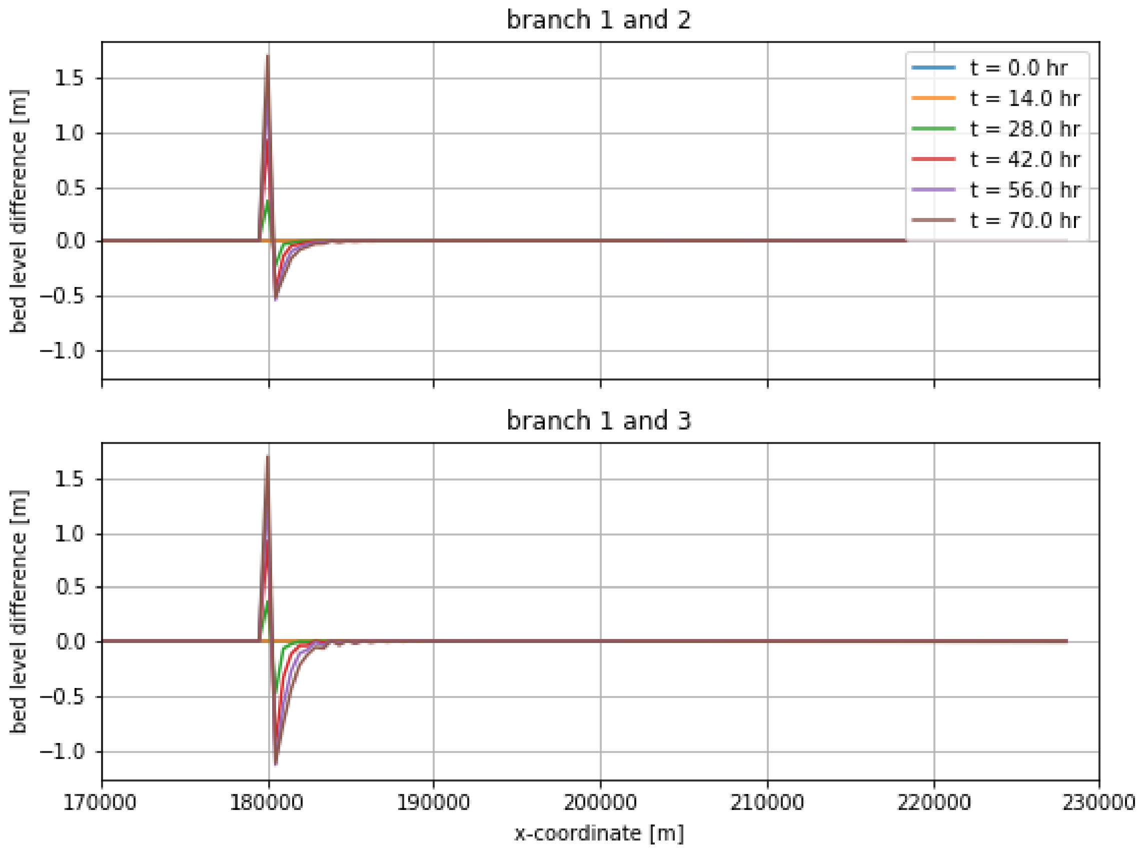

Figure 3: Bed development c11.

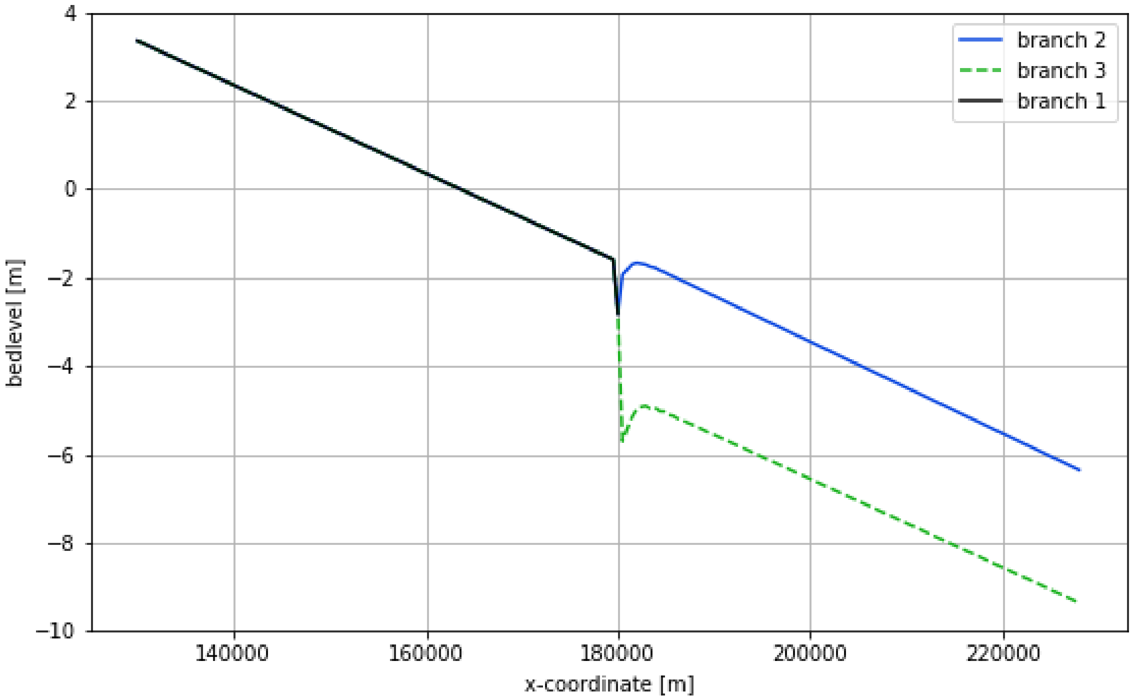

Figure 4: Bed level at the end of the simulation for c11.

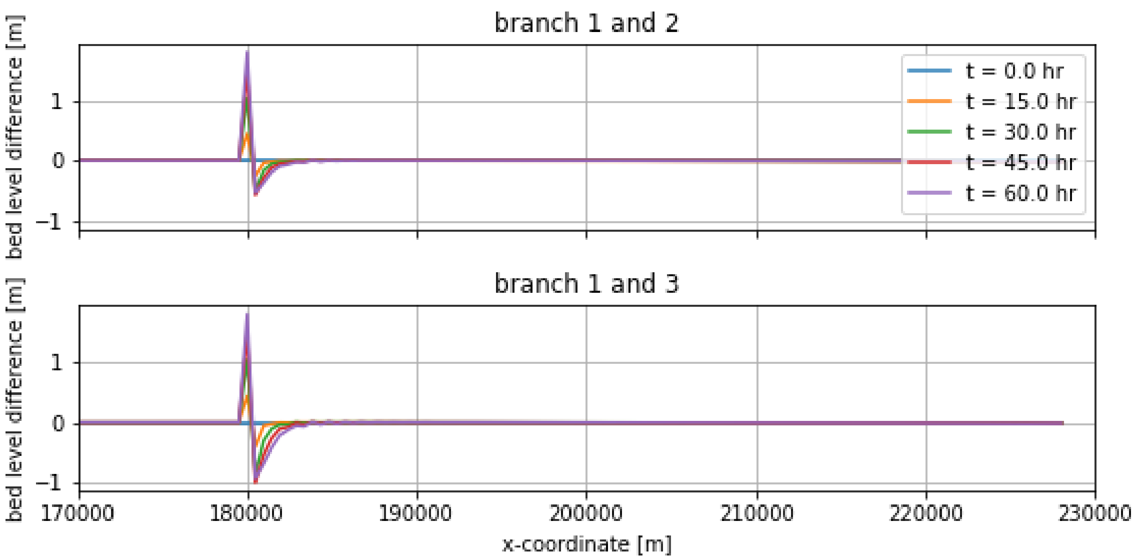

Figure 5: Bed development for c12.

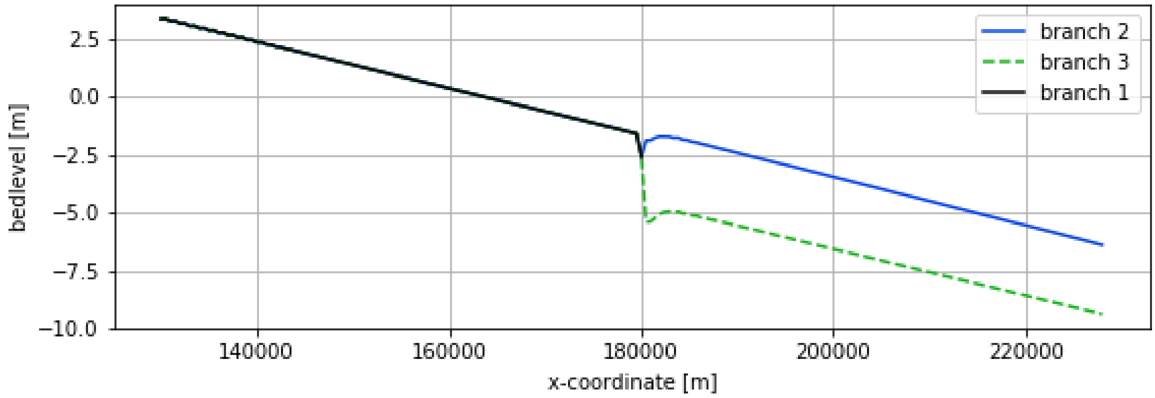

Figure 6: Bed level at the end of the simulation for c12.

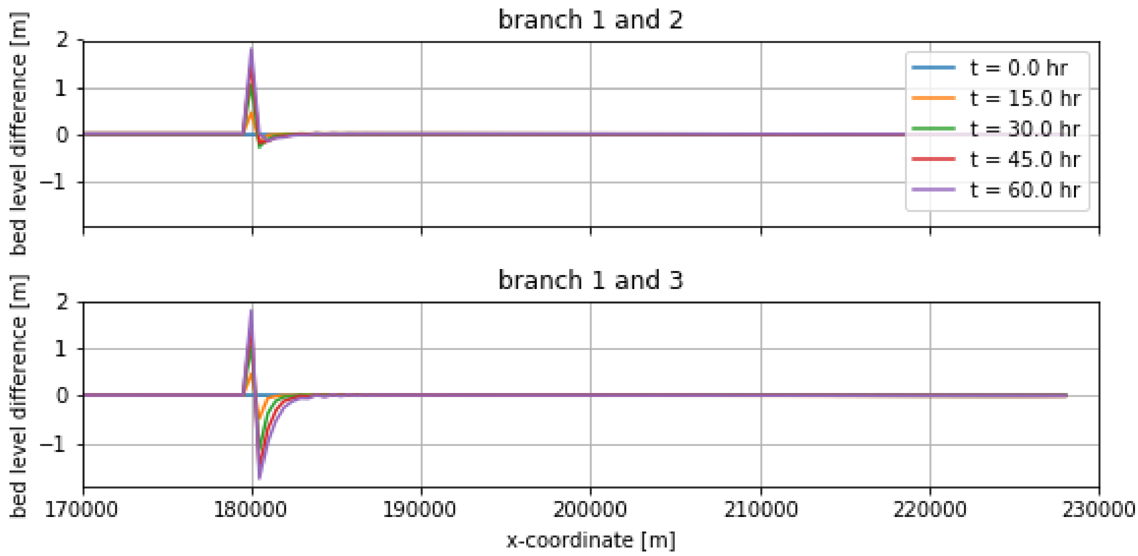

Figure 7: Bed development for c13.

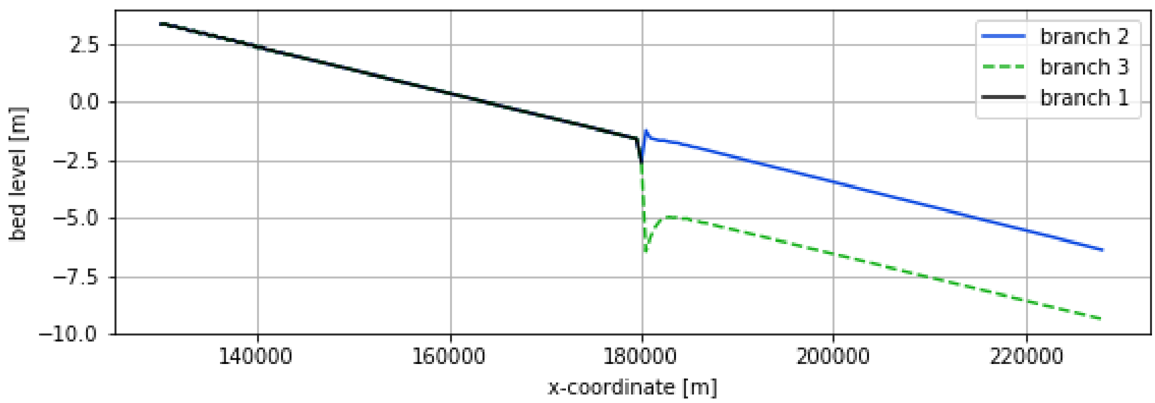

Figure 8: Bed level at the end of the simulation for c13.

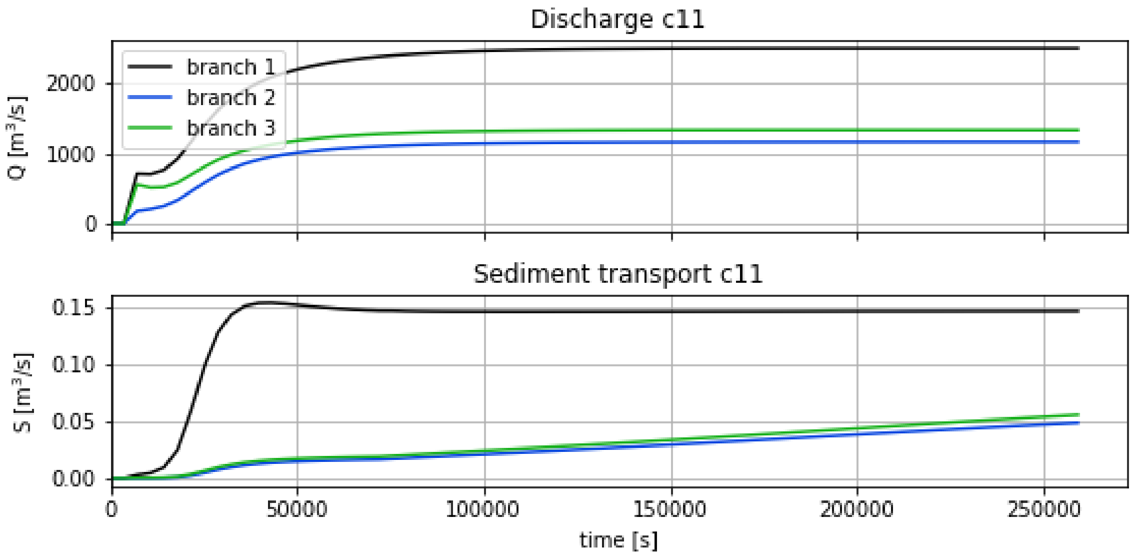

Figure 9: Discharge and sediment transport at node for c11.

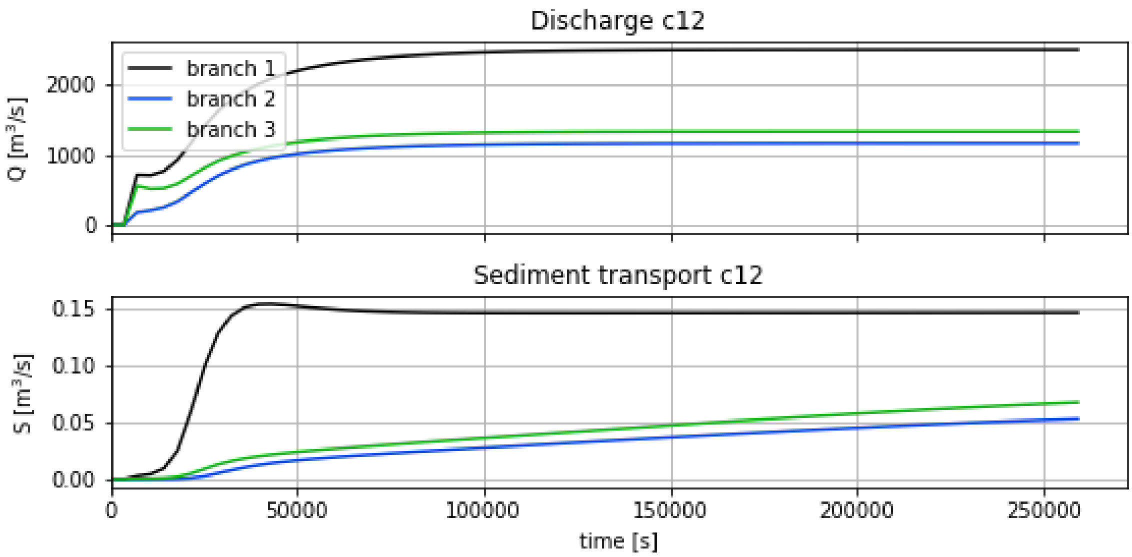

Figure 10: Discharge and sediment transport at node for c12.

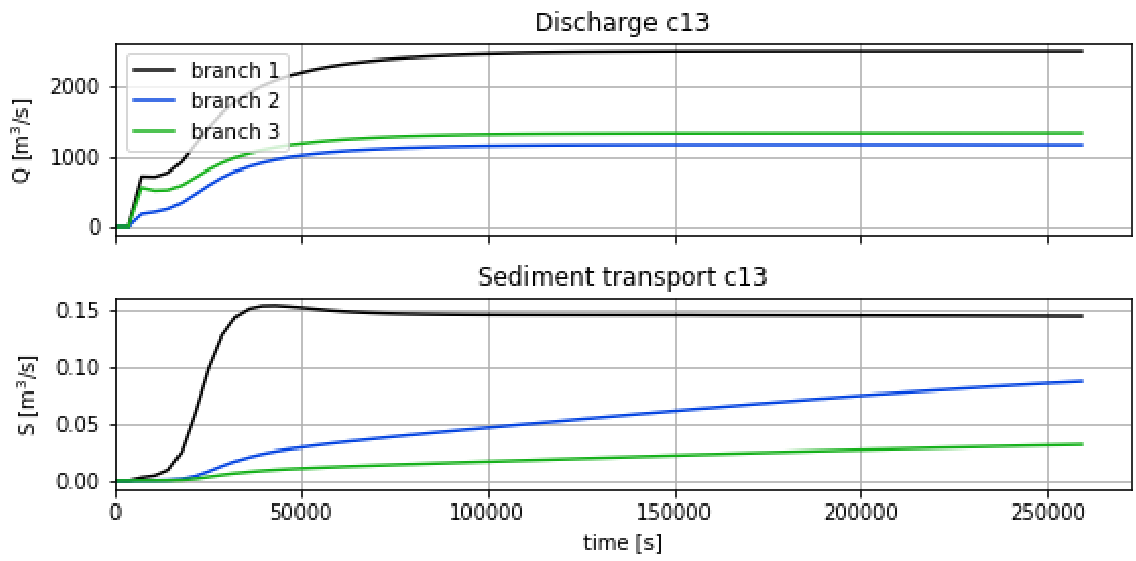

Figure 11: Discharge and sediment transport at node for c13.

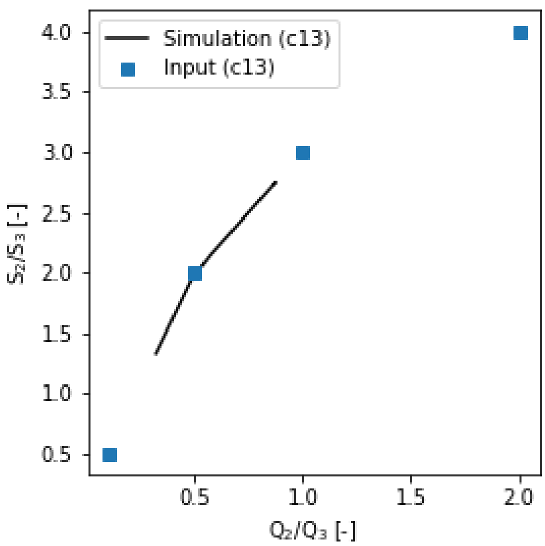

Figure 12: Sediment distribution as a function of discharge distribution for case c13.