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DG Rijkswaterstaat

Rijksinstituut voor Kust en Zee

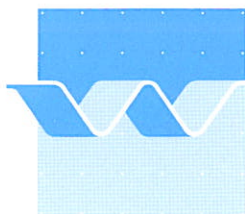# UNIBEST v204 documentation

Oktober 2000

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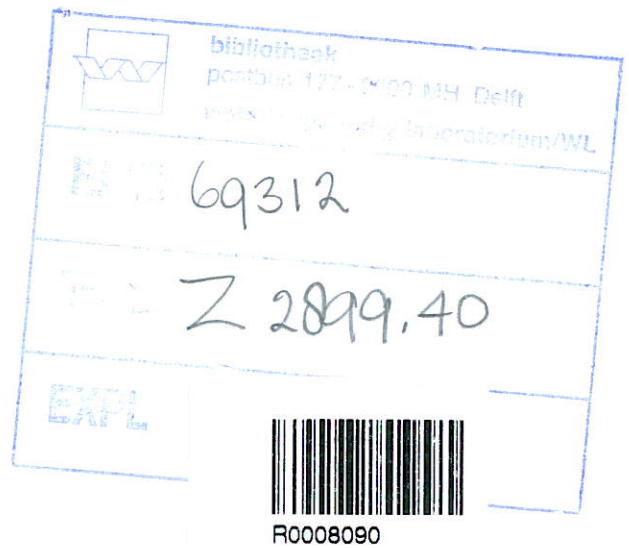
UNIBEST v204 documentation

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CLIENT:	DG Rijkswaterstaat; Rijksinstituut voor Kust en Zee

TITLE:	VOP2000 project 3.2: Improvement of UNIBEST-TC model

ABSTRACT:

This report describes the implementation and subsequent testing of several new expressions into UNIBEST-TC, a computer model predicting sediment transport in a cross-shore profile. The implementations made are:

1. wave asymmetry according to the Isobe (1982) formulation.
2. an engineering sand transport formula from TRANSPOR2000 (Van Rijn, 1999).
3. improved land boundary conditions according to Steetzel (1993).

The implementations have been tested by comparing results obtained with both the new and the original version of UNIBEST-TC with results from the engineering transport model TRANSPOR2000 and with laboratory tests in the Delta flume (LIP experiments). For the latter comparison use has been made of a test bank developed by Roelvink (2000).

The main conclusions are:
- In many (but not all) cases the calculated near-bed concentrations are much too high in the new UB version. This is mainly caused by a different expression for the efficiency factor for waves.
- The velocity profile to calculate suspended load transport remains unchanged.
- The 3rd order velocity moment is improved by implementation of the Isobe formulation. However, bed load transport formulation as function of the 3rd order velocity moment must be adapted to improve the prediction of bed load transport.
- Sediment transport at the land boundary is better described using the formulation of Steetzel (1993) than the formulation of Larson *et al.* (1990). The former formulation results in dune erosion by reducing the dune width instead of the dune height, which is more realistic.
- Linking the roughness values used for calculation of the suspended sediment transport to those for calculation of the velocity profile reduces the model performance for the present formulations.

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VER.	ORIGINATOR		DATE	REMARKS	REVIEW	APPROVED BY
2	T. van Kessel	TvK	27-10-2000		L.C. van Rijn 27/10	T. Schilperoort 27/10

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STATUS:	☐ PRELIMINARY	☐ DRAFT	☒ FINAL

Contents

Summary

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- Linking the roughness values used for calculation of the suspended sediment transport to those for calculation of the velocity profile reduces the model performance for the present formulations.

1   Introduction

Based on several evaluation studies, for example Egmond (Walstra *et al.*, 1999) and other experience with using Unibest-TC, a computer model predicting sediment transport in a cross-shore profile, the following weak points can be mentioned:

1. The landward migration of breaker bars during calm weather and the behaviour of the shoreface are not properly modelled owing to an insufficient accuracy of the prediction of net effects of the cross-shore transport mechanisms.
2. The present bottom slope formulations do not account for the combined effect of longshore current and bottom slope.
3. There is a clear need for a new 'engineering' sand transport formulation, in which also the wave related suspended sediment transport is taken into account (*e.g.* TRANSPOR2000)
4. Only one transport formulation can be chosen. The Bailard formulation is no longer operational.
5. The absence of long shore transport gradients is a clear limitation.
6. Modelling the wave-group bounded long waves and especially the phase difference between the long waves and the wave group, which influences the rate of sediment transport, should be paid attention to.
7. Unibest can not be used for a bimodal wave field, *i.e.* a wave field consisting of two separate contributions such as sea and swell.
8. The thickness of the wave boundary and its locally induced viscosity need attention in view of its large influence on the average near-bed velocity profile and sediment transport.
9. The coherence between the different modules of the UNIBEST-TC program is not optimal. For example, no relation exists between the viscosity profile and the diffusivity profile. In relation with this point, the expressions for bottom roughness (including input parameters) are not uniform.
10. Lateral mixing is neglected in the calculation of longshore current.
11. The calculation of sediment transport at the landward boundary results in an unrealistic profile development at the boundary.
12. The expressions for wave breaking should be improved.
13. The calculation of wave asymmetry can be improved, e.g. by implementation of the Isobe method.

In a discussion between WL and RIKZ it has been decided to prioritise items 3, 11 and 13 for the year 2000, *i.e.* wave asymmetry, an engineering sand transport formula and improved land boundary conditions. The implementation of improvements to the UNIBEST-TC model is carried out in the framework of the 'strategic cooperation' between RIKZ and WL (VOP2000 project 3.2).

This report has the following structure. In the next chapter the mathematical expressions are briefly discussed on which the adaptations are based. Implementation details are discussed in Appendices A and B. Chapter 3 presents test results obtained with the new version. Results are compared with the previous version of UNIBEST-TC, the engineering sand transport model TRANSPOR2000 and LIP11d experimental data. Finally conclusions are drawn in Chapter 4. Recommendations are made for further developments.

In this report only the changes made to the model are discussed and their implications for the end user. For a general overview of the model formulations the reader is referred to Bosboom *et al.* (2000). The UNIBEST-TC user manual (1999) discusses the methods to run the program.

2   Implementation of new formulations

2.1   Wave asymmetry

In the routine ISOBE the Rienecker and Fenton method to compute wave orbital velocities has been replaced with the Isobe and Horikawa (1982) method. The onshore and offshore wave velocity maxima U_{on} and U_{off} are calculated according to this method. The velocity time series are derived form these parameters according to $u(t) = z(4)\cos\omega t + z(5)\cos 2\omega t$ where $z(4) = (U_{on} + U_{off})/2$ and $z(5) = (U_{on} - U_{off})/2$.

The parameters U_{on} and U_{off} are also used to compute *factor*, needed to compute wave related suspended sediment transport:

$$factor = \gamma \, \frac{U_{on}^4 - U_{off}^4}{U_{on}^3 + U_{off}^3} \tag{1}$$

From Delta flume experiments it is derived that the 'wave efficiency factor' $\gamma = 0.2$. However, a recent analysis of Egmond COAST3D data suggests that $\gamma = 0.05$. For UNIBEST-TC a value of $\gamma = 0.2$ has been assumed, but it should be realised that this setting may not be optimal.

Details about the implementation are discussed in Appendix A. Implementation of the Isobe method does not result in any additional input parameter to be specified by the user.

2.2   Engineering sand transport formulation

The engineering sand transport formulation (TRANSPOR2000) discussed in Van Rijn (1999) is been implemented into UNIBEST-TC v204. The most important extension with respect to v203 is the modelling of wave-related suspended sediment transport. This should result in a better prediction of sand transport.

The basis for calculating wave-related suspended sediment transport is *factor* defined in Eq. (1). Wave-related suspended sediment transport s_w is subsequently calculated as $s_w = factor \int_0^{0.5} c \, dz$, where c is the suspended sediment concentration and z the vertical coordinate.

The expression for c_a, the near-bed reference concentration, is changed and also the (reference) level at which it is applied. Finally, some changes are made to the bed load transport formulation. The bed load transport q_b is now calculated as:

$$q_b = 0.5 \rho_s d_{50} D_*^{-0.3} \left[\left(\frac{\tau'_{b,cw}}{\rho} \right)^{0.5} \left(\frac{\tau'_{b,cw} - \tau_{b,cw}}{\tau_{b,cw}} \right) \right]^{1.0} \tag{2}$$

Details about the implementation are discussed in Appendix A. Implementation of engineering sand transport model does not result in any additional input parameter to be specified by the user.

2.3   Improved land boundary conditions

As the previous version of UNIBEST-TC resulted in unrealistic accretion at the waterline, the land boundary conditions have been improved. Sediment transport calculations stop when the water depth becomes too shallow, namely when the relative wave period T^*, defined by $T^* = T_p \sqrt{g / h}$, exceeds a user defined value. Here T_p is the peak period, g is the gravity acceleration and h is the water depth. The value of T^* differ for different orbital velocity models. The linear wave theory has a maximum relative wave period of 10. The generally applied value is some larger, around 40. After this point the sediment transport is linearly extrapolated to the last grid cell.

Steetzel (1993) proposed to extrapolate the sediment transport to the dry points with, instead of the relative distance, the relative altitude of these points. The formulation of the extrapolated sediment transport now becomes:

$$S(x) = S_s - \left[\frac{z(x) - z(x_s)}{z(x_e) - z(x_s)} \right] (S_s - S_e) \tag{3}$$

where $S(x)$ is the sediment transport at the dry points, S_s is the sediment transport in the last active point, x_s is the point where the calculation of the sediment transport stops, x_e is the last extrapolation point and S_e is the sediment transport in the last extrapolation point. Steetzel set the sediment transport at the end point of extrapolation (S_e) at a value of zero.

This model, together with the mass balance for sediment, leads to an advection description of the beach profile:

$$\frac{dz}{dt} + \frac{S_s - S_e}{z(x_e) - z(x_b)} \frac{dz}{dx} = 0 \tag{4}$$

Here $(S_s - S_e) / (z(x_e) - z(x_b))$ becomes the propagation speed of the dry beach. This model assumes a fixed shape of the dry area. If a sediment transport exists in the last active cell, the fixed shape shifts in cross-shore direction.

In the area between the shallow water (stop-point of calculating the sediment transport) and the dune face this model can generate unacceptable bottom irregularities. Steetzel coped with this problem by adding some numerical smoothing in the bottom variation equation (sediment mass balance).

3   Model testing and evaluation

The implementations discussed in Chapter 2 and Appendices A and B have been tested by comparison with TRANSPOR2000 results and LIP data (using the test bank developed by Roelvink, 2000). This comparison is discussed below.

3.1   Comparison between UNIBEST-TC and TRANSPOR2000

A comparison has been made among the new (v204) and old (v203c) versions of UNIBEST and the TRANSPOR2000 model. Although the expressions for bed load transport (including wave asymmetry) are the same for UBv204 and TRANSPOR2000, differences may be observed owing to different formulations for the vertical velocity profile and eddy diffusivity.

The comparison has been made using uniform conditions (constant depth) as specified in Table 1.

parameter name	symbol	value	dimension
depth	h	5	m
velocity in current direction	u	1	m/s
velocity in wave direction (bot.)	u	−0.02	m/s
velocity in wave direction (avg.)	u	−0.045	m/s
wave height	H_{rms}	1.5	m
significant wave height	H_s	2.12	m
wave period	T_p	7	s
temperature	T	15	°C
salinity	S	30	‰
wave related roughness	r_w	0.01	m
current related roughness	r_c	0.01	m
mean particle diameter	d_{50}	0.00025	m
90 percentile particle diameter	d_{90}	0.0005	m
mean diameter suspended sediment	d_s	0.00025	m
angle between current and waves	φ	90	deg

Table 1: Parameter settings for comparison of UNIBEST with TRANSPOR2000.

Figure 1 shows the vertical velocity profile in current direction. The old and new version of UNIBEST give identical results, as the model formulations have remained unchanged on this point. The velocity profile calculated by TRANPOR2000 is steeper than for UNIBEST: the near-bed velocity is lower, whereas the maximal velocity is higher.

Figure 2 shows the vertical velocity profile in wave direction. Again both UNIBEST versions give identical results. TRANSP2000 calculates a zero velocity in wave direction at the water surface (z=5 m). The velocity maximum is observed at z=2.8 m, for UNIBEST at z=1.9 m.

Figure 3 shows the vertical sediment concentration profile. Higher in the water column (z>1 m) the calculated concentration is higher for TRANSP2000 than for UNIBEST. Near the bed

($z<0.1$ m) the calculated concentration is higher for UNIBEST (both versions). Using a standard interpolation routine, the UNIBEST concentration profile is displayed down to a level of $z=0.01$ m, although the reference height in UB-v204 is 0.02 m. This causes the concentration at $z=0.01$ m to be about 8% higher than the reference concentration at $z=0.02$ m.
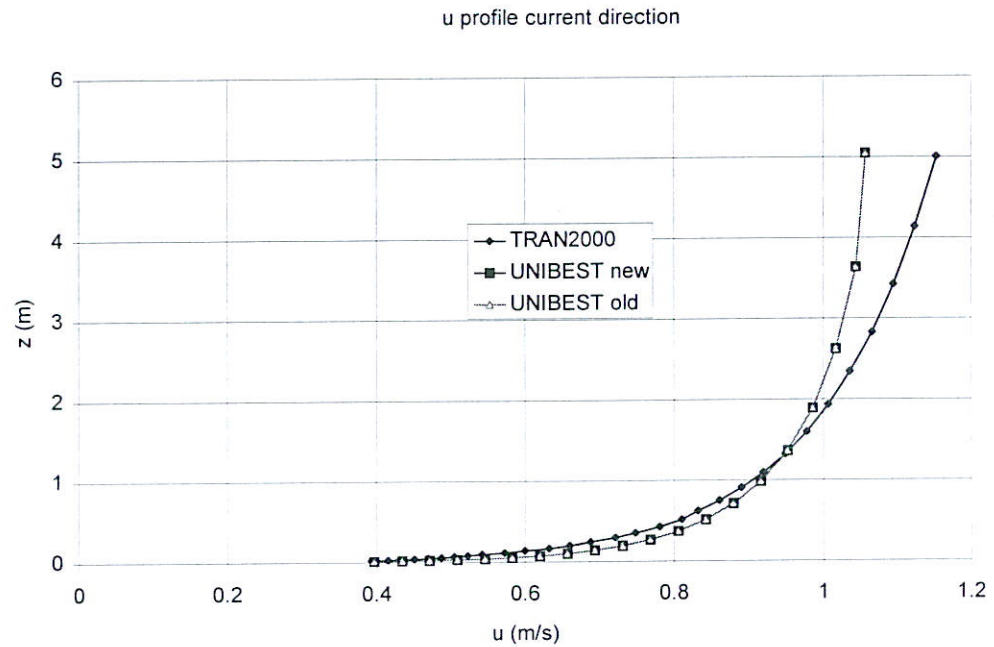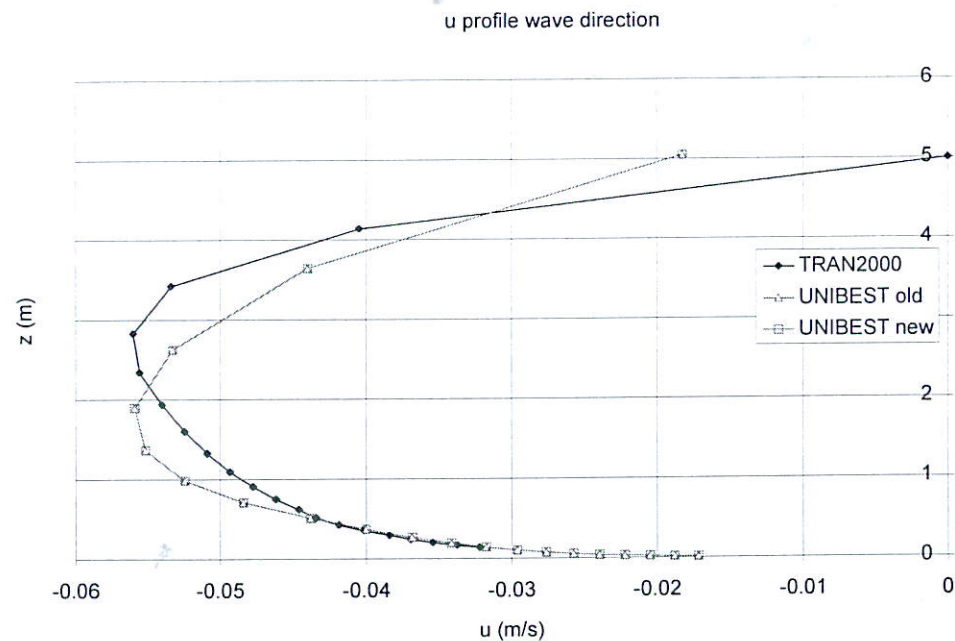
u profile current direction
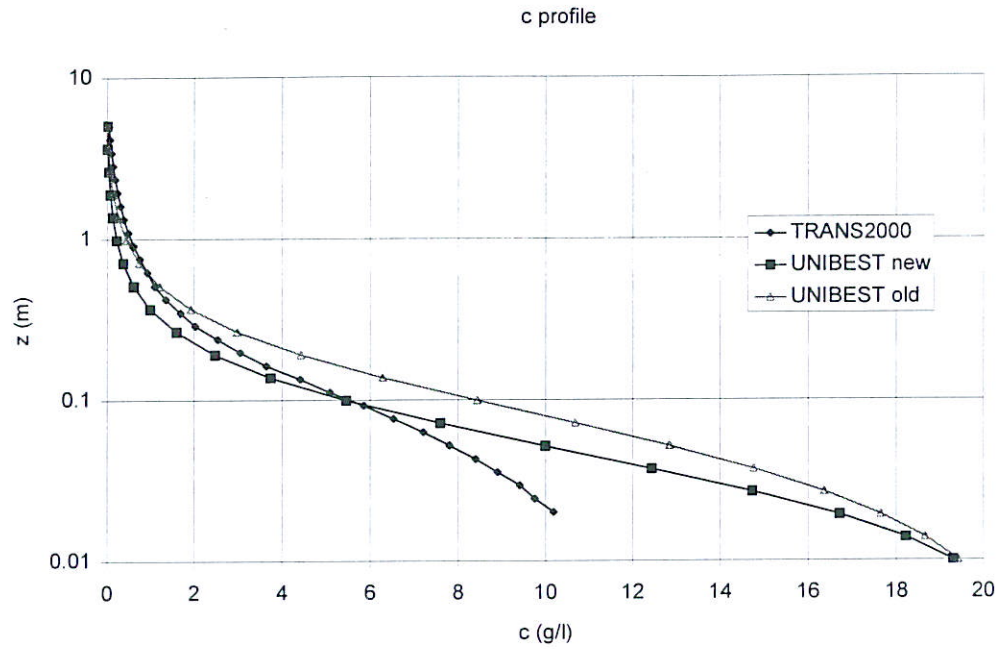

Figure 1: Velocity profile in current direction.

u profile wave direction

Figure 2: Velocity profile in wave direction.

c profile

Figure 3: Vertical sediment concentration profile.

suspended transport current direction
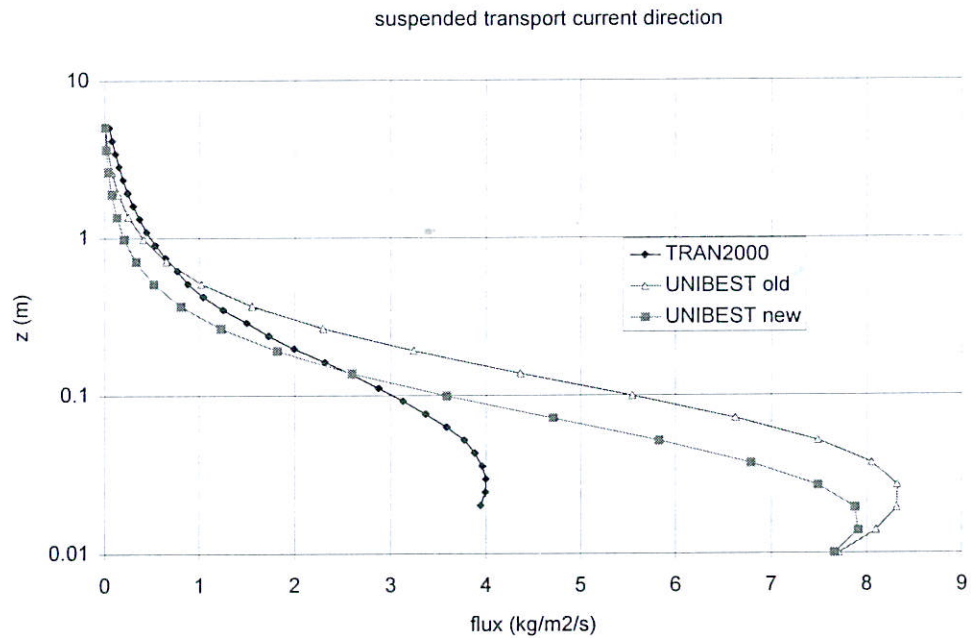

Figure 4: Sediment flux (in $kg/m^2/s$) in current direction.

Figure 4 shows the suspended sediment flux (in $kg/m^2/s$) in *current* direction. This flux is defined as the product of the velocity profile (Fig. 1) and the concentration profile (Fig. 3). Figure 5 shows the suspended sediment flux (in $kg/m^2/s$) in *wave* direction.

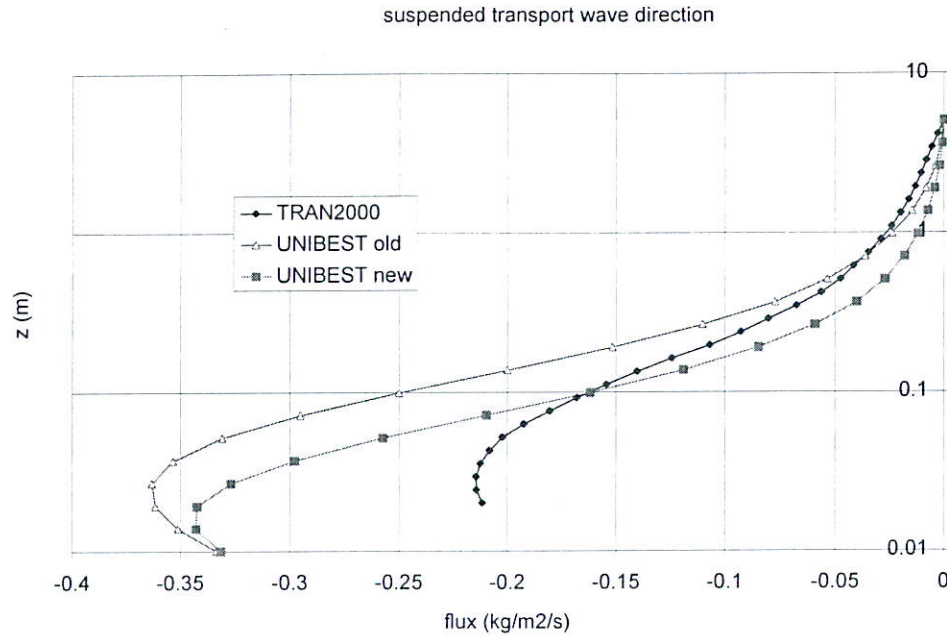suspended transport wave direction

Figure 5: Sediment flux (in kg/m²/s) in wave direction.

ubotx for bed load transport
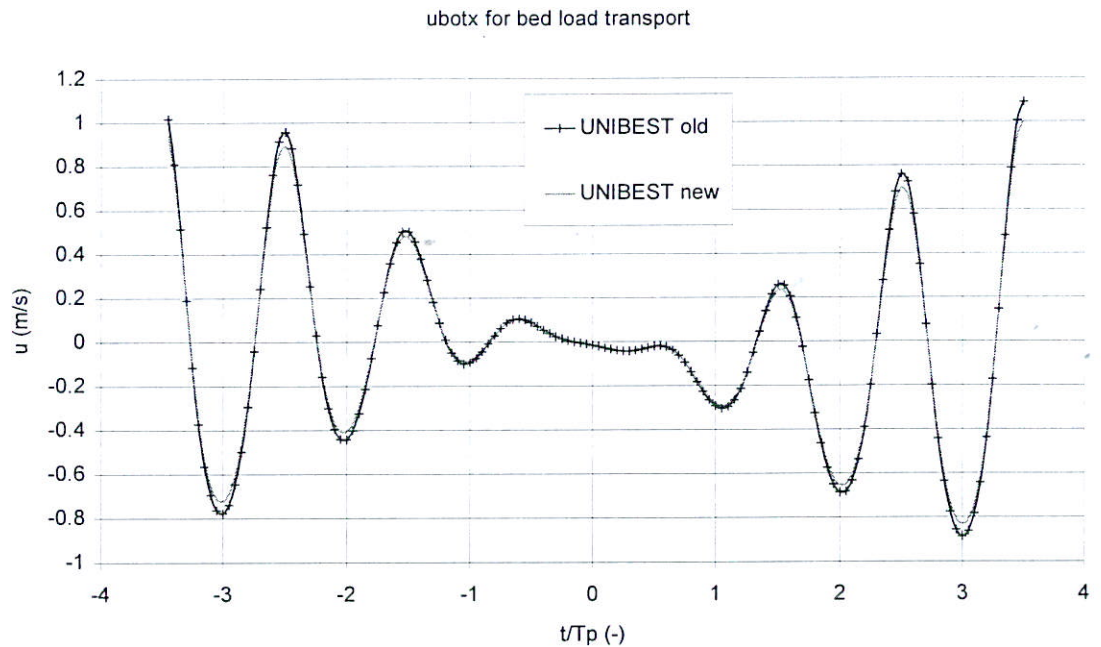
Figure 6: Velocity signal (in wave direction) used to calculate bed load transport. See also Table 2.

Figure 6 shows the near-bed velocity in time used to calculated bed load transport. The peak orbital velocity is slightly lower for the new version of UNIBEST than for the old version. In the former version the wave asymmetry is accounted for using the Isobe (1982) formulation. Resulting bed load transport is displayed in Table 2, together with the suspended sediment flux integrated over the vertical. Regarding suspended load, the old version of UNIBEST agrees better with TRANSPOR2000 than the new version, although the difference is small. Regarding the bed load transport, the difference between both versions

of UNIBEST and TRANSPOR2000 is large. Differences may be explained by the application of a wave group (Fig. 6) in UNIBEST to the bed load transport formulation, whereas in TRANSPOR2000 a single wave is used. The Isobe formulation for wave asymmetry results in a three times lower bed load transport.

The advantage of the Isobe formulation is a much better prediction of the third order velocity moment (see §3.2), which is an important input parameter for sediment transport formula. Adaptation of (some of) the remaining sediment transport parameters, which are presently calibrated applying a less accurate third order velocity moment, will result in better sediment transport predictions.

transport direction	UB new	UB old	TRANF	type
wave	0.0031	0.010	0.051	bed load
current	0.042	0.052	0.15	bed load
wave	−0.071	−0.12	−0.11	suspended load
current	1.50	2.41	2.03	suspended load

Table 2: Comparison of suspended and bed load transport (in kg/s/m) using several models and/or model versions.

3.2   Performance of UNIBEST-TC using the test bank

As a second test, UNIBEST results have been compared with LIP-data obtained in the wave tunnel. LIP11d test 1a has been selected. Use has been made of the test bank developed by Roelvink (2000). Figures 7–8 show the results regarding the new version of UNIBEST, whereas Figures 9–10 show the results regarding the old version of UNIBEST. Return flow profiles are not displayed, as both versions show identical results. Fig. 8 compared with Fig. 10 shows that the concentration profile in the new version is much steeper and in worse agreement with measured profiles. The difference is caused by the expression $\mu_w = 0.125$ $(1.5 - H_s/h_d)^2$ in the new version of UNIBEST instead of $\mu_w = 0.6/D^*$, where H_s is the significant wave height, h_d the water depth and D^* the non-dimensional grain size. As a result, the efficiency factor for waves μ_w is significantly higher in the new version of UNIBEST (about 2 times in experiment LIP11d, test 1a), increasing the bed shear stress and reference concentration. Fig. 11 shows the concentration profiles for the new version of UNIBEST, but with the original expression for μ_w. Calculated concentrations are now much closer to the measured concentrations.

In Fig. 3 no large concentration difference was observed between the old and new version of UNIBEST. This can be explained by different parameter settings (water depth, wave height and period, etc.).

Fig. 7 compared with Fig. 9 shows that the 3rd order velocity moment for the new UB version better agrees with the measured data. This can be explained by the implementation of the Isobe formulation for wave asymmetry.

The total sediment flux is predicted worse in the new version, mainly due to a larger suspended load transport term (compare Figs. 12 and 13). This is a direct result from the too high suspended sediment concentration.

Unibest-TC
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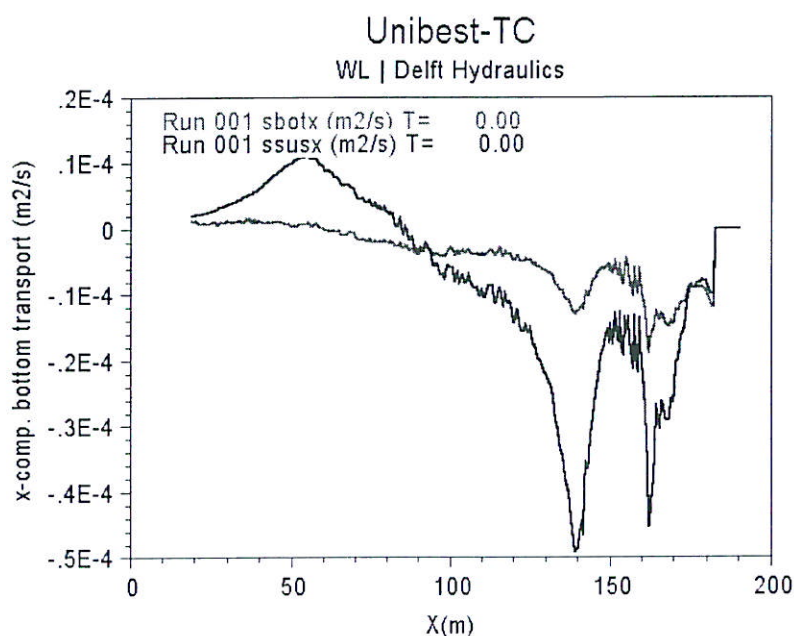
Fig. 12: Suspended en bed load transport calculated with new version of UNIBEST for dataset lip11d - test 1a.
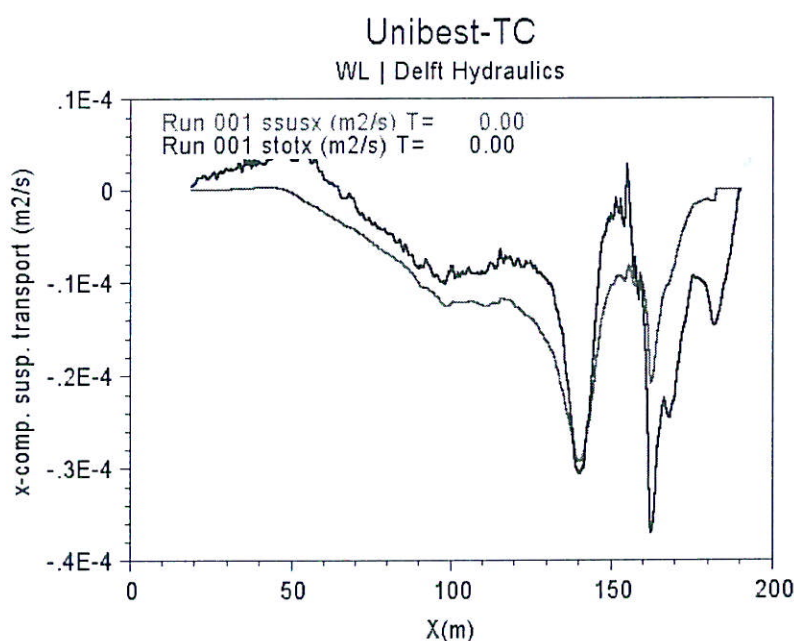
Unibest-TC
WL | Delft Hydraulics

Fig. 13: Suspended en bed load transport calculated with original version of UNIBEST for dataset lip11d - test 1a.

3.3   Improvement of land boundary conditions

Implementation of improved land boundary conditions according to Steetzel (1993) has been performed by Gootjes (2000). The implementation is tested using LIP11D data, test 2E. Here only a concise description of the implementation is presented; for more details the reader is referred to Gootjes (2000).

3.3.1   Description of test LIP11D, 2E

The test LIP11D,2E simulates a storm surge on a sand beach. The water level is around 4.6 meter above the concrete bottom. The waves that are generated by the wave board has a wave height (H_{rms}) of one meter and a peak period of five seconds. The grain diameter of the used sand is 0.22 mm. The test was carried out in the Delta Flume at WL | delft hydraulics in 1993 (de Voorst).

The bottom profile was measured with an automatic profile follower (PROVO) after each hour. In Figure 14 the profile is shown before the test begins (initial bottom profile), after six hours, after 12 hours and after 18 hours (end of the test). In a lose look at the profile of the dunes a clear transition of the bed slope at a height of 5.2 meter is seen. The bed slopes below and above this value do not change much in time.
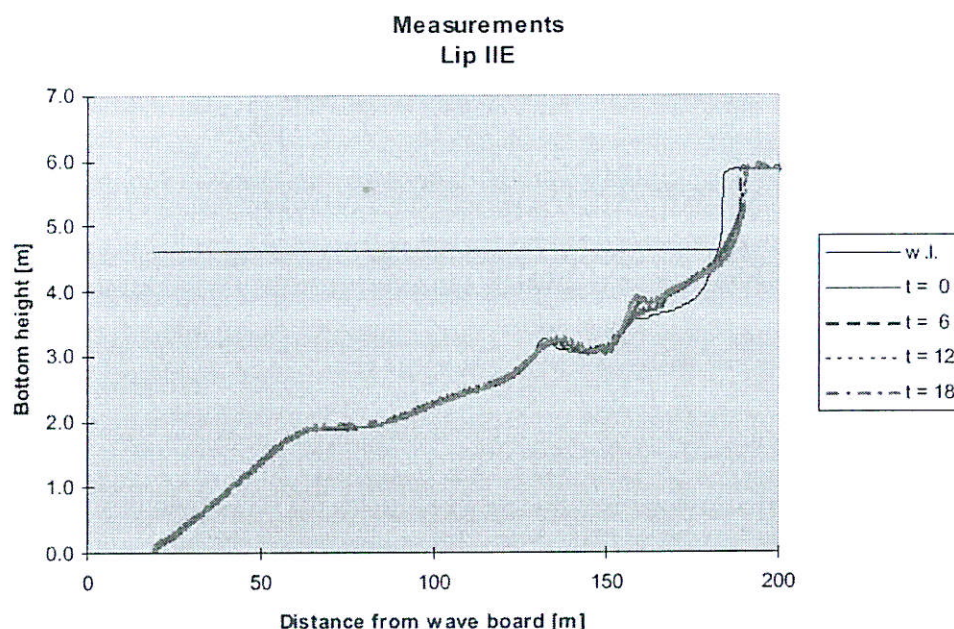
Figure 14 Measured profile development, LIP11D, test 2E.

3.3.2   Set up of the model

The calculation domain has a varying grid size. The first 100 ells have a grid size of one meter, hereafter a part of 250 cells with a half meter cell width is applied. The grid size varies to get a detailed calculation at the region of interest (near the waterline) and to limit the number of cells. The applied time step is one minute. The simulation period is 18 hours,

the time that the bottom change is measured. The LIP 2E model for UNIBEST-TC was not calibrated with the measurements, as this was not the primary goal of this work.

3.3.3 Results of original formulation

The results of the calculation of the bed level based on the original UNIBEST-TC formulation (based on Larson *et al.*, 1990) are presented in Figure 15. The bed level varies the most in the shallow and dry areas. The longer the simulation takes place the less changes there are in the bed levels. The profile comes closer to an equilibrium profile. The calculations of the bed level variation at the dry part do not match the measurements. The sediment transport is not well extrapolated on the dry part of the profile. In the next calculation the extrapolation model of Steetzel (1993) is applied.
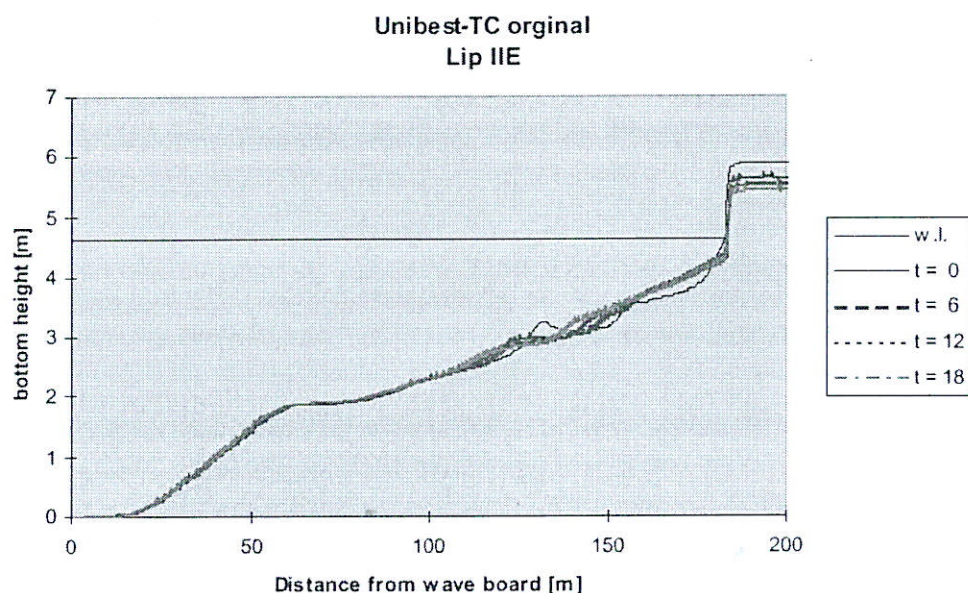
Figure 15 Computed bed level change, Unibest-TC, original boundary condition.

3.3.4 Results of adapted formulation

The input of the calculation is the same as described in the previous section. Only the distribution on the dry part of the profile is changed. The bottom changes are visualised in Figure 16. The extrapolation model of Steetzel (1993) gives, in this test case, a better representation of the measured bottom changes than the extrapolation model that is included in the original version of UNIBEST-TC.
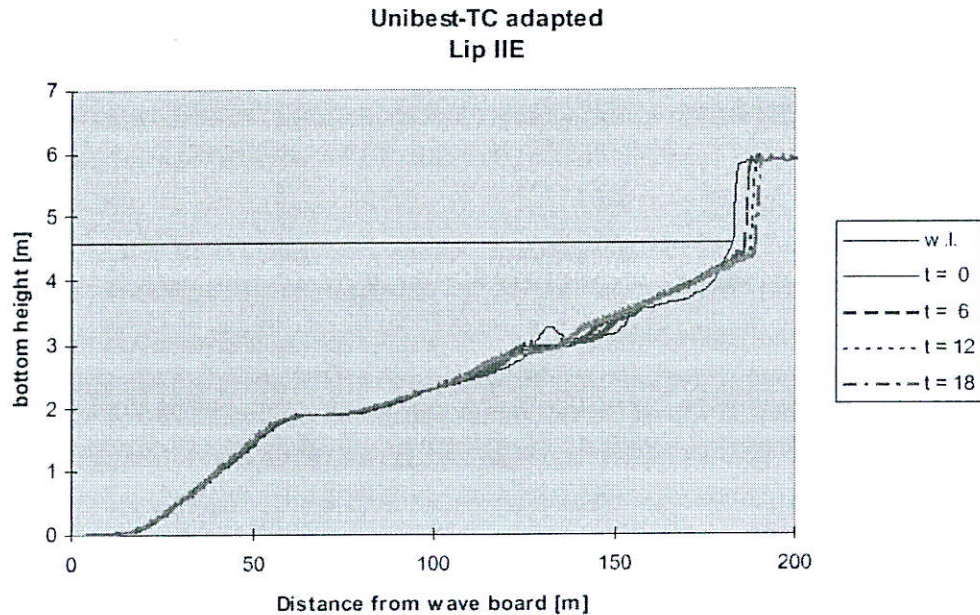
Unibest-TC adapted
Lip IIE

Figure 16 Computed bed level change, Unibest-TC, improved boundary condition

3.4 Unification of roughness parameters

In the current version of UNIBEST-TC, four roughness parameters have to be supplied by the user, i.e. the wave friction factor f_w (FWEE) used in the wave propagation model, the current roughness k_w (RKVAL) used in the mean current profile model and the wave and current related roughness $k_{s,w}$ (RW) and $k_{s,c}$ (RC) used in the suspended load model. This number should be reduced to two, as there is a strong physical link between the viscosity profile (related to f_w and k_w) and the diffusivity profile (related to $k_{s,w}$ and $k_{s,c}$). However, if in the current version of UNIBEST-TC f_w is set equal to $k_{s,w}$ and k_w equal to $k_{s,c}$, the agreement with experimental data becomes less. Unification of the roughness parameter therefore requires an adaptation of the expression either for the viscosity profile or the diffusivity profile. This should be a part of future work for UNIBEST-TC improvement.

4   Conclusions

A new version (v204) of UNIBEST-TC has been developed including the following additions:

1. wave asymmetry according to the Isobe (1982) formulation.
2. an engineering sand transport formula including wave related suspended sediment transport according to Van Rijn (1999).
3. improved land boundary conditions according to Steetzel (1993) regarding sediment exchange between the surf zone and the dry beach and dunes.

The model has been tested by comparison with (1) the previous version of UNIBEST-TC; (2) the engineering sand transport model TRANSPOR2000 and (3) Lip11d experiments. The following points are concluded.

- In many (but not all) cases the calculated near-bed concentrations are much too high in the new UB version, primarily caused by a different expression of the wave efficiency factor μ_w. Further model calibration is needed.
- The velocity profile to calculate suspended load transport remains unchanged.
- The 3rd order velocity moment is improved by implementation of the Isobe formulation. However, bed load transport formulation as function of the 3rd order velocity moment must be adapted to improve the prediction of bed load transport.
- Sediment transport at the land boundary is better described using the formulation of Steetzel (1993) than the formulation of Larson *et al.* (1990). The former formulation results in dune erosion by reducing the dune width instead of the dune height, which is more realistic.
- Linking the roughness values used for calculation of the suspended sediment transport to those for calculation of the velocity profile reduces the model performance for the present model formulations.

It is advised that prior to further improvements to the UNIBEST-TC model (a list of which is presented in §1), the current shortcomings of the UB model after implementation of the Isobe model for wave asymmetry and an engineering bed load transport formulation should be resolved first. As a first step, the deviation between model results and experimental data can probably be strongly reduced by calibration. Nevertheless further analysis of the ranges of validity of the empirical expressions used remains necessary. It should also be assessed to what extent results from more detailed models describing the physics of sand transport by current and waves may practically be implemented into UNIBEST-TC, reducing the need for empirical expressions.

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Appendices

A: Implementation of new expressions in UNIBEST v204c

TRAVEL.FOR

In TRAVEL.FOR the call to MAKSER.FOR is replaced with a call to ISOBE.FOR. The latter routine is based on the former. The main difference is that the Rienecker and Fenton method to compute wave orbital velocities has been replaced with the Isobe and Horikawa (1982) method. These changes are discussed in some more detail below. In a later stage of the project, the call to either ISOBE or MAKSER will be made user-selectable.

TRANSP.FOR

Additional parameters included into TRANSP are `factor` to account for wave-related suspended sediment transport and `theta`, the wave angle. `factor` is calculated in ISOBE from the orbital velocities; `theta` is needed to decompose the wave related suspended transport into the x and y directions.

In the calculation of `ca`, the near-bed reference concentration, the following is changed:

- the minimum value of `a` is set at 0.02
- the maximum value of `rmuc` is set at 1
- the calculation of `rmuwa` is changed

In the calculation of `dc/dy`, the expression for `ds`, the thickness of the sediment mixing layer, has been changed, including the `gambr` parameter. Also the expression for `emaxw` has been changed.

In the calculation of RMAT an expression for `ssw` has bee added to account for the wave-related suspended sediment transport. The integral `ssasym` $= \int_{0}^{0.5} c\,dz$ is calculated. Subsequently, `ssw` is calculates from `ssw=faktor*ssasym`. `faktor` is calculated in ISOBE.FOR. The total (both wave and current related) suspended transport in x and y direction is calculated from `ssx=ssx+ cos(theta)*ssw` and `ssy=ssy+sin(theta)*ssw`, where `ssx` and `ssy` on the right hand side of the =-sign are the current related suspended sediment transports calculated in TRANSP (unchanged). Here `theta` is the wave angle.

Finally, some changes are made to the bed load transport formulation. The bed load transport is calculated as:

$$q_b = 0.5\rho_s d_{50} D_*^{-0.3} \left[\left(\frac{\tau'_{b,cw}}{\rho} \right)^{0.5} \left(\frac{\tau'_{b,cw} - \tau_{b,cw}}{\tau_{b,cw}} \right) \right]^{1.0} \tag{1}$$

Details of the changes can be found in Appendix B.

MAKSER.FOR → ISOBE.FOR

MAKSER is renamed into ISOBE to avoid confusion. In ISOBE the Rienecker and Fenton method to compute wave orbital velocities has been replaced with the Isobe and Horikawa method. ubwfor and ubwback are calculated according to this method. The velocity time series are derived form these parameters according to $u_1 = z(4)\cos\omega t + z(5)\cos 2\omega t$ where z(4)=(ubwfor+ubwback)/2 and z(5)=(ubwfor-ubwback)/2. These amplitudes are used instead of the amplitudes derived from the Rienecker and Fenton amplitude table. To calculate ubwfor and ubwback, the parameters hs (significant wave height), hd (water depth), rls (wave length based on peak period), ubw (peak orbital velocity) and tp1 (relative wave period) are needed. These are calculated according to:

- hs = √2 hrms;
- hd is known;
- rls = 2π/km;
- ubw = uorb (**attention!**) and
- tp1=tp (waves perpendicular to currents).

The parameters on the right hand side of the equations above are all known prior to calling ISOBE except km, which is calculated within ISOBE.

ubwfor and ubwback are also used to compute faktor, needed to compute wave related suspended sediment transport in TRANSP:

$$\text{faktor} = \gamma \frac{U_{on}^4 - U_{off}^4}{U_{on}^3 + U_{off}^3}, \text{ where } \gamma = 0.2. \tag{2}$$

Apart from these changes, ISOBE is identical to MAKSER. The exact differences between the modified files and the original v203c files are listed in Appendix B, which is obtained using a file comparison tool.

During a later stage it will be assessed if the four friction parameters (fwee, rkval, rw, rc) can be decreased to two (rw and rc, for example) without decreasing the model performance. This change would make a proper choice of the parameter values more straightforward.

B : File changes with respect to UNIBEST v203c

TRAVEL.FOR

```
Compare: (<) F:\My_Documents\Z2899(UnibestJB)\unibest-code\vxxx\travel.for
    with: (>) F:\My_Documents\Z2899(UnibestJB)\unibest-code\v203c(origineel)\travel.for


101,107c101,105
< c   Is this statement required at this location?
<          dzbdy=0.
<          call isobe (hrms   ,hd      ,tp       ,corr,
<       *               n      ,m       ,uorb    , dzbdx, dzbdy,
<       *               u1     ,u2      ,u3       ,u4     , faktor,
<       *               stdvu  ,stdvhi,stdvlo ,
<       *               gu2u   ,guss    ,guls,tabel,iih,iit)
---
>          call makser (hrms   ,hd      ,tp       ,corr,
>       *                n      ,m       ,
>       *                u1     ,u2      ,u3       ,u4     ,
>       *                stdvu  ,stdvhi,stdvlo ,
>       *                gu2u   ,guss    ,guls,tabel,iih,iit)
158c156
<          dzbdy=0.
---
>          dzbdy=0.
171c169
<       *               c,cux,cuy,uxmean,uymean,faktor,theta)
---
>       *               c,cux,cuy,uxmean,uymean)
```

TRANSP.FOR

```
Compare: (<) F:\My_Documents\Z2899(UnibestJB)\unibest-code\vxxx\transp.for
    with: (>) F:\My_Documents\Z2899(UnibestJB)\unibest-code\v203c(origineel)\transp.for


4c4
<       *                     uxmean,uymean,faktor,theta)
---
>       *                     uxmean,uymean)
13c13
< c  dsscor          : diameter suspensiemateriaal
---
> c  dsscor          : diameter suspensiemateriaal
87,91d87
< C TvK: change!
<        if(a.le.0.02)a=0.02
< C TvK: change commented out as this leads to a twice as high reference level
< C TvK: for the LIP experiments (a=max(rc,rw)=0.01 -> a=0.02)
< C TvK: concentration profile then becomes too steep
99,103c94,95
< C TvK: change!
<        if(rmuc.gt.1.)rmuc=1.
<        reffect=(1.5-HS/HD)**2.
<        if(Reffect.le.0.5)reffect=0.5
<        RMUWA=0.125*reffect
---
>        rmuwa=0.6/dster
>        if(dster.gt.10.)rmuwa=0.06
156,166c148,154
```

```
<   C TvK: change!
<         gambr=1.
<           hs=1.41*hrms
<         if(hs/hd.gt.0.4)gambr=1.+((HS/hd)-0.4)**0.5
<         DS=5.*gambr*DELW
<         if(ds.le.10.*rw)ds=10.*gambr*rw
<         if(ds.gt.0.5)ds=0.5
<         if(ds.le.0.1)ds=0.1
<         ebw=.004*dster*ds*ubw
<         if (tp.ge.1.) then
<            emaxw=0.035*gambr*hd*hs/tp
---
>         hs=1.41*hrms
>         ds=0.3*hd*(hs/hd)**0.5
>         if(ds.gt.0.2)ds=0.2
>         if(ds.le.0.05)ds=0.05
>         ebw=.004*dster*ds*ubw
>         if (tp.ge.1.) then
>            emaxw=0.035*hd*hs/tp
214d202
<         ssasym=0.
267,279c254,256
< c
< c TvK: integration of c over z (near bed, up to z=0.5 m)
< c to account for wave related suspension transport
< c
<           if(zz.le.0.5)then
<             ssasym=ssasym+(rmat(it,2)+rmat(it-1,2))/2.*dz
<           endif
< c TvK: end of integration from bottom to z=0.5 m)
<           it = it+1
<       if (.not. bo) goto 100
<
<        ssw=faktor*ssasym
<
---
>           it = it+1
>       if (.not. bo) goto 100
> c
297,304c274
< c TvK: add wave-related suspension transport to current transport
< c note that ssw is in wave direction,
< c whereas ssx and ssy are in (x,y)-direction
< c correction with angle theta between wave and x direction
<       ssx=ssx+cos(theta)*ssw
<        ssy=ssy+sin(theta)*ssw
< c TvK end of implementation
<       do 255 i=1,nz
---
>       do 255 i=1,nz
327d297
< c      TvK: identical to TRANFRAC: not changed
357,358d326
< c      TvK: different from TRANFRAC: sbt formulation changed
< c
364c331
<             udtvec=(ud(i)**2+vd(i)**2)**0.5
---
>             udtvec=(ud(i)**2+vd(i)**2)**0.5
371,390c338,339
< C TvK begin origibal UB bed load transport formulation
< C          if(arg.gt.0.)then
< C            sbt=9.1*fak2*rhos*fsl1*arg**1.8
< C          else
< C            sbt=0.
< C          endif
< C TvK end origibal UB bed load transport formulation C
< C
< C
< C TvK begin TRANFRAC bed load transport implementation
< C TvK note: next statement only valid if percentage mud <= 1%
```

```
   <          taucr1=taucr
< C TvK end note
   <          taucr2=taucr1*fsl2
   <          tt=(tault-taucr2*(dsscor/d50cor))/
   <      *(taucr*(dsscor/d50cor)**0.5)
   <          tt=max(0.0001,tt)
   <          uster1t=(tault/rhow)**0.5
   <          if(arg.gt.0.)then
   <            sbt=0.5*fsl1*dsscor*rhos*uster1t*tt**1.0/(dster**0.3)
---
   >          if(arg.gt.0.)then
   >            sbt=9.1*fak2*rhos*fsl1*arg**1.8
394,395d343
< C TvK end TRANFRAC bed load transport implementation
< C
```

MAKSER.FOR → ISOBE.FOR

```
Compare: (<) F:\My_Documents\Z2899(UnibestJB)\unibest-code\vxxx\isobe.for
   with: (>) F:\My_Documents\Z2899(UnibestJB)\unibest-code\v203c(origineel)\makser.for


1,3c1,3
   <          subroutine isobe (hrms   ,hd      ,Tp      ,corr,
   <      &                     n      ,m       ,uorb    ,dzbdx   ,dzbdy,
   <      &                     u1     ,u2      ,u3      ,u4      , faktor,
---
   >          subroutine makser (hrms   ,hd      ,Tp      ,corr,
   >      &                     n      ,m       ,
   >      &                     u1     ,u2      ,u3      ,u4      ,
9,14c9,12
< * ISOBE generates a representative time-series of the bottom orbital    *
< * velocity, to be used in the computation of bottom transports. The     *
< * time-series is required to exhibit a realistic amplitude modulation,  *
< * non-linearity and long-wave influence.                               *
< * ISOBE is an adaptation of the MAKSER routine by Thijs van Kessel      *
< * d.d.  06-06-200                                                       *
---
> * MAKSER generates a representative time-series of the bottom orbital   *
> * velocity, to be used in the computation of bottom transports. The     *
> * time-series is required to exhibit a realistic amplitude modulation,  *
> * non-linearity and long-wave influence                                *
19,22c17,20
< * Isobe and Horikawa model:                                             *
< *            u1 =  sum (u_k cos (k omega t) ), k=1,2                     *
< * Second, this time series is modulated, according to:                  *
< *            u2 =  sum (u_k cos (k omega t) eps^k ), k=1,2               *
---
> * Rienecker and Fenton model:                                           *
> *            u1 =  sum (u_k cos (k omega t) ), k=1,8                     *
> * Second, this time series is modulated, according to:                  *
> *            u2 =  sum (u_k cos (k omega t) eps^k ), k=1,8               *
34a32
> * Qb         I   Real   1      Fraction of breaking waves               *
85c84
< *      call of ISOBE
---
> *      call of MAKSER
97c96
   <          do 3 i=1,2
---
   >          do 3 i=1,8
111a110,121
   >          do 5 it=1,iit
   >            do 6 ih=1,iih
   >              if (ih.gt.1) then
   >                do 7 if=4,11
   >                  if (tabel(if,ih,it).lt.tabel(if,ih-1,it)) then
   >                    tabel(if,ih,it)=tabel(if,ih-1,it)
   >                  endif
```

```
>   7                continue
>                 endif
>   6           continue
>   5      continue
>
135a146,164
>  *      Interpolate Fourier components of dimensionless velocity from
>  *      table
>  *----------------------------------------------------------------------
>         ih0=int(h0/dh)
>         it0=int(T0/dt)
>         ih1=ih0+1
>         it1=it0+1
>         p=(h0-ih0*dh)/dh
>         q=(T0-it0*dt)/dt
>
>         f0=(1.-p)*(1.-q)
>         f1=p*(1.-q)
>         f2=q*(1.-p)
>         f3=p*q
>
>         do 20 if=4,11
>            z(if)=f0*tabel(if,ih0,it0)+f1*tabel(if,ih1,it0)+
>     *           f2*tabel(if,ih0,it1)+f3*tabel(if,ih1,it1)
>  20     continue
170,211d200
<  c
<  c      asymmetrie ISOBE
<  *----------------------------------------------------------------------
<         hs=1.4142*hrms
<          rhs=hs/hd
<         rls=2.*pi/km
<          r11=1.
<         r22=3.2*(hs/rls)**0.65
<         r33=(hs/rls)**(3.4*hd/rls)
<         rr=r11-r22*r33
<  C TvK note that in TRANFRAC ubw = TRANSPOR uorb ...
<          umax=rr*2.*uorb
<         t1=tp*(g/hd)**0.5
<         uliso=umax/(g*hd)**0.5
<         a55=0.0032*t1**2+0.00008*t1**3
<         if(t1.gt.30.)a55=0.0056*t1**2-0.00004*t1**3
<         a44=-15.+1.35*t1
<         if(t1.gt.15.)a44=-2.7+0.53*t1
<         a33=(0.5-a55)/(a44-1.+exp(-a44))
<         a22=a33*a44+a55
<         a11=0.5-a33
<         ra=a11+a22*uliso+a33*exp(-a44*uliso)
<         bs=((dzbdx)**2+(dzbdy)**2)**0.5
<         rmax=0.62+0.001/max(bs,0.01)
<         ubwfor=umax*(0.5+(rmax-0.5)*tanh((ra-0.5)/(rmax-0.5)))
<         ubwback=umax-ubwfor
<  *----------------------------------------------------------------------
<  c      end of Isobe
<         z(4)=(ubwfor+ubwback)/2
<          z(5)=(ubwfor-ubwback)/2
<  C      TvK 29-5-2000: implementation of Isobe wave assymetry
<  C      still to be checked!
<  C      z(i) from tabel initab replaced by z according to Isobe.
<
<         UBF3=UBWFOR**3.
<         UBF4=UBWFOR**4.
<         UBB3=UBWBACK**3.
<         UBB4=UBWBACK**4.
<         FAKTOR=0.
<         IF(ABS(UBF3+UBB3).GT.0.0001)FAKTOR=0.2*(UBF4-UBB4)/(UBF3+UBB3)
<
<
226c214
<         do 520 i=1,2
---
```

```
>              do 520 i=1,8
244,250c232,233
< C TvK removed as amplitudes are derived from ufor and uback,
< C      not from dimensionless table
< C        wghcor=wgh*corfac
< C TvK end removed
< C TvK changed wghcor**3 -> corfac**3
<         su32=su32*corfac*corfac*corfac/mn
< C TvK end change
---
>         wghcor=wgh*corfac
>         su32=su32*wghcor*wghcor*wghcor/mn
260,264c243,244
< C TvK changed as amplitudes are derived from ufor and uback,
< C      not from dimensionless table
< C          u1(it)=u1(it)*wgh
<           u2(it)=u2(it)*corfac
< C end change
---
>           u1(it)=u1(it)*wgh
>           u2(it)=u2(it)*wghcor
```
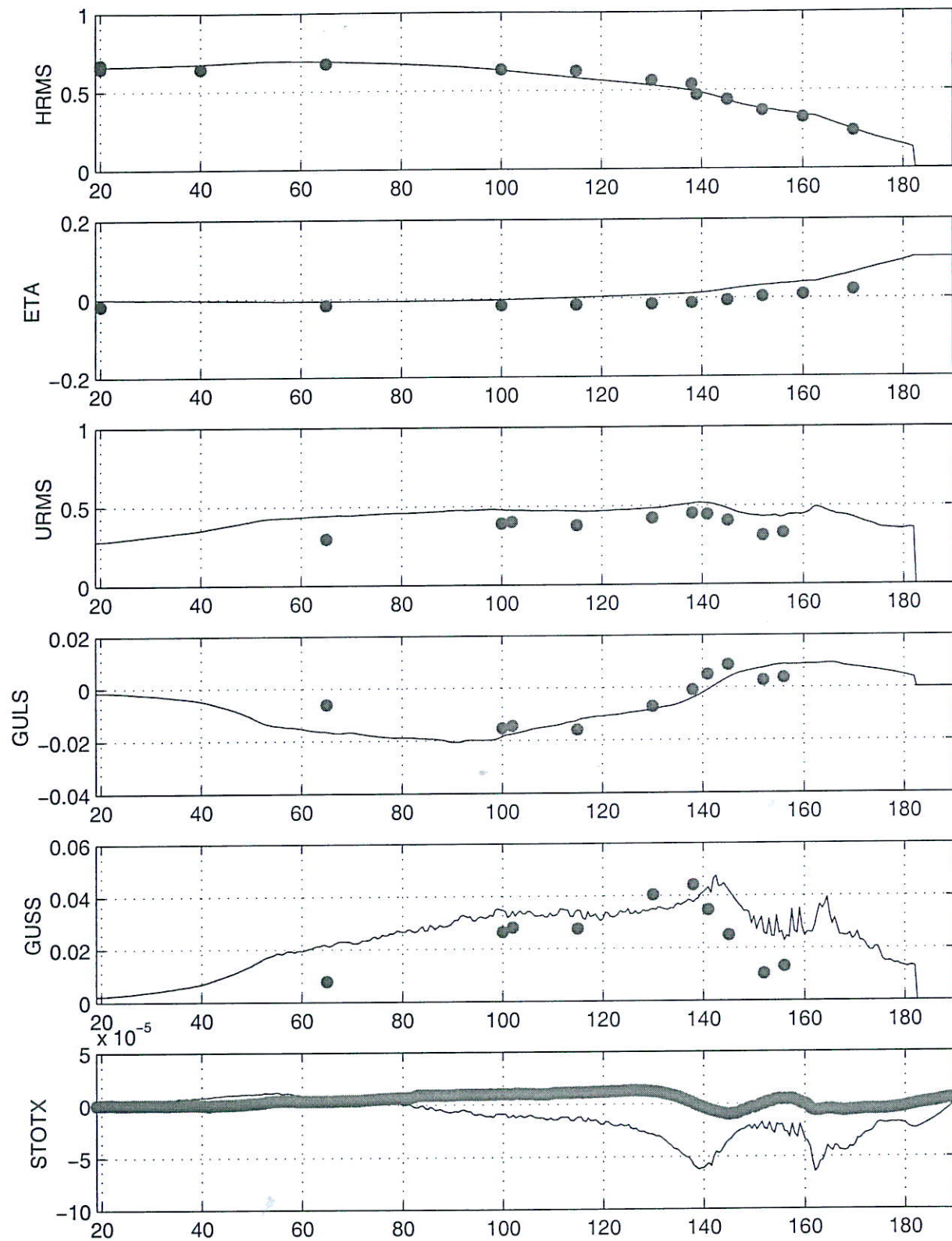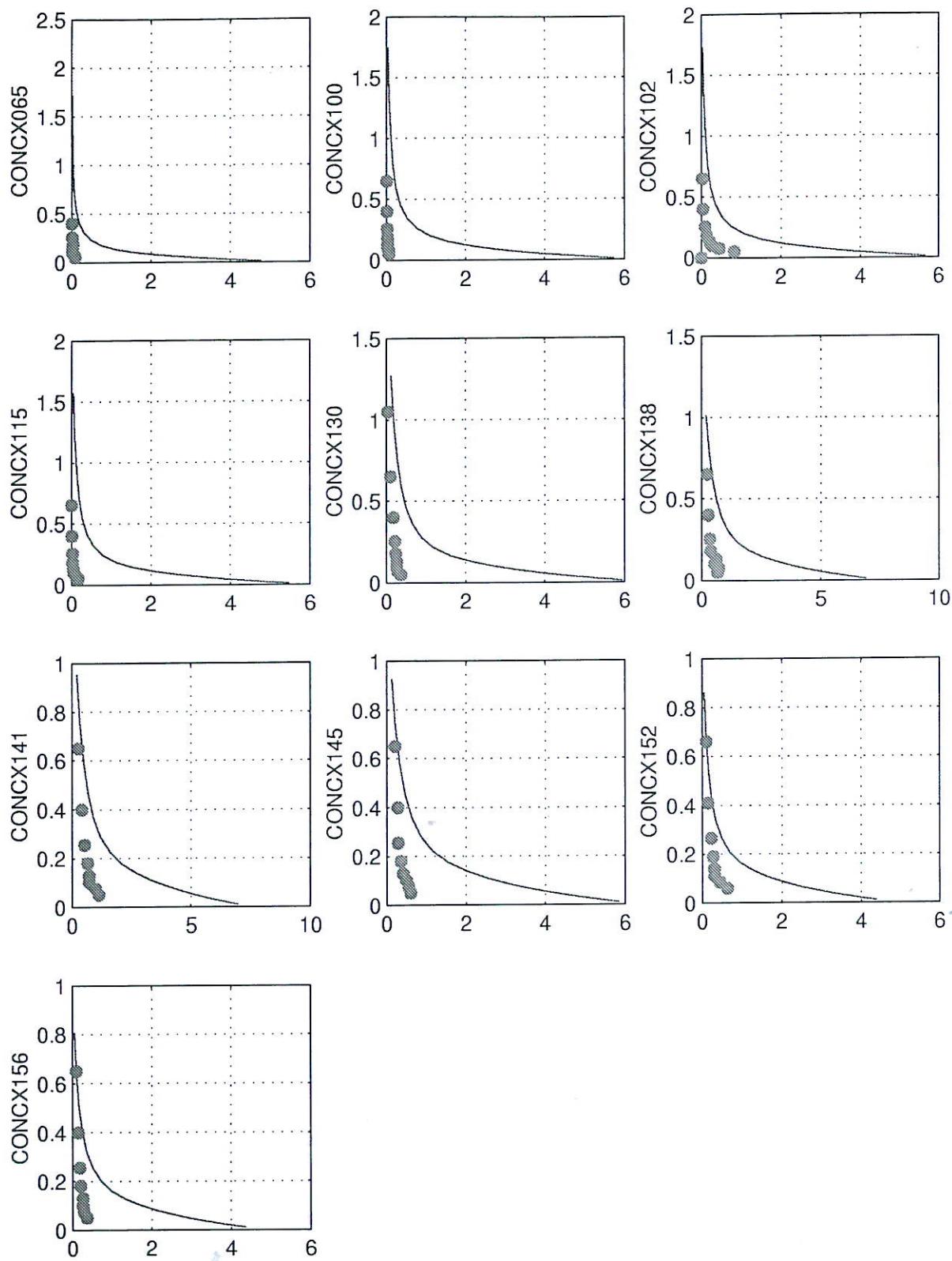
Dataset lip11d – test 1a
Cross-shore distribution – new

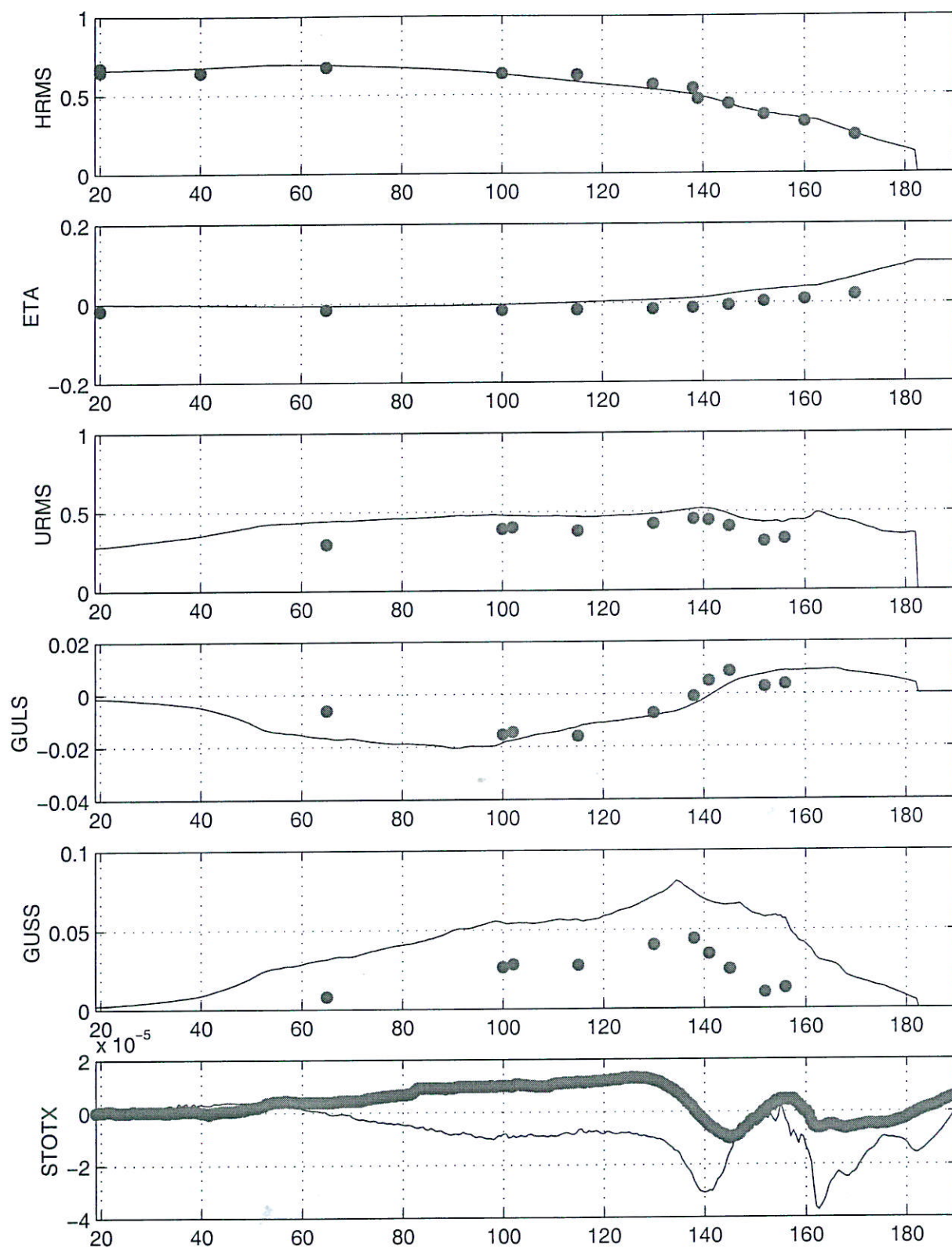Unibest–TC   Run v204

WL | DELFT HYDRAULICS

Fig. 7

Dataset lip11d – test 1a
Concentration profiles –new

Unibest–TC

Run v204

WL | DELFT HYDRAULICS

Fig. 8
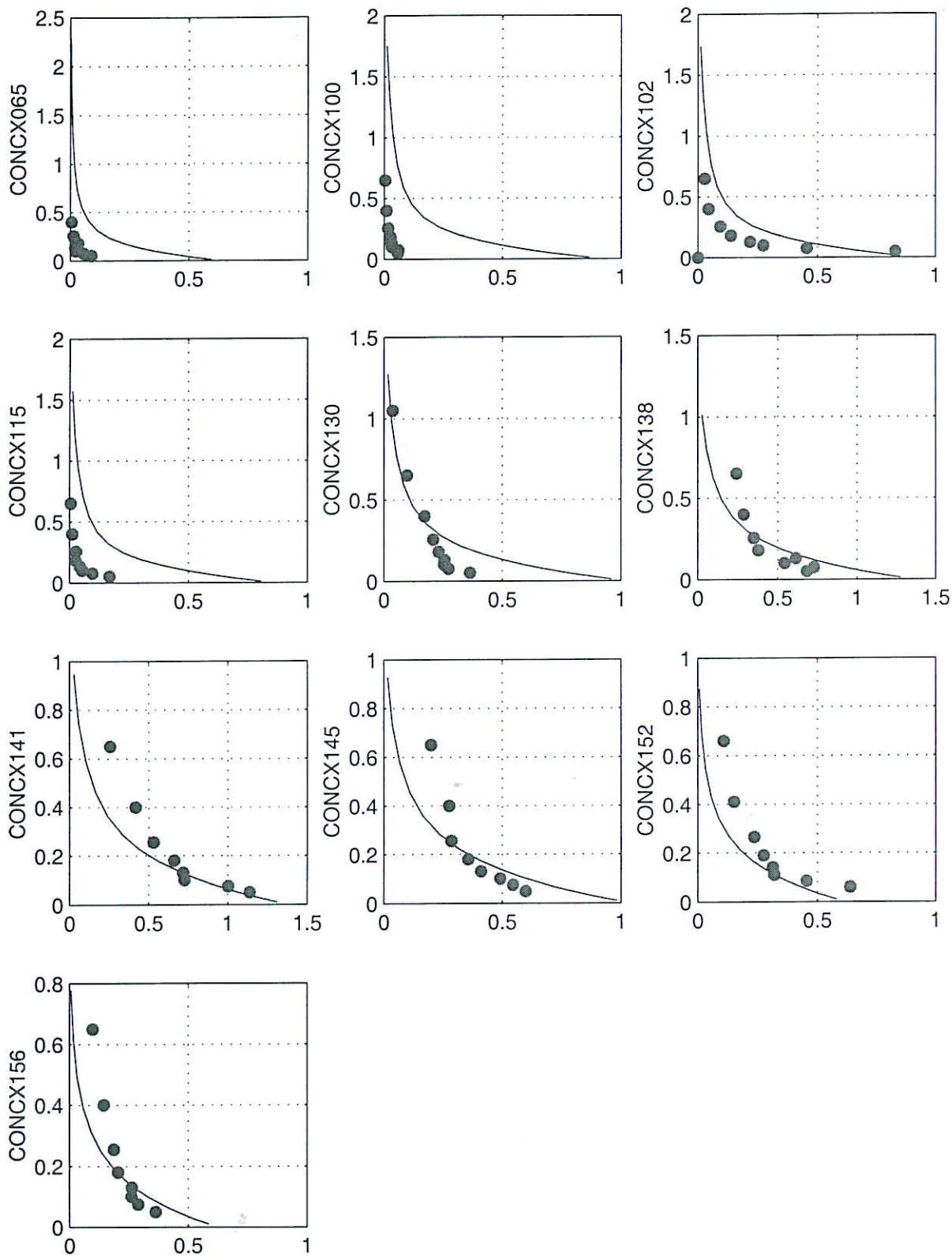
Dataset lip11d – test 1a
Cross-shore distribution – old

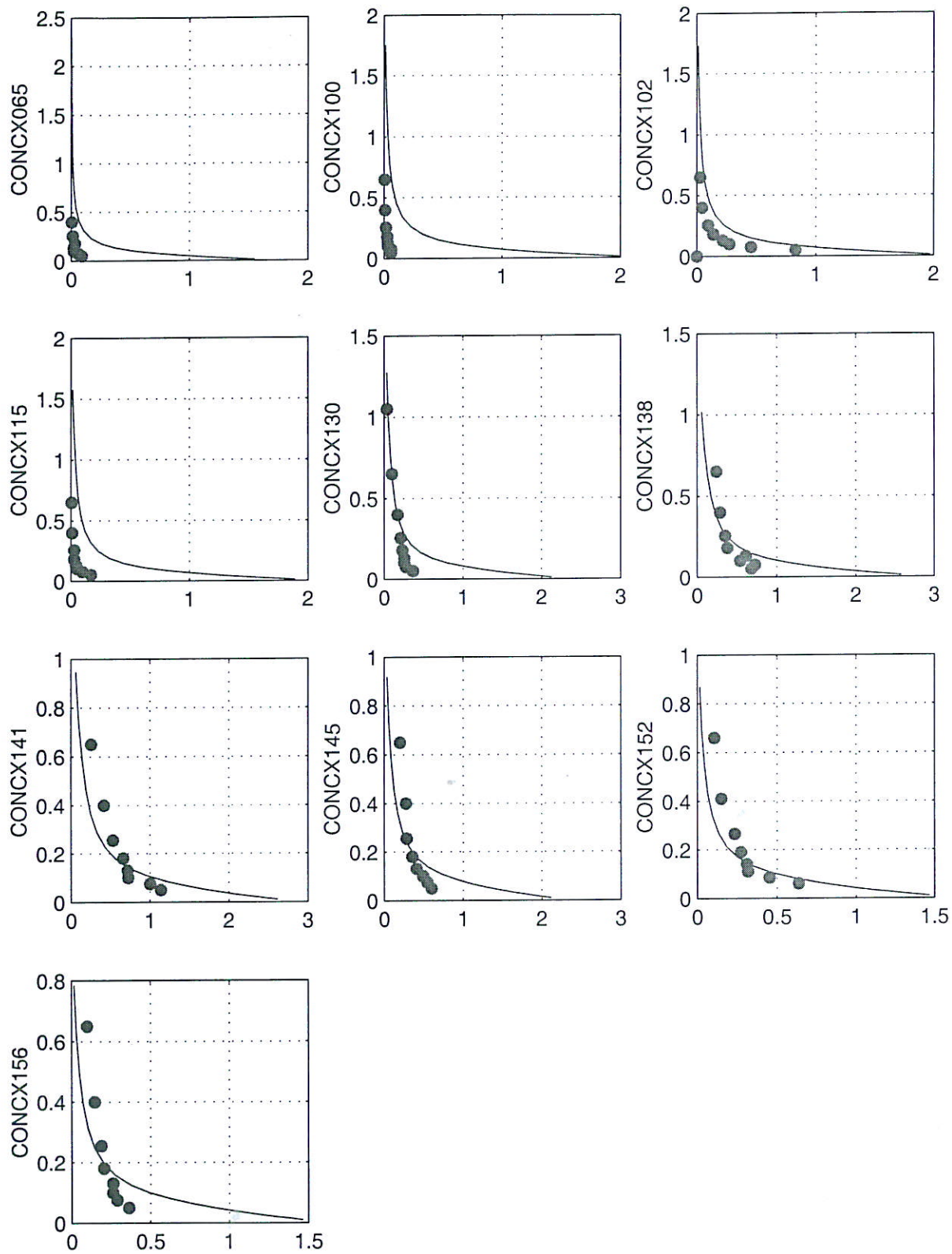| Unibest–TC | Run v203 |

WL | DELFT HYDRAULICS

Fig. 9

Dataset lip11d – test 1a	Unibest–TC	Run v204
Concentration profiles – new, org. exp. for rmuwa		
WL | DELFT HYDRAULICS		Fig. 11

WL | Delft Hydraulics

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