Prepared for:

National Institute for Coastal and Marine Management/RIKZ

Large-scale sandpits

Hydrodynamic and morphological modelling of large-scale sandpits

M.Sc. Thesis

June 1999

WL | delft hydraulics

Large-scale sandpits

Hydrodynamic and morphological modelling of large-scale sandpits

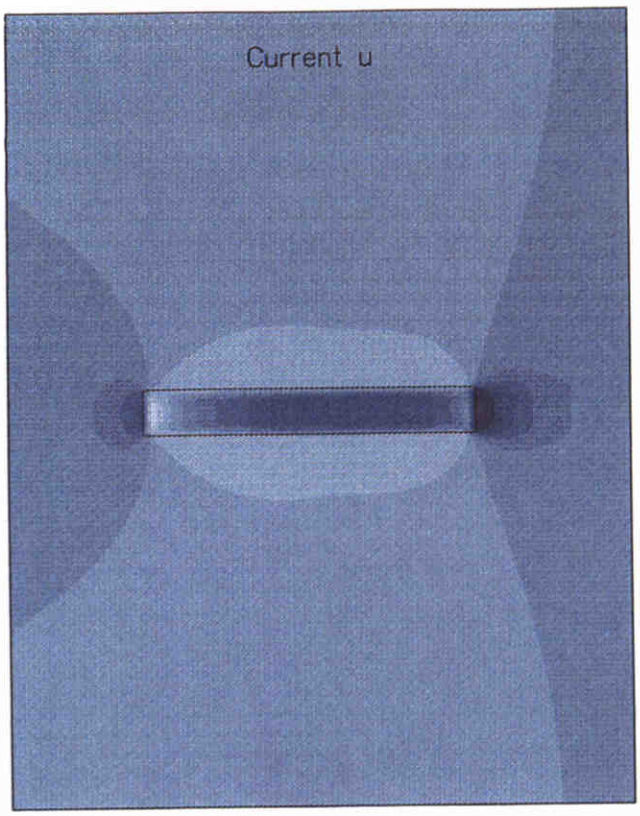
M.D. Klein

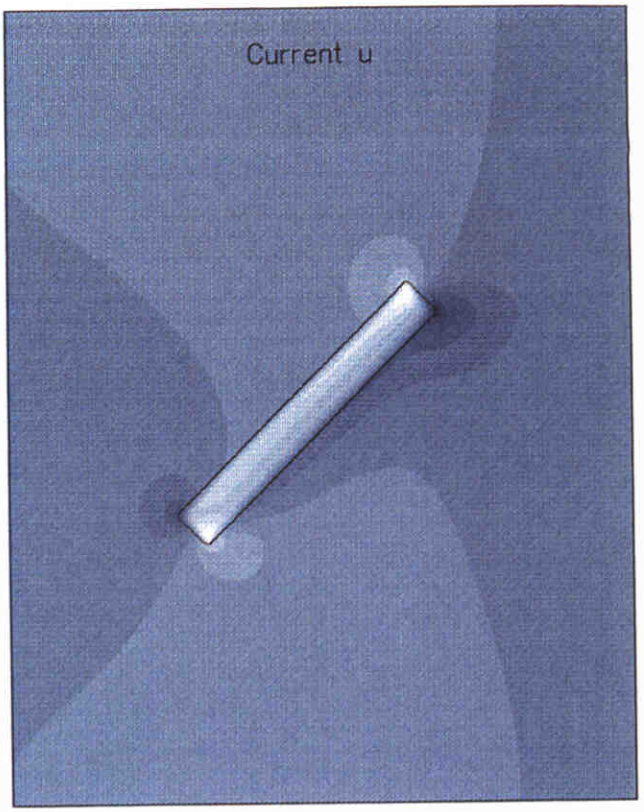
M.Sc. Thesis

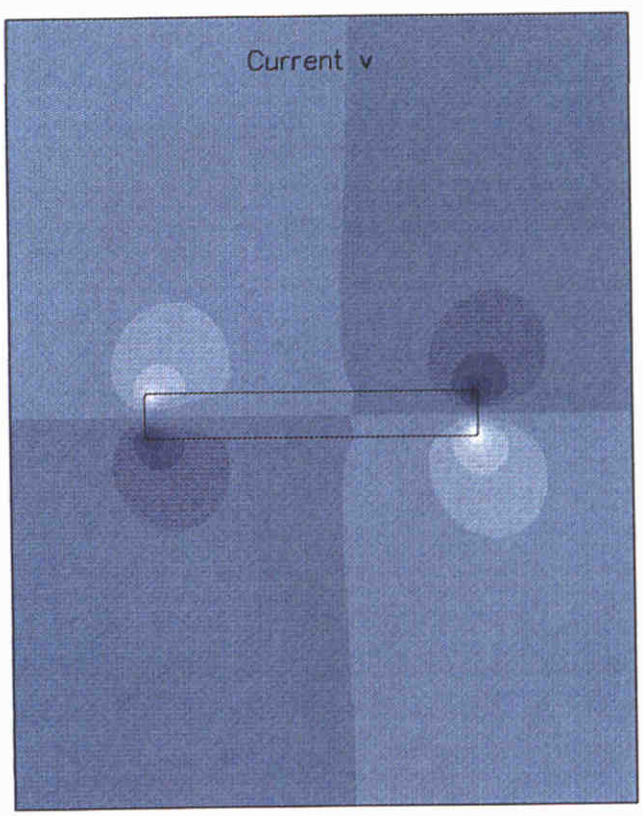
WL | delft hydraulics

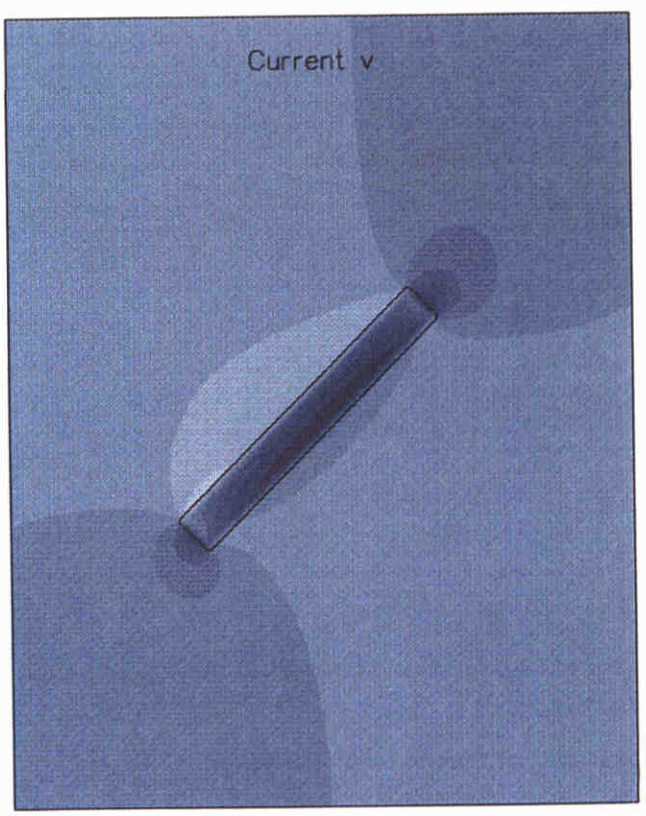
List of Figures

*) These figures are included in the text









Current velocity components u and v [m/s]

Influence of obliquity of a 40x5 km^2 sandpit

Stationary boundary conditions

WL | DELFT HYDRAULICS

z2615

Figure 5.1

Figure 5.2: Current velocities in the center longitudinal section of a 40x5 km ^ 2 sandpit

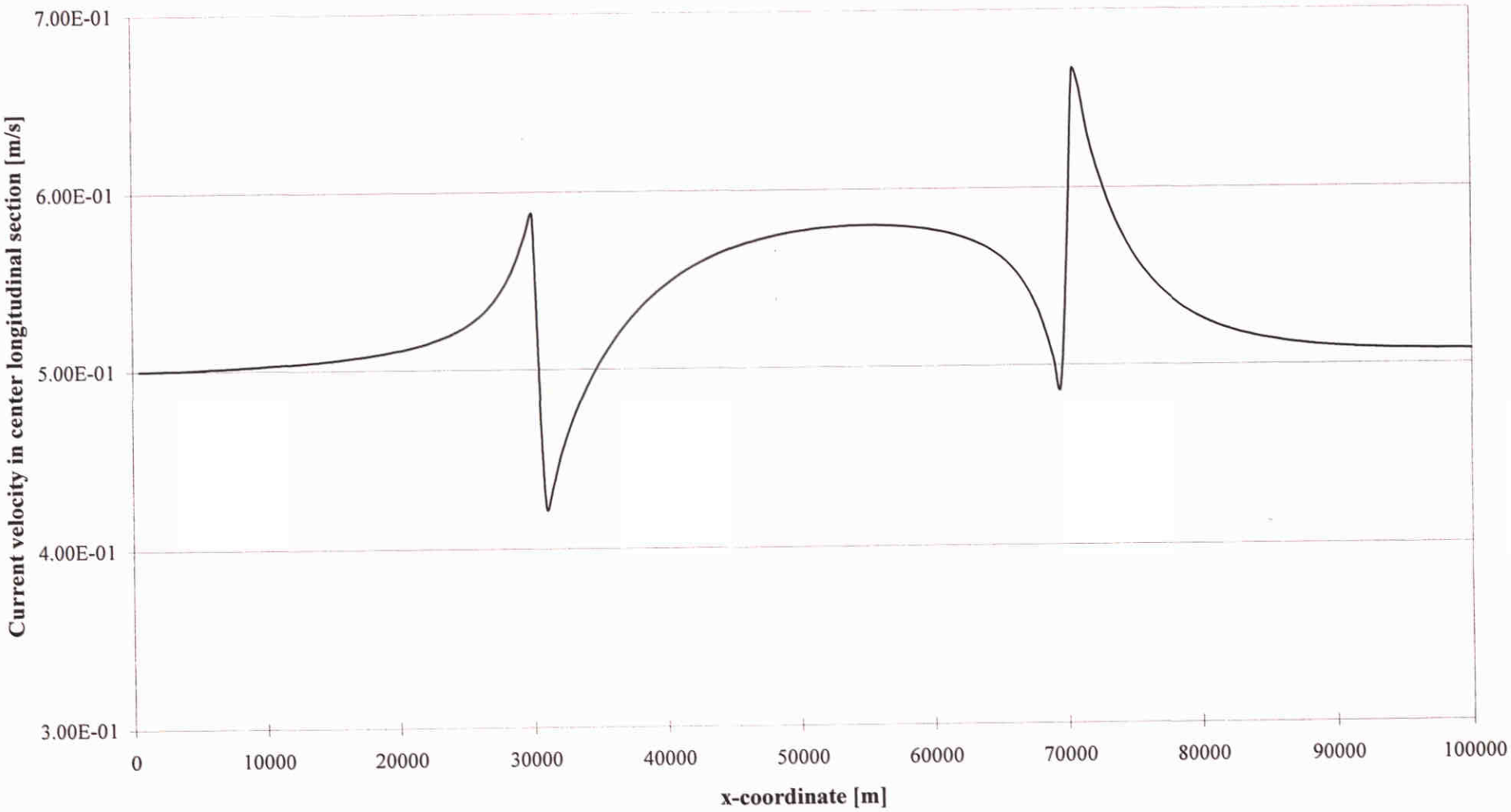
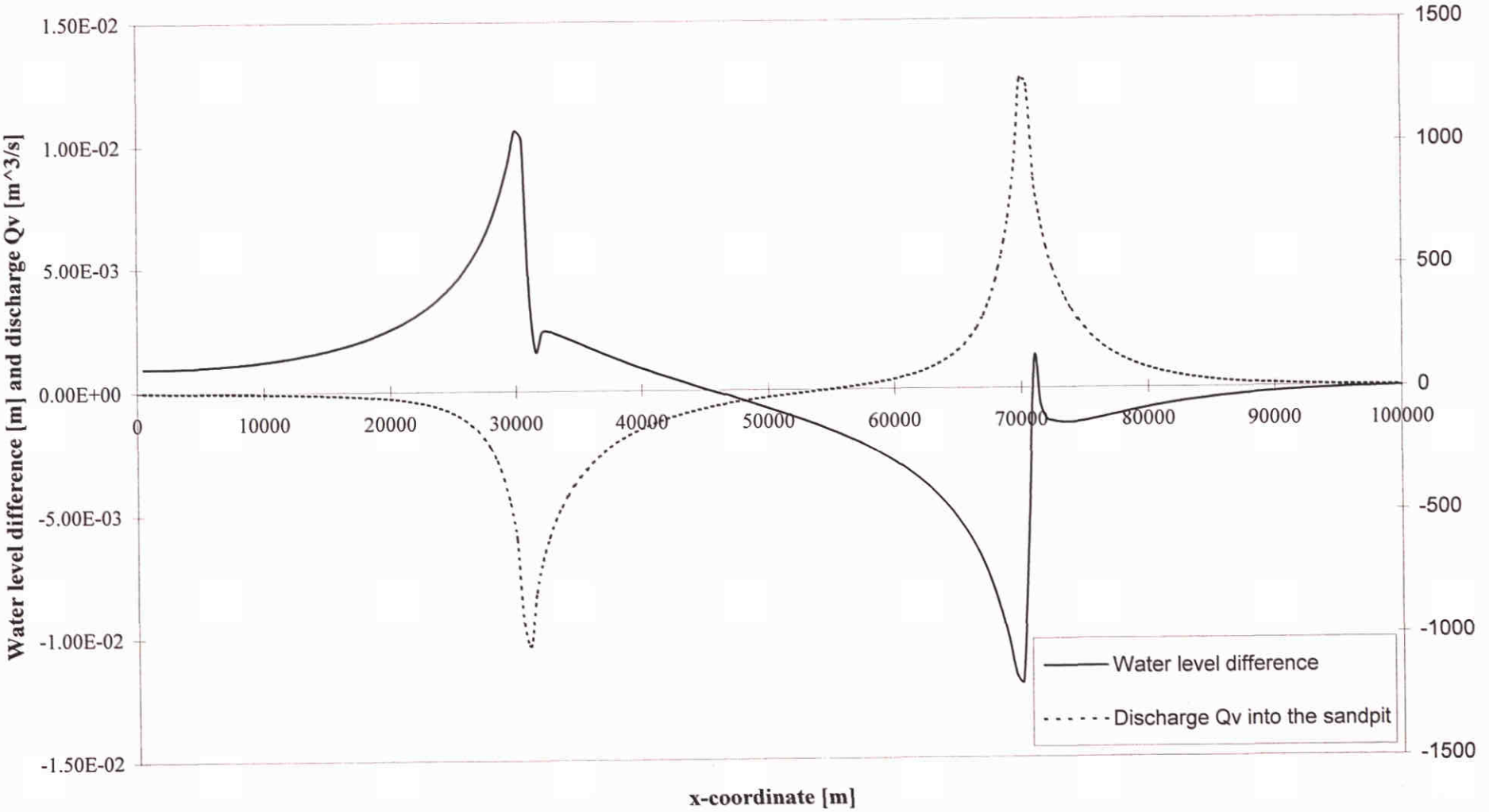
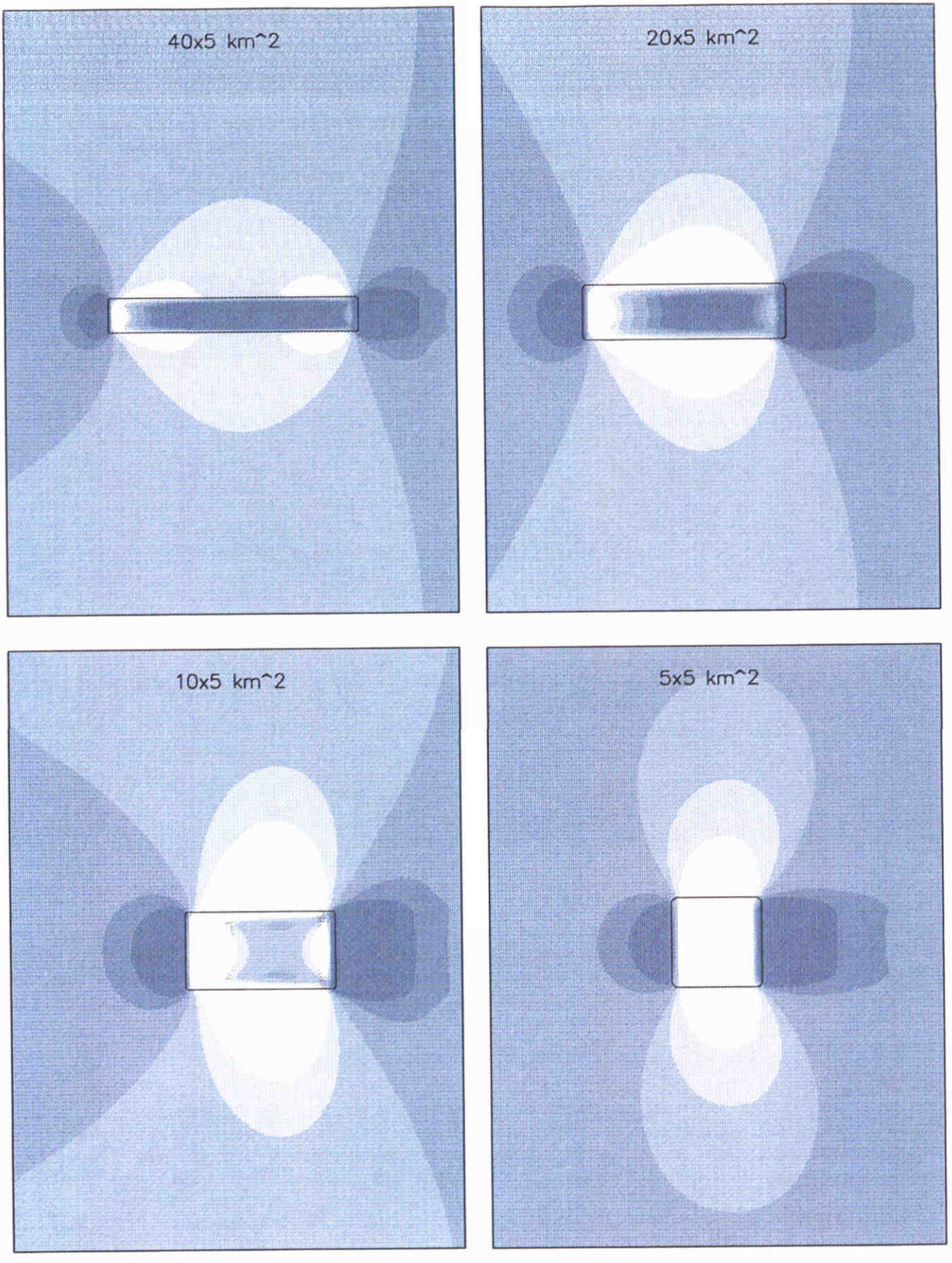


Figure 5.3: Relation between water level difference and discharge into the sandpit





Current magnitude [m/s]

Area of influence around 30 m deep sandpits, varying in length

Stationary boundary conditions

WL | DELFT HYDRAULICS

z2615

Figure 5.6

Figure 5.7: Current velocities in an infinitely wide and a 5 km wide sandpit

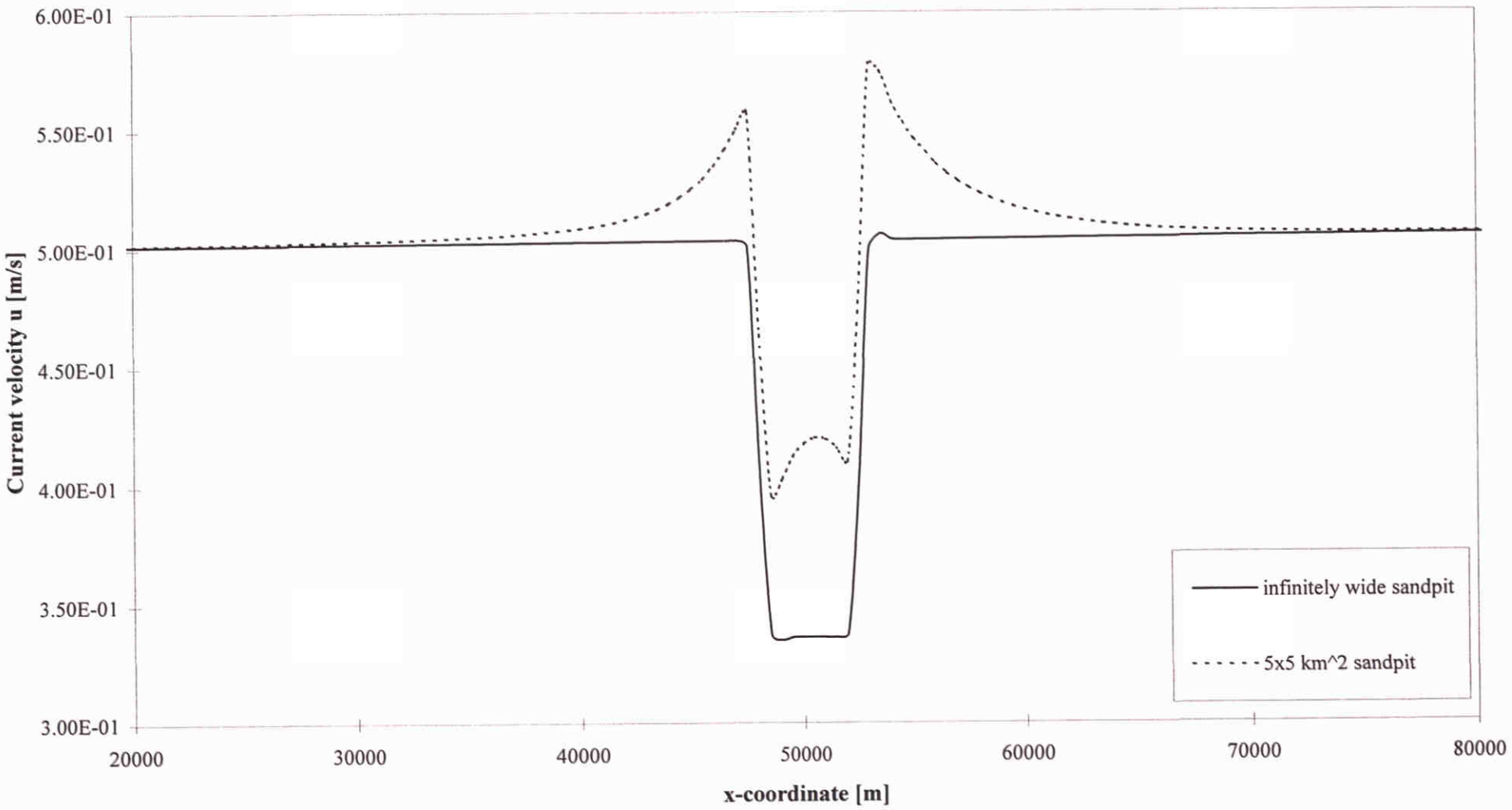
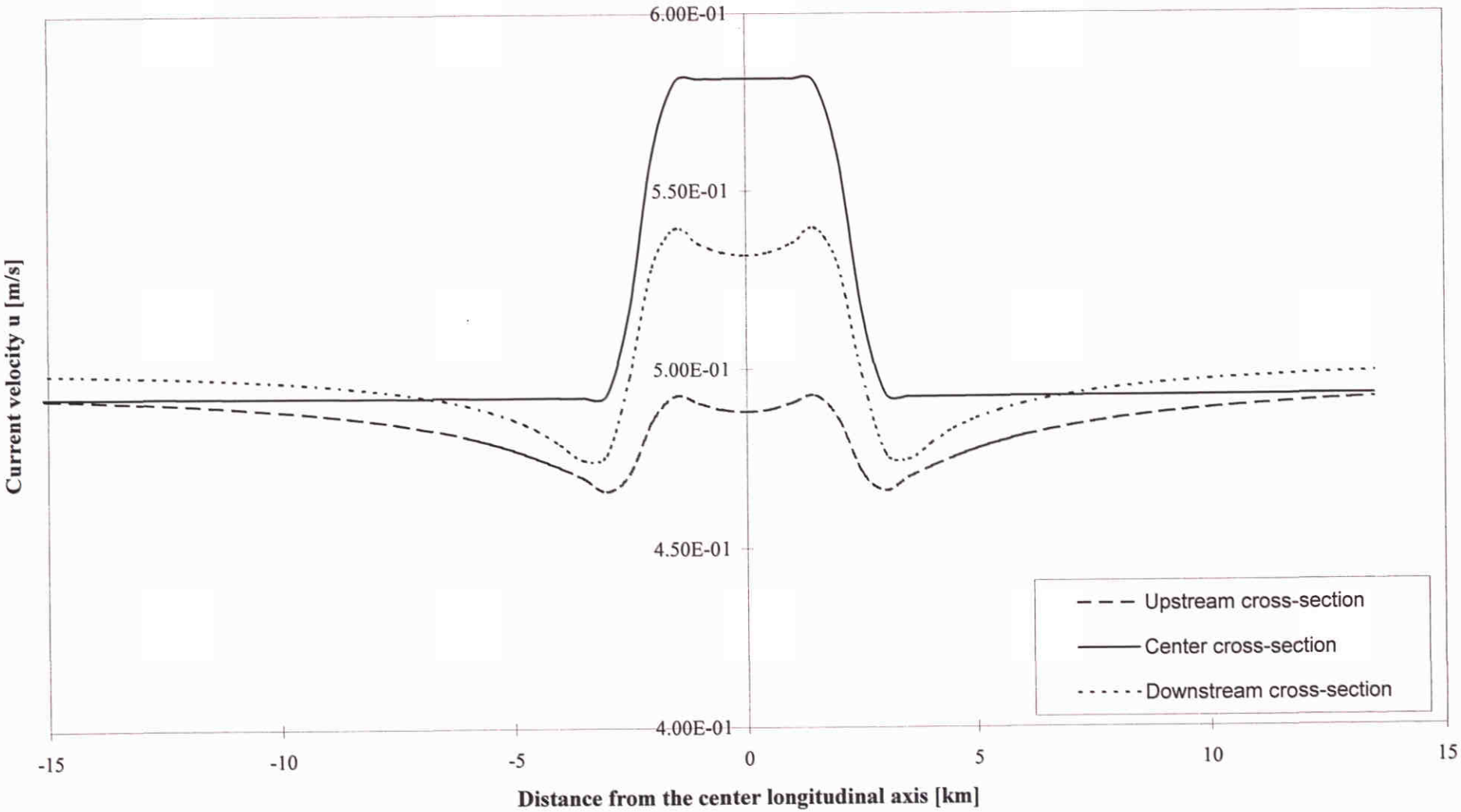
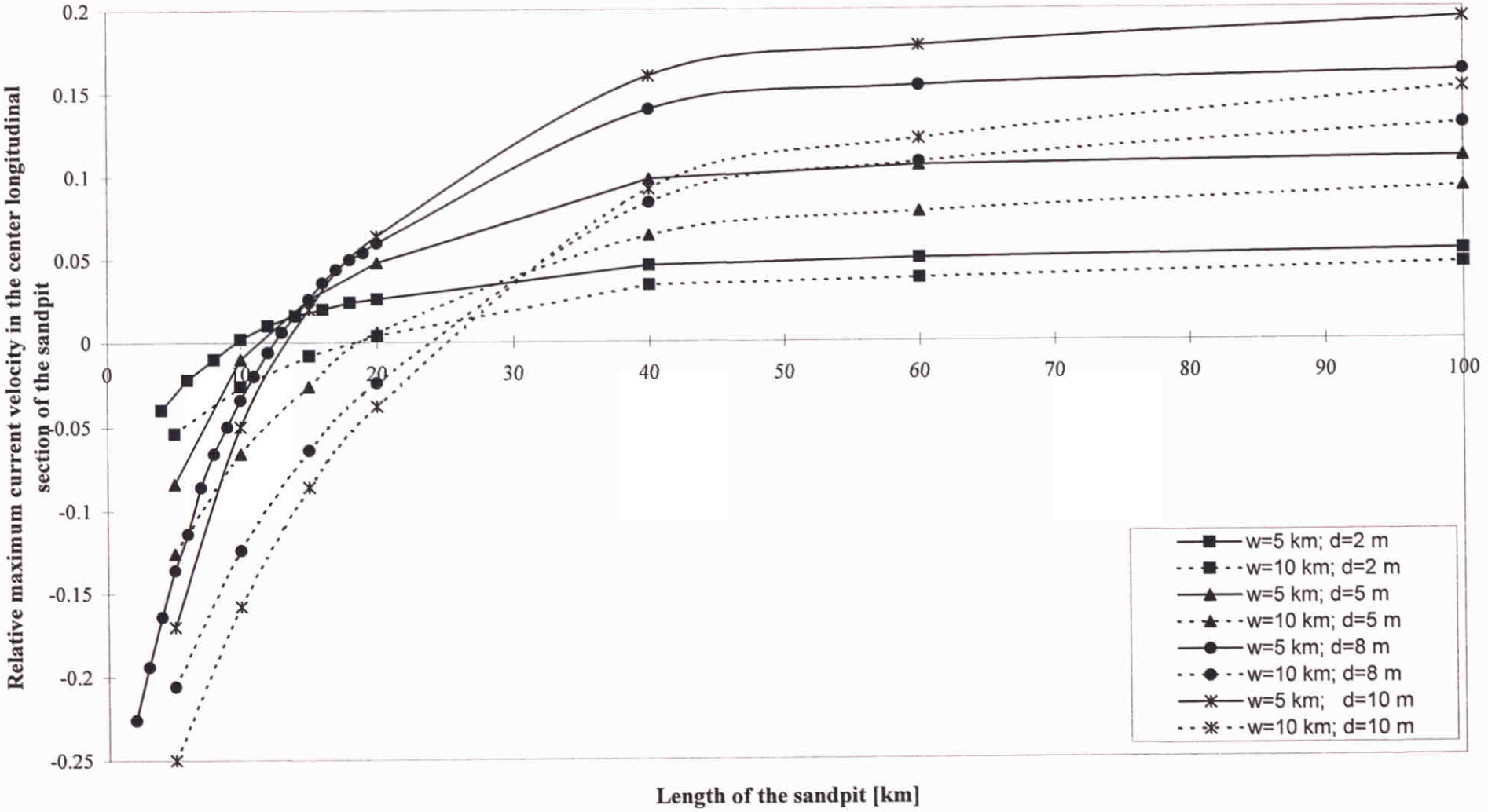


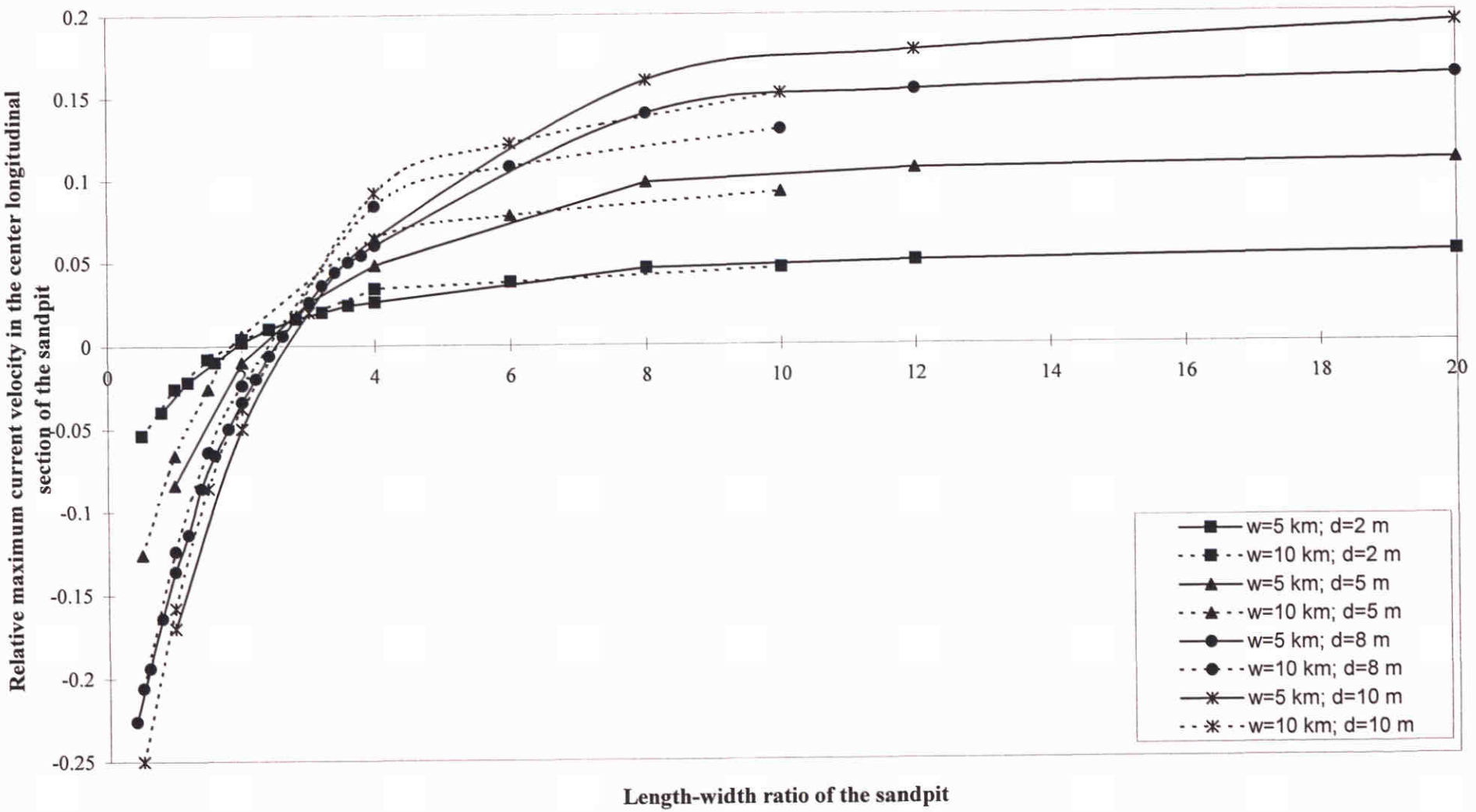
Figure 5.8: Distribution of u-velocity in three cross-sections



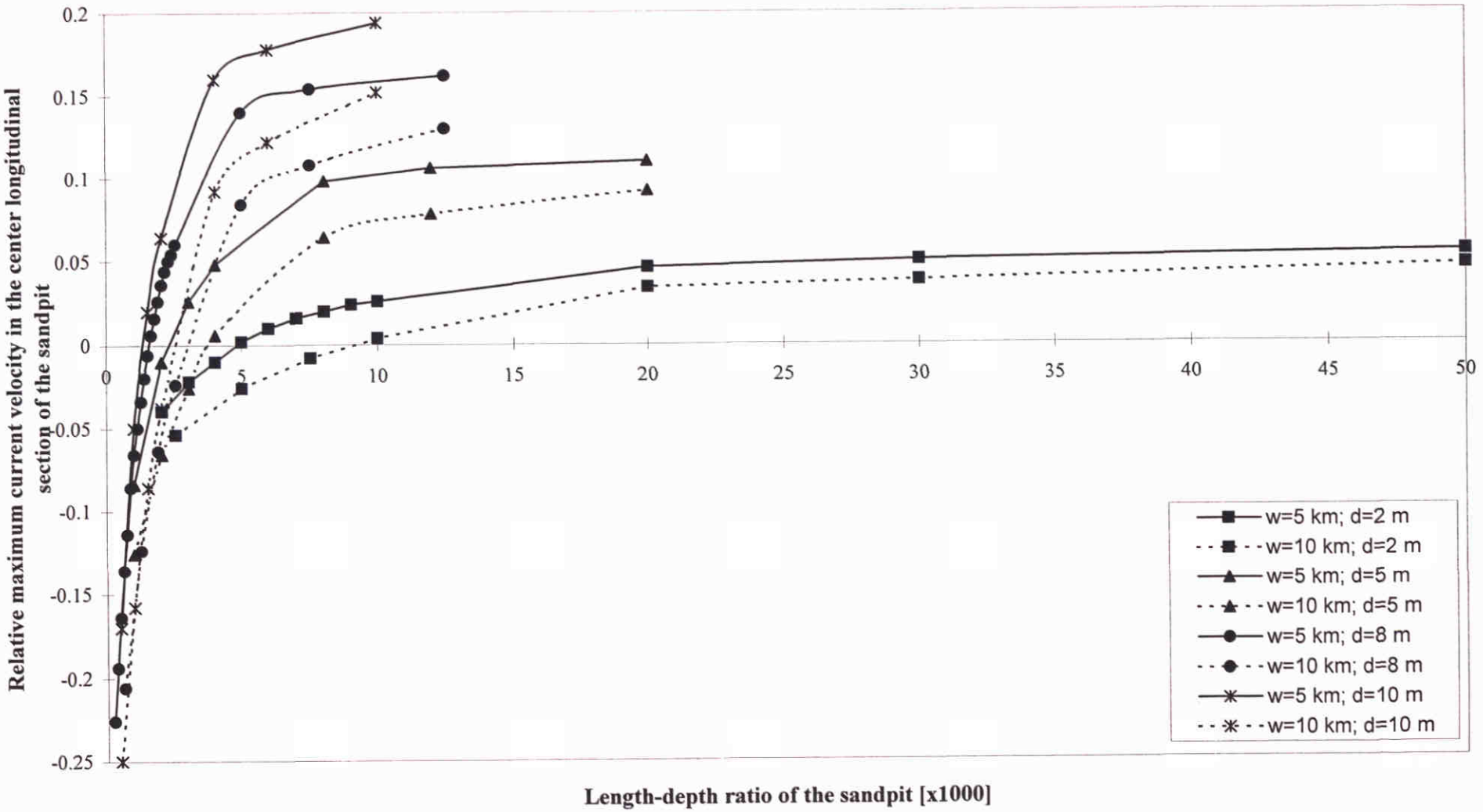
Figuur 5.9: Maximum current velocity vs. length of the sandpit

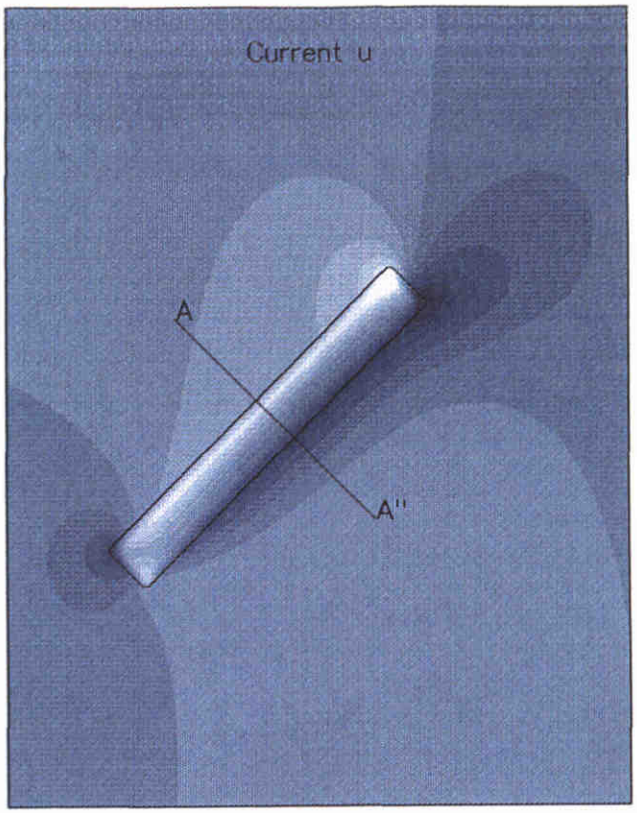


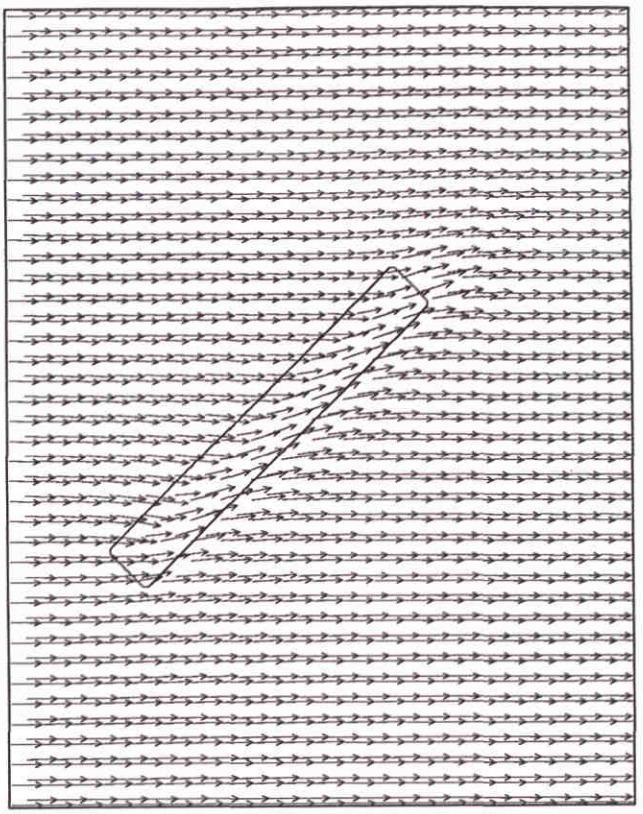
Figuur 5.10: Maximum current velocity vs. length-width ratio of the sandpit

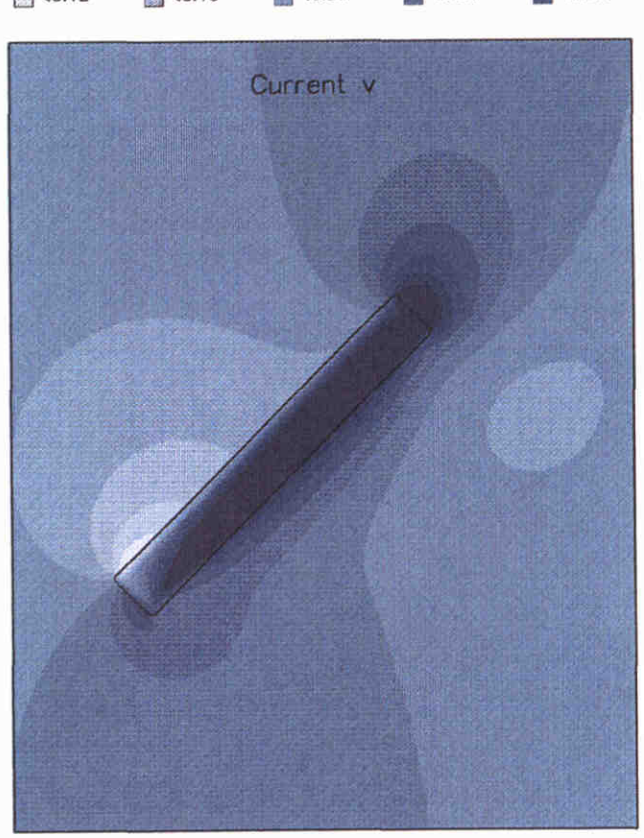


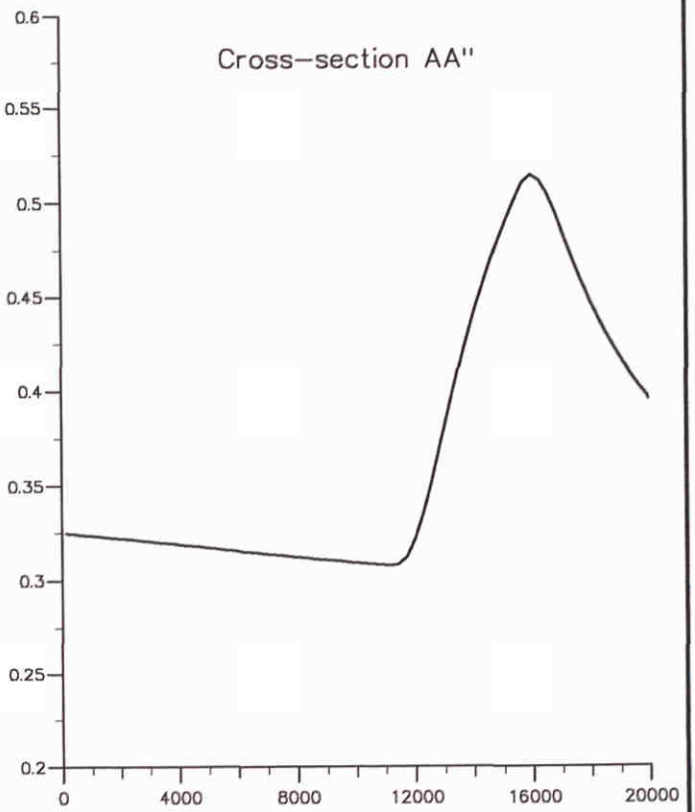
Figuur 5.11: Maximum current velocity vs. length-depth ratio of the sandpit











<0.40	<0.44	<0.48	<0.52	<0.56	<0.60
<0.42	<0.46	<0.50	<0.54	<0.58	>0.60

<-0.10	<-0.06	<-0.02	<0.02	<0.06	<0.10
<-0.08	<-0.04	<0.00	<0.04	<0.08	>0.10

Current velocities u and v [m/s]

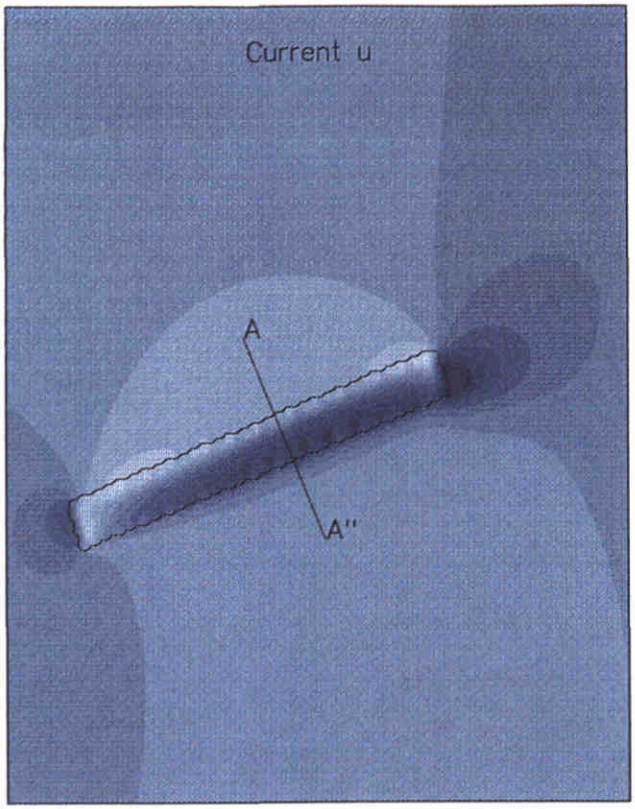
Stationary current pattern and current velocities in cross-section AA''

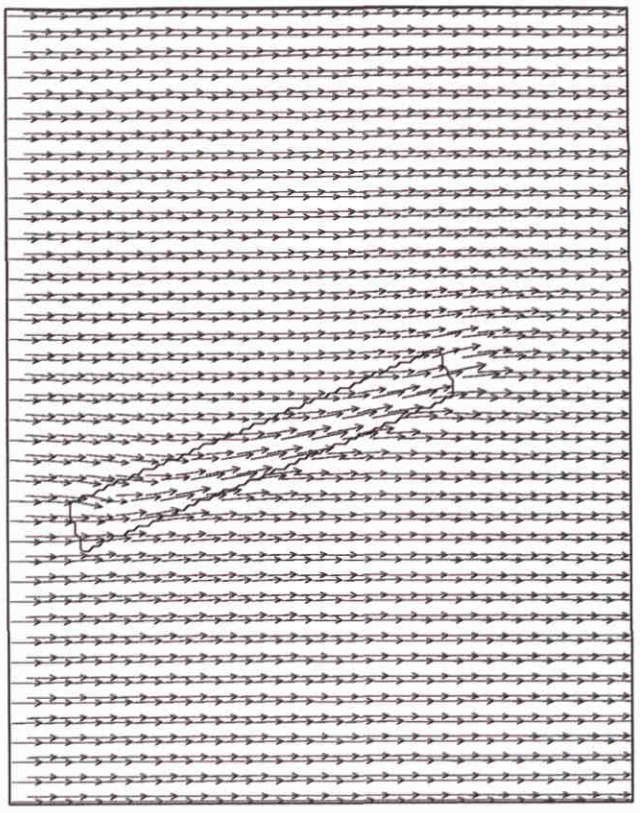
Stationary boundary conditions including Coriolis

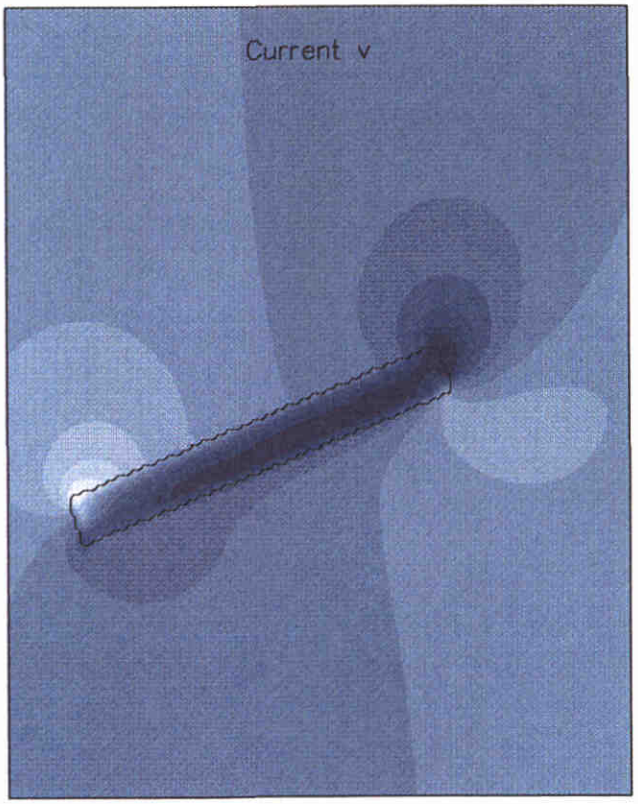
WL | DELFT HYDRAULICS

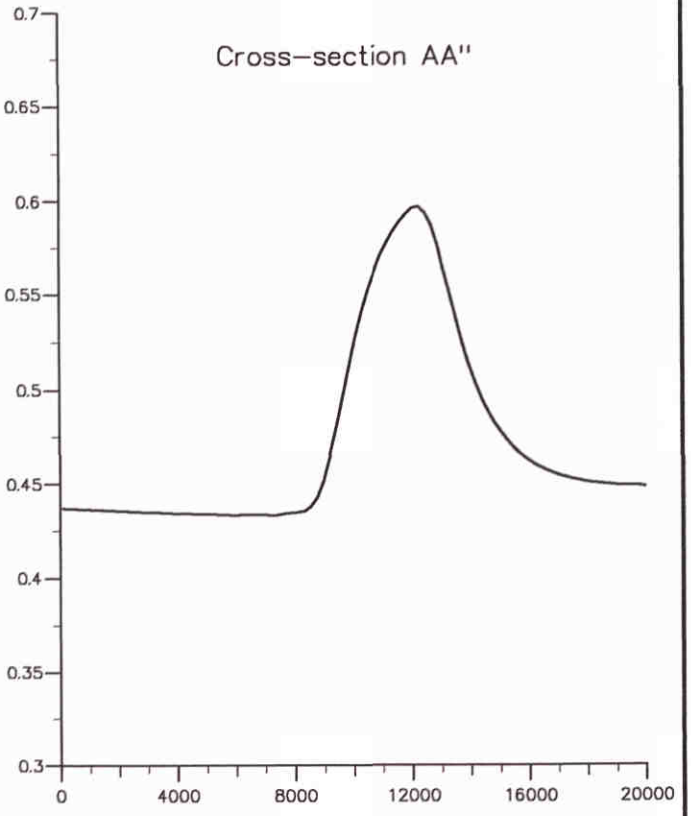
z2615

Figure 6.2









<0.40	<0.44	<0.48	<0.52	<0.56	<0.60
<0.42	<0.46	<0.50	<0.54	<0.58	>0.60

<–0.10	<–0.06	<–0.02	<0.02	<0.06	<0.10
<–0.08	<–0.04	<0.00	<0.04	<0.08	>0.10

Current velocities u and v [m/s]

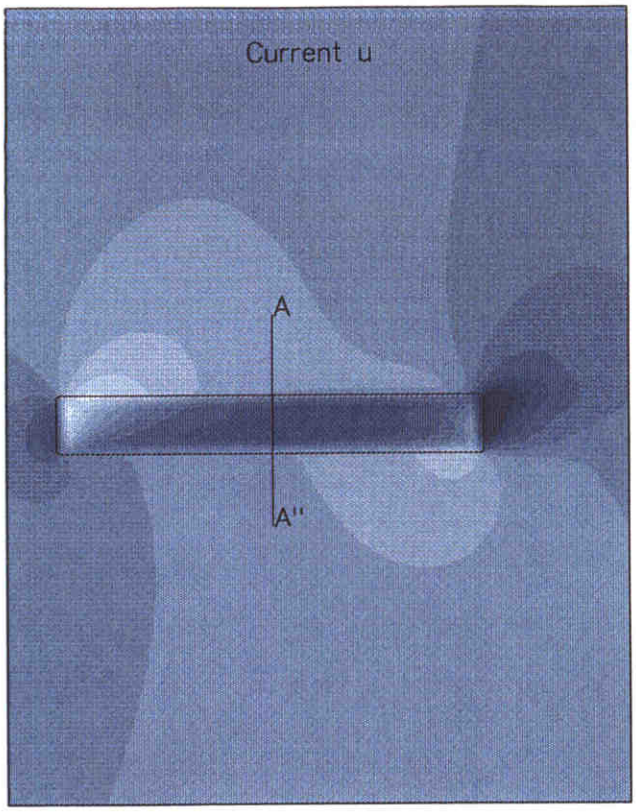
Stationary current pattern and current velocities in cross–section AA''

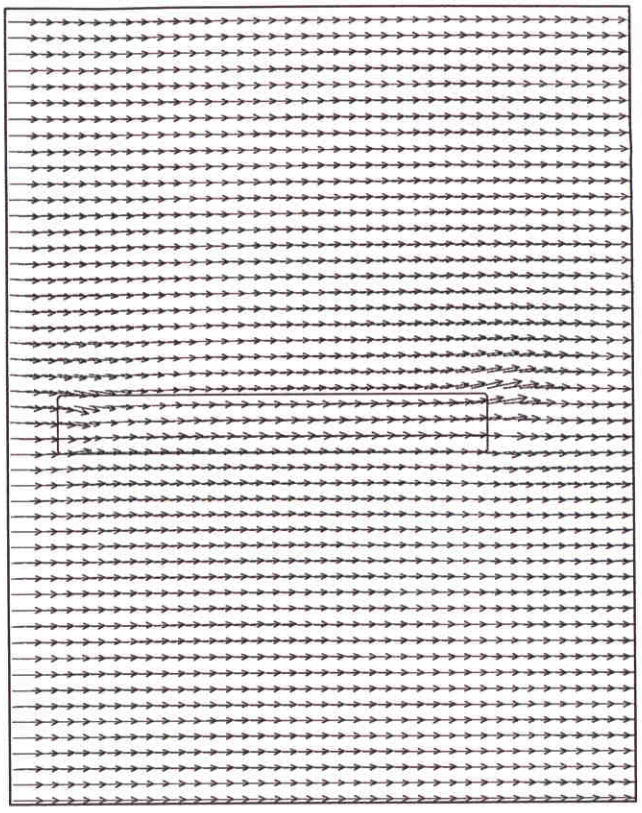
Stationary boundary conditions including Coriolis

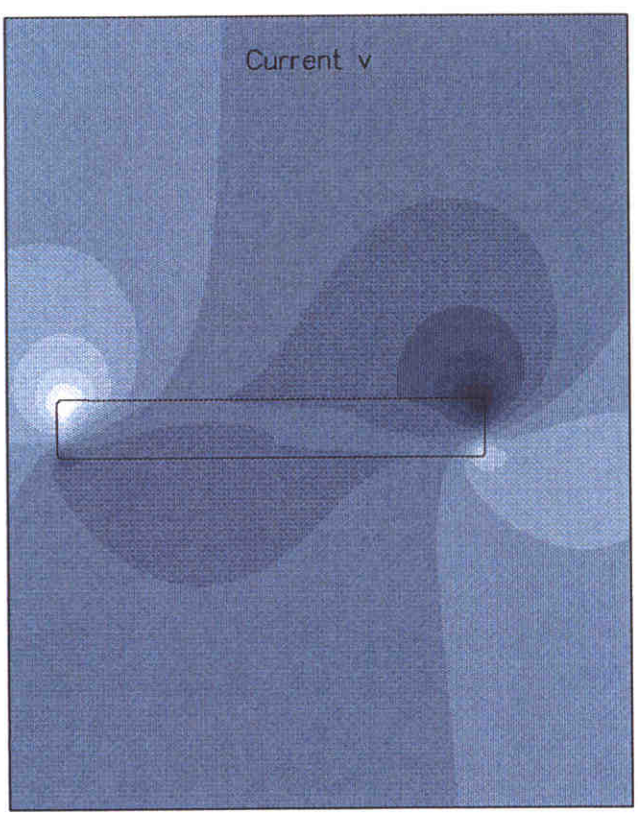
WL | DELFT HYDRAULICS

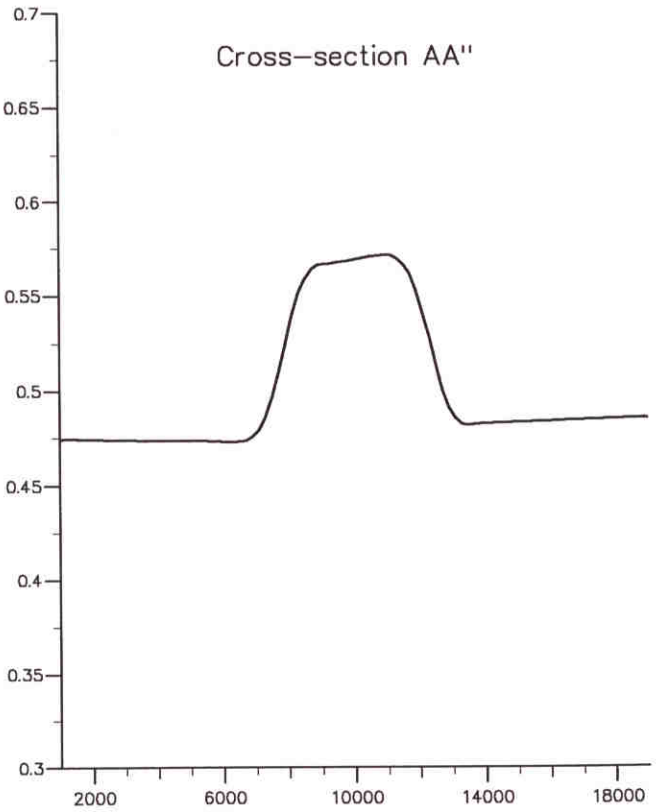
z2615

Figure 6.3









Current velocities u and v [m/s]

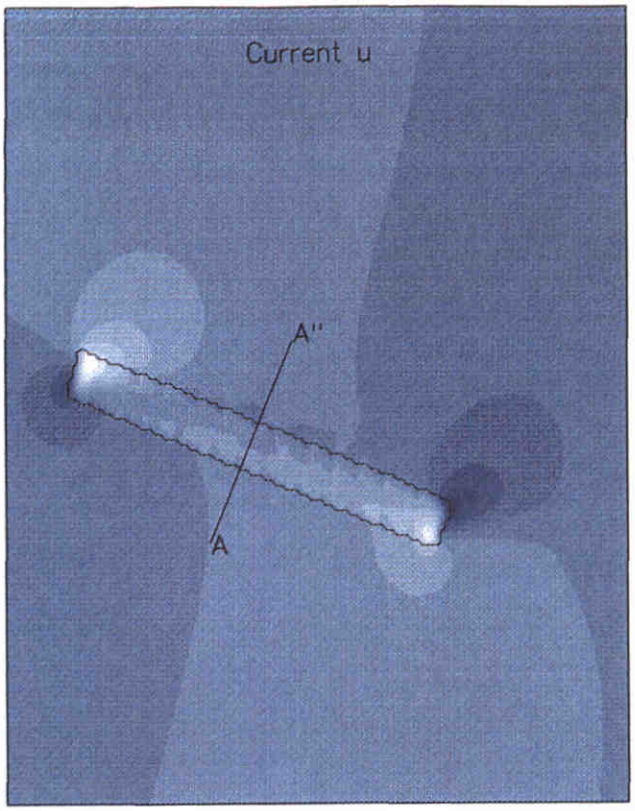
Stationary current pattern and current velocities in cross-section AA''

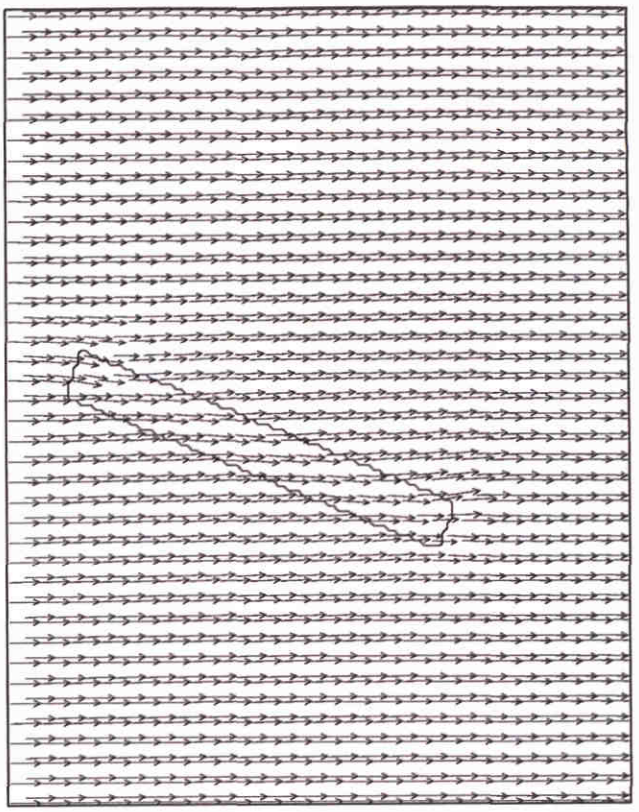
Stationary boundary conditions including Coriolis

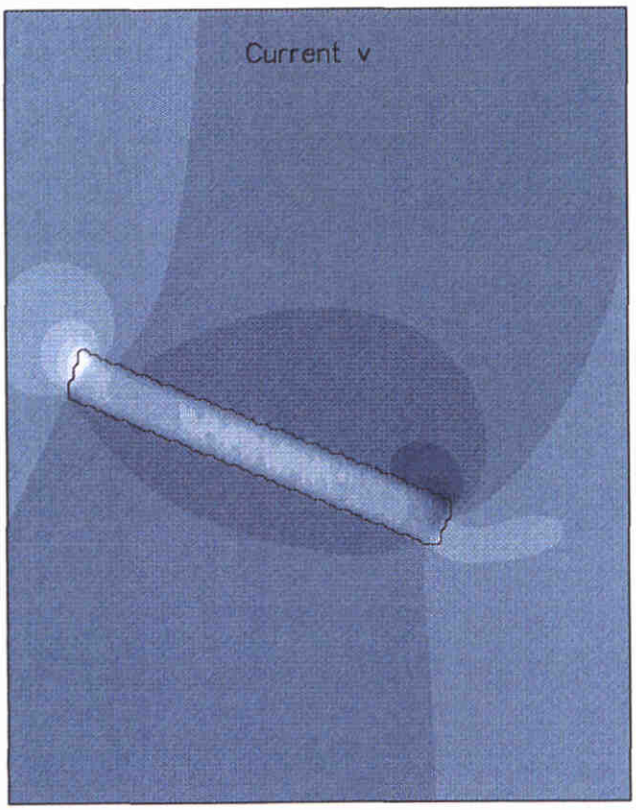
WL | DELFT HYDRAULICS

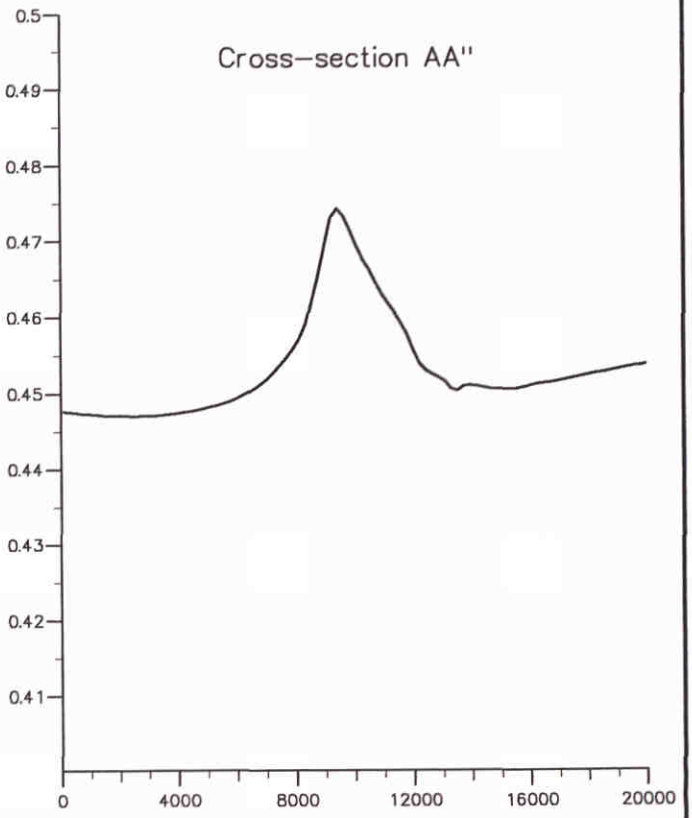
z2615

Figure 6.4

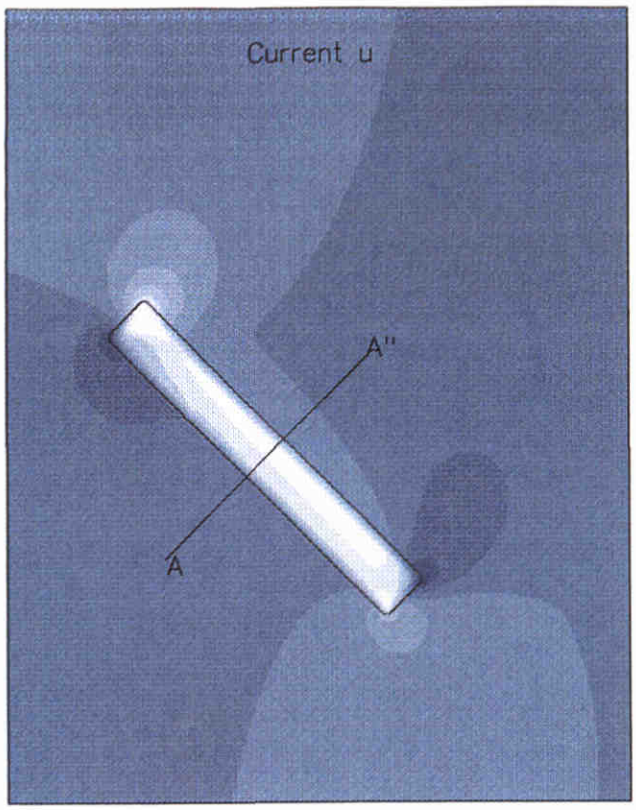


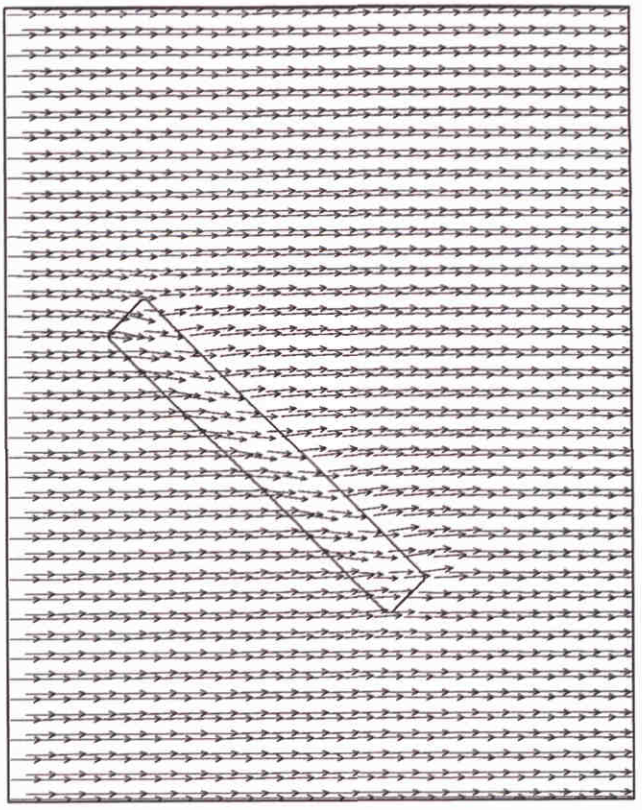


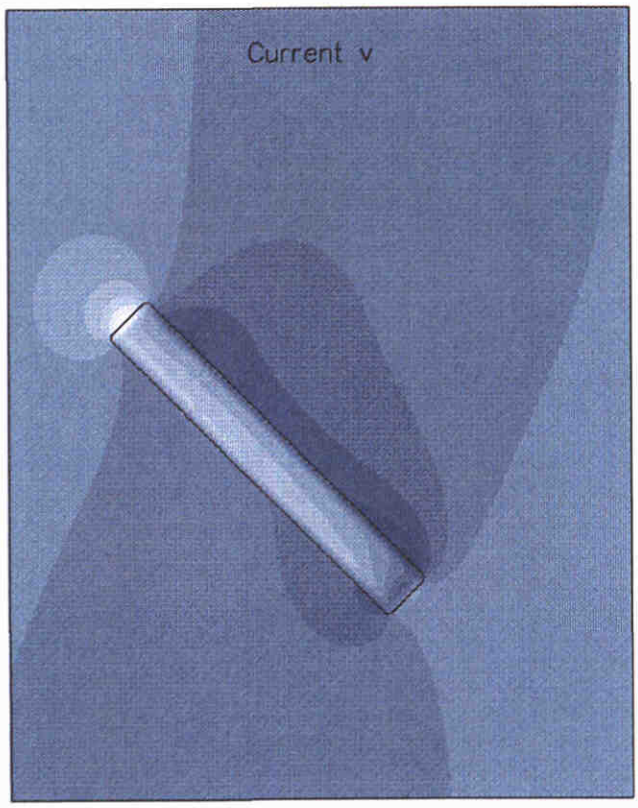


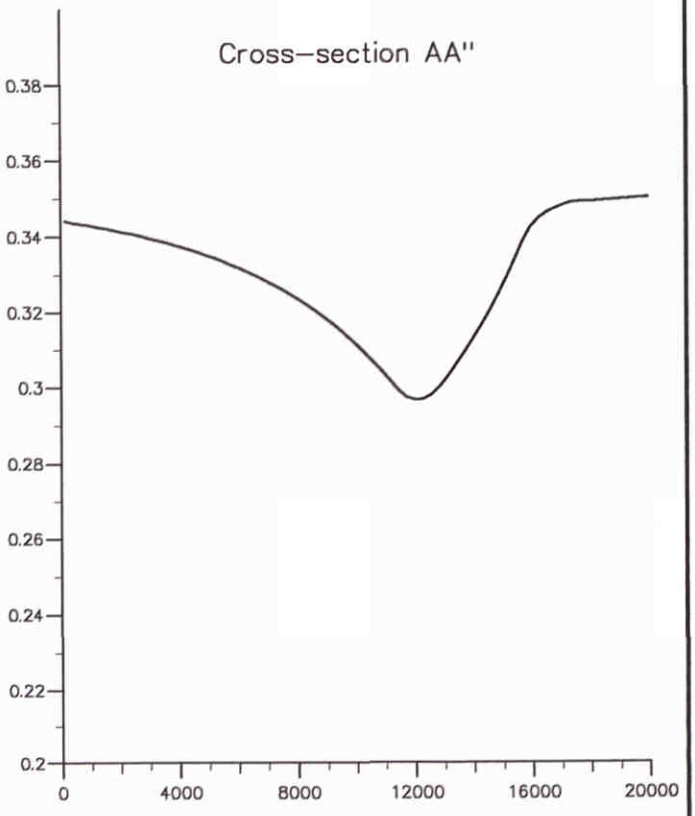


Current velocities u and v [m/s] Stationary current pattern and current velocities in cross-section AA'' Stationary boundary conditions including Coriolis		
WL | DELFT HYDRAULICS	z2615	Figure 6.5









<0.40	<0.44	<0.48	<0.52	<0.56	<0.60
<0.42	<0.46	<0.50	<0.54	<0.58	>0.60

<–0.10	<–0.06	<–0.02	<0.02	<0.06	<0.10
<–0.08	<–0.04	<0.00	<0.04	<0.08	>0.10

Current velocities u and v [m/s]

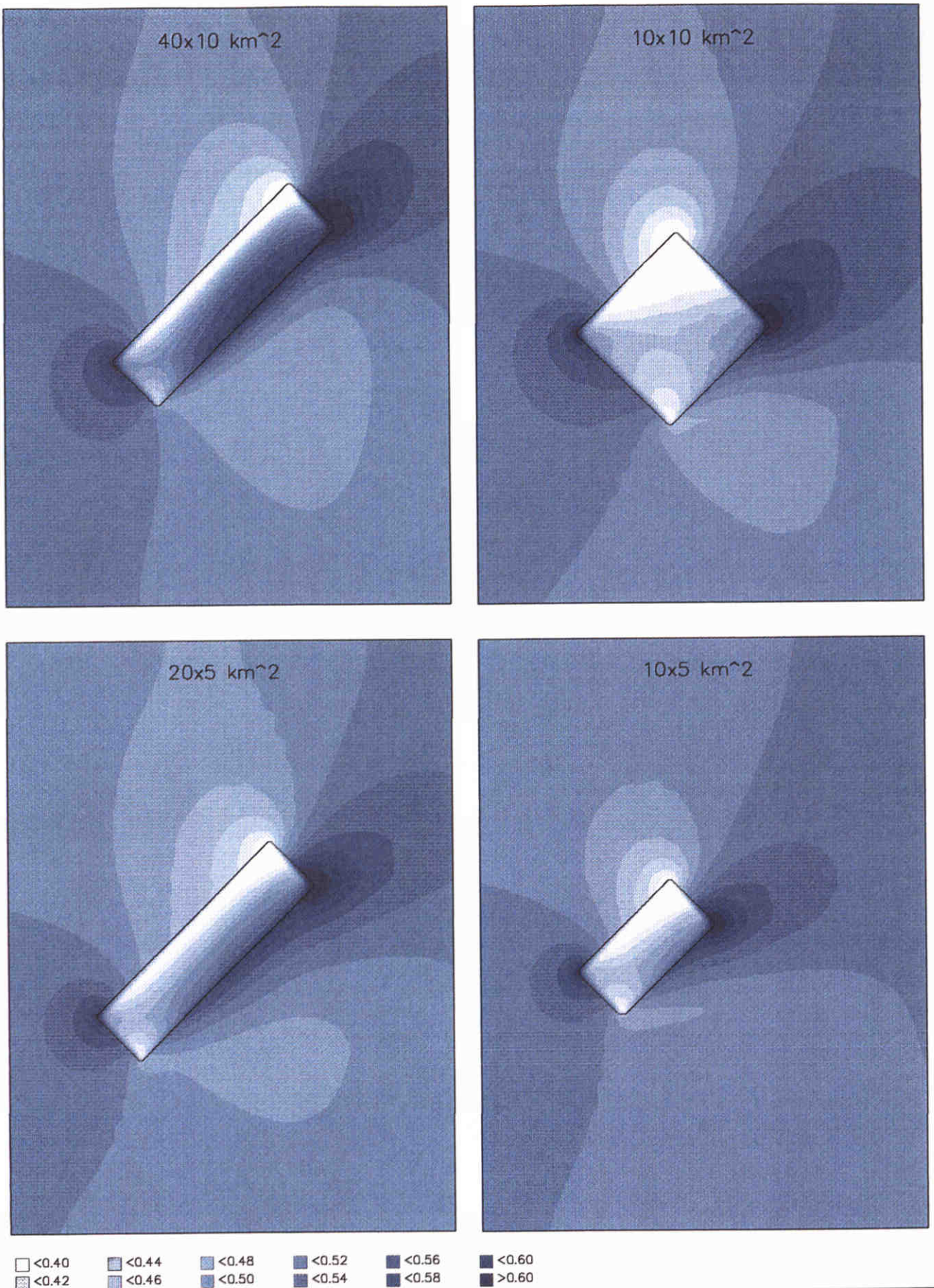
Stationary current pattern and current velocities in cross–section AA''

Stationary boundary conditions including Coriolis

WL | DELFT HYDRAULICS

z2615

Figure 6.6



Current magnitude [m/s]

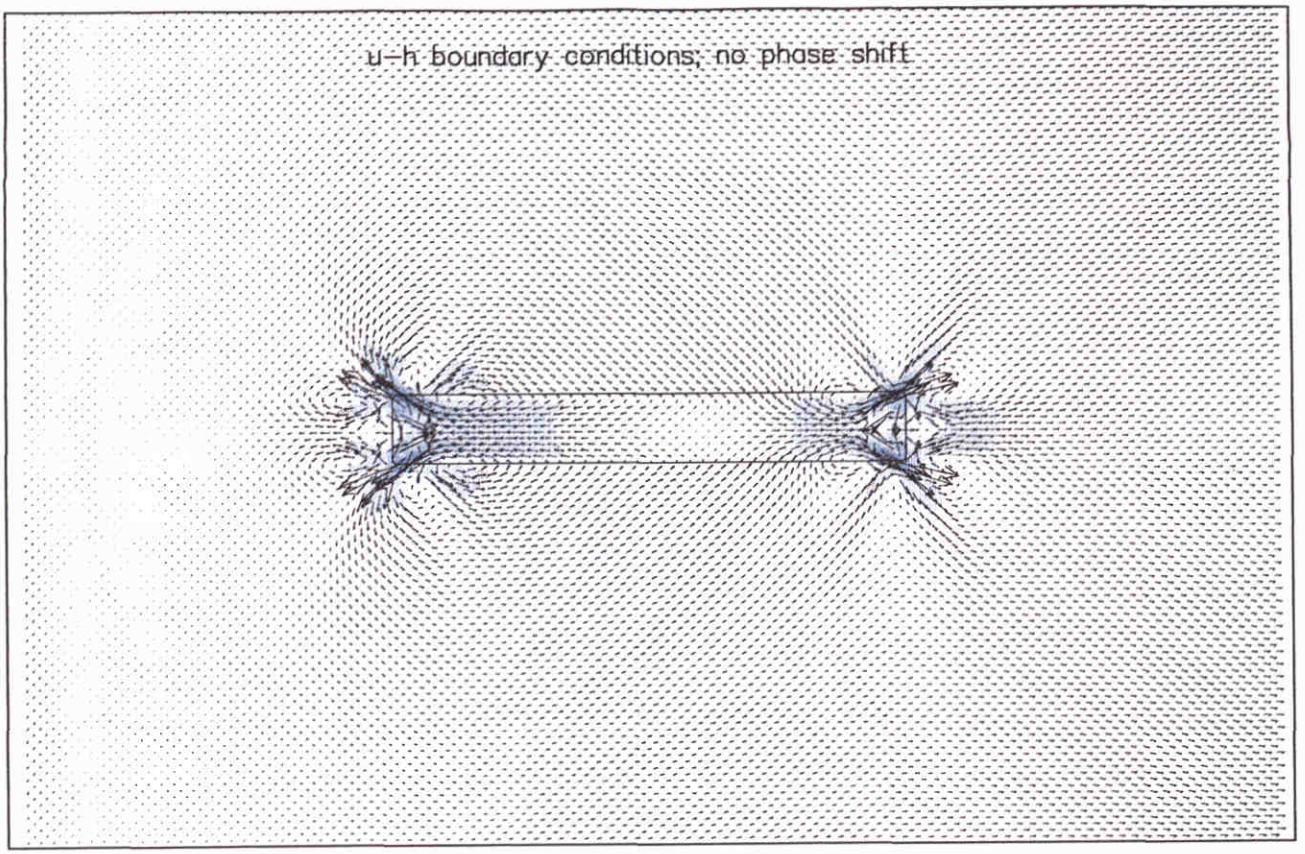
Influence of the length and the width on the current pattern

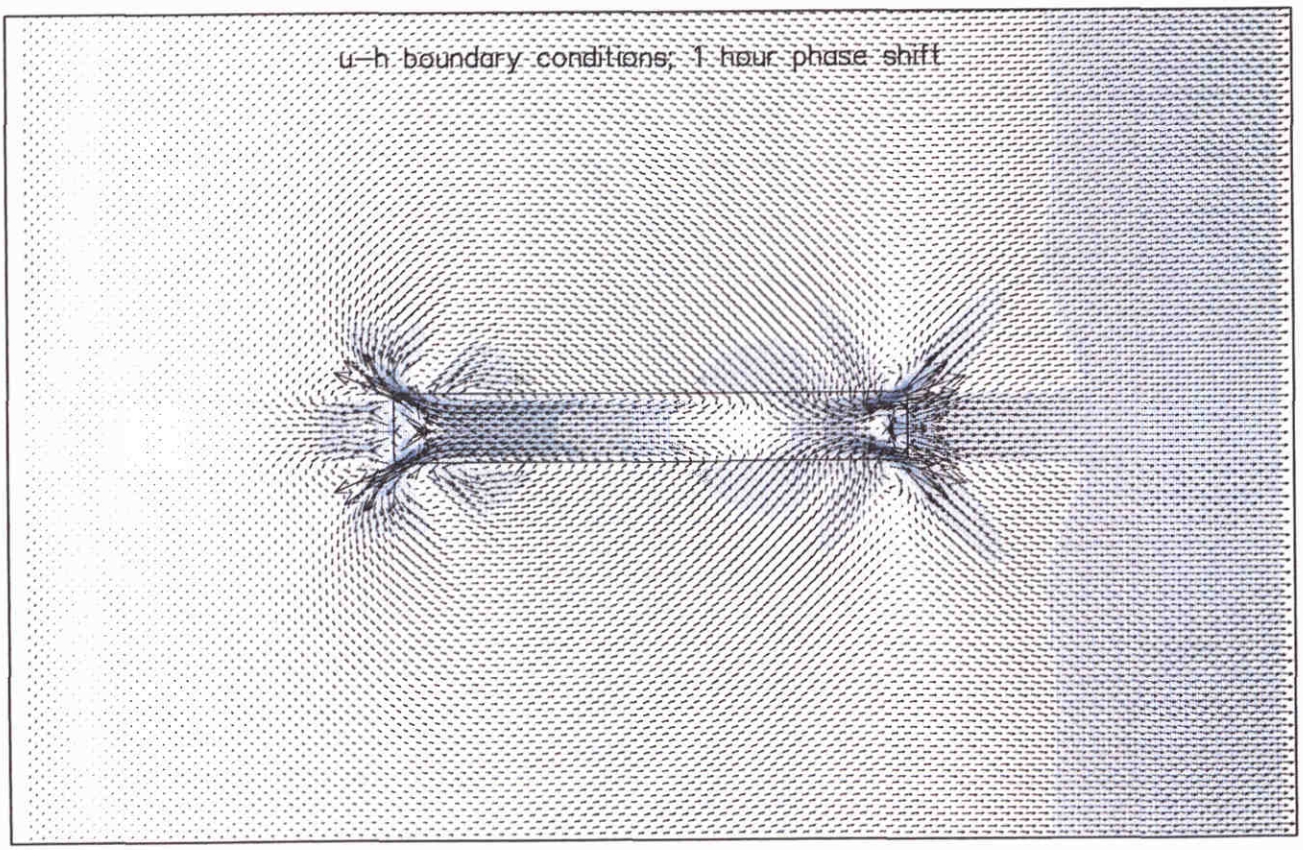
Stationary boundary conditions including Coriolis

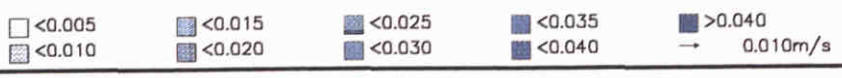
WL | DELFT HYDRAULICS

z2615

Figure 6.7







Tide–averaged current velocities [m/s]

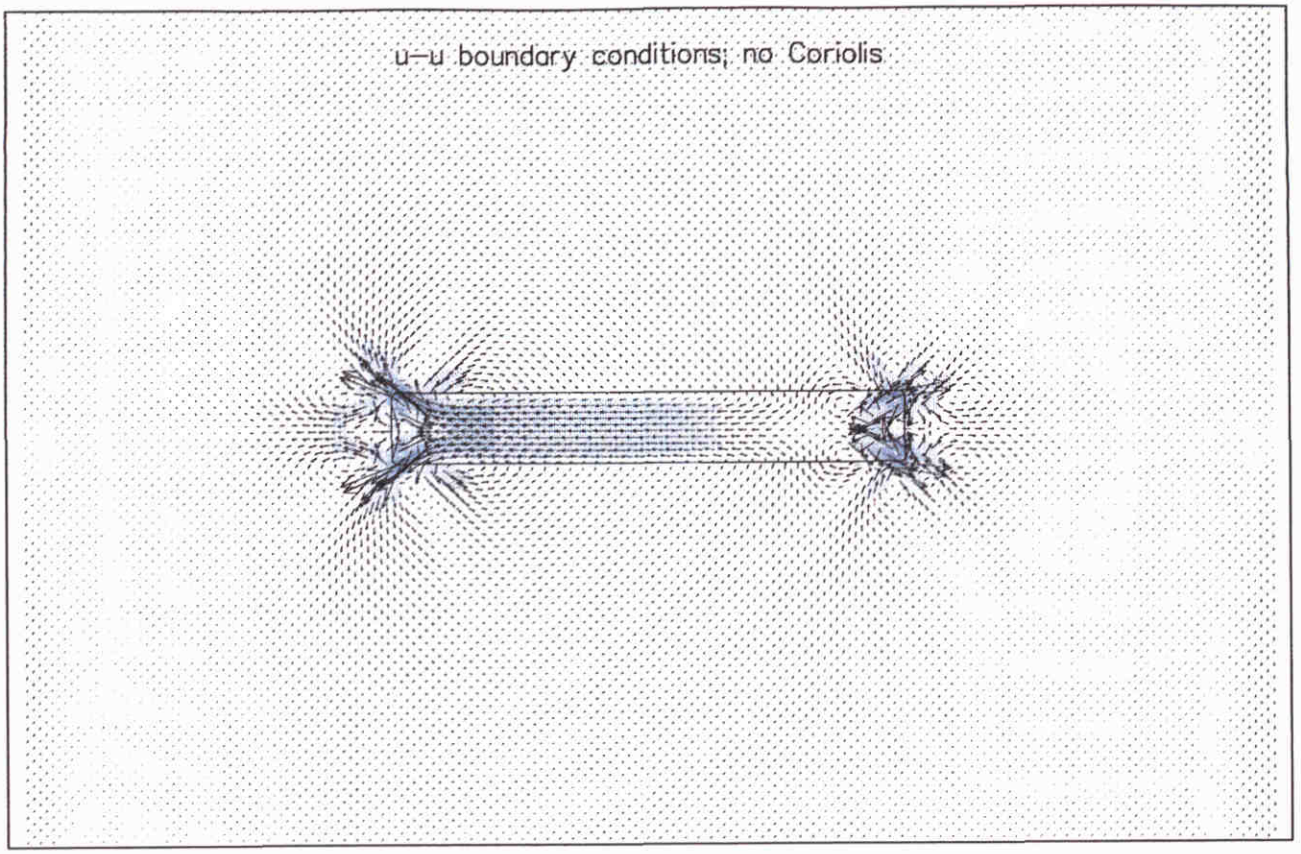
Influence of the boundary conditions on the tide–averaged current pattern

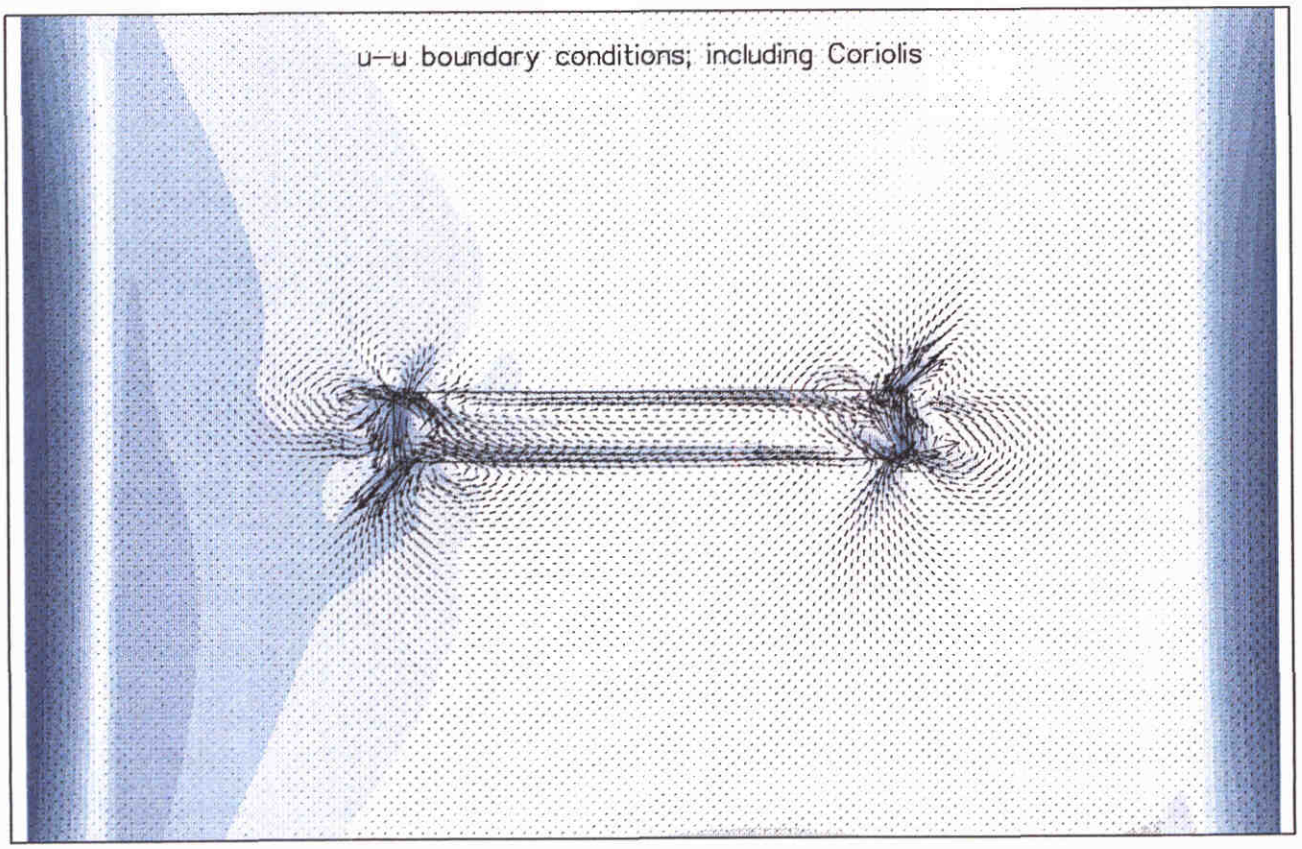
Tidal boundary conditions

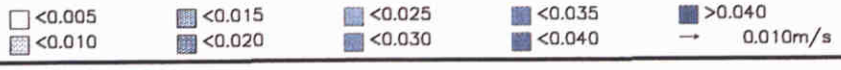
WL | DELFT HYDRAULICS

z2615

Figure 7.1







Tide–averaged current velocities [m/s]

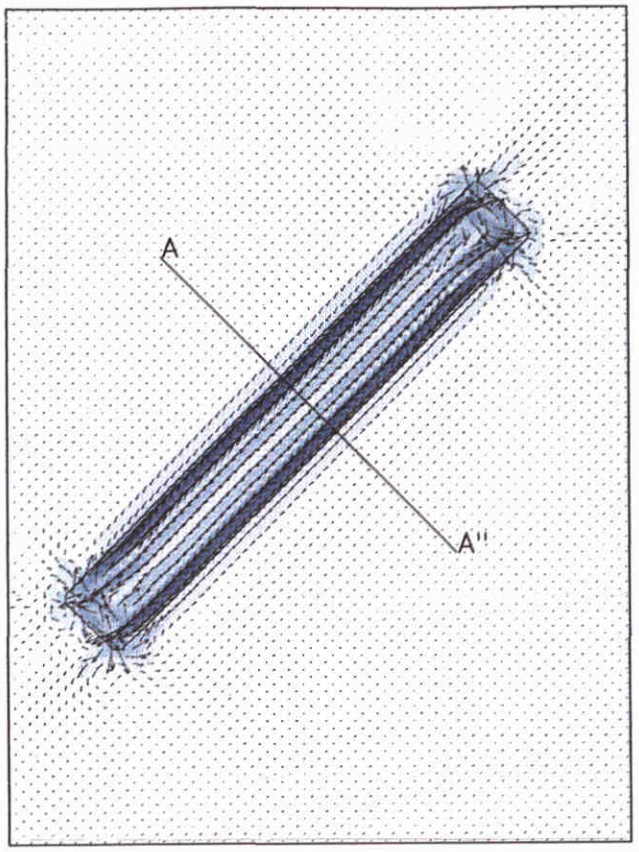
Influence of Coriolis on the tide–averaged current pattern

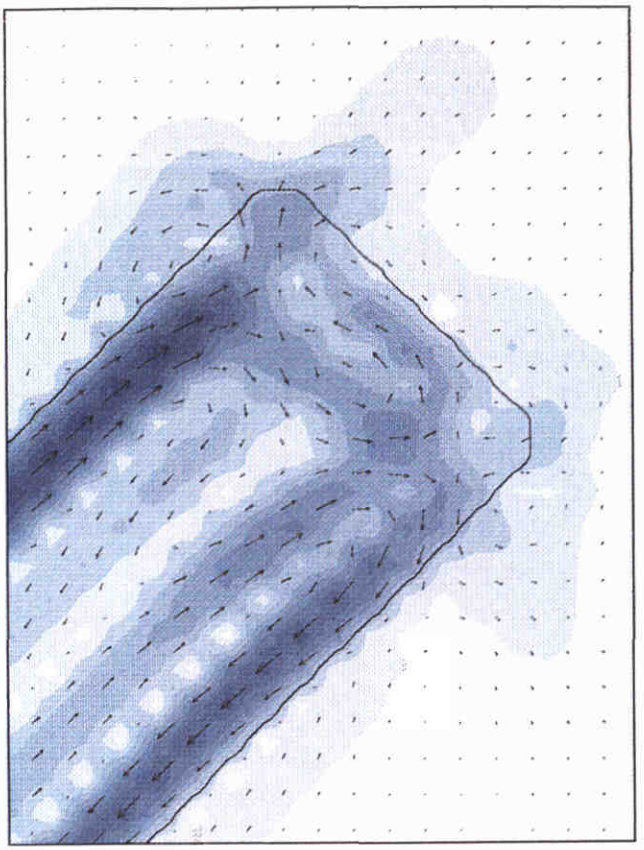
Tidal boundary conditions with and without Coriolis

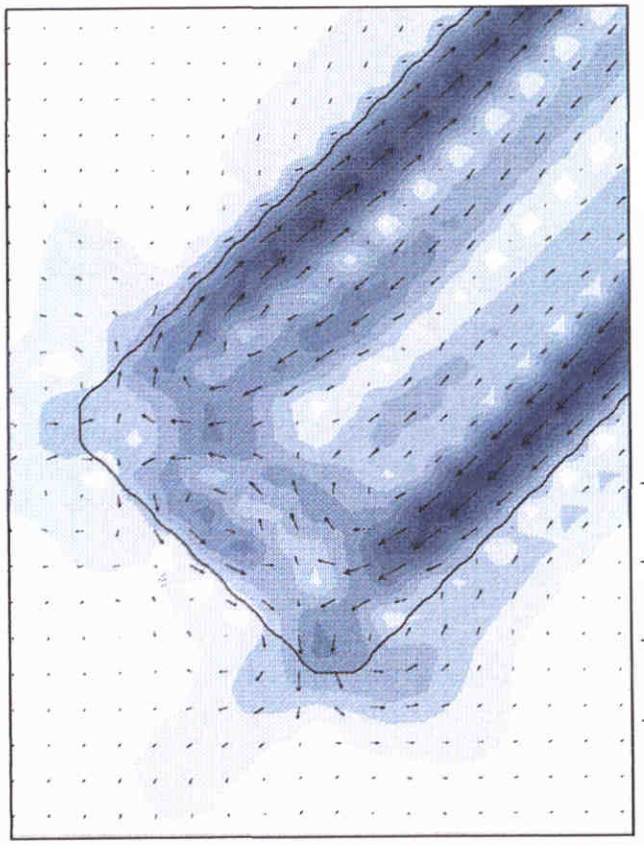
WL | DELFT HYDRAULICS

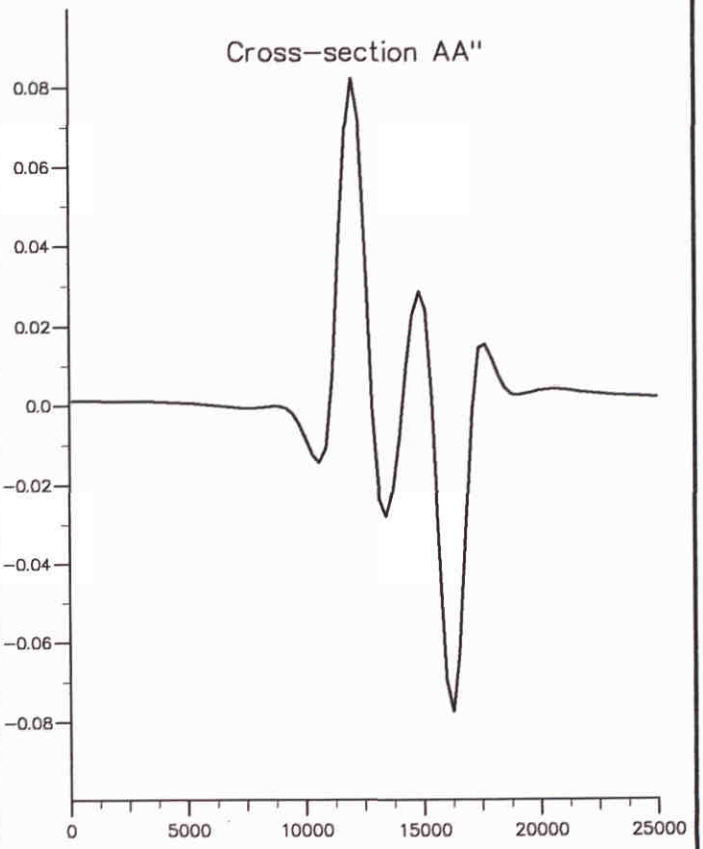
z2615

Figure 7.2









Tide–averaged current velocities [m/s]

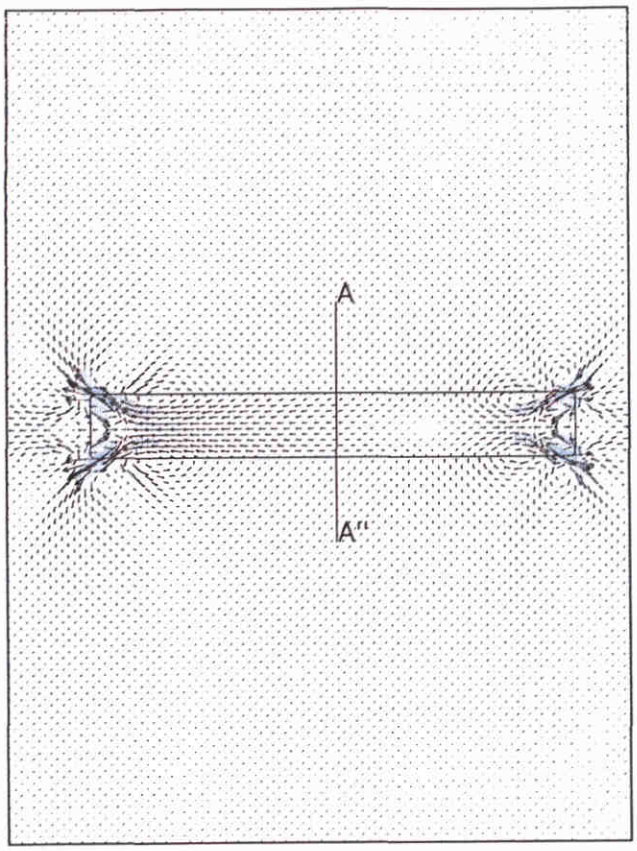
Tide–averaged current pattern and tide–averaged velocities in cross–section AA''

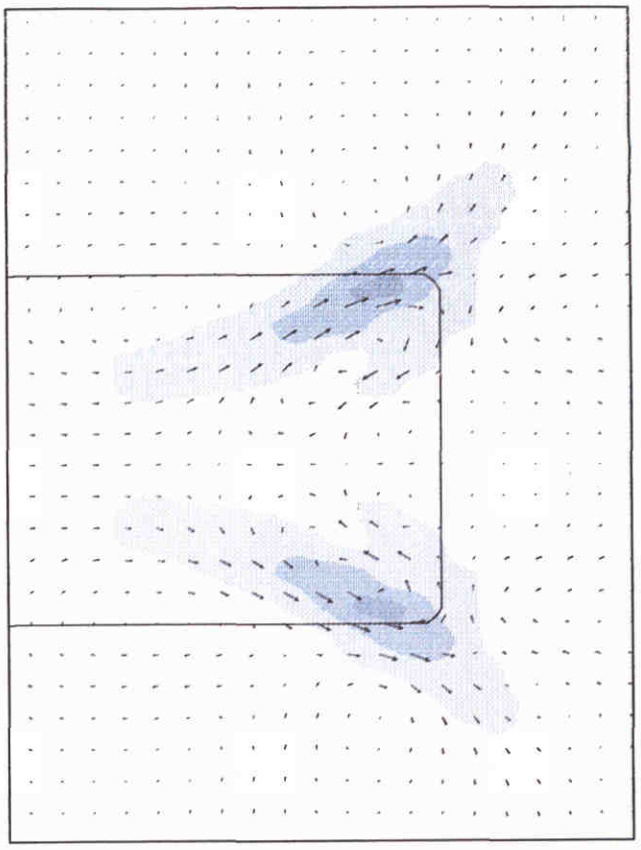
Tidal boundary conditions

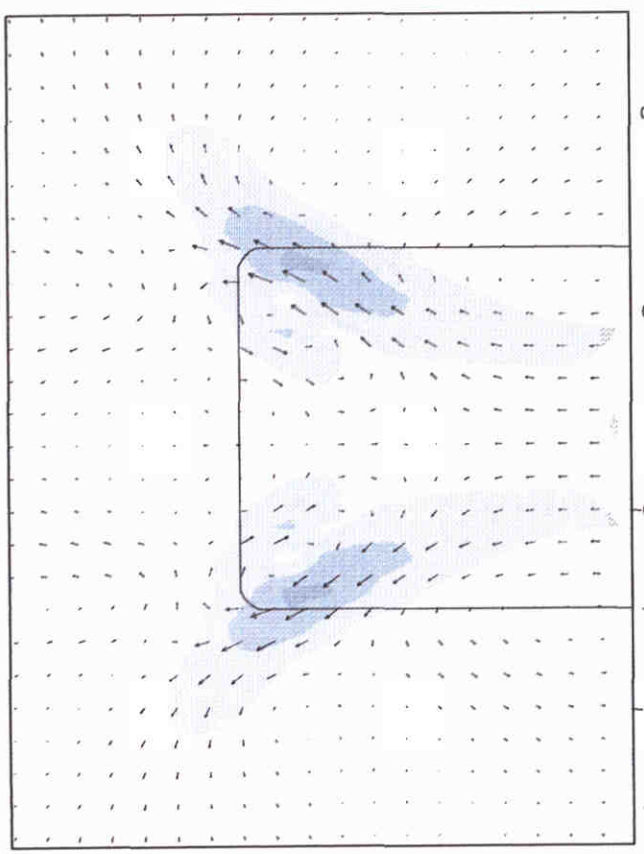
WL | DELFT HYDRAULICS

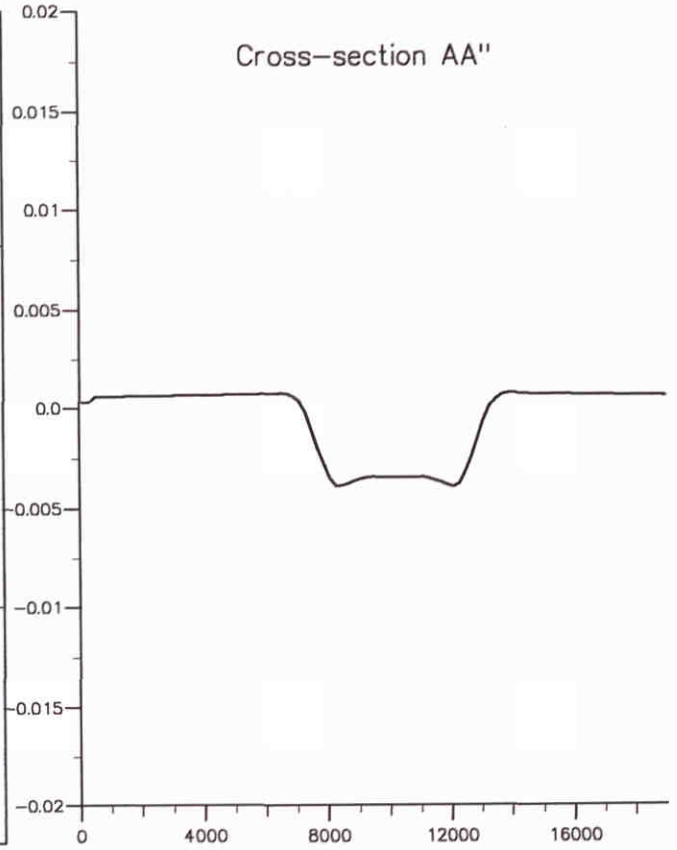
z2615

Figure 7.3









Tide–averaged current velocities

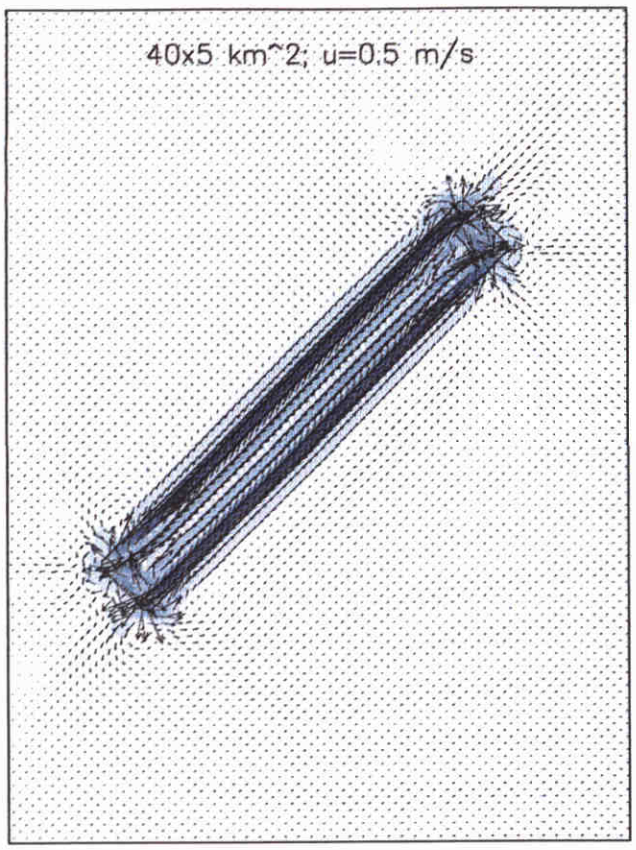
Tide–averaged current pattern and tide–averaged velocities in cross–section AA''

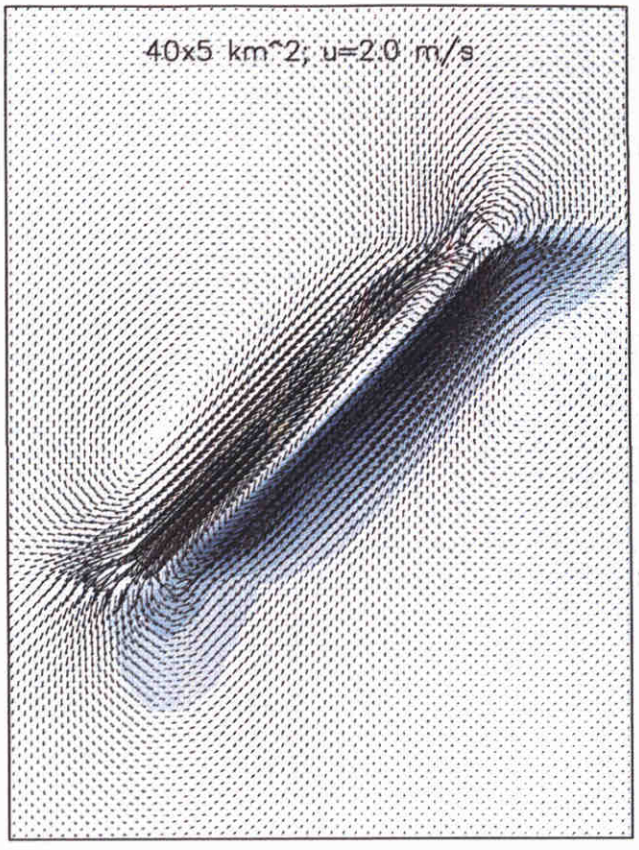
Tidal boundary conditions

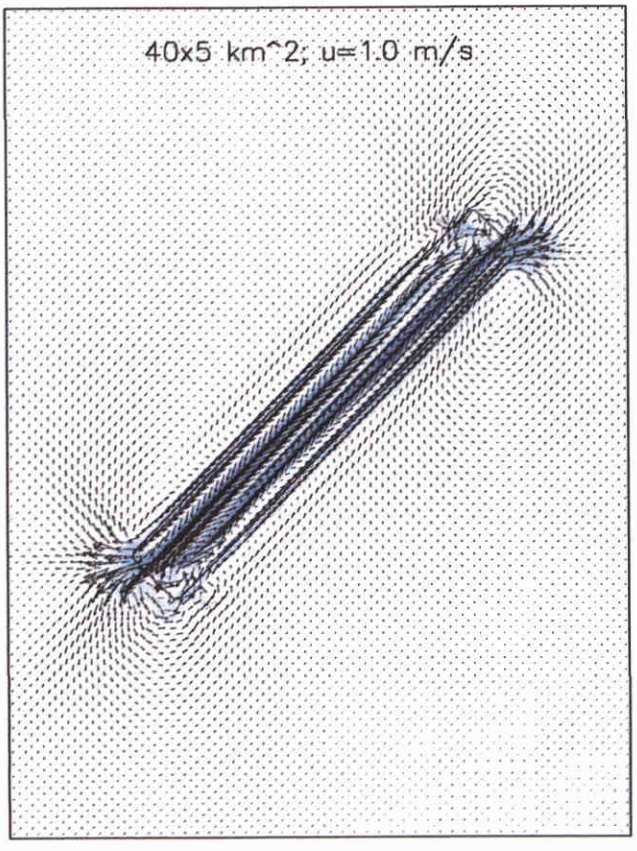
WL | DELFT HYDRAULICS

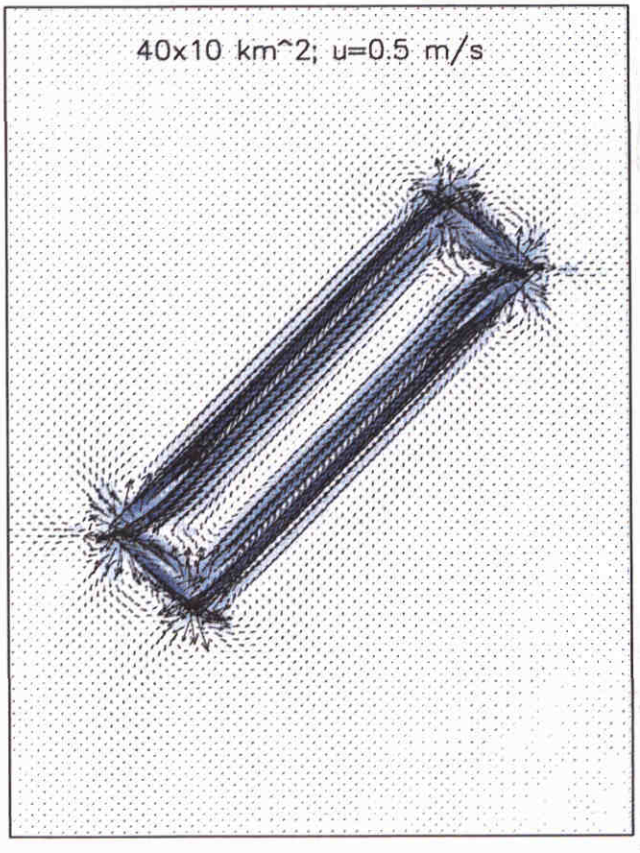
z2615

Figure 7.4









Tide–averaged current velocities [m/s]

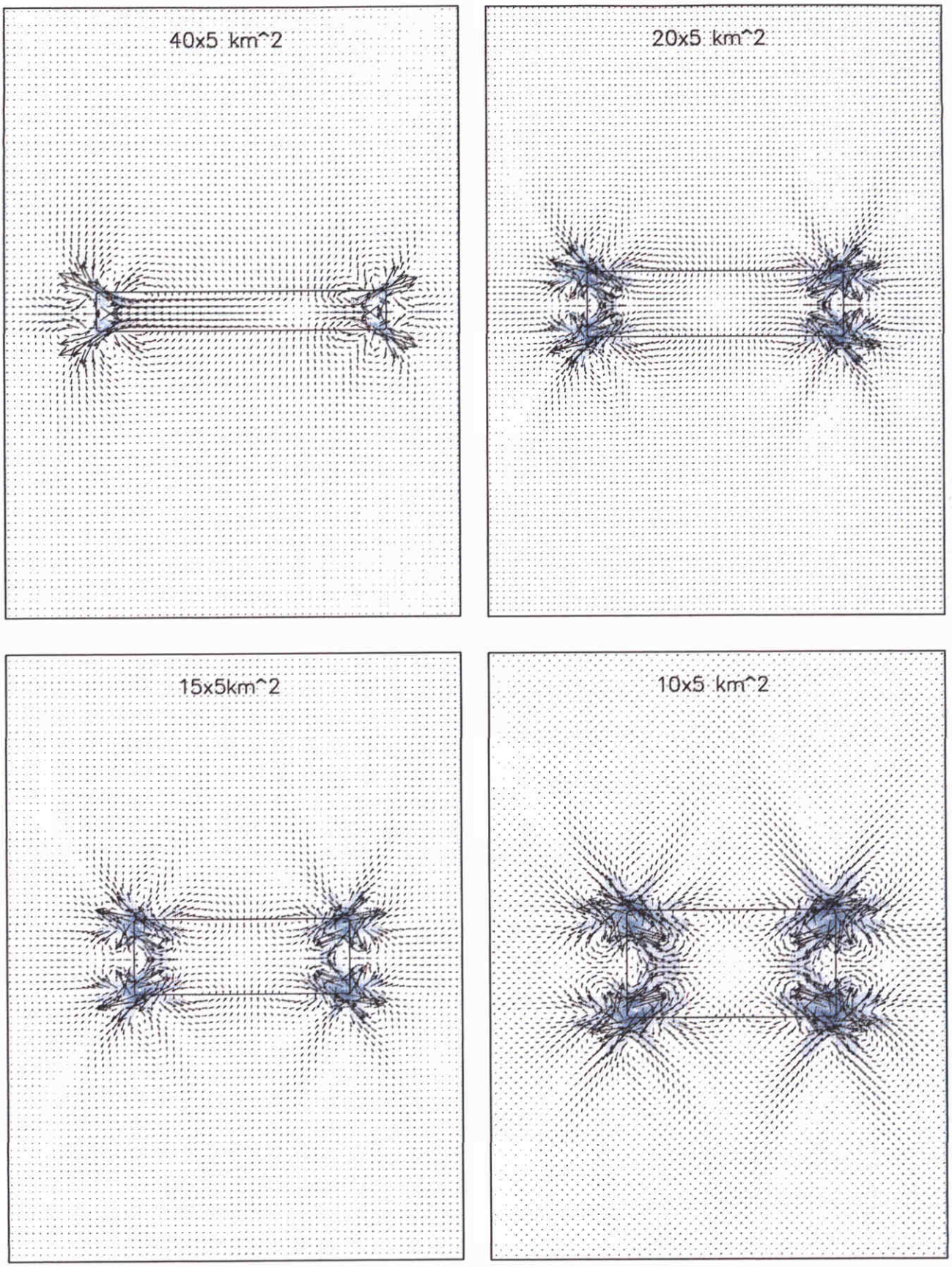
Influence of the tidal amplitude and the width on the tide–averaged current pattern

Tidal boundary conditions

WL | DELFT HYDRAULICS

z2615

Figure 7.5



Tide–averaged current velocities [m/s]

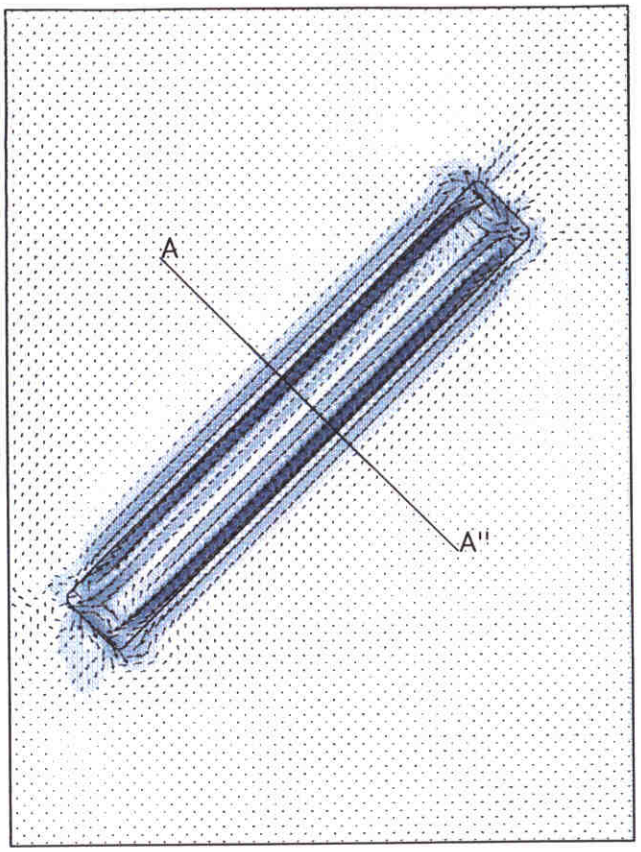
Influence of the length on the tide–averaged current pattern

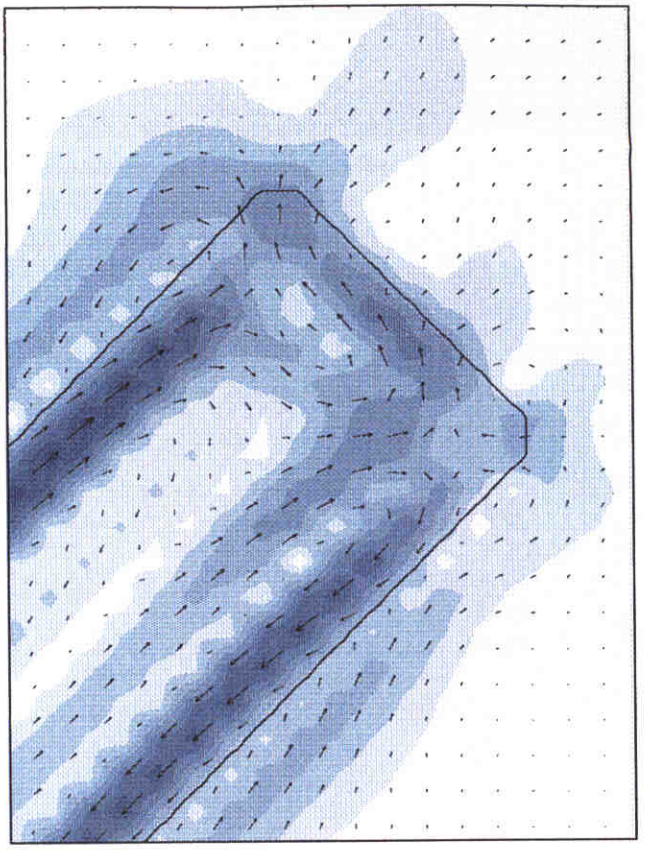
Tidal boundary conditions

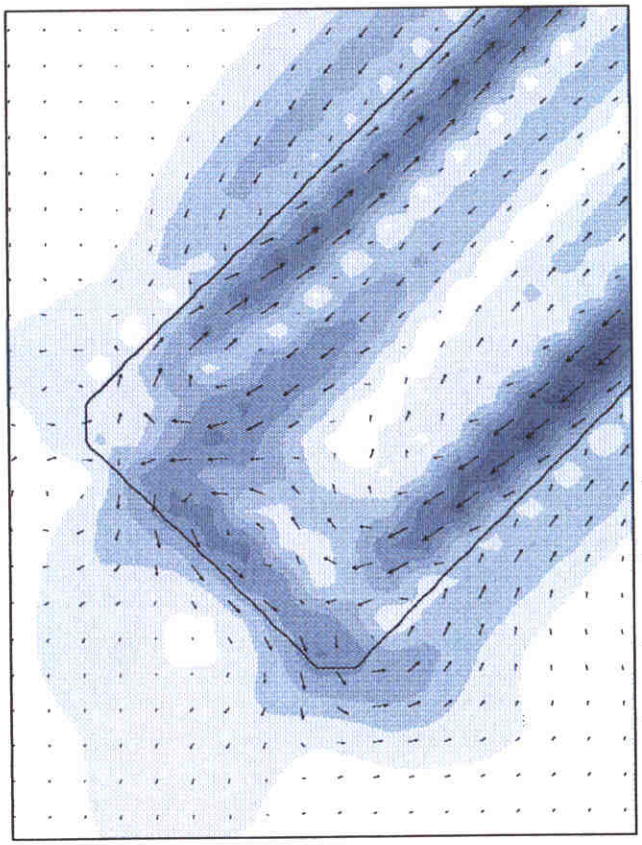
WL | DELFT HYDRAULICS

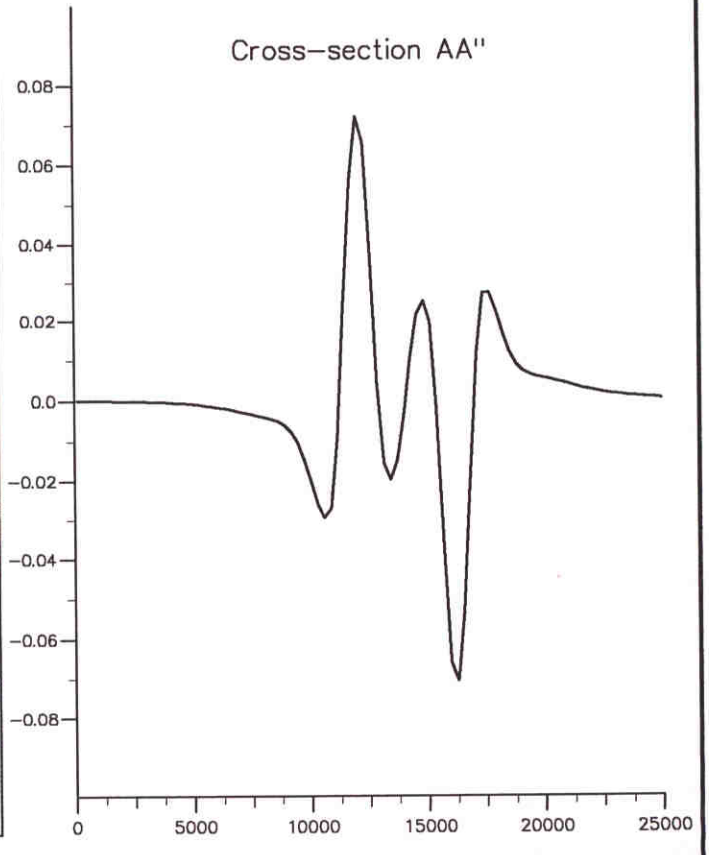
z2615

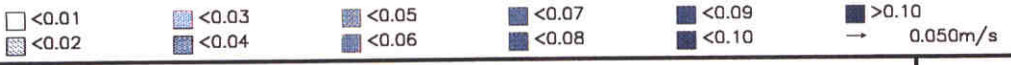
Figure 7.6











Tide–averaged current velocities [m/s]

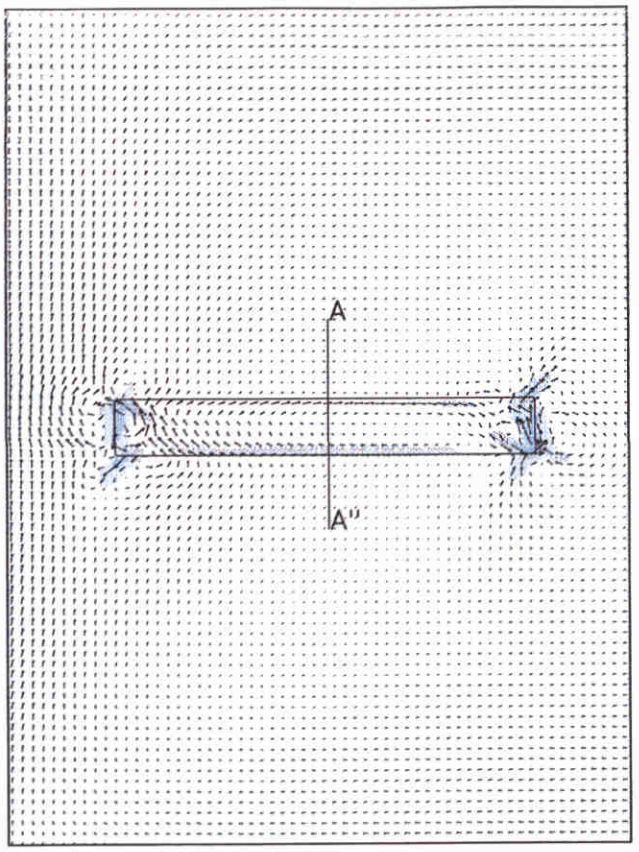
Tide–averaged current pattern and tide–averaged velocities in cross–section AA''

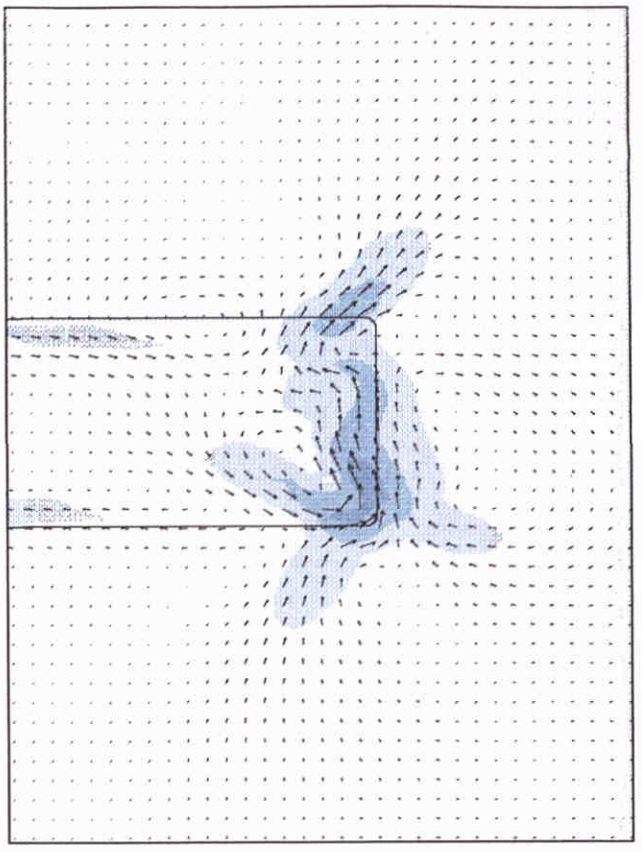
Tidal boundary conditions including Coriolis

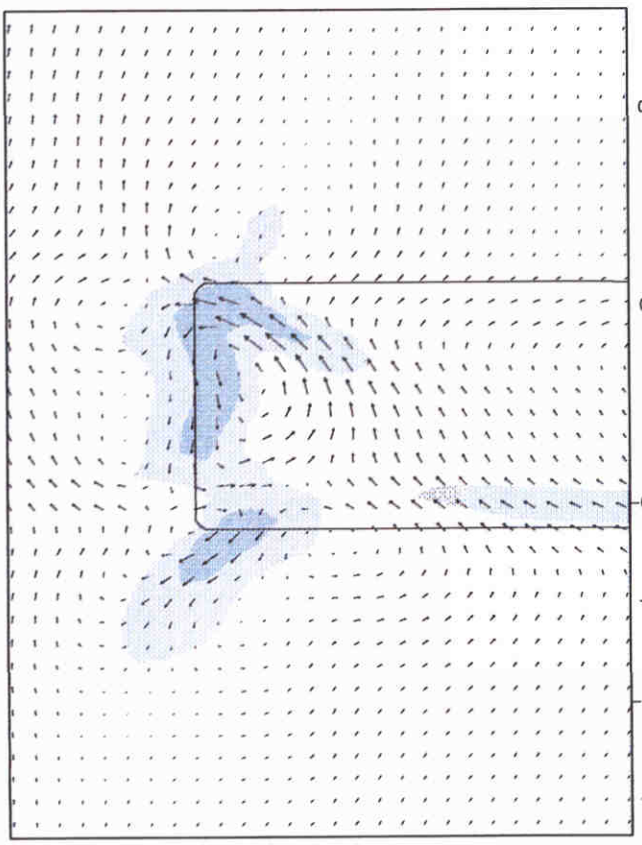
WL | DELFT HYDRAULICS

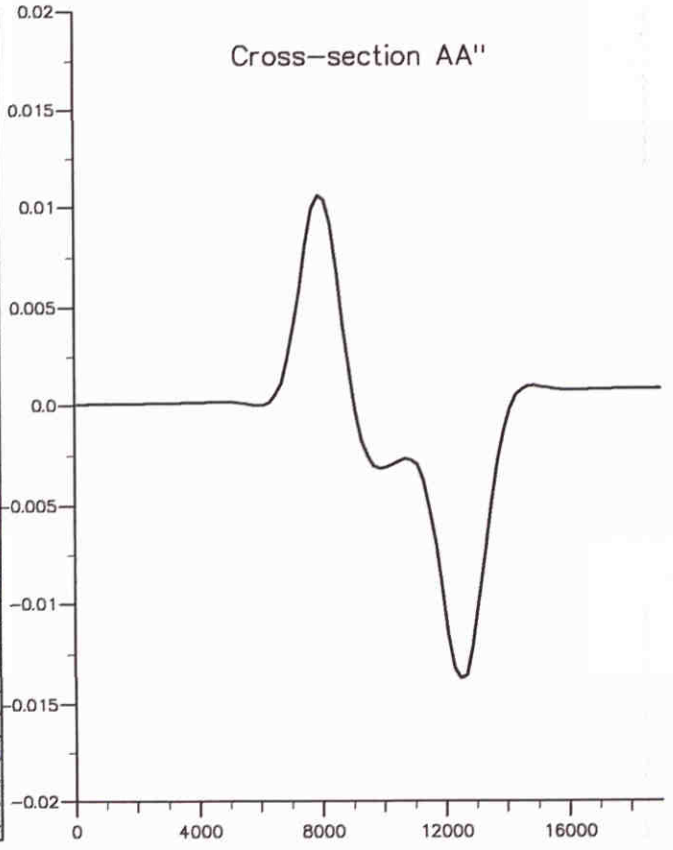
z2615

Figure 7.7









Tide–averaged current velocities [m/s]

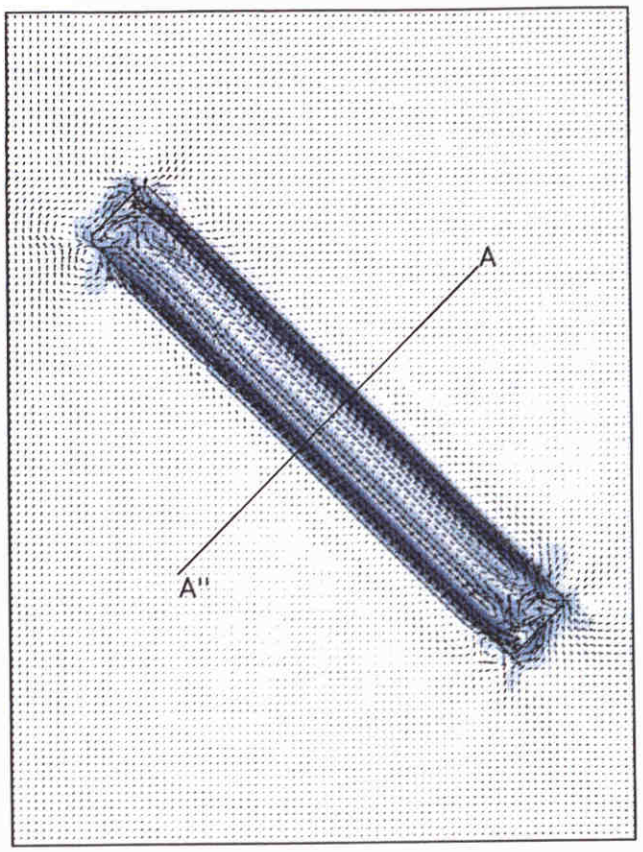
Tide–averaged current pattern and tide–averaged velocities in cross–section AA''

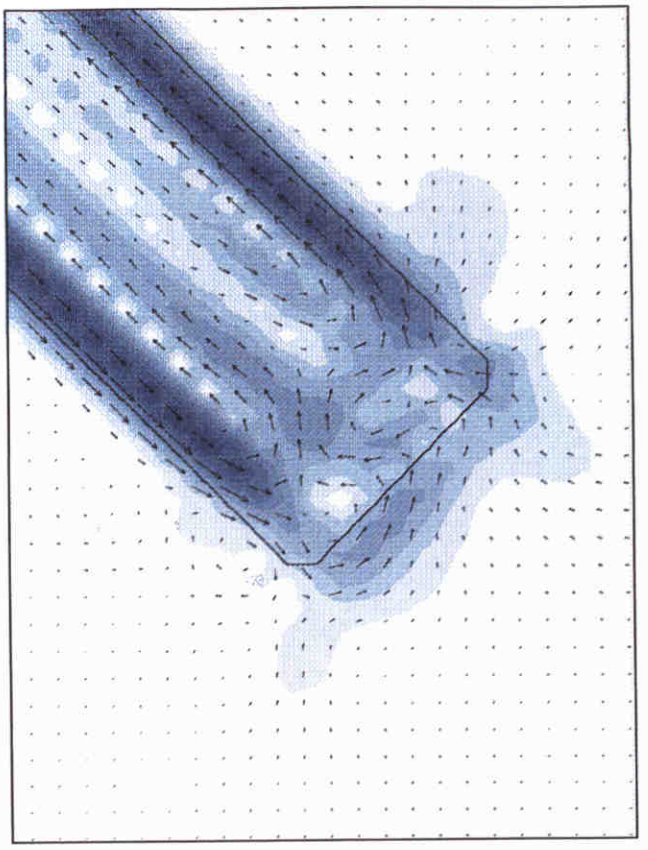
Tidal boundary conditions including Coriolis

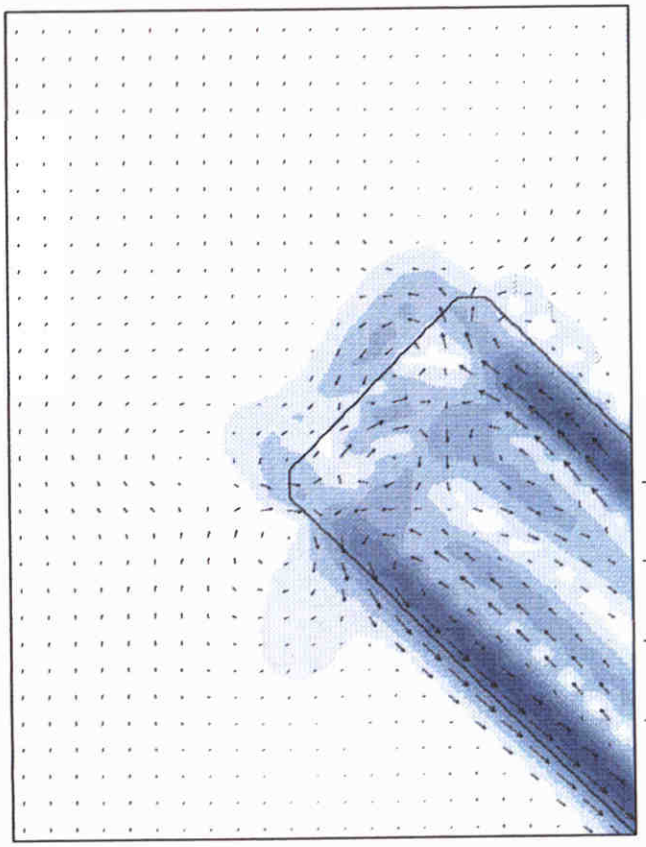
WL | DELFT HYDRAULICS

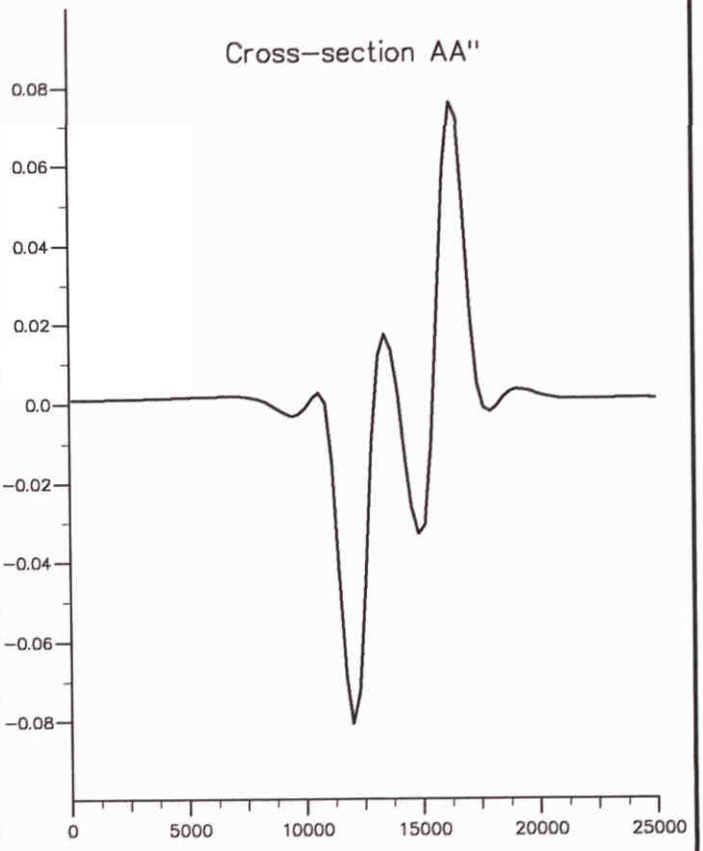
z2615

Figure 7.8









Tide–averaged current velocities [m/s]

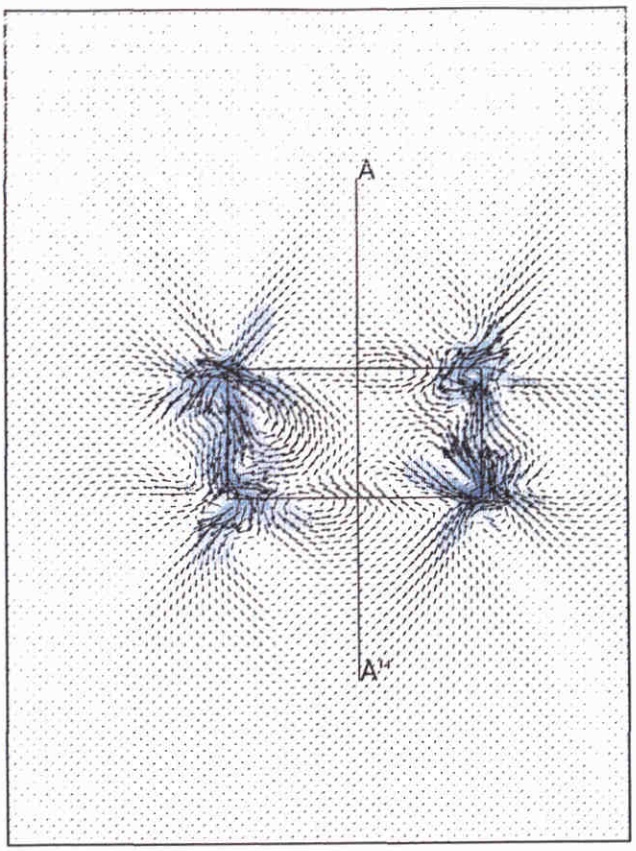
Tide–averaged current pattern and tide–averaged velocities in cross–section AA''

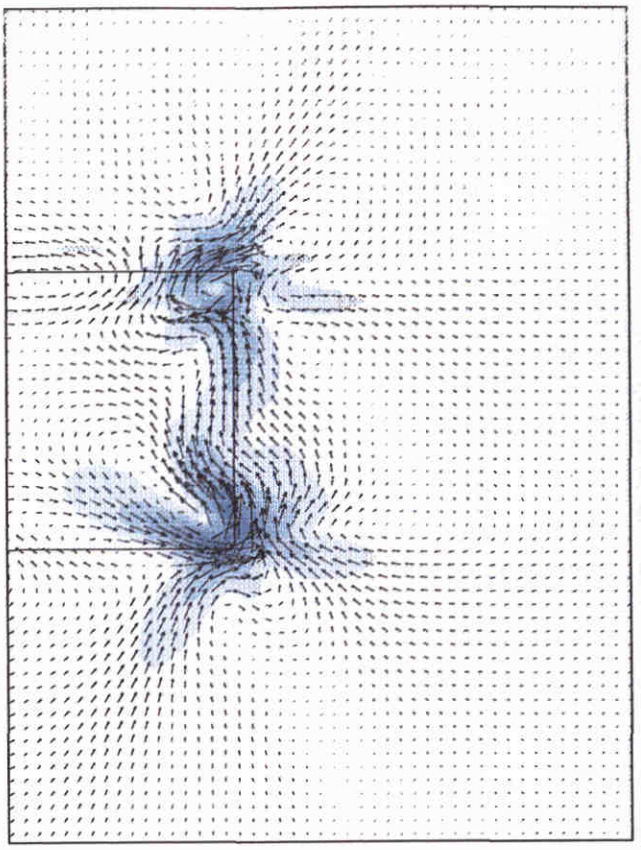
Tidal boundary conditions including Coriolis

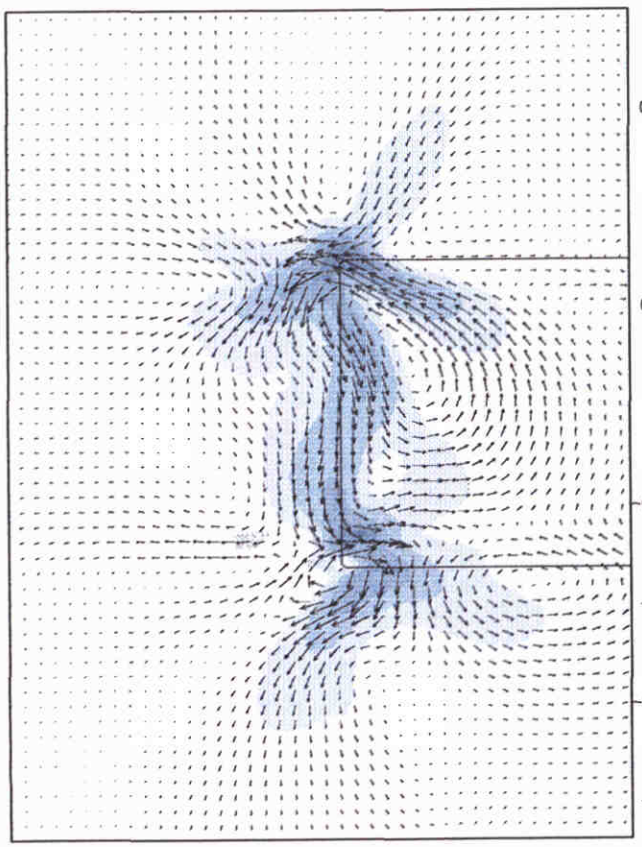
WL | DELFT HYDRAULICS

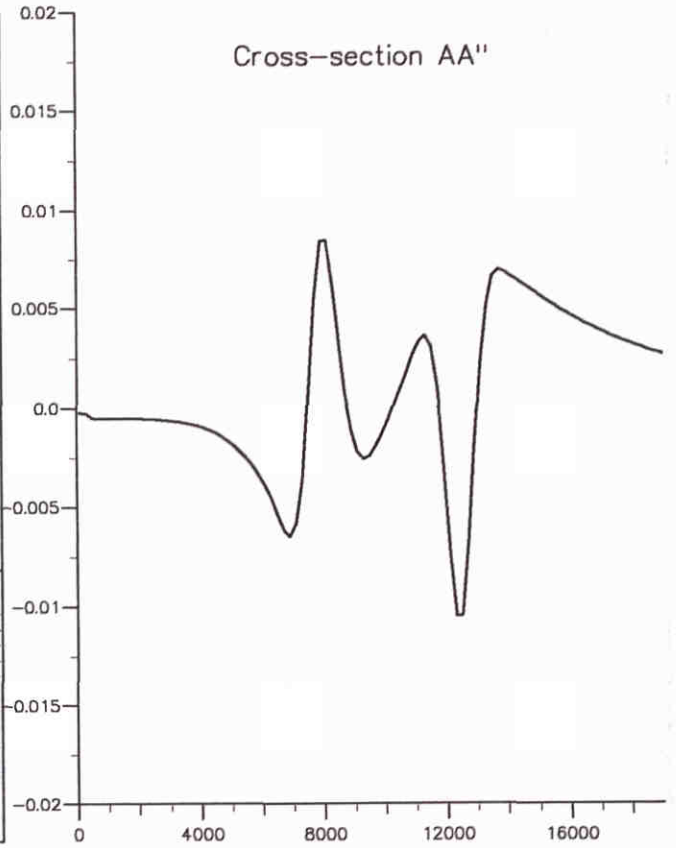
z2615

Figure 7.9









Tide-averaged current velocities [m/s]

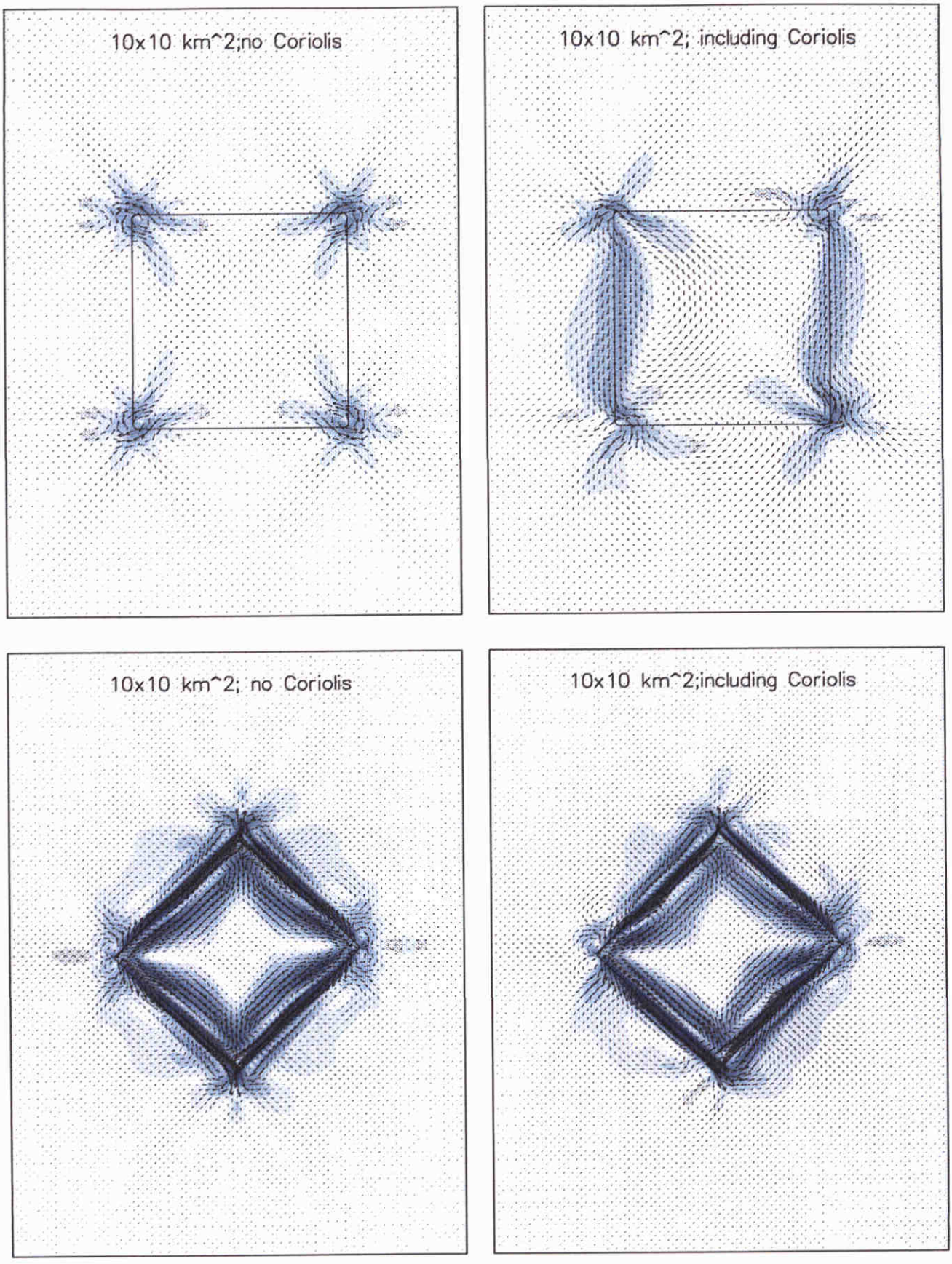
Tide-averaged current pattern and tide-averaged velocities in cross-section AA''

Tidal boundary conditions including Coriolis

WL | DELFT HYDRAULICS

z2615

Figure 7.10



Tide-averaged current velocities [m/s]

Tide-averaged current pattern

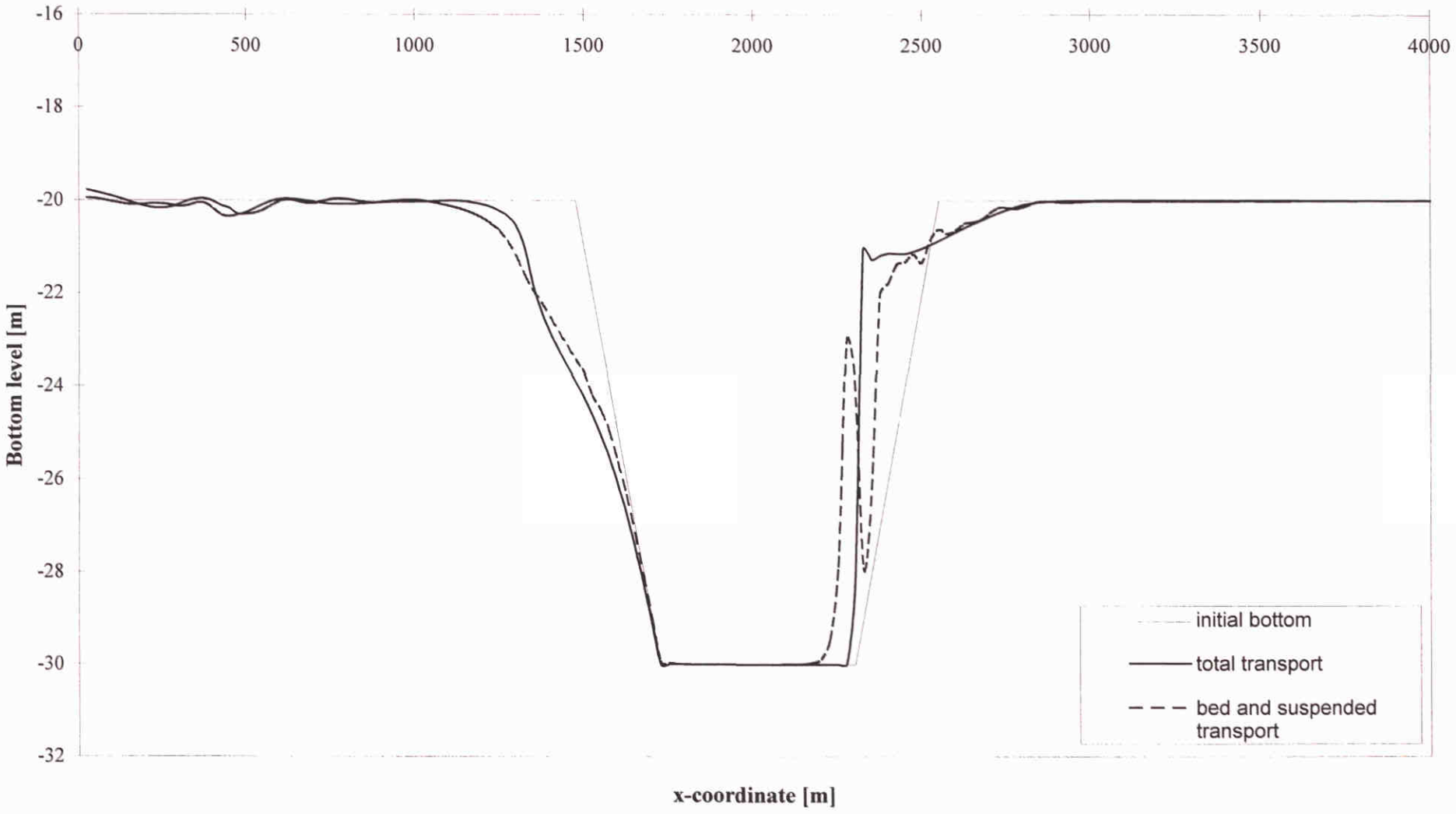
Tidal boundary conditions with and without Coriolis

WL | DELFT HYDRAULICS

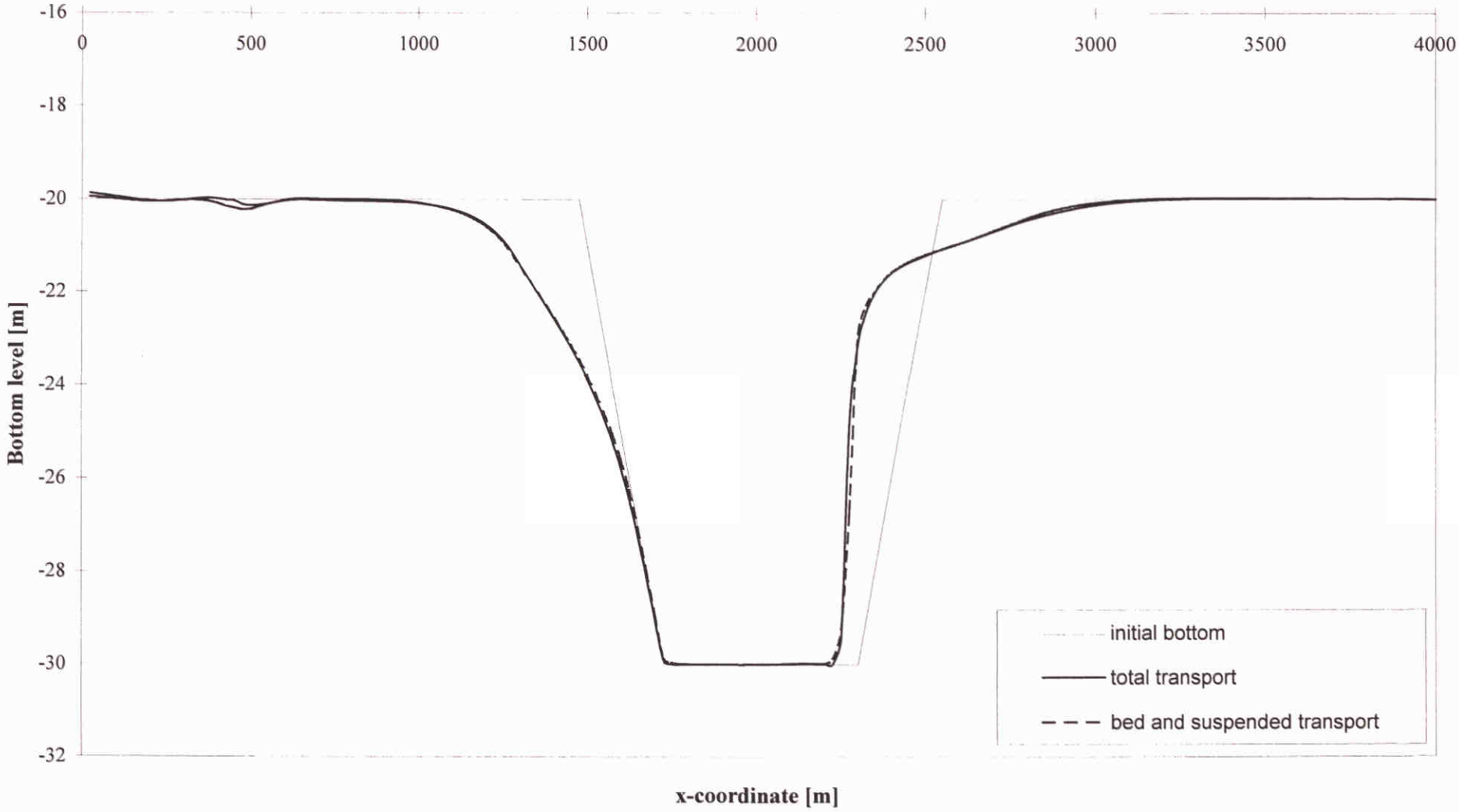
z2615

Figure 7.11

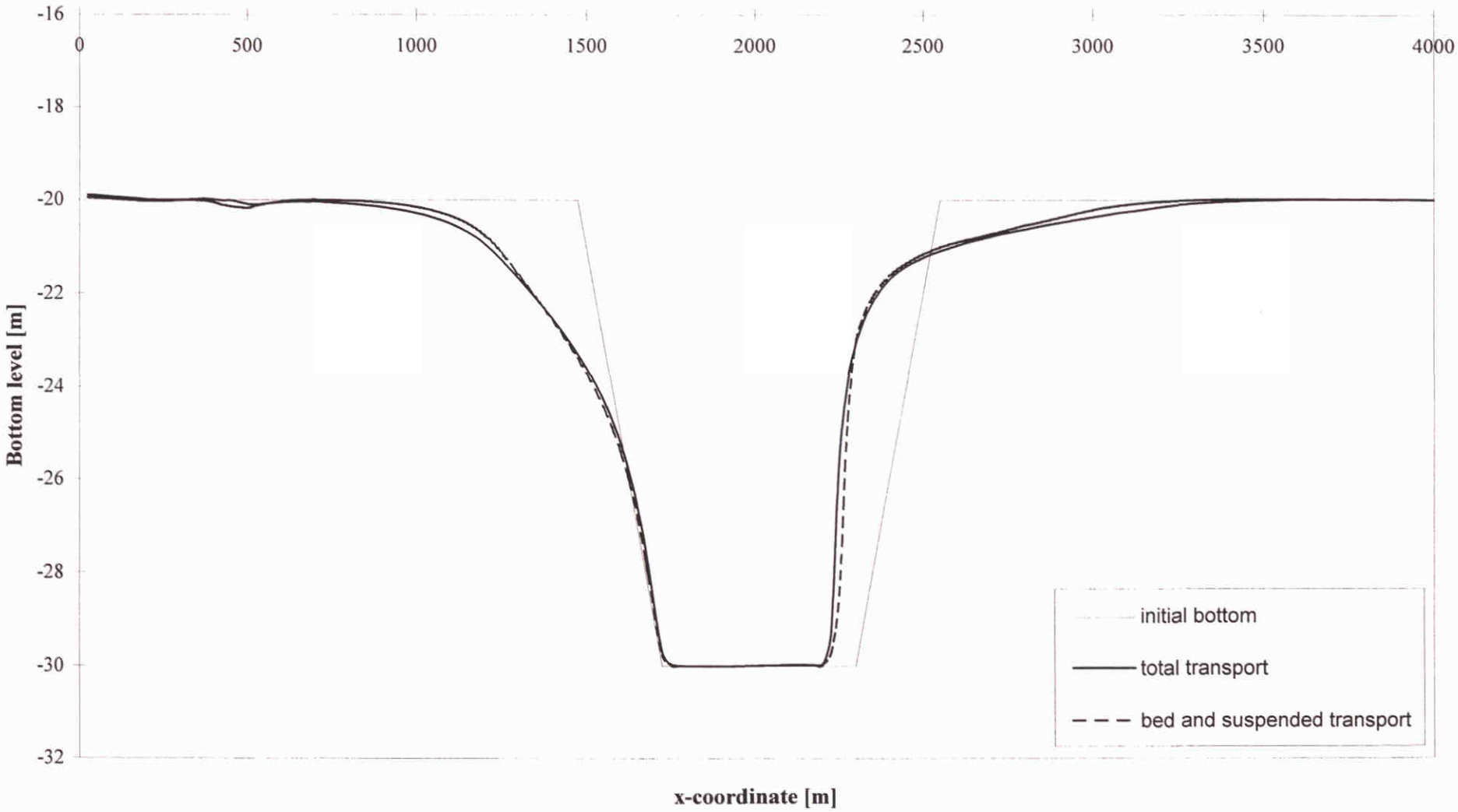
Figuur 8.2: Influence of the transport mode, while ALFABD is 1



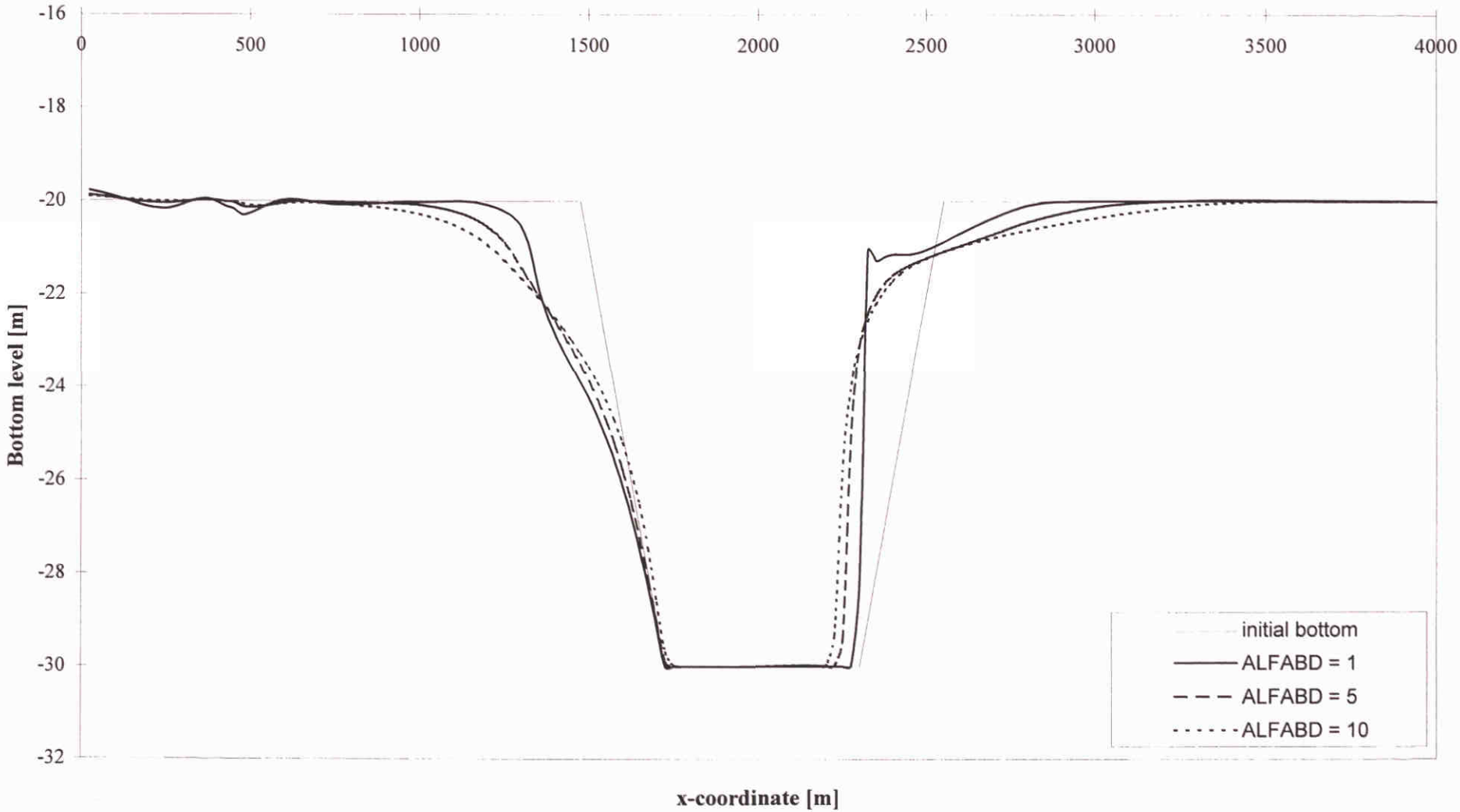
Figuur 8.3: Influence of the transport mode, while ALFABD is 5



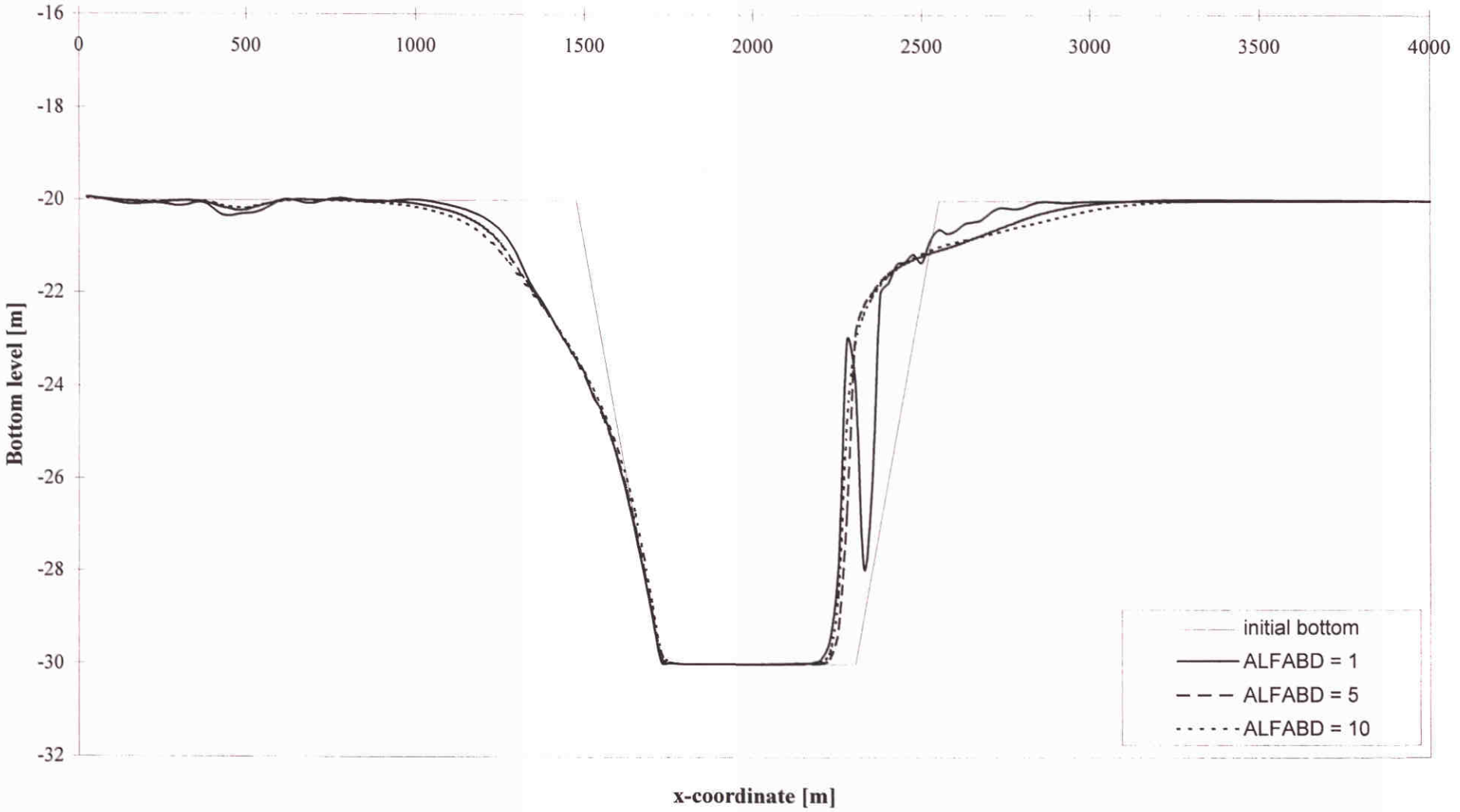
Figuur 8.4: Influence of the transport mode, while ALFABD is 10



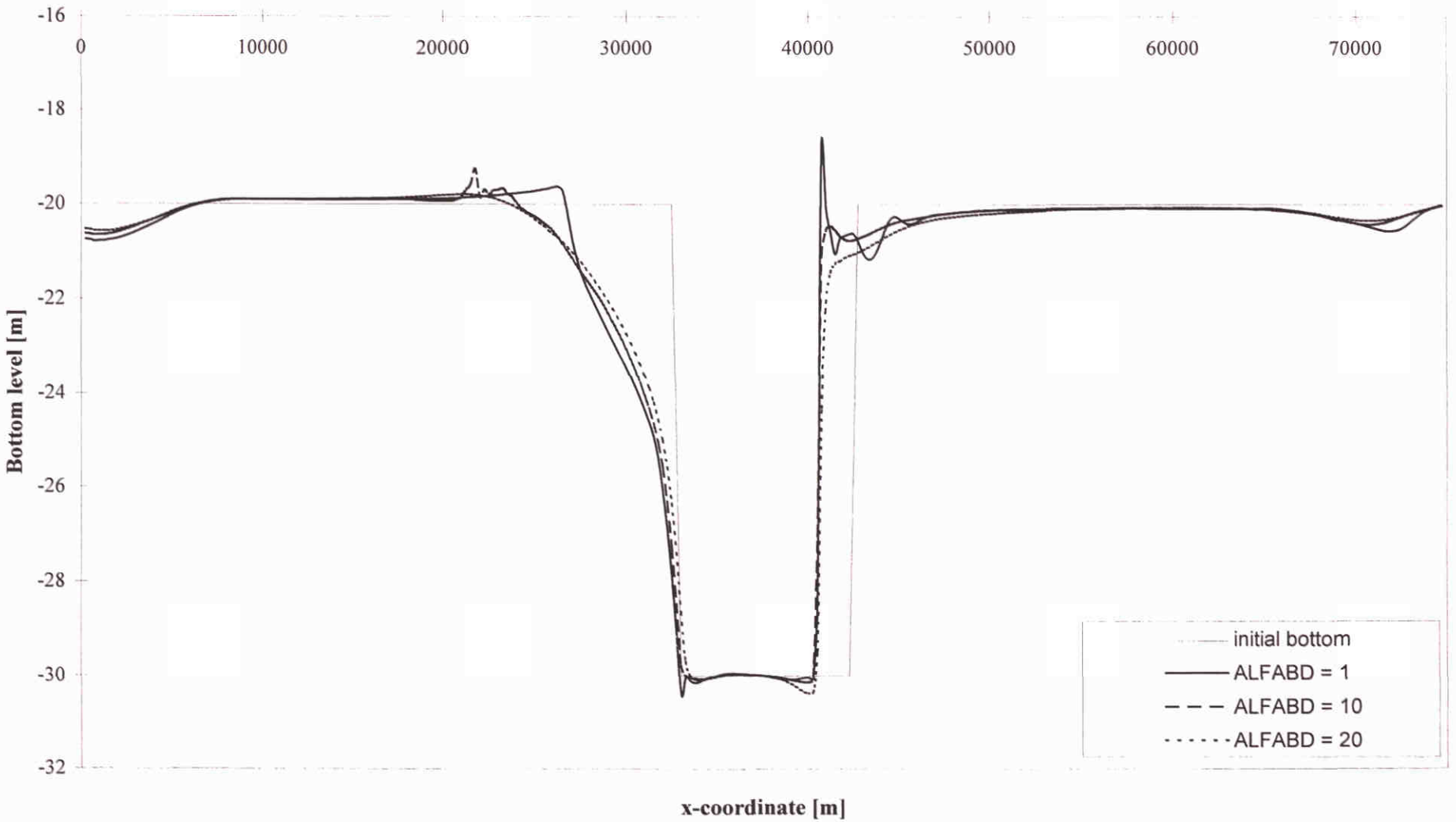
Figuur 8.5: Influence of ALFABD on the results of the total transport mode



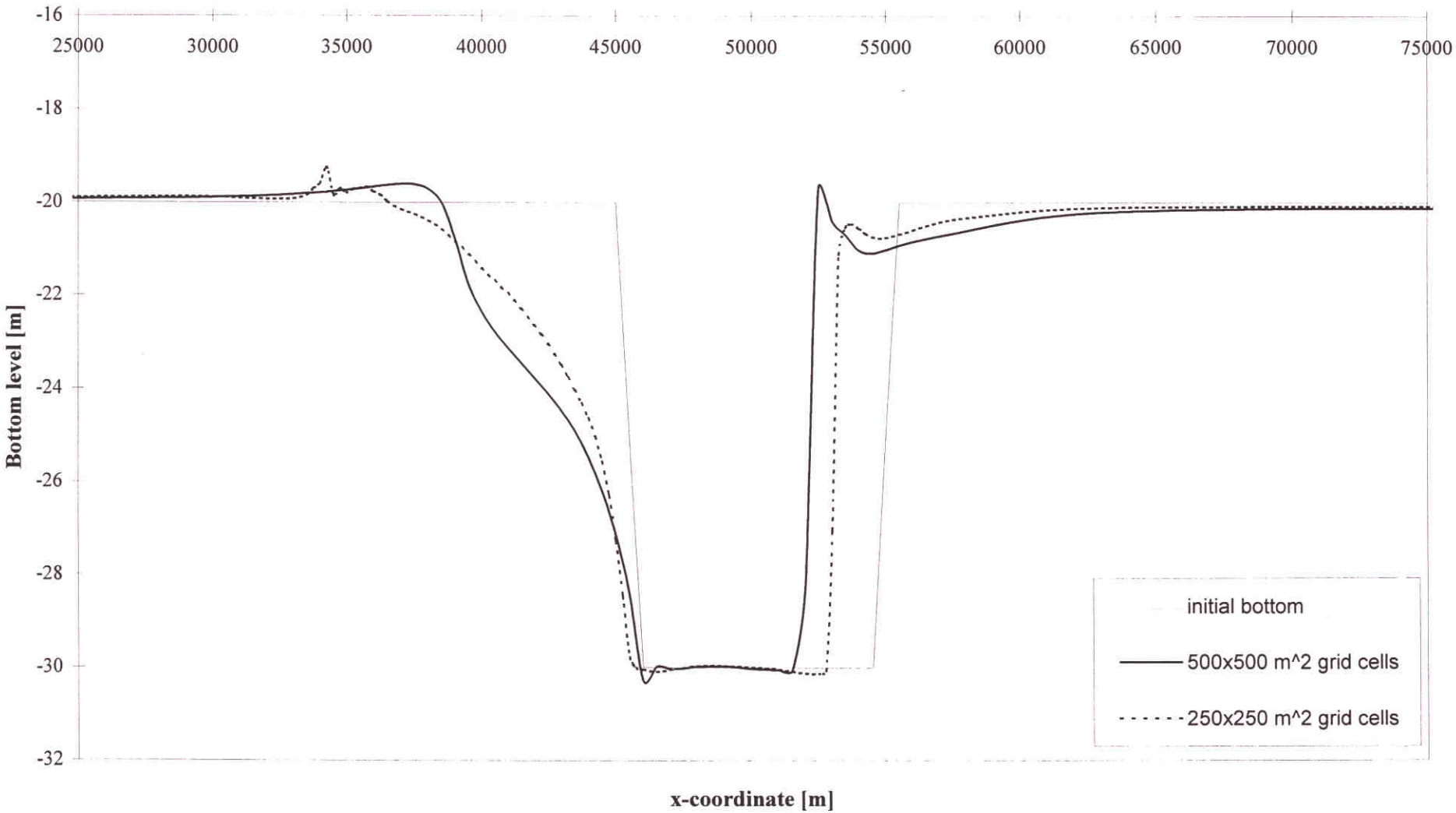
Figuur 8.6: Influence of ALFABD on the results of the bed and suspended transport mode



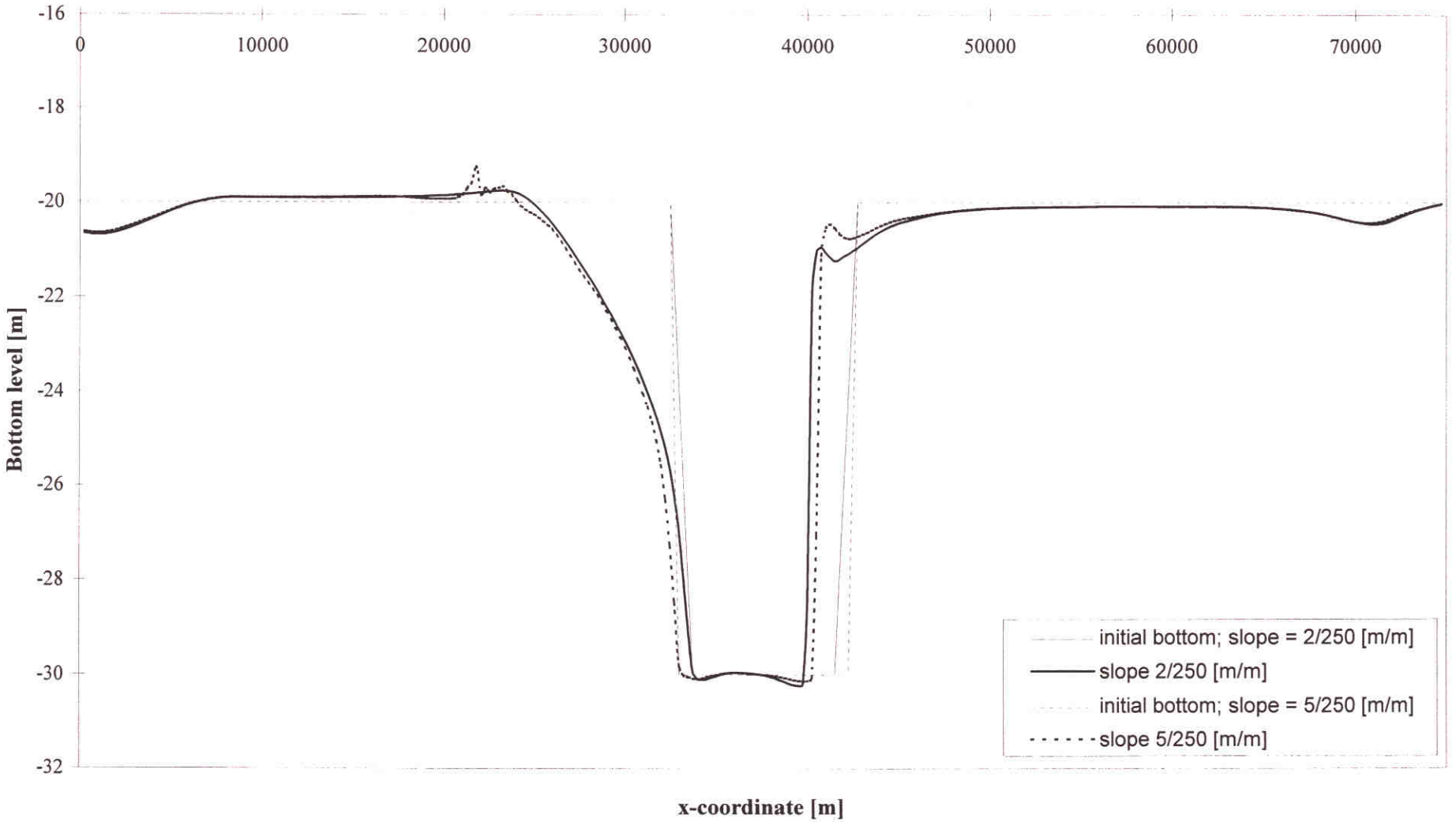
Figuur 8.7: Influence of ALFABD on a 10x10 km ^ 2 sandpit with total transport



Figuur 8.8: Influence of the grid cell size on the morphological results



Figuur 8.9: Influence of the slope of the sandpit on the morphological results



Figuur 8.10: Influence of the number of bottom computations per flow computation

Figure 8.11: Data points for tide analysis

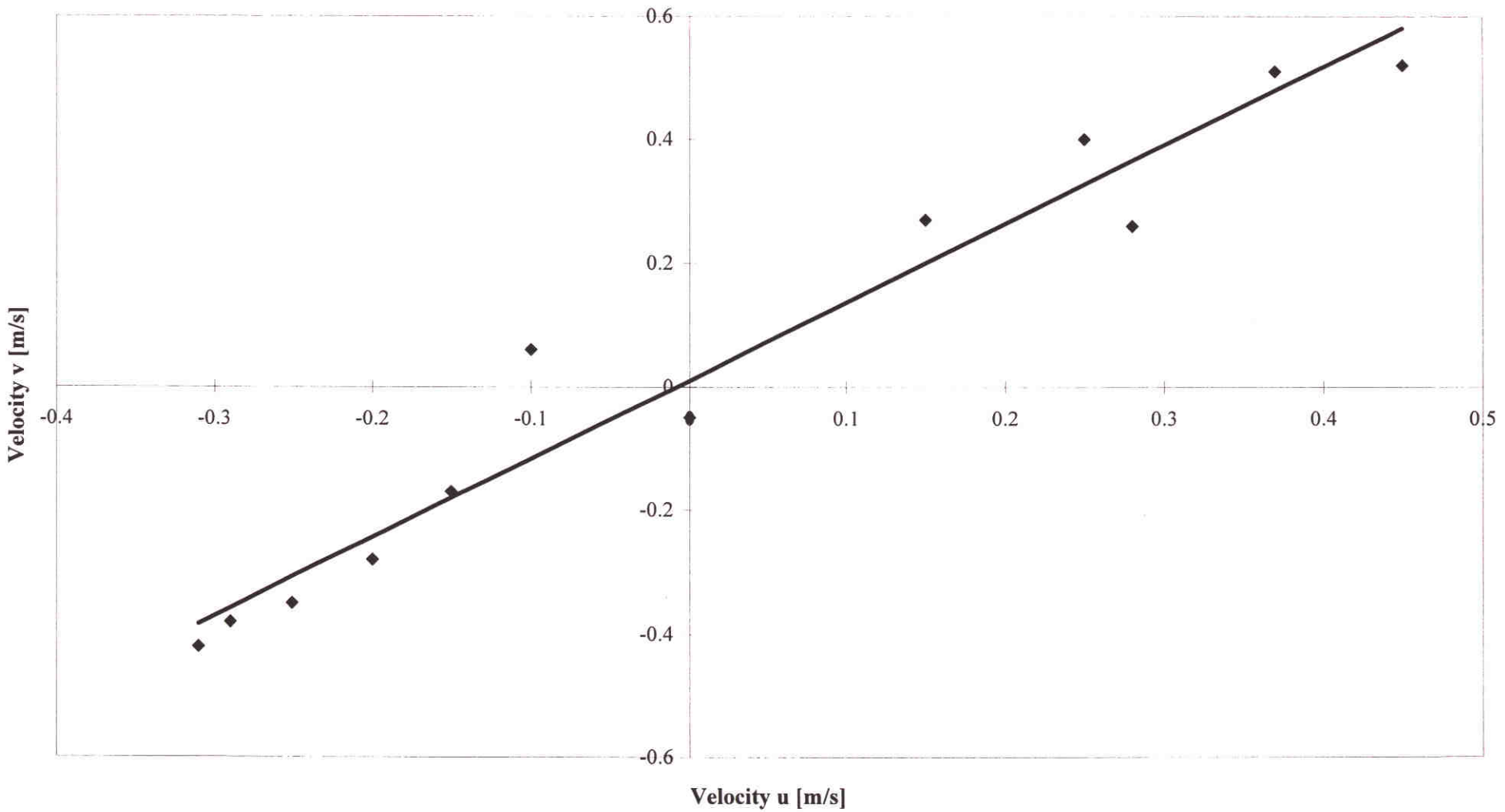
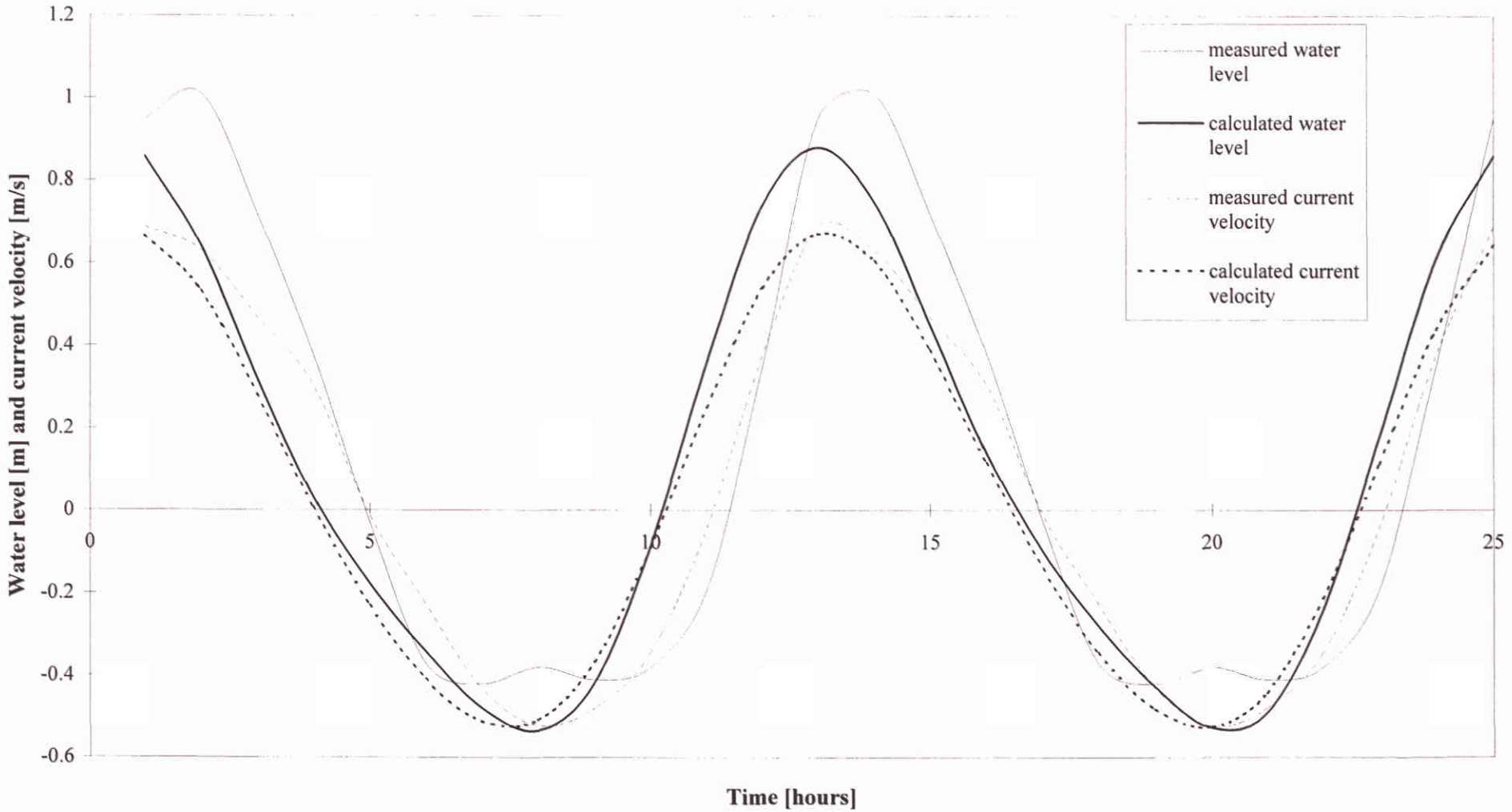
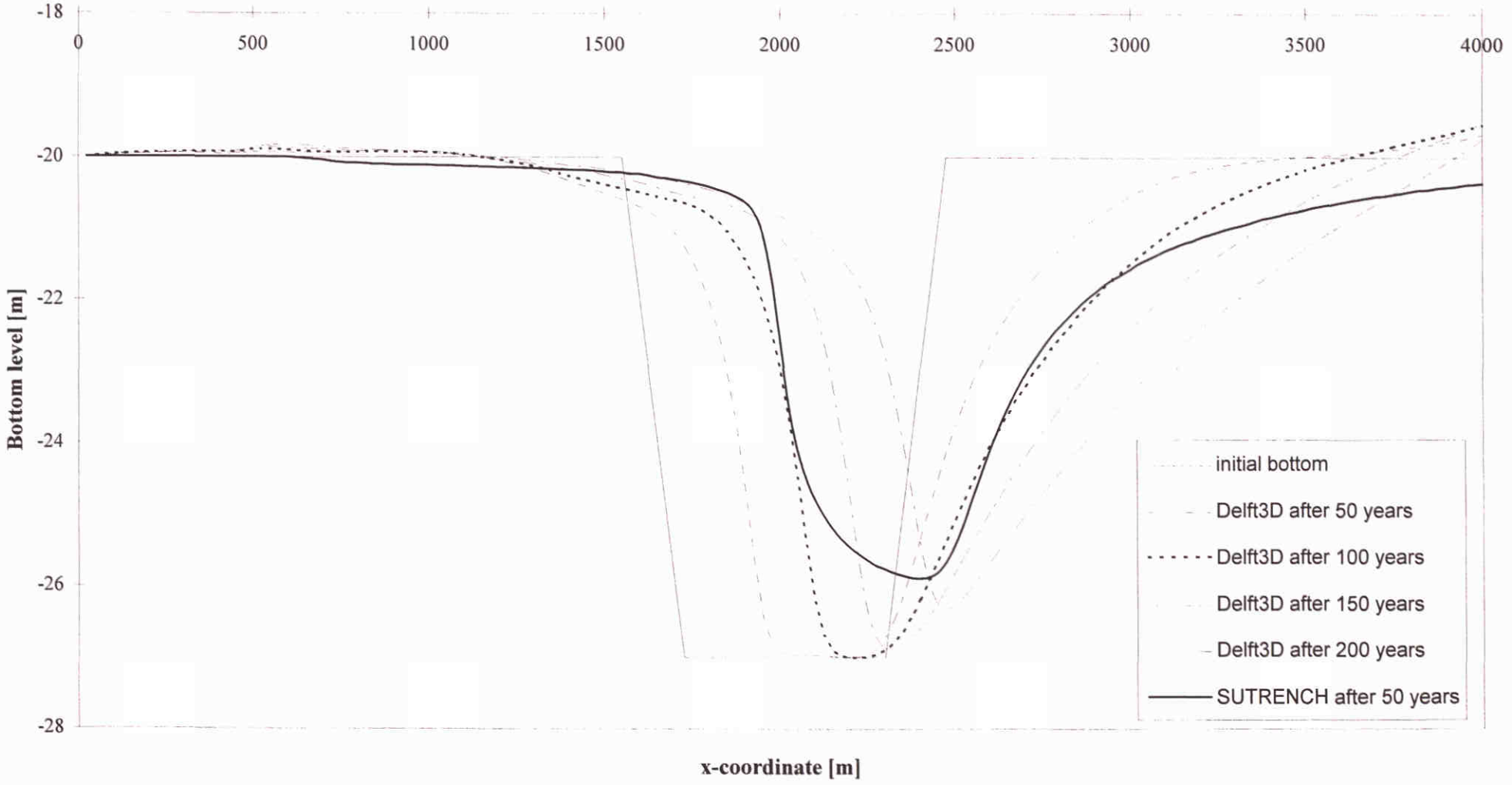


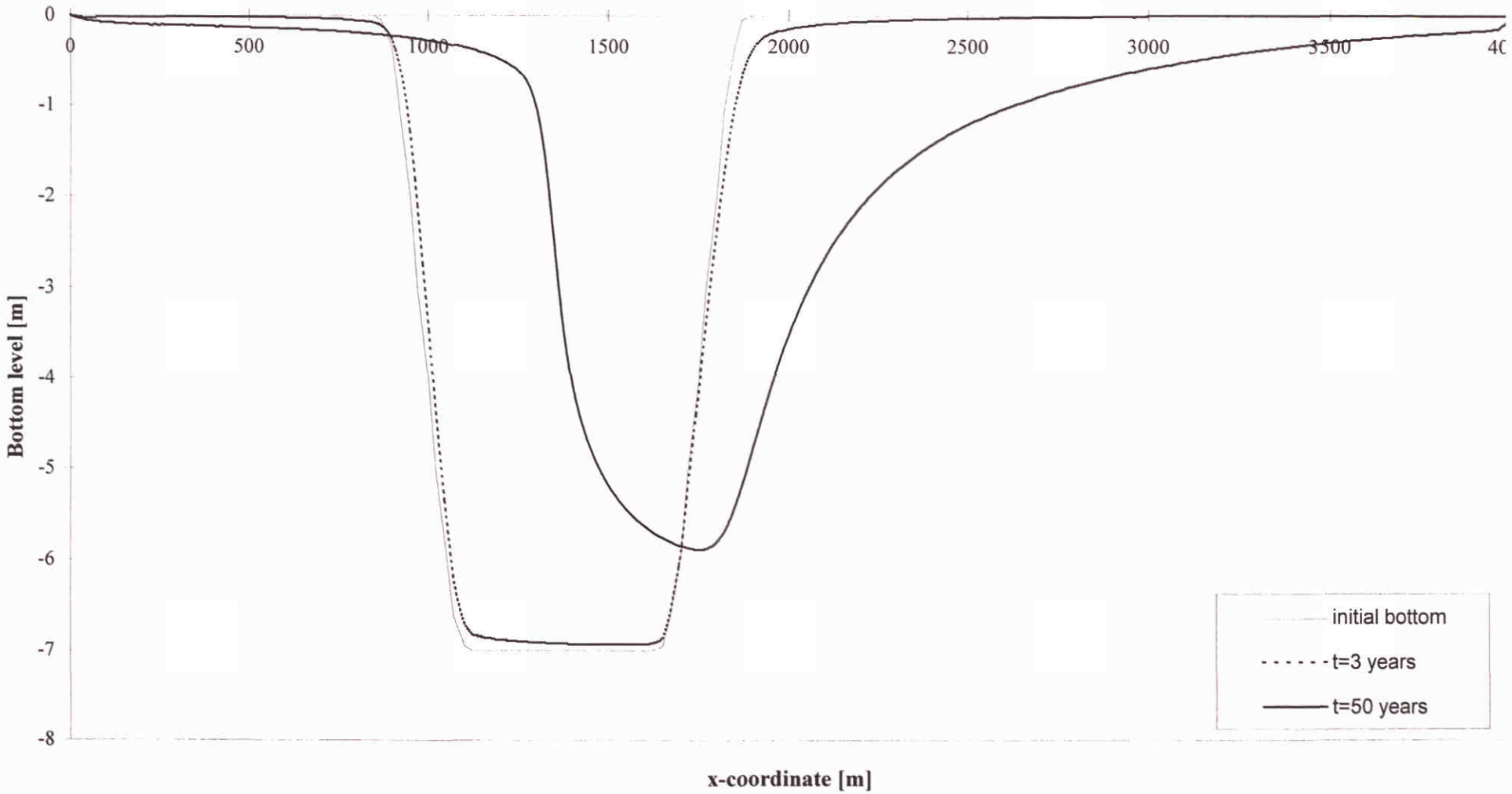
Figure 8.12: Results of the tide analysis

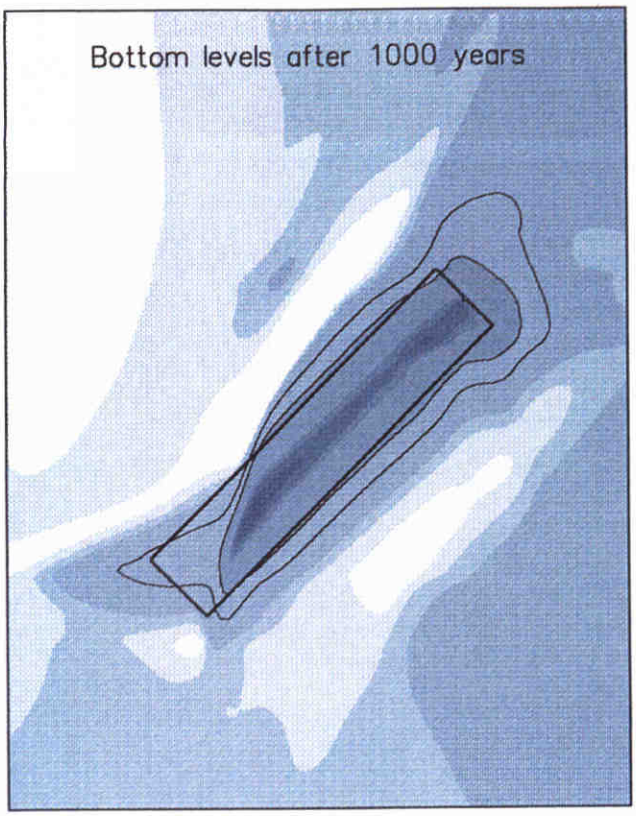


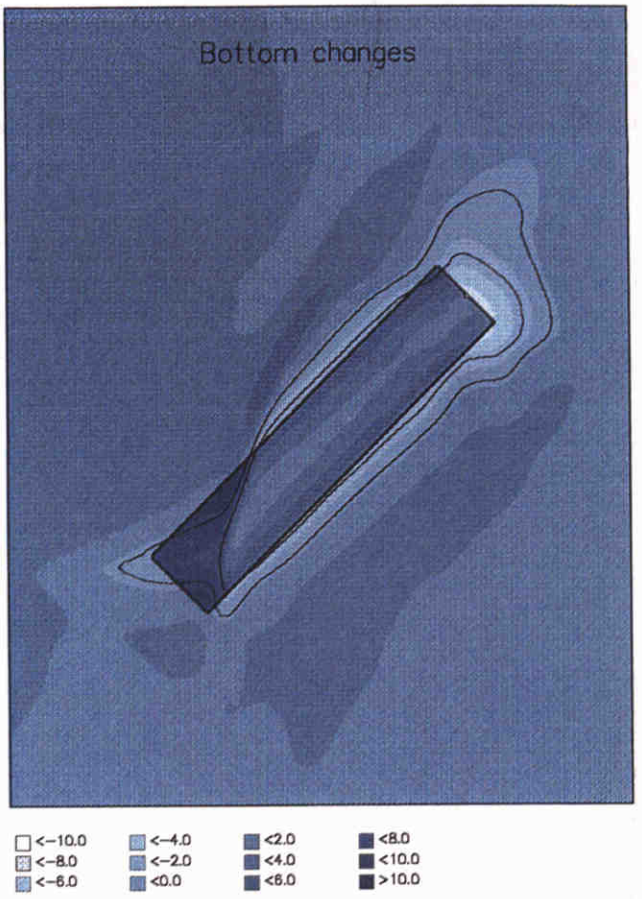
Figuur 8.13: SUTRENCH and Delft3D results of a reference trench

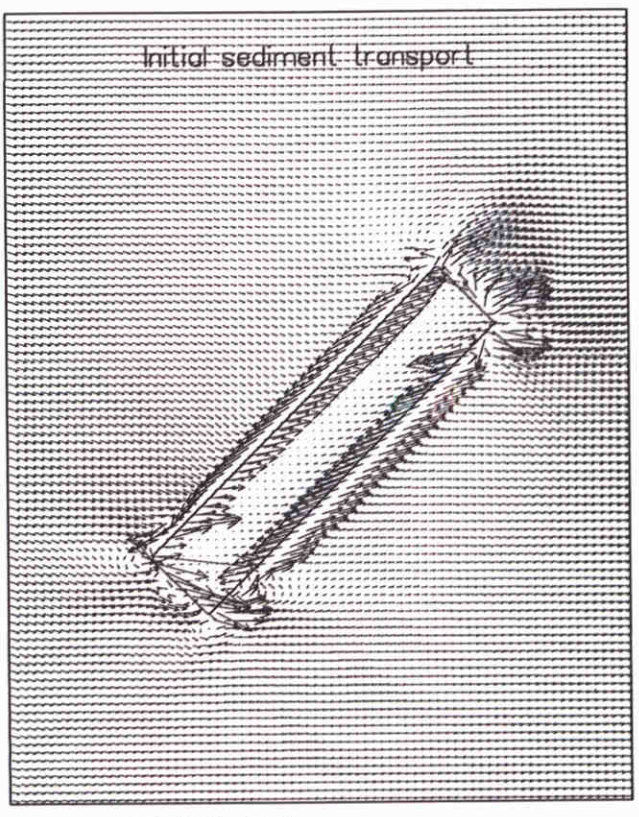


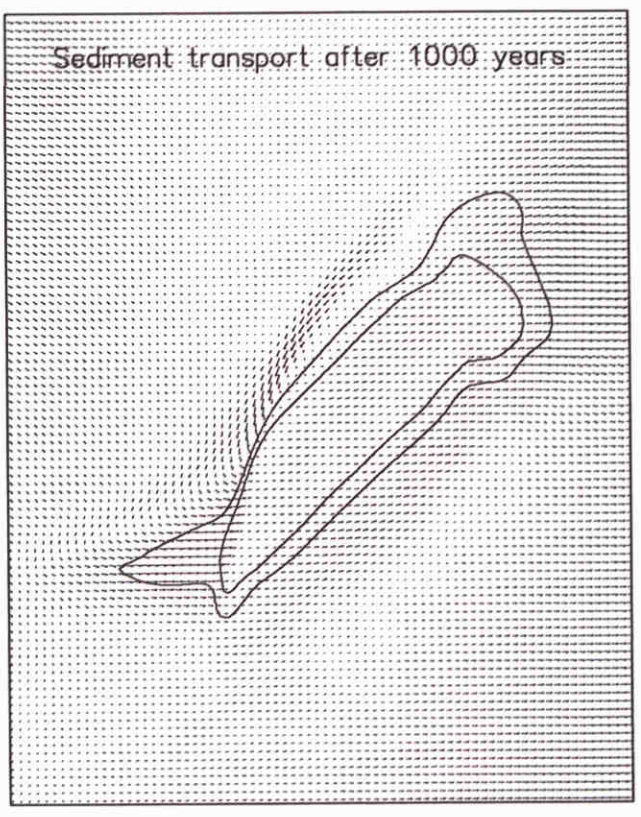
Figuur 8.14: SUTRENCH results of Walstra (1998)











→ 2.0*10^-5 m^2/s

Bottom levels and changes [m]; sediment transport [m^2/s]

+45 degrees rotated 25x5 km^2 sandpit

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.15a

Figure 8.15b: Bottom levels in the longitudinal section of a +45° rotated 25x5 km ^ 2 sandpit

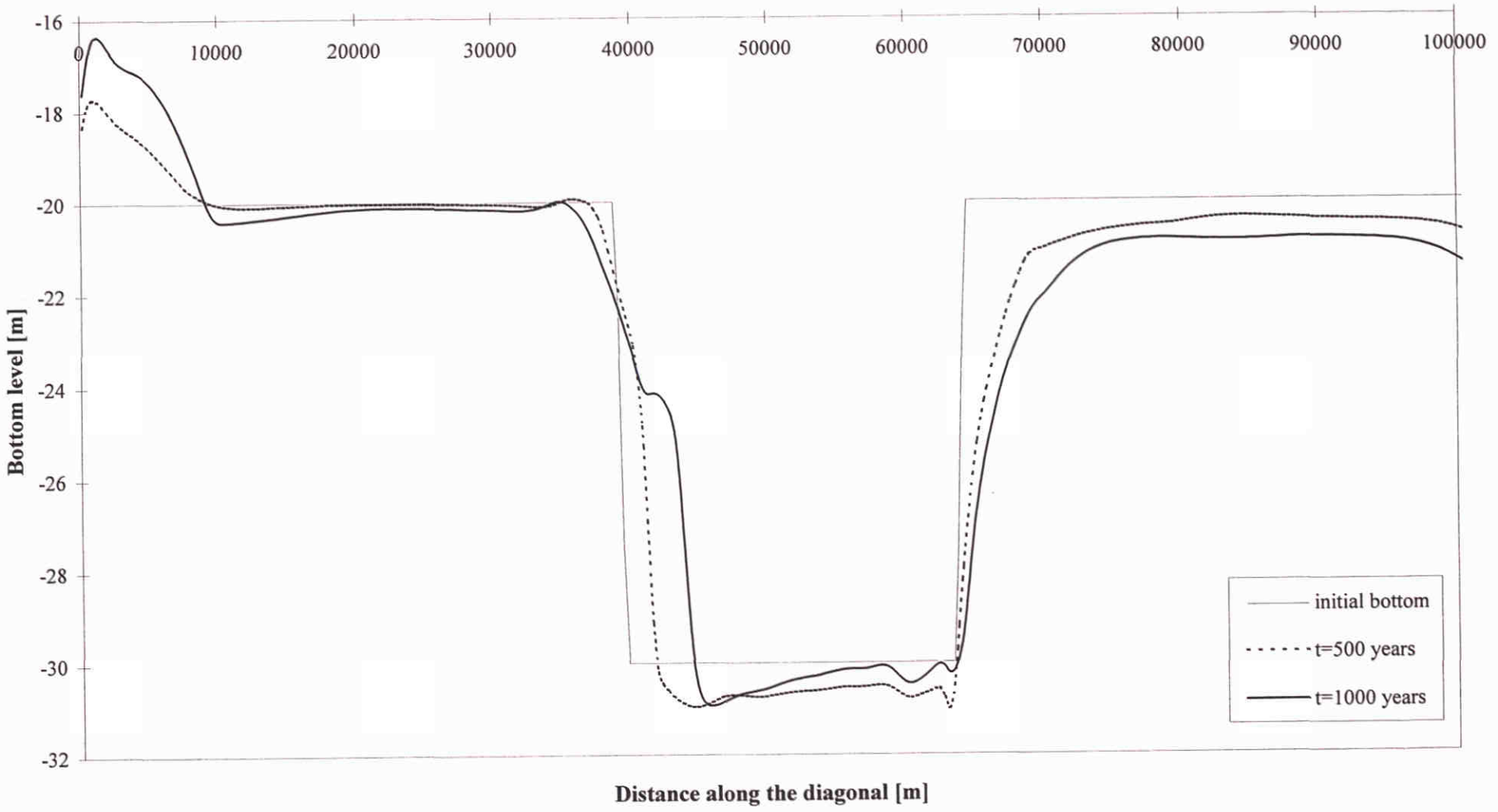
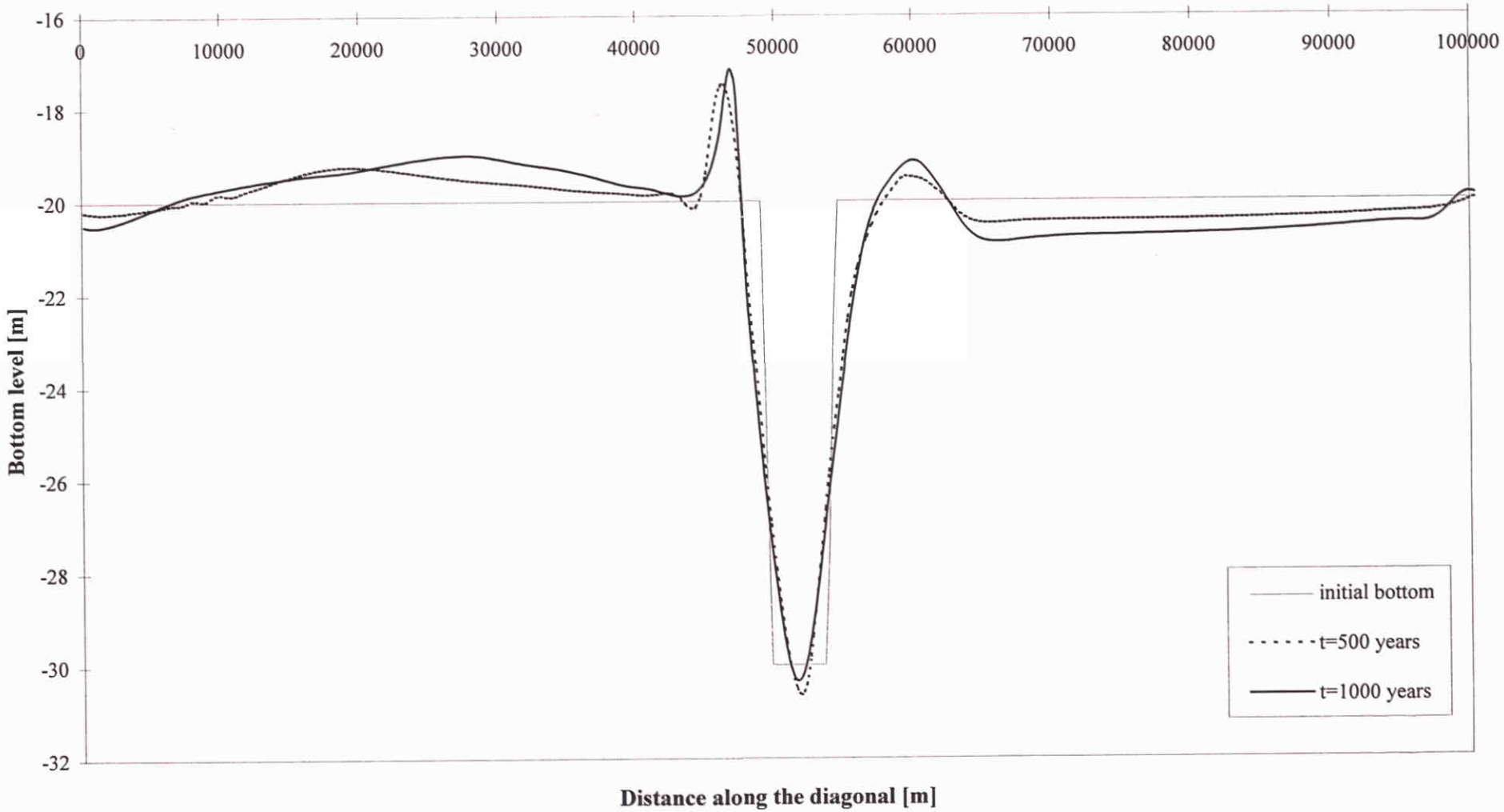
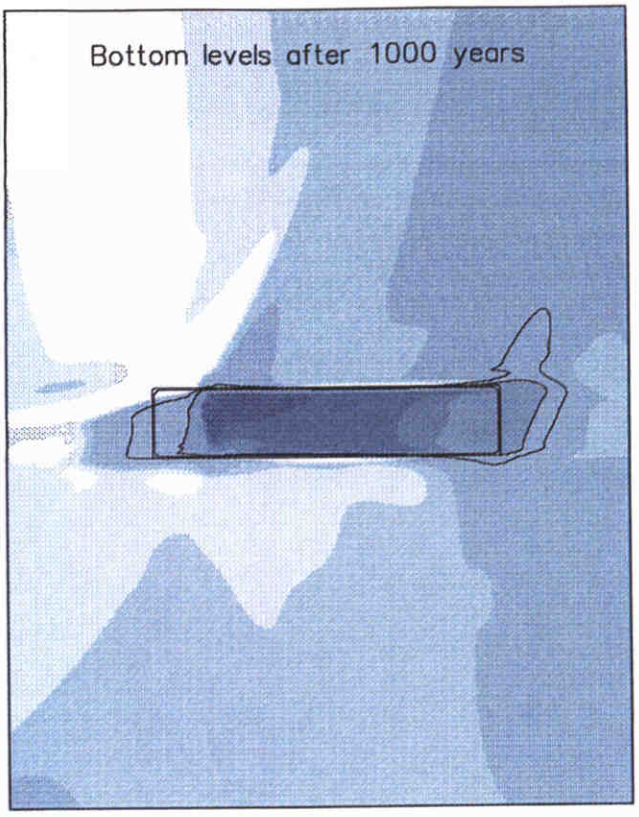
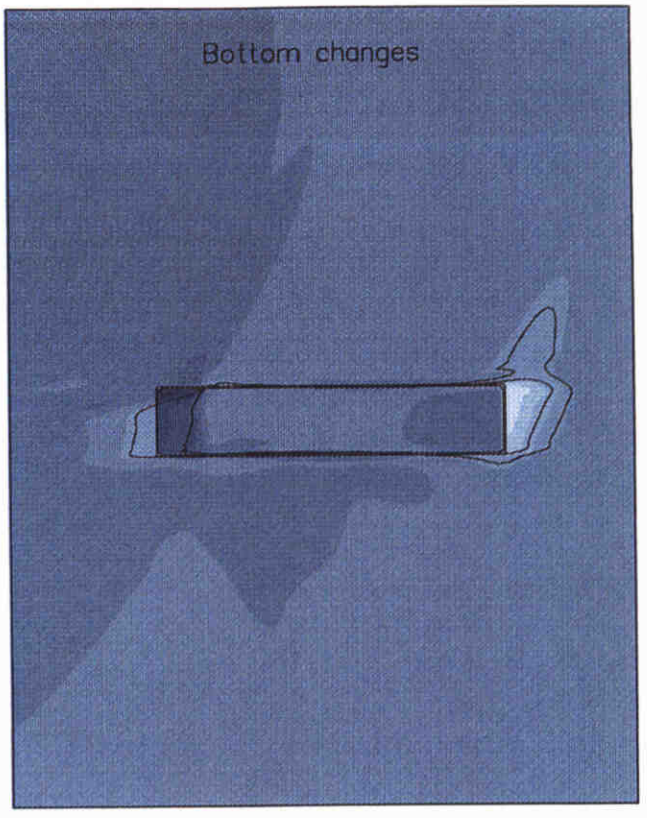
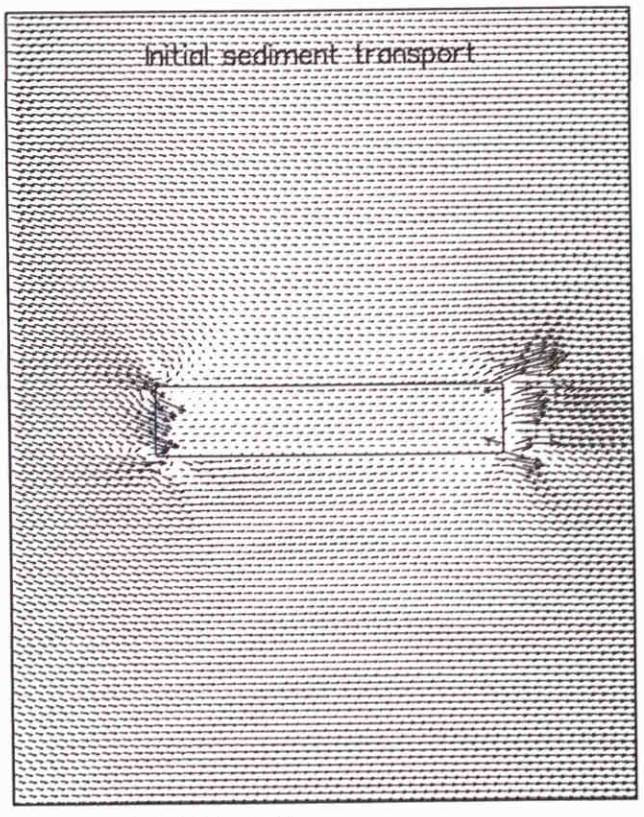


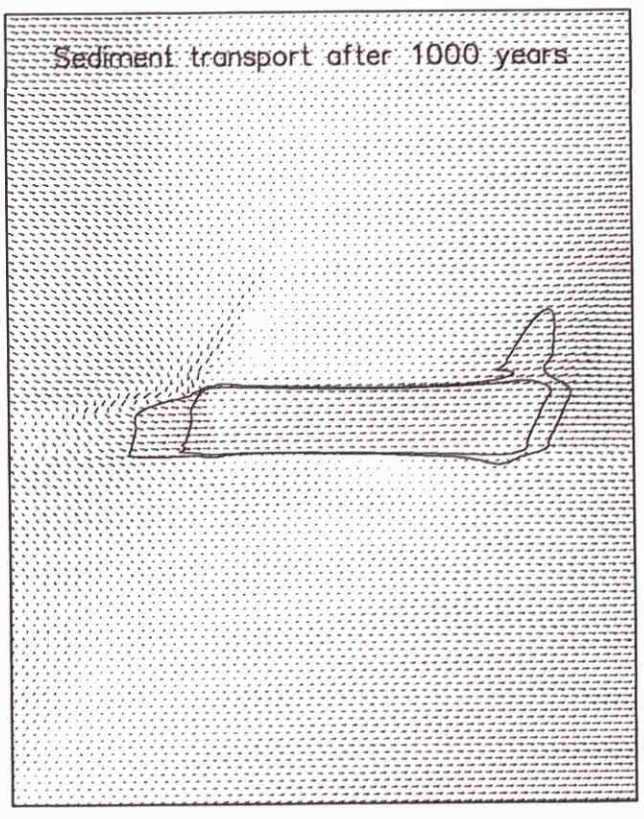
Figure 8.15c: Bottom levels in the center cross-section of a +45° rotated 25x5 km2 sandpit











$\longrightarrow$ $2.0*10^{-5}$ m^2/s

Bottom levels and changes [m]; sediment transport [m^2/s]

Parallel 25x5 km^2 sandpit

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.16a

Figuur 8.16b: Bottom levels in the center longitudinal section of a parallel 25x5 km ^ 2 sandpit

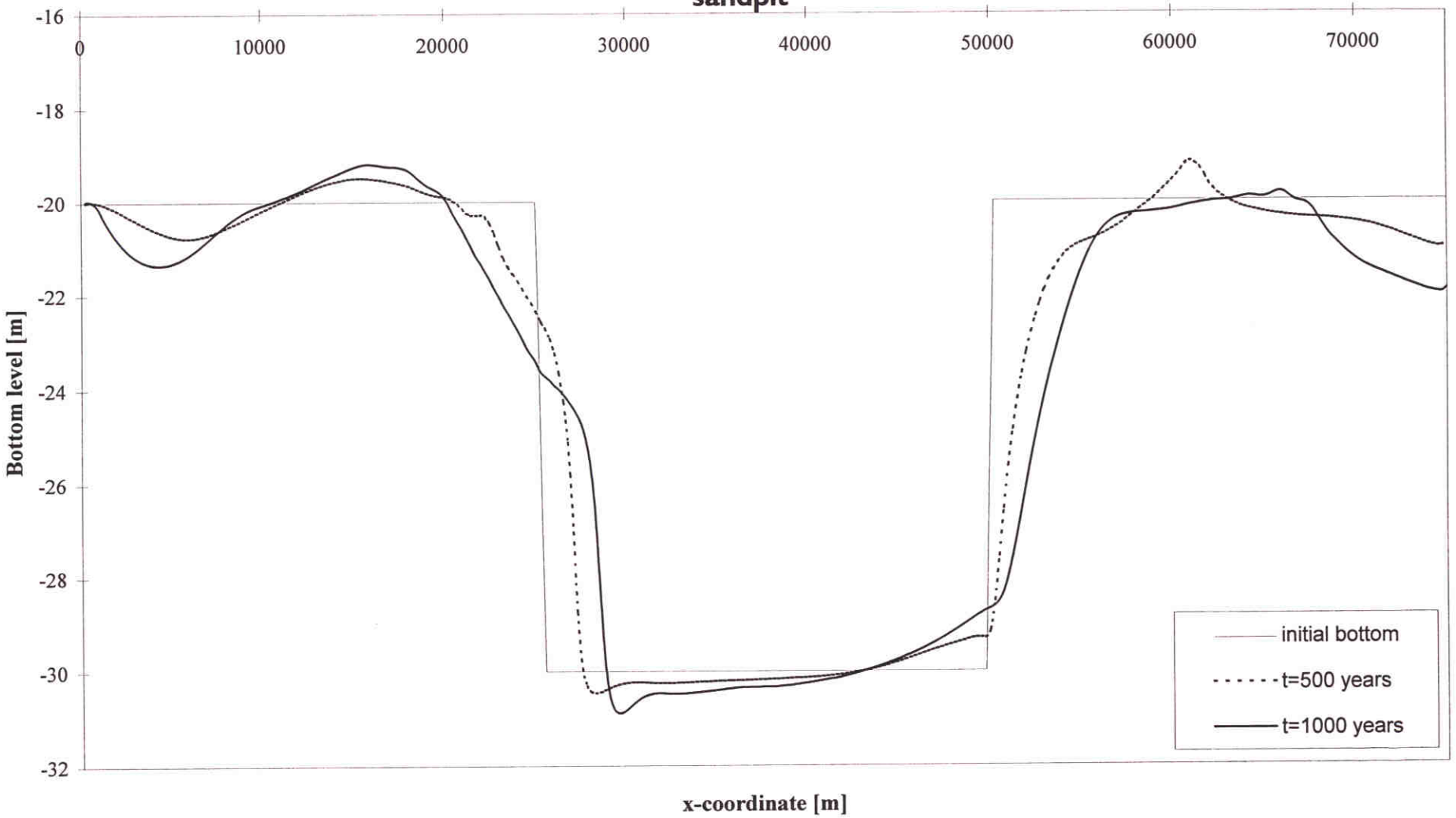
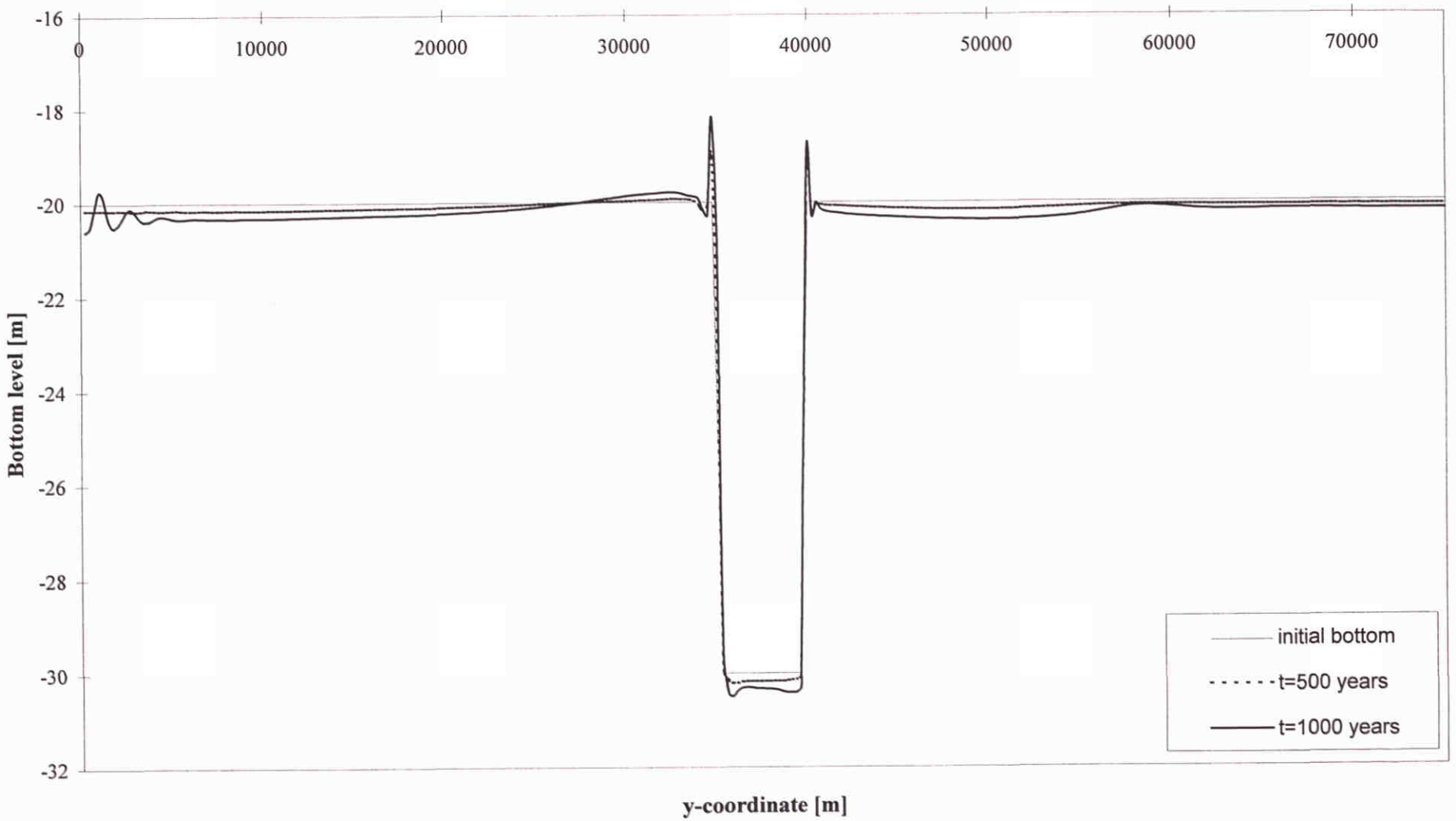
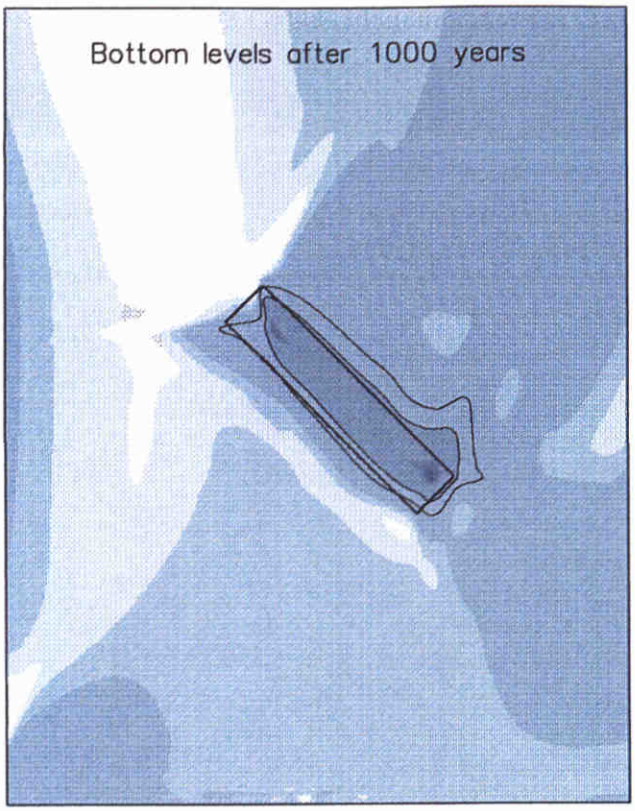
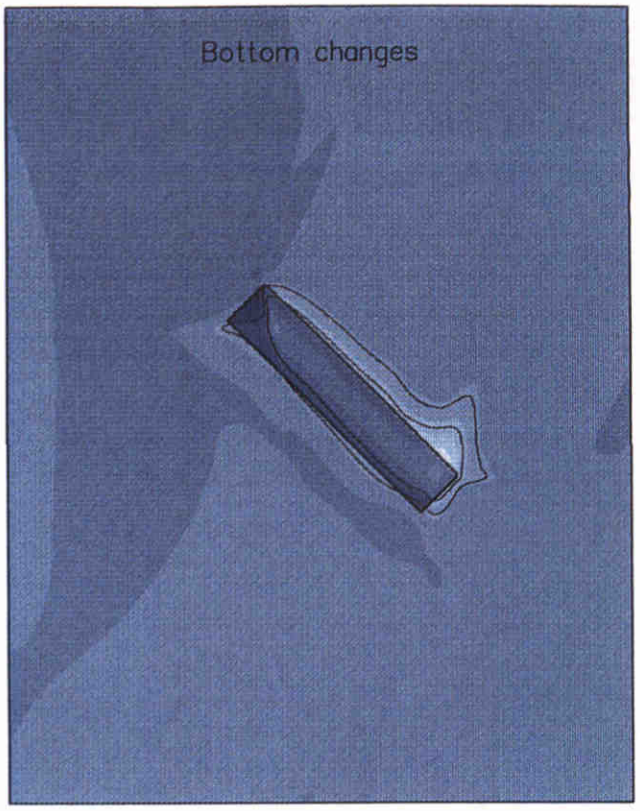
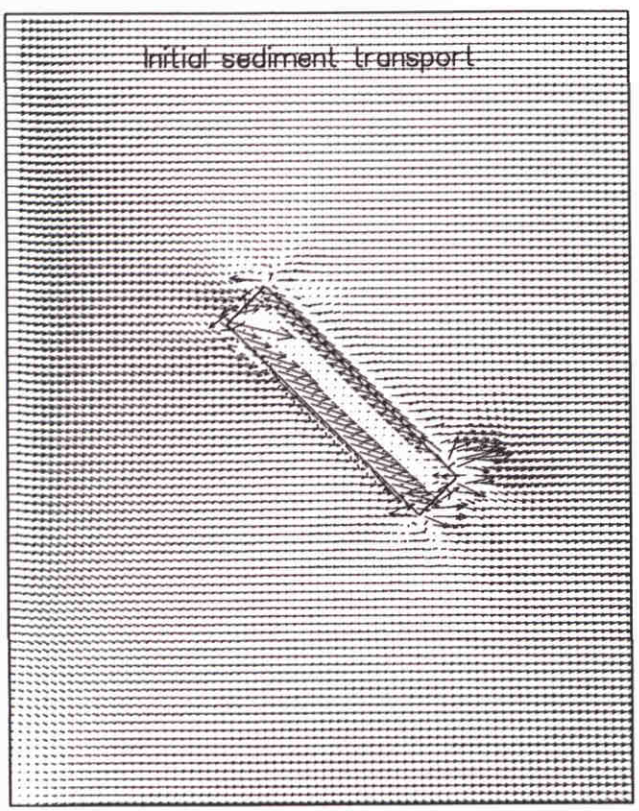


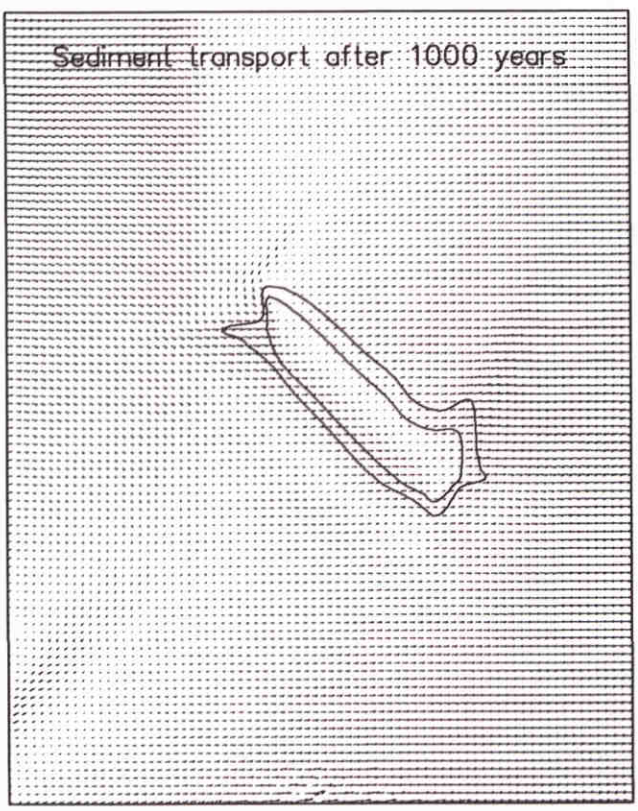
Figure 8.16c: Bottom levels in the center cross-section of a parallel 25x5 km ^ 2 sandpit











→ 2.0*10^-6 m^2/s

Bottom levels and changes [m];sediment transport [m^2/s]

-45 degrees rotated 25x5 km^2 sandpit

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.17a

Figure 8.17b: Bottom levels in the center longitudinal section of a -45° rotated 25x5 km ^ 2 sandpit

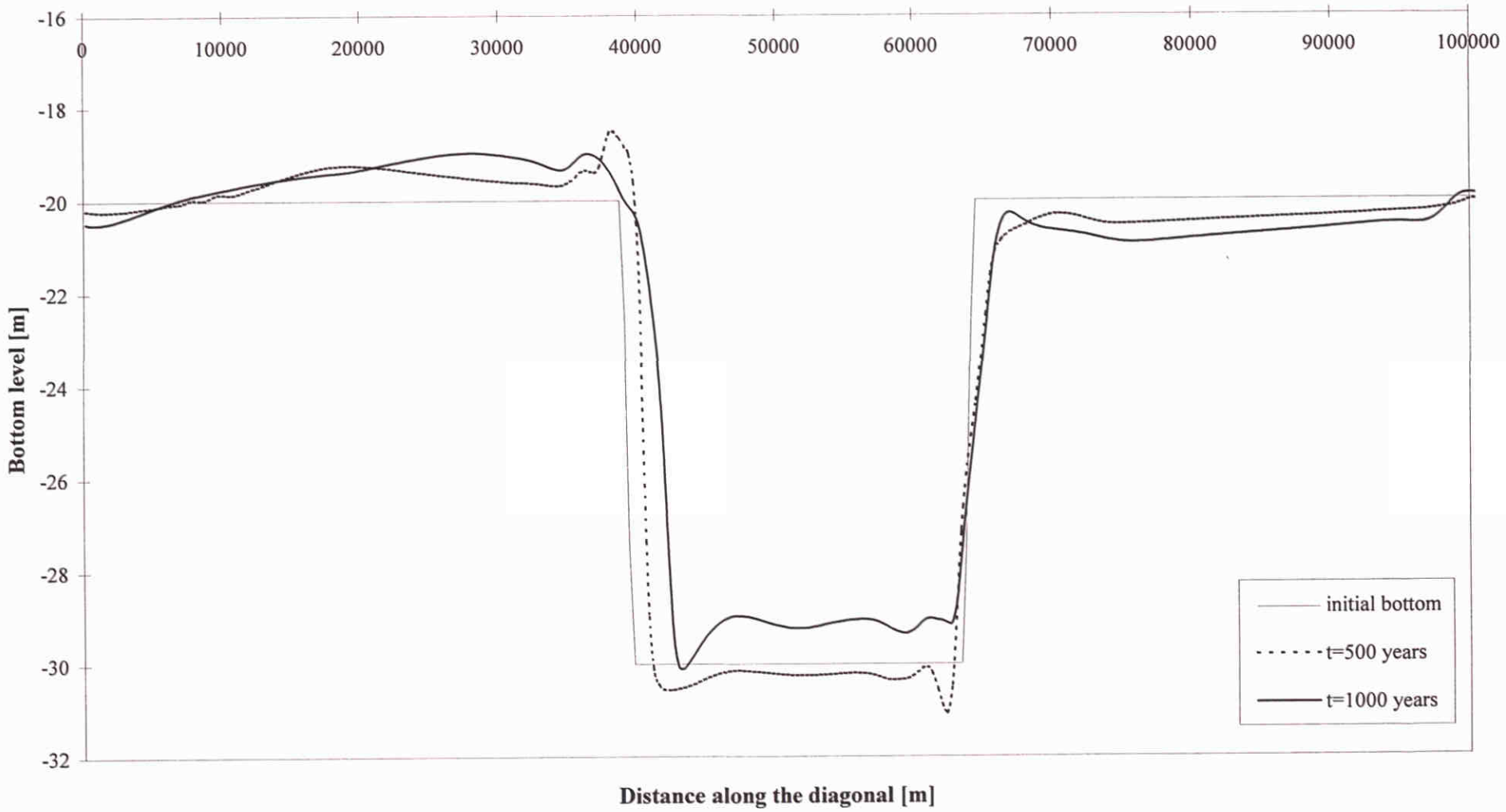
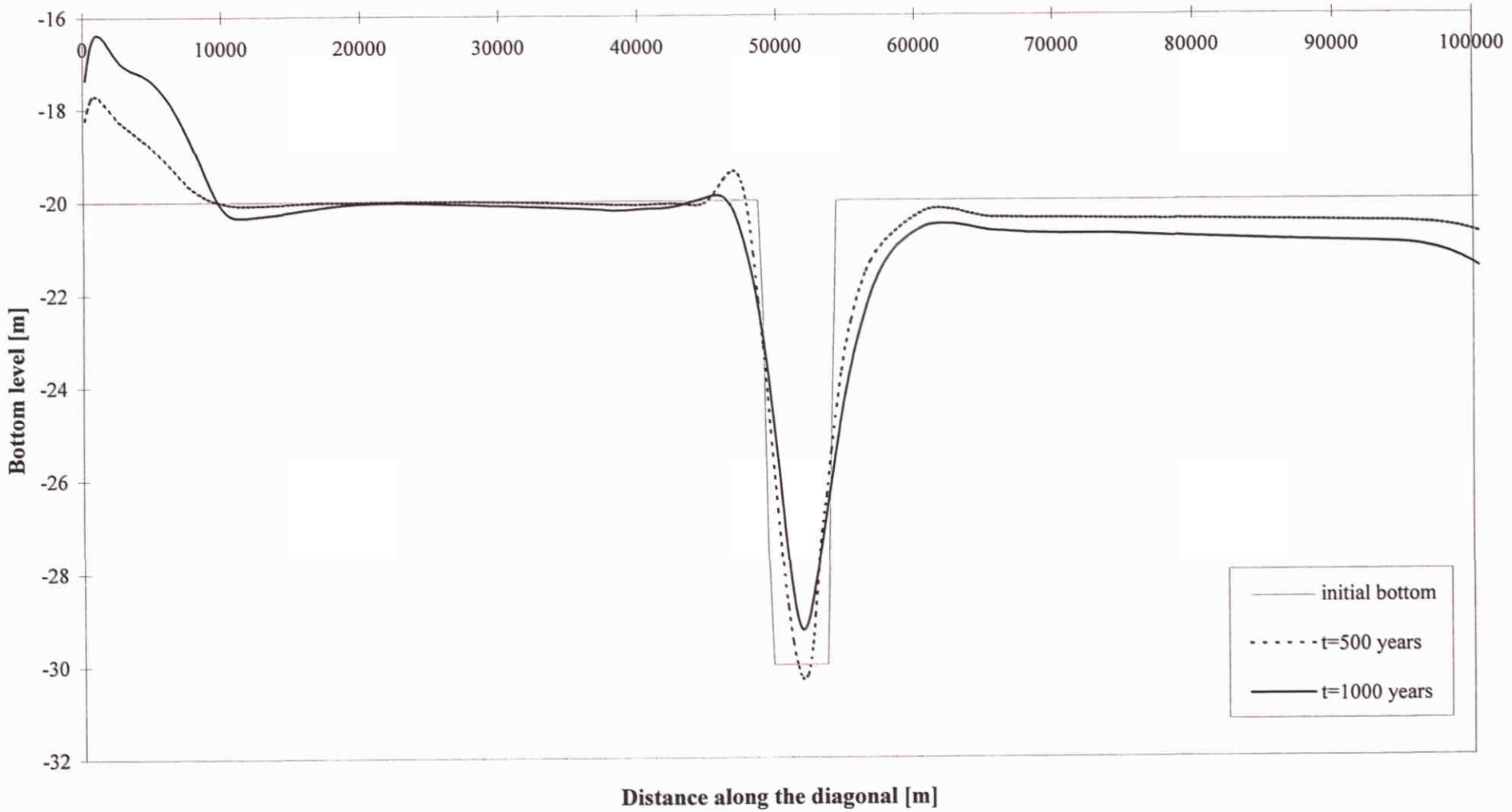
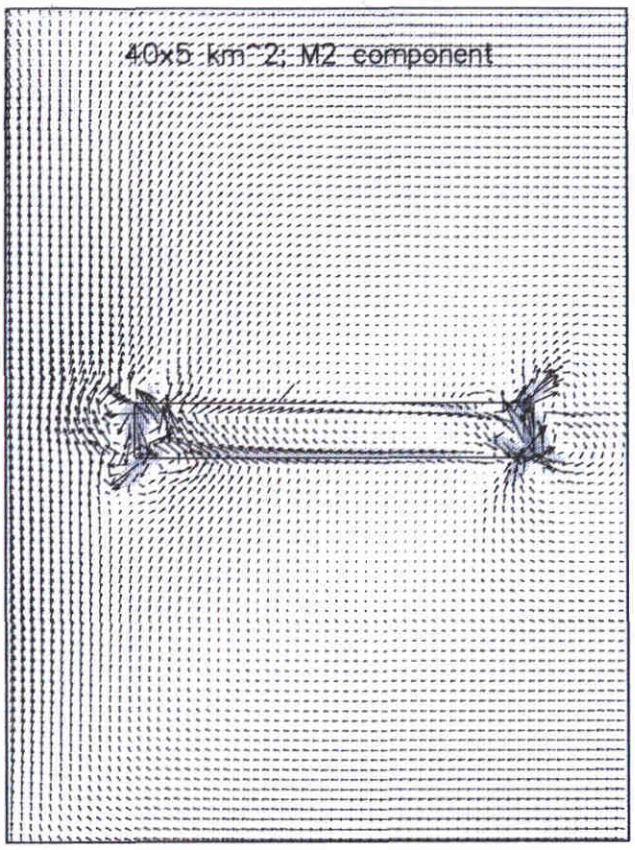
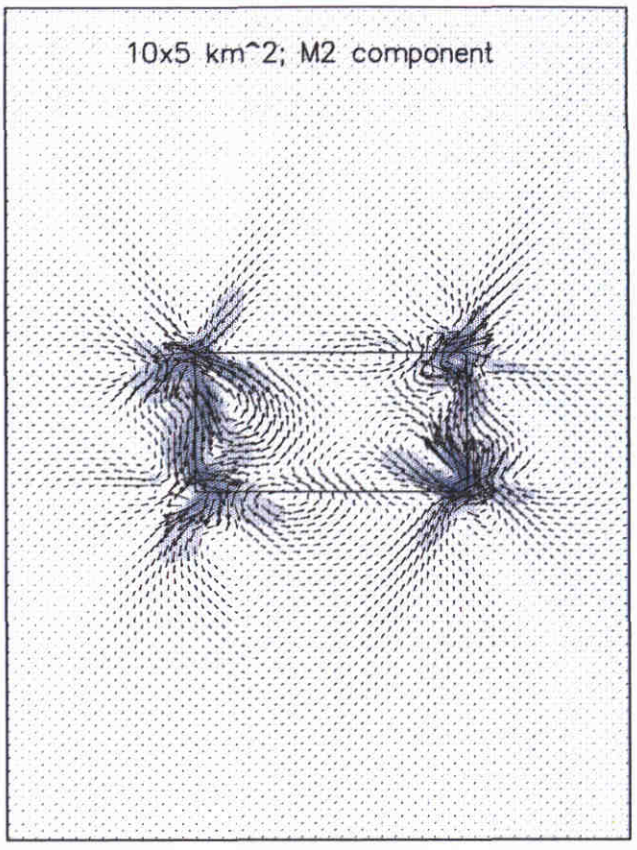
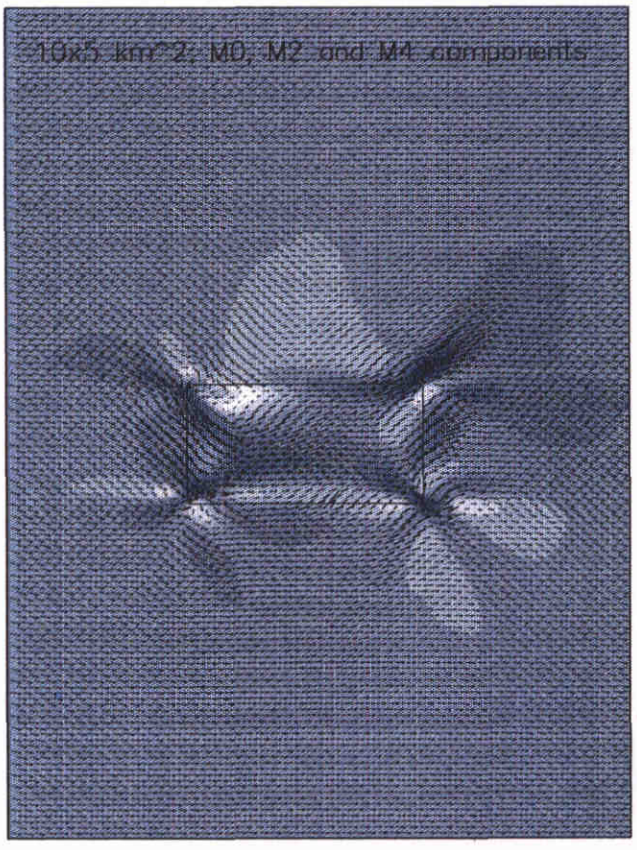


Figure 8.17c: Bottom levels in the center cross-section of a -45° rotated 25x5 km2 sandpit









Tide–averaged current velocities [m/s]

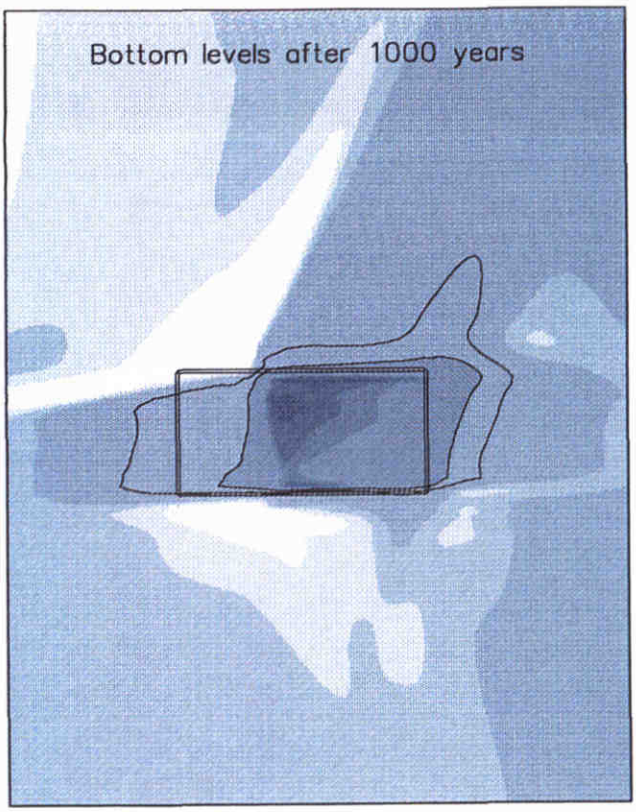
Influence of the tidal motion and the length on the averaged current pattern

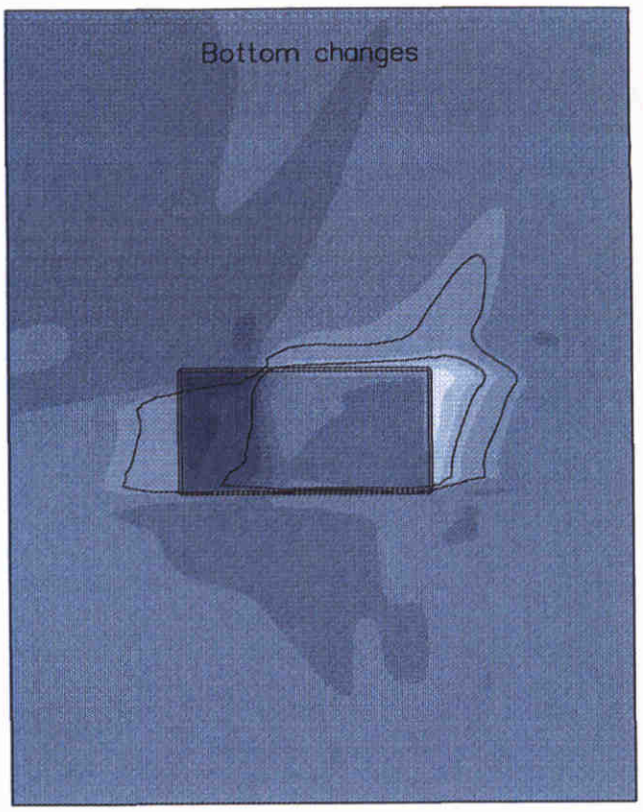
Tidal boundary conditions including

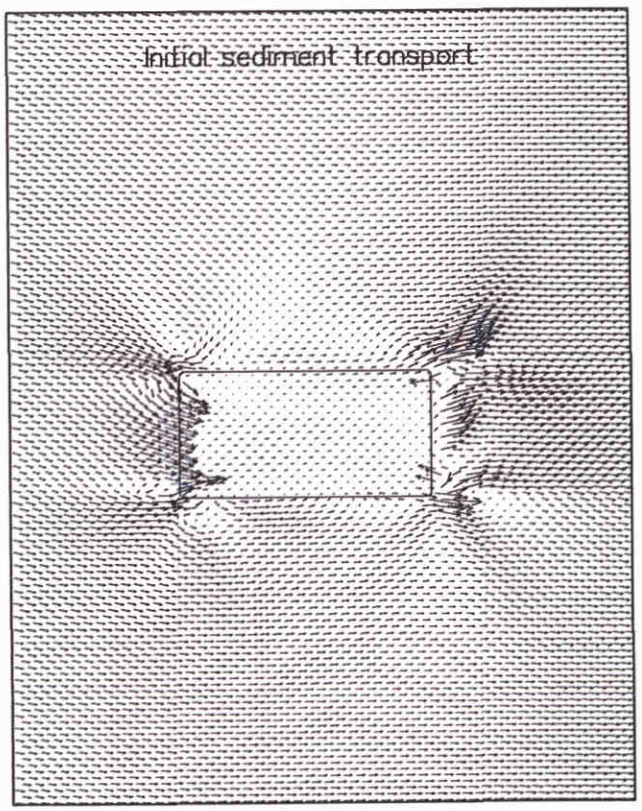
WL | DELFT HYDRAULICS

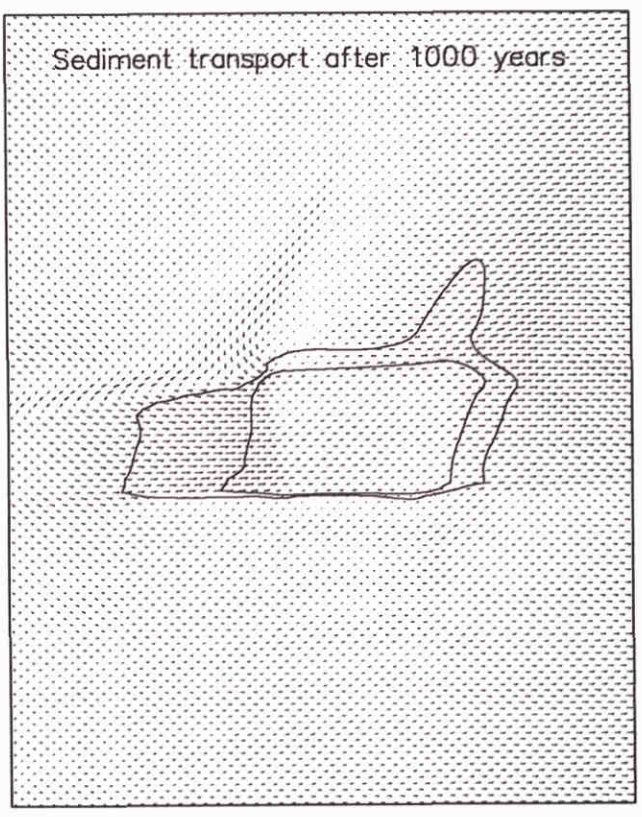
z2615

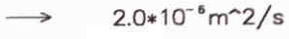
Figure 8.18











Bottom levels and changes [m]; sediment transport [m^2/s]

Parallel 10x5 km^2 sandpit

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.19a

Figure 8.19b: Bottom levels in the longitudinal section of a parallel 10x5 km ^ 2 sandpit

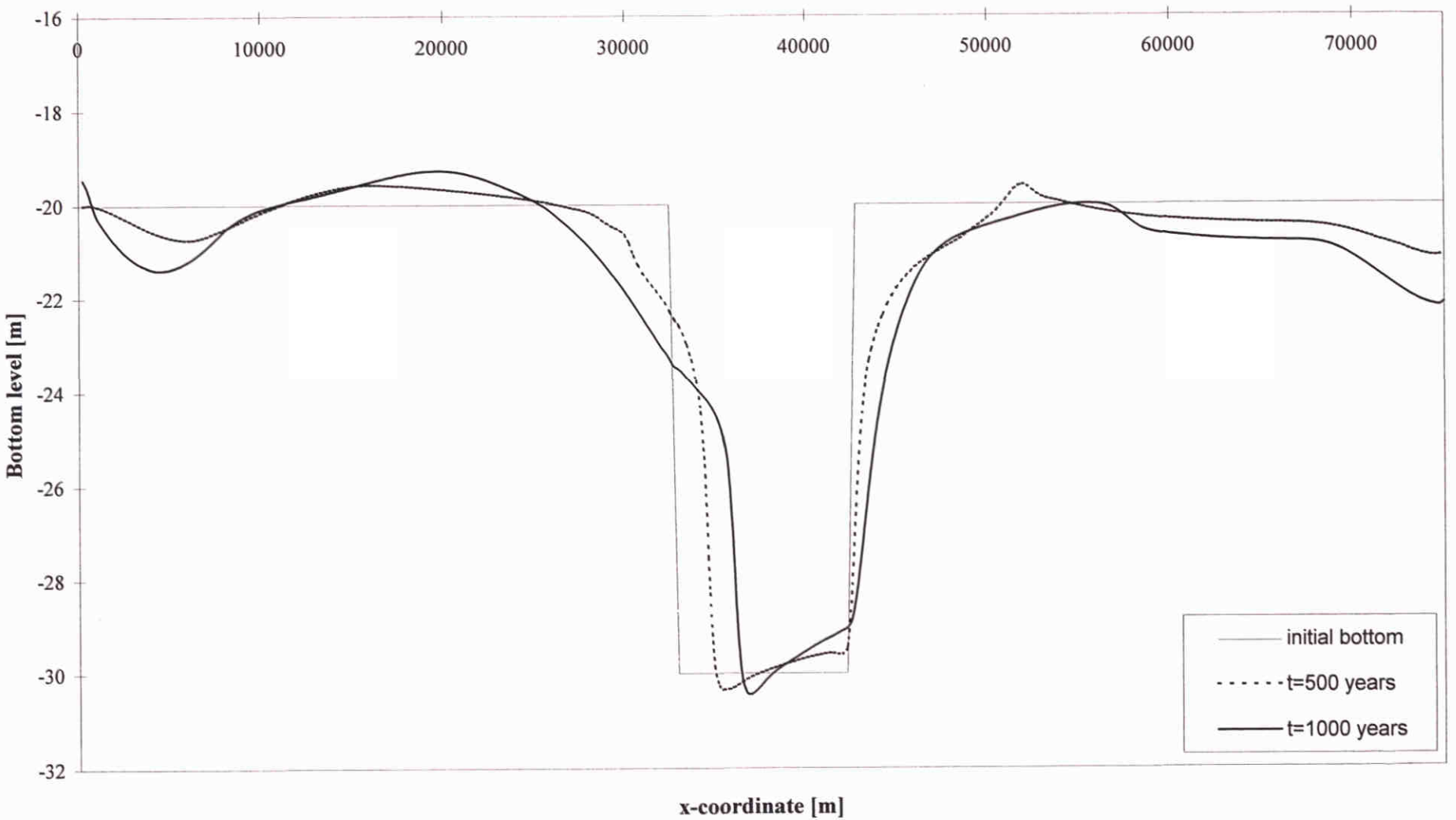
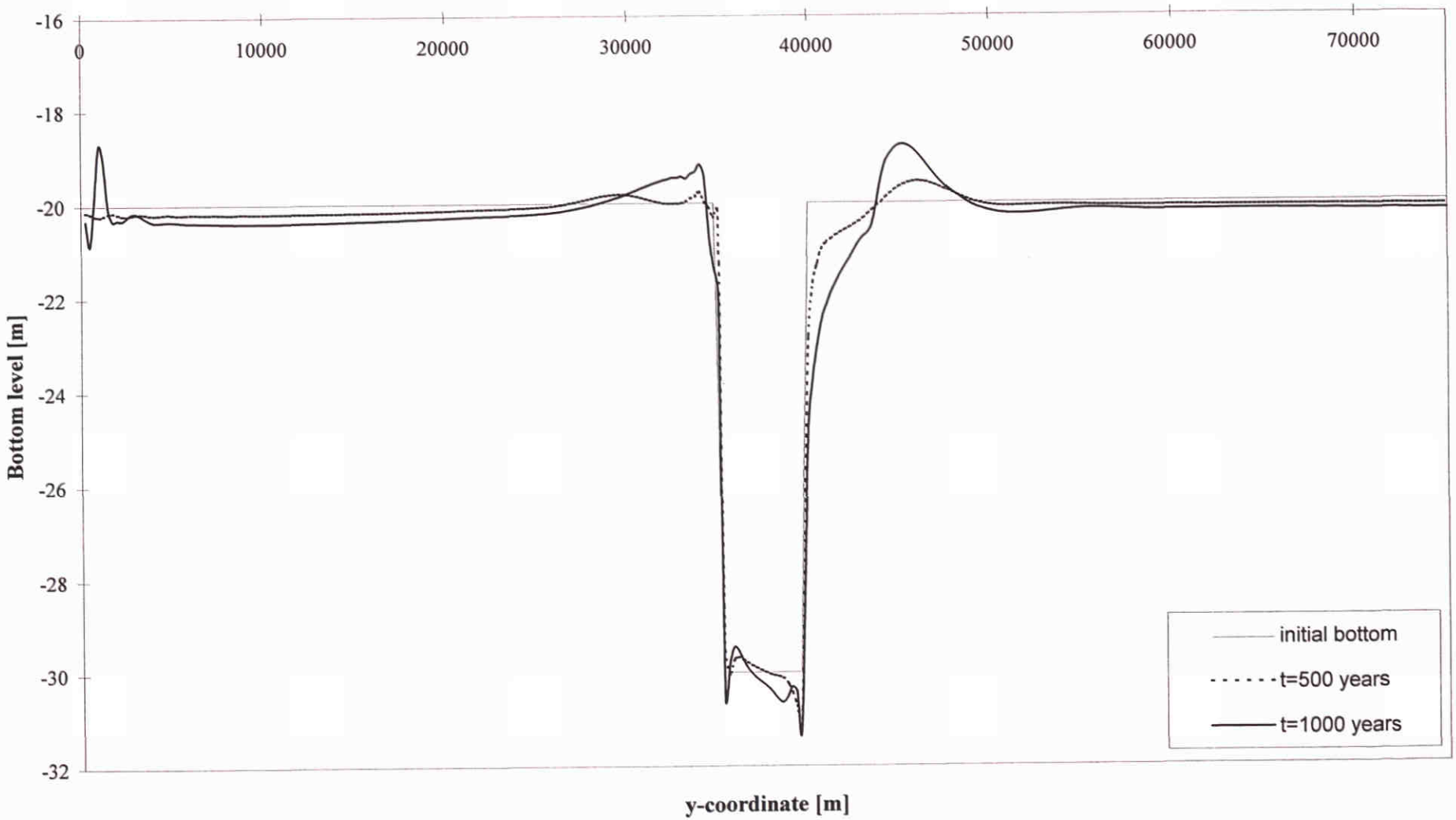
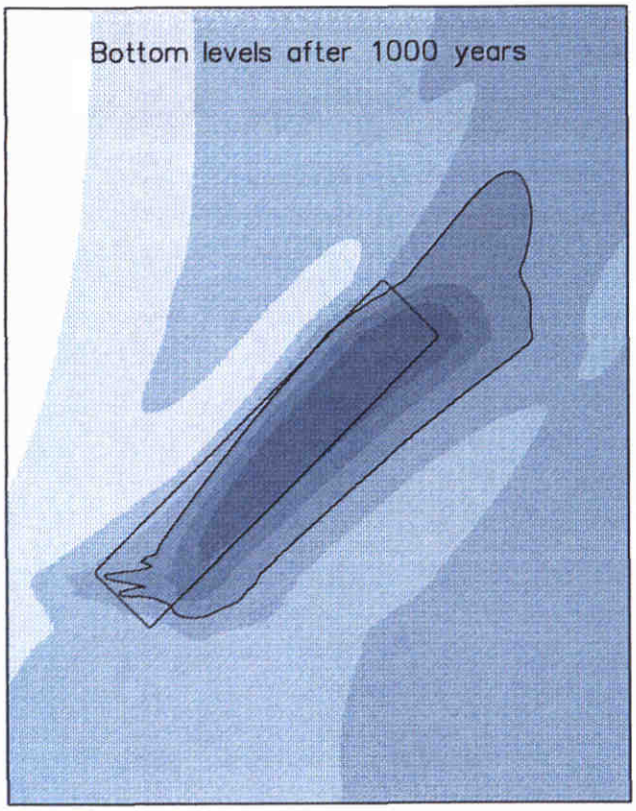
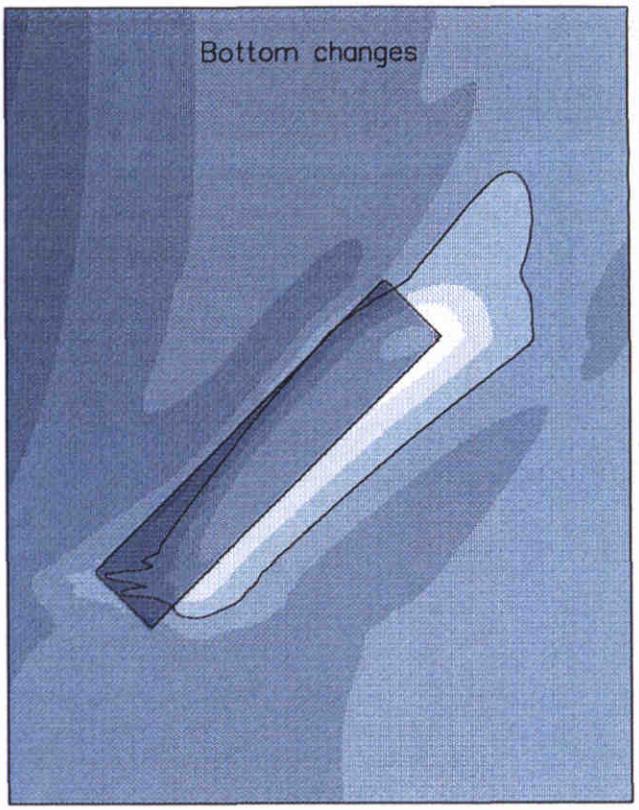
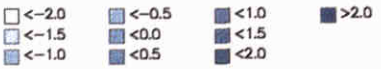


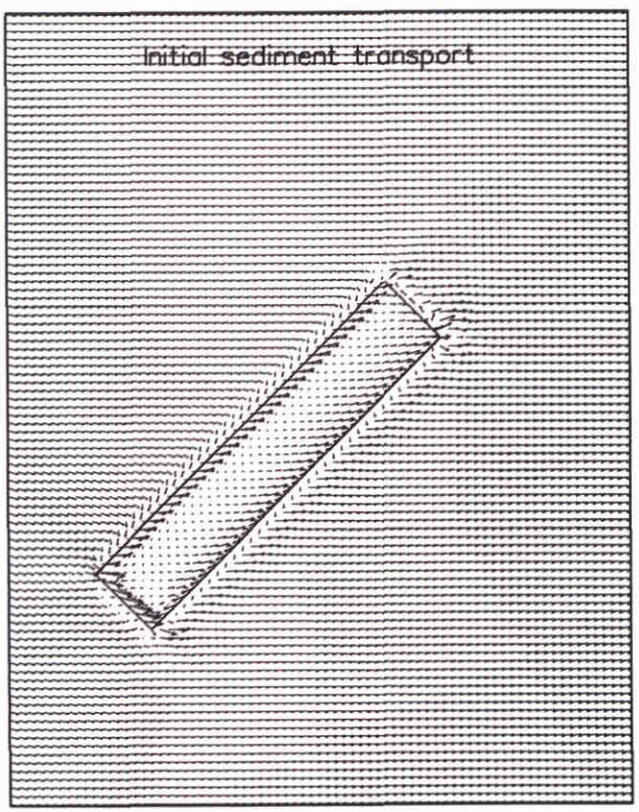
Figure 8.19c: Bottom levels in the center cross-section of a parallel 10x5 km ^ 2 sandpit

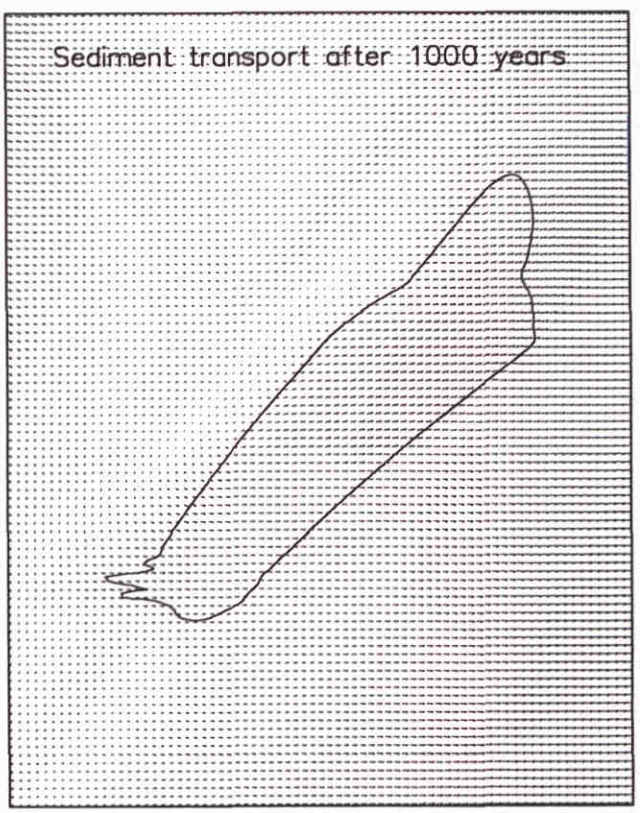












Bottom levels and changes [m]; sediment transport m^2/s

+45 degrees rotated, 22m deep 25x5 km^2 sandpit

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.20a

Figure 8.20b: Bottom levels in the center longitudinal section of a +45° rotated 25x5 km ^ 2, 22m deep sandpit

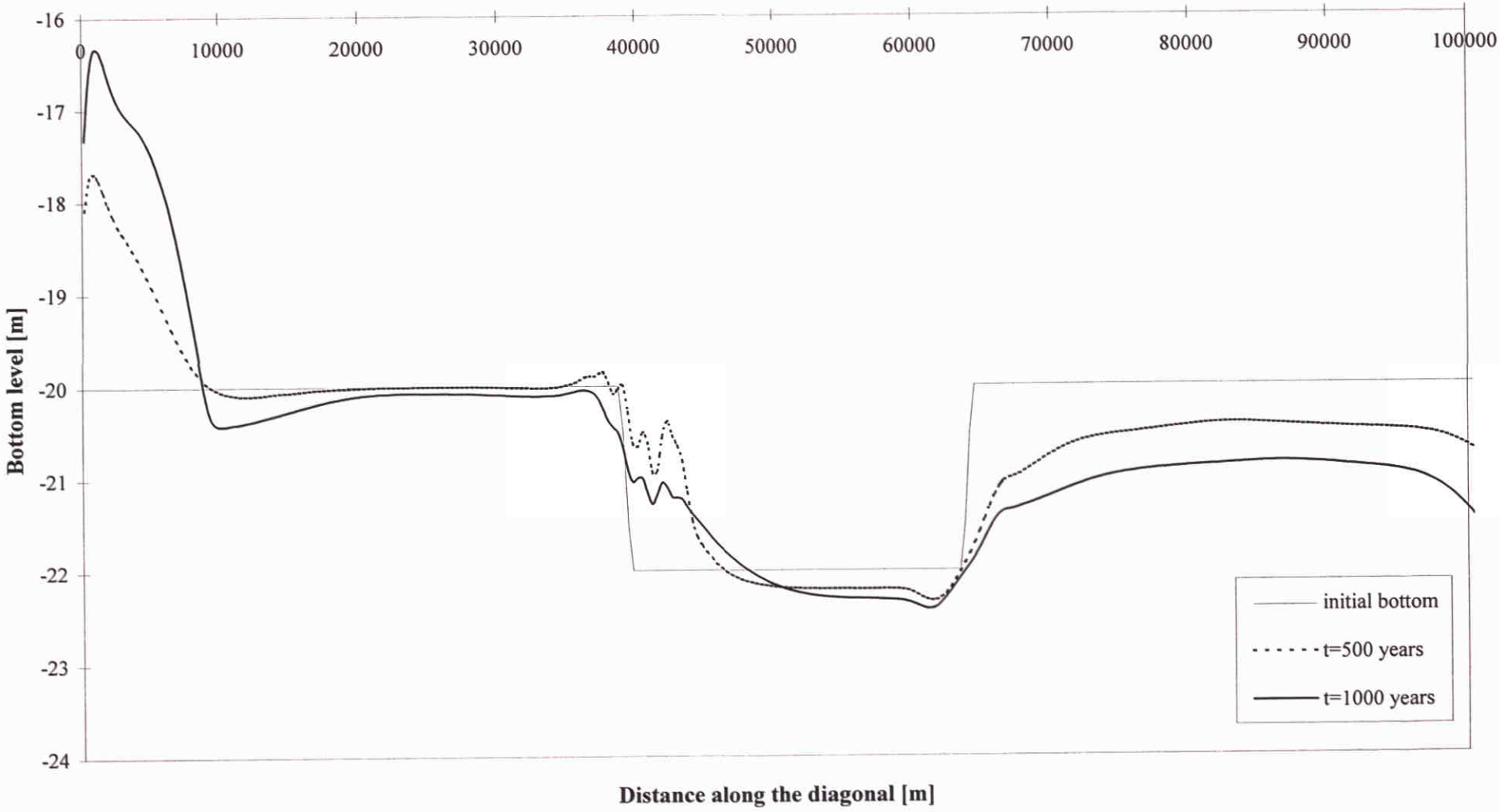
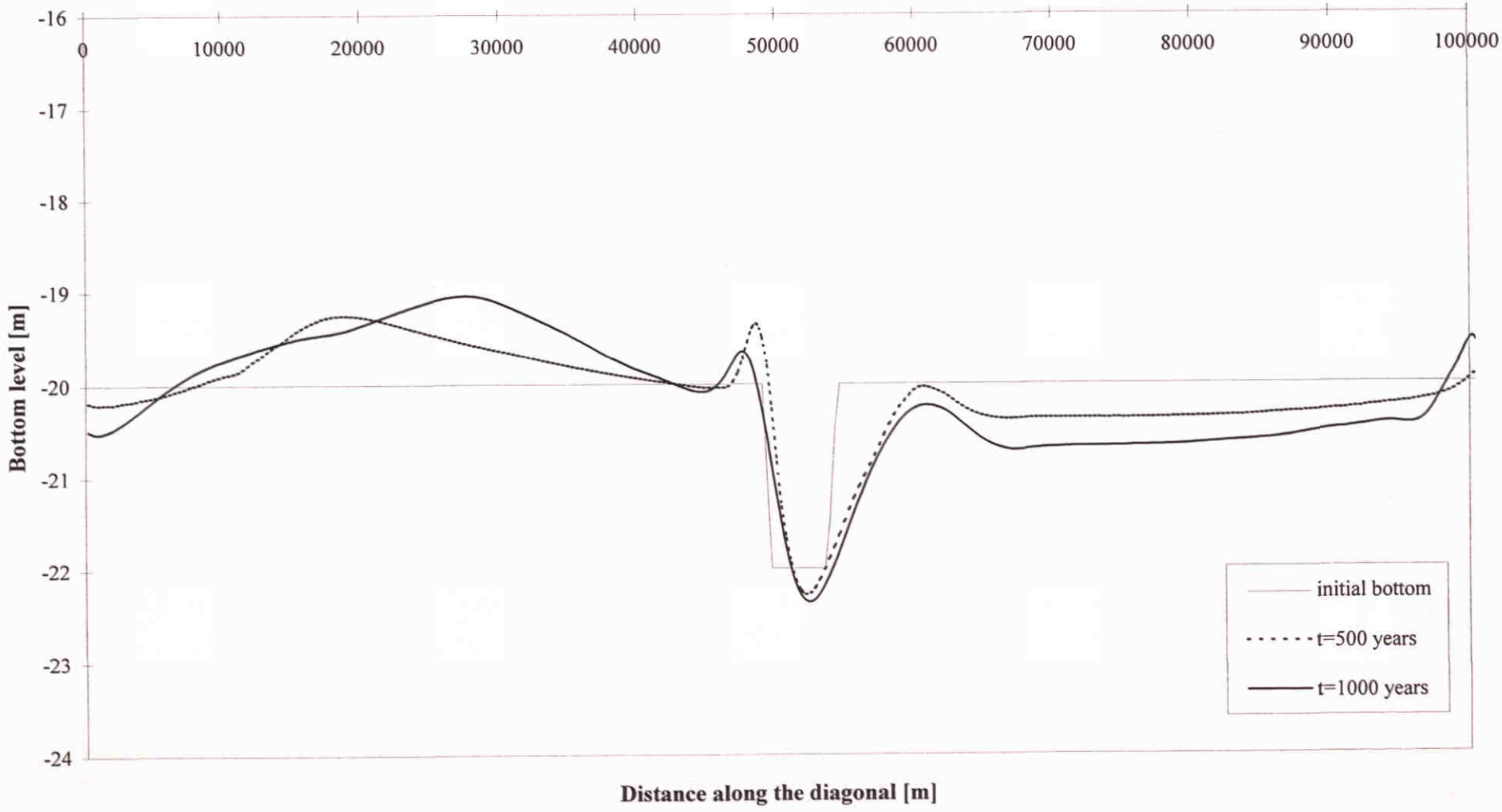
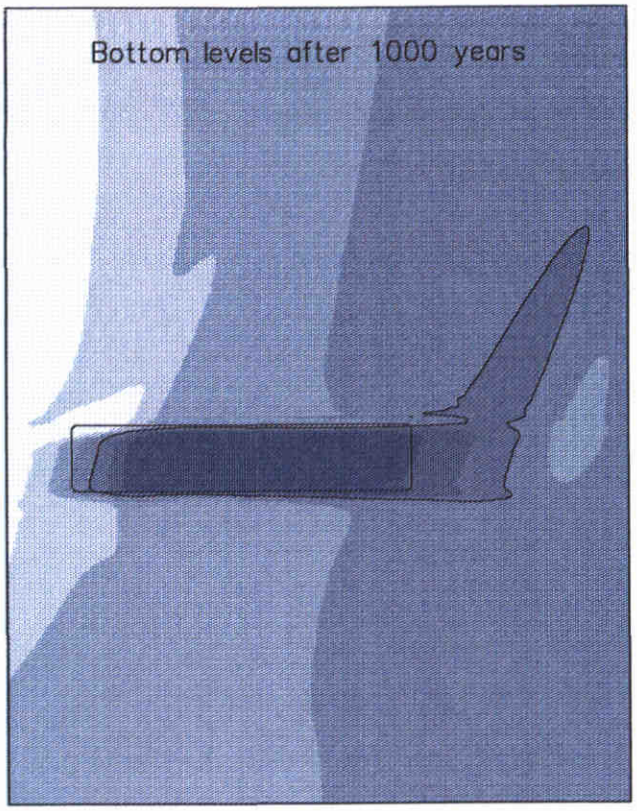
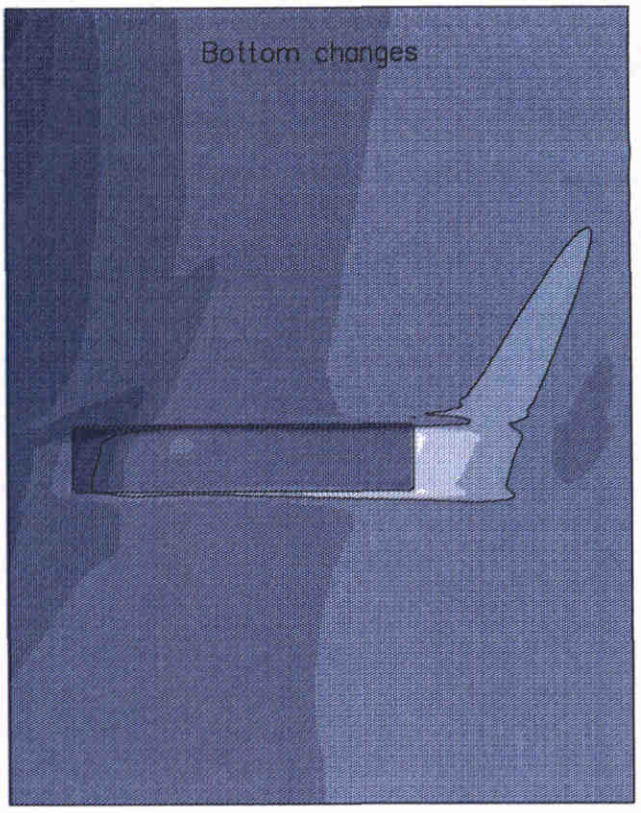
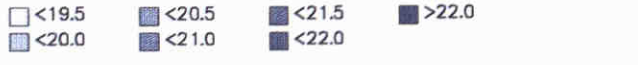


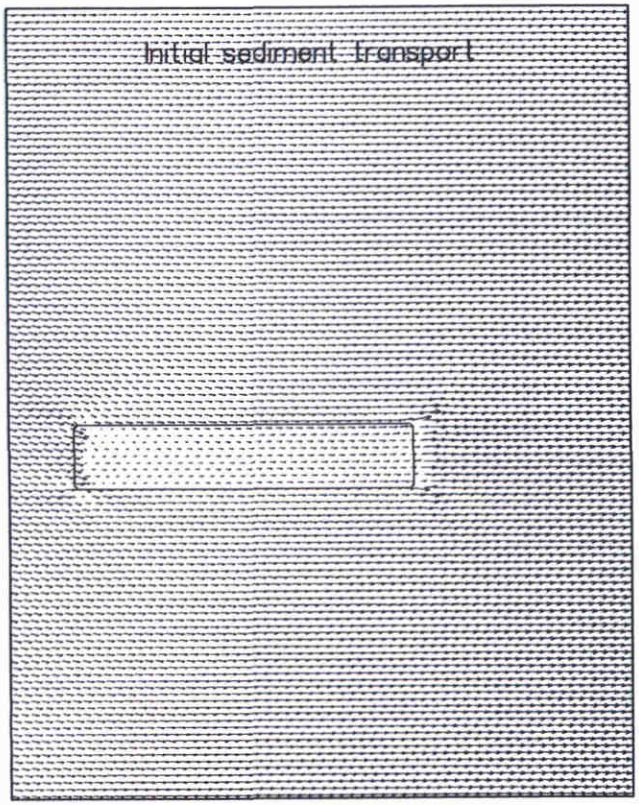
Figure 8.20c: Bottom levels in the center cross-section of a +45° rotated, 22 m deep 25x5 km ^ 2 sandpit

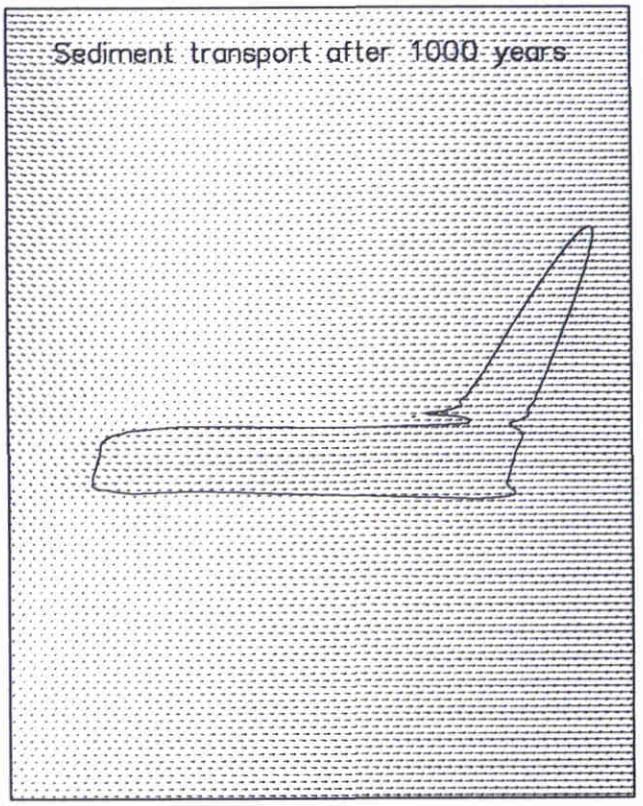












→ $2.0*10^{-5}$ m^2/s

Bottom levels and changes [m]; sediment transport [m^2/s]

Parallel, 22 m deep 25x5 km^2

Morphological results

WL | DELFT HYDRAULICS

z2615

Figure 8.21a

Figure 8.21b: Bottom levels in the center longitudinal section of a parallel, 22 m deep, 25x5 km ^ 2 sandpit

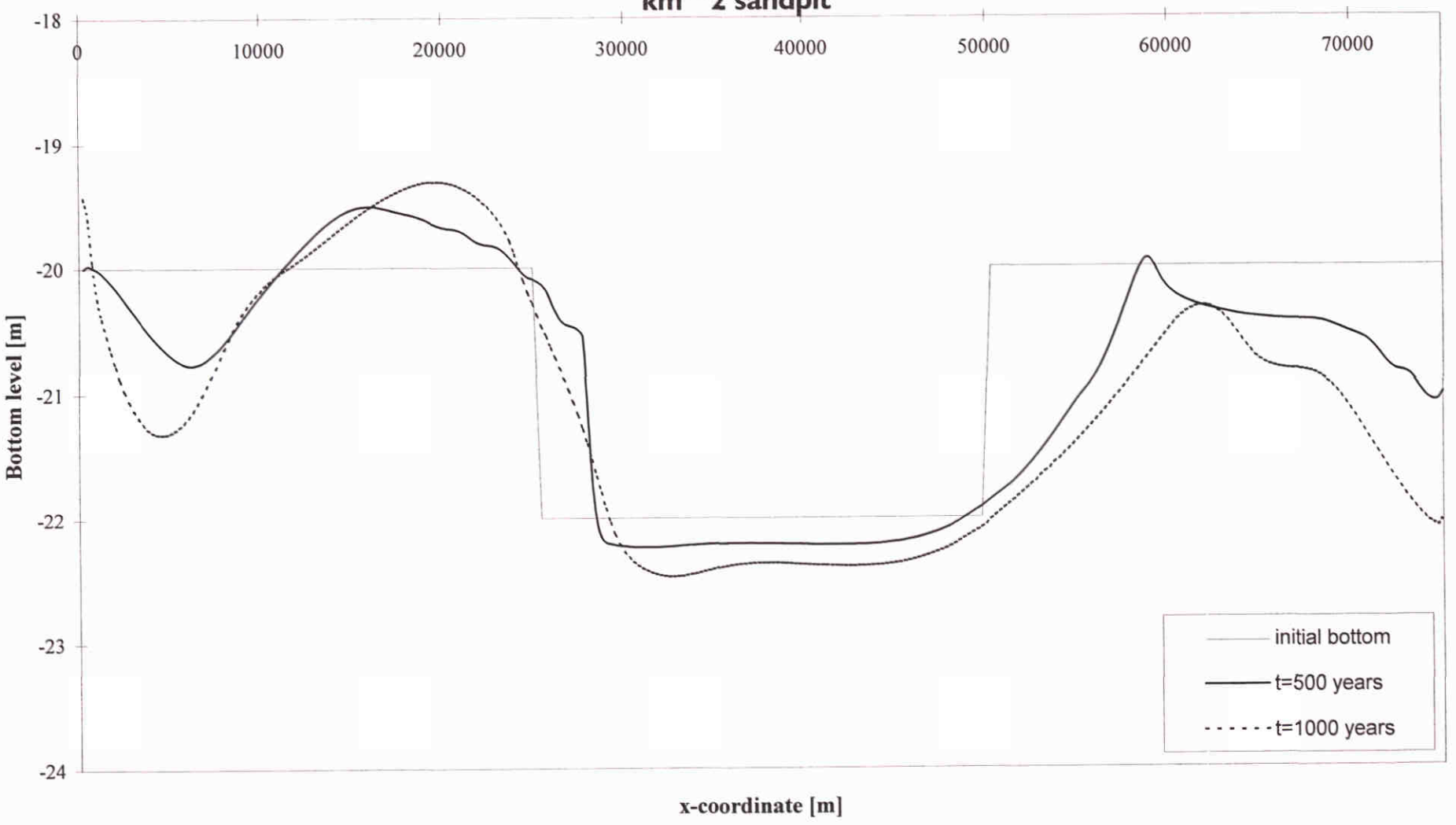
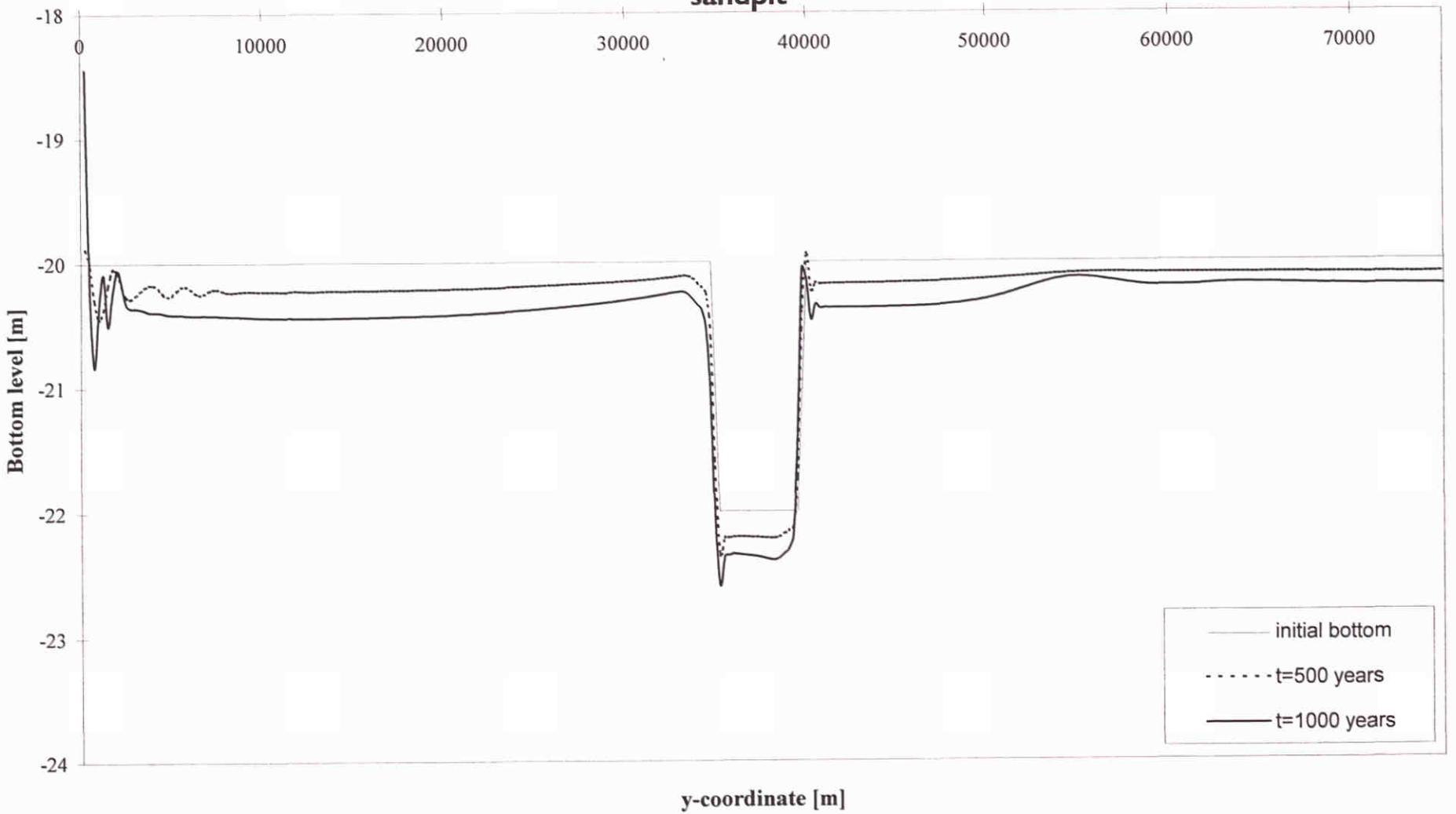
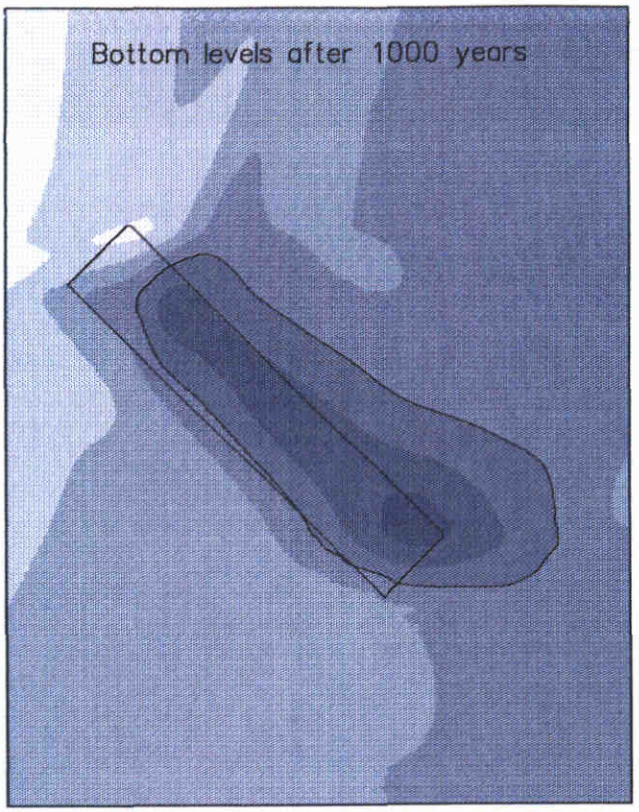
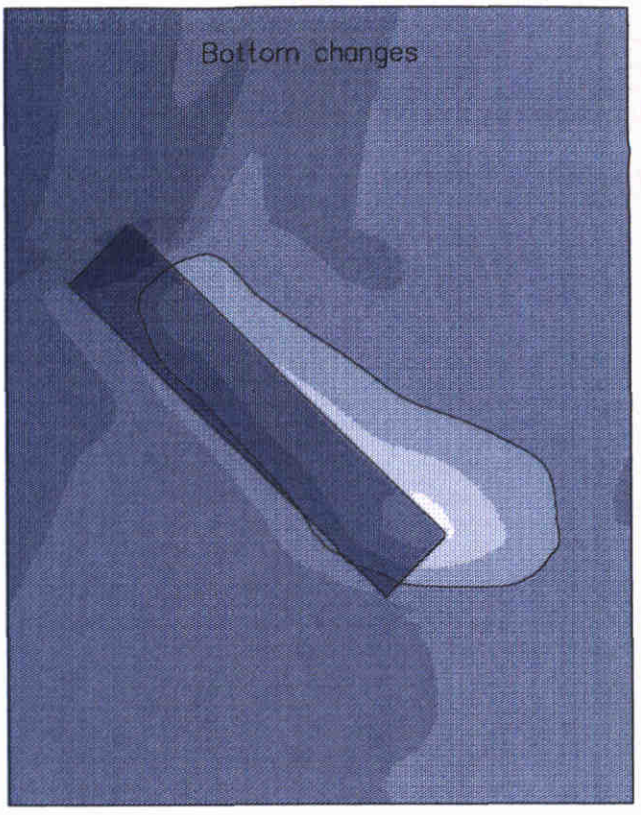
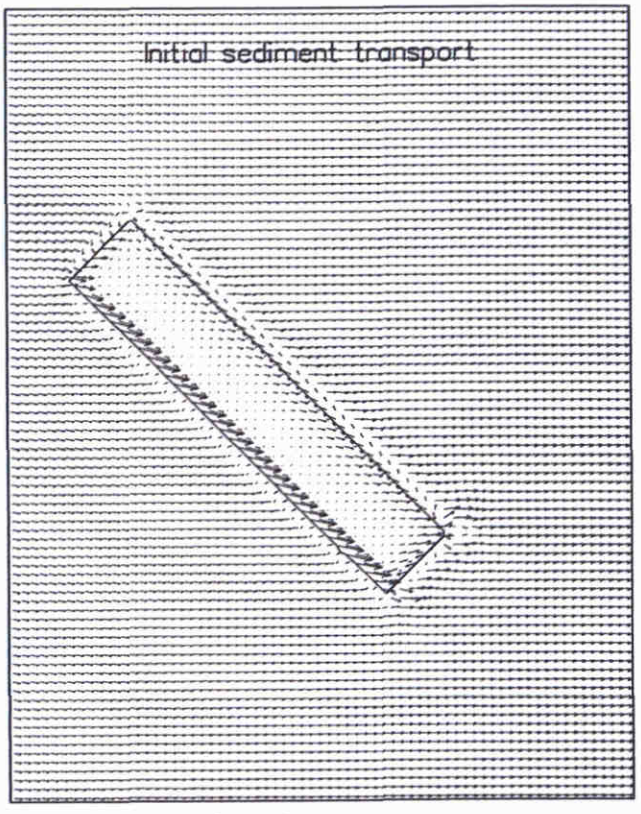


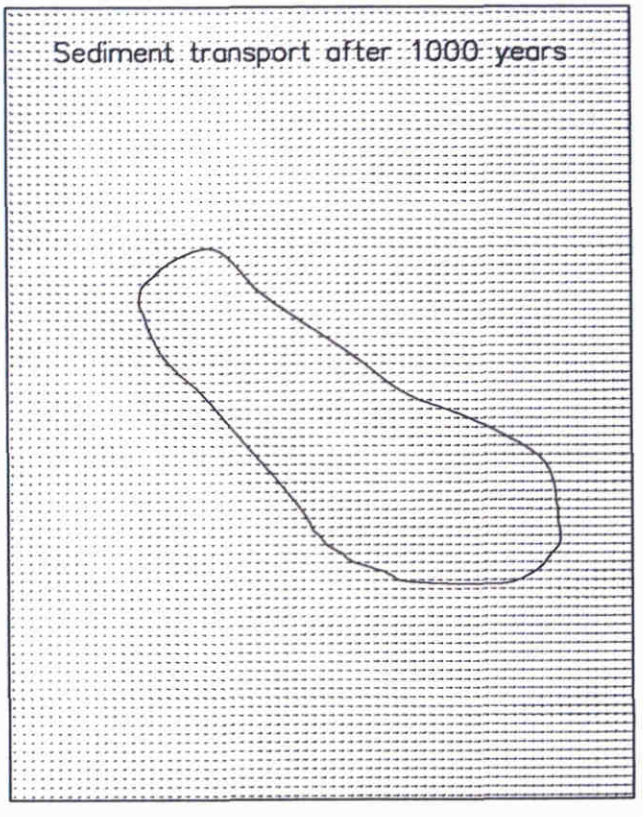
Figure 8.21c: Bottom levels in the center cross-section of a parallel, 22 m deep, 25x5 km ^ 2 sandpit











Bottom levels and changes [m]; sediment transport [m^2/s]

−45 degrees rotated, 22m deep 25x5 km^2 sandpit

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.22a

Figure 8.22b: Bottom levels in the longitudinal section of a +45° rotated, 22 m deep 25x5 km ^ 2 sandpit

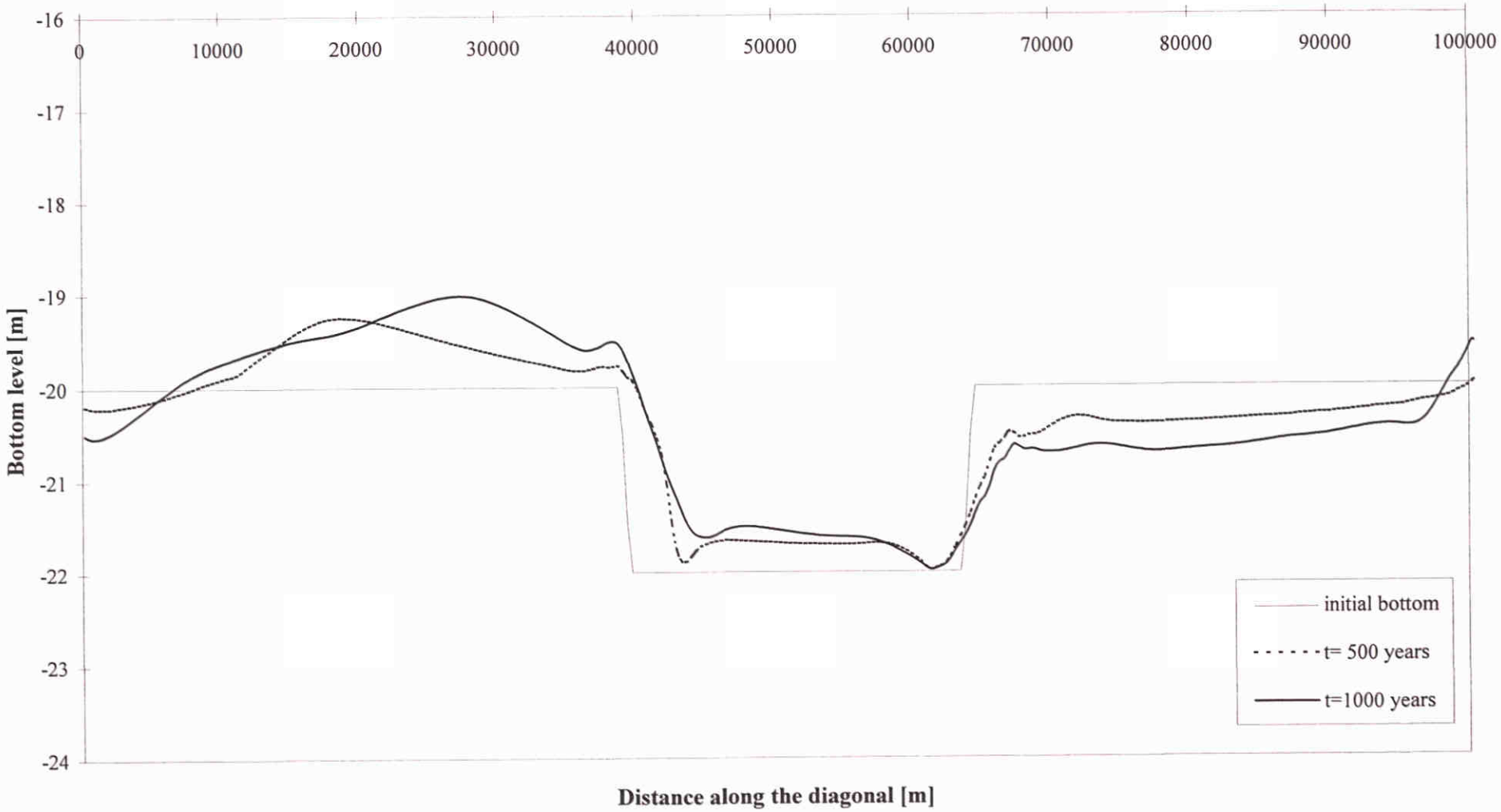
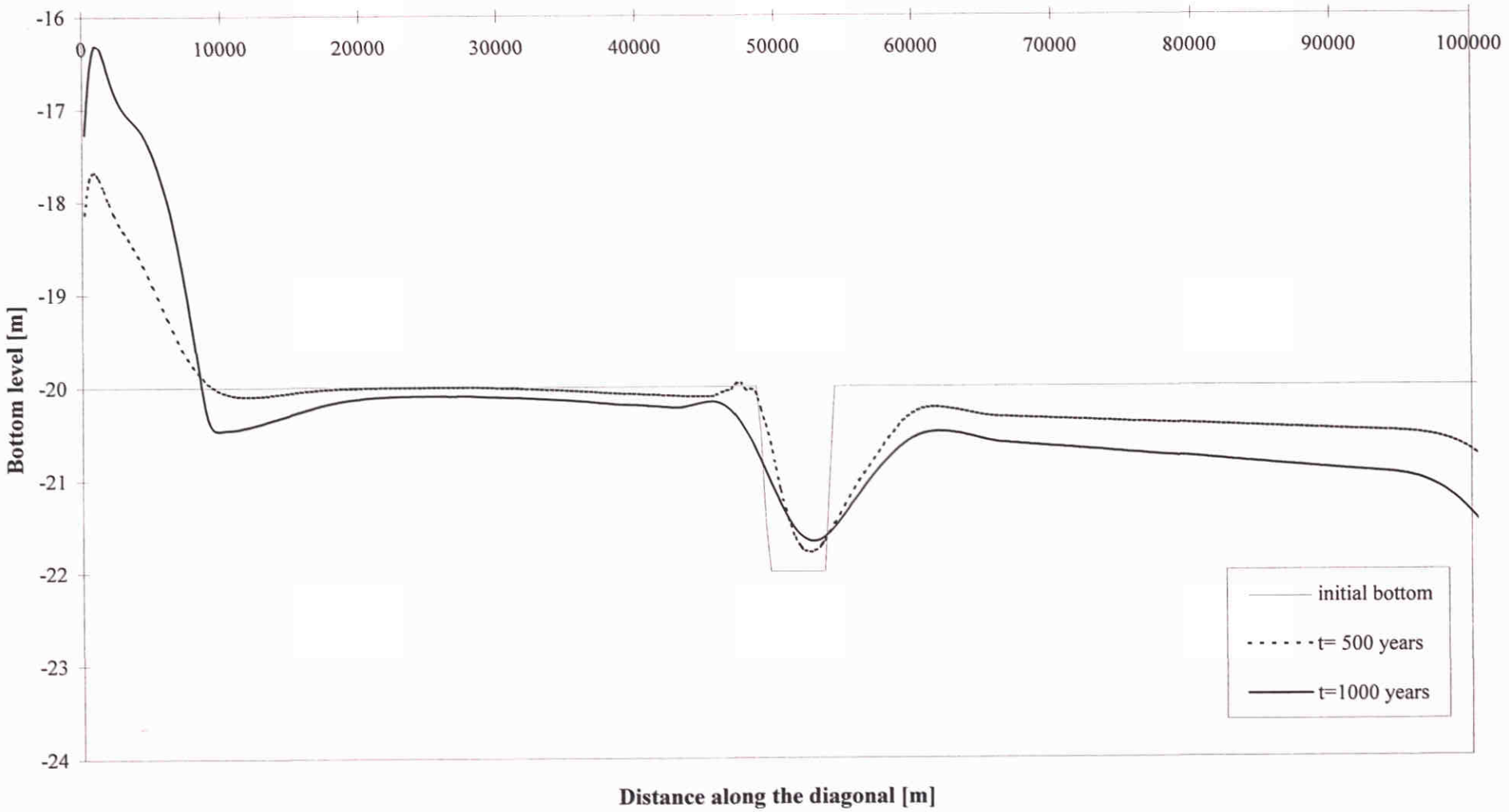
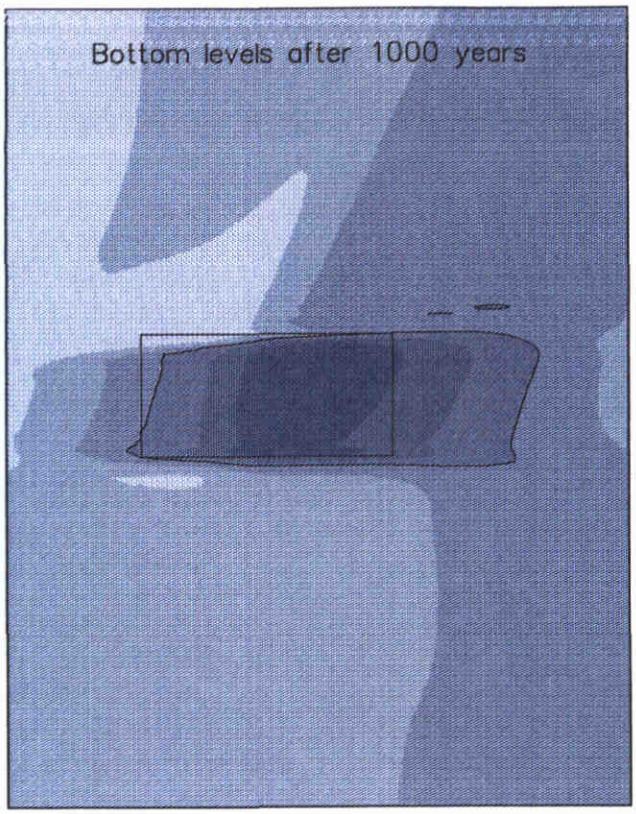
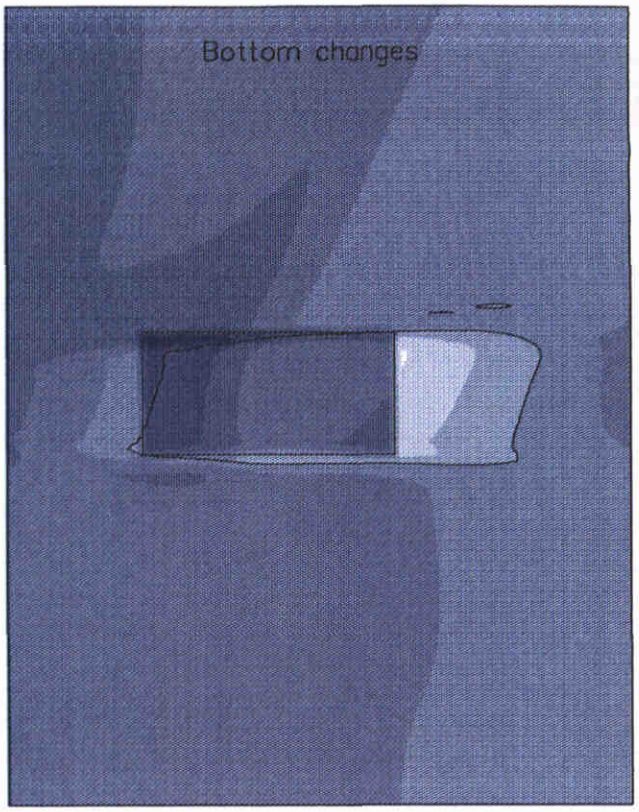
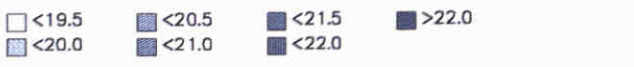


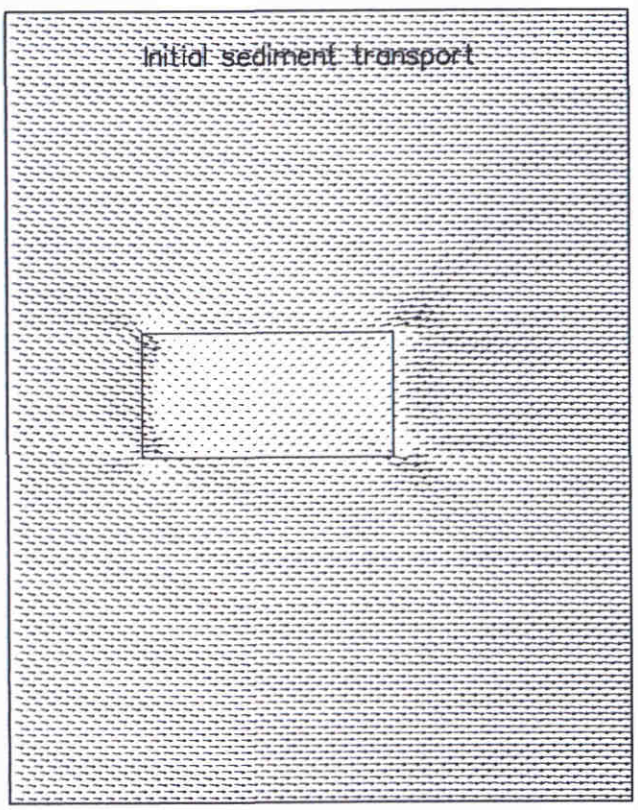
Figure 8.22c: Bottom levels in the center cross-section of a -45° rotated, 22m deep 25x5 km2 sandpit

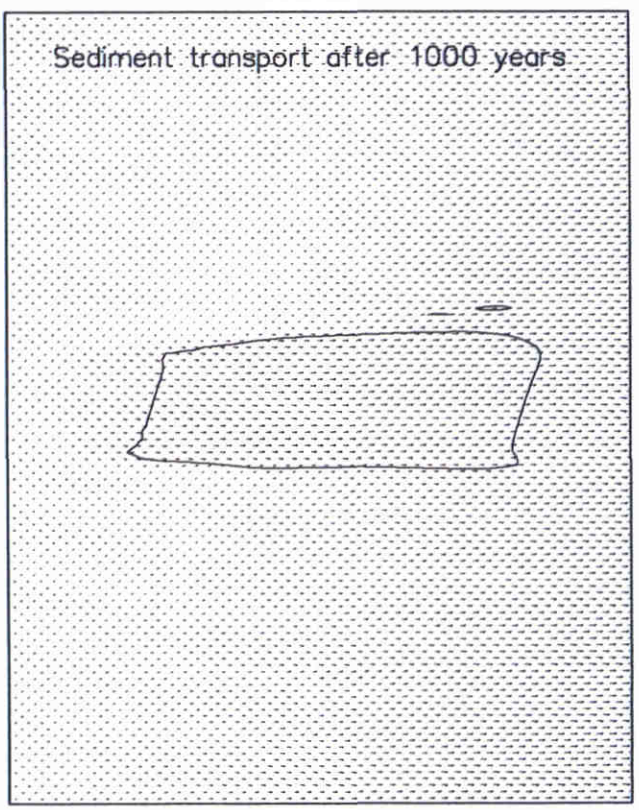












⟶ $2.0*10^{-5}$ m^2/s

Bottom levels and changes [m]; sediment transport [m^2/s]

Parallel, 22 m deep 10x5 km^2 sandpit

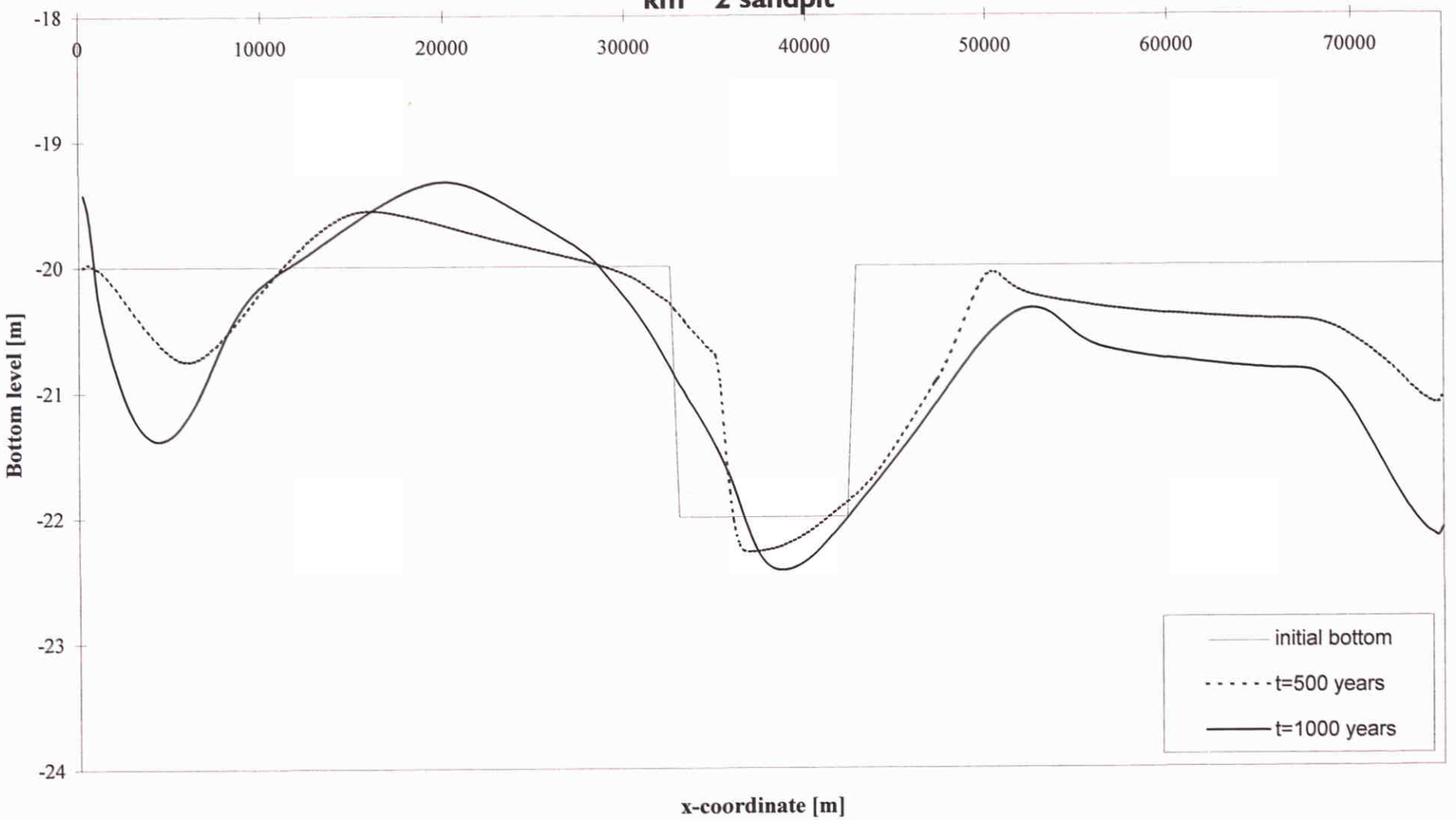
Morphological results after 1000 years

WL | DELFT HYDRAULICS

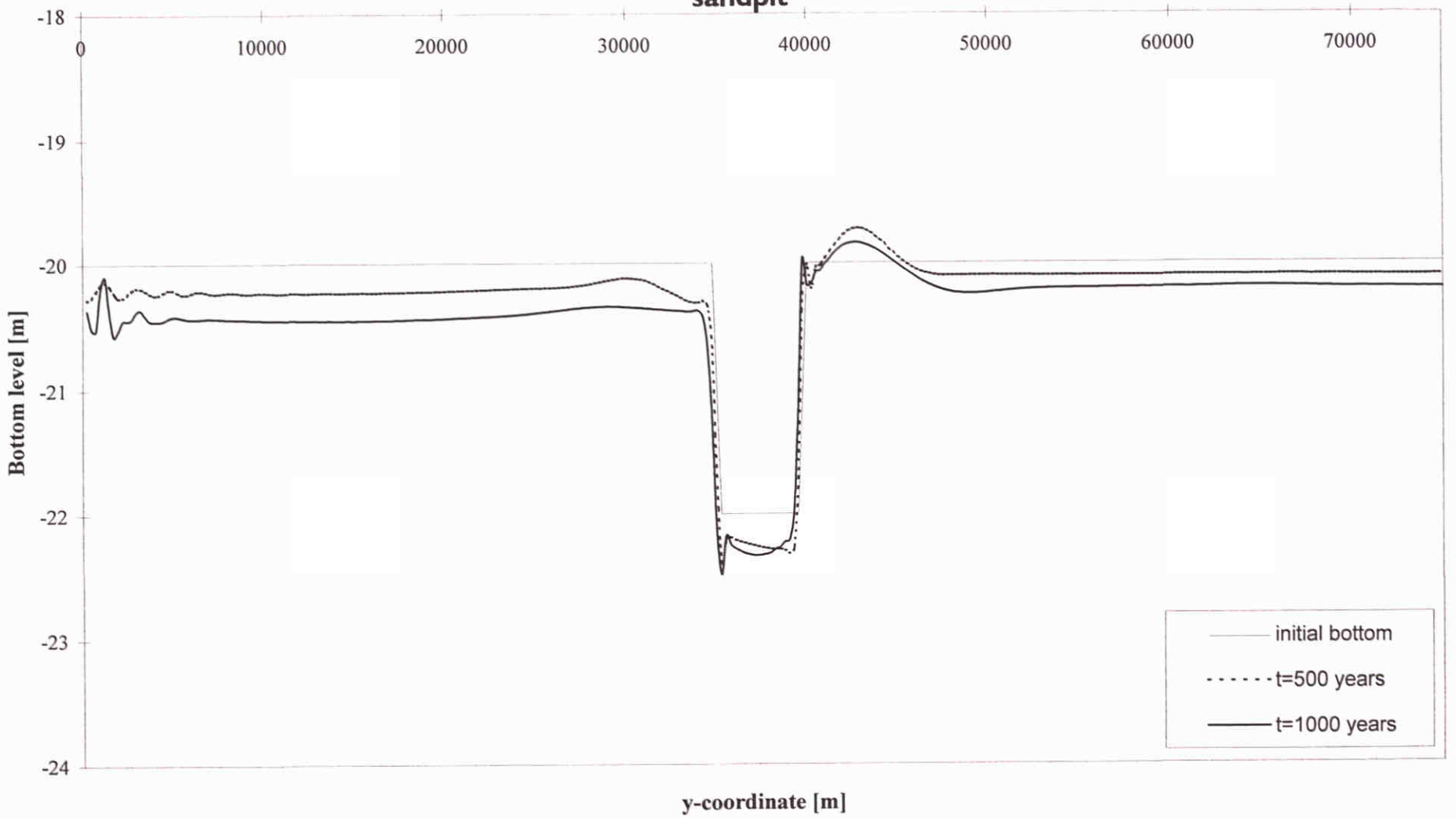
z2615

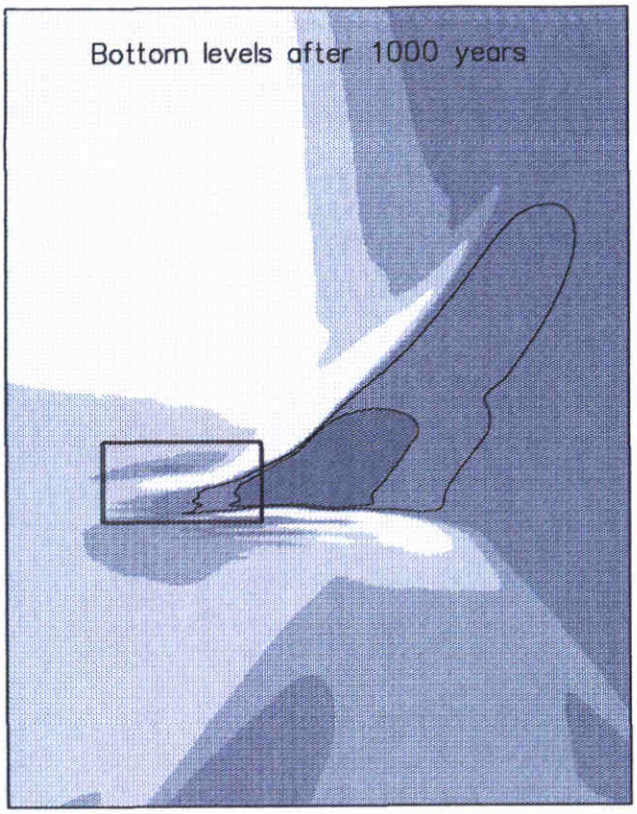
Figure 8.23a

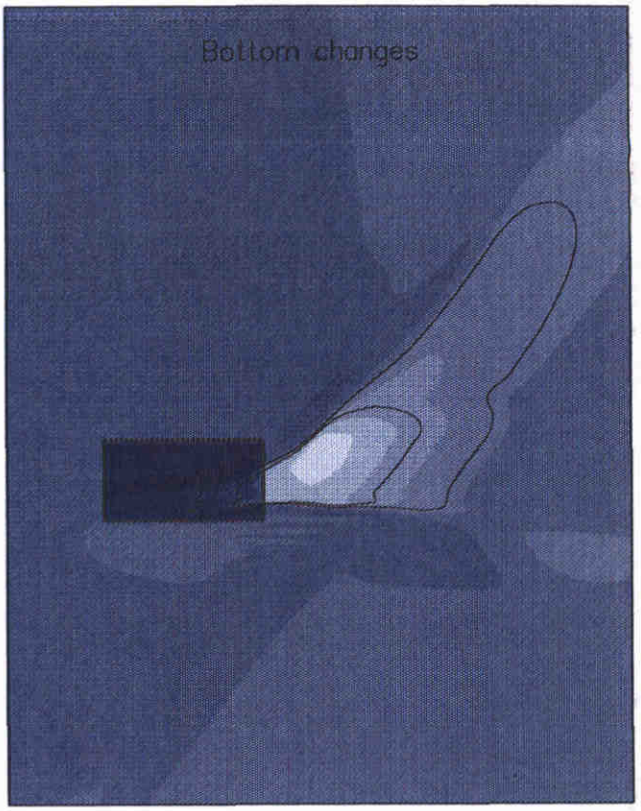
Figuur 8.23b: Bottom levels in the center longitudinal section of parallel, 22 m deep 10x5 km ^ 2 sandpit

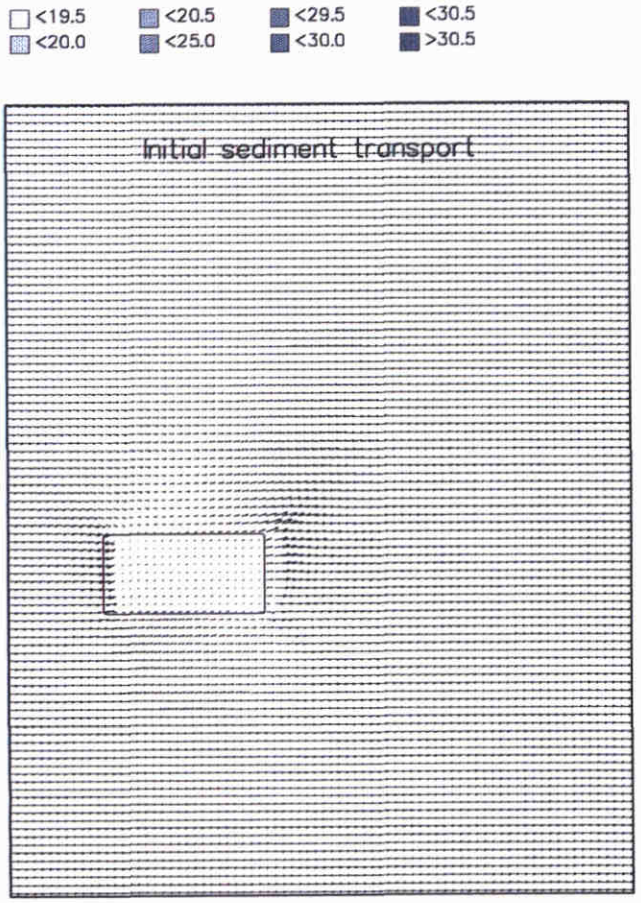


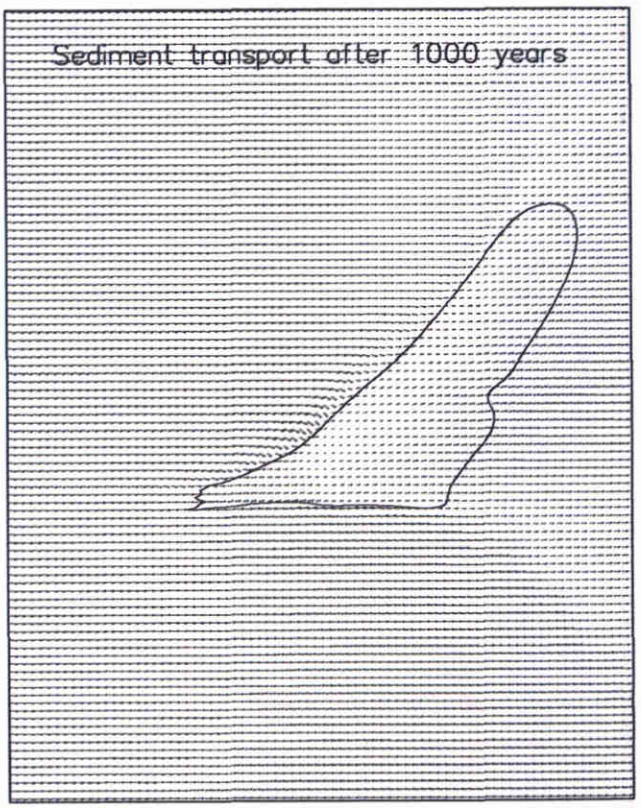
Figuur 8.23c: Bottom levels in the center cross-section of parallel, 22 m deep 10x5 km ^ 2 sandpit











Bottom levels and changes [m]; sediment transport [m^2/s]

Parallel 10x5 km^2 sandpit; variant with increased M0 velocity

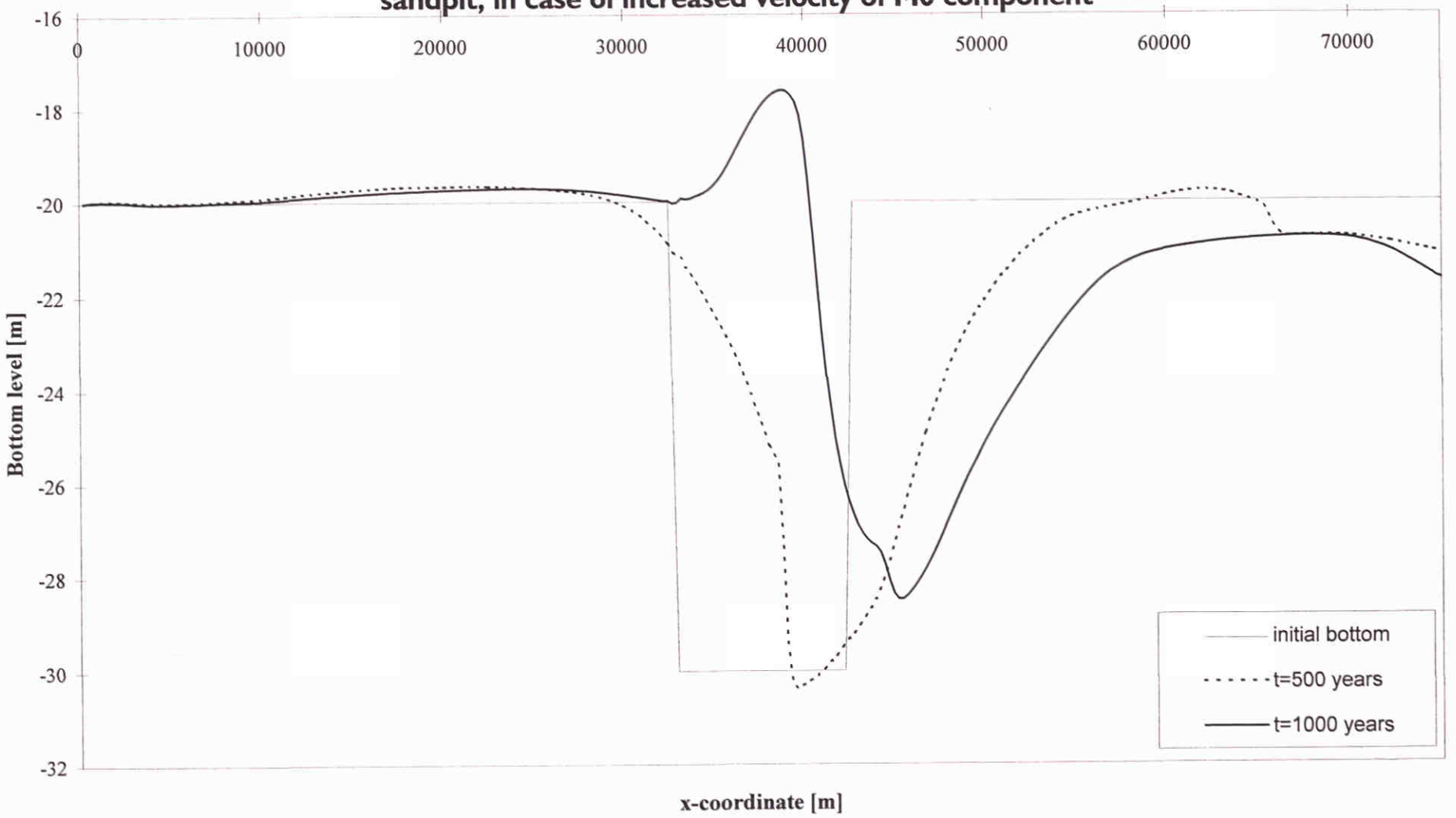
Morphological results after 1000 years

WL | DELFT HYDRAULICS

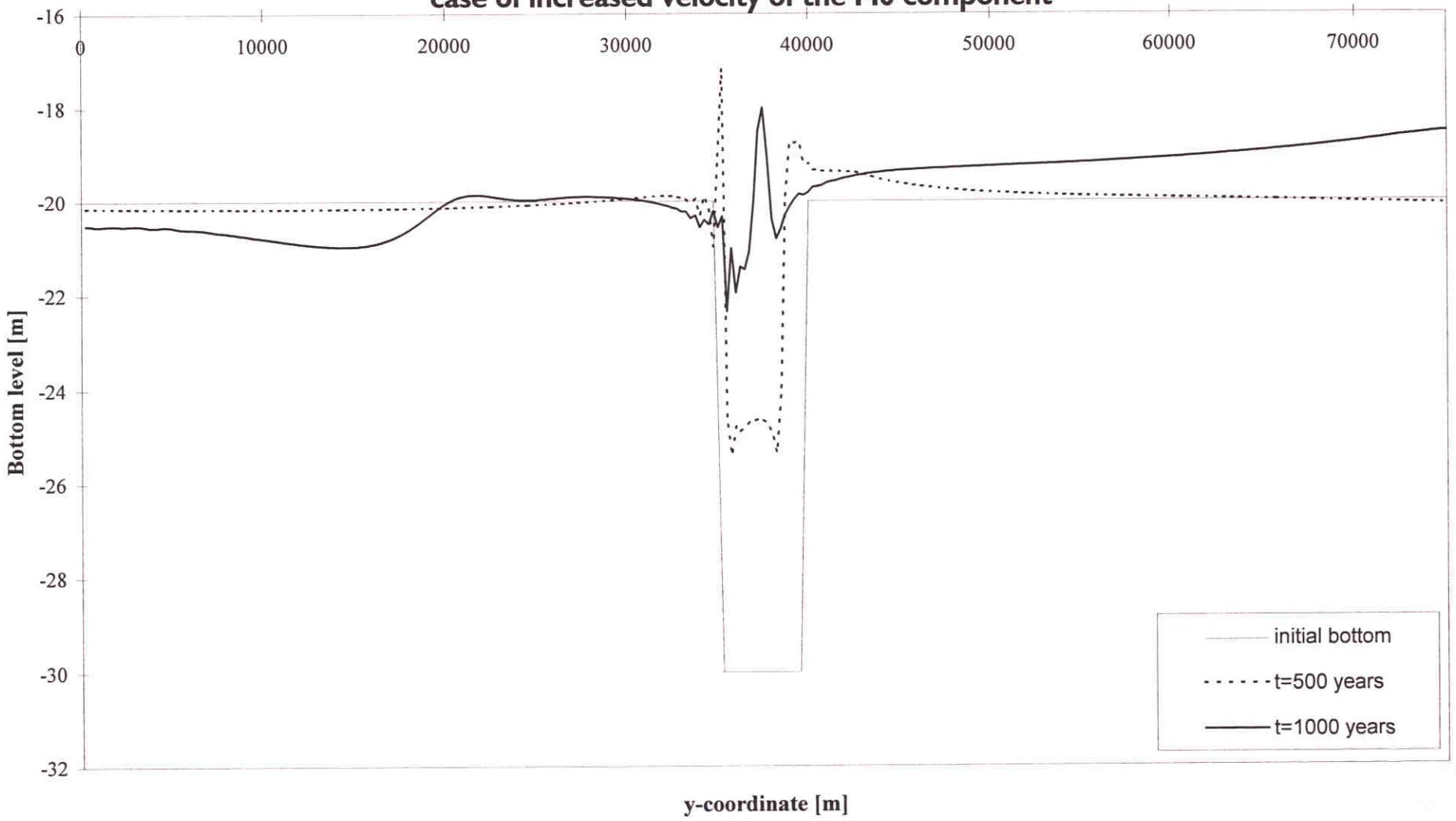
z2615

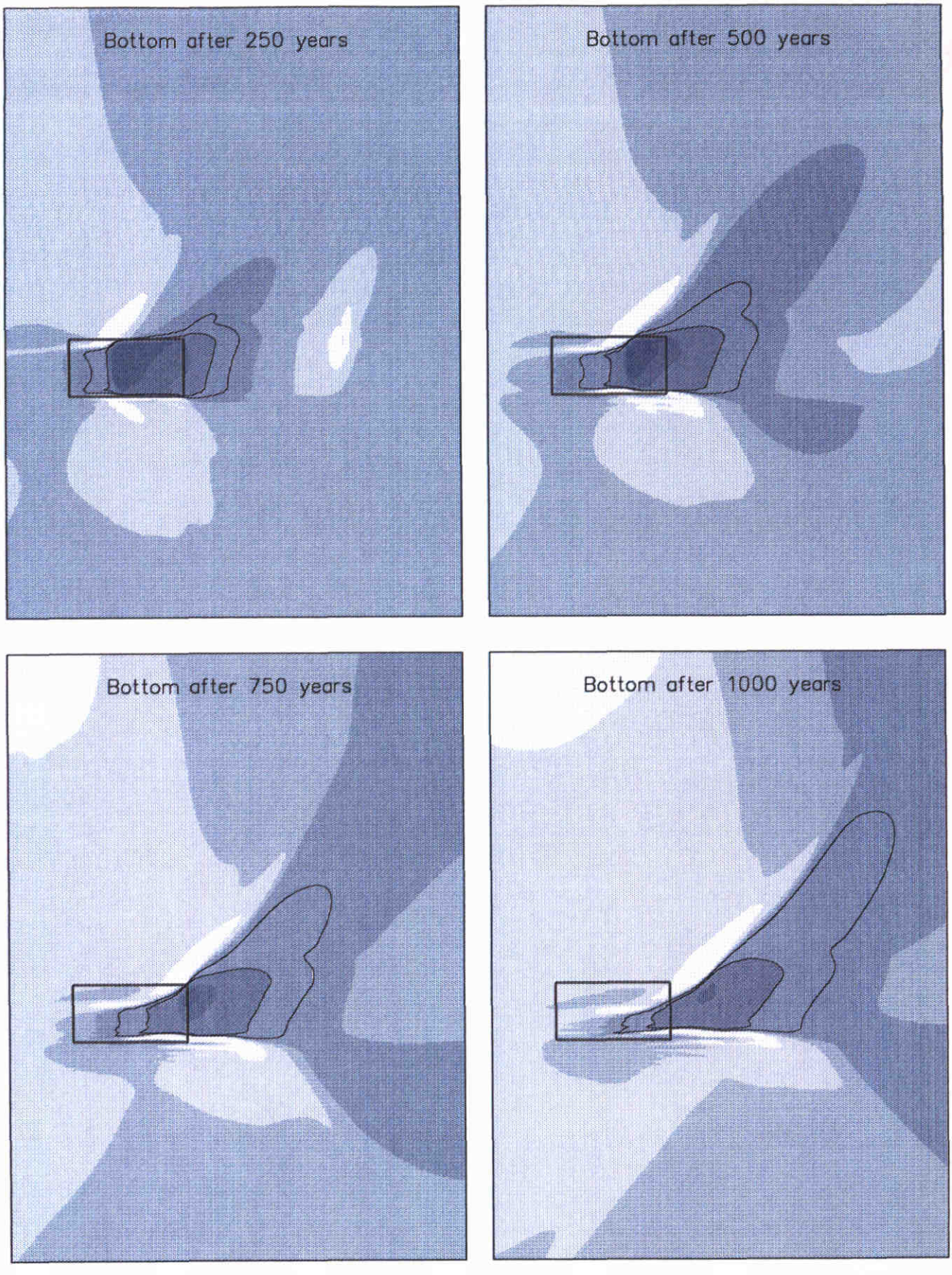
Figure 8.24a

Figuur 8.24b: Bottom levels in the center longitudinal section of a parallel 24x5 km ^ 2 sandpit, in case of increased velocity of M0 component



Figuur 8.24c: Bottom levels in the center cross-section of a parallel 10x5 km ^ 2 sandpit, in case of increased velocity of the M0 component





Bottom levels [m]

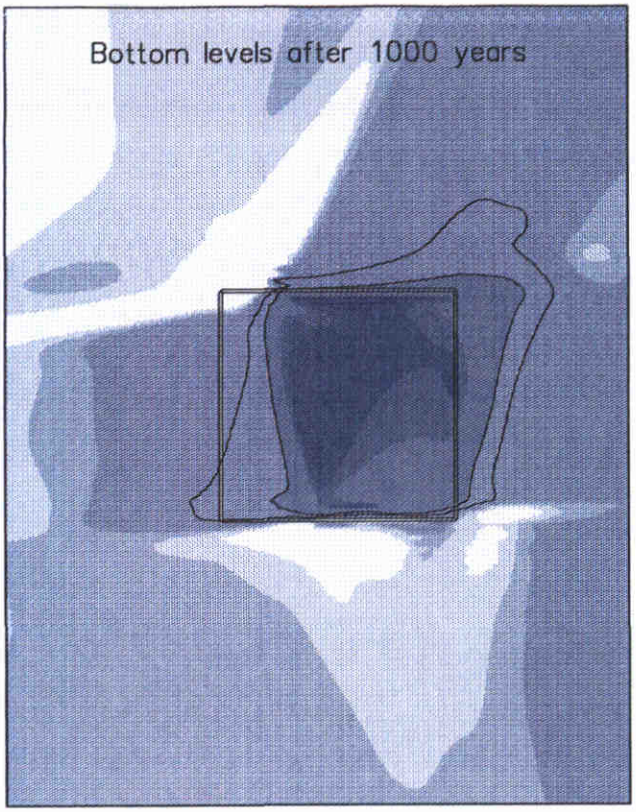
Parallel 10x5 km^2 sandpit; velocity variant

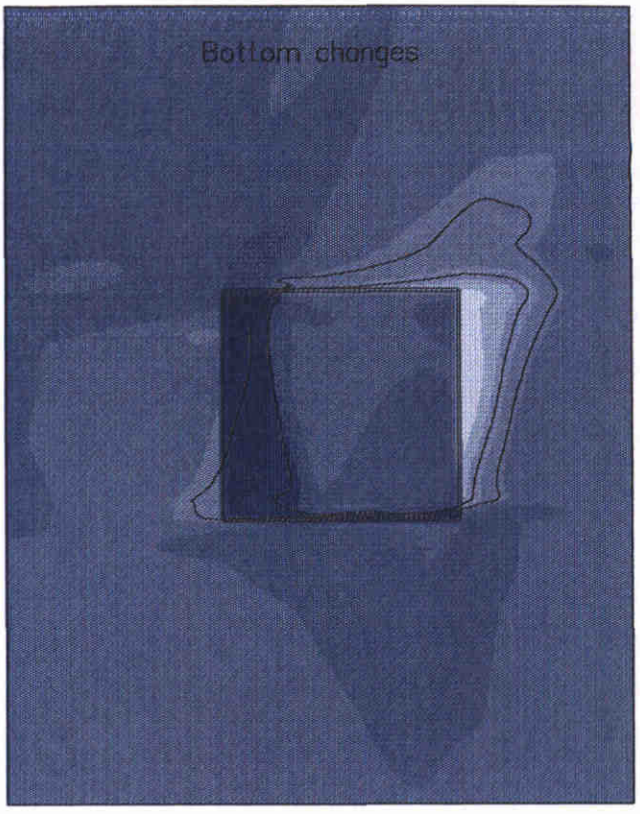
Morphological development in time

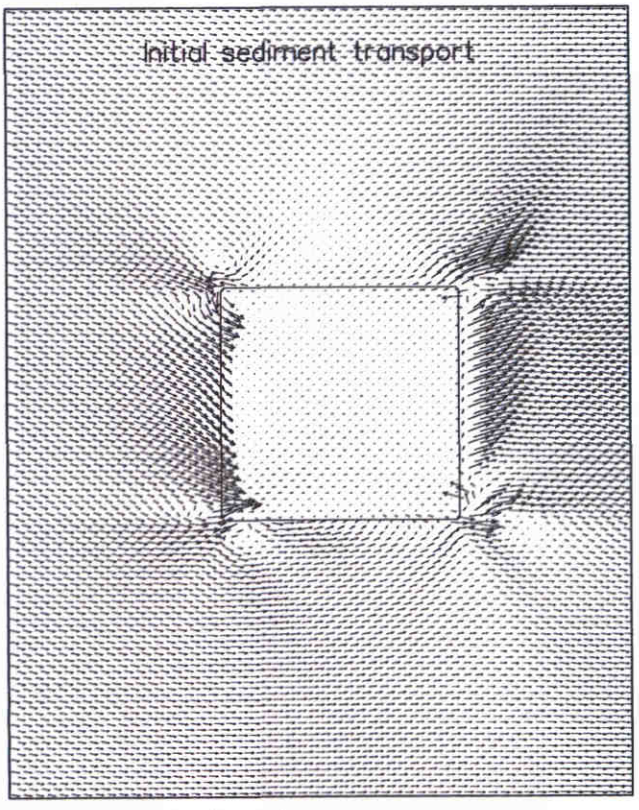
WL | DELFT HYDRAULICS

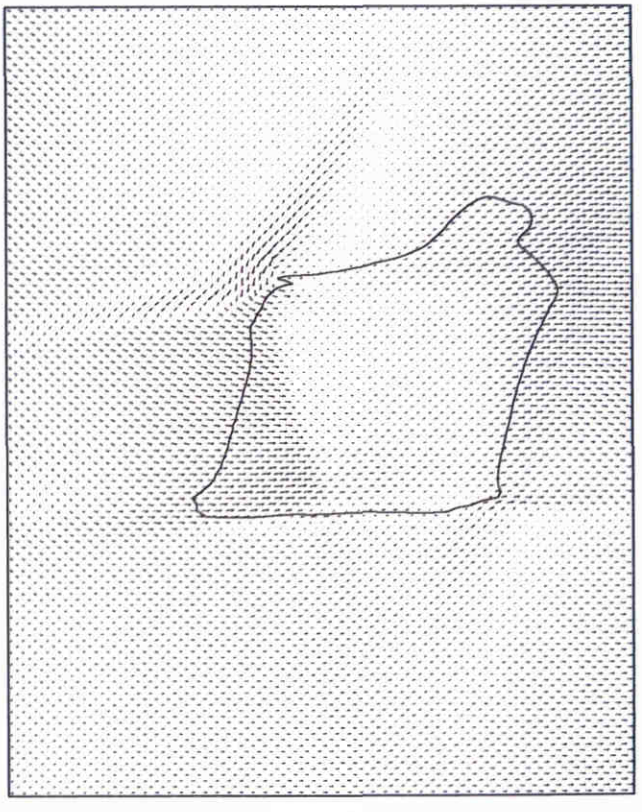
z2615

Figure 8.25









Bottom levels and changes [m]; sediment transport [m^2/s]

+45 degrees rotated 10x10 km^2 sandpit

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.26a

Figure 8.26b: Bottom levels in the center longitudinal section of a parallel 10x10 km ^ 2 sandpit

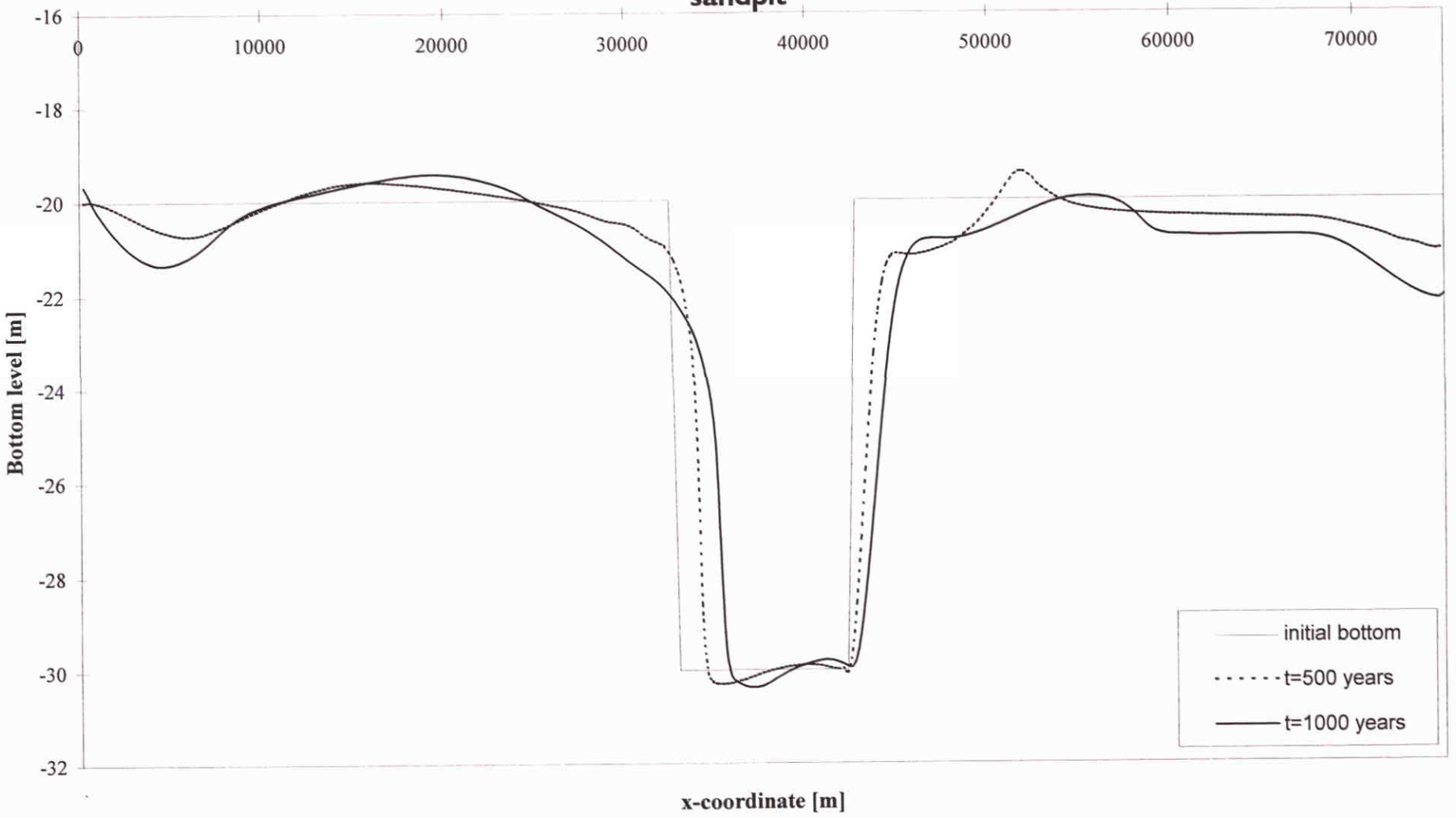
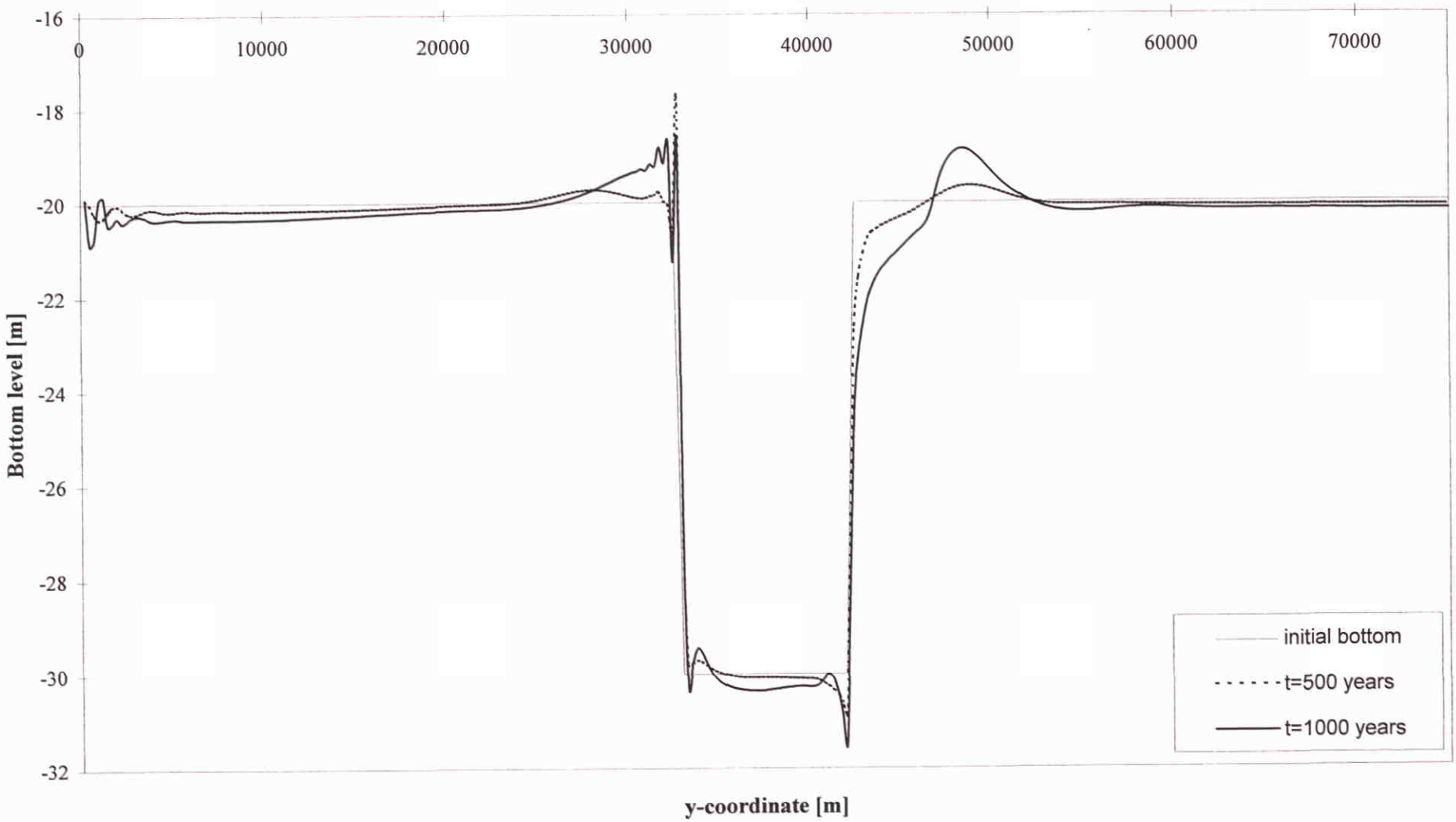
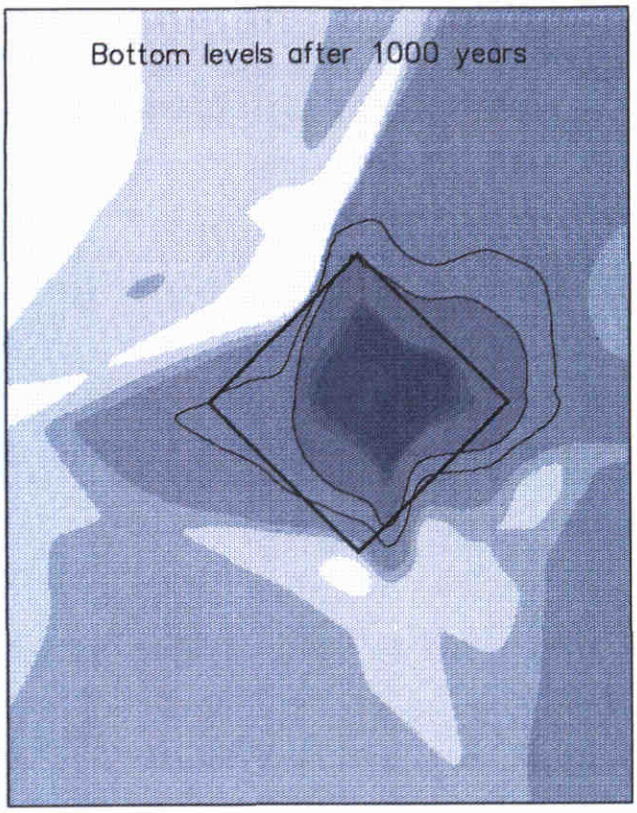
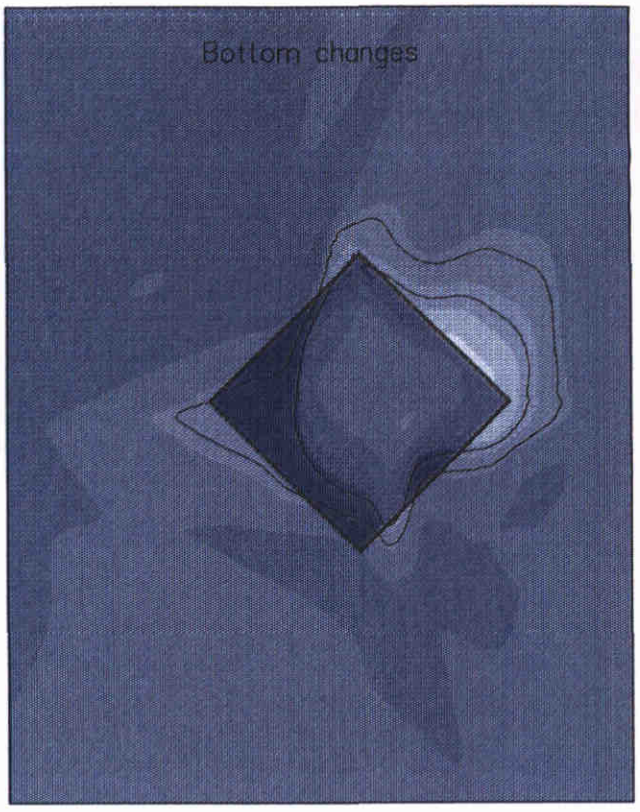
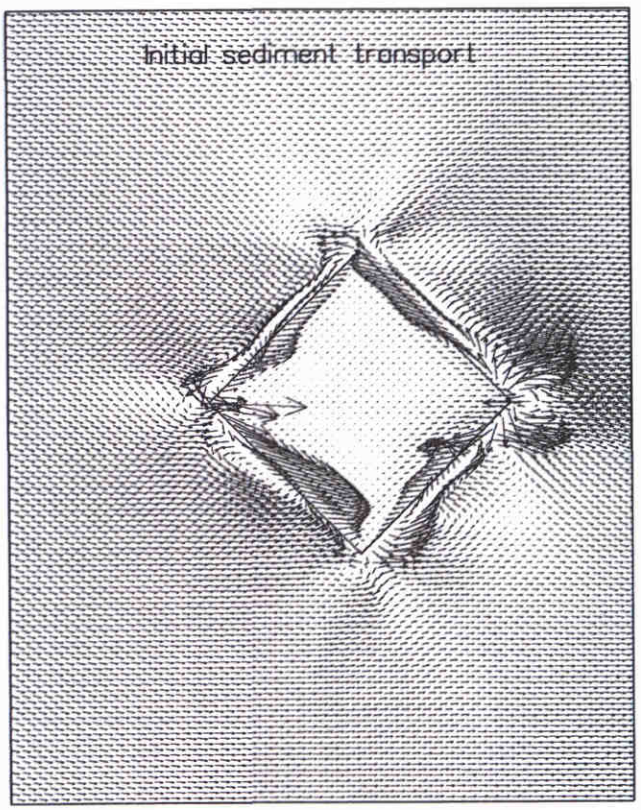


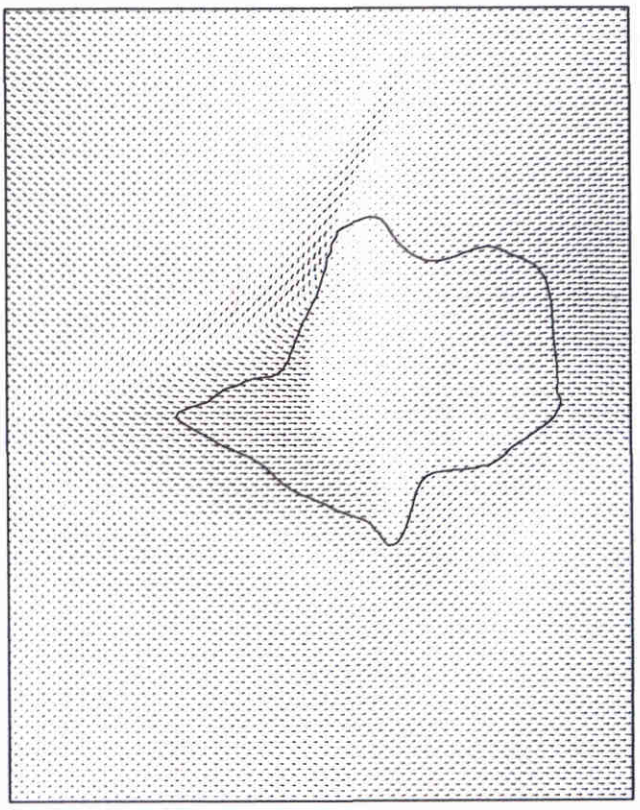
Figure 8.26c: Bottom levels in the center cross-section of a parallel 10x10 km ^ 2 sandpit











Bottom levels and changes [m]; sediment transport [m^2/s]

+45 degrees rotated 10x10 km^2 sandpit

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.27a

Figure 8.27b: Bottom levels in the longitudinal section of a +45° rotated 10x10 km ^ 2 sandpit

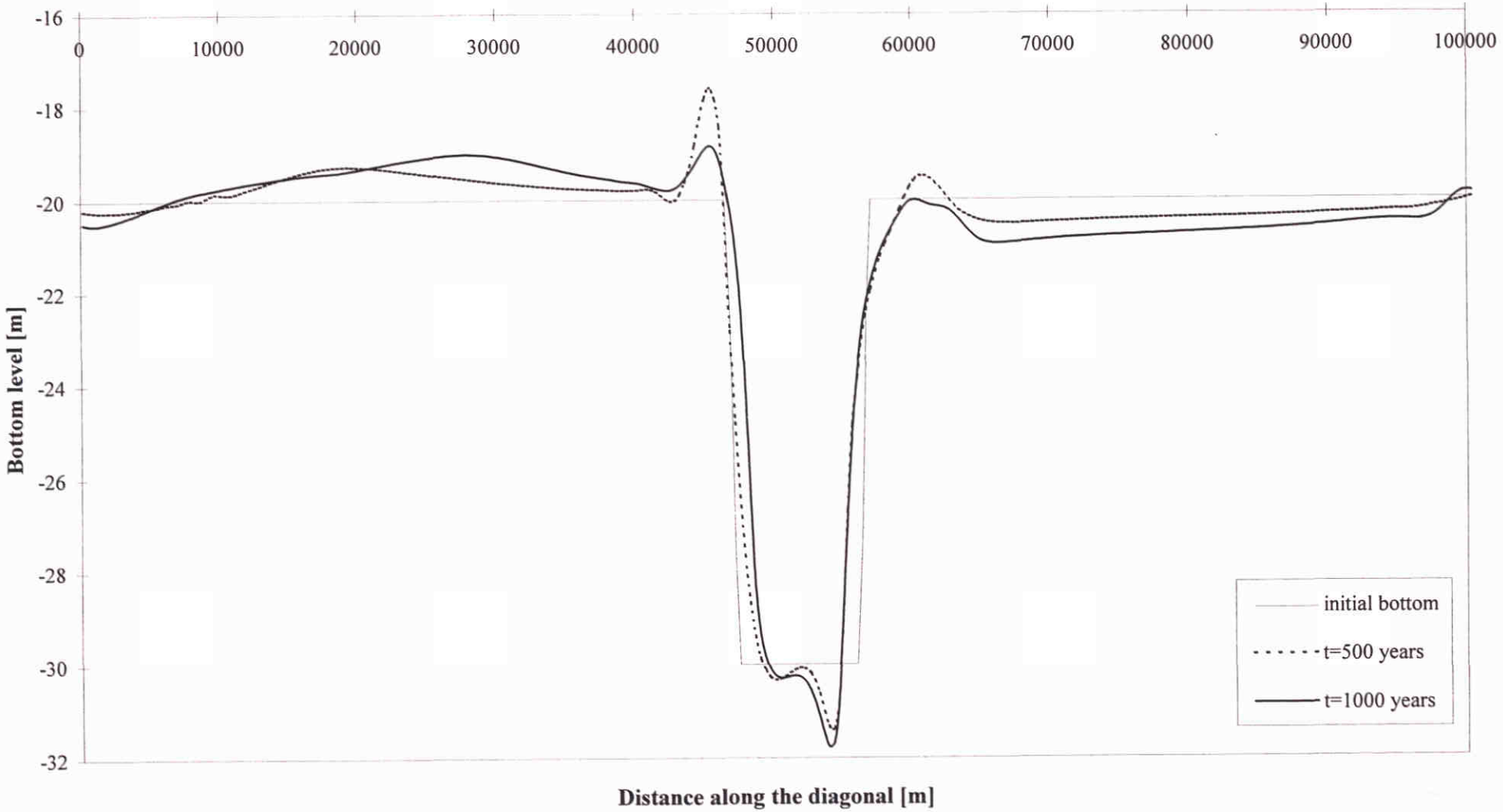
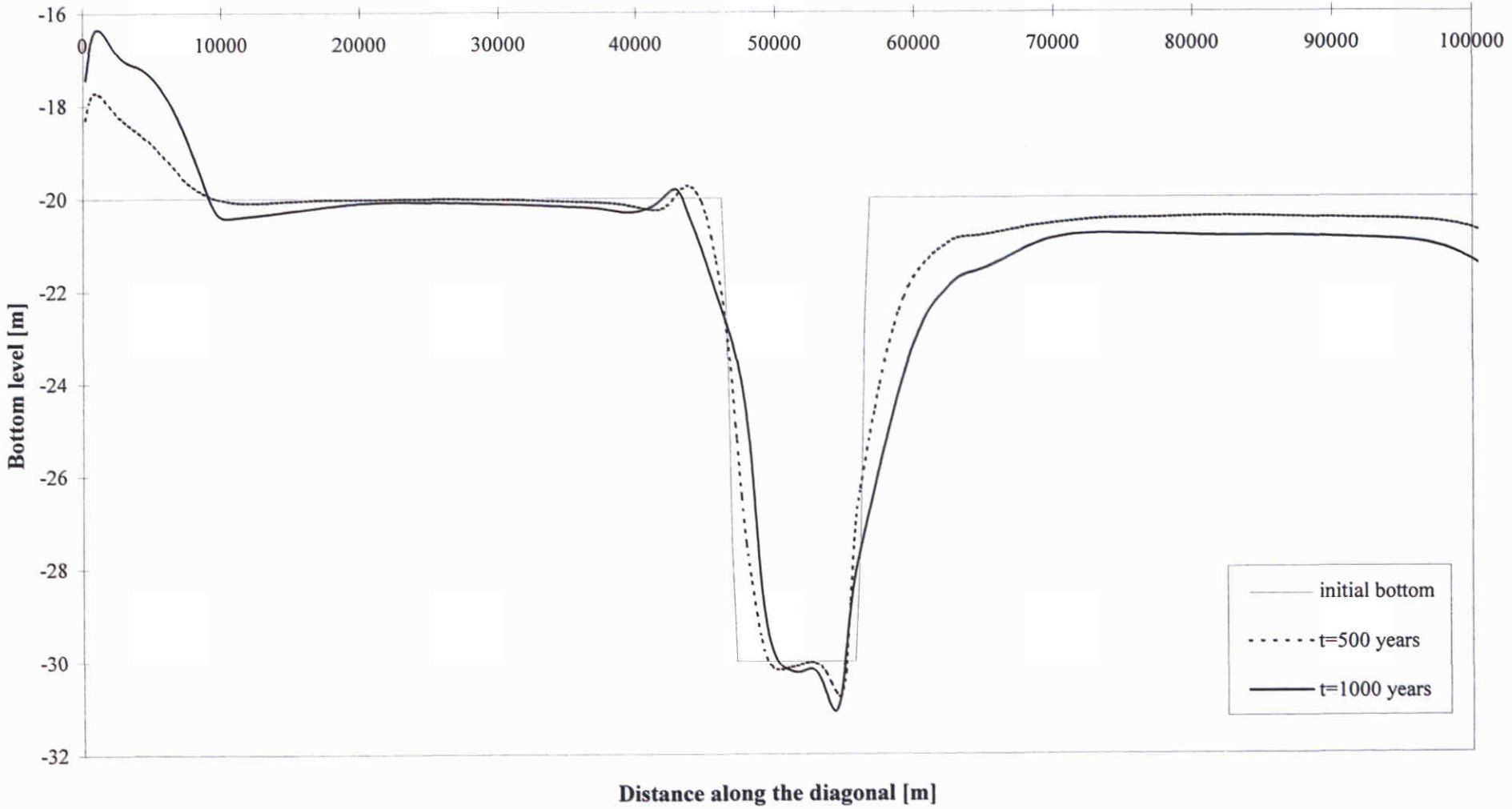
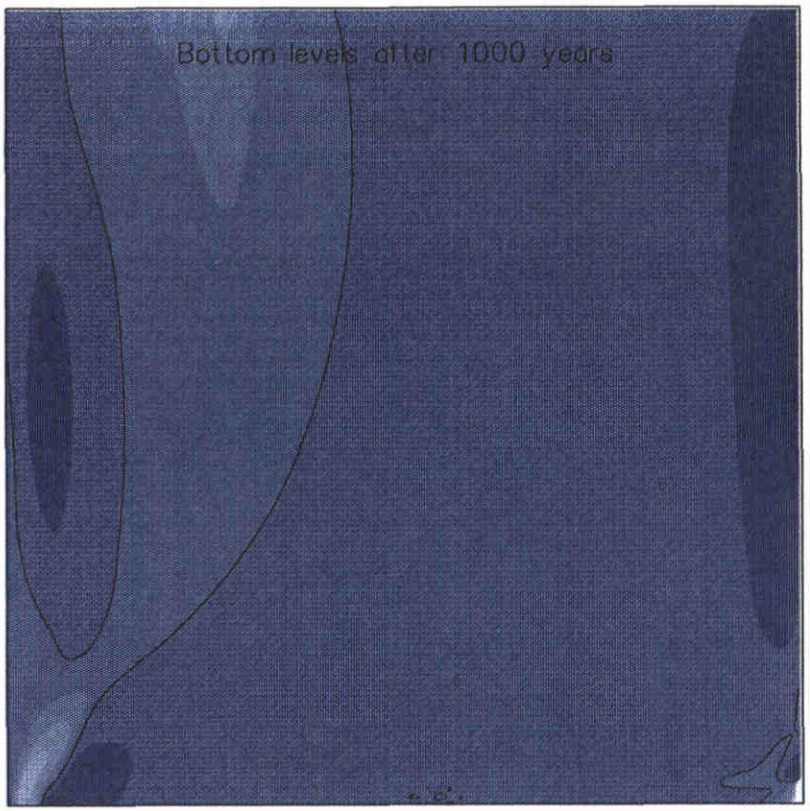
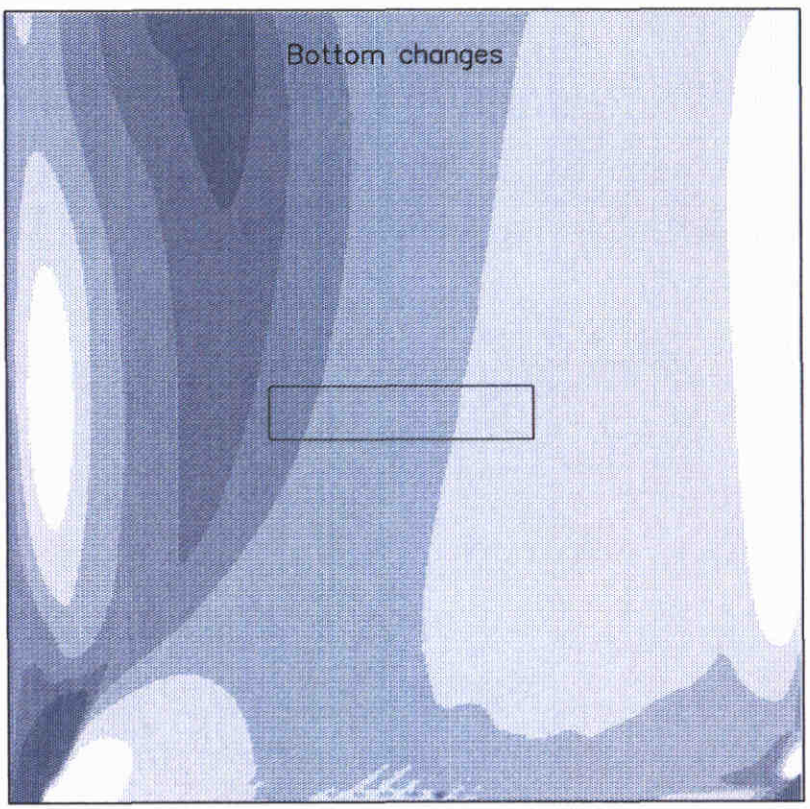


Figure 8.27c: Bottom levels in the center cross-section of a +45° rotated 10x10 km2 sandpit







Bottom levels and changes [m]

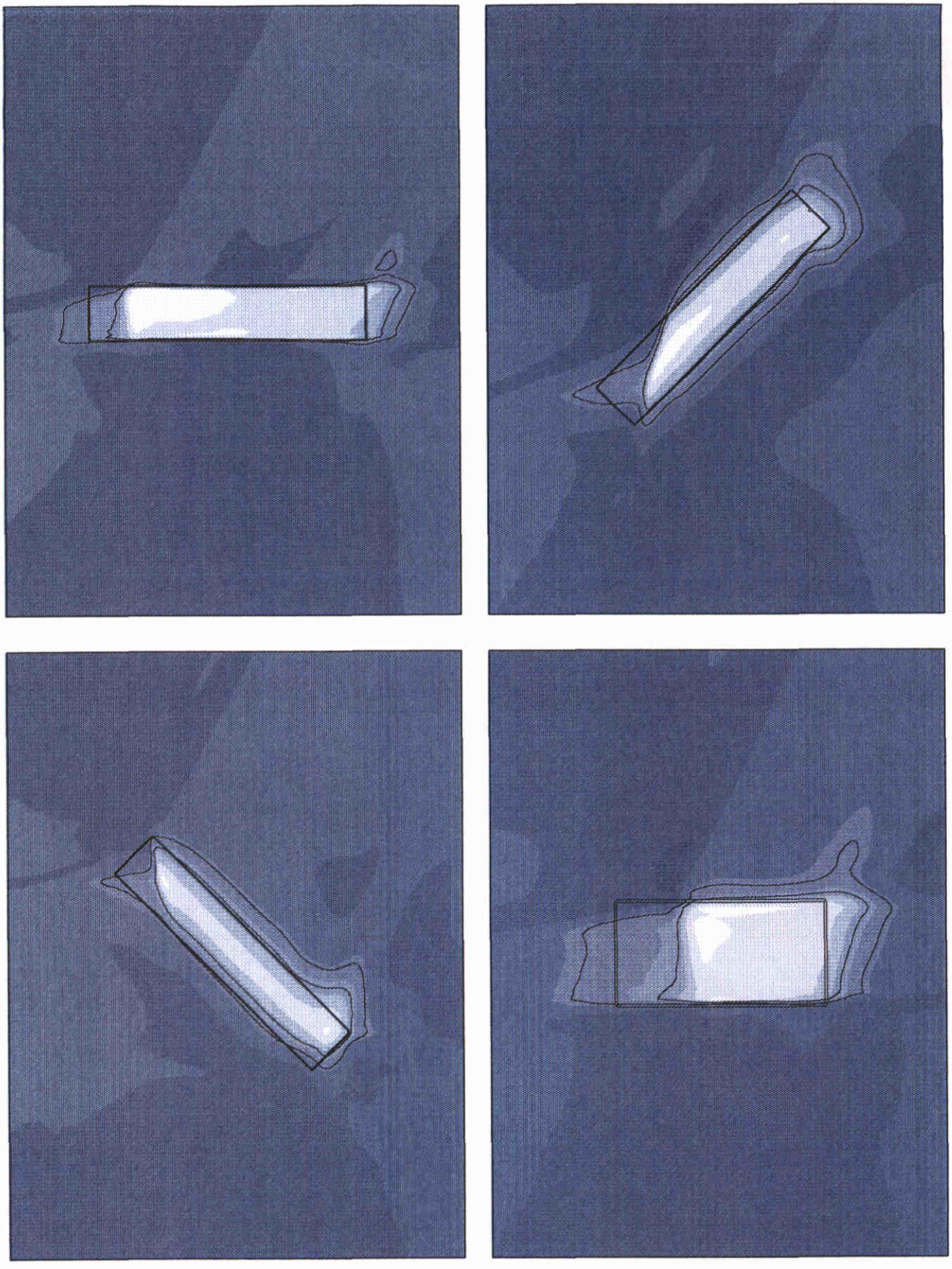
Flat bottom without a sandpit

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.28



Bottom levels [m] with respect to undisturbed sea bottom

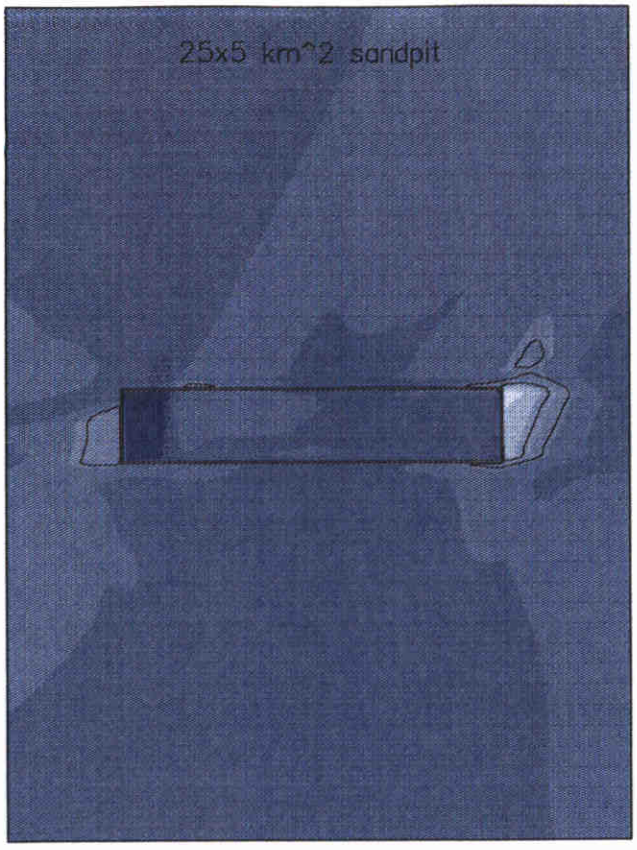
Correction for the influence of the boundary conditions

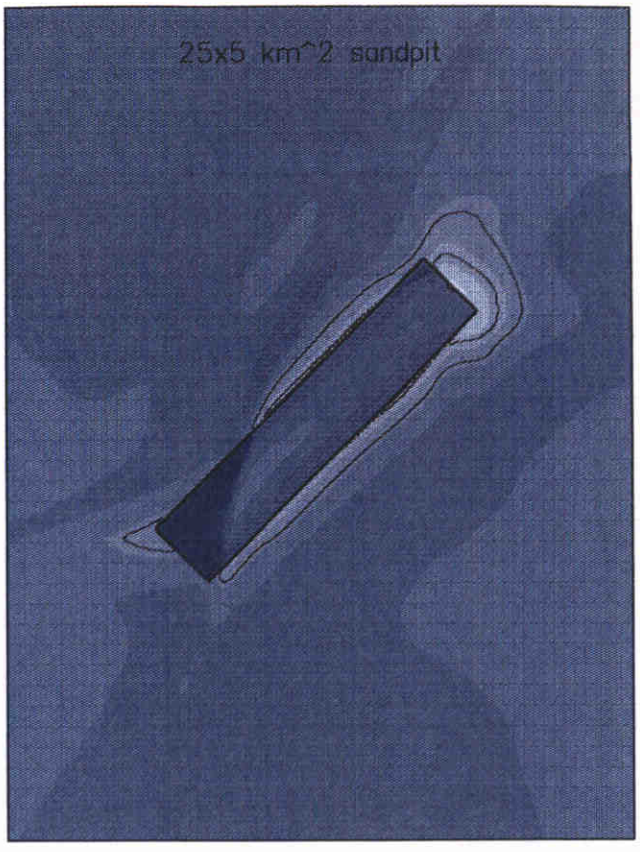
Morphological results after 1000 years

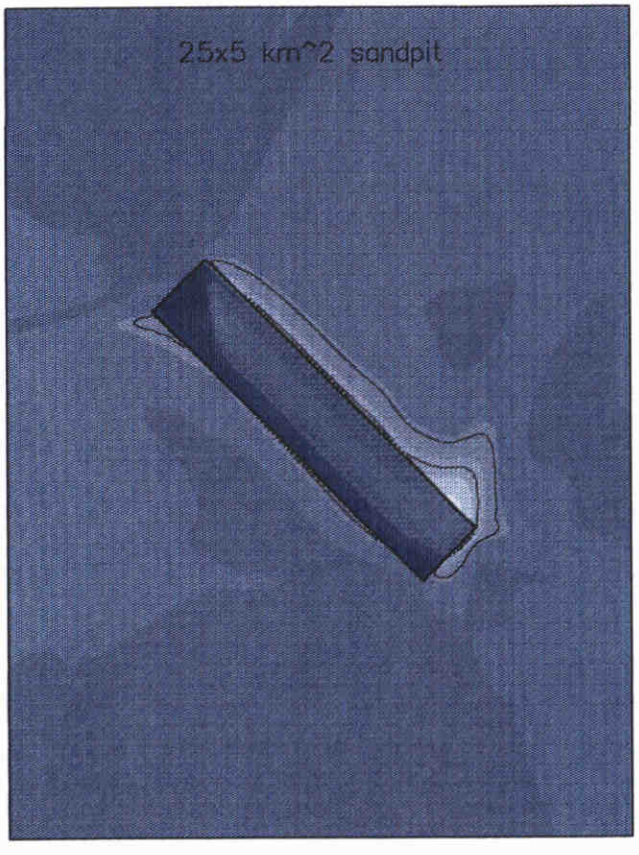
WL | DELFT HYDRAULICS

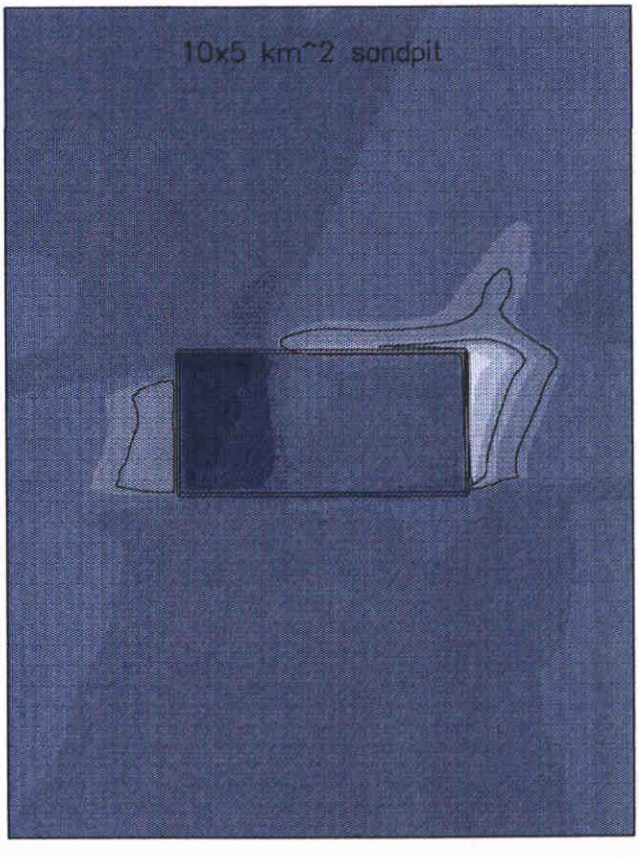
z2615

Figure 8.29









Bottom changes [m]

Correction for the influence of the boundary conditions

Morphological results after 1000 years

WL | DELFT HYDRAULICS

z2615

Figure 8.30

WL | delft hydraulics

Rotterdamseweg 185
postbus 177
2600 MH Delft
telefoon 015 285 85 85
telefax 015 285 85 82
e-mail info@wldelft.nl
internet www.wldelft.nl

Rotterdamseweg 185
p.o. box 177
2600 MH Delft
The Netherlands
telephone +31 15 285 85 85
telefax +31 15 285 85 82
e-mail info@wldelft.nl
internet www.wldelft.nl