

# CALIBRATION AND VALIDATION OF PRACTICAL MODELS FOR CHANNEL SILTATION

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Marine contractors and consultants have a need for quick and practical tools to make estimates of siltation rates of channels and trenches. Three such models have been calibrated and validated against both laboratory and field data. With calibration, the models are well capable of reproducing measured bed level changes and siltation volumes. The set with optimum parameters settings, however, varied from case to case. Without the opportunity to calibrate the models, the models should be used with common sense and accounting for the provided recommendations. As the models are quick, they enable an extensive sensitivity study or even a Monte Carlo approach, which largely overcomes the models' sensitivity to parameter settings.

*Keywords: channel siltation, trench siltation, siltation prediction, engineering tools, calibration and validation, quick assessment*

## INTRODUCTION

In early stages of maritime project developments, tenders and projects, data are usually scarce and time for studies is usually limited. This motivates the need for quick assessment tools for various applications. One of those applications is the prediction of siltation of access channels, and cable and pipeline trenches, and the deformation of the slopes.

Trenches are sometimes needed to enable burial of cables and pipelines sufficiently deep below the non-mobile seabed to prevent exposure of the cable or pipeline. Such trenches are exposed to siltation for typical periods of days to weeks. Dredging of new access channels may take months to even years, before formal handover at target depth. During this time the channel is exposed to siltation as well. This means that the relevant time scales a quick assessment tool ideally should be able to cover, range from days to years.

This paper discusses the application of three practical engineering models: SEDPIT, SEDTUBE and SUSTIM2DV. SEDPIT is a semi-empirical sediment trapping model originally set-up in MS Excel, which is very easy to apply. SEDTUBE is a semi-analytical 1D model for the simulation of the morphological evolution of a sandy channel or trench under the influence of currents and waves. The SEDPIT and SEDTUBE models are part of the engineering tools and databases that come along with Van Rijn (2015). At Boskalis, these two models have been programmed in MATLAB and Python as well, expanding their functionality and enabling automated sensitivity studies or Monte Carlo approaches. The SUSTIM2DV model is a 2DV, time-dependent suspended sediment transport model for clay, silt and sand, see Van Rijn et al. (2024). All three models are practical models which can be used for quick-scan studies of trench or channel siltation.

The main purpose of this paper is to study to what extent SEDPIT, SEDTUBE and SUSTIM2DV can reproduce observed channel and trench siltation and migration. The purpose is also to investigate whether one set of parameter values is sufficient to cover a wide range of applications or that each case requires its own optimized set of parameters. As the tools are often used when data is still scarce, it would have great benefits if a generic set of optimized parameters could be found.

This paper first describes the underlying physics of the models. Next, the various calibration and validation data sets as well as the methodology are presented. Then the calibration and validation of the models against the data is step by step presented. Finally, the conclusions and recommendations for use of the three models in prototype applications are provided.

## MODEL DESCRIPTION

### SEDPIT

SEDPIT is the simplest model to estimate the trapping of sediment inside a pit, trench or channel. The flow conditions in SEDPIT are calculated using the stream tube approach, see Eq. 1. The trench or channel is schematized as a rectangular depression of the otherwise uniform bed. It is common practice to take the width halfway the slopes as representative width, see Figure 1. The bed load and the equilibrium suspended sediment concentration are based on Van Rijn (2007a, b, c). Silt and clay fractions can be incorporated by simply defining a background concentration and assigning a fall velocity to these fractions.

The deposition layer of mud, silt and sand is computed as a multiplication of a trapping efficiency factor and the incoming sediment load from both sides of the channel. The trapping efficiency factor depends on the geometrical channel dimensions, the sediment characteristics and the hydrodynamic conditions. For bed load transport the trapping efficiency is set to one, meaning that the entire differential

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sediment flux between the undisturbed bed and the channel will deposit. For the trapping of suspended load transport, the formulation of Van Rijn (1987) is used. The model neglects the erosion of sediment which may occur at the downstream channel slope.

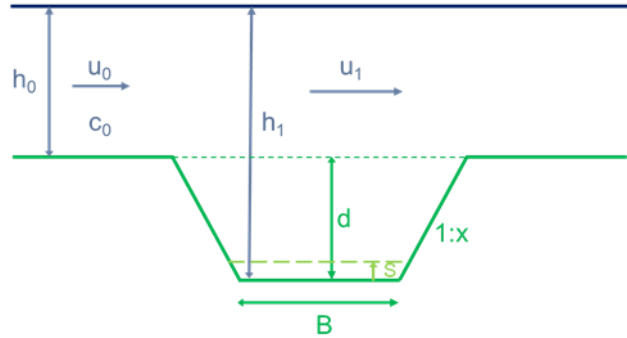


Figure 1. Schematization of a trench and flow condition in SEDPIT

A demonstration of the model's performance is provided in Figure 2 showing validation results of the SEDPIT model for a trial pipeline trench dredged in the bed of the Dutch Sector of the North Sea near the harbour of Scheveningen in March 1964. The length of the trench normal to the shore was about 700 m, the bottom width of the trench was about 10 m, the side slopes of the trench were approximately 1 to 7 and the trench depth below the surrounding seabed was roughly 2 m. The grain size varied between 0.2 and 0.3 mm. In all, about 30,000 m<sup>3</sup> was dredged. The local peak flood and ebb currents are estimated to be in the range of respectively 0.6 and 0.5 m/s parallel to the shore. The measured deposition volumes are 12 m<sup>3</sup>/m after 48 days and 35 m<sup>3</sup>/m after 173 days. The computed sedimentation volume is in good agreement with measured values when the bed and suspended load transports are scaled with a factor 0.5. Later in this paper, the validation and calibration of SEDPIT using other test cases is further pursued.

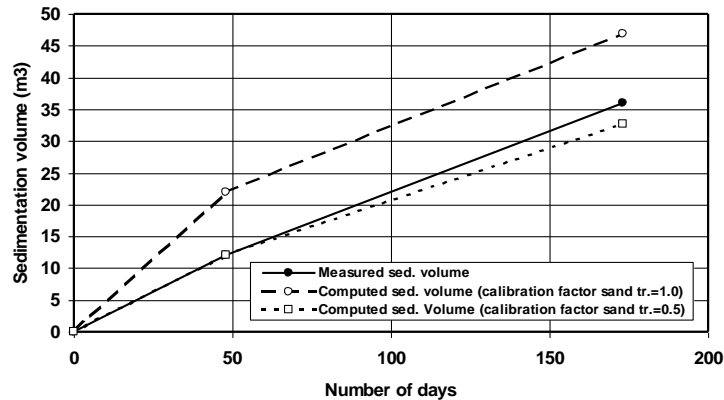


Figure 2. Calibration of SEDPIT against observed channel siltation

### SEDTUBE

The flow conditions in SEDTUBE are also calculated using the stream tube approach, see Eq. 1. The discharge  $Q$  at the boundary is prescribed and in the remainder of the model mass conservation dictates the current velocity  $u_x$ . Both the width  $b_x$  and depth  $h_x$  of the stream tube can vary along the stream tube.

$$u_x = \frac{Q}{b_x h_x} \quad (1)$$

The bed load and the equilibrium suspended sediment concentration are based on Van Rijn (2007a, b, c) and are therefore equal to the ones used in SEDPIT. The adjustment of the depth-average suspended sediment concentration to changing flow conditions is approximated by Eq. 2. The adjustment factor  $A$  has been determined for a wide range of conditions by calculations with the detailed, process-based

suspended sediment transport model SUTRENCH developed by Van Rijn (1987). A calibration of the SUTRENCH model is provided in Walstra et al. (1999). The resulting equation for A is given in Eq. 3.

$$\frac{dc}{dx} = -A(c_x - c_{x,eq}) \quad (2)$$

$$A = \frac{f_A}{h} \cdot \frac{w_s}{u_*} \cdot \left(1 + \frac{2w_s}{u_*}\right) \cdot \left(1 + \frac{H_s}{h}\right)^2 \quad (3)$$

Factor  $f_A$  is a calibration factor which default value has been established at 0.1 – 0.2, based on bespoke SUTRENCH calibration, but its value may vary from case to case. The adjustment of the suspended transport proceeds relatively rapid in the presence of waves governed by the  $H_s/h$  term. Larger values for A – i.e. larger fall velocity, smaller bed-shear velocity and/or larger relative wave height – lead to more sedimentation at the upstream slope and to less sedimentation in the middle of channel in case of wide channels. In other words, a larger A-value means a more rapid adjustment to the equilibrium conditions. The impact of  $f_A$  in a simulation of 60 days is depicted in Figure 3. In addition, the equilibrium transport rates  $c_{x,eq}$  calculated with simple engineering formulations based on Van Rijn (2007) can be adjusted with calibration coefficients as well.

In the present study, the parameters that are used to calibrate SEDTUBE are only  $f_A$ ,  $f_{Qb}$  and  $f_{Qs}$ . The latter two are parameters to scale the magnitude of the bed load and suspended load, respectively.

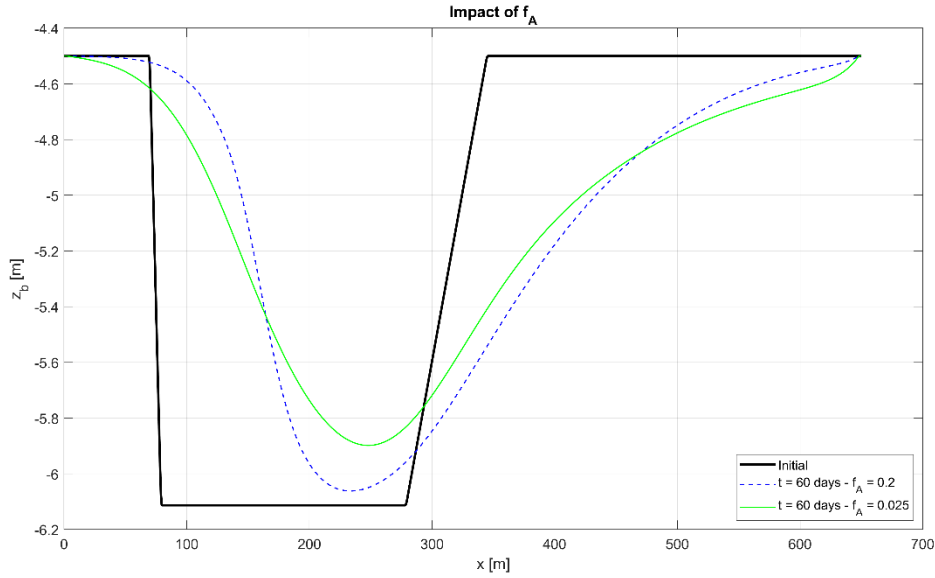


Figure 3. Impact of  $f_A$  on channel development

### SUSTIM2DV

SUSTIM2DV is a practical, easy to use, time-dependent, 2DV model for the simulation of sand and mud concentrations, transport, and bed level changes under the forcing of waves and currents. Just like in SEDTUBE, the flow conditions in SUSTIM2DV are calculated using the stream tube approach. The resulting depth-average current velocity is consequently transferred into a vertical velocity profile.

The SUSTIM2DV model is furthermore based on a numerical solution of the 2DV advection-diffusion equation for sediment, see Eq. 4. The vertical distribution of the sediment mixing coefficient is described by simple and flexible expressions based on flow and wave parameters. The settling velocity is constant or dependent on the sediment concentration to represent mud flocculation and hindered settling processes. The bed boundary condition for sand is modelled by a bed sand concentration as function of the bed-shear stress due to currents and waves, see Eq. 5.

$$\frac{\partial c}{\partial t} - \frac{\partial cw_s}{\partial z} - \frac{\partial}{\partial z} \left( \varepsilon_s \frac{\partial c}{\partial z} \right) = 0 \quad (4)$$

$$c_{a,sand} = 0.015 \cdot \alpha_c \cdot (1 - p_{mud}) \cdot \frac{d_{50}}{a} \cdot \left( \frac{\tau'_{b,cw} - \tau_{b,cr,o}}{\tau_{b,cr,o}} \right)^{1.5} \cdot D_*^{-0.3} \quad (5)$$

In Eq. 5,  $\alpha_c$  is a calibration coefficient with a default value of 1.0,  $\tau'_{b,cw}$  is the effective bed shear stress due to currents and waves, and  $\tau_{b,cr,o}$  is the critical bed shear stress for sand based on  $d_{50}$ .

### CALIBRATION AND VALIDATION DATA AND METHODOLOGY

For the calibration and validation of the models five different datasets have been used so far. An overview of the datasets used is provided in Table 1. Three datasets (1, 4 and 5) concern flume experiments, and sets 2 and 3 concern prototype data in a river and an estuary. In Tests 4 and 5 waves are imposed as well. The models are set up, and the forcings are imposed in a similar – simplified – manner as would have been done in an engineering application.

**Table 1. Datasets used for calibration and validation**

Test	Type of experiment	Conditions		Reference
1	Migration and sedimentation of a trench in a flow flume	Depth	0.39 m	Van Rijn (1986a, 1986b & 1987)
		Velocity	0.51 m/s	
		D50	0.16 mm	
2	Sedimentation of a trial trench in the River IJssel, the Netherlands	Depth	4 -7 m	Van Rijn (2001)
		Velocity	1.75 m/s	
		D50	0.6 mm	
3	Sedimentation of a trial channel in the Western Scheldt Estuary, the Netherlands	Depth	7.5 – 10.5 m	Van Rijn (1986a, 1986b & 1987)
		Velocity	0.5 – 1.1 m/s	
		D50	0.18 mm	
4	Migration and sedimentation of a trench in a waves and flow flume	Depth	0.24 m	Van Rijn (1986a & 1986b)
		Velocity	0.18 m/s	
		Wave height	0.08 m	
		Wave period	1.5 s	
		D50	0.16 mm	
5	Migration and sedimentation of a trench in a wave and flow basin	Depth	0.42 m	Havinga (1992)
		Velocity	0.24 m/s	
		Wave height	0.11 m	
		Wave period	2.2 s	
		D50	0.10 mm	

The calibration and validation of SEDTUBE using dataset 1 is described in detail in the next section. In addition, that section aims to provide insight into the model's sensitivity to parameter settings. It also shows the calibration results of SUSTIM2DV.

The section thereafter discusses more briefly the calibration of SEDTUBE and SUSTIM2DV using datasets 2 to 5, focusing on the end result. As SEDPIT only results in estimates of the siltation volumes and not on profile shapes, the validation and calibration of SEDPIT is discussed separately thereafter.

### CALIBRATION AND VALIDATION USING DATASET 1

Test 1 consists of three experiments with varying angles of the side slopes, namely 1:10, 1:7 and 1:3 referred to as Test 1.1, 1.2 and 1.3, respectively. This test is therefore suitable for calibration and validation.

Each test lasted 15 hours during which the feed of sediment was controlled at 0.04 kg/s/m. It is estimated that 0.01 kg/s/m took place as bed load transport and 0.03 kg/s/m as suspended load. Figure 4 depicts the profiles and the settings of the experiments.

Test 1.1 having the mildest slope of 1:10 is used for calibration, whilst sets 1.2 and 1.3 are used for validation. At the same time the calibration steps aim to provide insight into the sensitivity of the profile development to variations in the parameters  $f_\Lambda$ ,  $f_{Qb}$  and  $f_{Qs}$ .

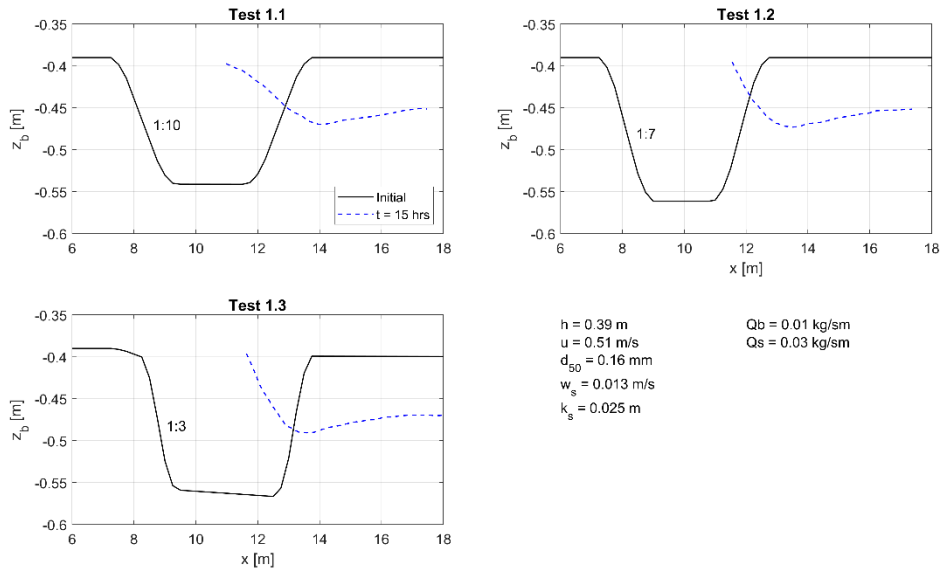


Figure 4. Initial profiles (in black), measured profiles after 15 hrs (dashed blue lines), and parameters of Tests 1.1 to 1.3

### Calibration of SEDTUBE

The step-by-step calibration of SEDTUBE using Test 1.1 is depicted in Figure 5. Table 2 summarizes the settings and the results of the calibration steps. The reported sediment fluxes are the fluxes at the upstream end of the flume and model.

With default settings SEDTUBE reproduces the bed and suspended sediment fluxes remarkably well. The predicted profile development, however, is not reproduced at all; the trench (red solid line) nearly vanishes contrary to what happened in the experiment. Adjusting  $f_A$  to 0.025 - calibration step 1 in Table 2 - does not affect the magnitude of sediment fluxes but greatly improves the prediction of the profile (dashed green line). It is remarkable though that  $f_A$  seems to have an opposite impact on the profile development as demonstrated in Figure 3; this may be attributed to the small scale of the trench. In a number of calibration steps, of which two are presented, the bed and suspended load calibration factors  $f_{Q_b}$  and  $f_{Q_s}$  are adjusted, aiming to reproduce the measured sediment fluxes and the profile development as well as possible.

The optimal setting for this test appears to be one in which bed and suspended load have an equal contribution to the total sediment transport in combination with a relatively small time lag factor  $f_A$ . The predicted total sediment flux matches exactly the one imposed in the laboratory test. To achieve that, the bed load transport is scaled with a factor 3.6 and the suspended load with a factor 0.6. It be noted that the in the test, the distinction between bed and suspended load was estimated meaning that the actual ratio between suspended and bed load might have been different than 3.

In conclusion, SEDTUBE with default settings yields an accurate prediction of the bed load and suspended load fluxes. In order to reproduce the profile development and maintaining the correct total sediment flux, the ratio of bed and suspended load had to be changed, and the factor  $f_A$  had to be reduced significantly.

Table 2. Settings and results of step-by-step calibration of SEDTUBE on Test 1.1

	$f_A$ [-]	$f_{Q_b}$ [-]	$f_{Q_s}$ [-]	$Q_b$ [kg/s/m]	$Q_s$ [kg/s/m]	$Q_t$ [kg/s/m]	$Q_s/Q_b$ [-]
Measured	n/a	n/a	n/a	0.01	0.03	0.04	3.0
Default	0.200	1.0	1.0	0.006	0.033	0.038	5.8
Step 1	0.025	1.0	1.0	0.006	0.033	0.038	5.8
Step 2	0.025	2.0	1.0	0.011	0.033	0.044	3.0
Calibrated	0.025	3.6	0.6	0.201	0.020	0.040	1.0

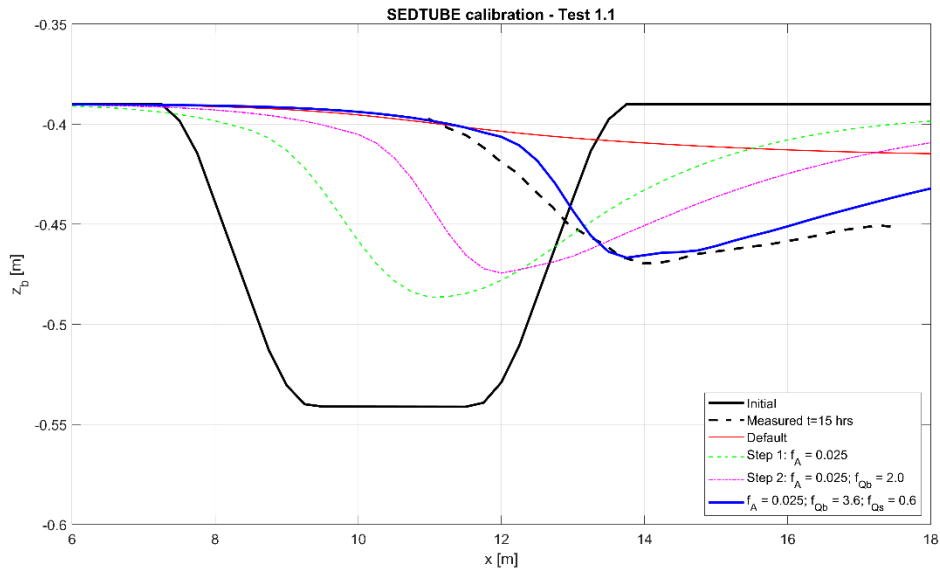


Figure 5. Step-by-step calibration of SEDTUBE on Test 1.1

### Validation of SEDTUBE

With the settings obtained from the calibration on Test 1.1, Tests 1.2 and 1.3 have been used to validate SEDTUBE and the derived settings. The predicted profiles after 15 hours for all three tests are presented in Figure 6. It demonstrates that with the derived settings, the model also accurately reproduces the profile development of Tests 1.2 and 1.3. SEDTUBE and the optimum settings are thus robust for changes in the slope of the trench, even for a fairly steep slope of 1:3.

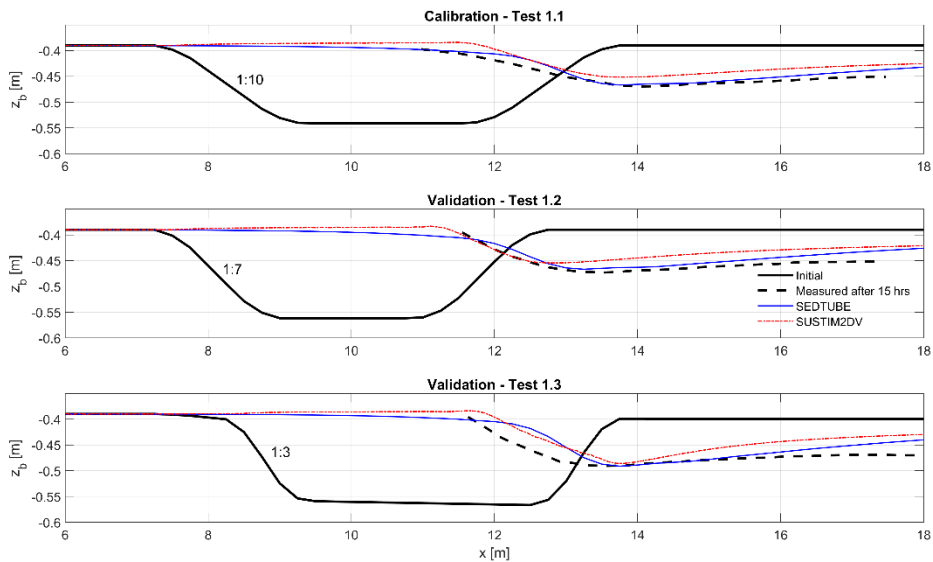


Figure 6. Calibration and validation of SEDTUBE on Tests 1.1 to 1.3 (solid blue line), and calibration of SUSTIM2DV (dash-dotted red line)

### Comparison of SEDTUBE and SUSTIM2DV

The calibration results of the SUSTIM2DV model are also depicted in Figure 6. Just like SEDTUBE, SUSTIM2DV is capable of accurately reproducing the measured bed profiles. In order to obtain these results, SUSTIM2DV is calibrated by adjusting the coefficient  $\alpha_c$  which scales the near bed sediment

concentration  $c_a$ , see Eq. 5. Optimum results are obtained for  $\alpha_c = 1.5$  instead of the default value of 1.0. As for SUSTIM2DV holds that the model is robust for changes in the slope of the trench.

### CALIBRATION USING DATASETS 2 to 5

In this section, the SEDTUBE and SUSTIM2DV models are calibrated using datasets 2 to 5, see Table 1.

#### Dataset 2 – IJssel River

This dataset concerns measurements of a trial trench in the River IJssel in the Netherlands with coarse bed sediment ( $d_{50} = 0.6$  mm), suggesting that bed load transport is the dominant mode of transport. Bathymetrical data is available after 30, 60 and 90 days, but only in a schematized form. For this case no SUSTIM2DV results are available. The discussion of this case focusses on SEDTUBE results after 30 and 60 days, see Figure 7.

These results are obtained with a calibration factor for bed load of 1.2 whereas suspended load transport is eliminated. This result of governing bed load transport matches well with what could be expected beforehand based on the current regime and the grain size. With this only slightly enhanced bed load transport, the time scale of the predicted changes matches the observed ones quite well. The low resolution of the bathymetrical data impedes a detailed comparison of profile shapes but the basic shape of the trench is fairly well reproduced by the model.

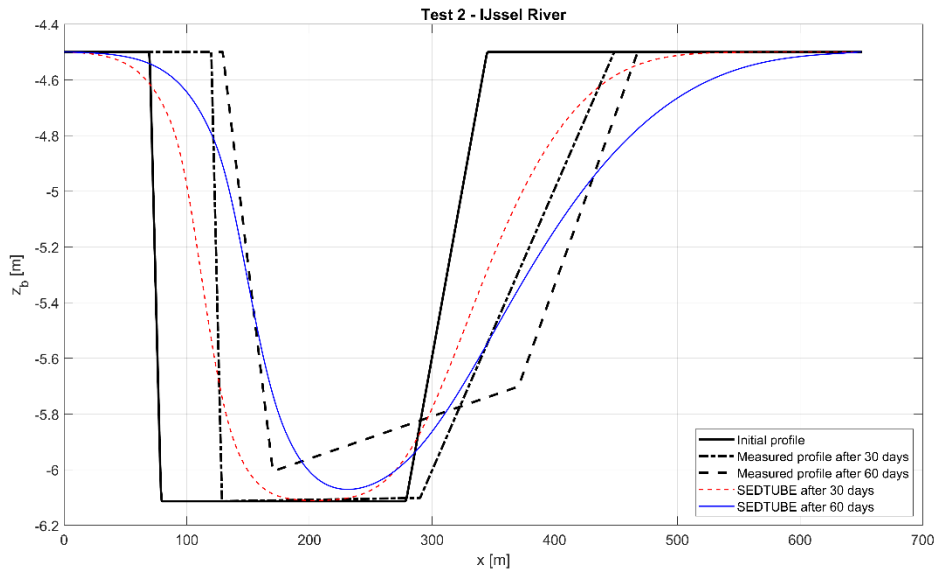


Figure 7. Calibration result of SEDTUBE for Test 2

#### Dataset 3 – Western Scheldt

Figure 8 depicts the initial profile and the measured profile after 22 days of a trench in the Western Scheldt estuary. The models are forced with current velocities measured for 12 hours, which are assumed representative for the entire simulation period of 22 days. Both SEDTUBE (solid blue line) and SUSTIM2DV (dash-dotted red line) are capable of reproducing the change in the bottom level of the trench, as well as a fair reproduction of the development of the left slope. A distinctive difference between the two models exists in the right slope, which is well represented by SUSTIM2DV but not so well by SEDTUBE.

SEDTUBE results are obtained by setting  $f_A$  to 0.020; no scaling of the bed and suspended load was required. Sediment transport in SEDTUBE is dominated by suspended load being nearly a factor 25 larger than the bed load at maximum current velocity. SUSTIM2DV results are obtained by applying a correction factor of 1.2 to both the bed and suspended load transport.

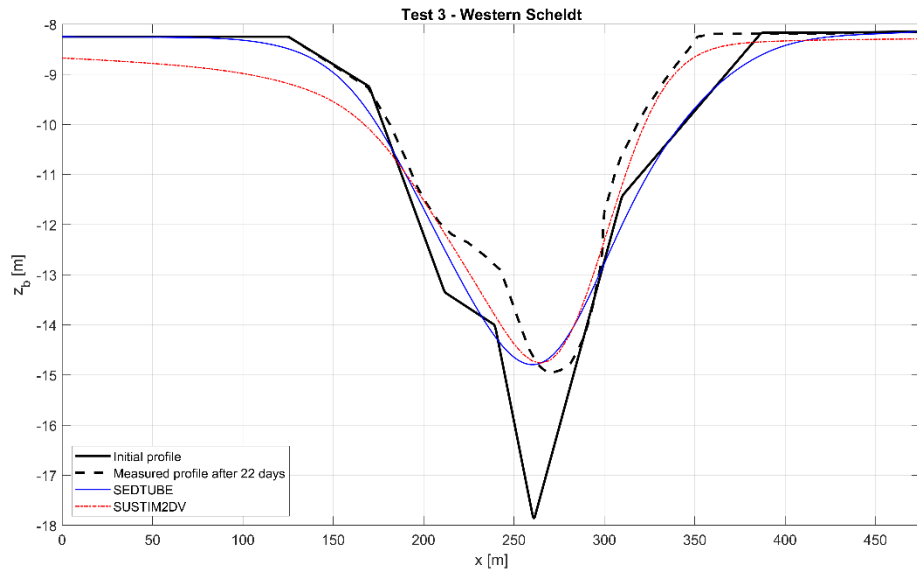


Figure 8. Calibration result of SEDTUBE (solid blue line) and SUSTIM2DV (dash-dotted red line) for Test 3

#### Dataset 4 – wave and flow flume

Figure 9 depicts the initial profile and the measured profile after 10 hours of a trench in a flow flume with wave forcing as well. SEDTUBE (solid blue line) is very well capable of reproducing the measured profile. Both the depth of the trench and the side slopes are well represented. This result is obtained by  $f_A = 0.050$ , and bed and suspended load scaling factors of 6.0 and 3.0. This means that with the default values the siltation of the trench is significantly underestimated. With the calibrated settings the ratio between suspended and bed load amounts to 2.2.

The SUSTIM2DV (dash-dotted red line) result is obtained with a suspended load scaling factor of 1.7 and setting bed load to zero. SUSTIM2DV overestimates the deposition at the upstream slope (left) and the erosion of the downstream slope (right). In addition, also the deposition of the bottom of the trench is slightly overestimated. These results suggest that the performance could be improved by a reduction of the suspended sediment flux, but a further calibration is not pursued.

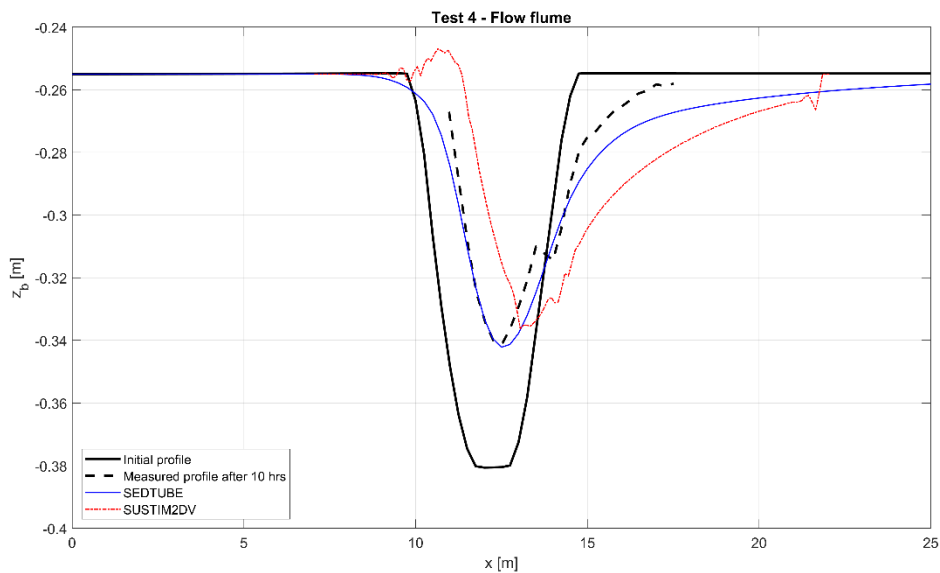


Figure 9. Calibration result of SEDTUBE (solid blue line) and SUSTIM2DV (dash-dotted red line) for Test 4

### Dataset 5 – wave and flow basin

Figure 10 depicts the initial profile and the measured profile after 25.5 hours of a trench in a wave and flow basin. SEDTUBE (solid blue line) is very well capable of reproducing the measured profile. Both the depth of the trench and the side slopes are well represented. This result is obtained by applying a bed load scaling factor of 5.0 and setting the suspended load factor to zero.

The SUSTIM2DV result is obtained with a suspended load scaling factor of 1.5 and setting bed load to zero. With these settings the siltation of the trench is overestimated. Also for this experiment holds that an improvement may be achieved by further reducing the sediment fluxes.

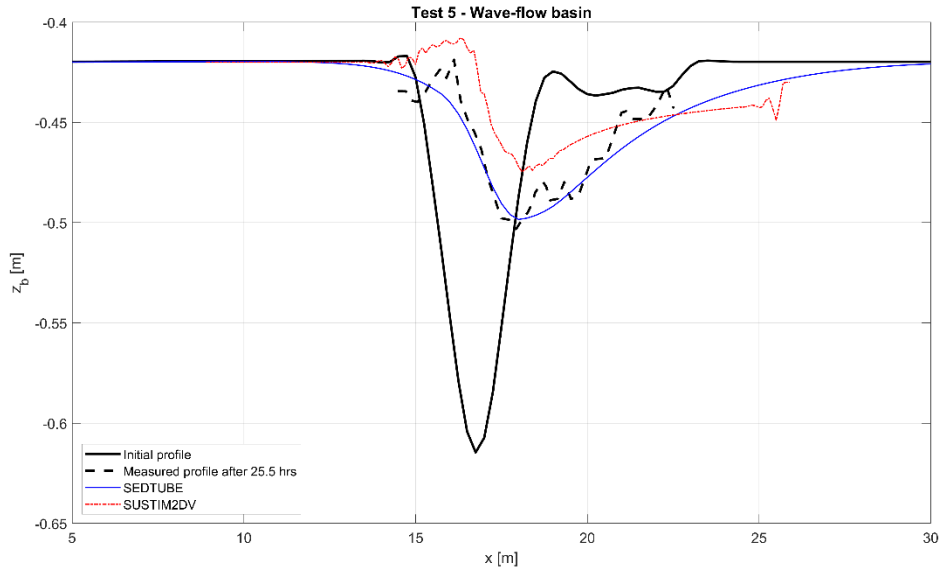


Figure 10. Calibration result of SEDTUBE (solid blue line) and SUSTIM2DV (dash-dotted red line) for Test 5

### Summary and discussion

Table 3 summarizes the optimum parameters settings for SEDTUBE and SUSTIM2DV for all five sets. It demonstrates that the optimum sets of parameter settings differ from test to test. However, for the prototype tests 2 and 3, SEDTUBE does not require large adjustments of sediment transport scaling factors except for the River IJssel case where the suspended load transport has to be eliminated. The required adjustments for the flume tests are quite large certainly when waves are involved (tests 4 and 5). A consistent result of the calibration of SEDTUBE is that the factor  $f_A$  should be a factor ten smaller than its default value of 0.2.

SUSTIM2DV requires limited adjustments of the sediment transport factors except for the need to set the bed load to zero in two flume tests. Note that this concerns the tests which may be improved by further calibration.

Table 3. Summary of optimized SEDTUBE and SUSTIM2DV settings

Test	Type	SEDTUBE				SUSTIM2DV	
		$f_A$ [-]	$f_{Ob}$ [-]	$f_{Os}$ [-]	$Q_s/Q_b$ [-]	$\alpha_c$ bed load [-]	$\alpha_c$ susp. load [-]
1	Flow flume	0.025	3.6	0.6	1.0	1.5	1.5
2	River IJssel	n/a	1.2	0	n/a	-	-
3	Western Scheldt	0.020	0.67	0.67	25	1.2	1.2
4	Wave & flow flume	0.050	6.0	3.0	2.2	0	1.7
5	Wave & flow basin	n/a	5.0	0	n/a	0	1.5

### CALIBRATION AND VALIDATION OF SEDPIT

In this section the calibration and validation results of SEDPIT using tests 1 to 3 are presented. Since the sand transport formulations in SEDPIT are identical to the ones in SEDTUBE, SEDPIT is validated using the default settings as well as the optimum SEDTUBE settings as per Table 3. In addition, the

optimum SEDPIT settings, obtained by calibration of SEDPIT, are determined. All results of the calibration and validation of SEDPIT are summarized in Table 4. Note that the calibration focusses on siltation volumes only.

With default settings, SEDPIT underestimates the siltation of the laboratory test 1 by 39 to 53%. On the other hand, it overestimates the siltation of the prototype tests 2 and 3 by 73 and 38% respectively.

Using the optimum SEDTUBE settings improves the siltation prediction of test 1 to a level that is acceptable in engineering practice, namely an underestimation between 19 to 33%. In test 2 the optimum SEDTUBE setting – i.e. no suspended load and  $f_{Qb}$  of 1.2 - changes the overestimation into a underestimation of 43%. For test 3 the optimum SEDTUBE setting – i.e.  $f_{Qs} = f_{Qb} = 0.67$  – yields an underestimation of only 4%.

In order to calibrate SEDPIT onto the measured siltation volumes, use is made of the sand calibration factor  $\alpha_s$ , that scales the bed load and suspended load to the same extent. This calibration factor is thus a factor to  $f_{Qb}$  and  $f_{Qs}$  as obtained from the SEDTUBE calibration, see Table 3.

First of all, it has to be remarked that the observed siltation volume of  $0.64 \text{ m}^3/\text{m}$  in test 1.3 is as large as the schematized trench volume, owing to a too simplified schematization. The trapping efficiency decreases with decreasing depth difference between the undisturbed bed and the bottom of the trench and therefore the siltation volume will only asymptotically approach a siltation volume equal to the trench volume. Hence the required large calibration coefficient of 3. The calibration result for Test 1.3 is therefore best be discarded.

For tests 1.1 and 1.2 a further enhancement of the sediment fluxes of 40 and 70%, respectively, is required. This relatively large increase of the sediment fluxes required to achieve a limited increase of the siltation volume is also mostly related to the decreasing trapping efficiency with decreasing depth difference.

**Table 4: Summary of the validation and calibration of SEDPIT**

Test	Observed siltation	Siltation with default settings		Siltation with optimum SEDTUBE settings		Calibration of SEDPIT
	[ $\text{m}^3/\text{m}$ ]	[ $\text{m}^3/\text{m}$ ]	$\Delta$	[ $\text{m}^3/\text{m}$ ]	$\Delta$	$\alpha_s$
1.1	0.59	0.36	-39%	0.48	-19%	1.4
1.2	0.61	0.33	-46%	0.46	-25%	1.7
1.3	0.64	0.30	-53%	0.43	-33%	(3.0)
2	148	256	+73%	84	-43%	1.9
3	228	315	+38%	218	-4%	1.05

## CONCLUSIONS AND RECOMMENDATIONS

By means of calibration using only two or three parameters, all three models SEDPIT, SEDTUBE and SUSTIM2DV are capable of reproducing measured bed levels and/or siltation volumes fairly accurately. It should also be noted that the models are set up in a similar way as is done in engineering practice, with a high degree of schematization of the hydrodynamic conditions. Given that, the calibrated models perform well.

The range in the optimum parameter settings of SUSTIM2DV is limited, making this quite a robust model, though for some tests the bed load component has to be eliminated. This means that without calibration data, SUSTIM2DV is expected to provide fairly accurate predictions of profile development and thus of siltation estimates, if the user knows whether bed load transport should best be eliminated.

For SEDTUBE there is a large difference between the prototype cases and the laboratory tests. The required calibration factors for bed and suspended load for the prototype tests are not so much deviating from 1, which for practical applications is beneficial. For laboratory tests, larger calibration factors are required, especially when waves are involved. The results for SEDTUBE also suggest that  $f_A$  should a factor ten smaller than the default value of 0.1 - 0.2, both for prototype and laboratory tests.

With default settings, SEDPIT seems to underestimate the siltation in laboratory tests, probably owing to the too strong decrease of the trapping efficiency with decreasing relative depth of the trench. For large-scale applications like tests 2 and 3, SEDPIT overestimates the siltation volumes. Using calibrated SEDTUBE settings significantly improves the predictions of SEDPIT, to an accuracy level that is acceptable for engineering practice.

For practical, prototype applications, in absence of calibration data, it is recommended to acknowledge that 1) SUSTIM2DV probably requires limited adjustment of the calibration factors, 2) SEDTUBE factor  $f_A$  should be about a factor 10 smaller than its default value, 3) SEDTUBE factors  $f_{Qs}$

and  $f_{0b}$  probably vary between 1 and 1.5 and 4) SEDPIT overestimates the siltation rates using default settings.

With these recommendations and use of common sense, the three models are useful tools to make predictions of siltation rates and slope deformation. Even more so if the models' sensitivities are elaborately studied or the models are used in a Monte Carlo approach, quantifying the uncertainty in the siltation rates.

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