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Large-scale sandpits

Hydrodynamic and morphological modelling of large-scale sandpits



M.Sc. Thesis

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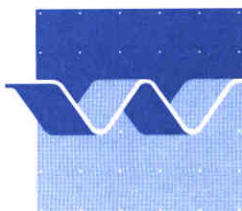
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Large-scale sandpits

Hydrodynamic and morphological modelling of large-scale sandpits

M.D. Klein

M.Sc. Thesis



wl | delft hydraulics

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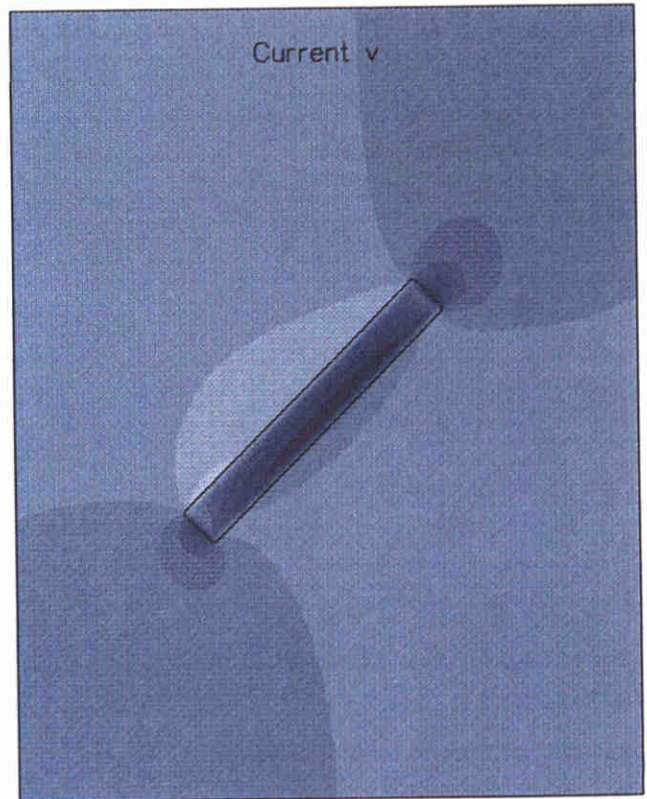
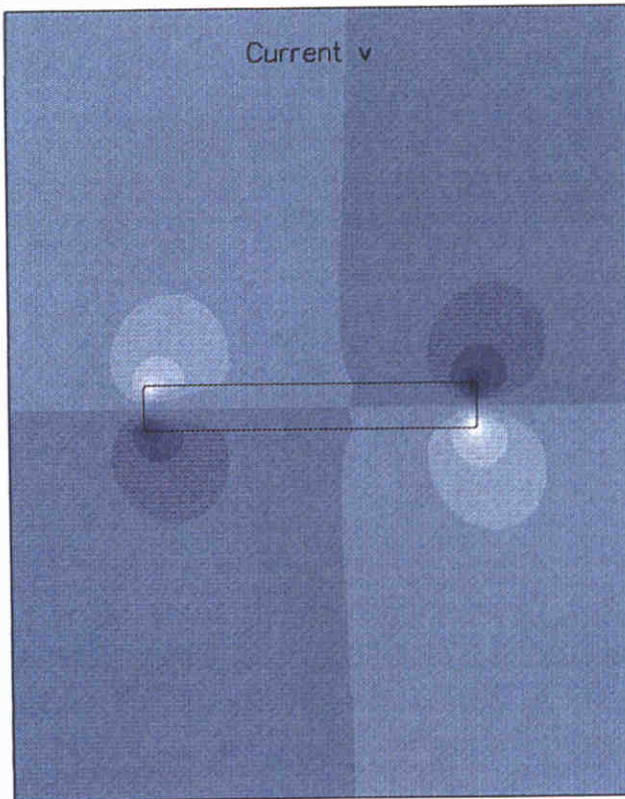
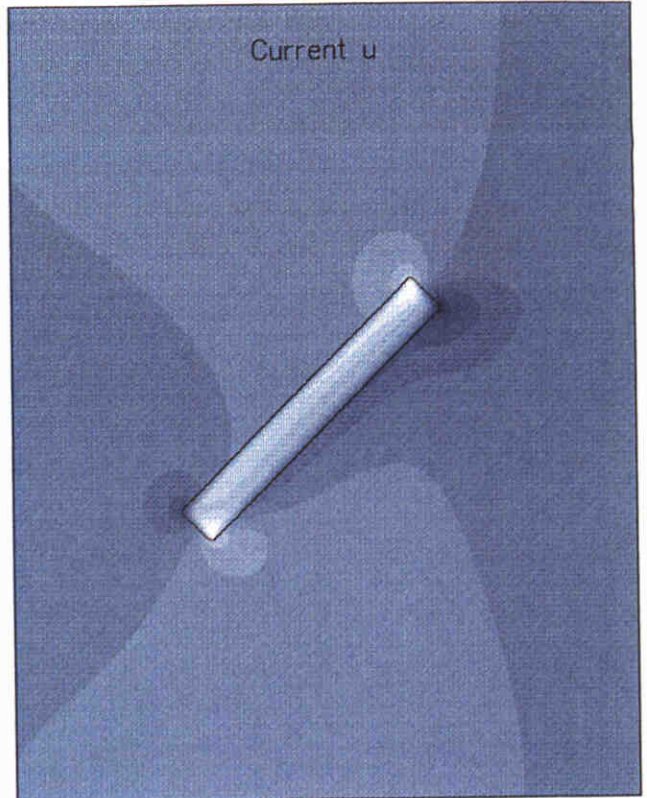
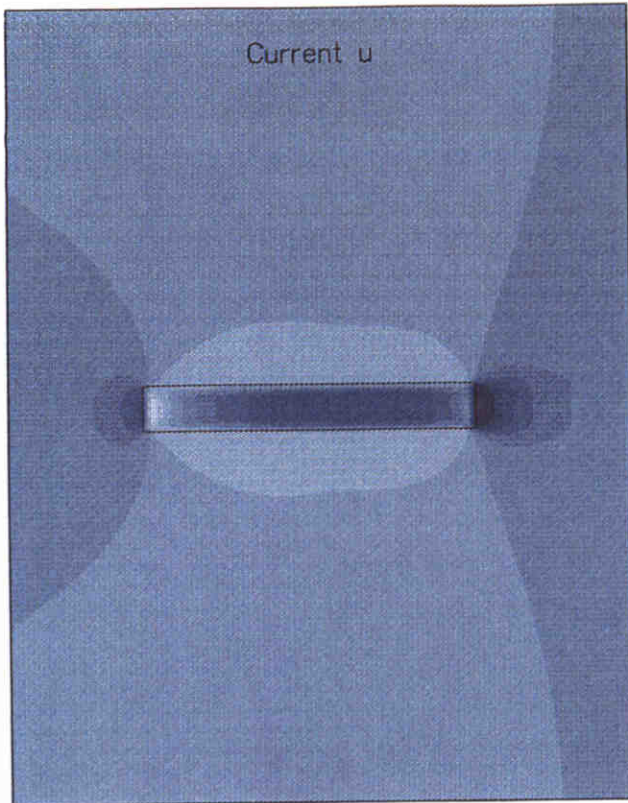
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*) These figures are included in the text



Current velocity components u and v [m/s]
 Influence of obliquity of a 40x5 km² sandpit
 Stationary boundary conditions

Figure 5.2: Current velocities in the center longitudinal section of a $40 \times 5 \text{ km}^2$ sandpit

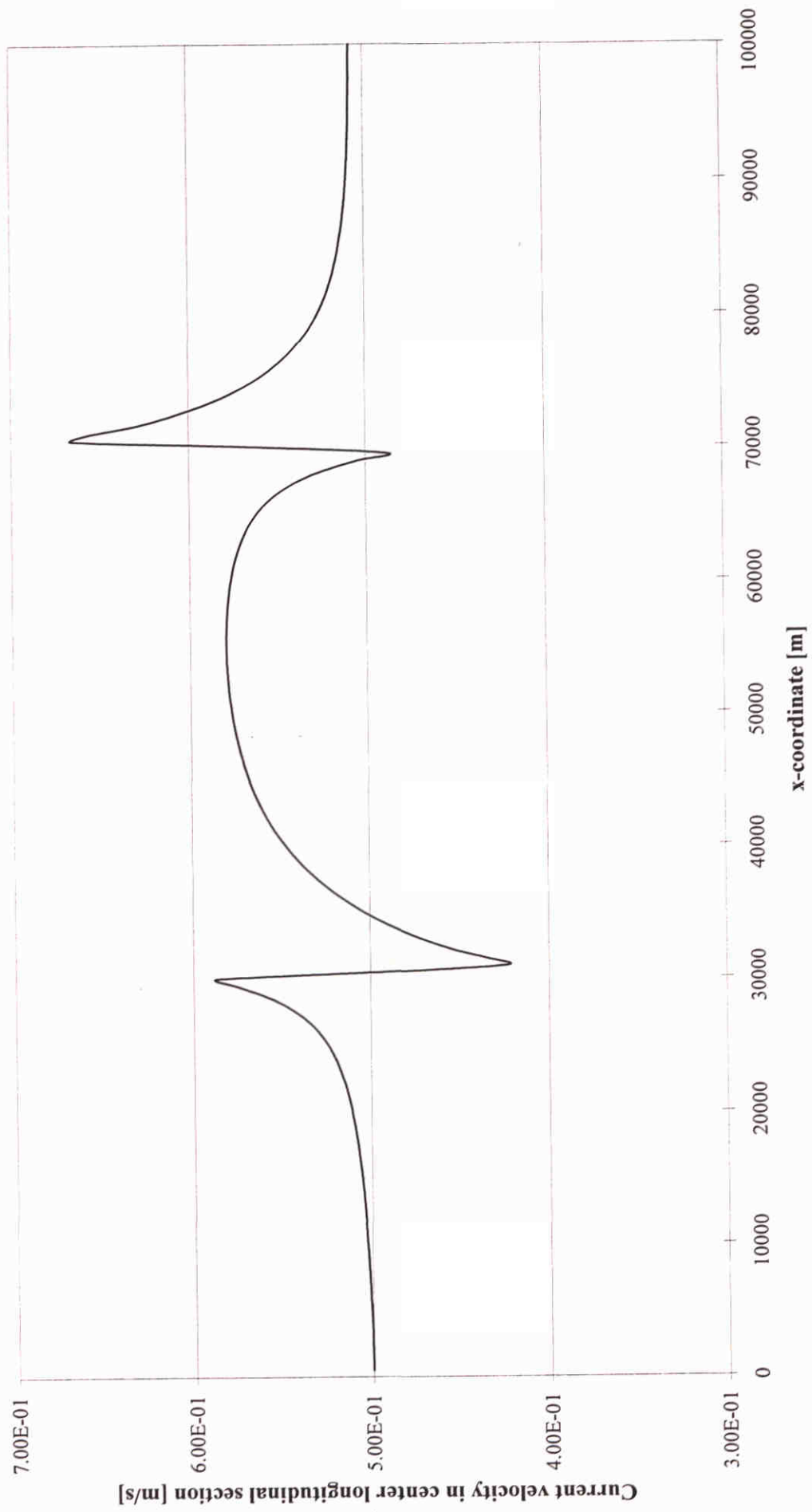
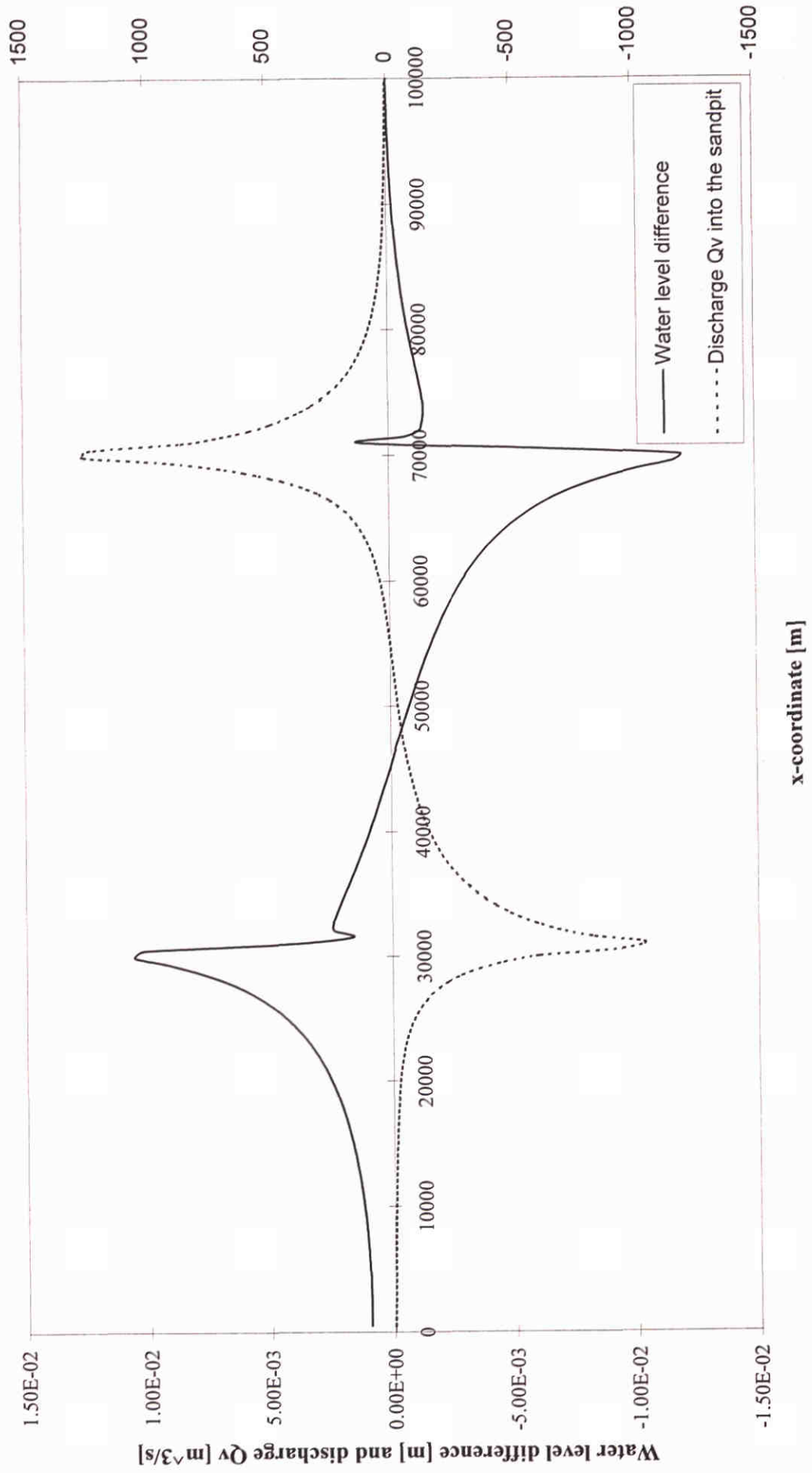
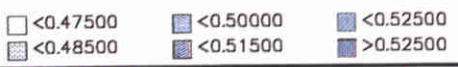
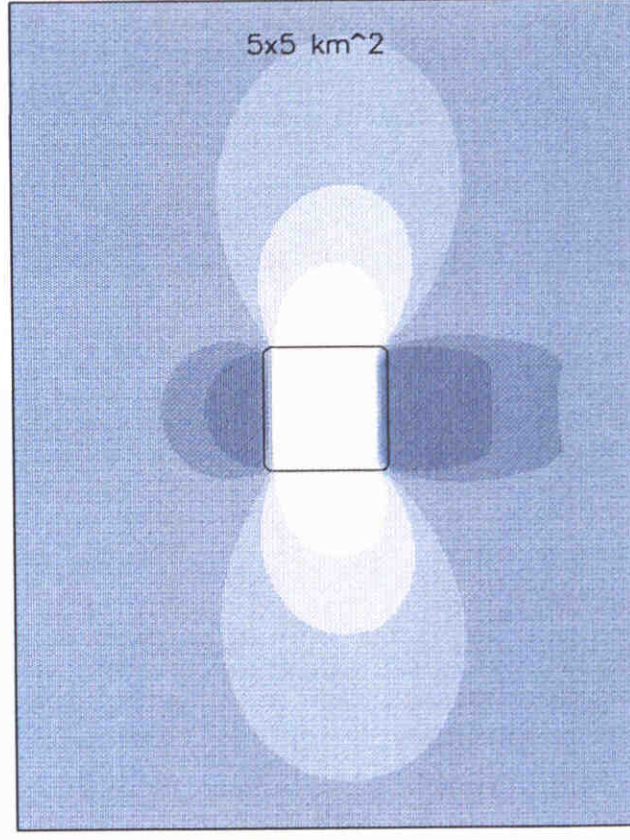
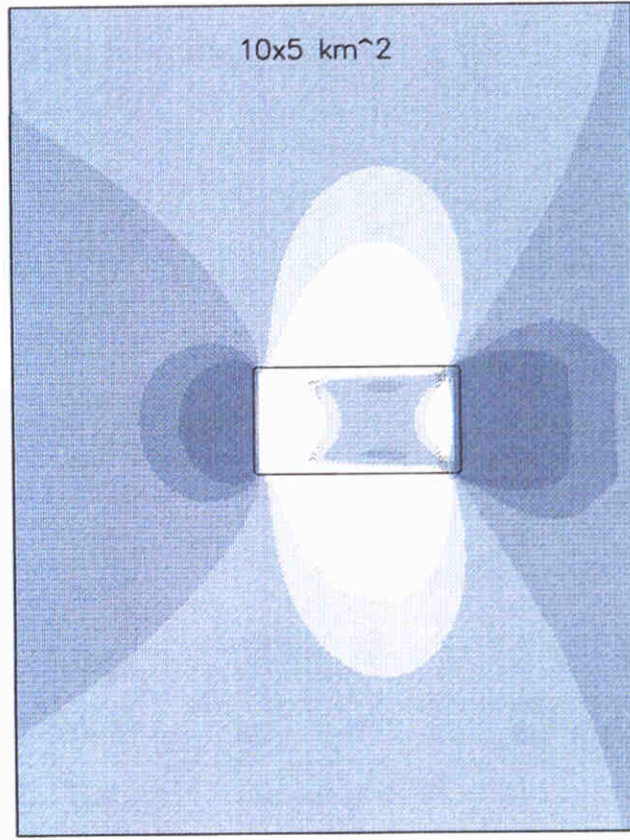
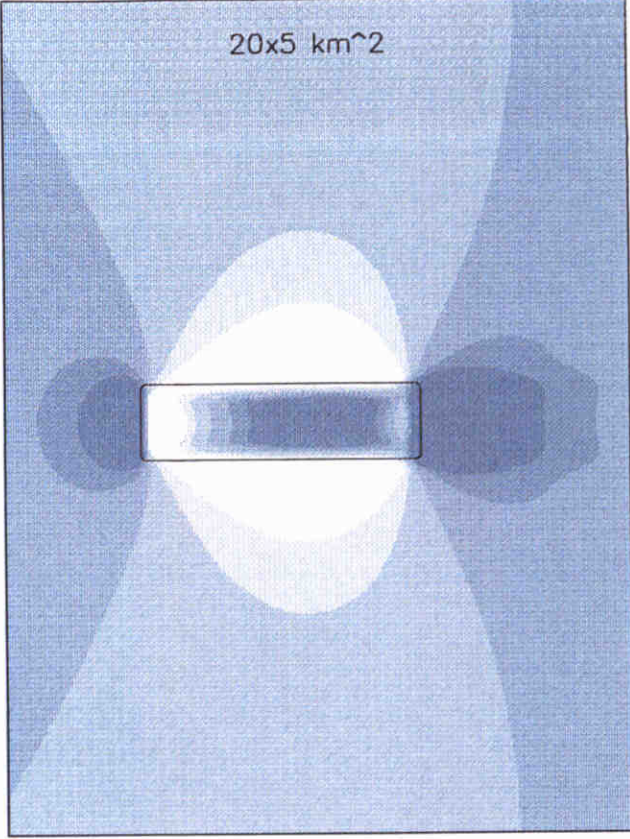
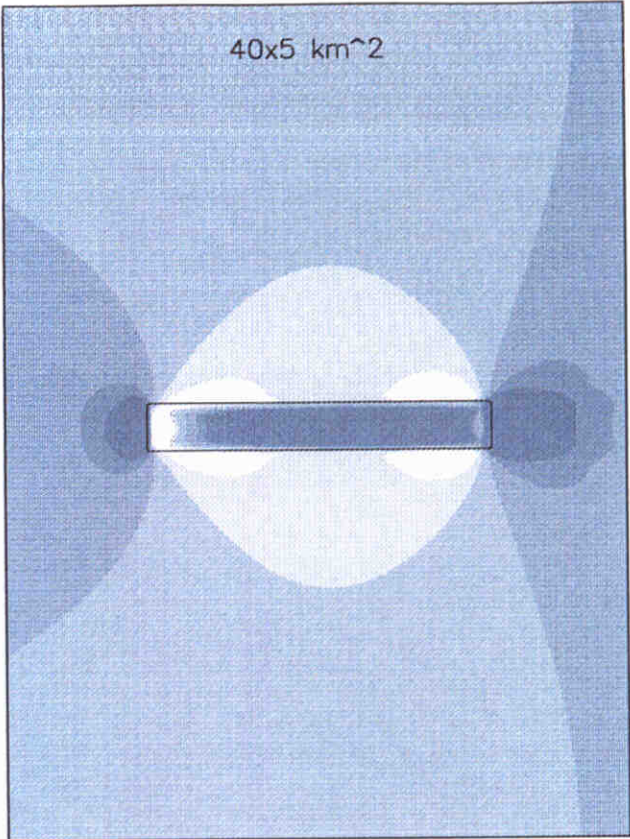


Figure 5.3: Relation between water level difference and discharge into the sandpit





Current magnitude [m/s]
 Area of influence around 30 m deep sandpits, varying in length
 Stationary boundary conditions

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

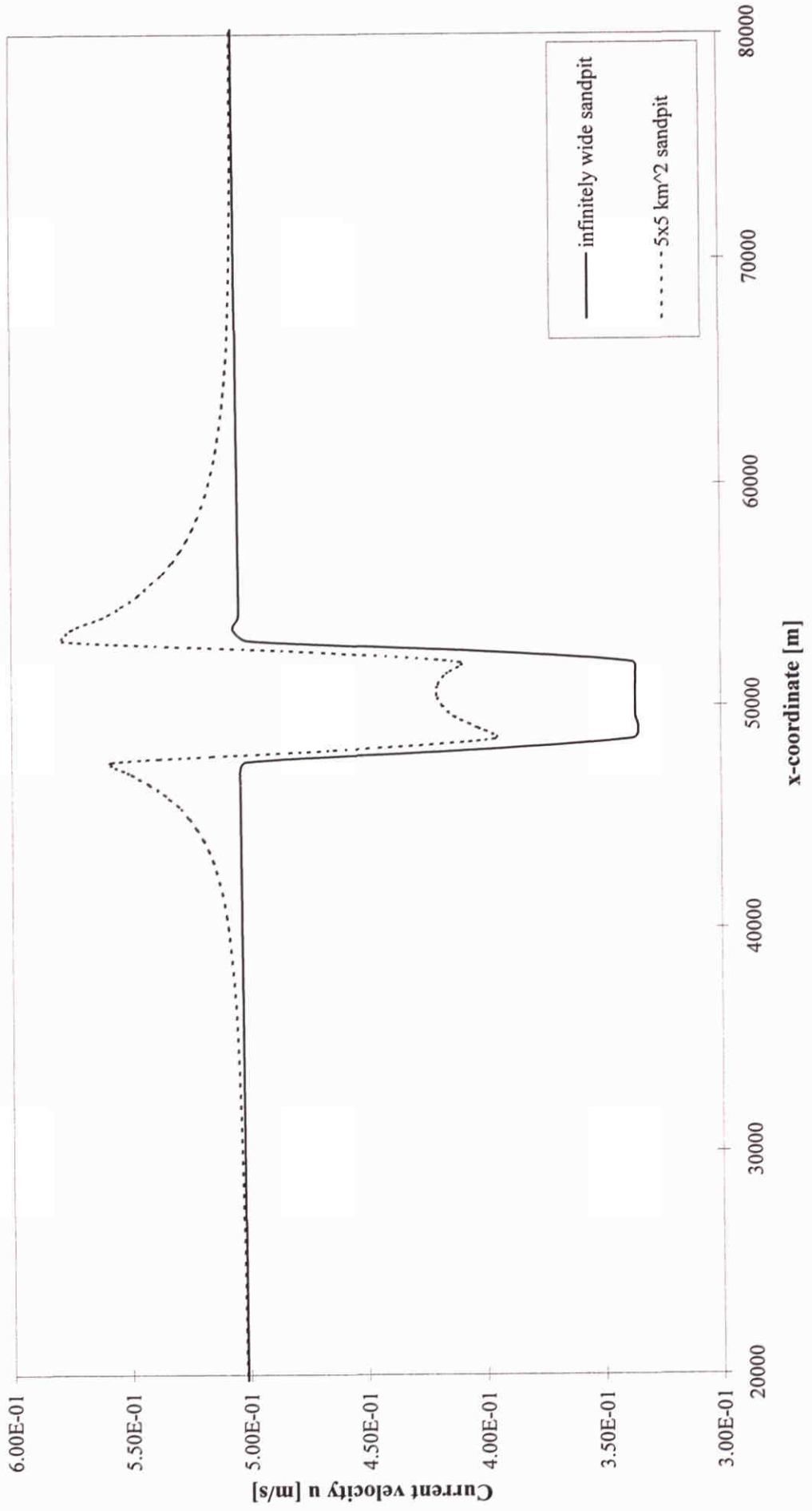
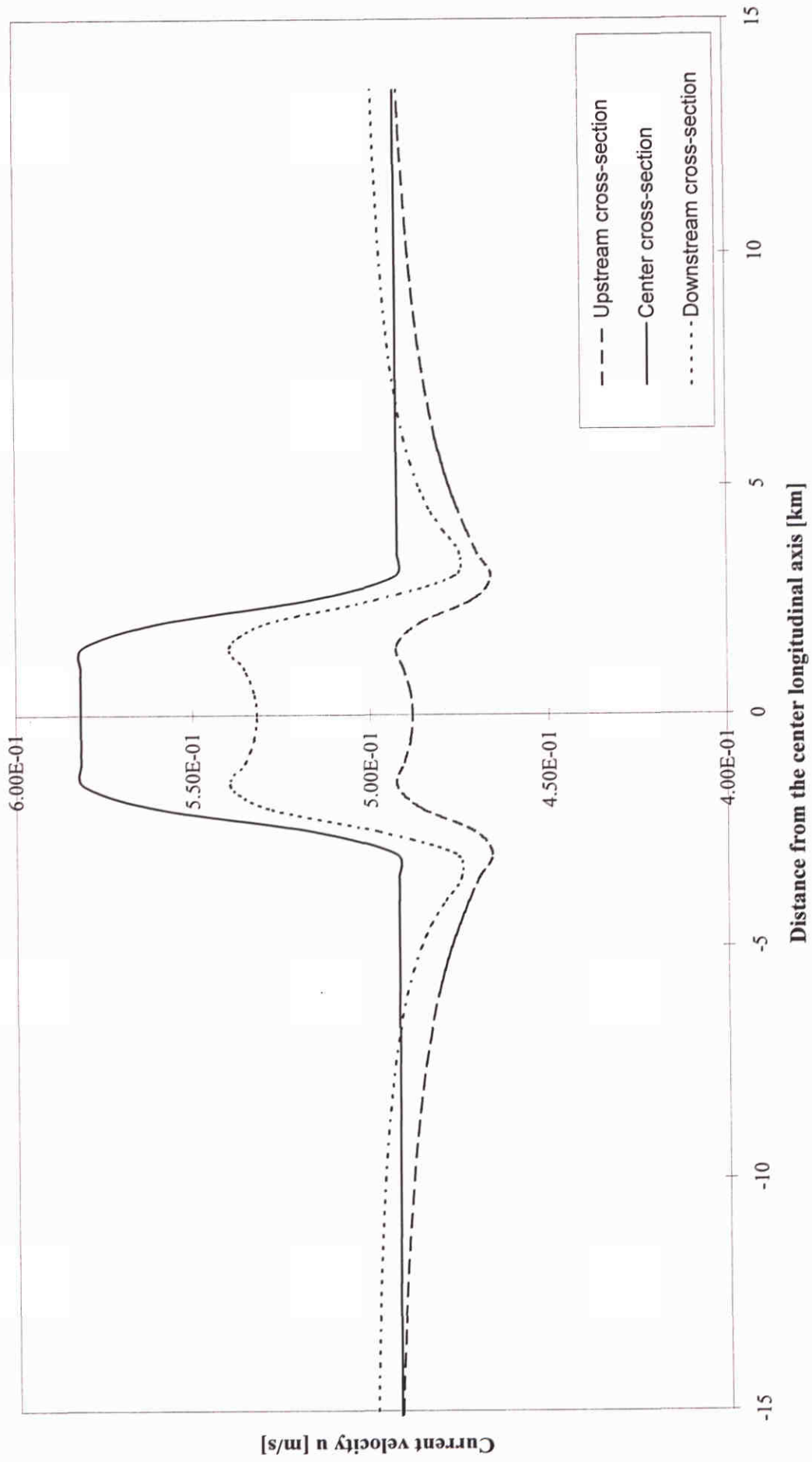
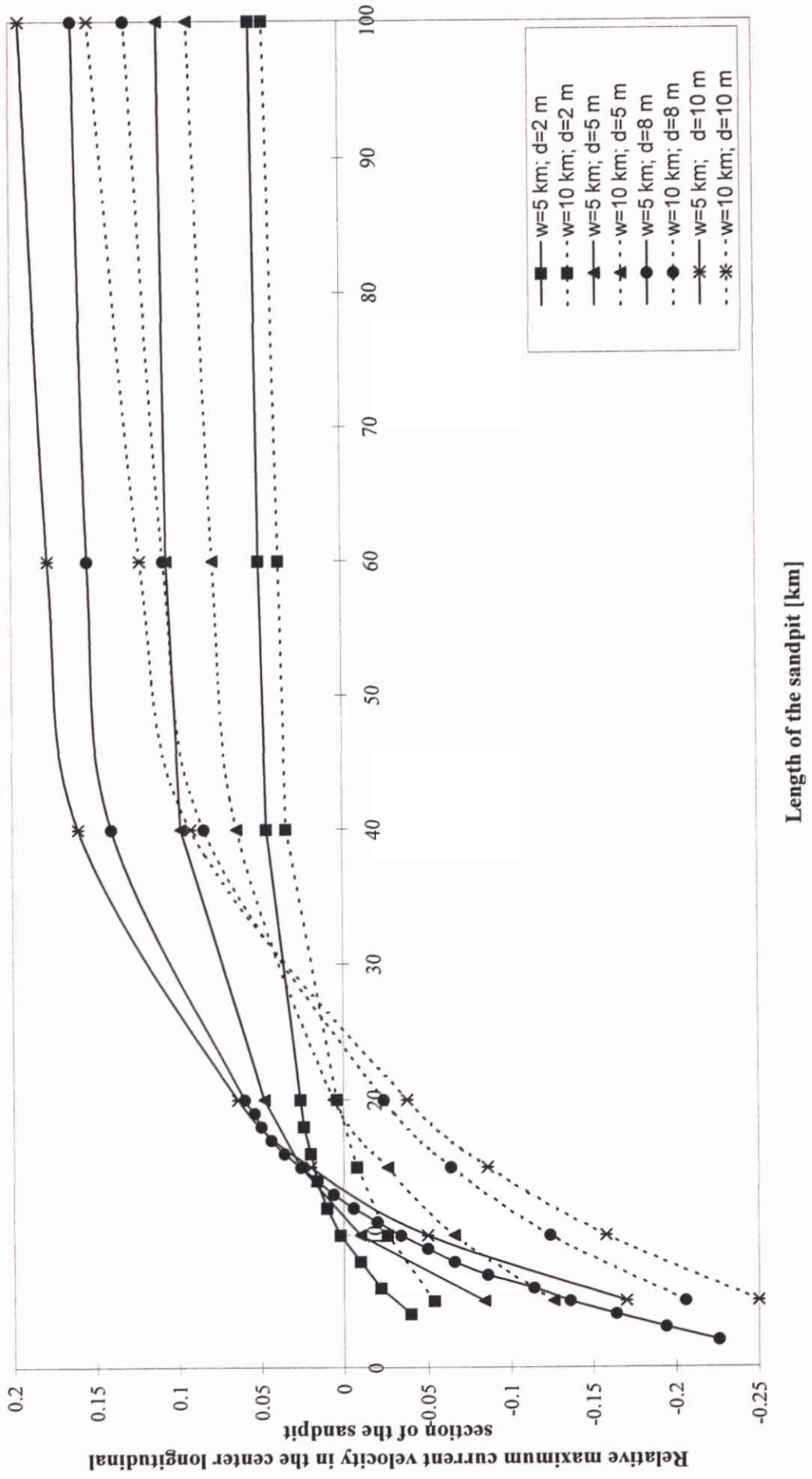


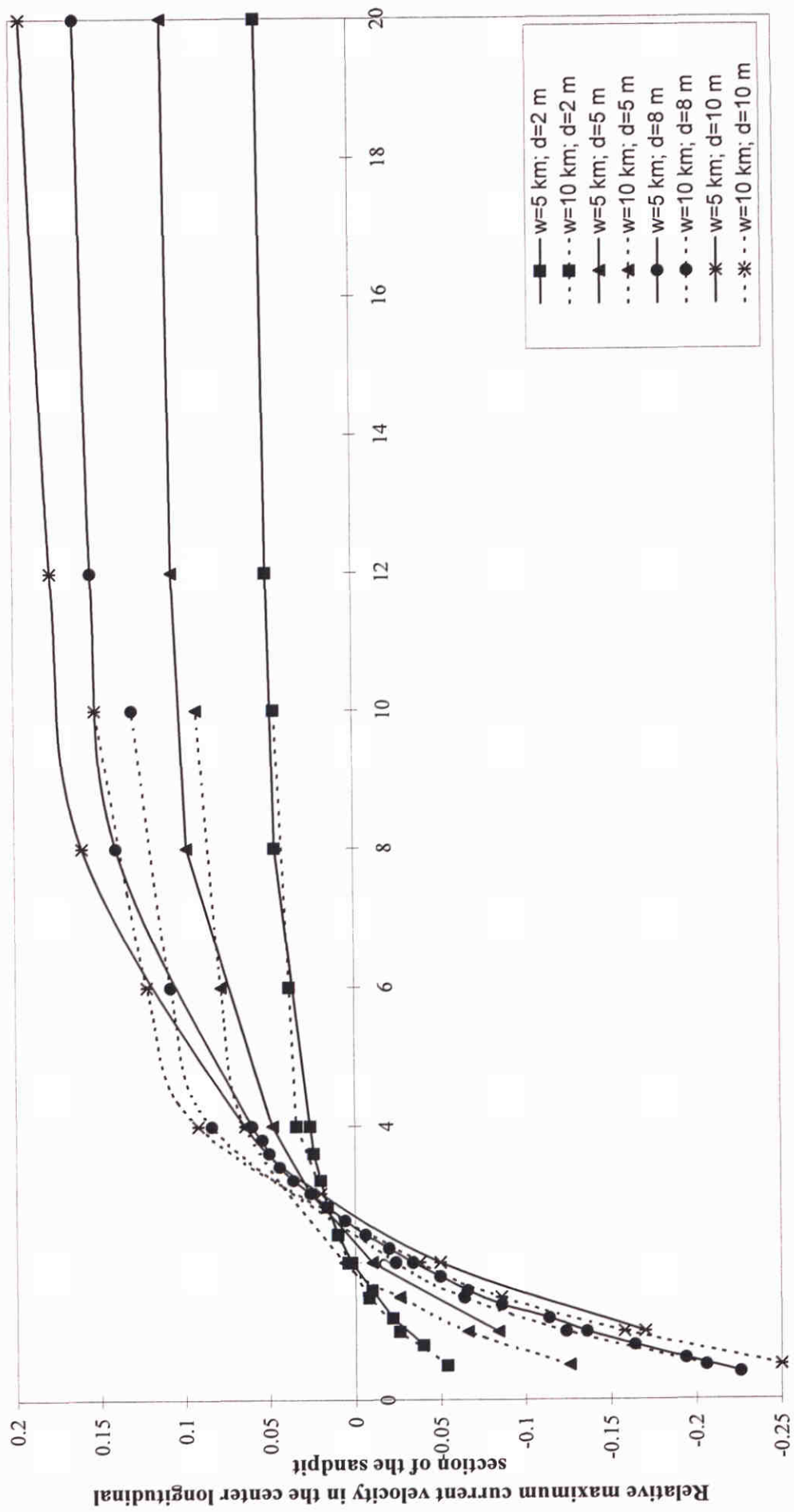
Figure 5.8: Distribution of u-velocity in three cross-sections



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

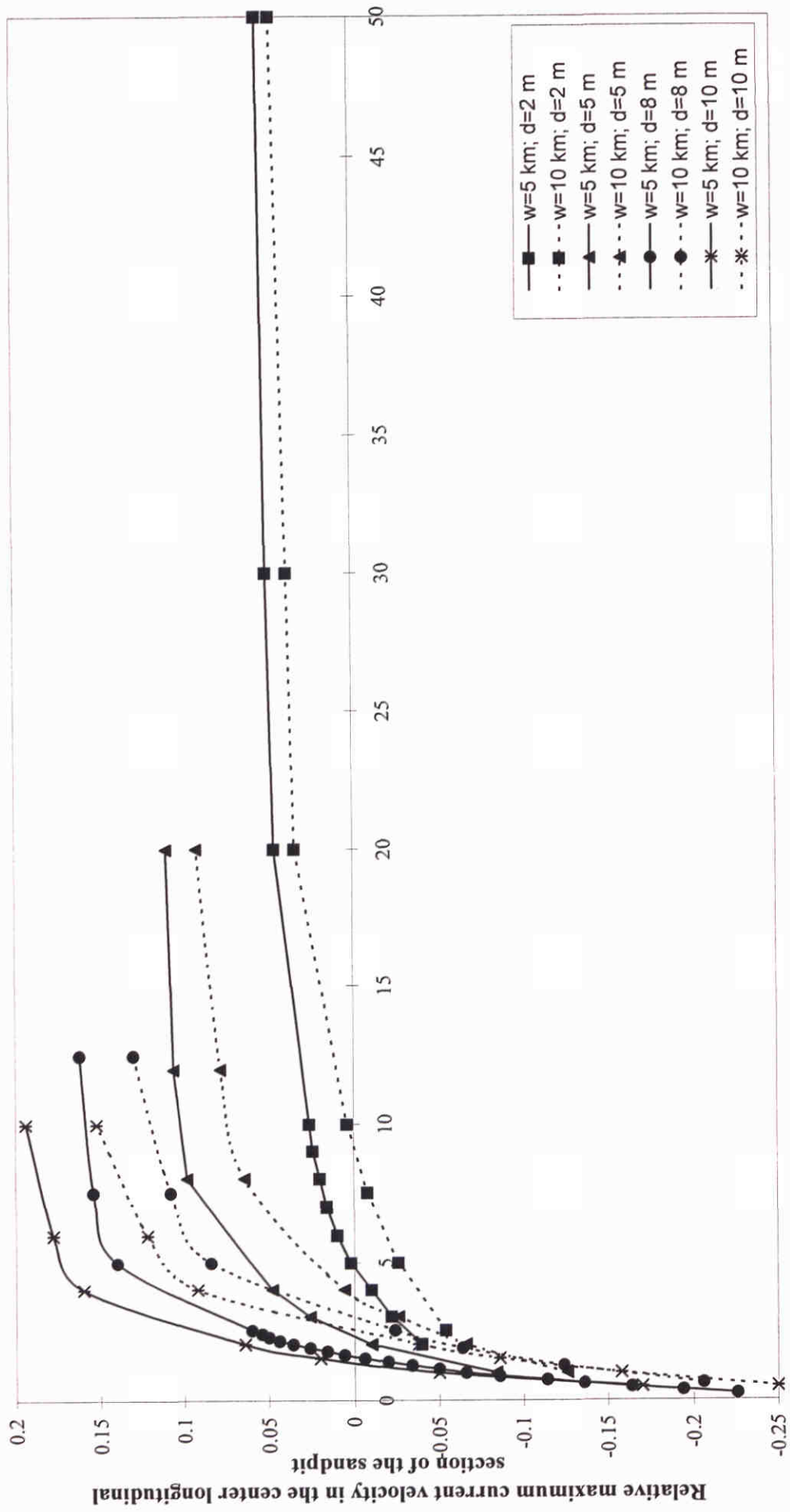


Figuur 5.10: Maximum current velocity vs. length-width ratio of the sandpit

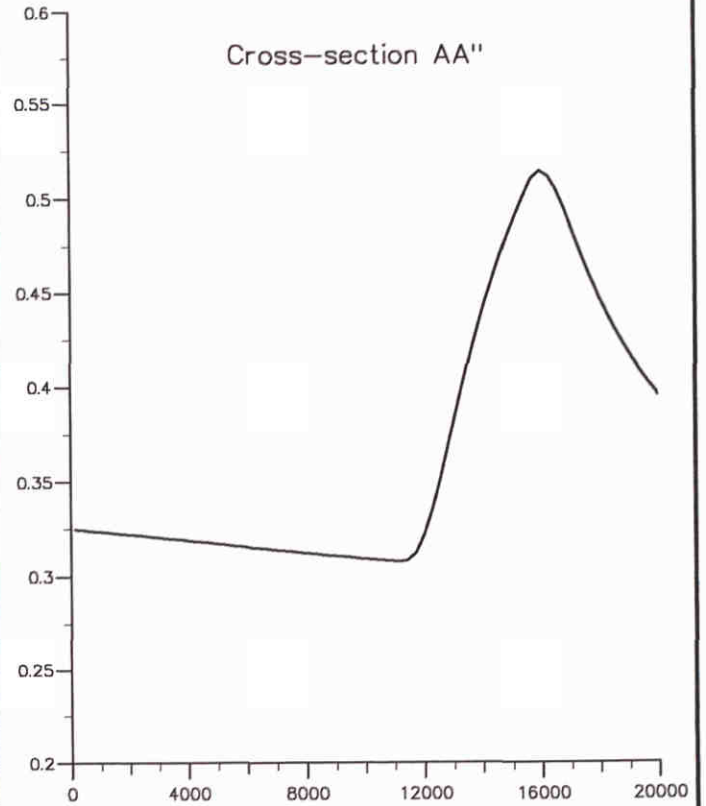
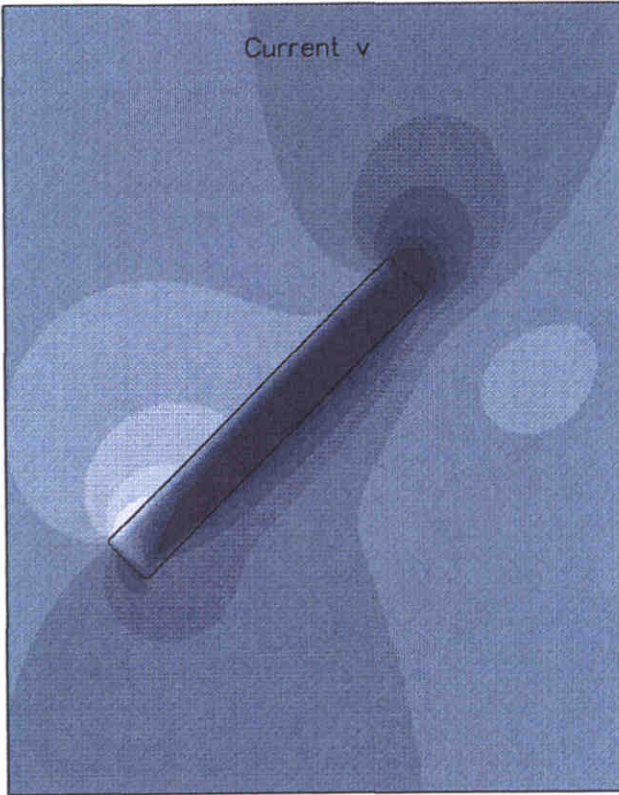
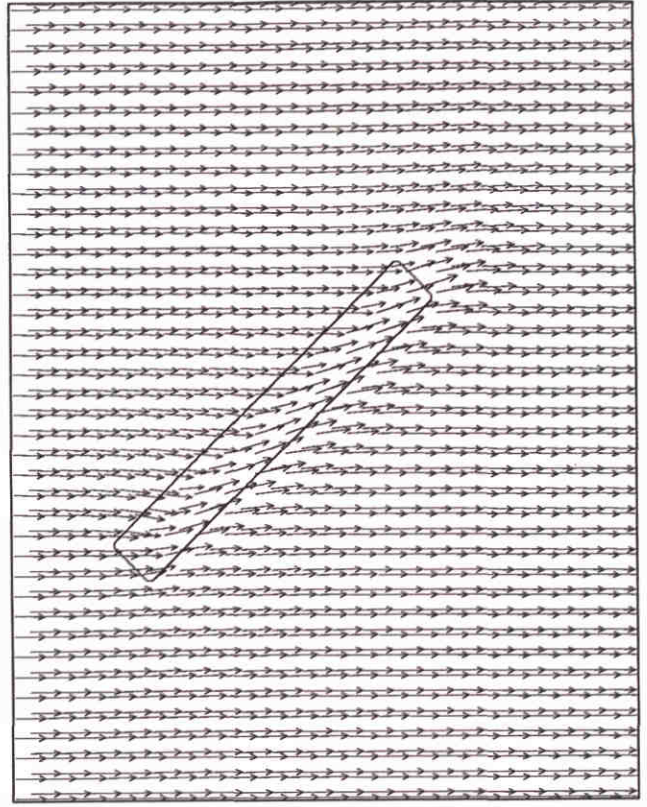
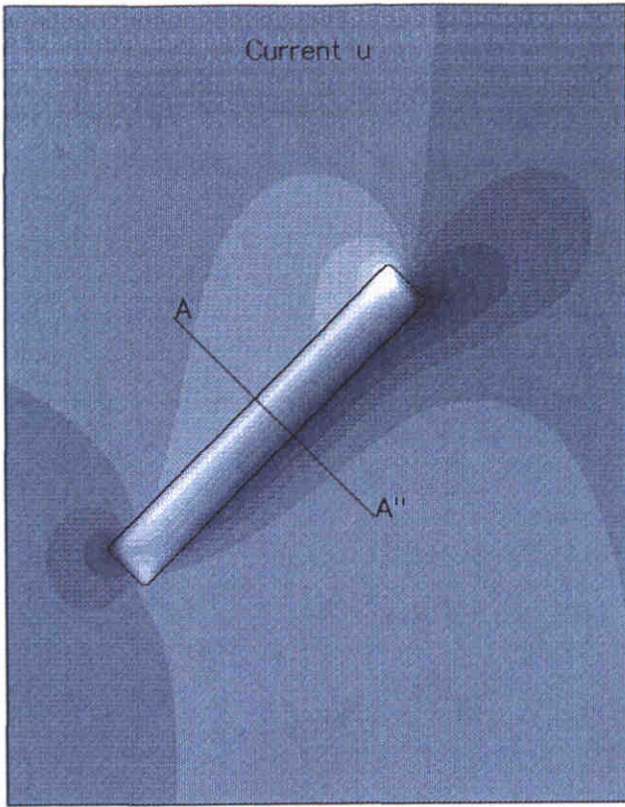


Length-width ratio of the sandpit

Figuur 5.1.1: Maximum current velocity vs. length-depth ratio of the sandpit



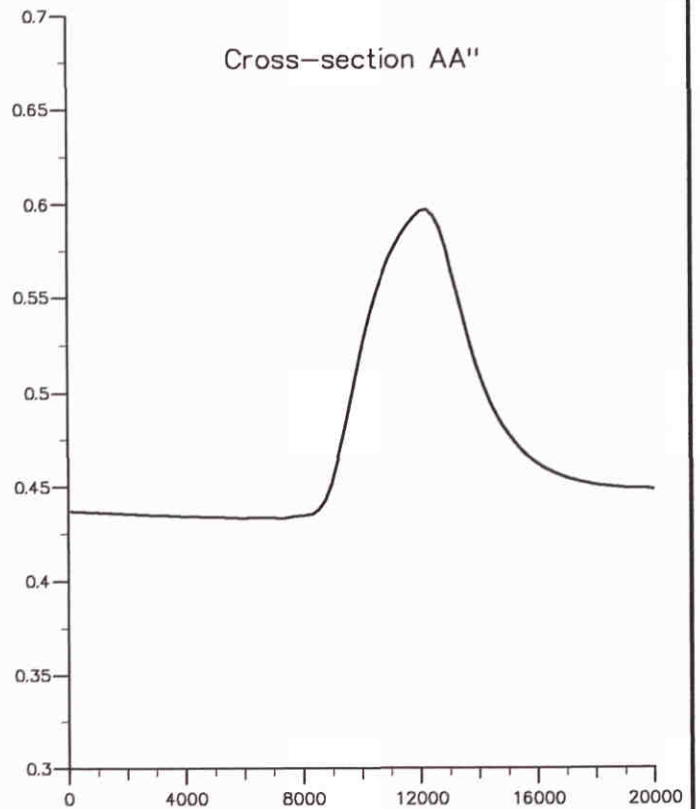
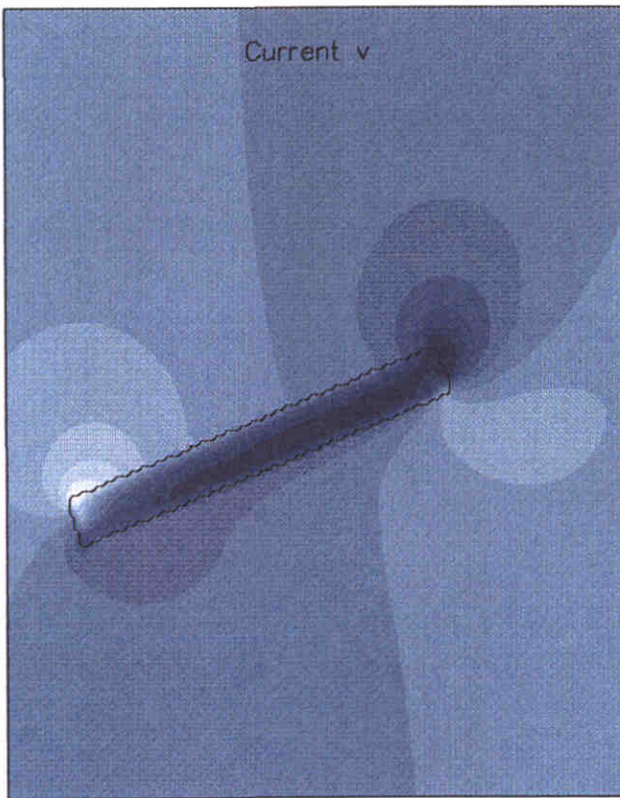
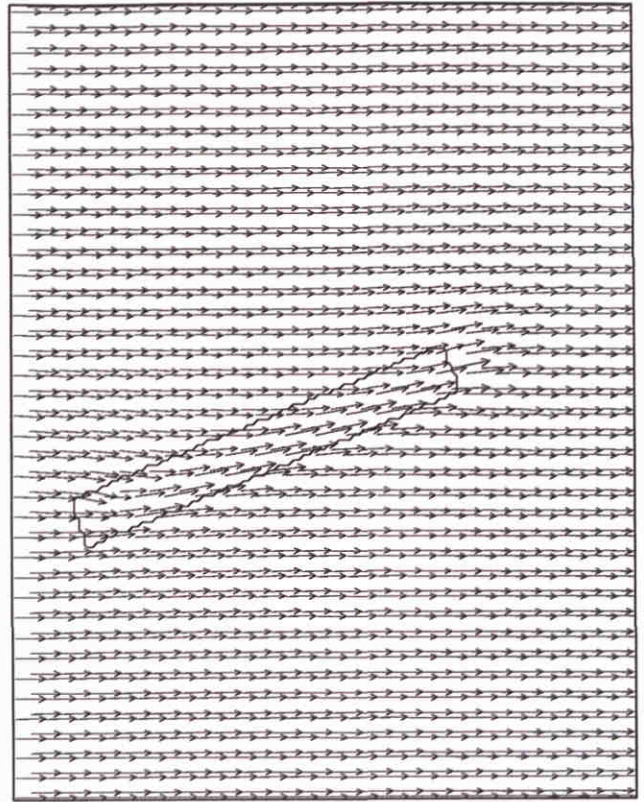
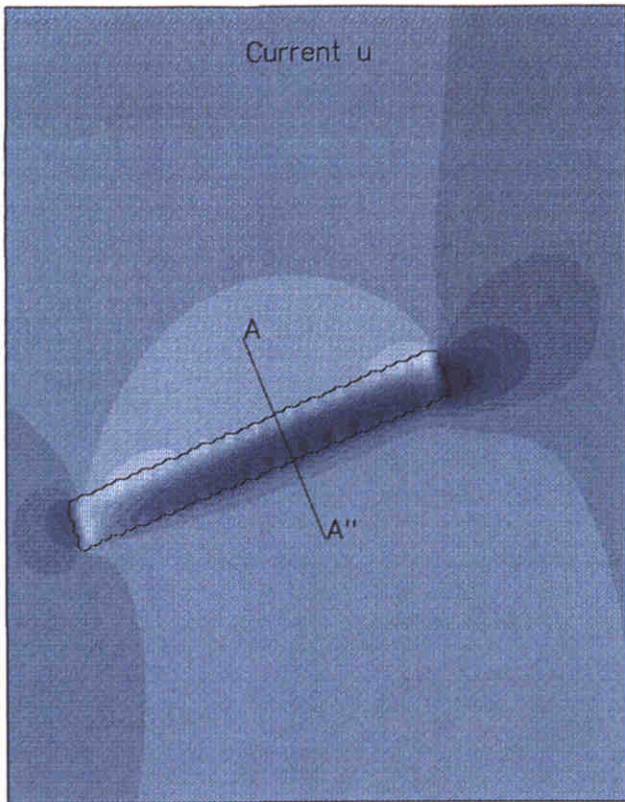
Length-depth ratio of the sandpit [x1000]



Current velocities u and v [m/s]

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

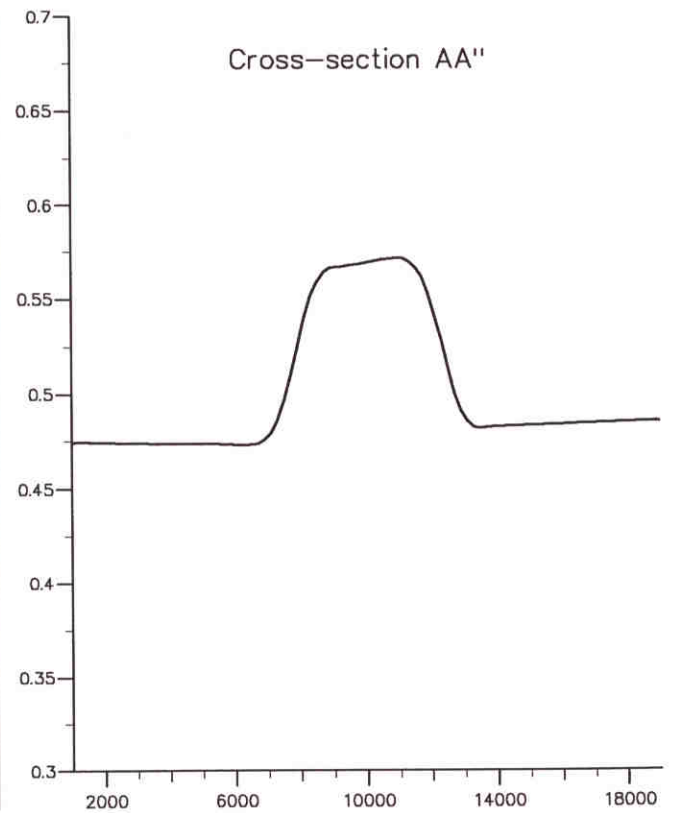
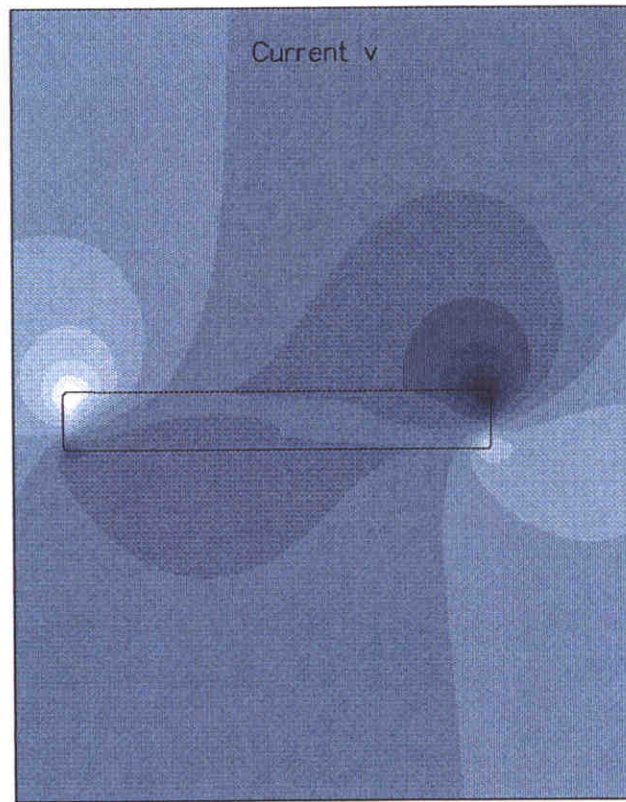
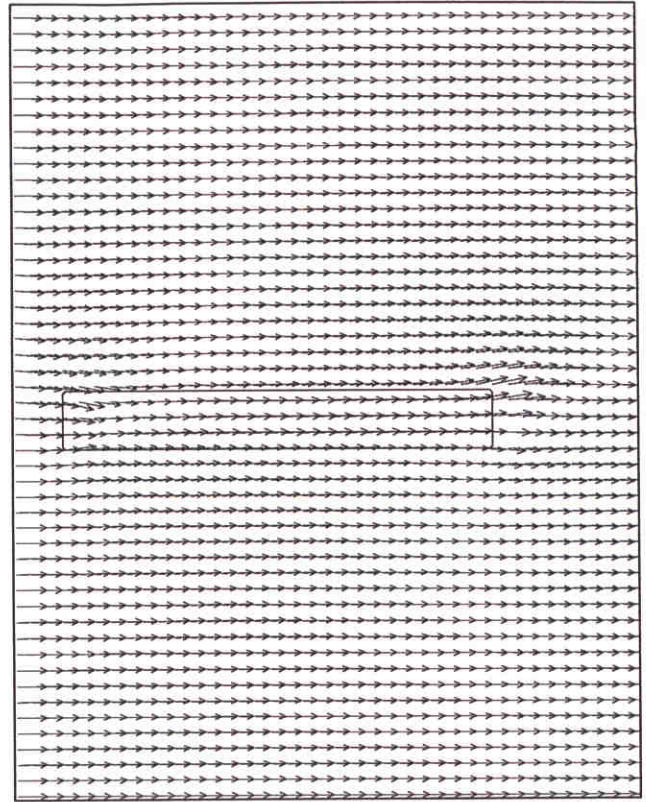
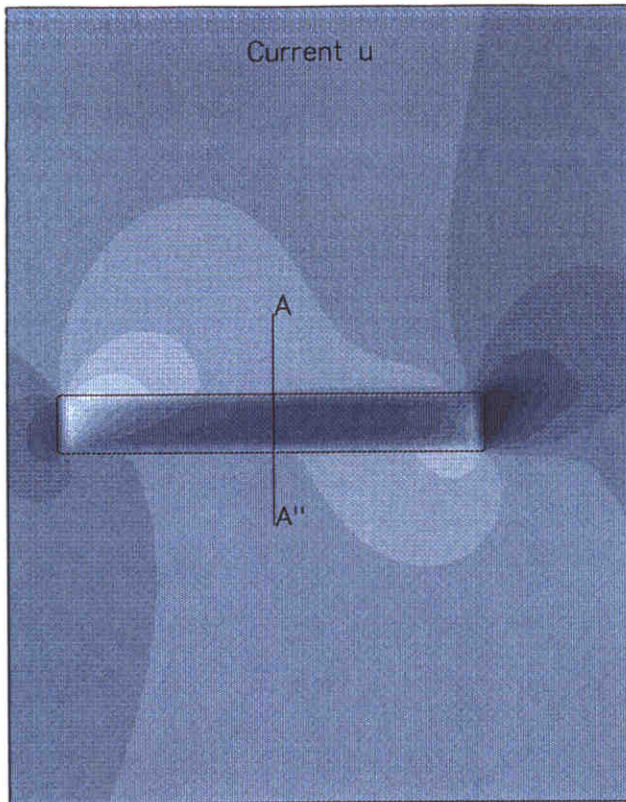
Stationary boundary conditions including Coriolis



Current velocities u and v [m/s]

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

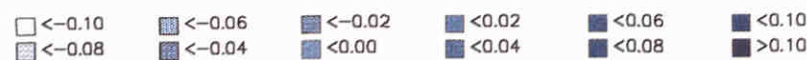
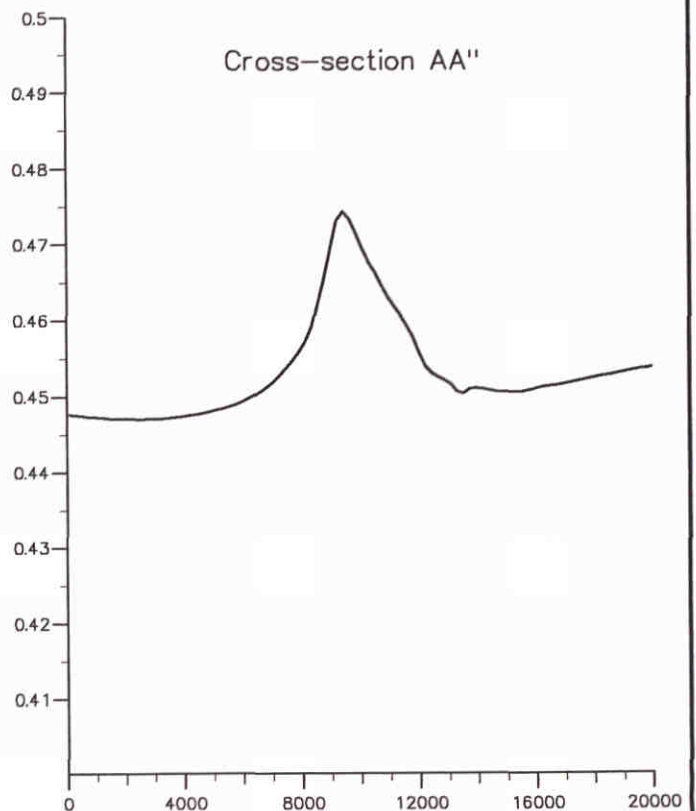
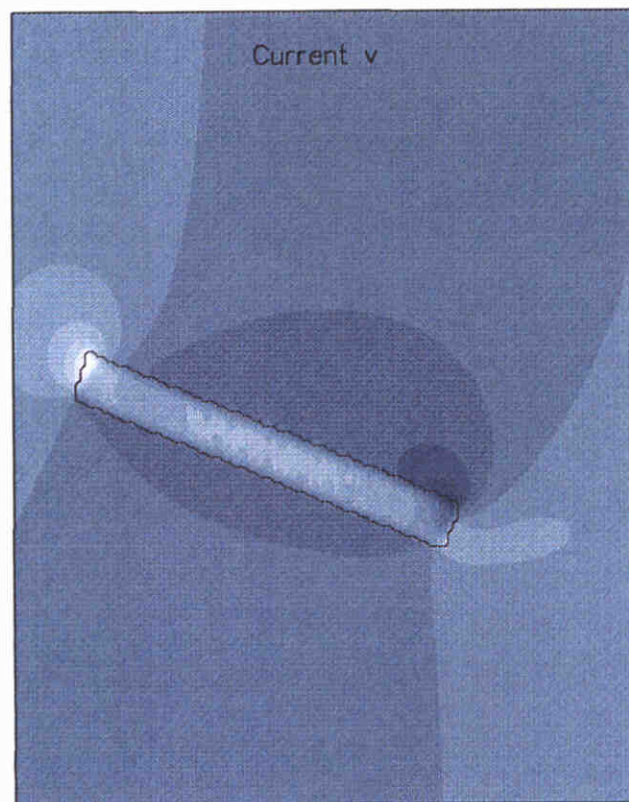
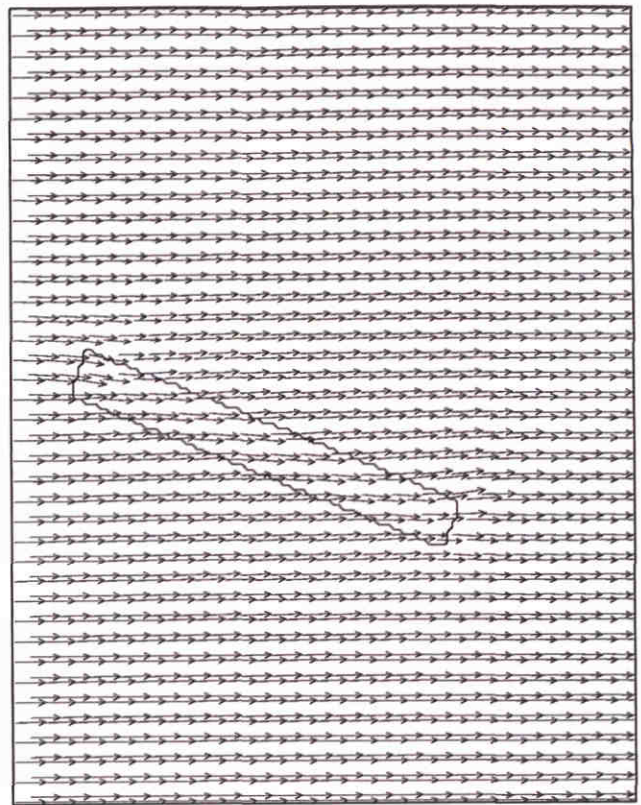
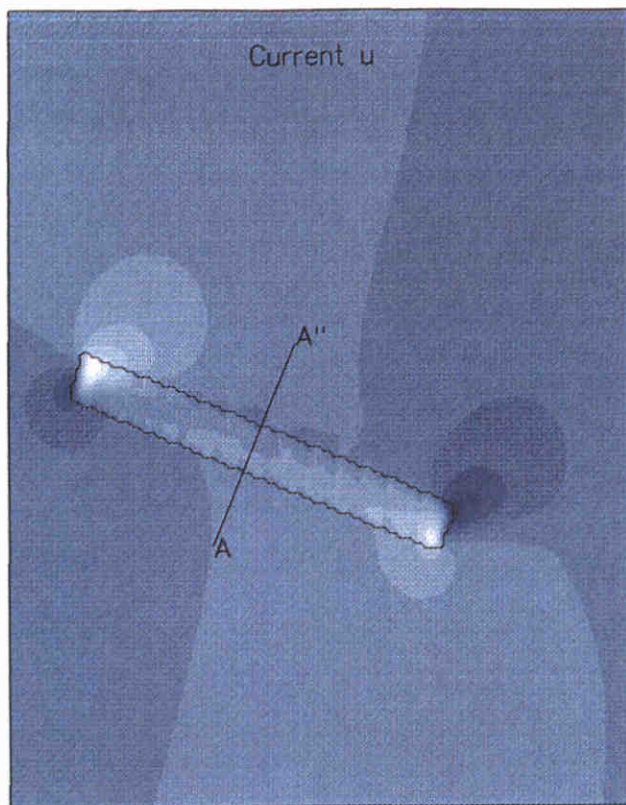
Stationary boundary conditions including Coriolis



Current velocities u and v [m/s]

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

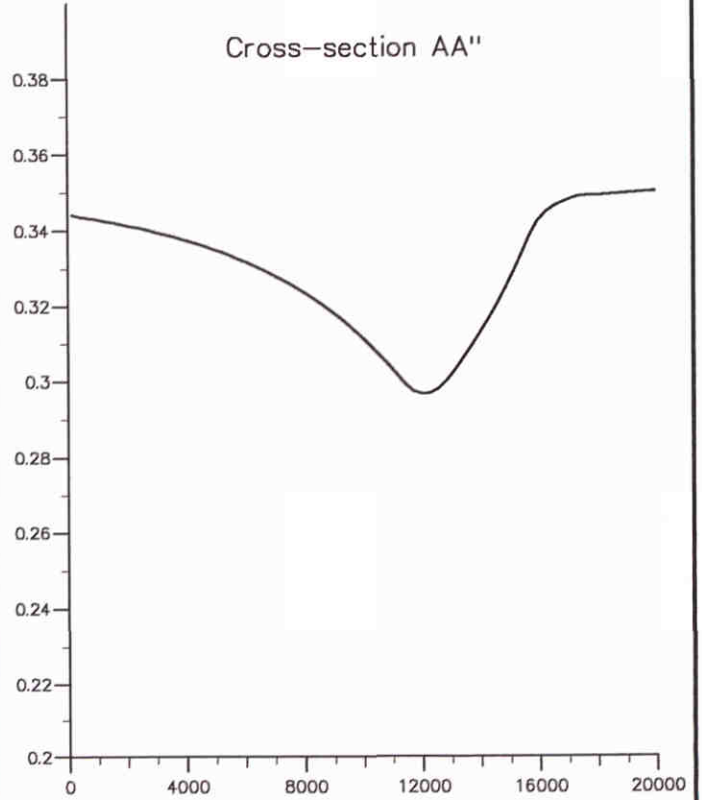
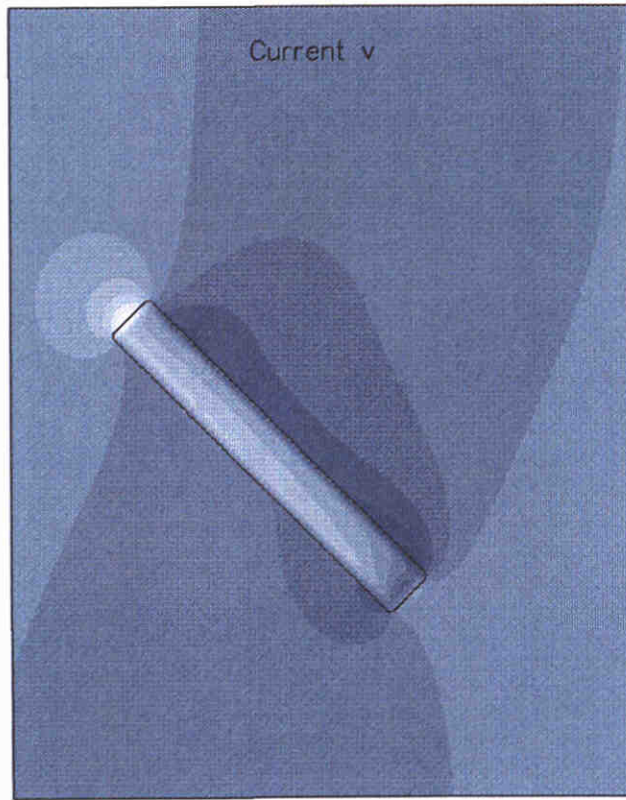
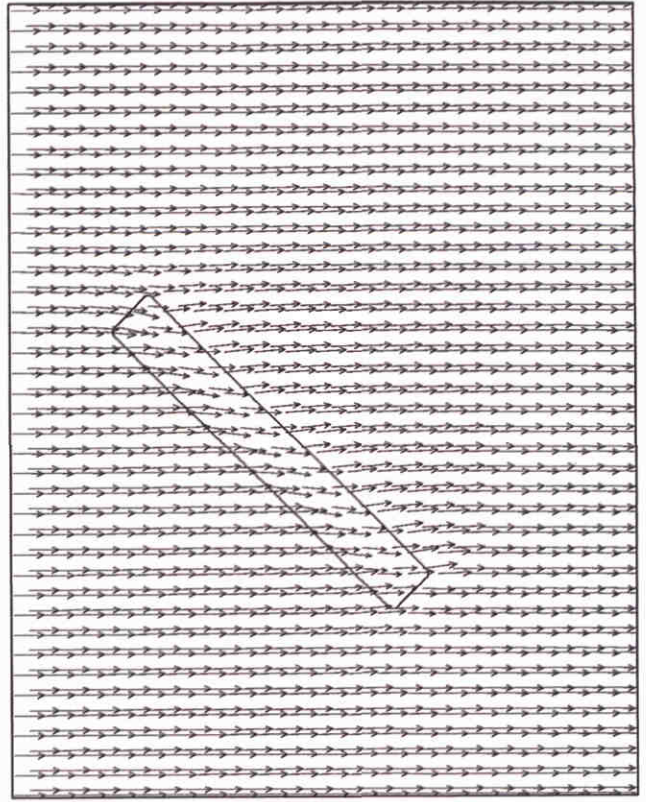
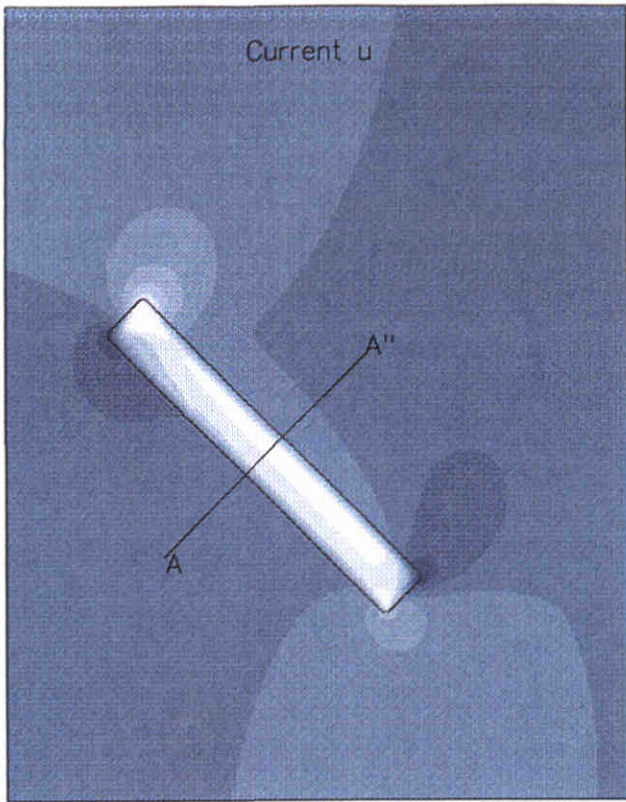
Stationary boundary conditions including Coriolis



Current velocities u and v [m/s]

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

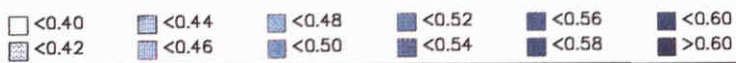
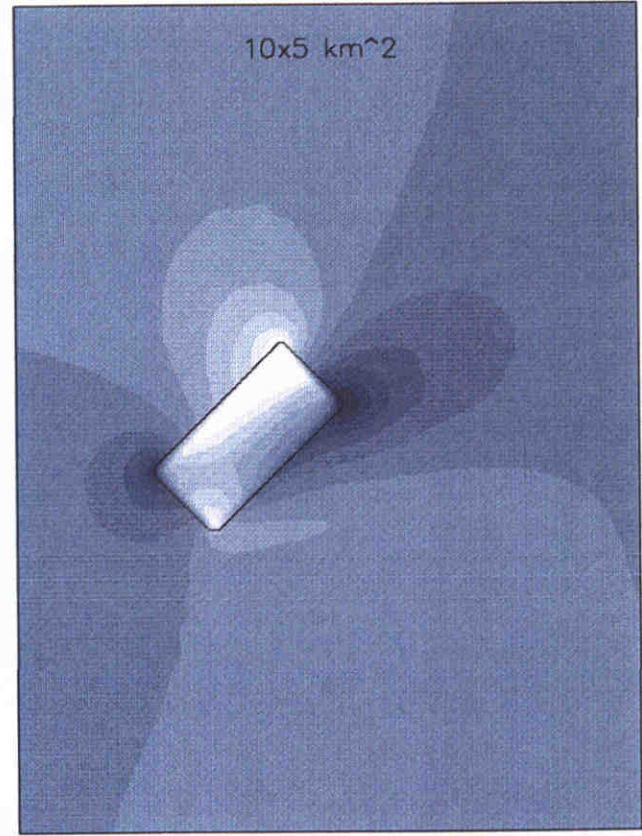
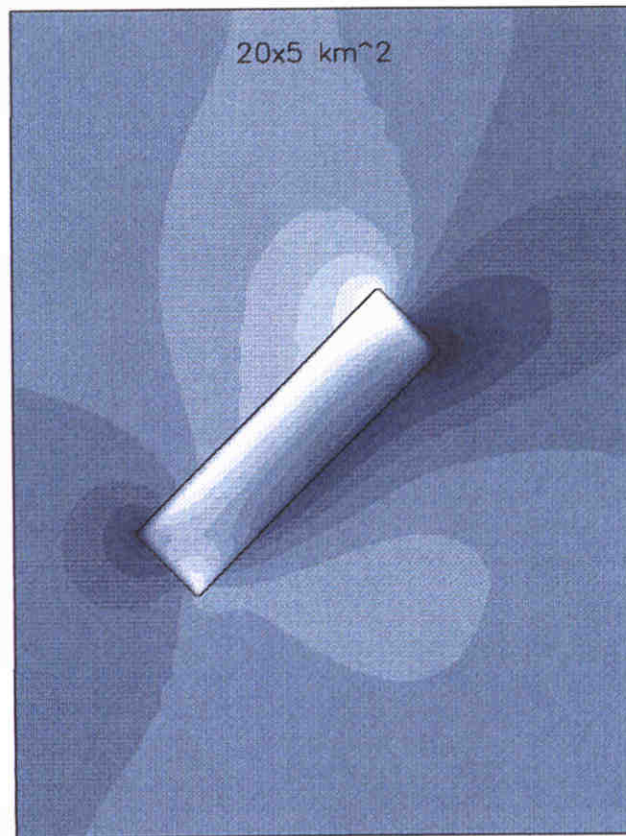
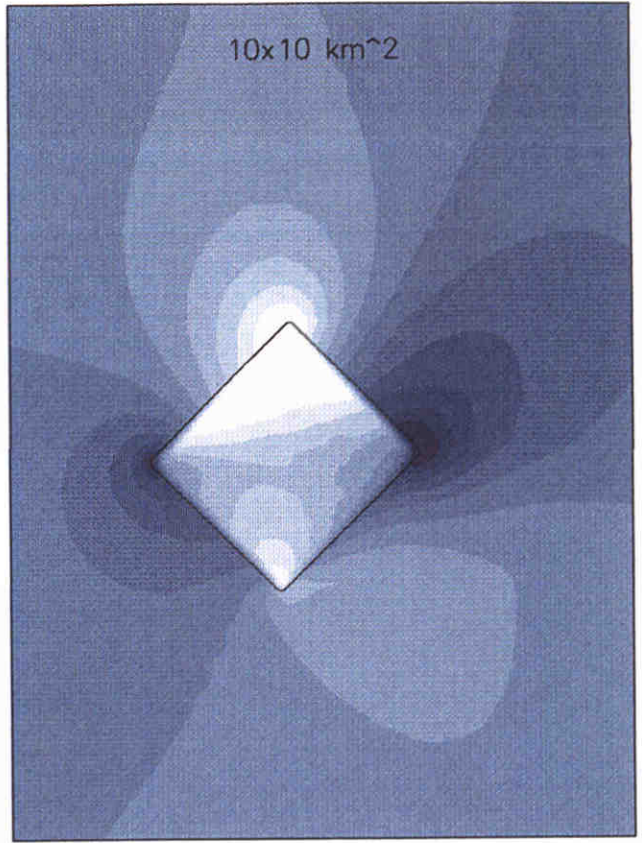
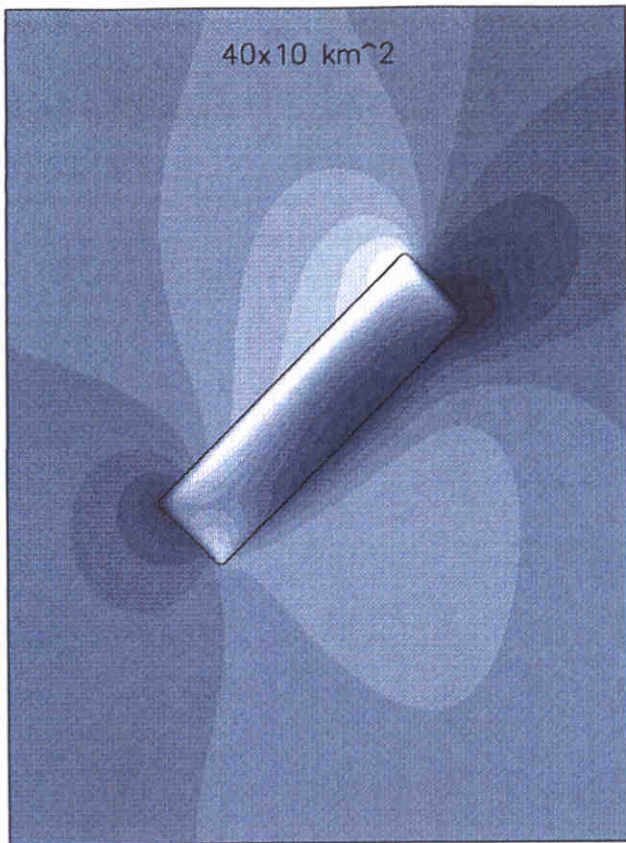
Stationary boundary conditions including Coriolis



Current velocities u and v [m/s]

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

Stationary boundary conditions including Coriolis

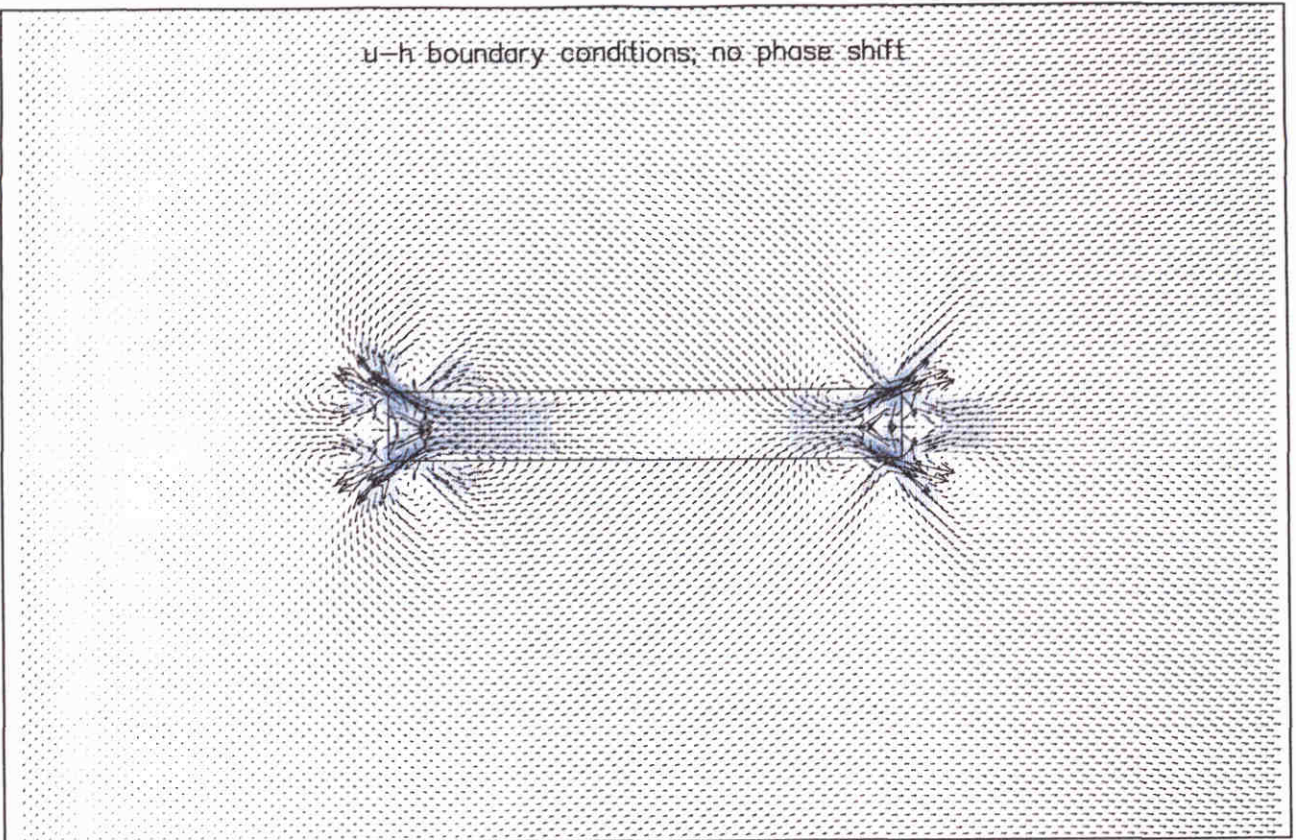


Current magnitude [m/s]

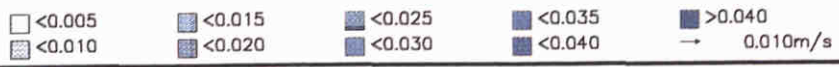
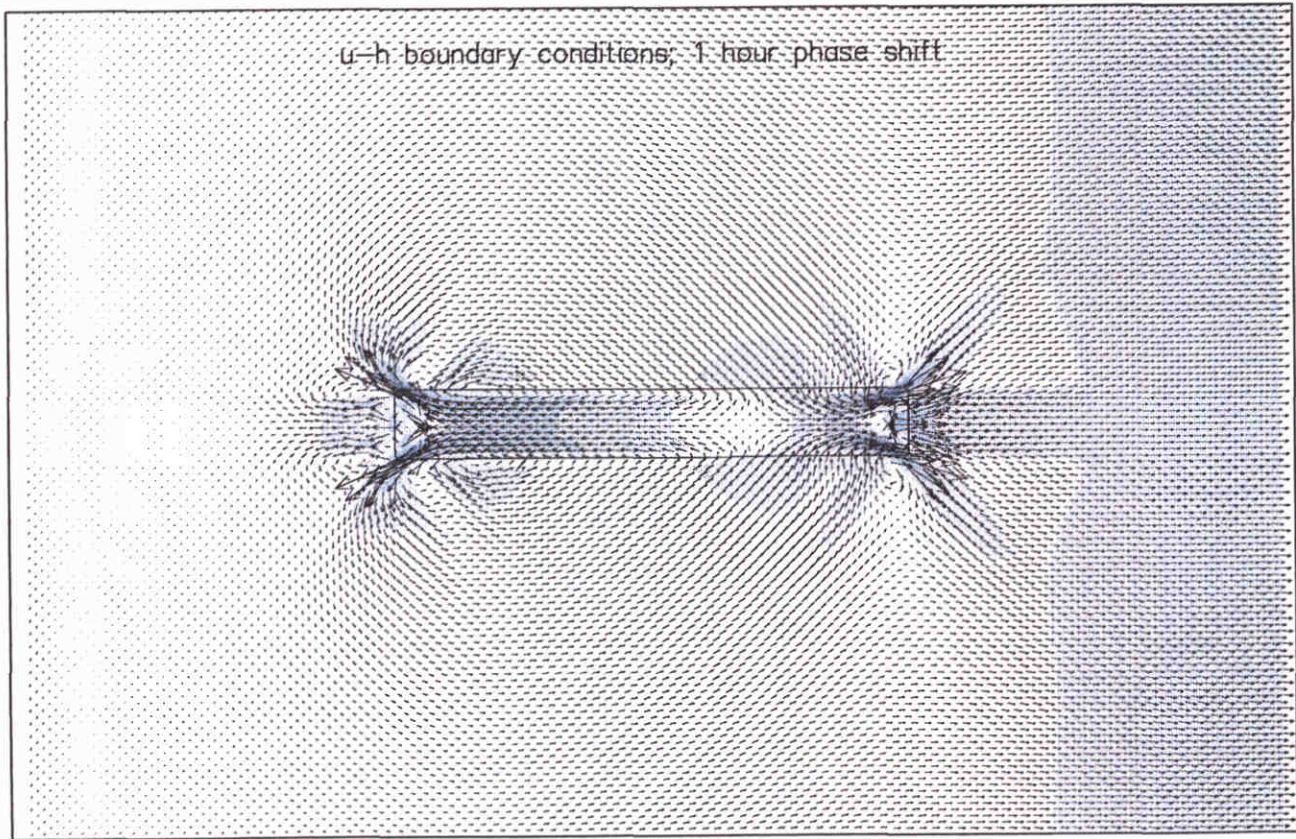
Influence of the length and the width on the current pattern

Stationary boundary conditions including Coriolis

u-h boundary conditions; no phase shift



u-h boundary conditions; 1-hour phase shift

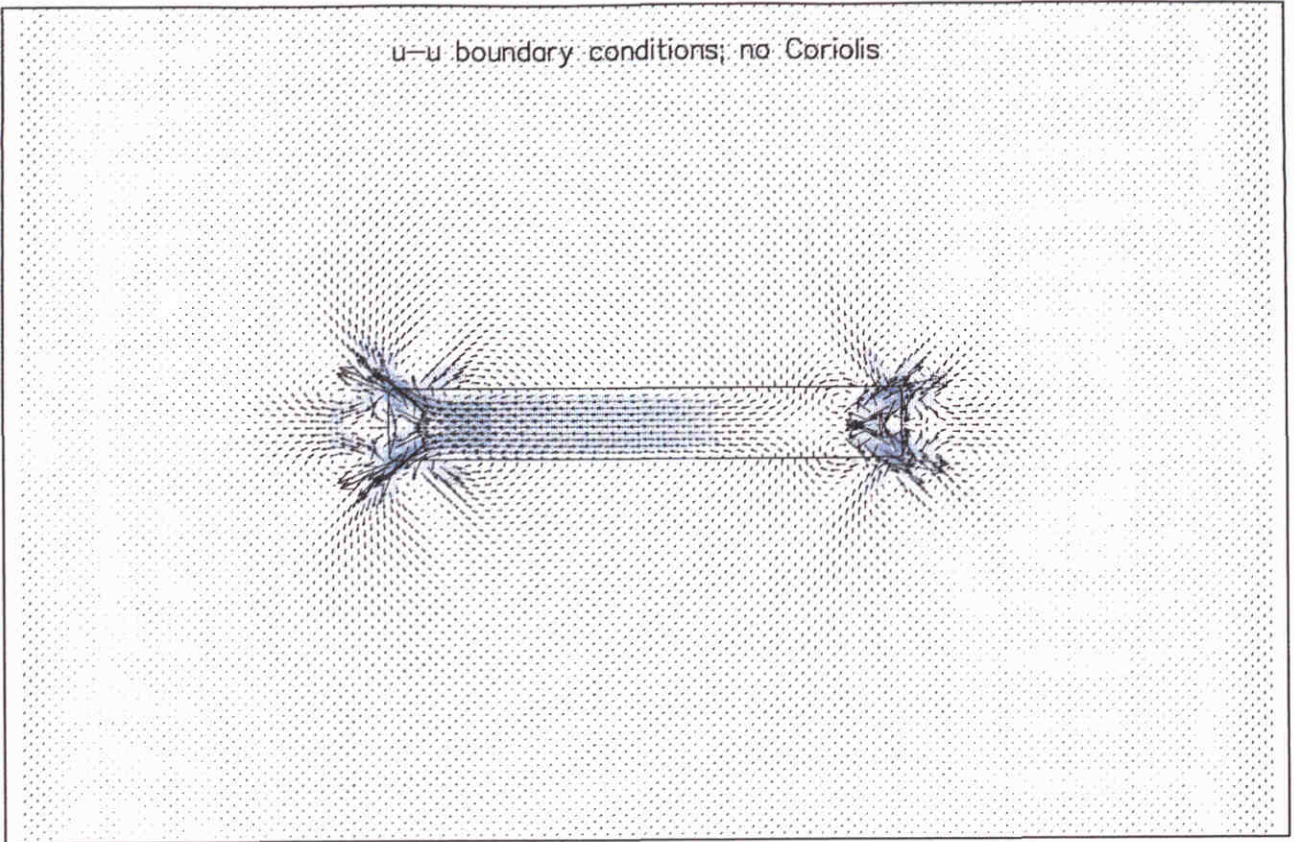


Tide-averaged current velocities [m/s]

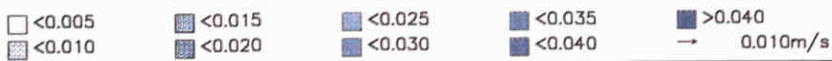
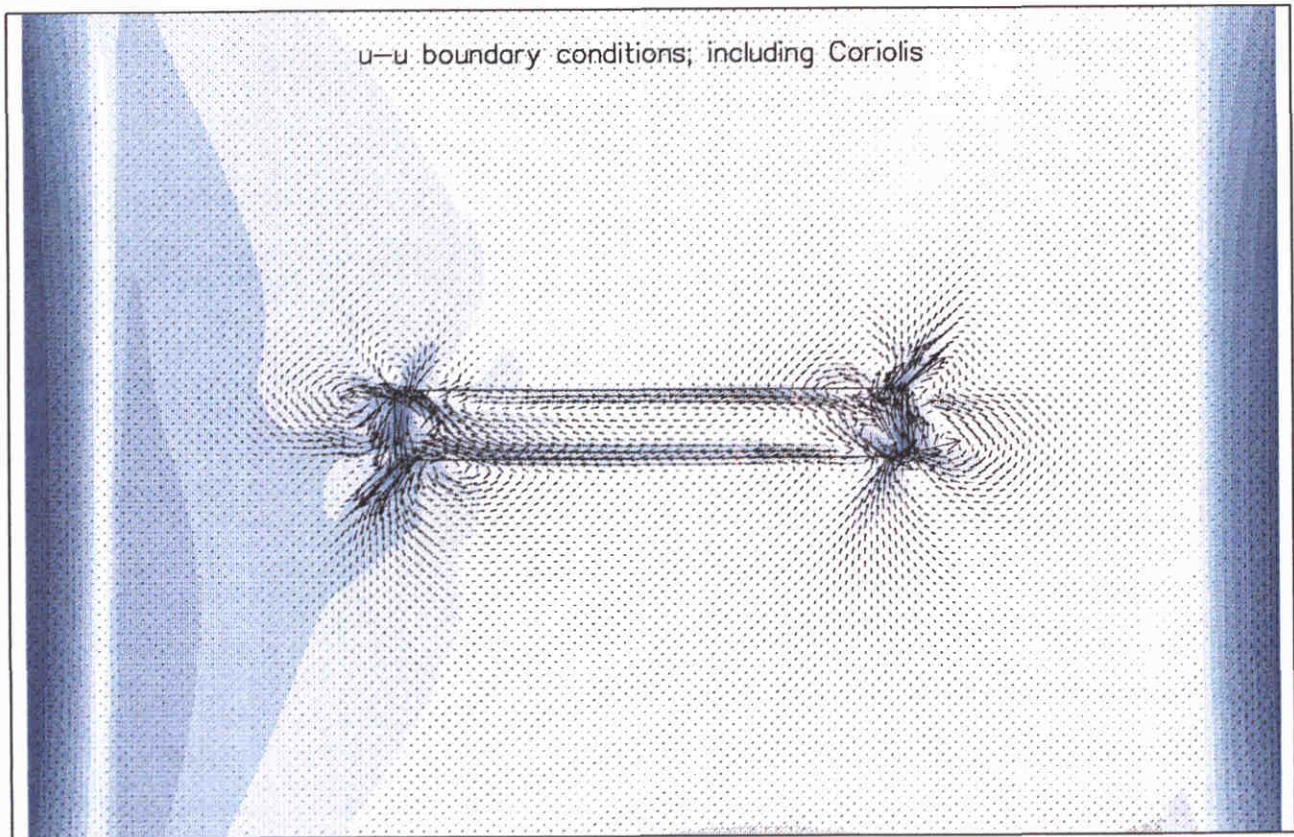
Influence of the boundary conditions on the tide-averaged current pattern

Tidal boundary conditions

u-u boundary conditions; no Coriolis



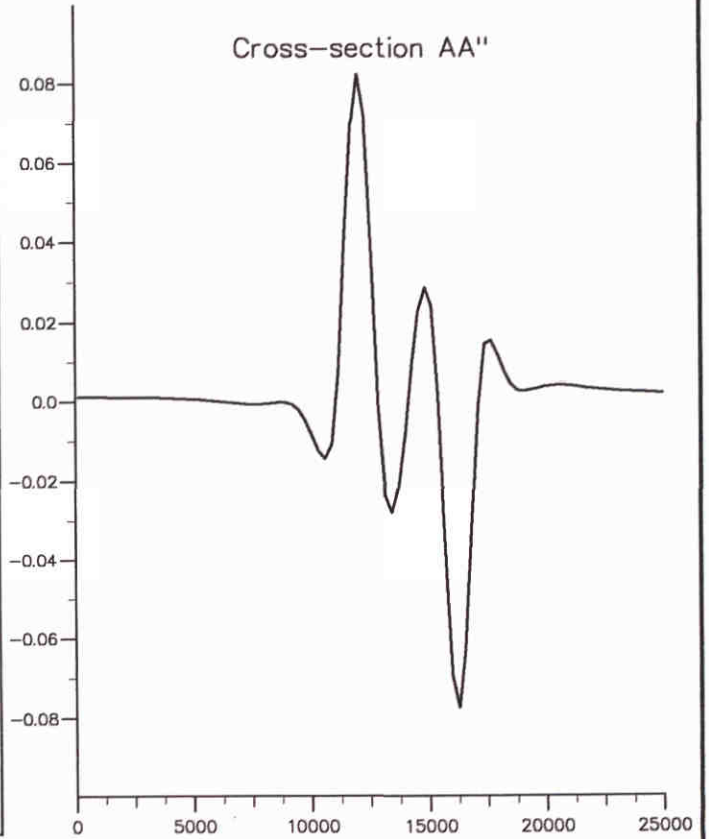
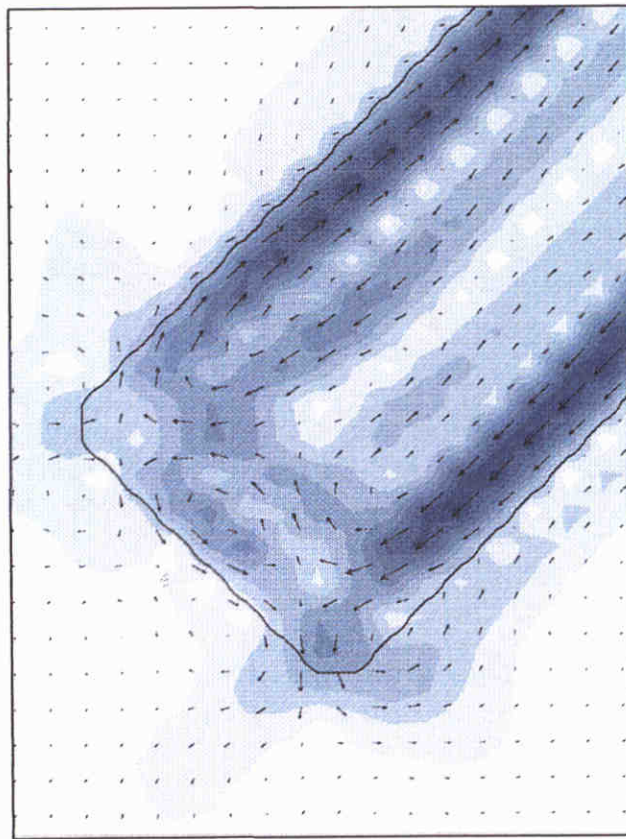
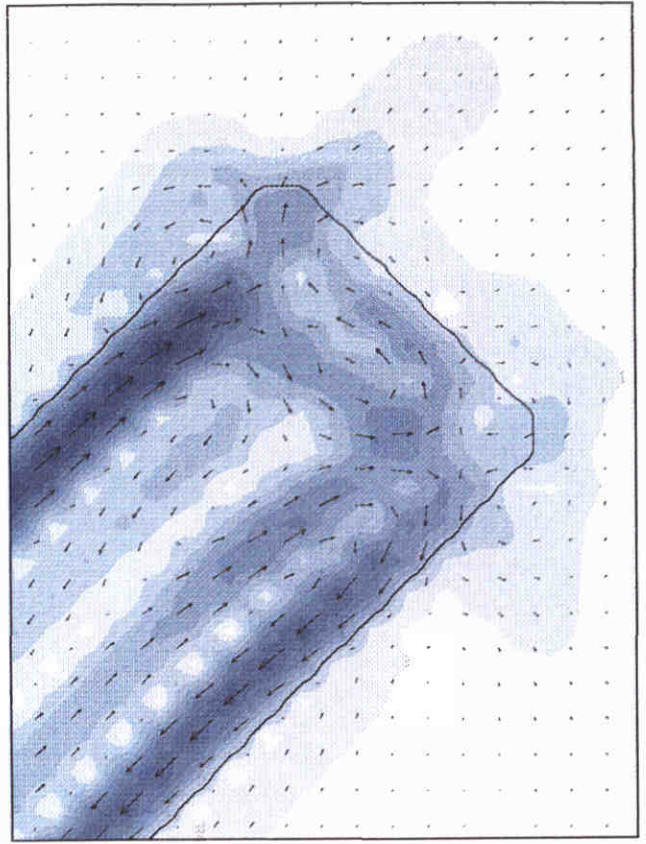
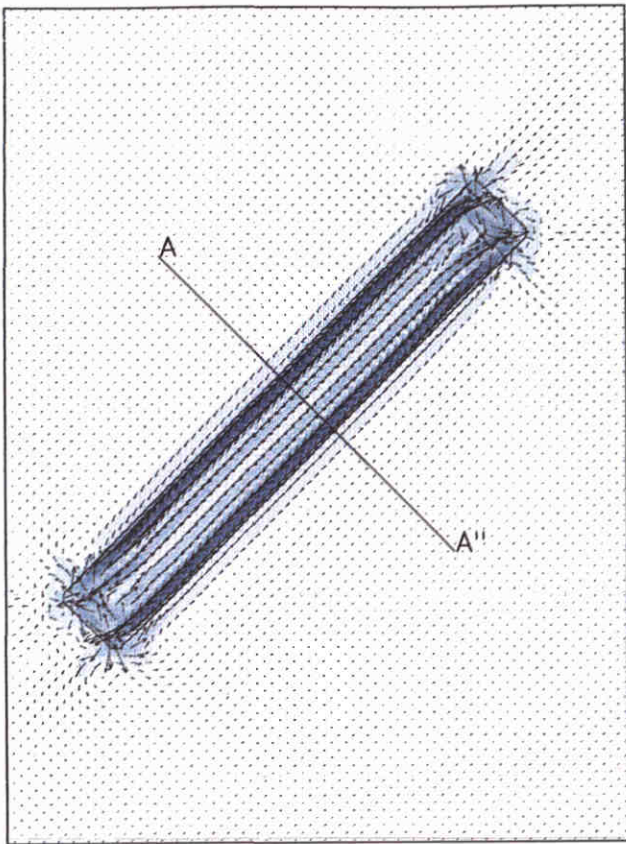
u-u boundary conditions; including Coriolis



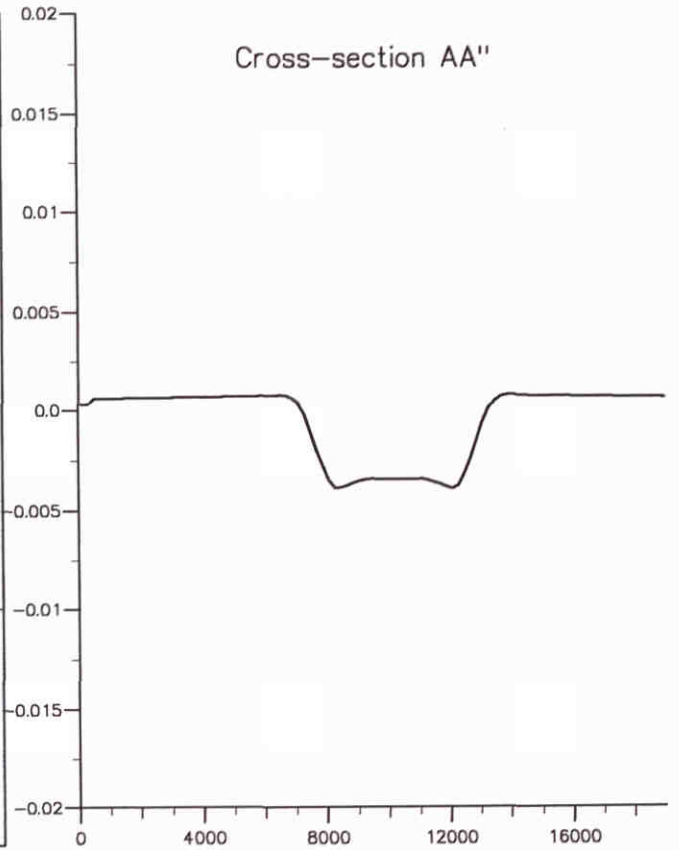
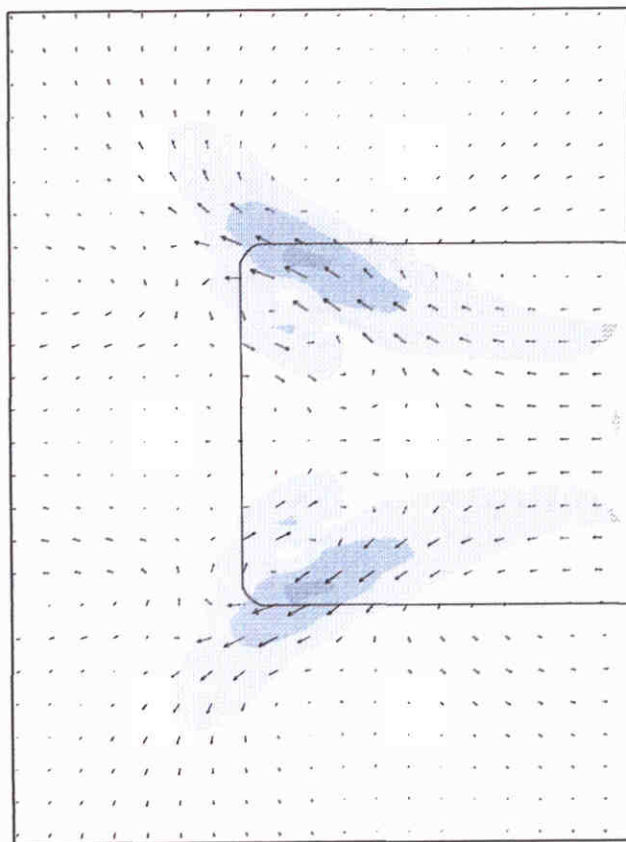
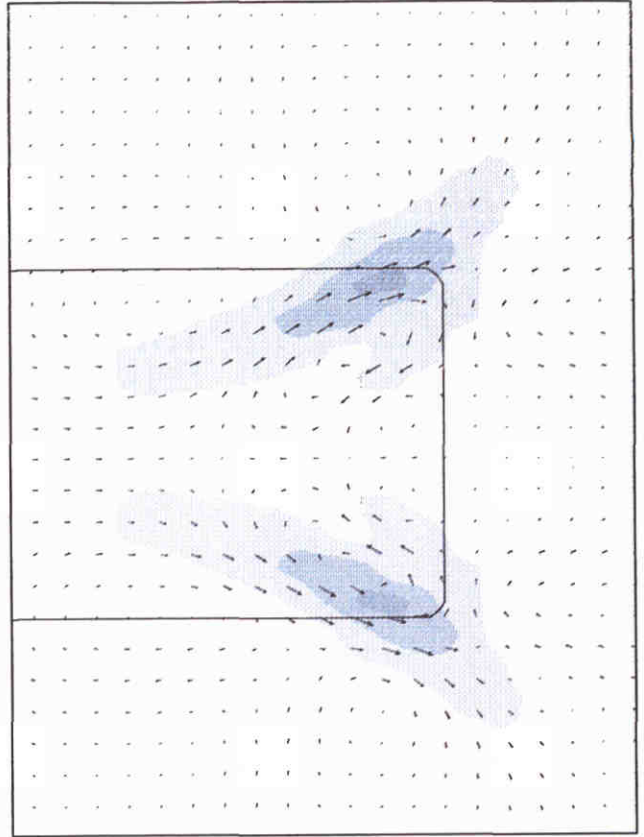
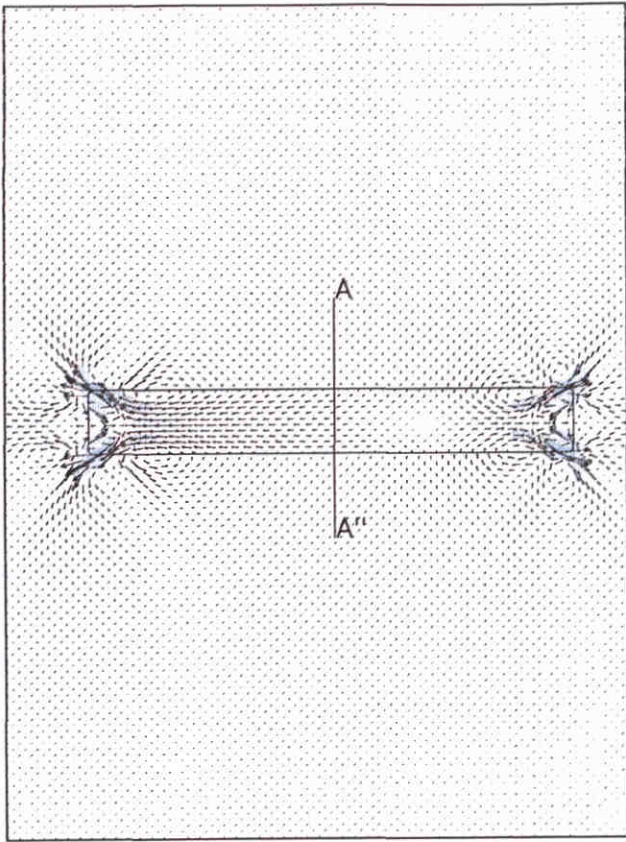
Tide-averaged current velocities [m/s]

Influence of Coriolis on the tide-averaged current pattern

Tidal boundary conditions with and without Coriolis



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

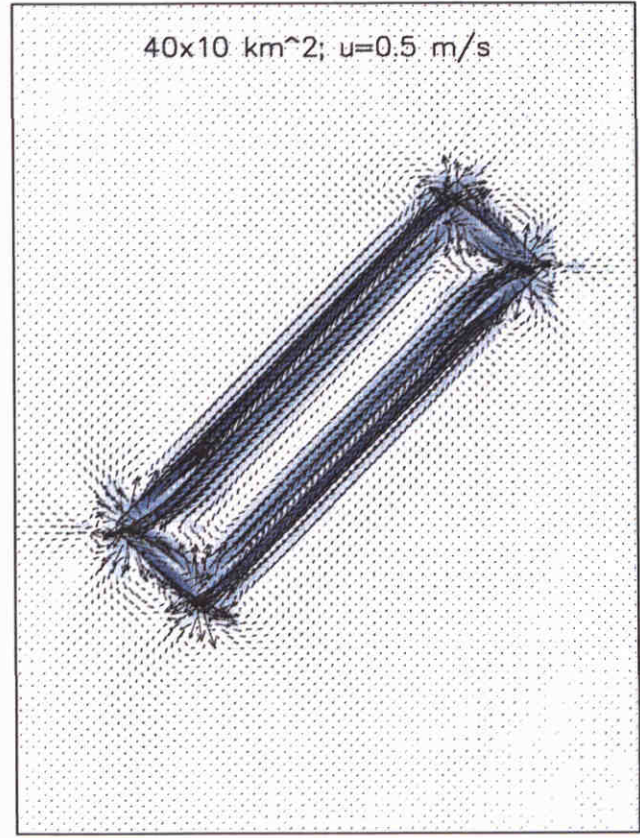
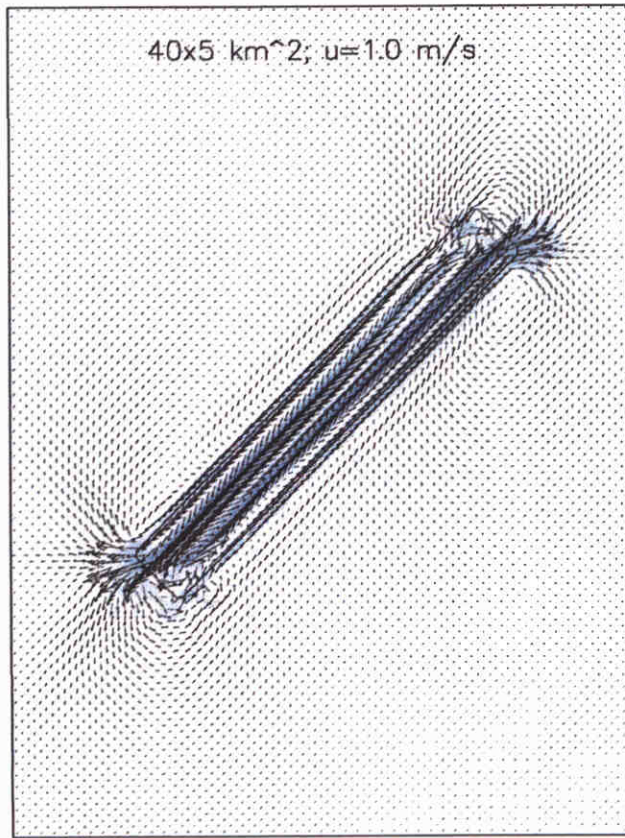
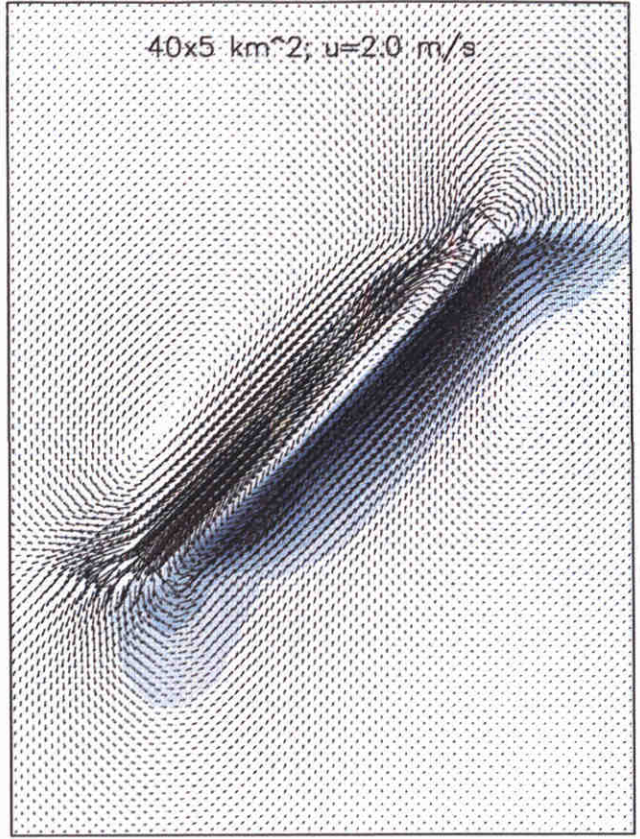
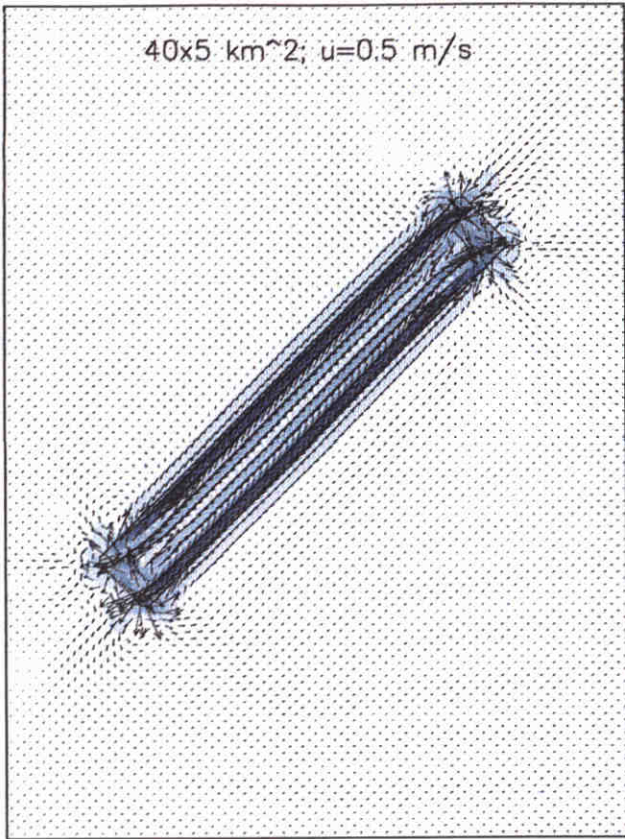


- <0.01
- <0.02
- <0.03
- <0.04
- <0.05
- <0.06
- <0.07
- <0.08
- <0.09
- <0.10
- >0.10
- 0.050m/s

Tide-averaged current velocities

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

Tidal boundary conditions

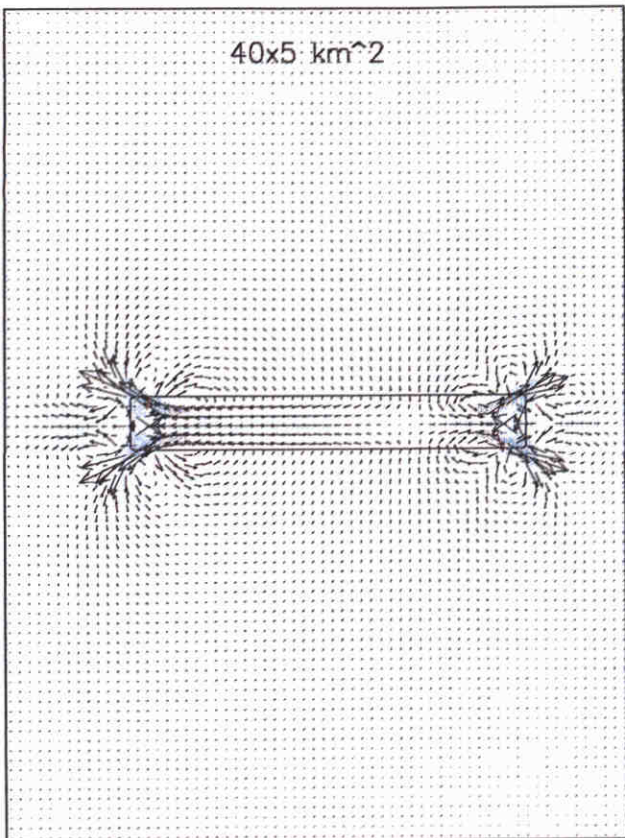


Tide-averaged current velocities [m/s]

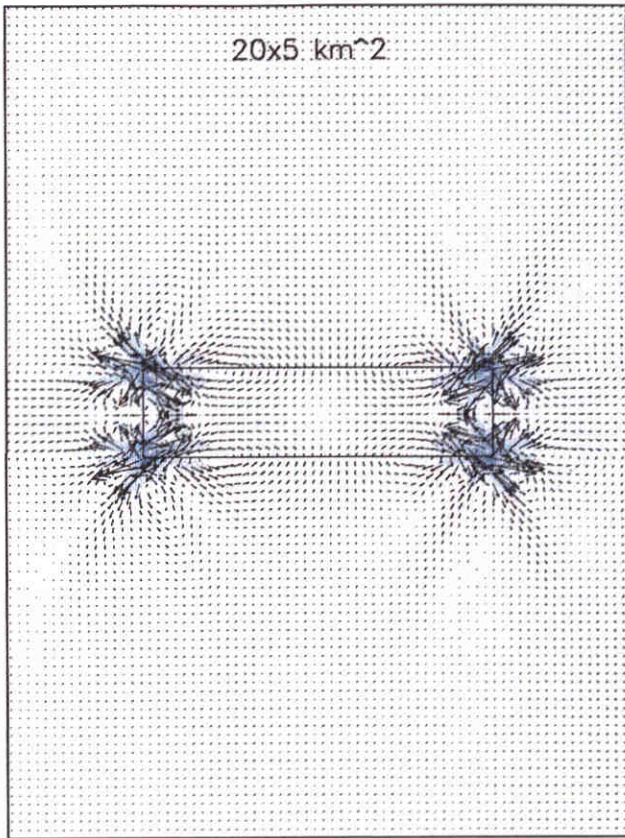
Influence of the tidal amplitude and the width on the tide-averaged current pattern

Tidal boundary conditions

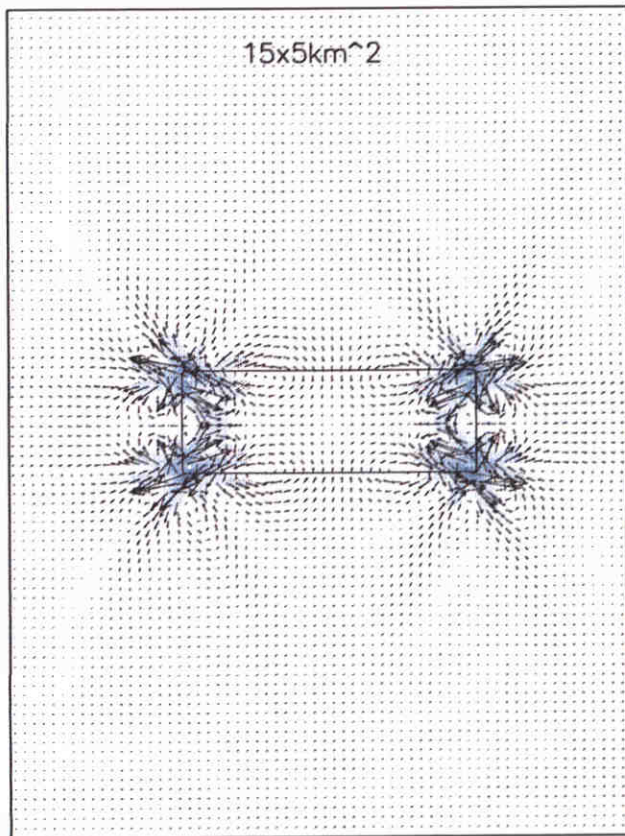
40x5 km²



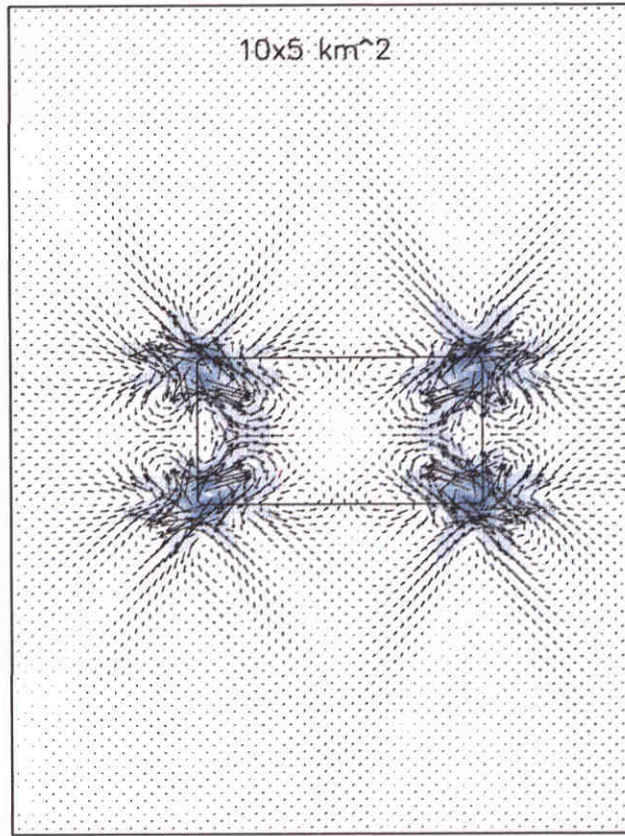
20x5 km²



15x5 km²



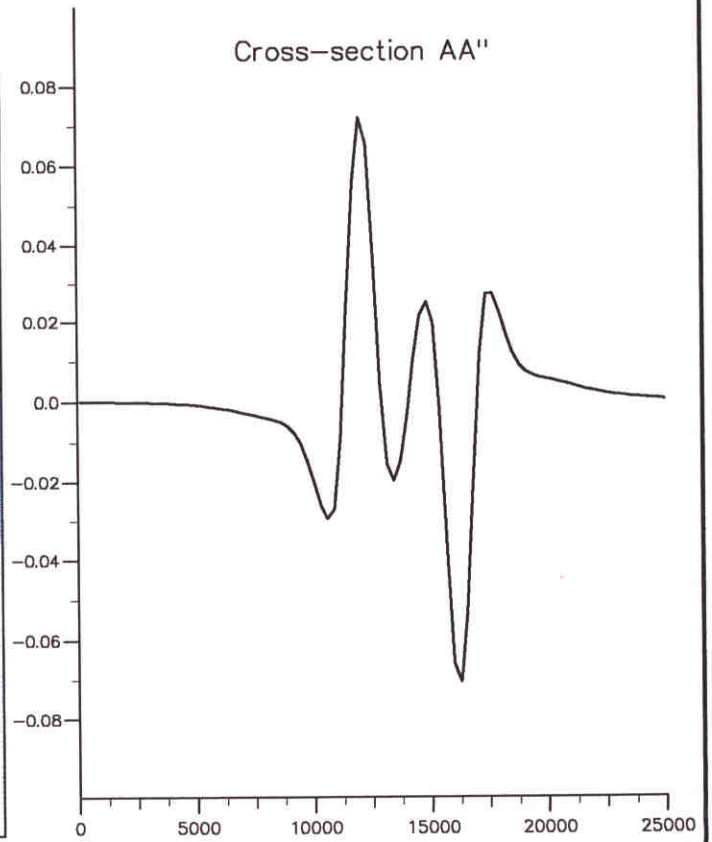
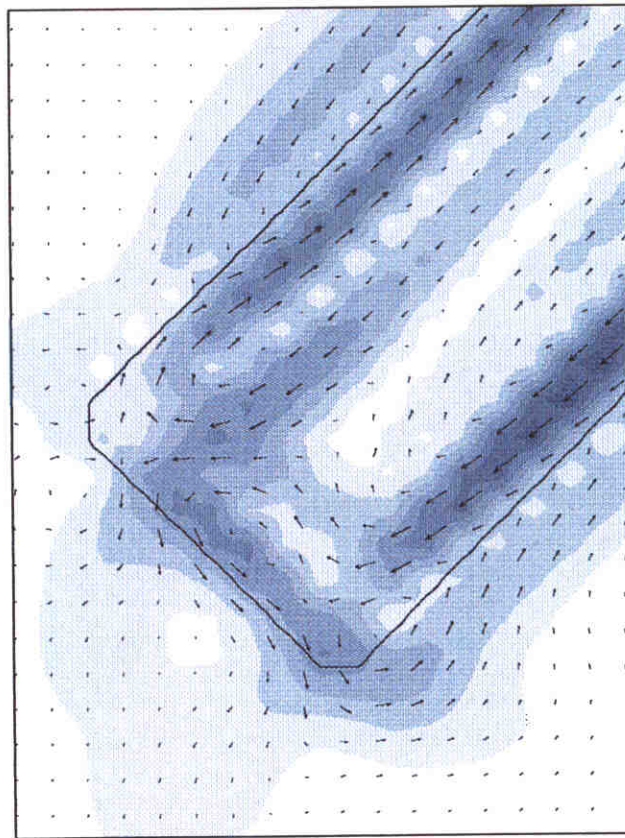
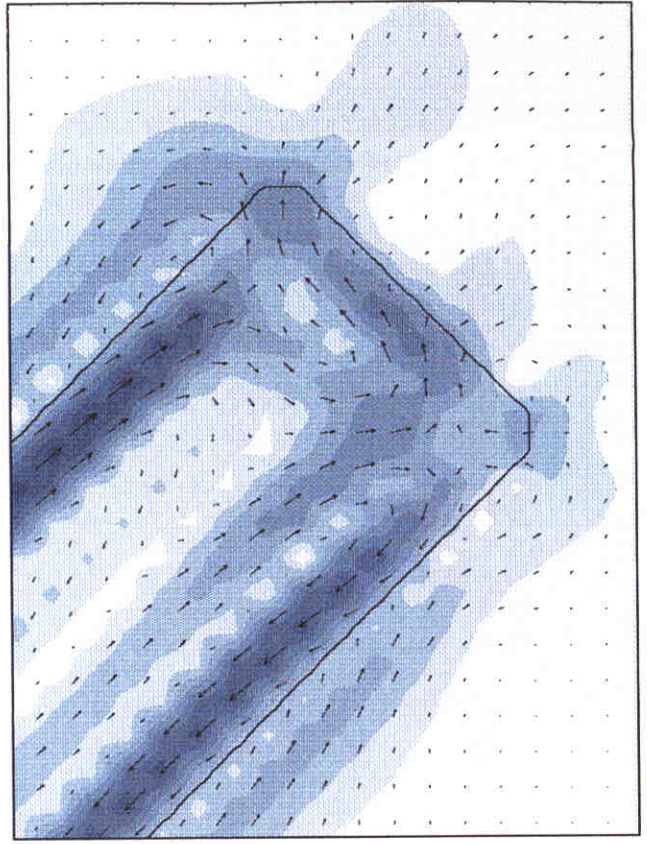
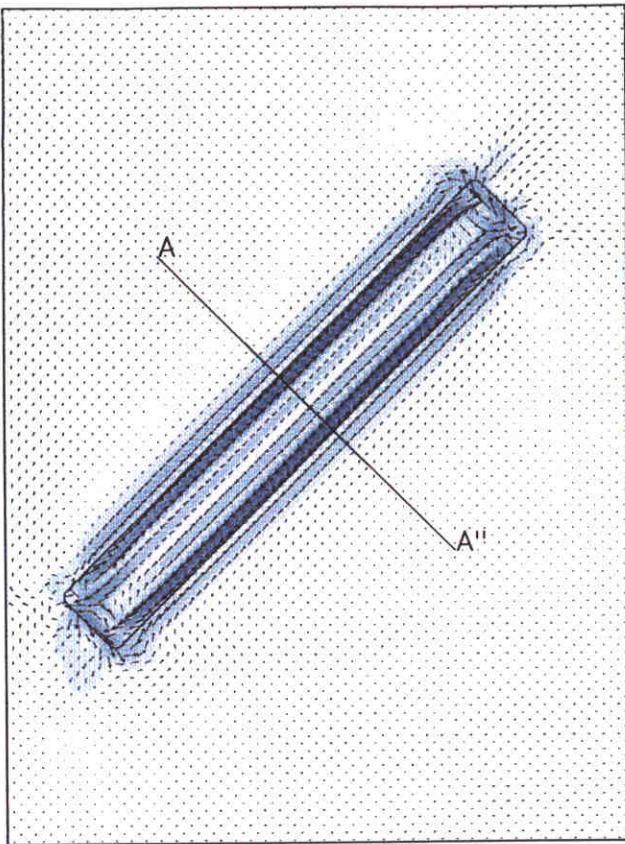
10x5 km²



Tide-averaged current velocities [m/s]

Influence of the length on the tide-averaged current pattern

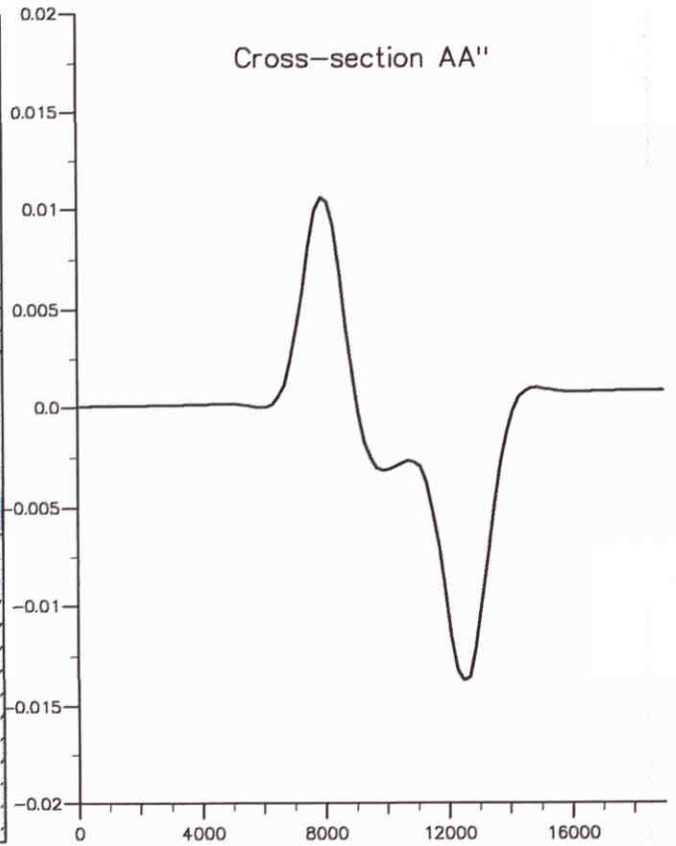
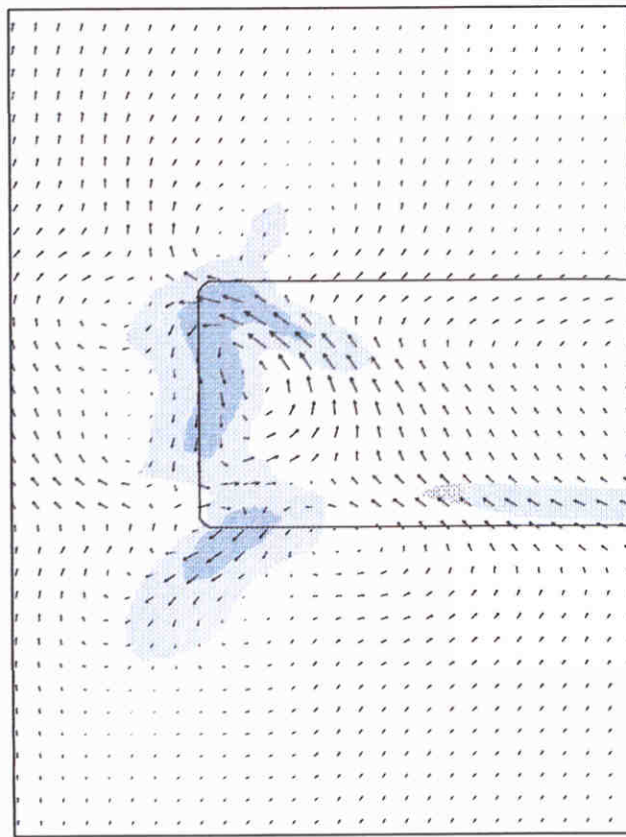
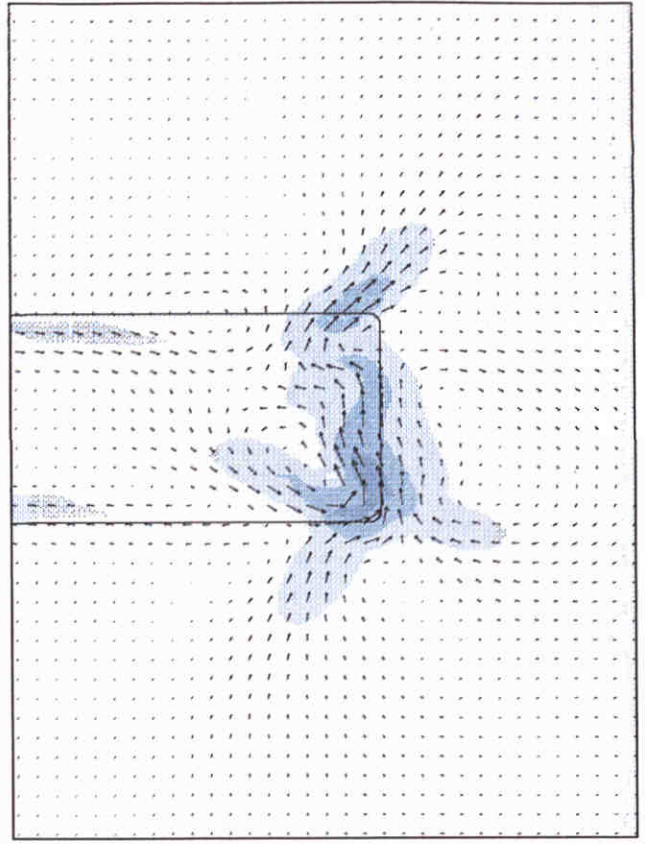
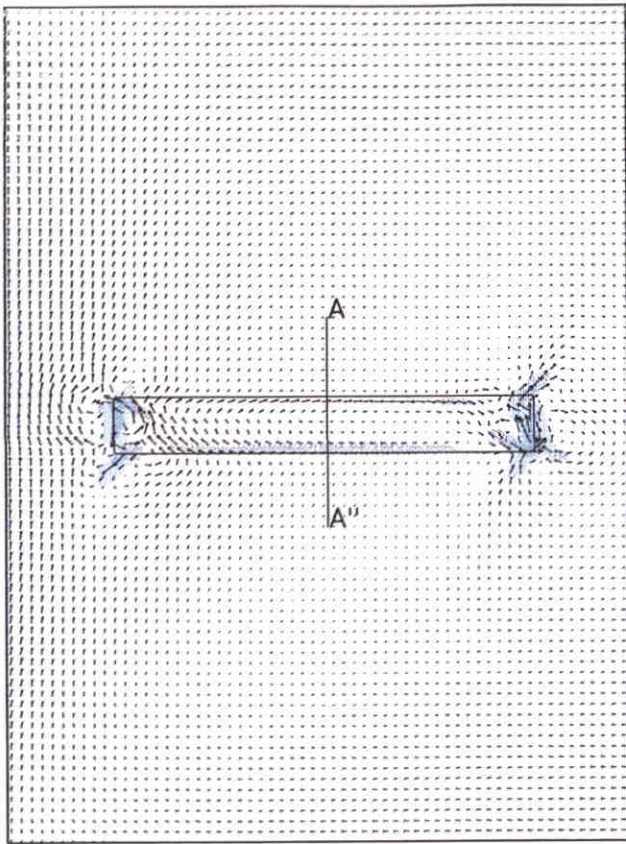
Tidal boundary conditions



Tide-averaged current velocities [m/s]

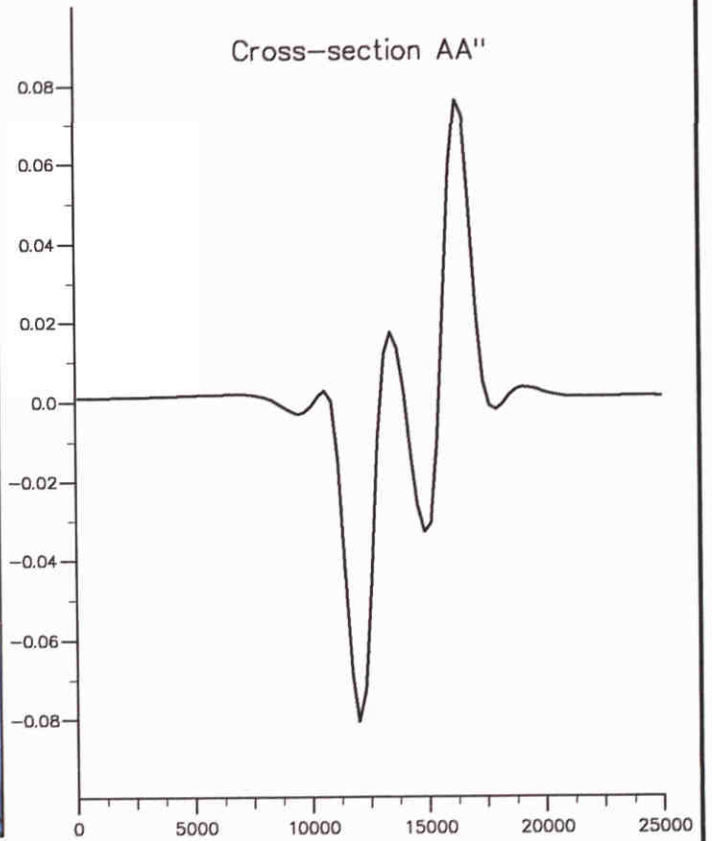
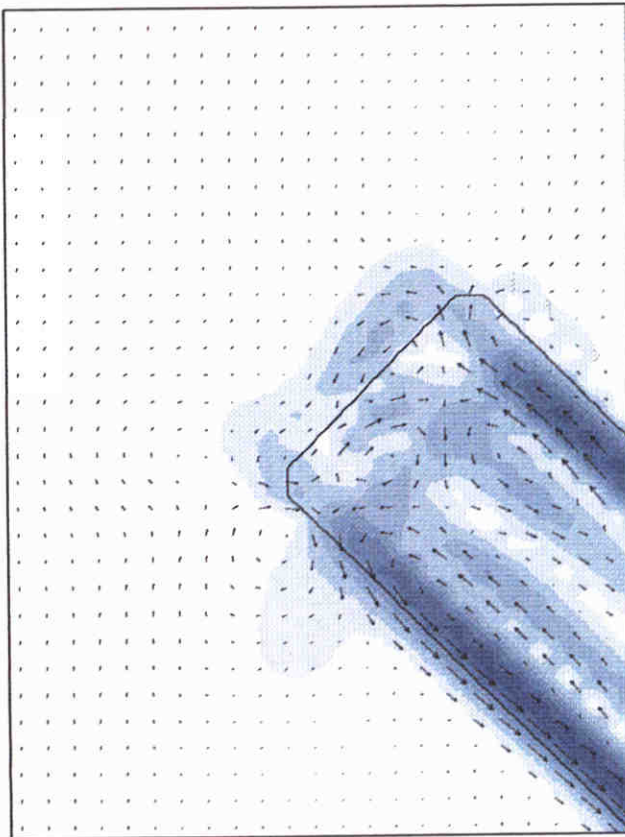
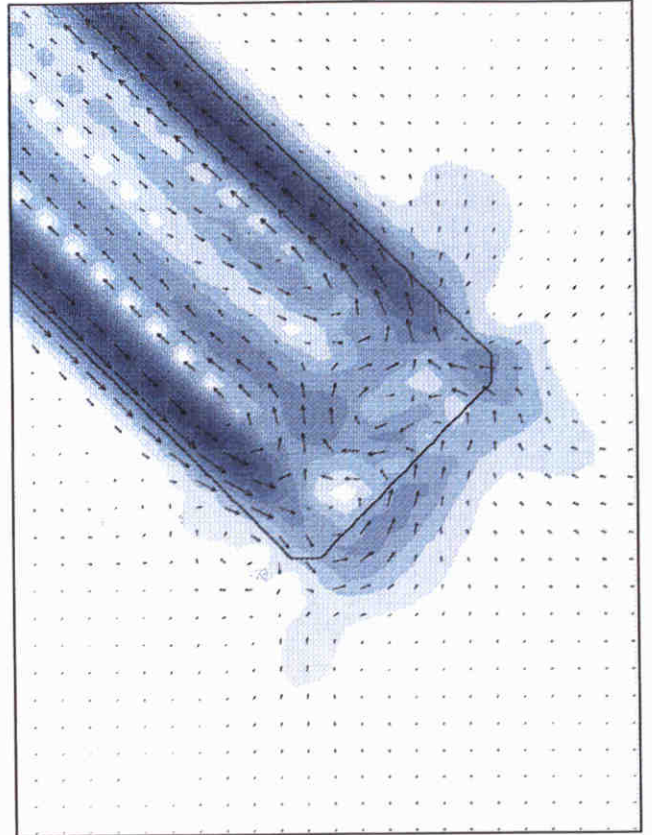
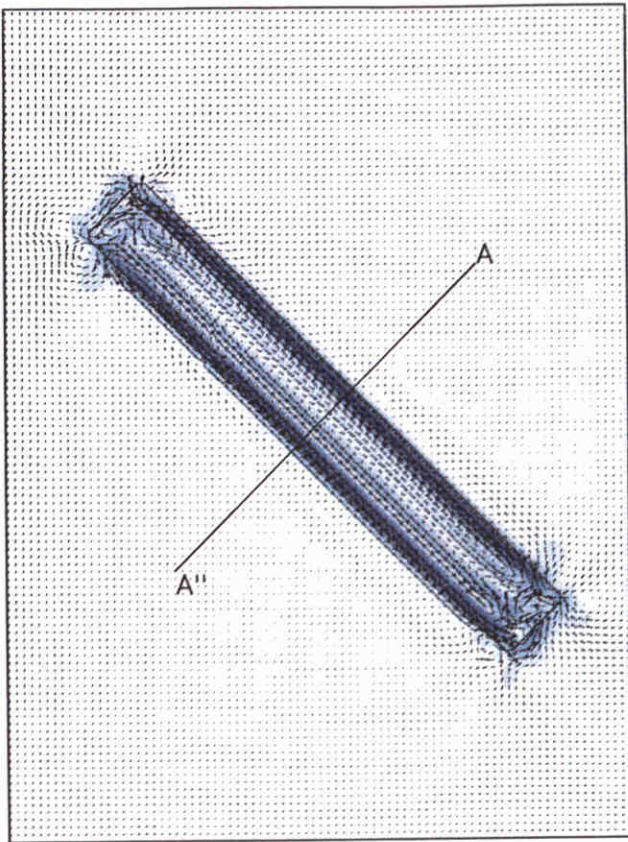
Tide-averaged current pattern and tide-averaged velocities in cross-section AA''

Tidal boundary conditions including Coriolis



- <0.01
- <0.02
- <0.03
- <0.04
- <0.05
- <0.06
- <0.07
- <0.08
- <0.09
- <0.10
- >0.10
- 0.050m/s

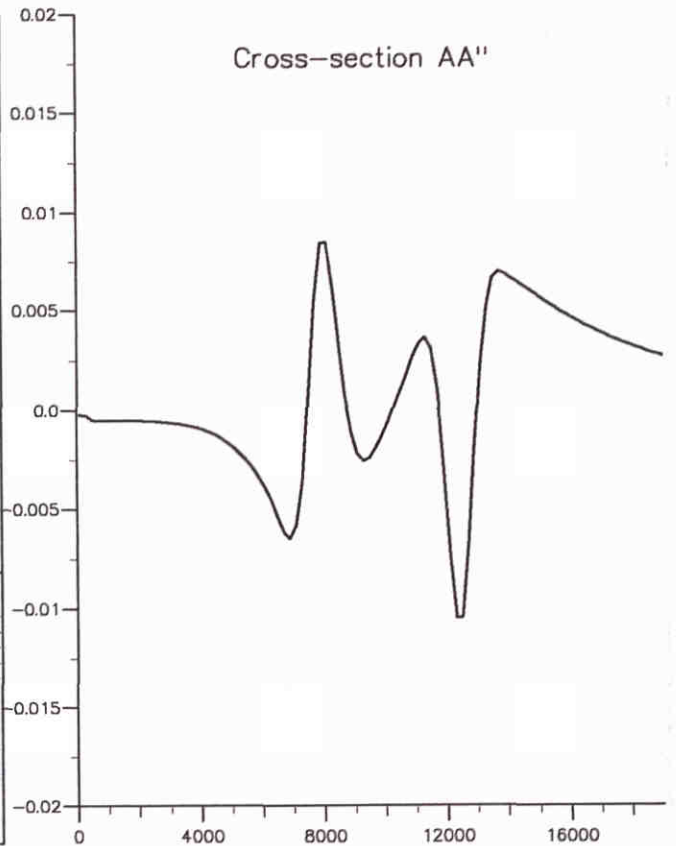
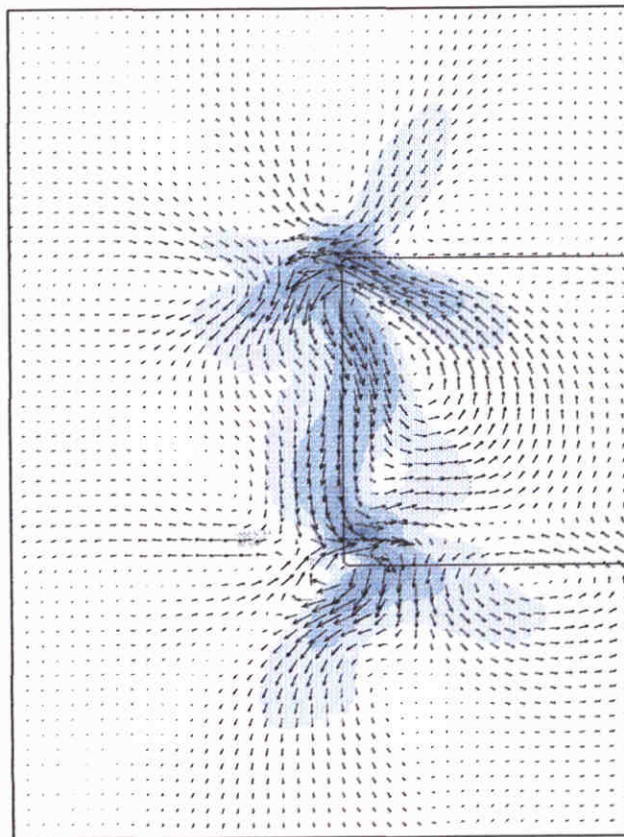
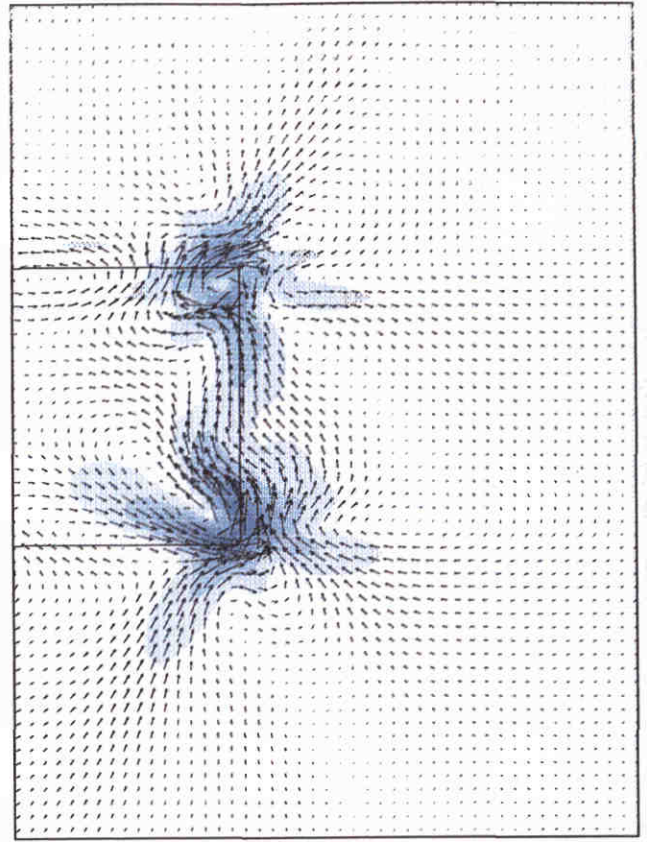
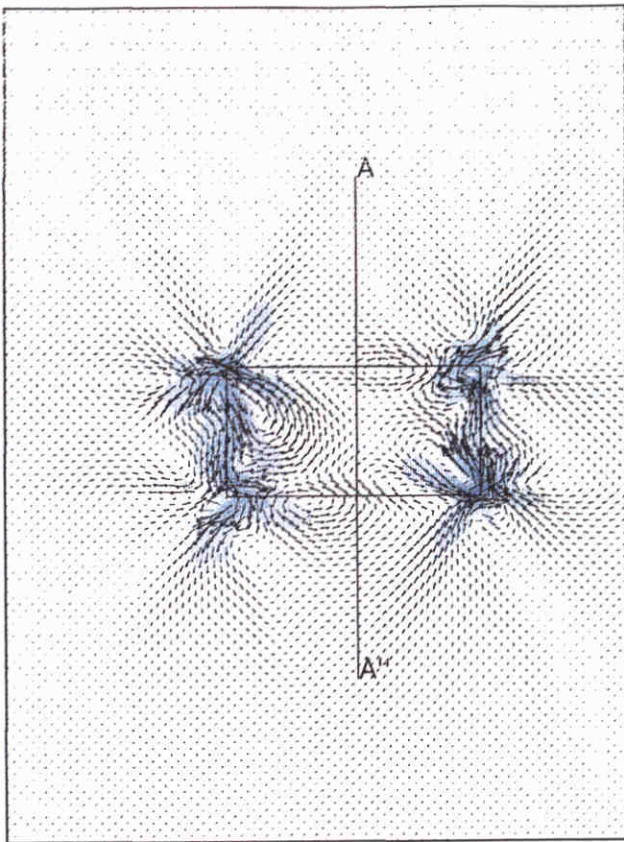
Tide-averaged current velocities [m/s]
 Tide-averaged current pattern and tide-averaged velocities in cross-section AA''
 Tidal boundary conditions including Coriolis



Tide-averaged current velocities [m/s]

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

Tidal boundary conditions including Coriolis

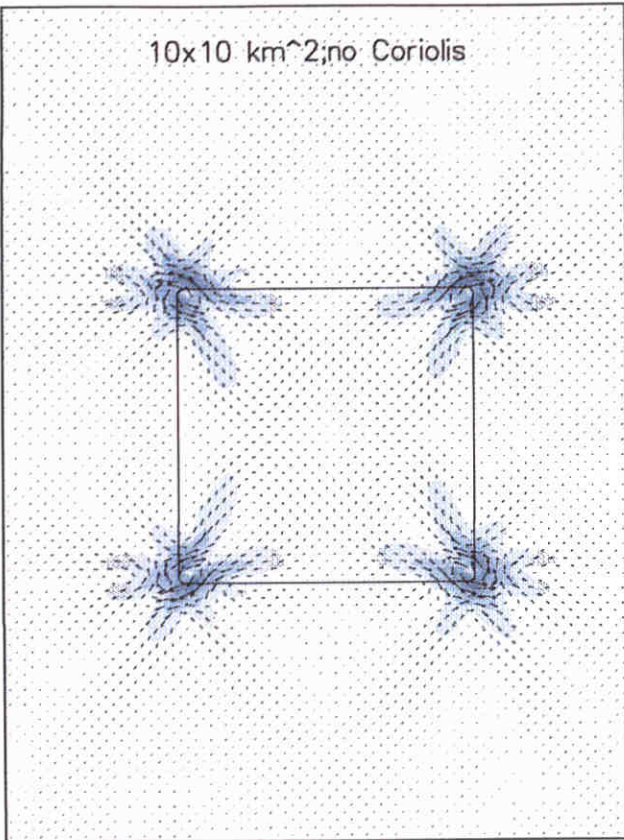


Tide-averaged current velocities [m/s]

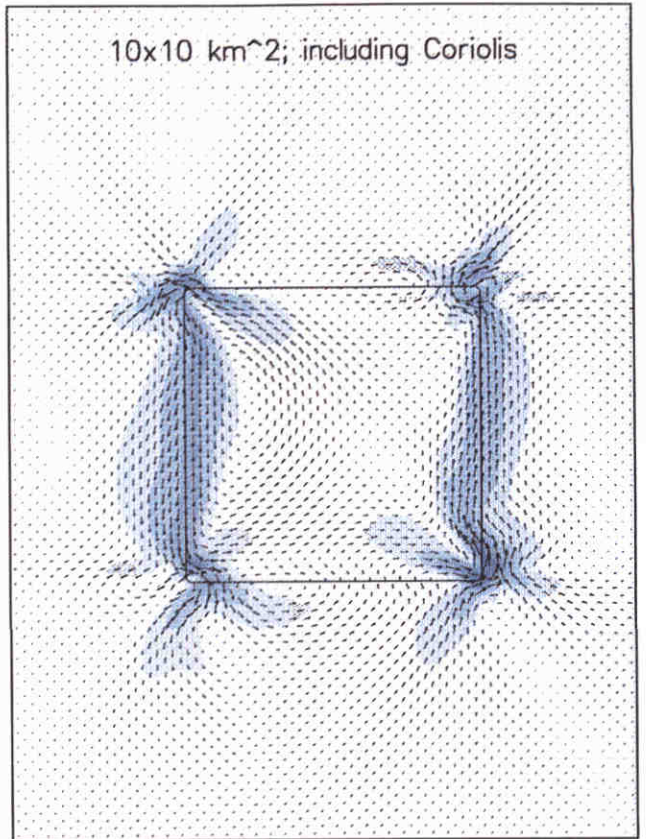
Tide-averaged current pattern and tide-averaged velocities in cross-section AA''

Tidal boundary conditions including Coriolis

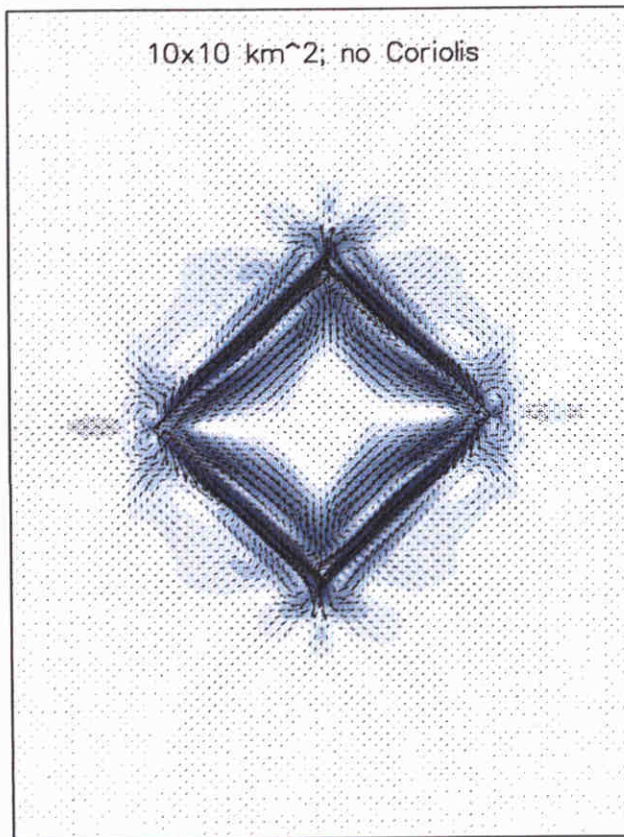
10x10 km²; no Coriolis



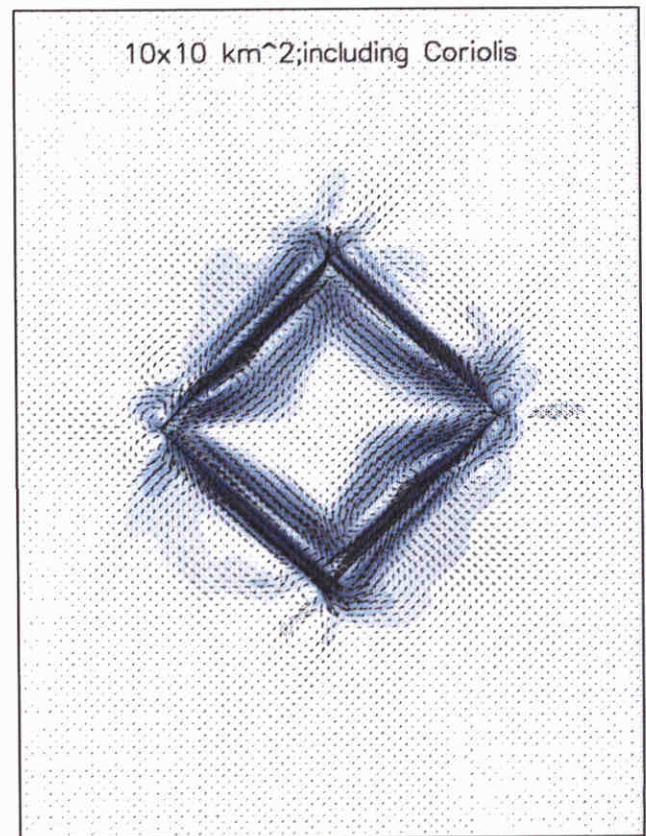
10x10 km²; including Coriolis



10x10 km²; no Coriolis



10x10 km²; including Coriolis



Tide-averaged current velocities [m/s]

Tide-averaged current pattern

Tidal boundary conditions with and without Coriolis

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



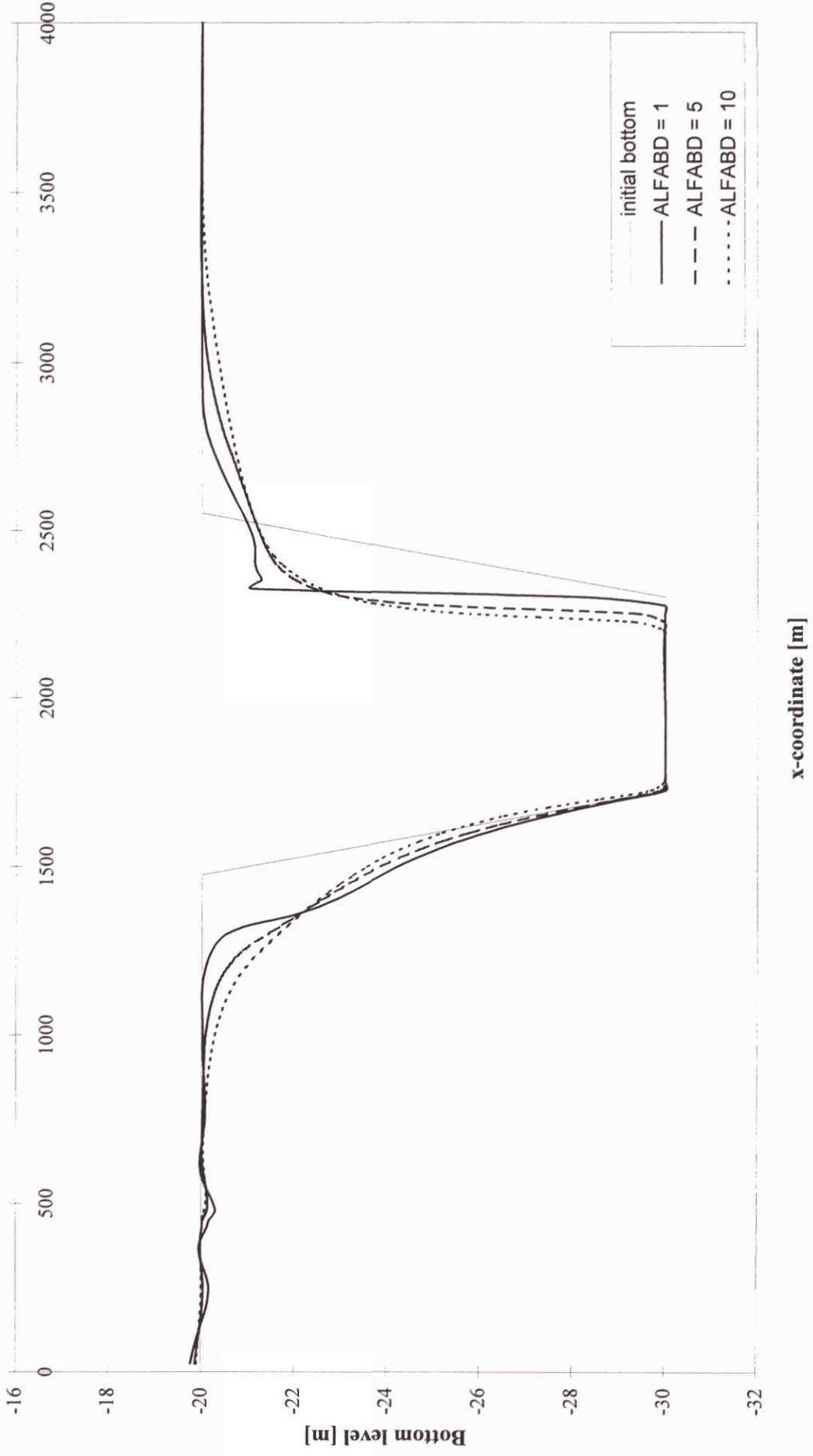
Figuur 8.3: Influence of the transport mode, while ALFABD is 5



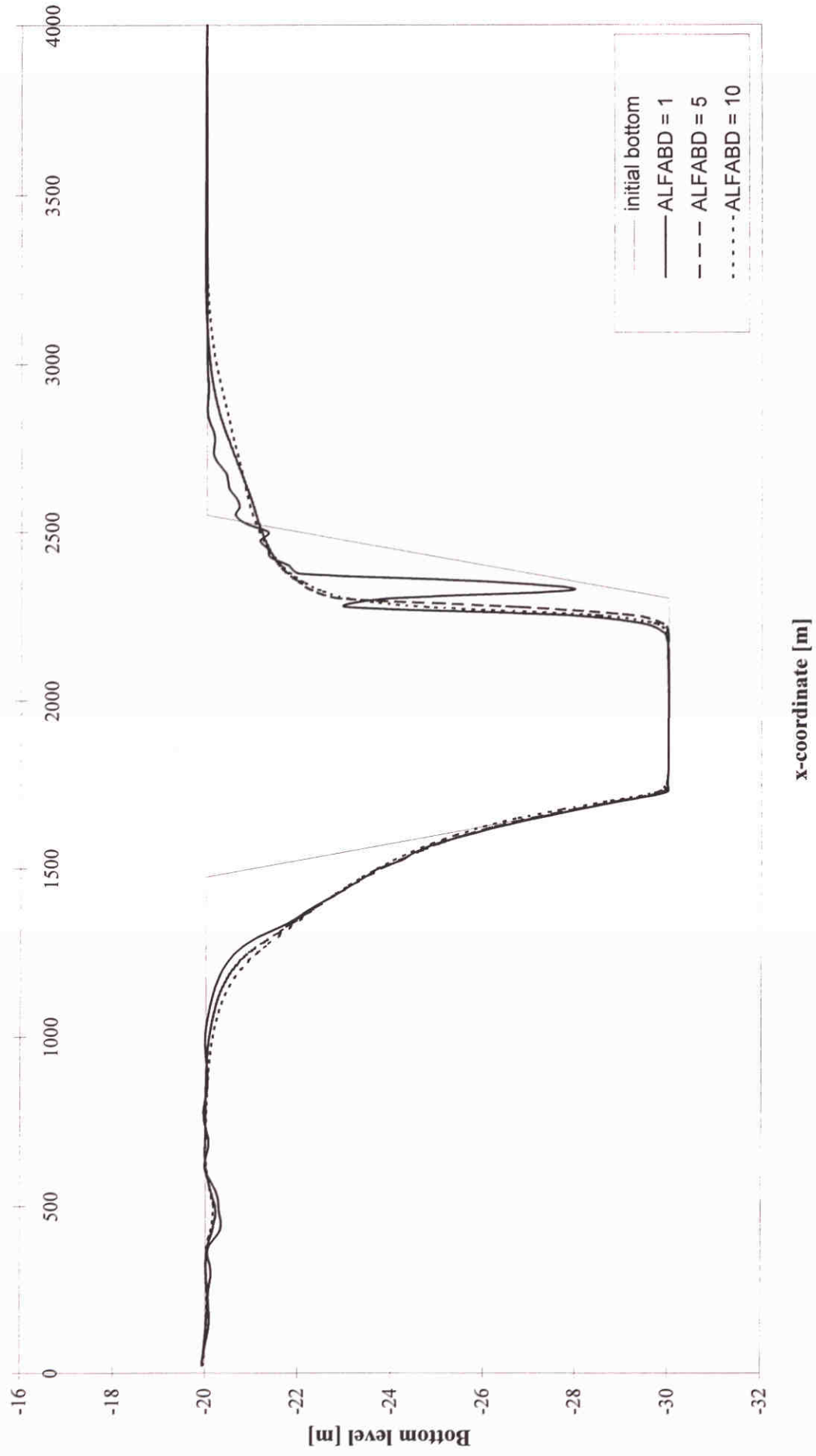
Figuur 8.4: Influence of the transport mode, while ALFABD is 10



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



Figur 8.7: Influence of ALFABD on a $10 \times 10 \text{ km}^2$ sandpit with total transport

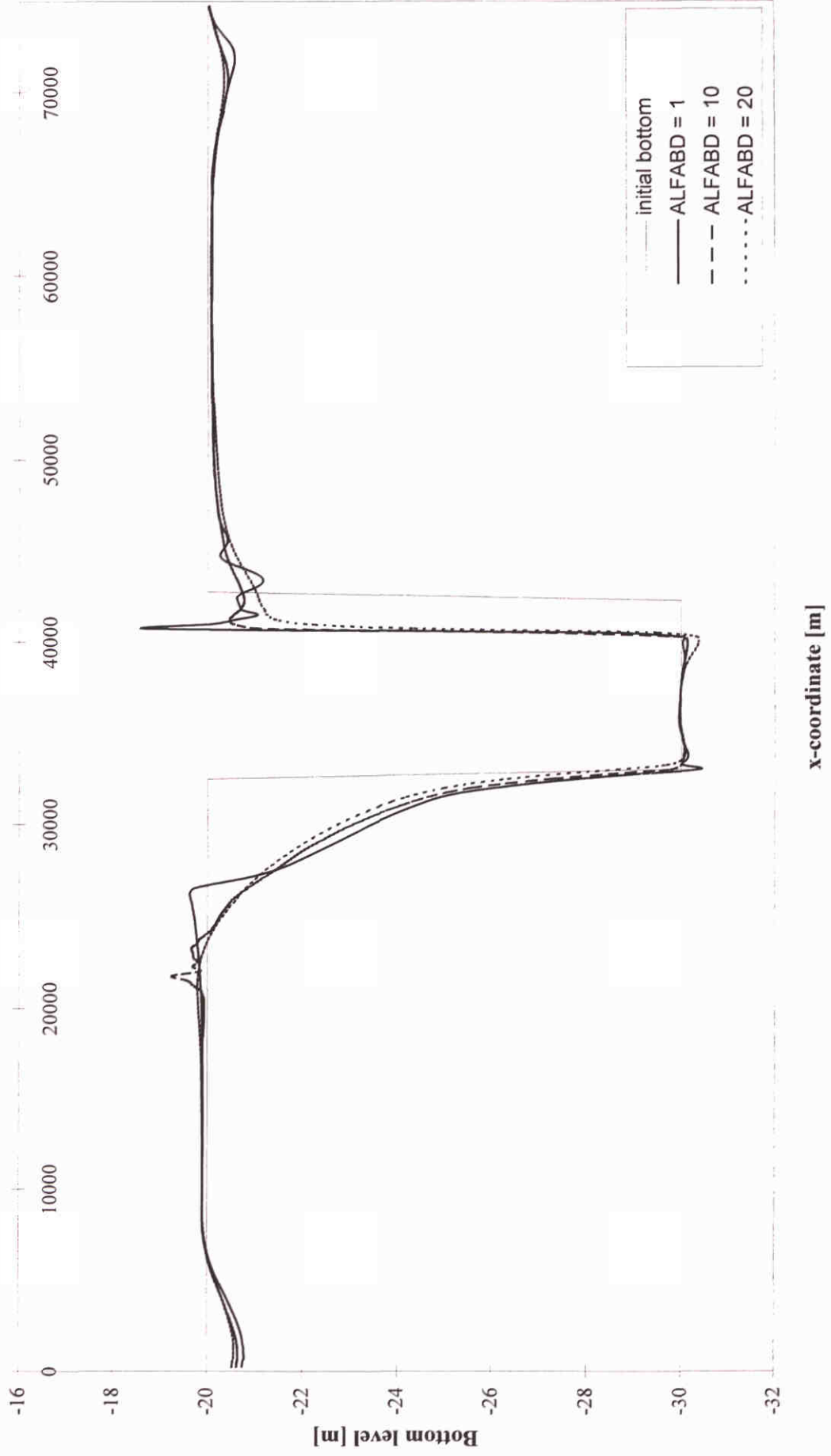
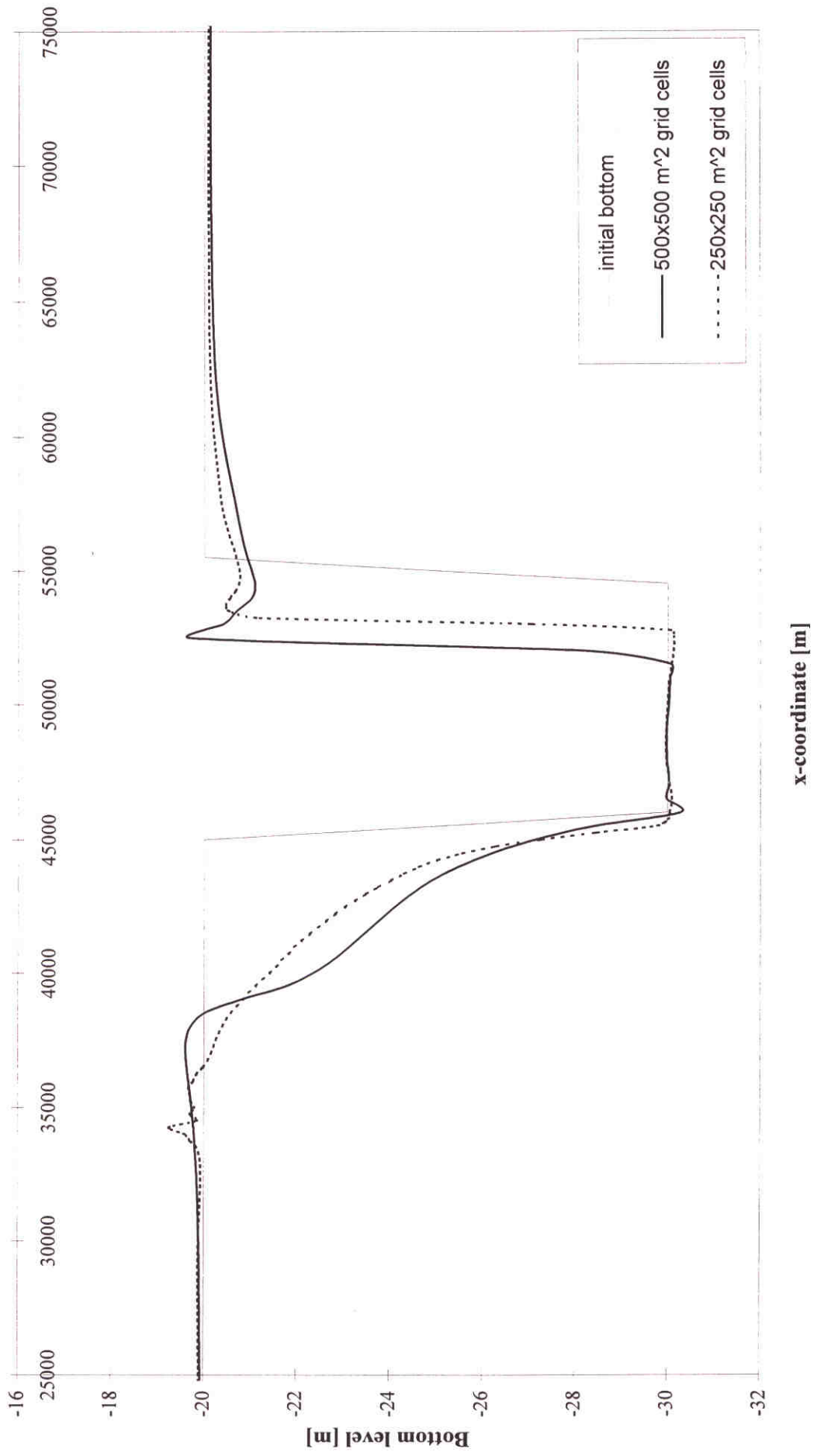
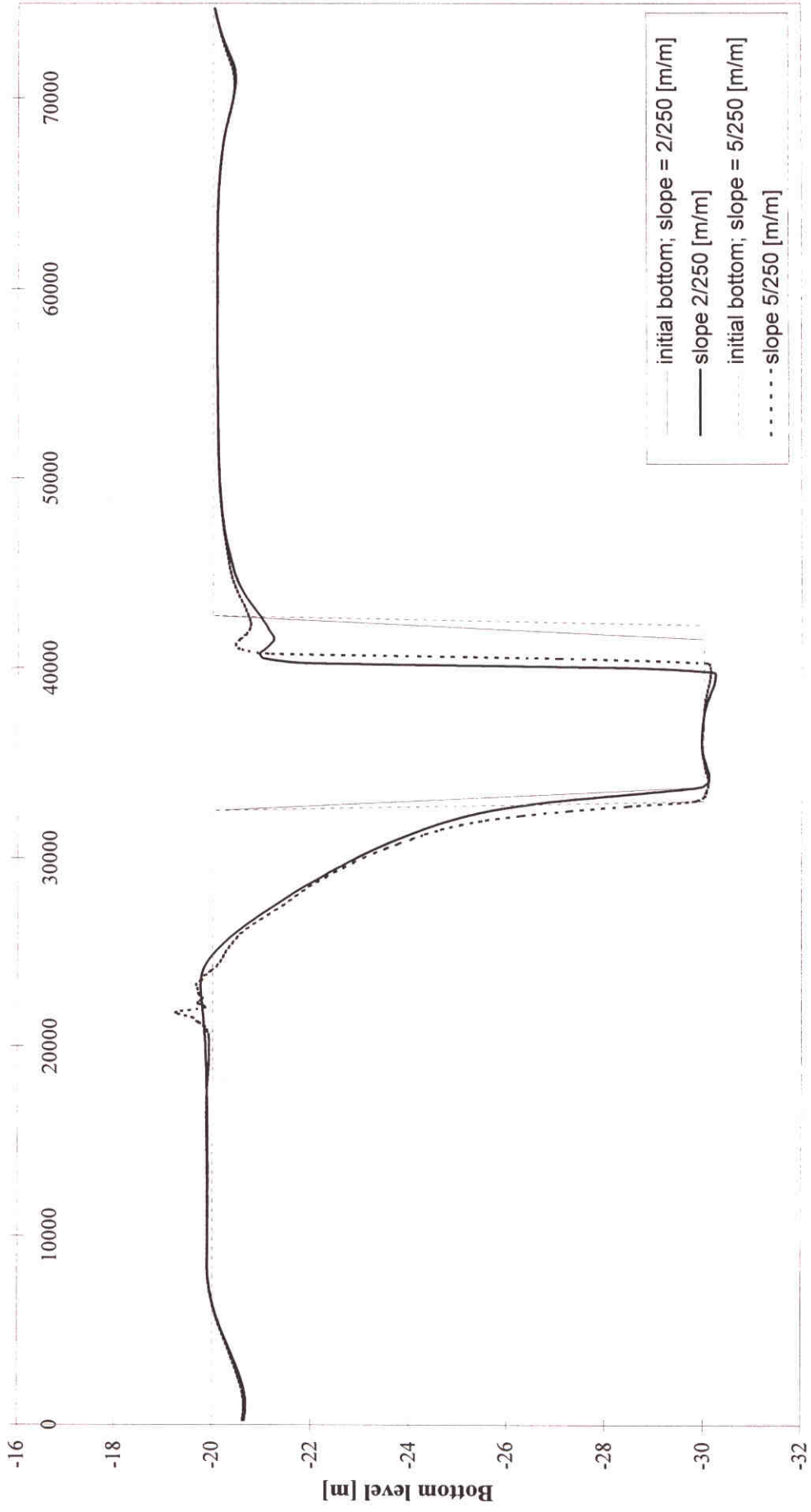


Figure 8.8: Influence of the grid cell size on the morphological results



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



x-coordinate [m]

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

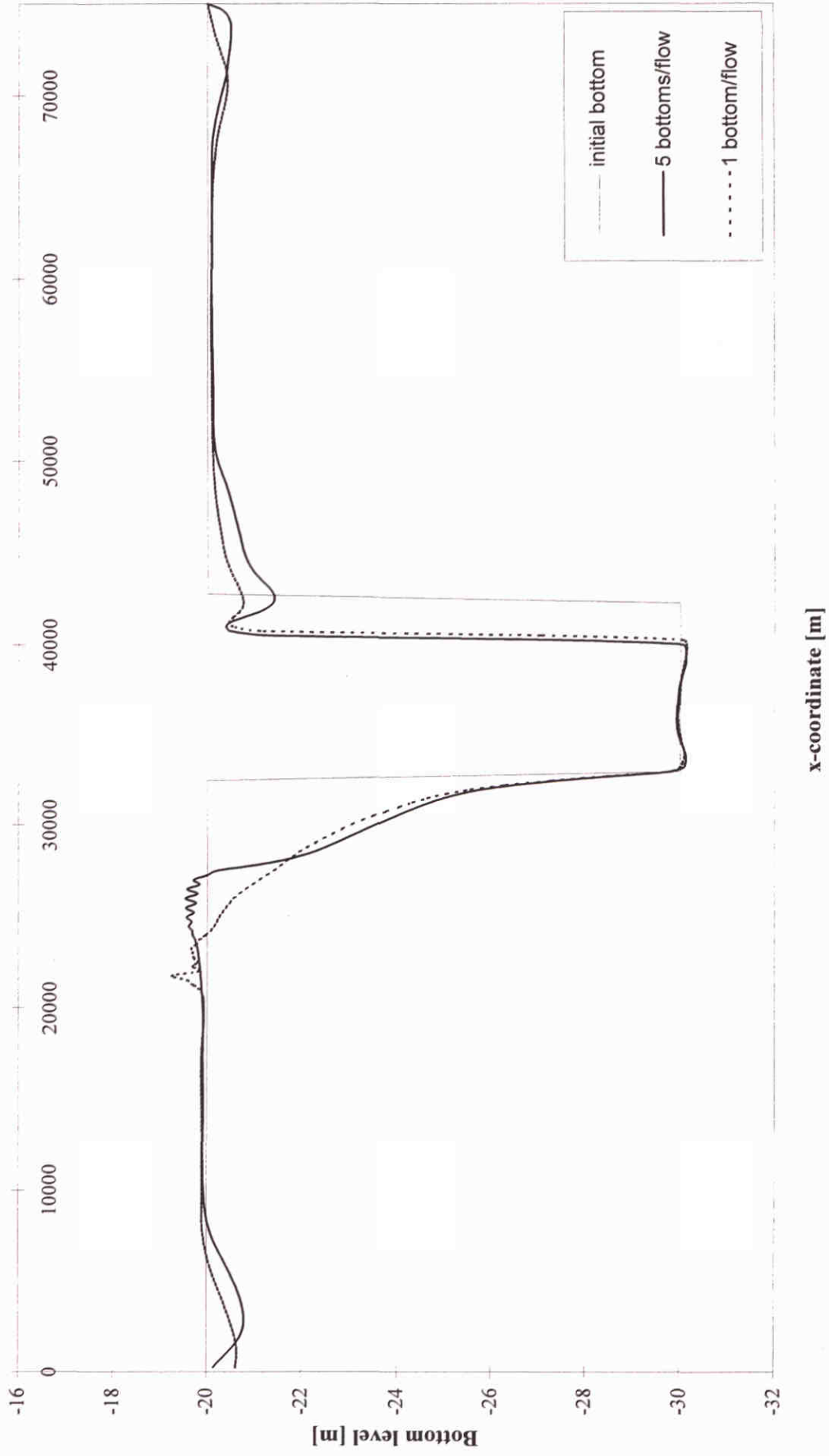


Figure 8.11: Data points for tide analysis

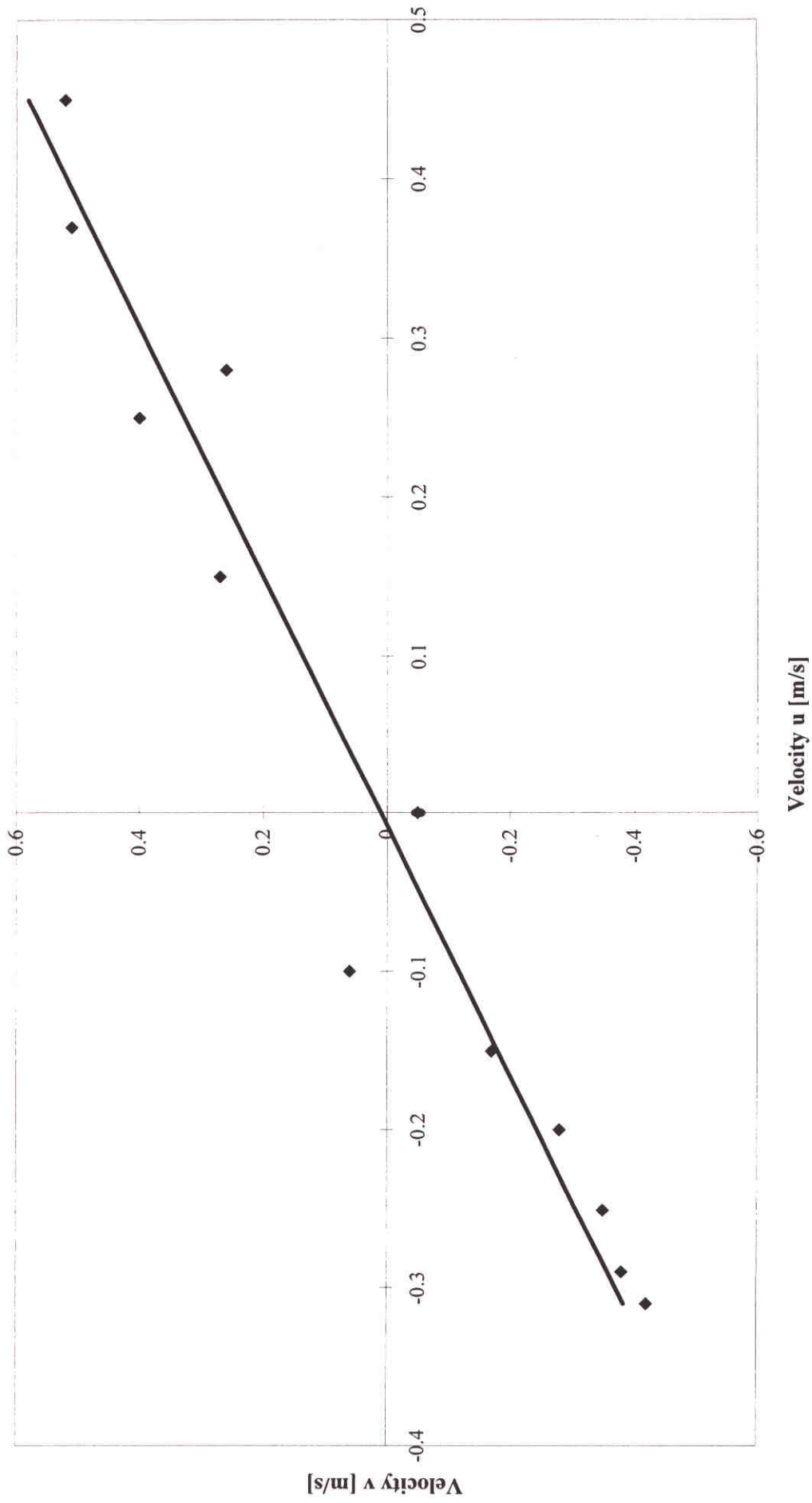


Figure 8.12: Results of the tide analysis

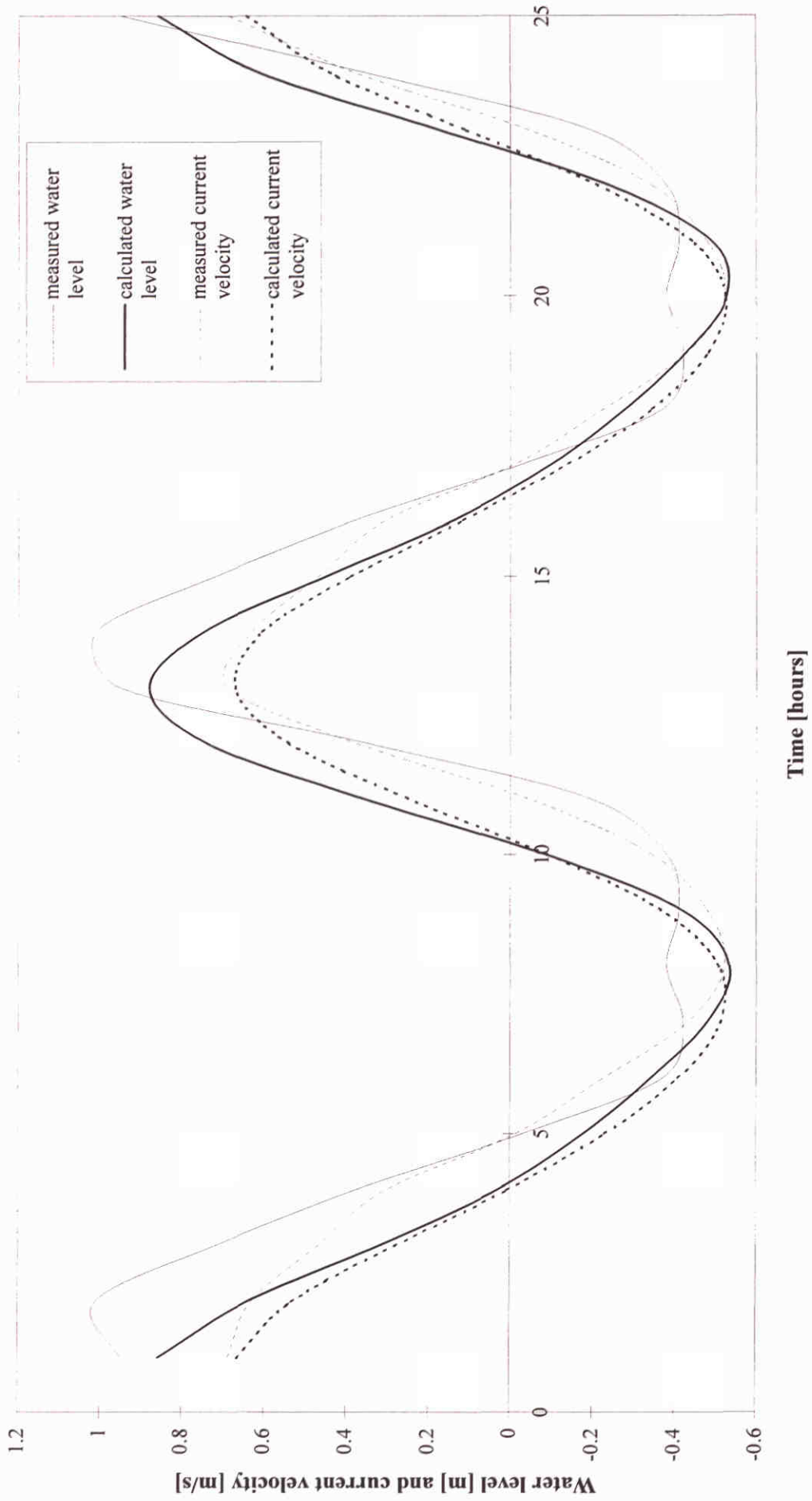
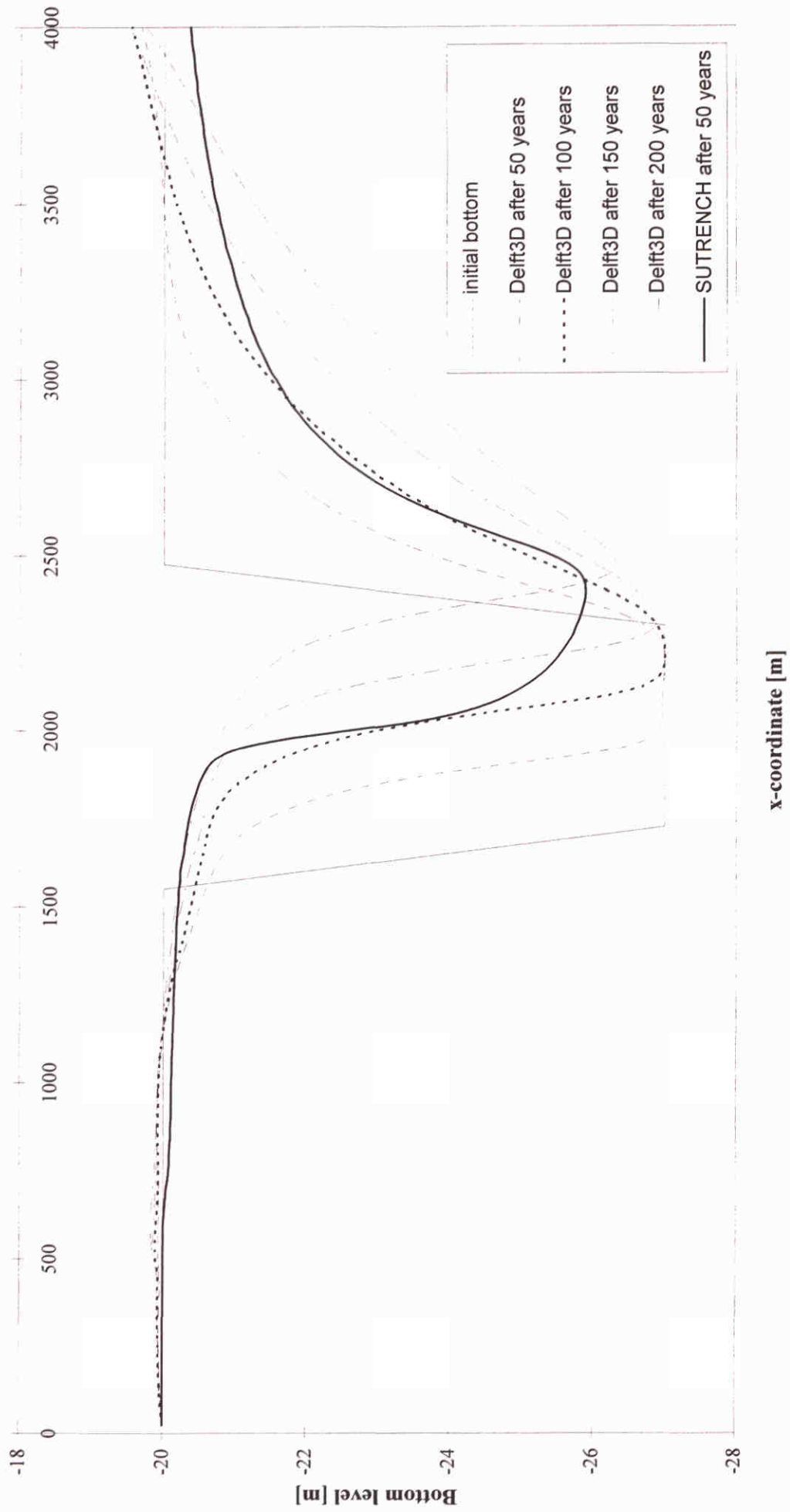
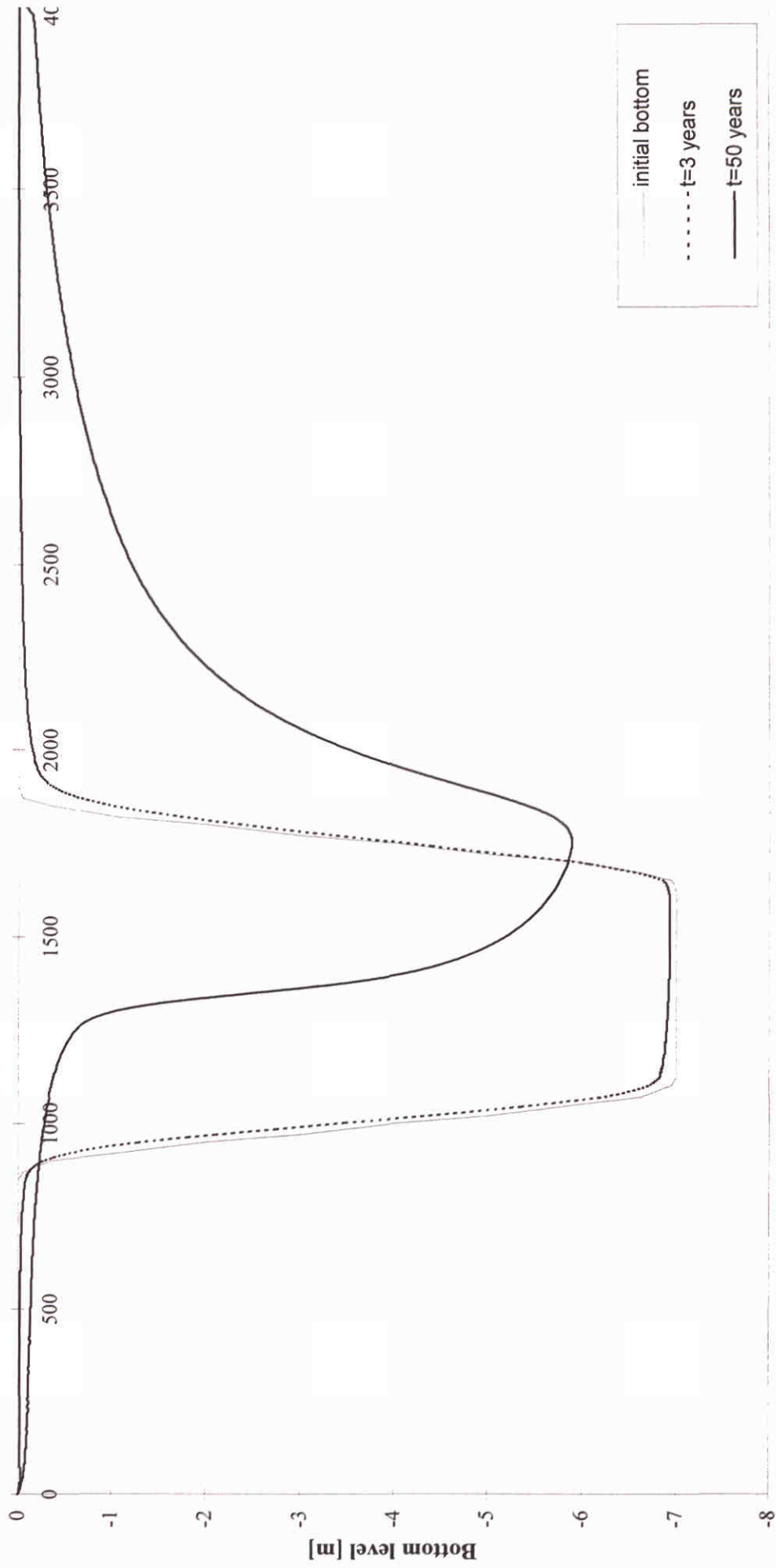


Figure 8.13: SUTRENCH and Delft3D results of a reference trench

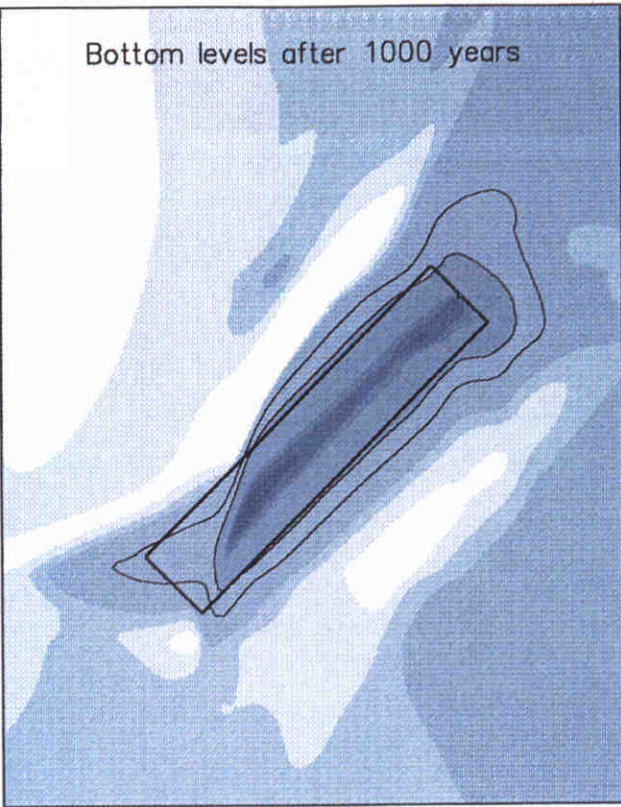


Figuur 8.14: SUTRENCH results of Walstra (1998)



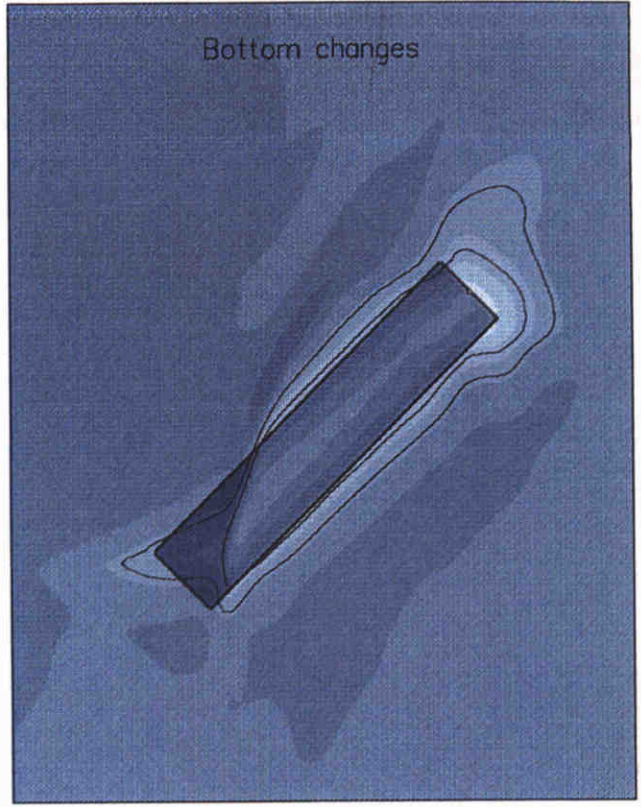
x-coordinate [m]

Bottom levels after 1000 years



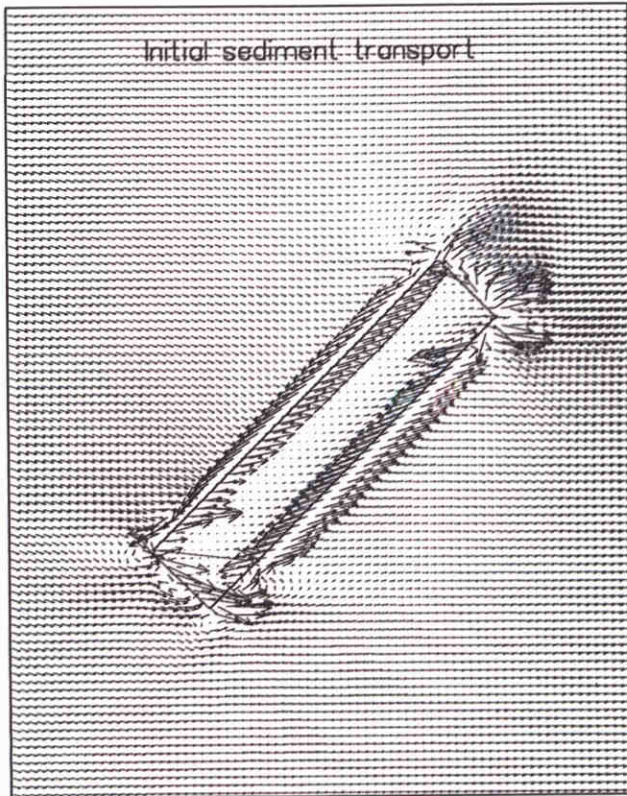
- <19.5
- <20.0
- <20.5
- <25.0
- <29.5
- <30.0
- <30.5
- >30.5

Bottom changes



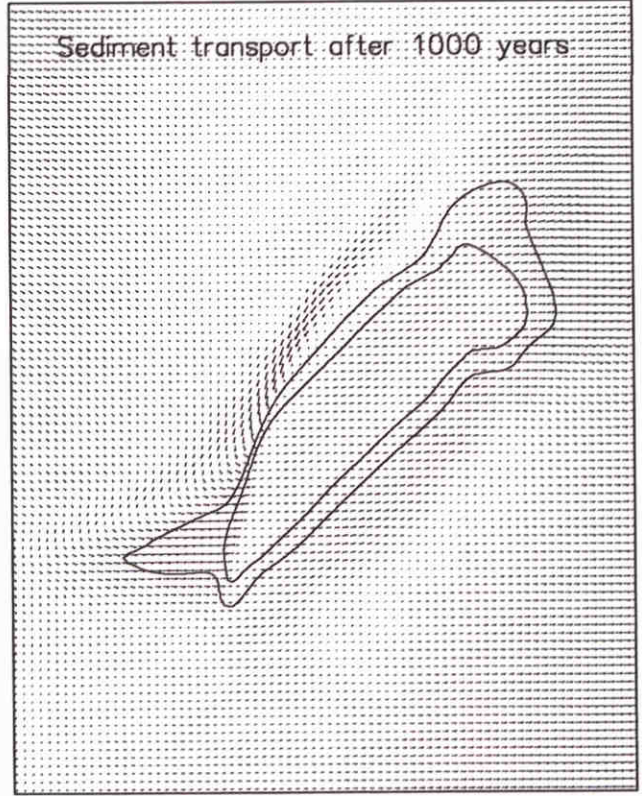
- <-10.0
- <-8.0
- <-6.0
- <-4.0
- <-2.0
- <0.0
- <2.0
- <4.0
- <6.0
- <8.0
- <10.0
- >10.0

Initial sediment transport



→ $2.0 \cdot 10^{-5} \text{ m}^2/\text{s}$

Sediment transport after 1000 years



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

+45 degrees rotated $25 \times 5 \text{ km}^2$ sandpit

Morphological results after 1000 years

Figure 8.15b: Bottom levels in the longitudinal section of a +45° rotated 25x5 km² sandpit

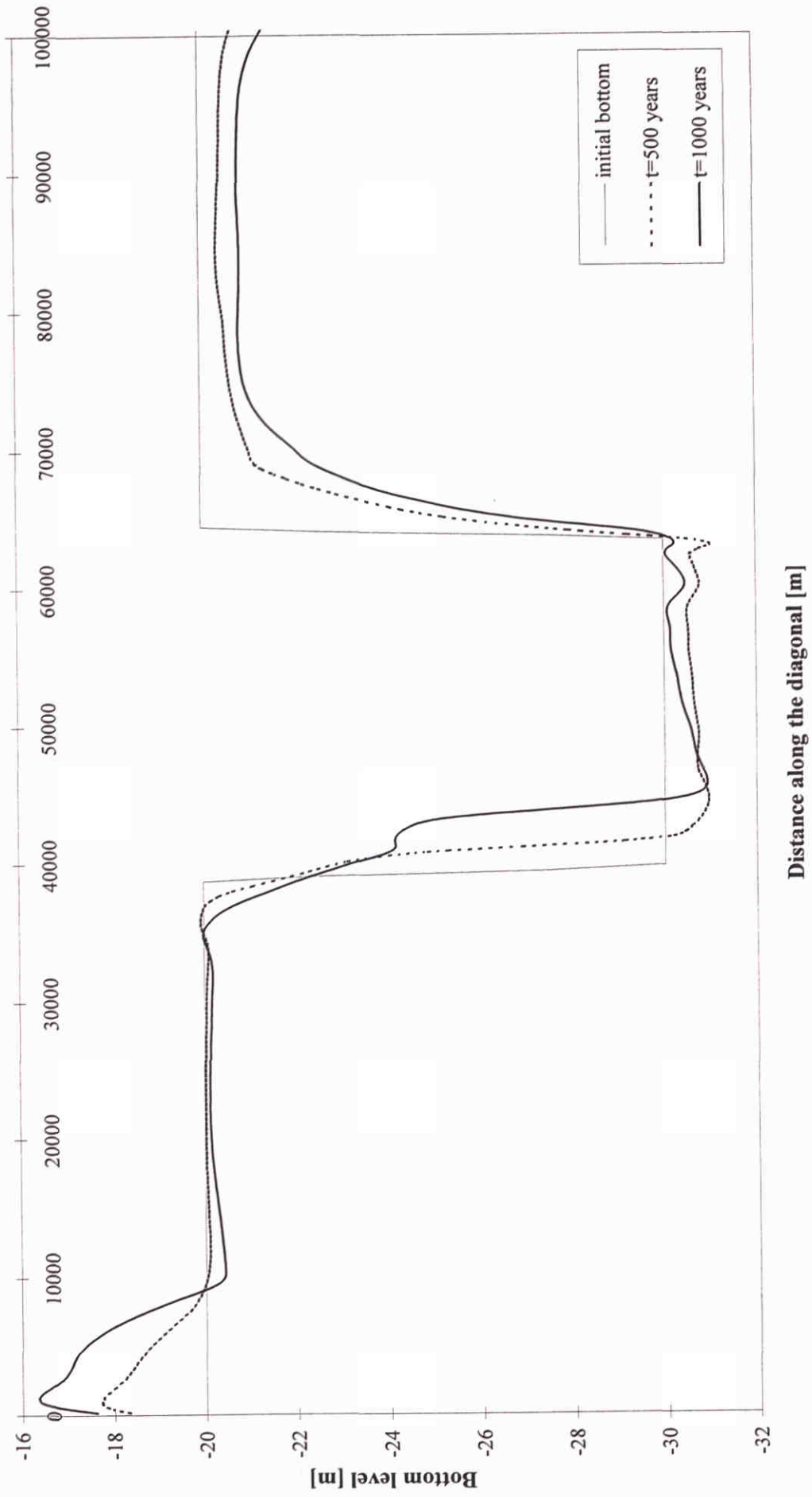
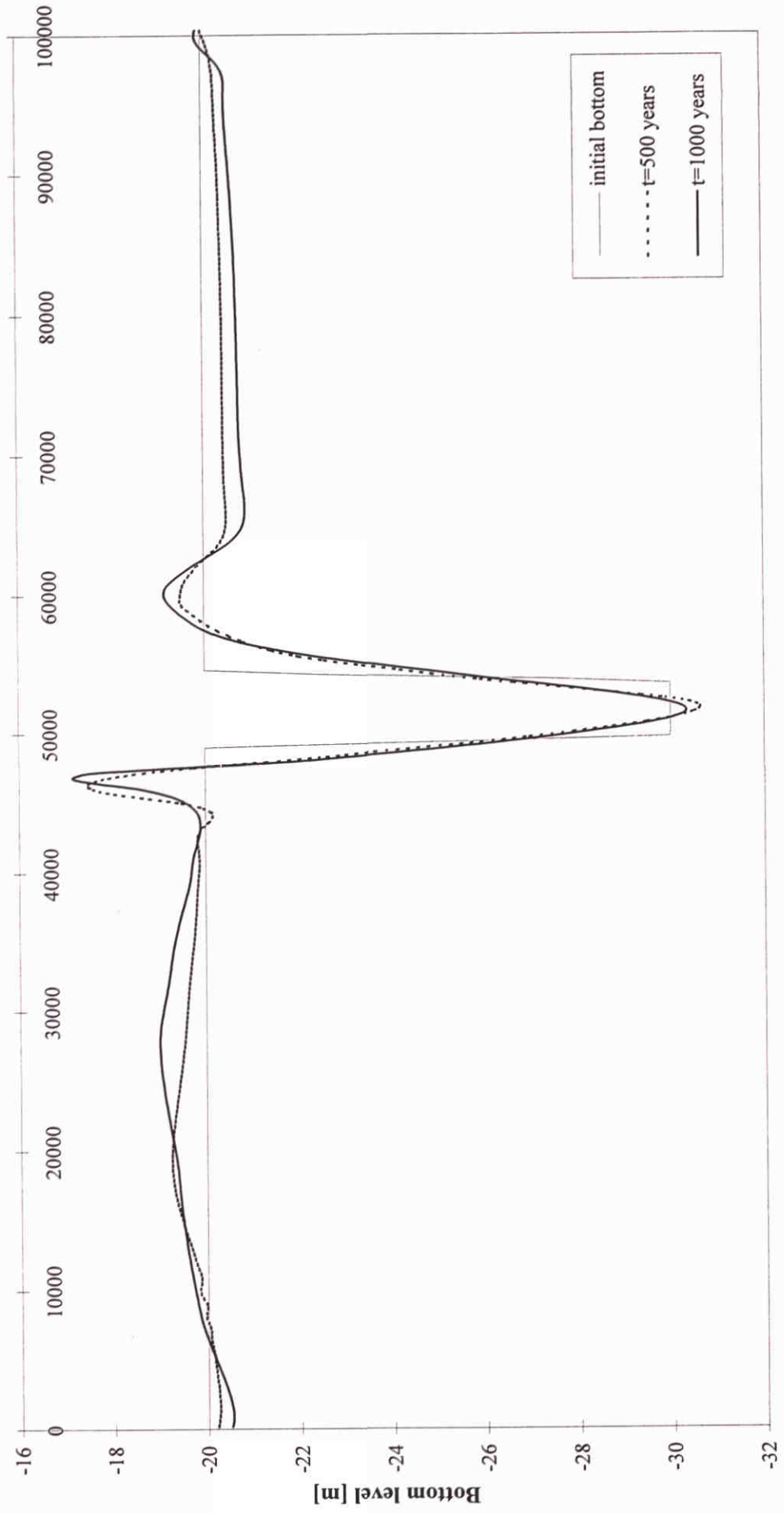
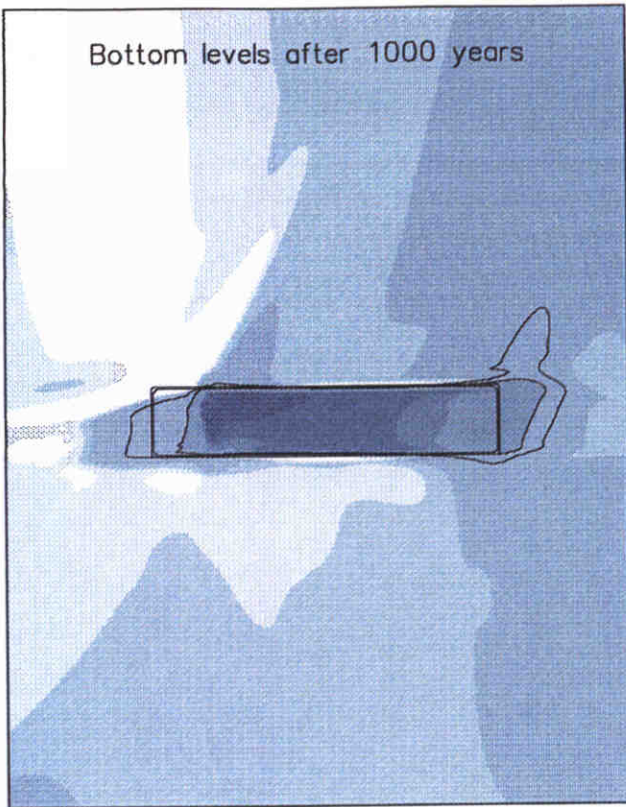


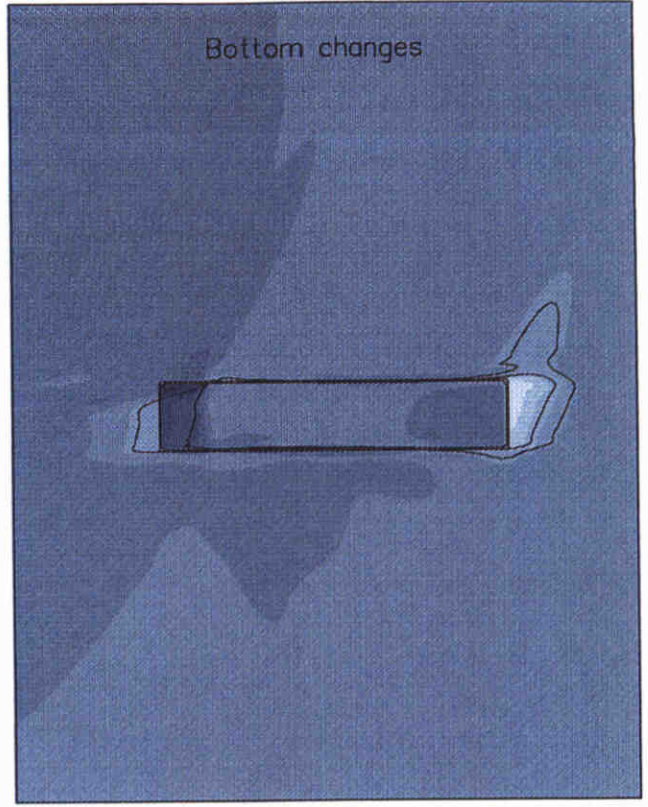
Figure 8.15c: Bottom levels in the center cross-section of a +45° rotated 25x5 km² sandpit



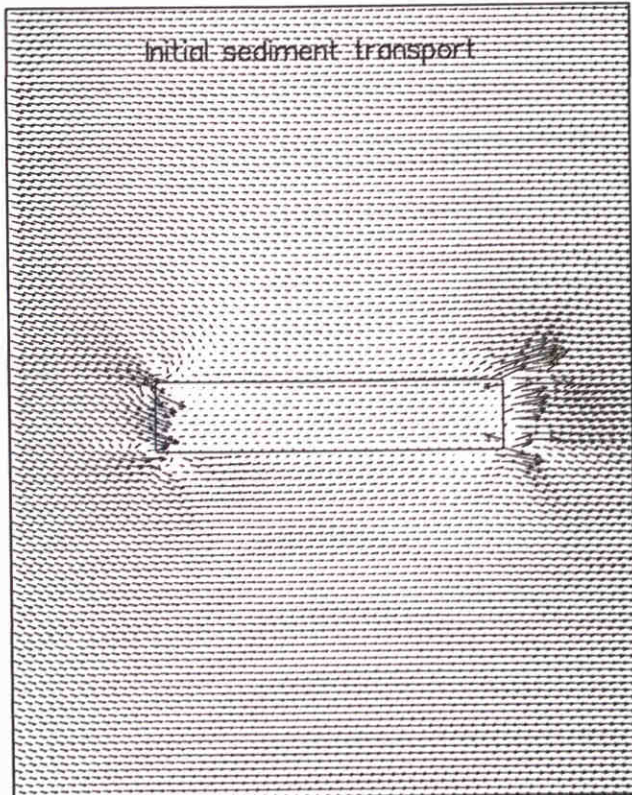
Distance along the diagonal [m]



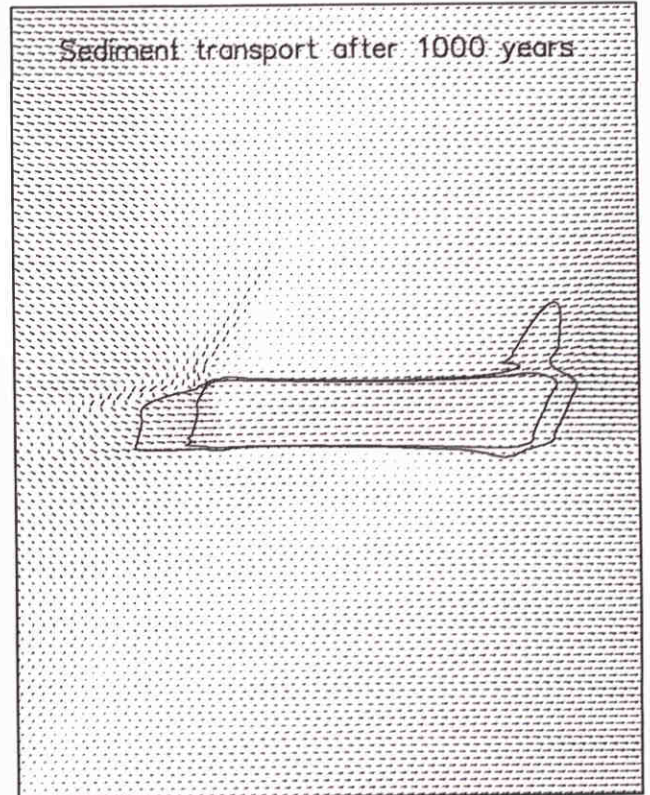
- <19.5
- <20.5
- <29.5
- <30.5
- <20.0
- <25.0
- <30.0
- >30.5



- <-10.0
- <-4.0
- <2.0
- <8.0
- <-2.0
- <4.0
- <10.0
- <-8.0
- <0.0
- <6.0
- >10.0



→ $2.0 \cdot 10^{-6} \text{ m}^2/\text{s}$



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

Parallel $25 \times 5 \text{ km}^2$ sandpit

Morphological results after 1000 years

Figure 8.16b: Bottom levels in the center longitudinal section of a parallel $25 \times 5 \text{ km}^2$ sandpit

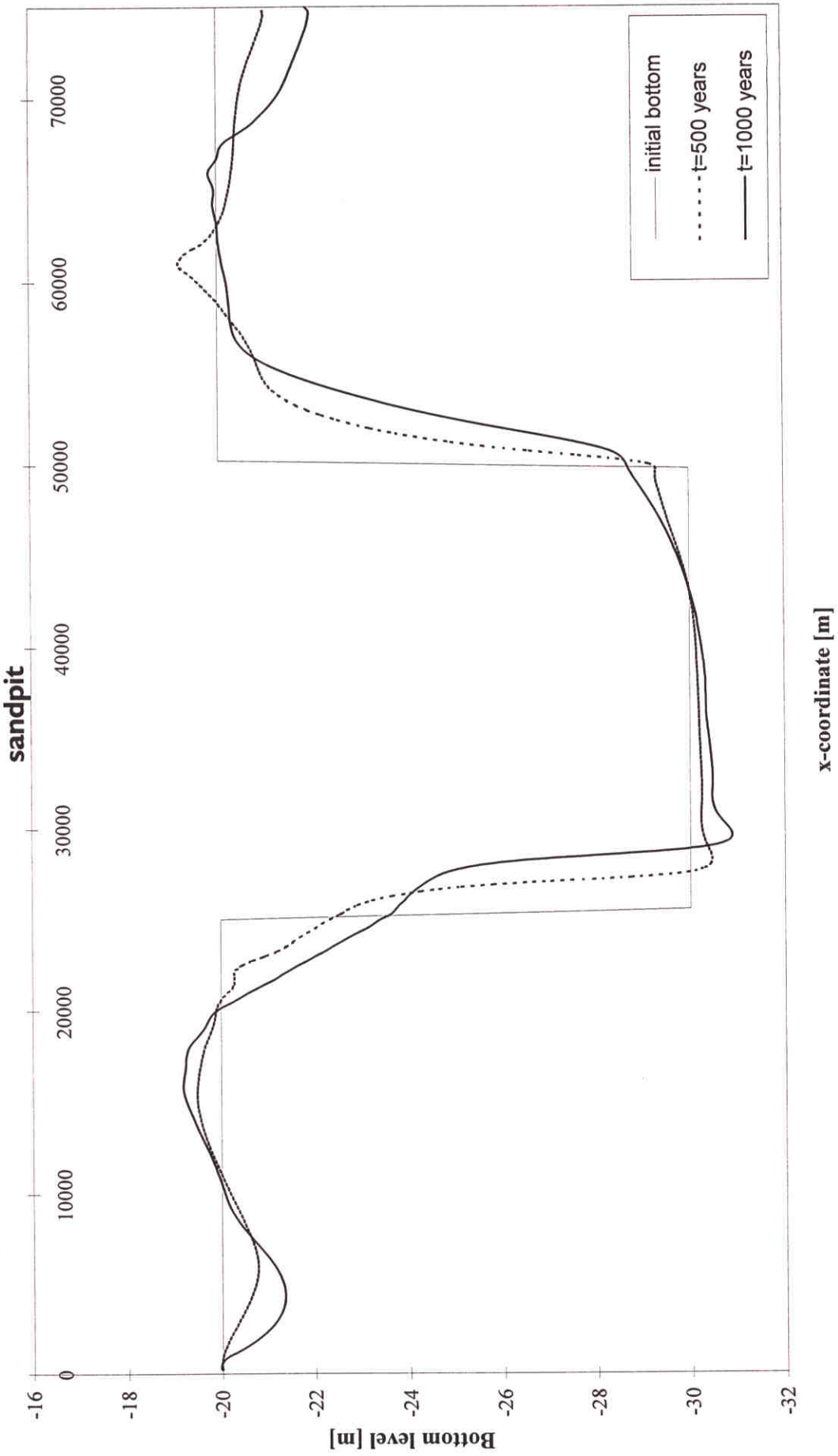
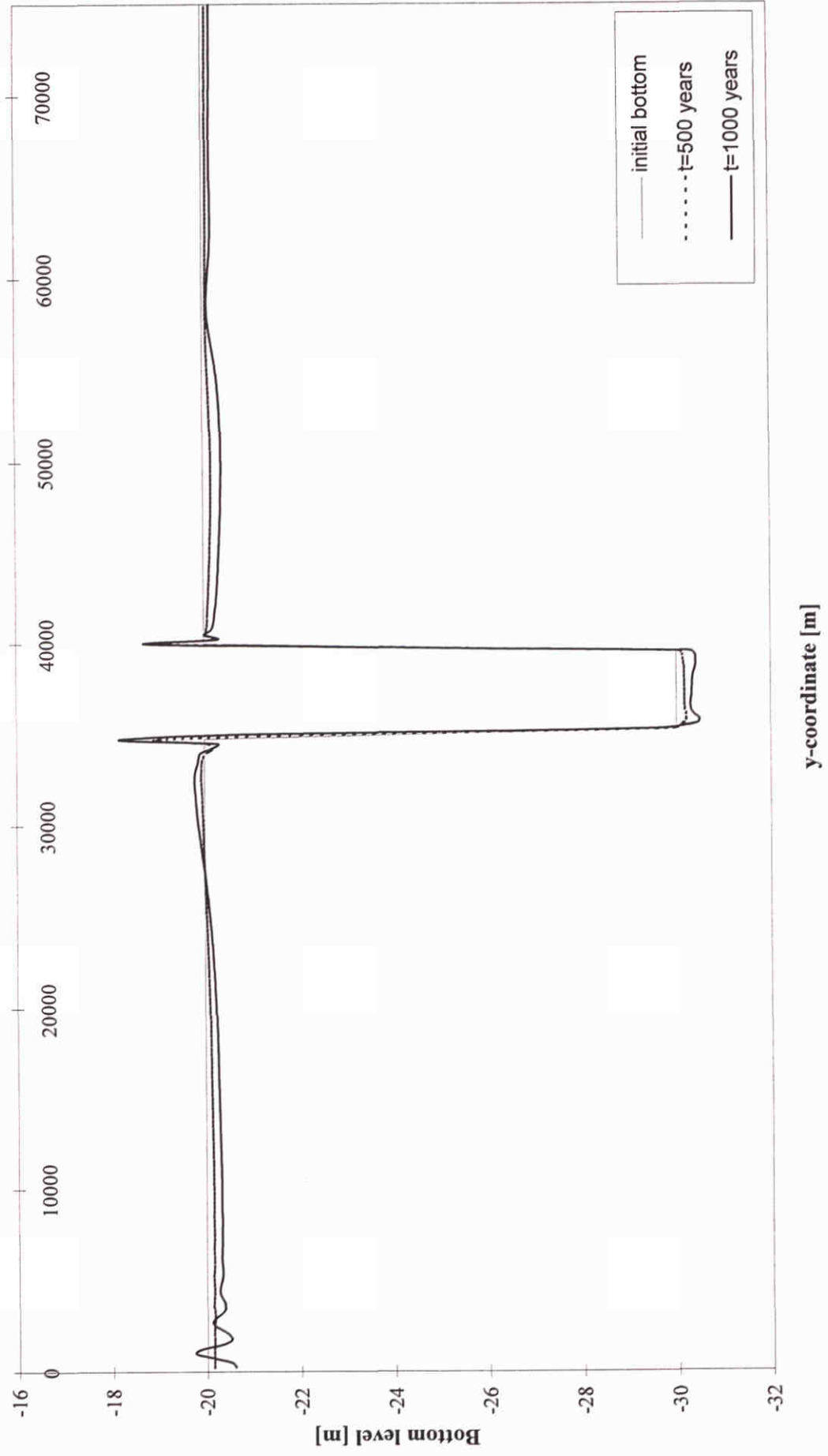
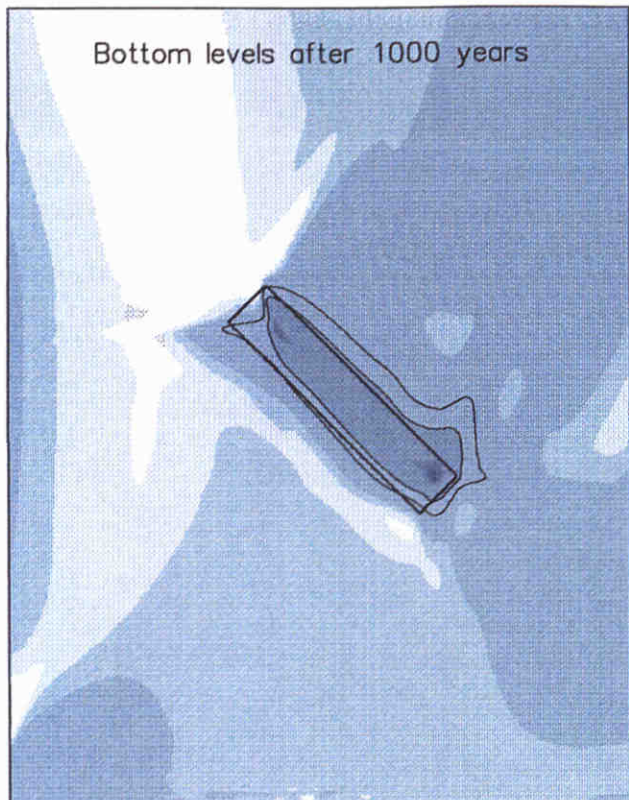


Figure 8.16c: Bottom levels in the center cross-section of a parallel $25 \times 5 \text{ km}^2$ sandpit

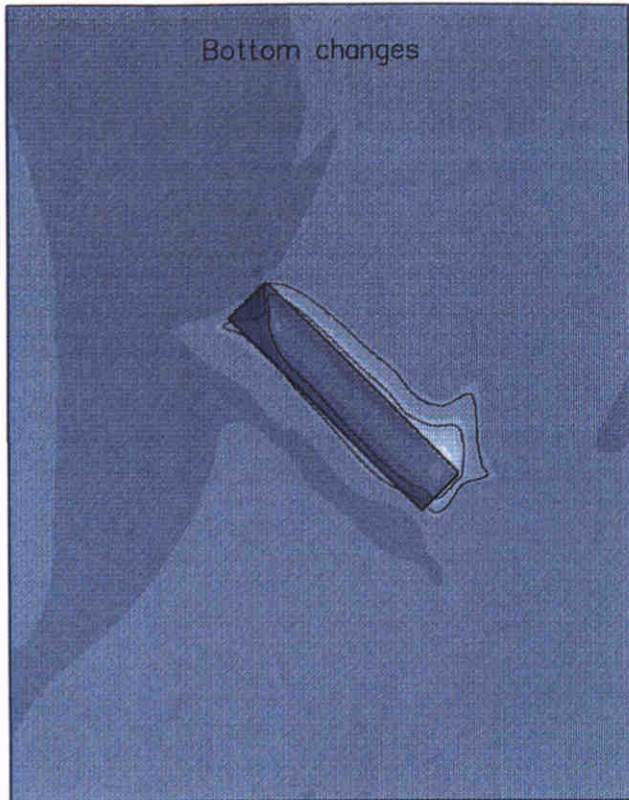


Bottom levels after 1000 years



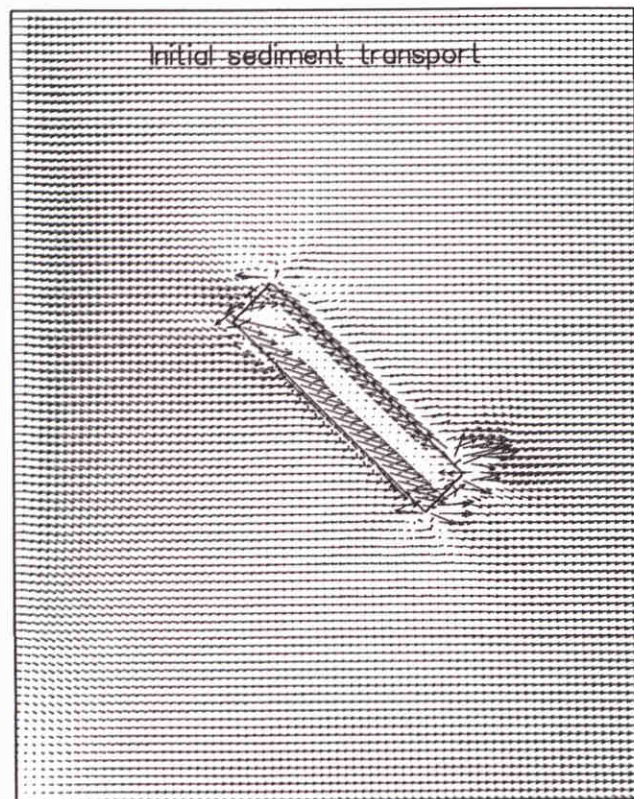
- <19.5
- <20.5
- <29.5
- <30.5
- <20.0
- <25.0
- <30.0
- >30.5

Bottom changes



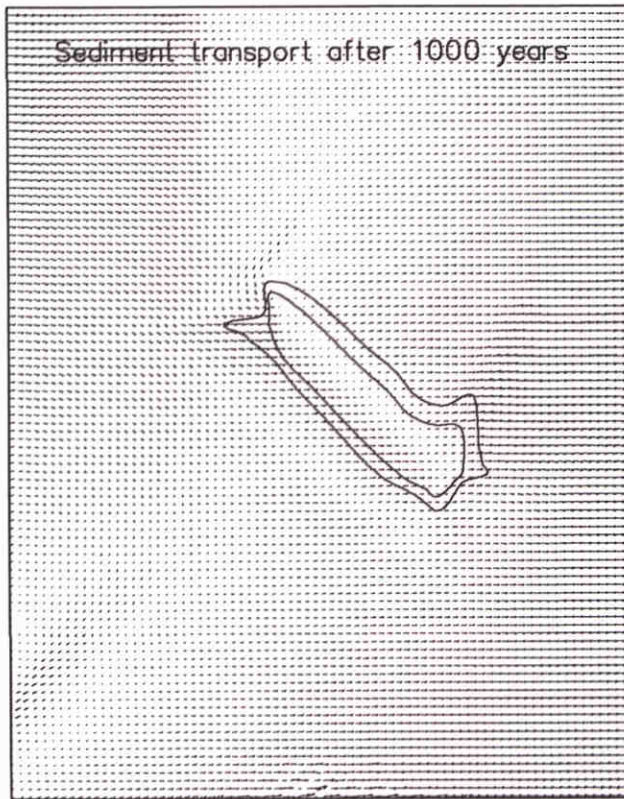
- <-10.0
- <-4.0
- <2.0
- <8.0
- <-8.0
- <-2.0
- <4.0
- <10.0
- <-6.0
- <0.0
- <6.0
- >10.0

Initial sediment transport



→ $2.0 \cdot 10^{-6} \text{ m}^2/\text{s}$

Sediment transport after 1000 years



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

-45 degrees rotated $25 \times 5 \text{ km}^2$ sandpit

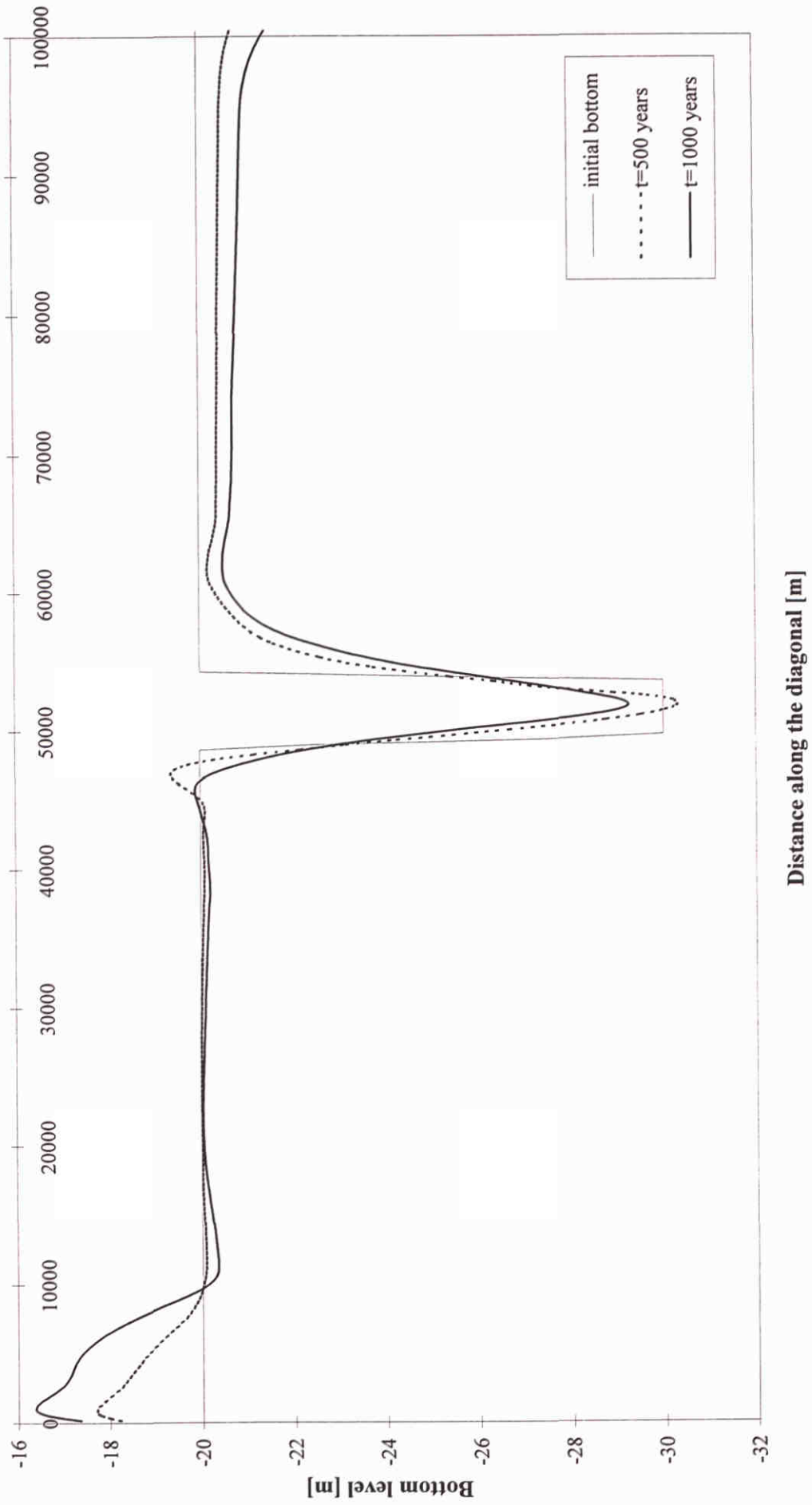
Morphological results after 1000 years

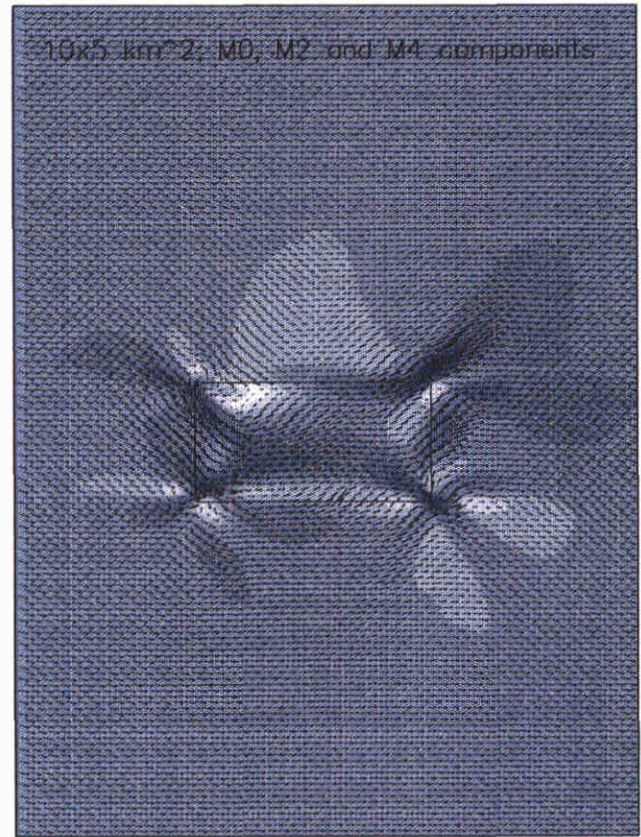
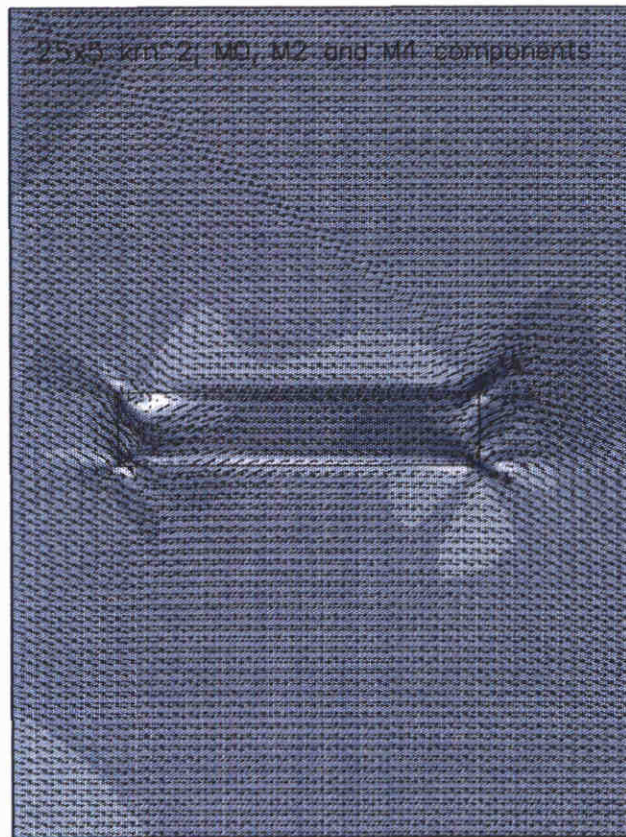
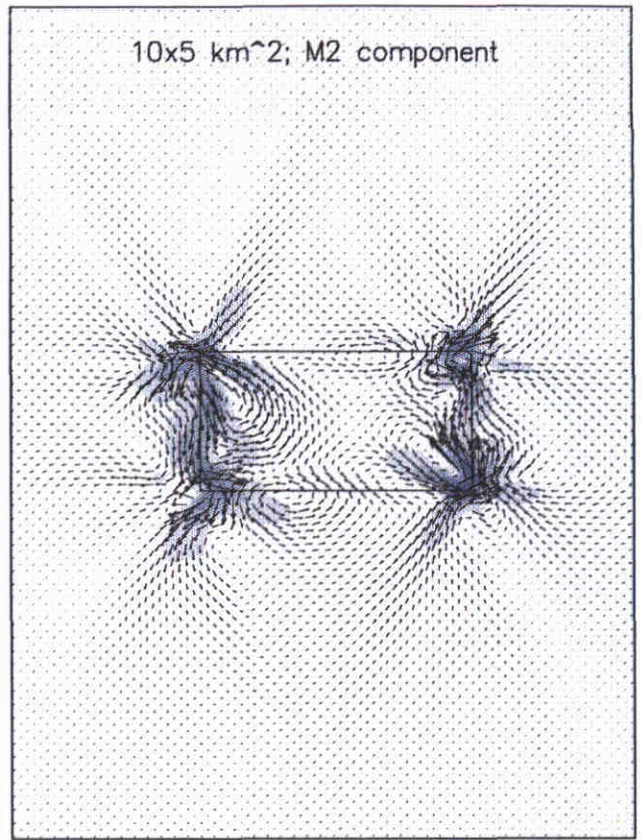
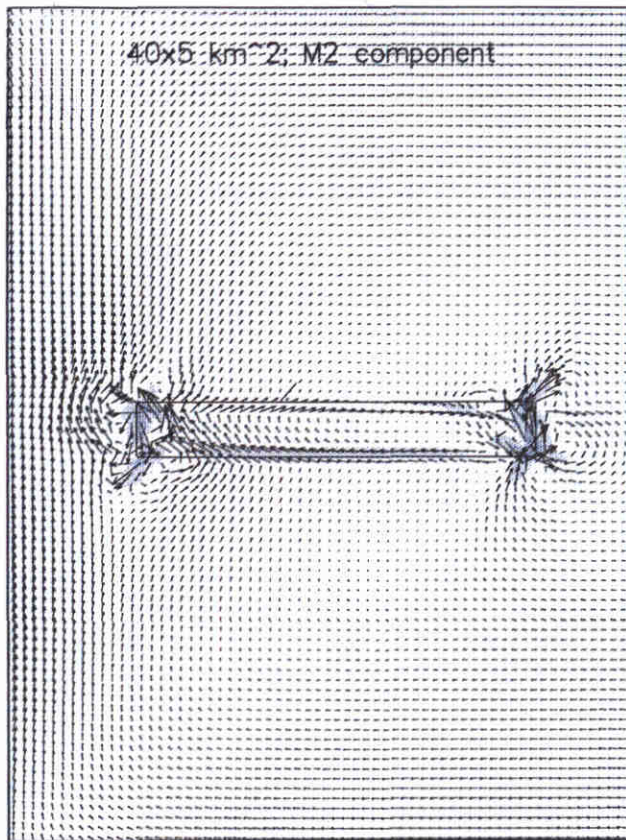
Figure 8.17b: Bottom levels in the center longitudinal section of a -45° rotated 25x5 km² sandpit



Distance along the diagonal [m]

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

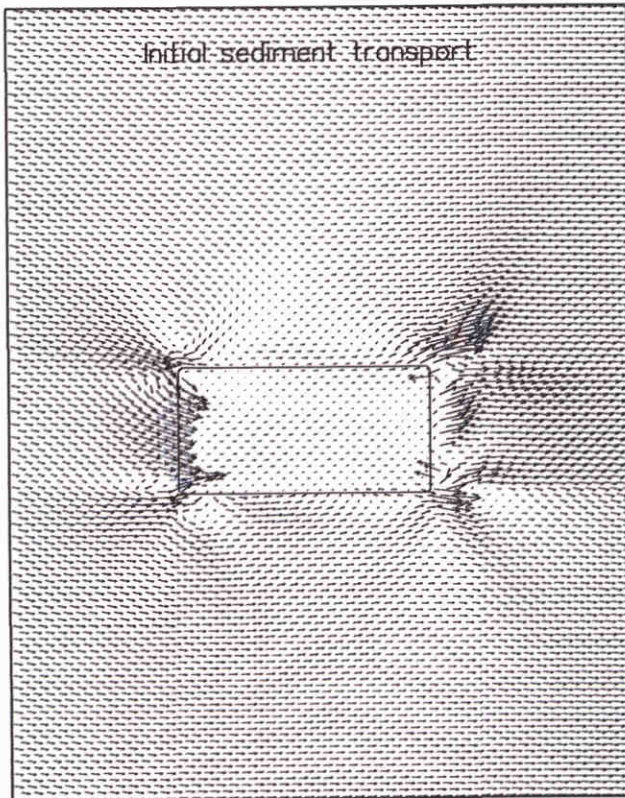
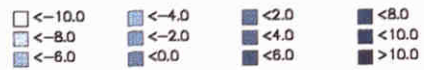
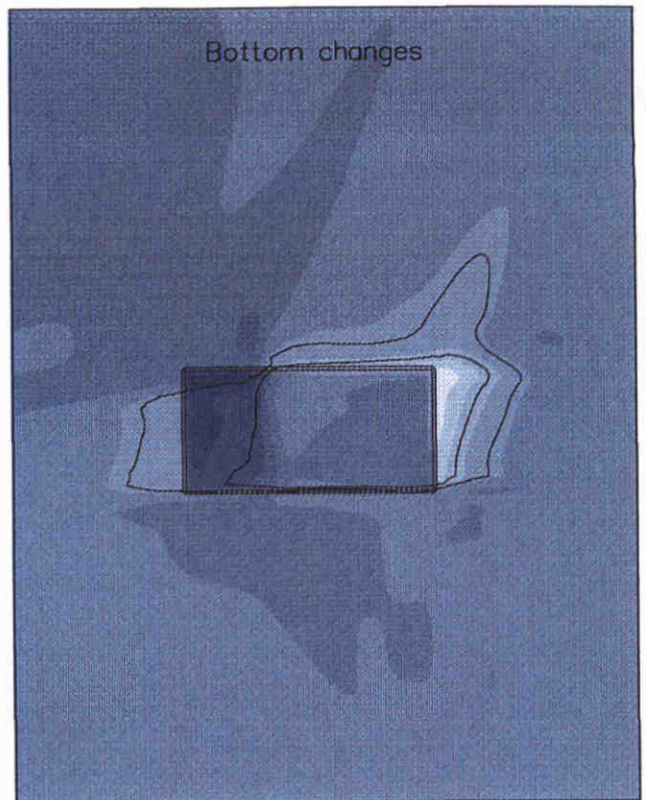
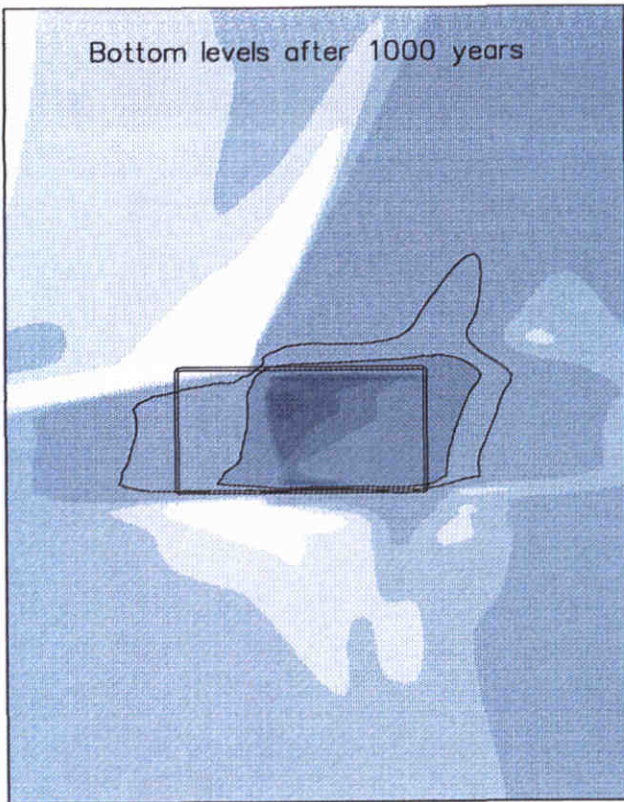




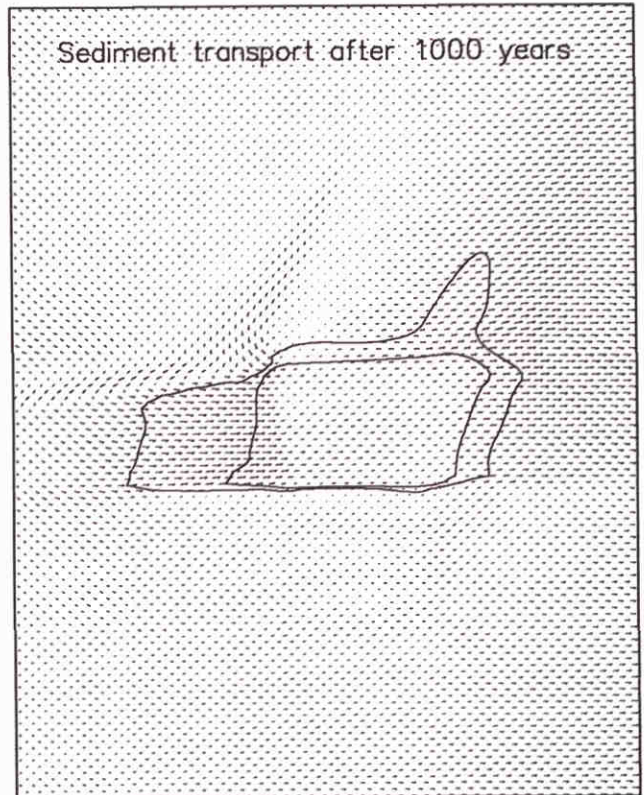
Tide-averaged current velocities [m/s]

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

Tidal boundary conditions including



→ $2.0 \cdot 10^{-6} \text{ m}^2/\text{s}$



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

Parallel $10 \times 5 \text{ km}^2$ sandpit

Morphological results after 1000 years

Figure 8.19b: Bottom levels in the longitudinal section of a parallel $10 \times 5 \text{ km}^2$ sandpit

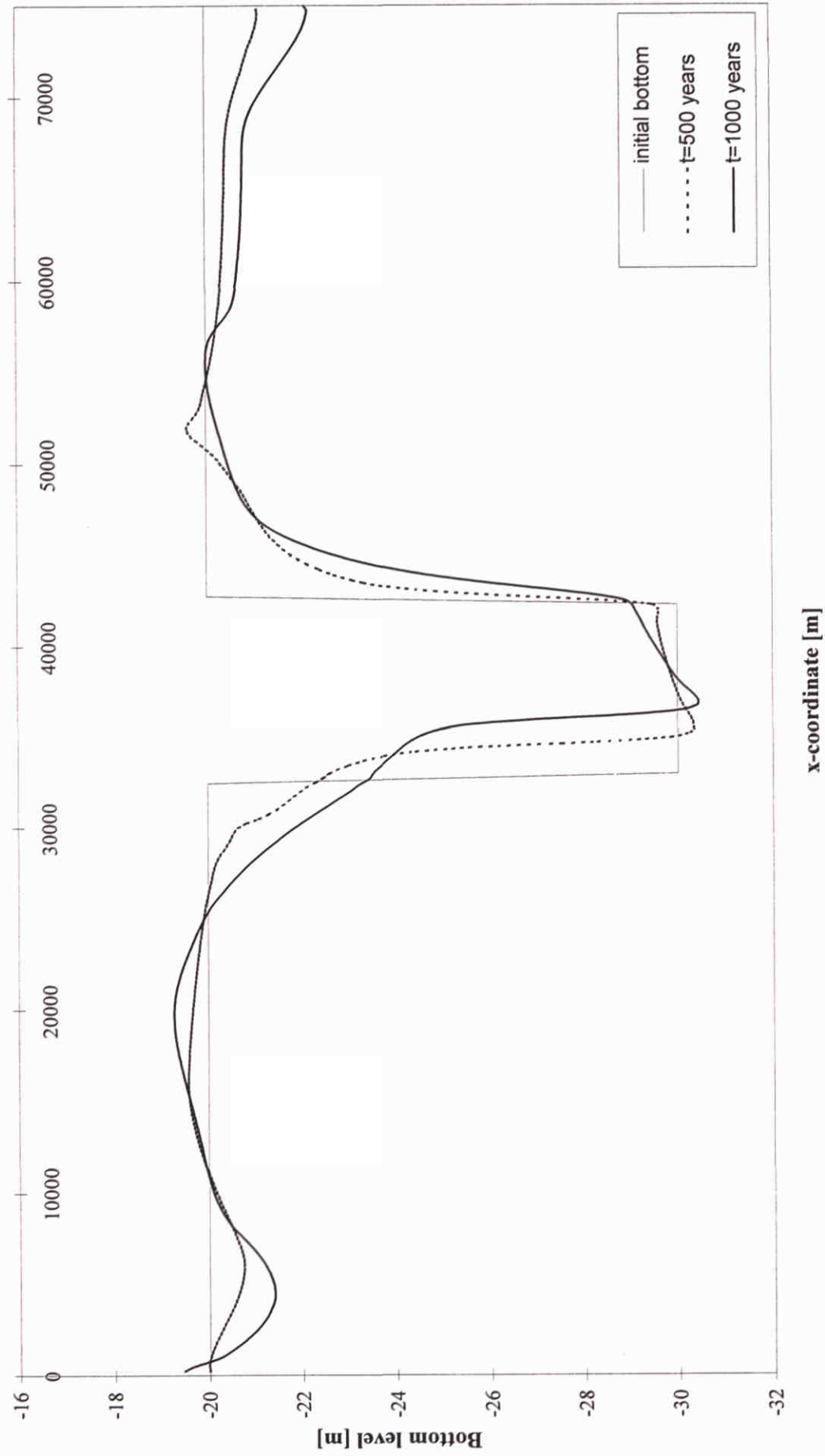
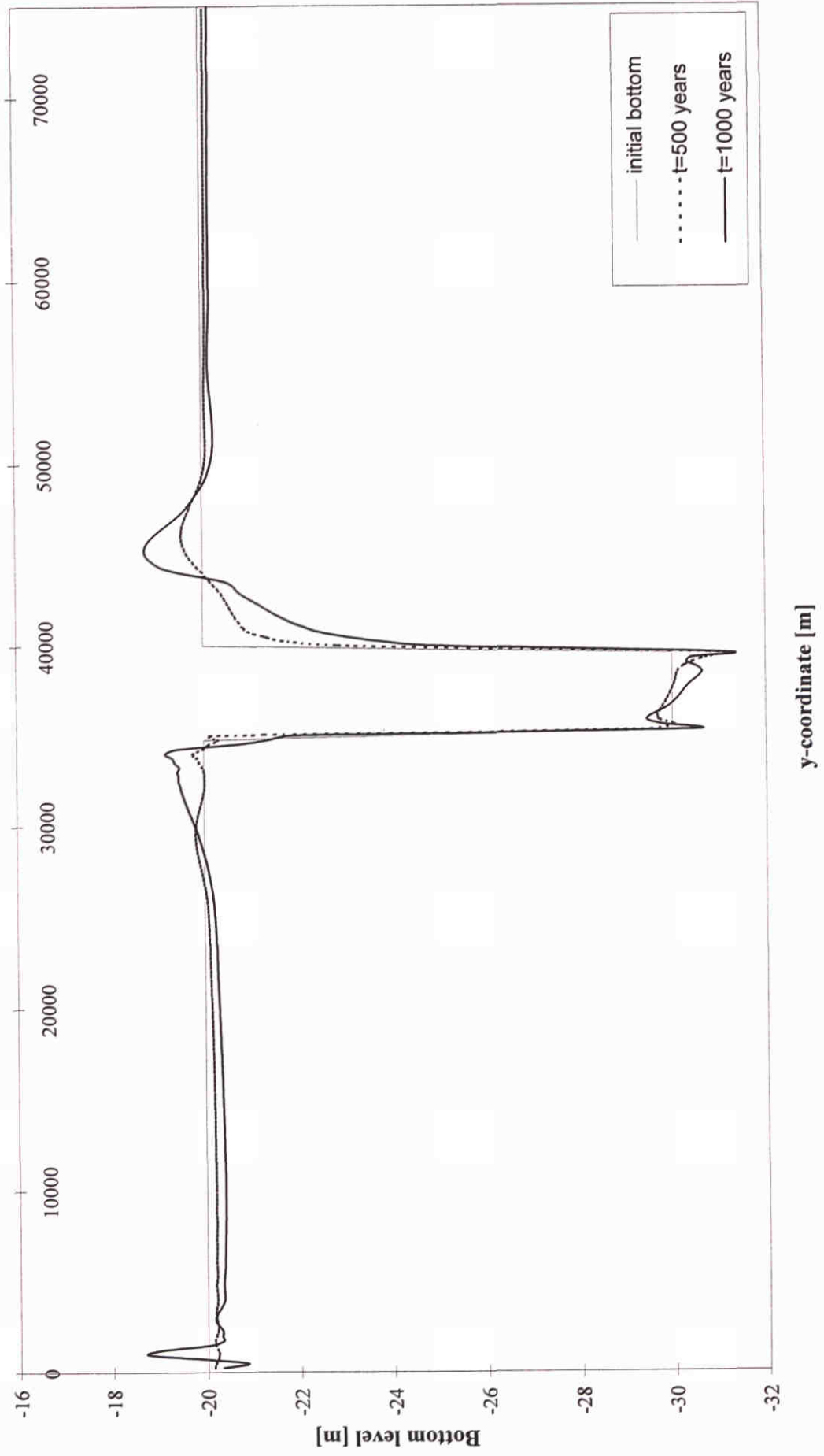
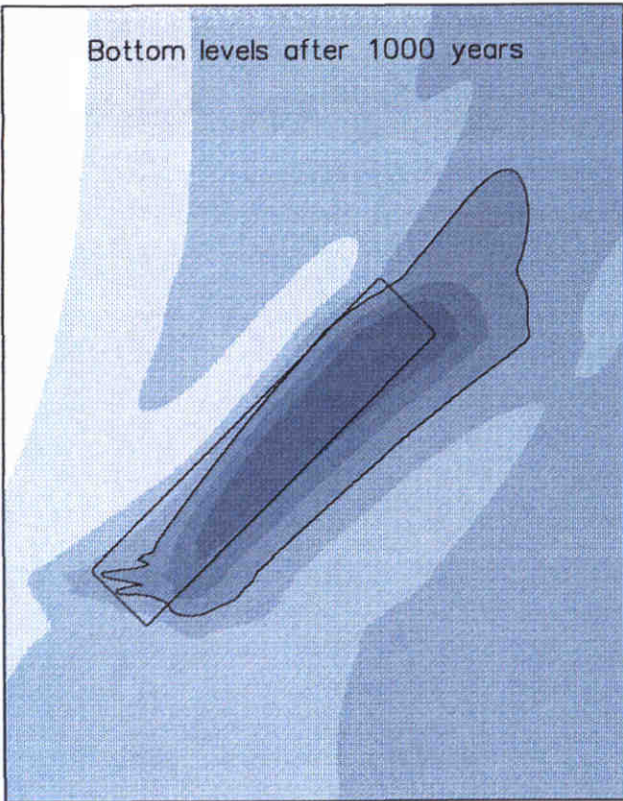


Figure 8.19c: Bottom levels in the center cross-section of a parallel $10 \times 5 \text{ km}^2$ sandpit

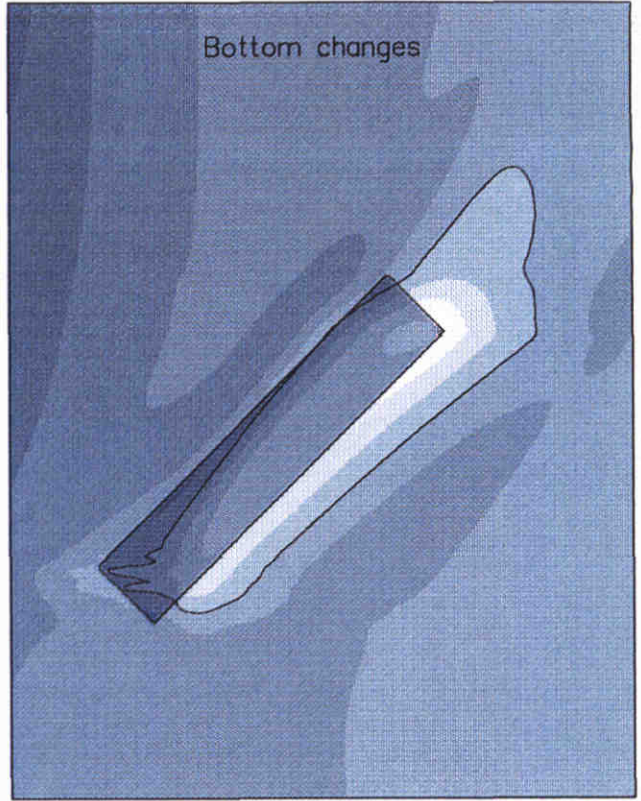


Bottom levels after 1000 years



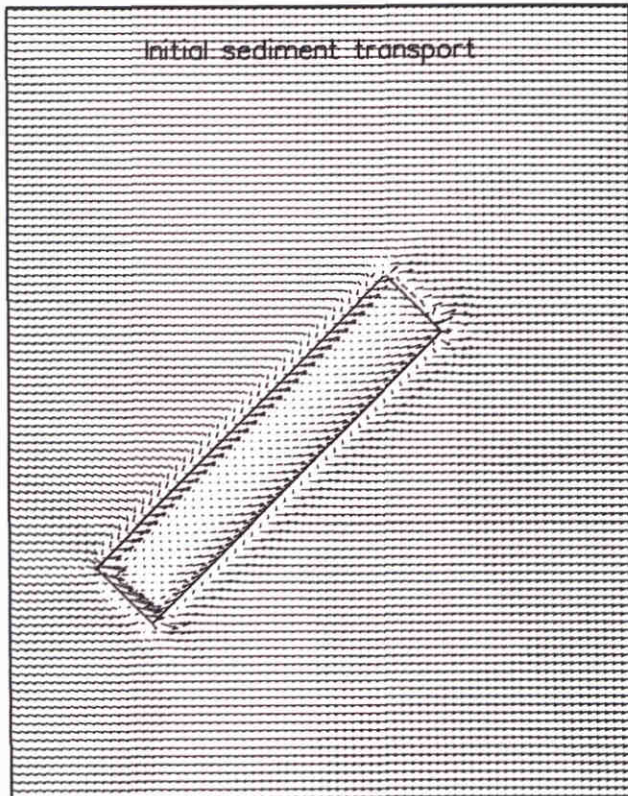
- <19.5
- <20.5
- <21.5
- >22.0
- <20.0
- <21.0
- <22.0

Bottom changes



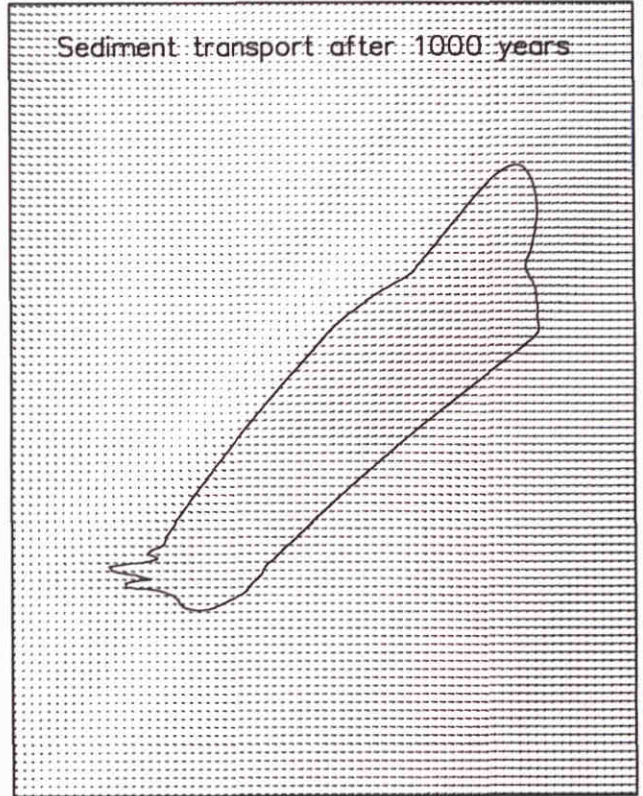
- <-2.0
- <-1.5
- <-1.0
- <-0.5
- <0.0
- <0.5
- <1.0
- >2.0

Initial sediment transport



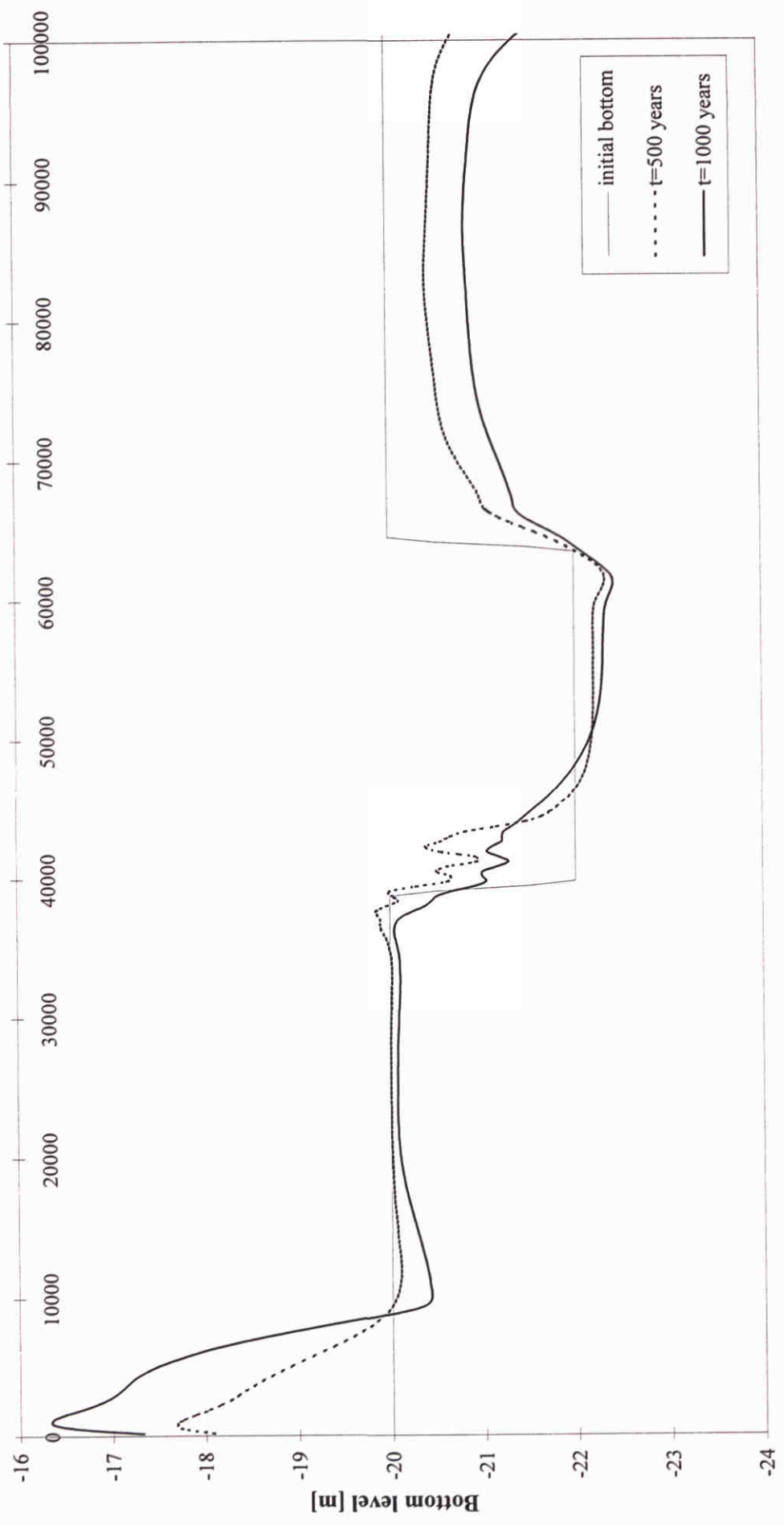
→ $2.0 \cdot 10^{-5} \text{ m}^2/\text{s}$

Sediment transport after 1000 years



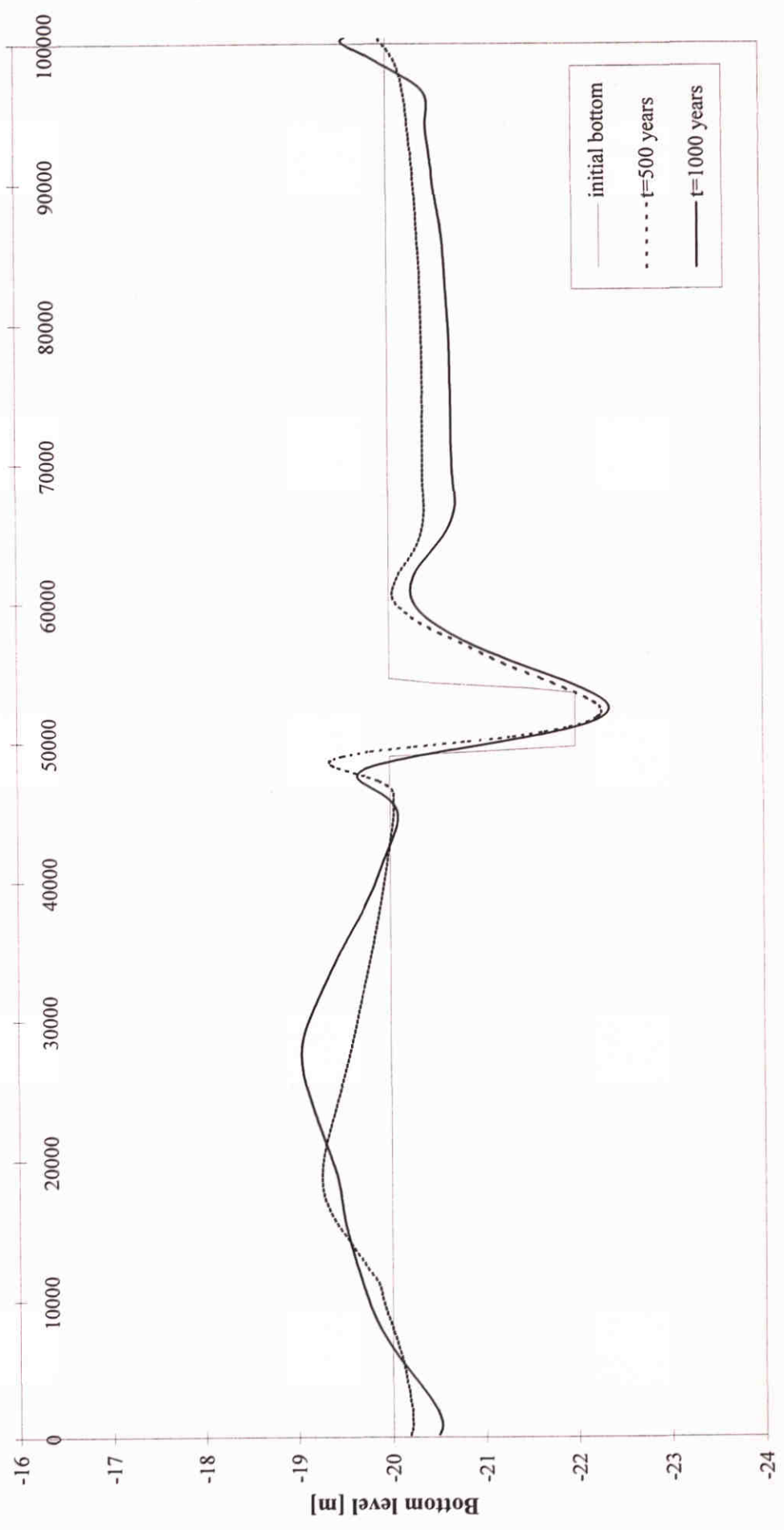
Bottom levels and changes [m]; sediment transport m^2/s
 +45 degrees rotated, 22m deep $25 \times 5 \text{ km}^2$ sandpit
 Morphological results after 1000 years

Figure 8.20b: Bottom levels in the center longitudinal section of a +45° rotated 25x5 km², 22m deep sandpit

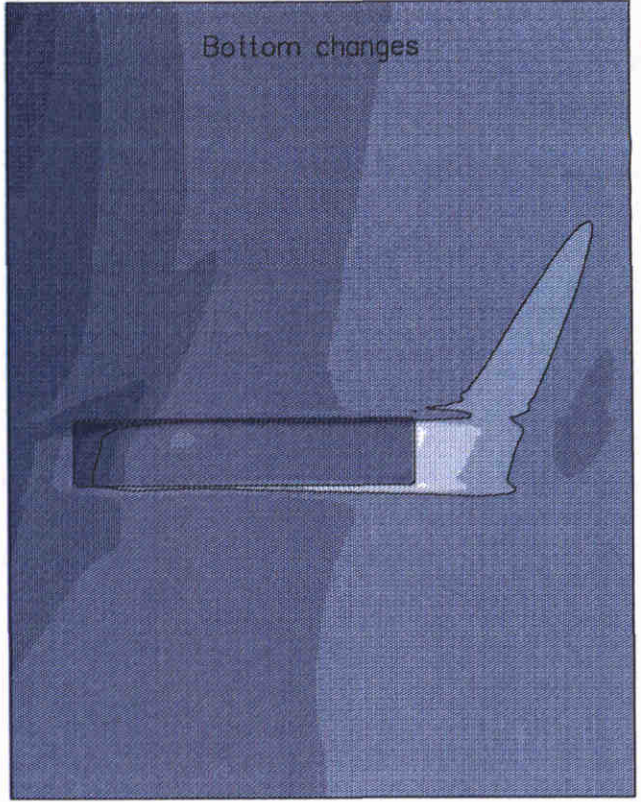
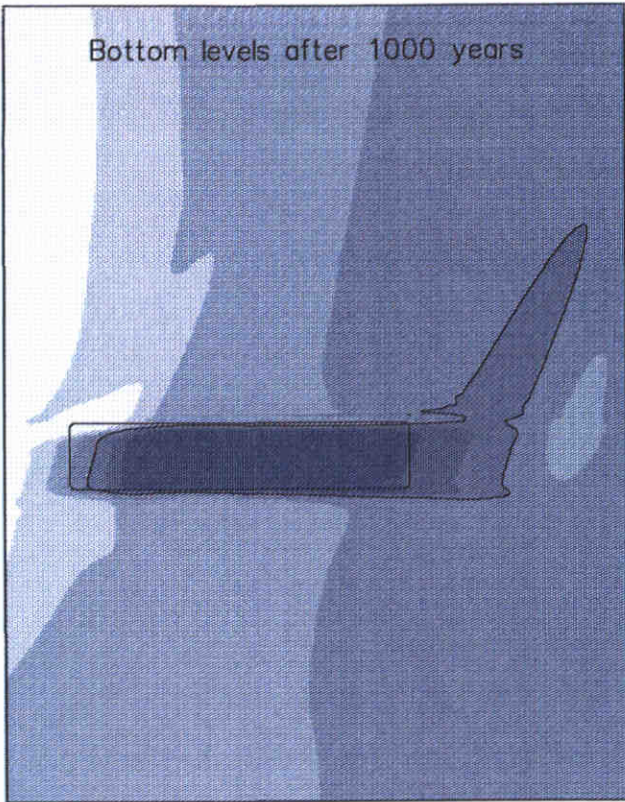


Distance along the diagonal [m]

Figure 8.20c: Bottom levels in the center cross-section of a +45° rotated, 22 m deep 25x5 km² sandpit

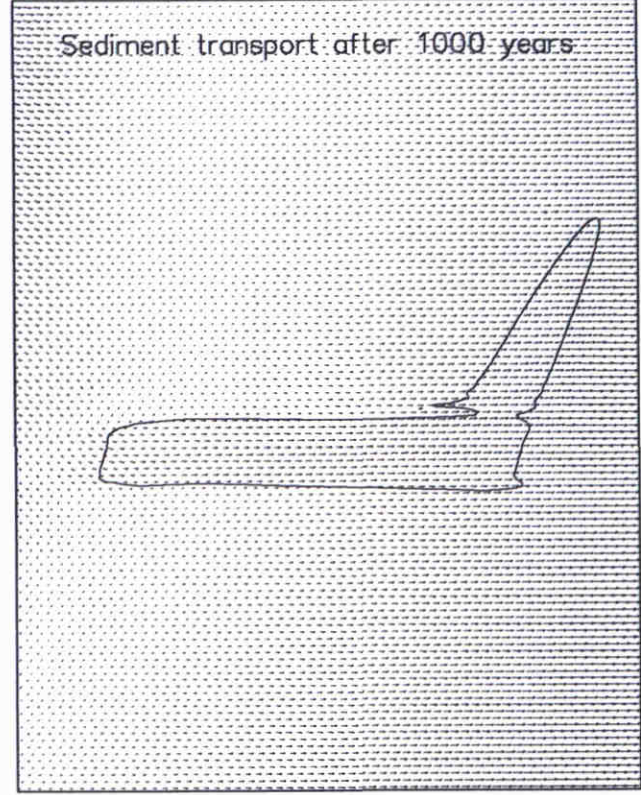
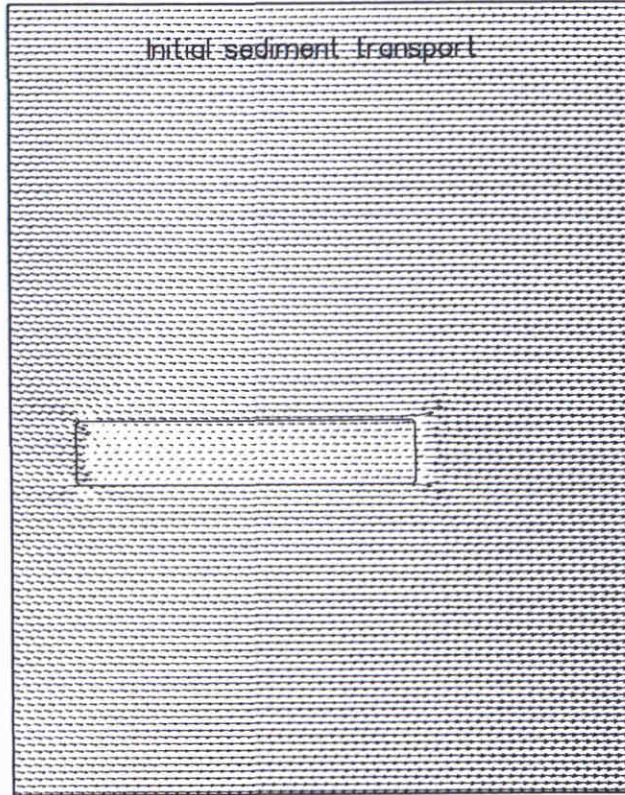


Distance along the diagonal [m]



- <19.5
- <20.0
- <20.5
- <21.0
- <21.5
- <22.0
- >22.0

- <-2.0
- <-1.5
- <-1.0
- <-0.5
- <0.0
- <0.5
- <1.0
- <1.5
- <2.0
- >2.0



→ $2.0 \cdot 10^{-6} \text{ m}^2/\text{s}$

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

Parallel, 22 m deep $25 \times 5 \text{ km}^2$

Morphological results

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

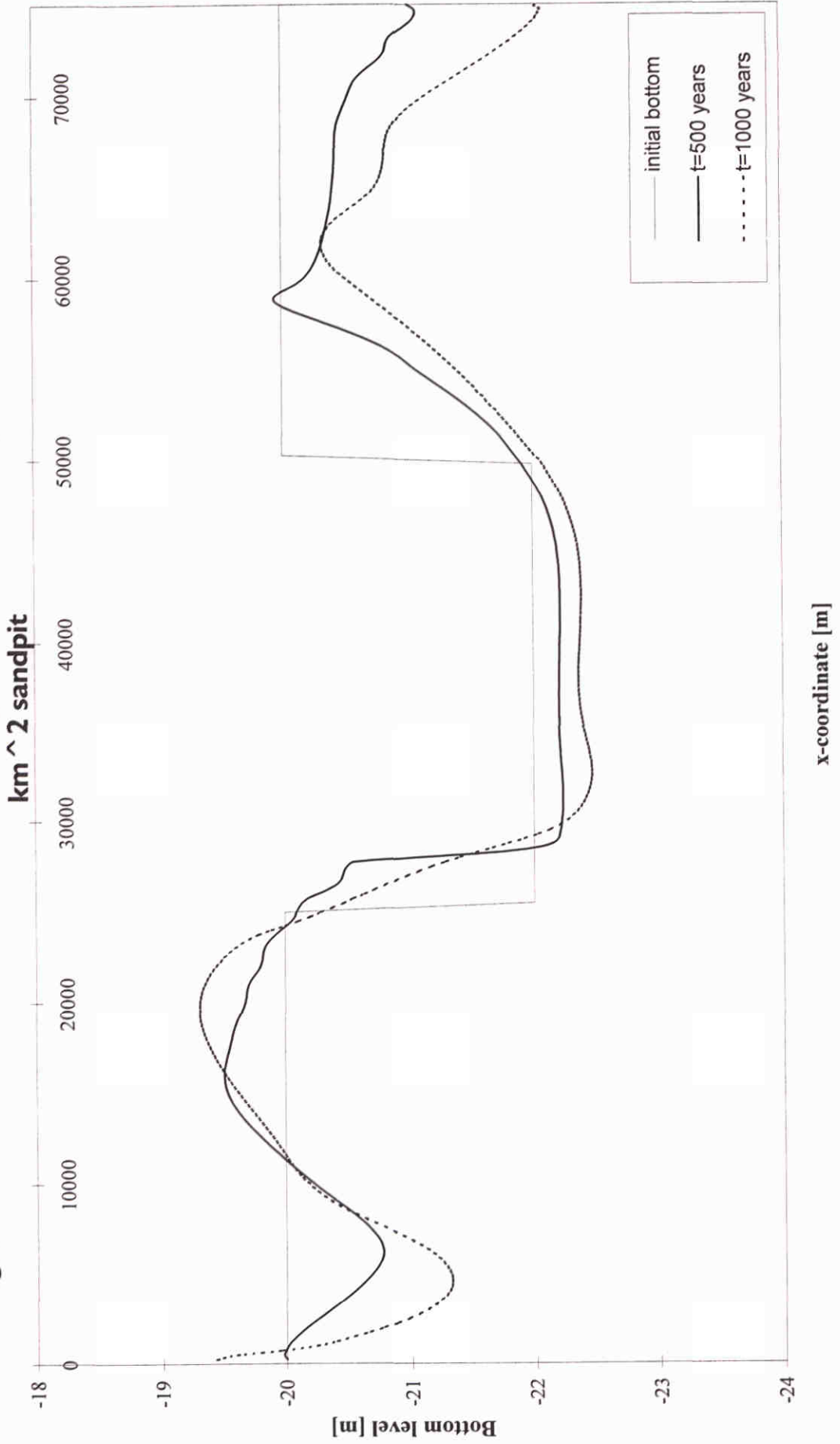
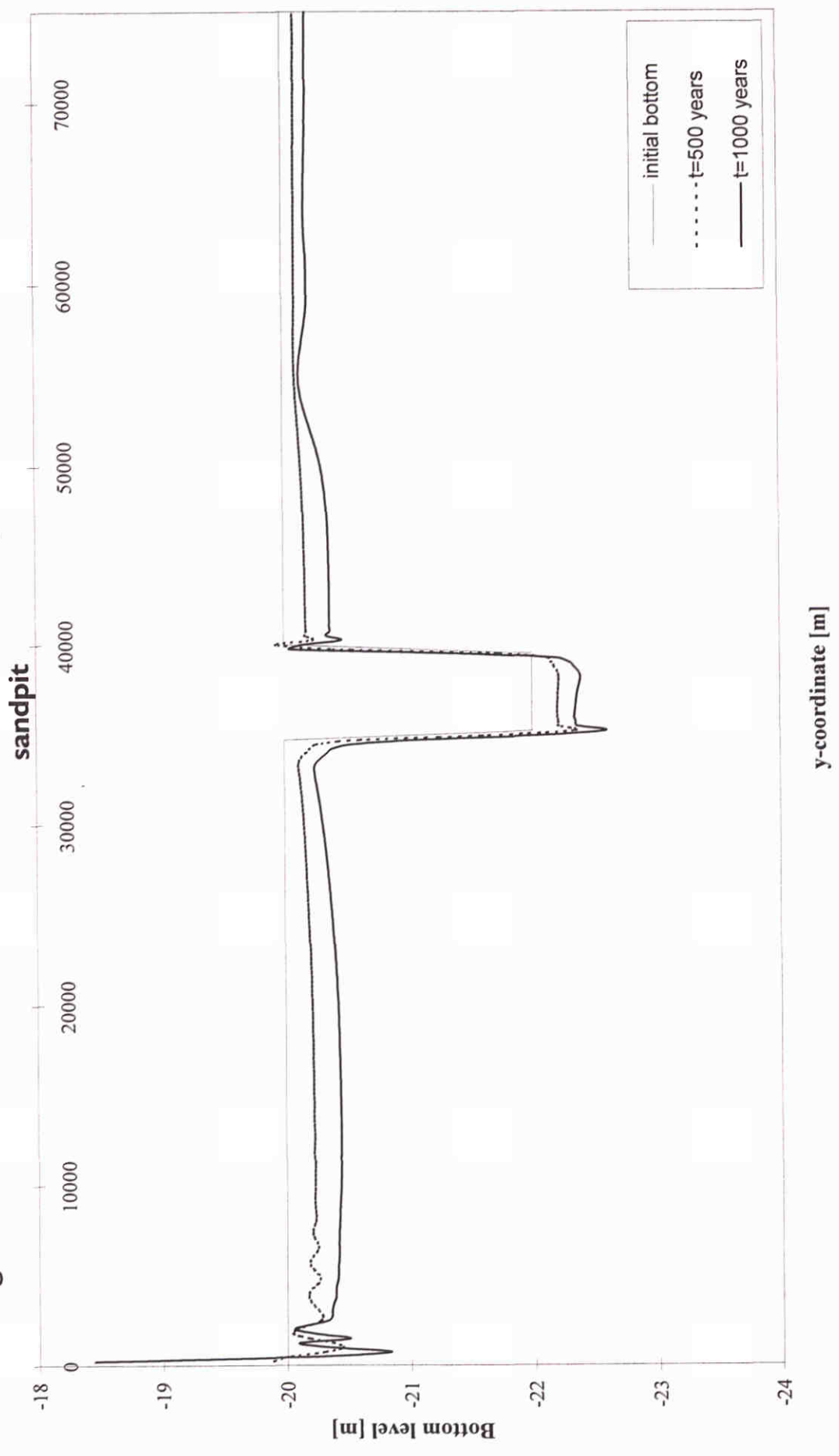
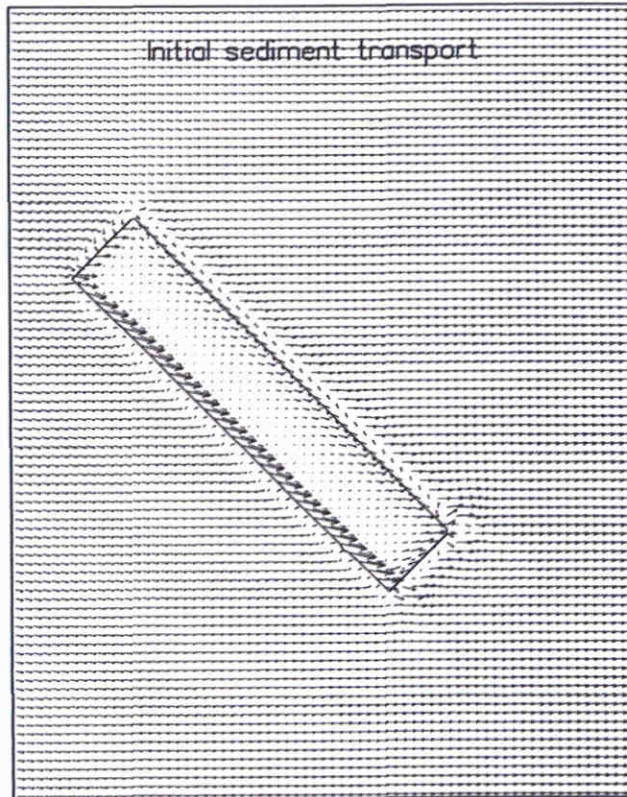
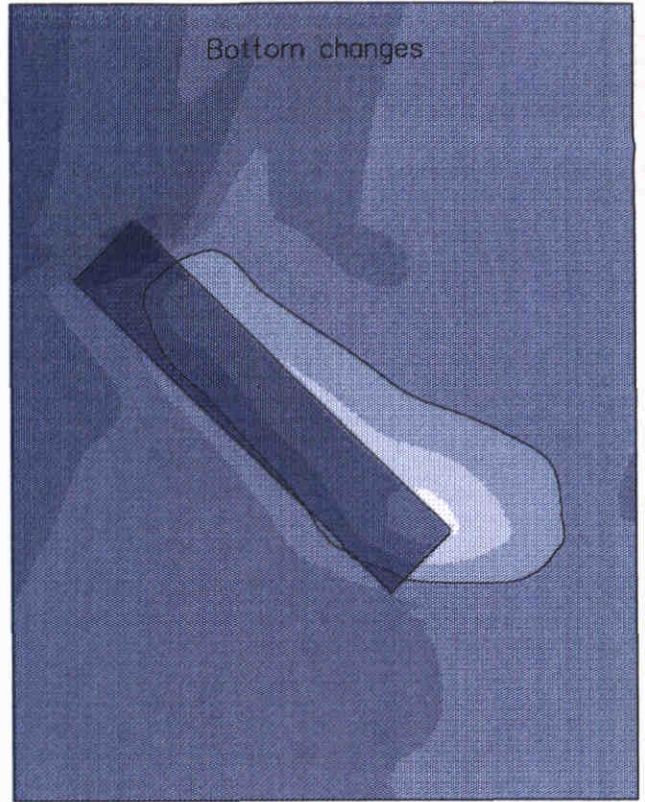
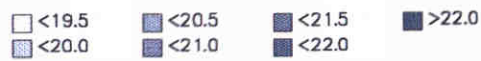
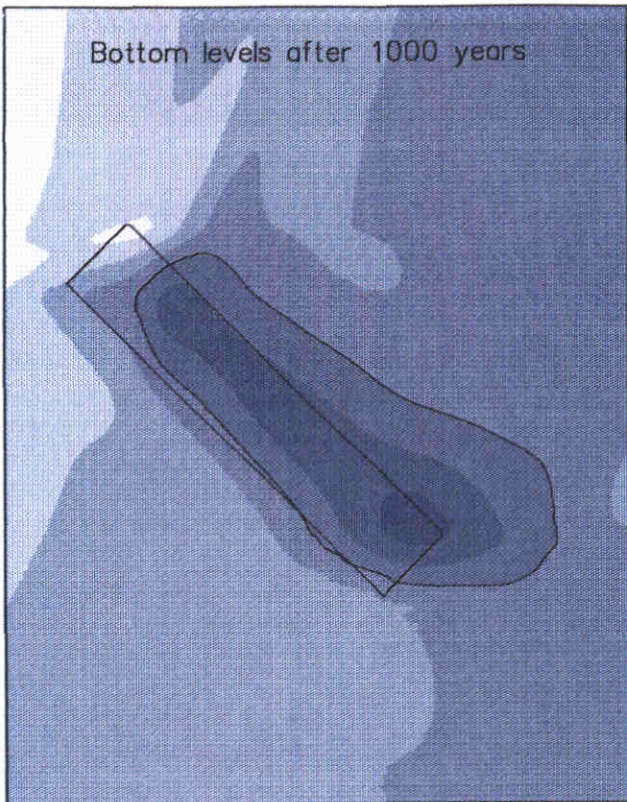
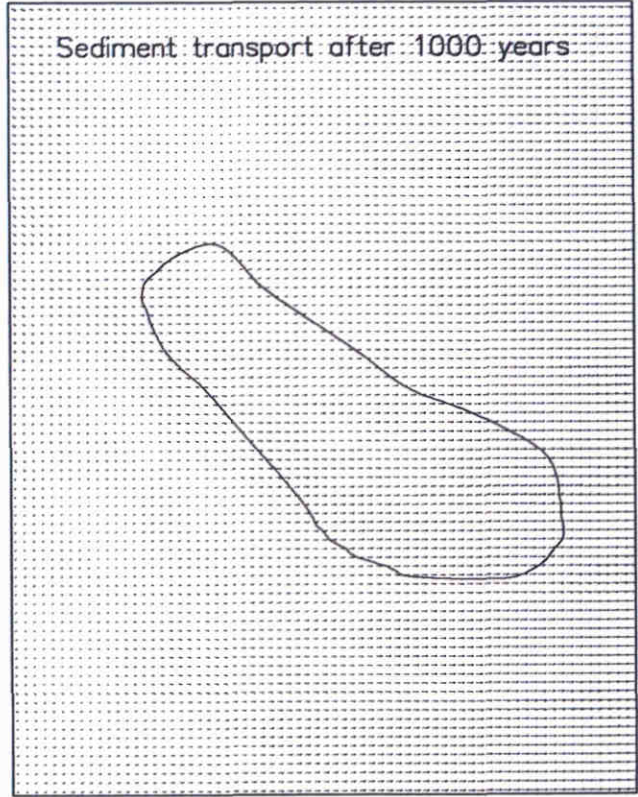


Figure 8.21 c: Bottom levels in the center cross-section of a parallel, 22 m deep, 25x5 km² sandpit





→ $2.0 \cdot 10^{-8} \text{ m}^2/\text{s}$



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

-45 degrees rotated, 22m deep 25x5 km² sandpit

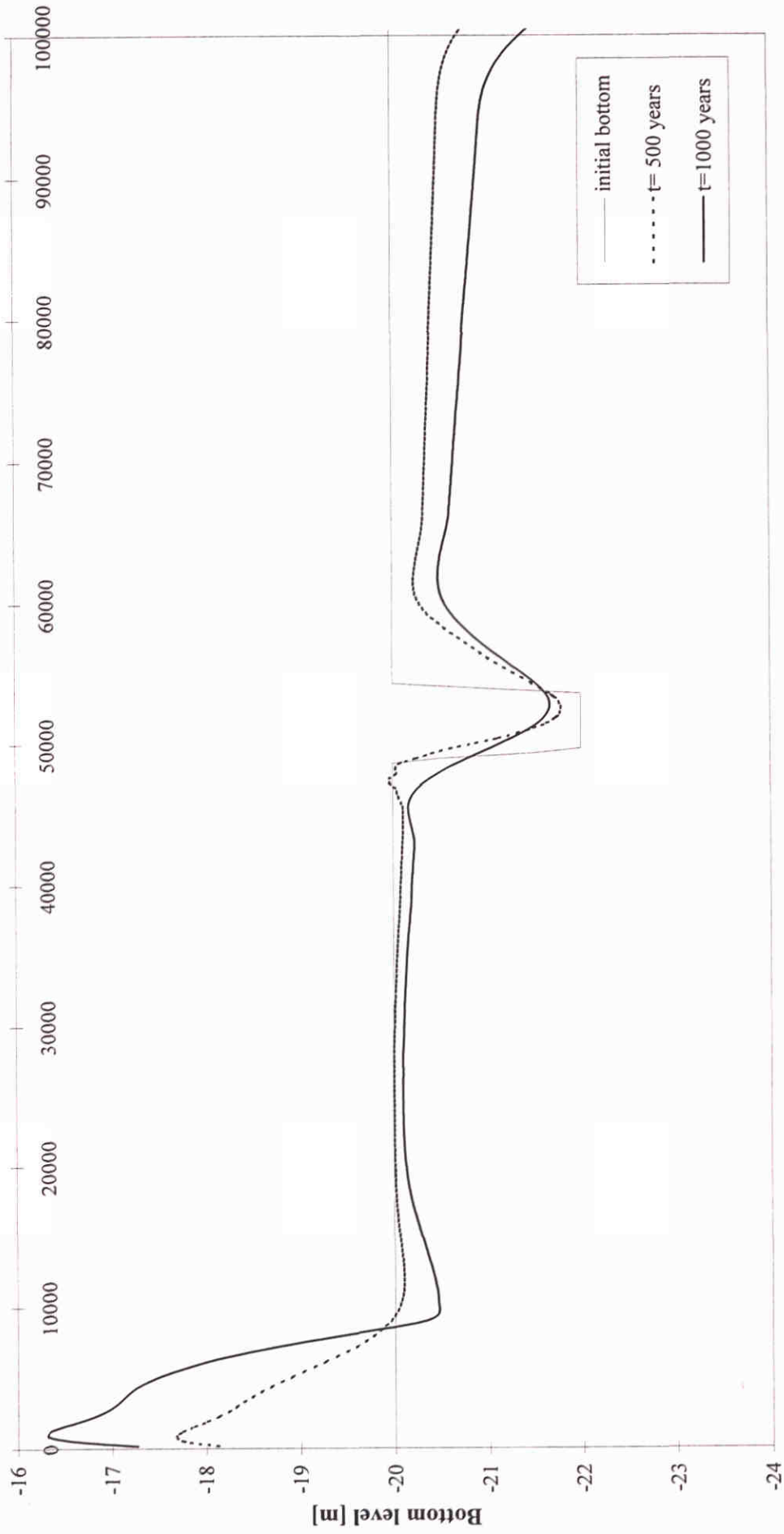
Morphological results after 1000 years

Figure 8.22b: Bottom levels in the longitudinal section of a +45° rotated, 22 m deep 25x5 km² sandpit

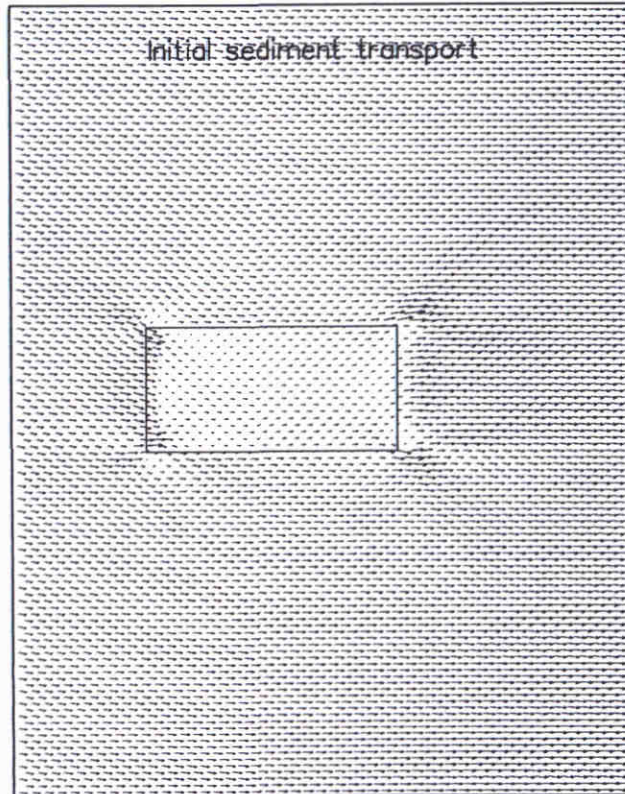
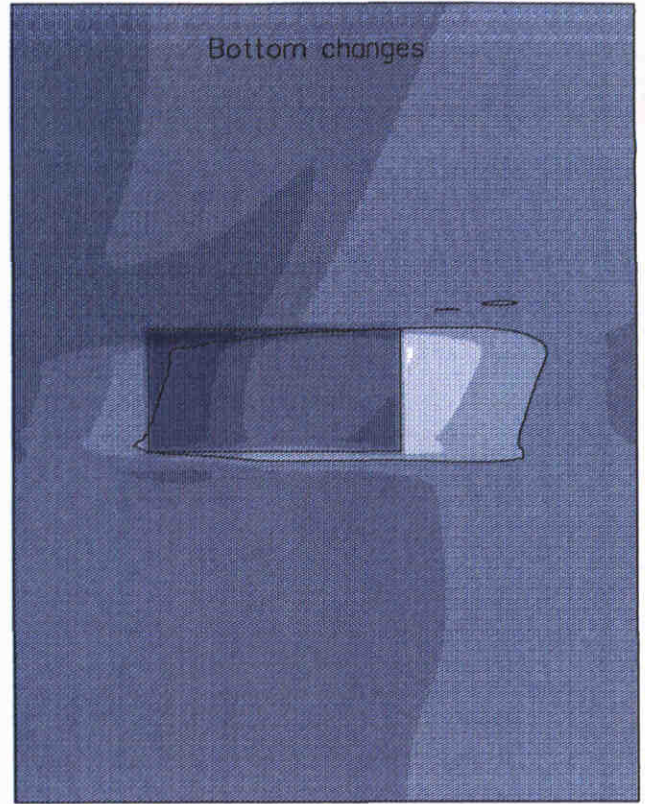
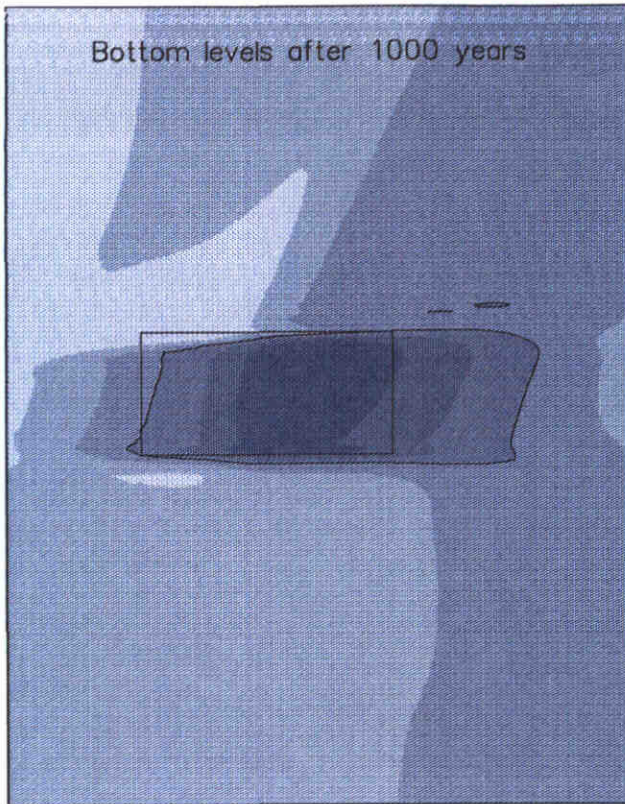


Distance along the diagonal [m]

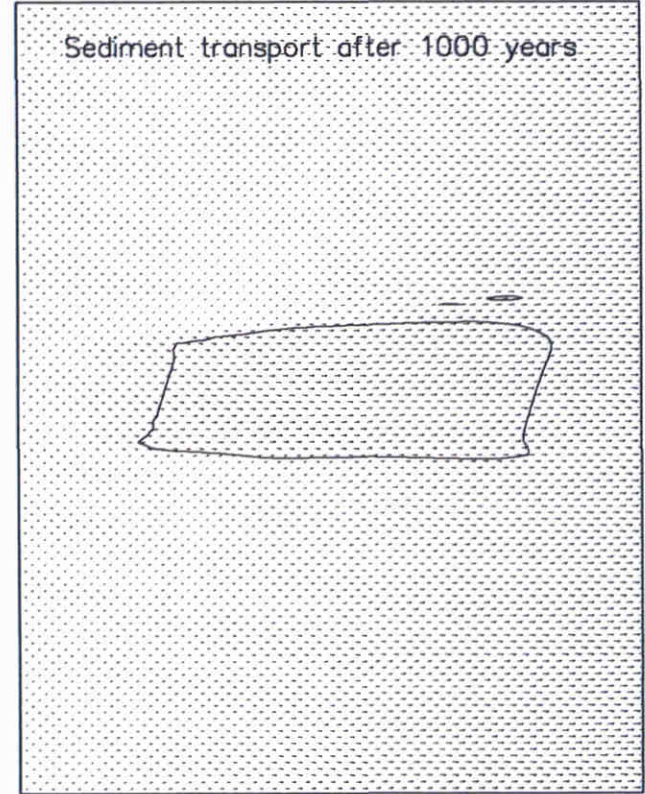
Figure 8.22c: Bottom levels in the center cross-section of a -45° rotated, 22m deep 25x5 km² sandpit



Distance along the diagonal [m]



→ $2.0 \cdot 10^{-5} \text{ m}^2/\text{s}$

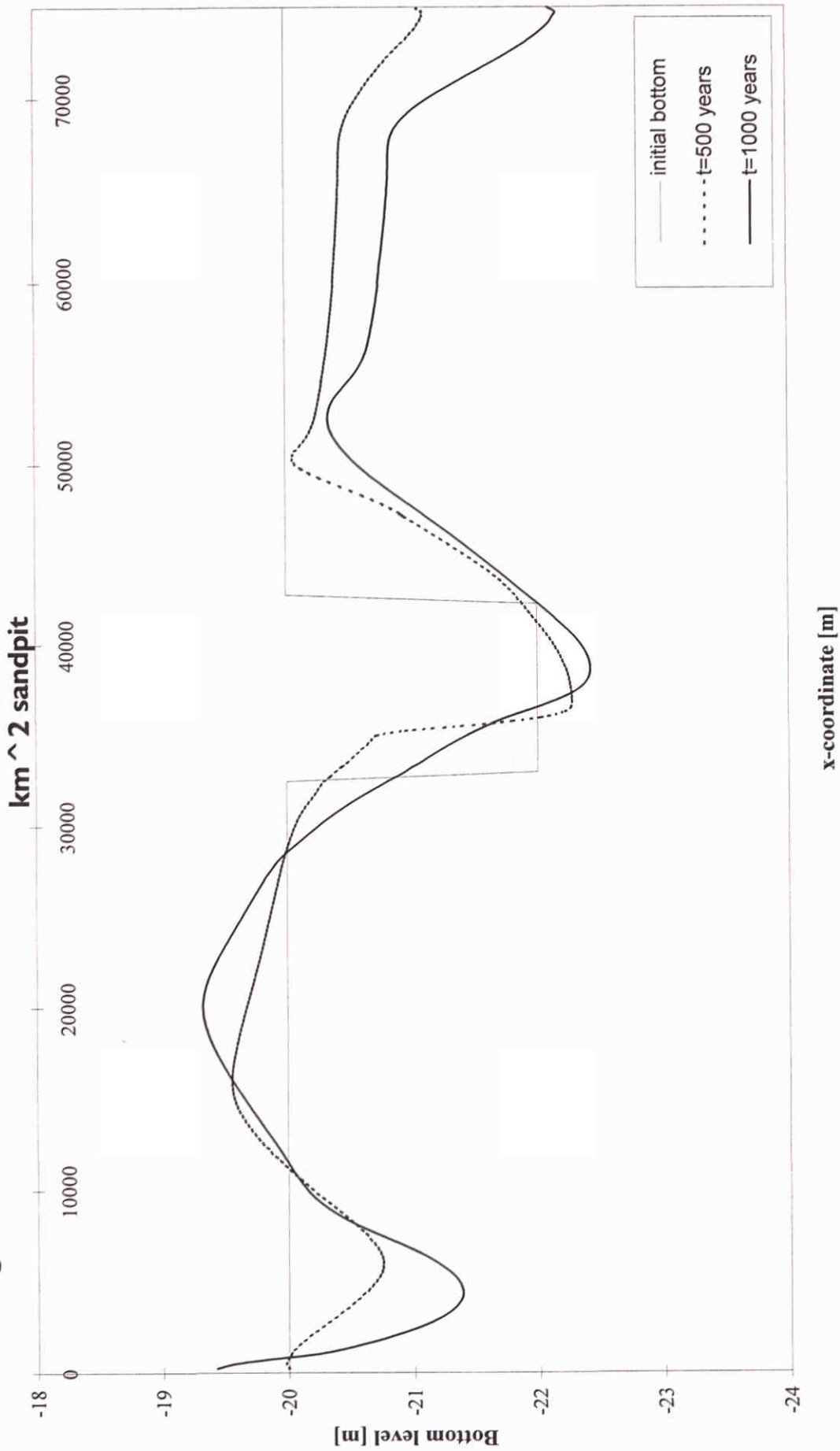


Bottom levels and changes [m]; sediment transport [m^2/s]

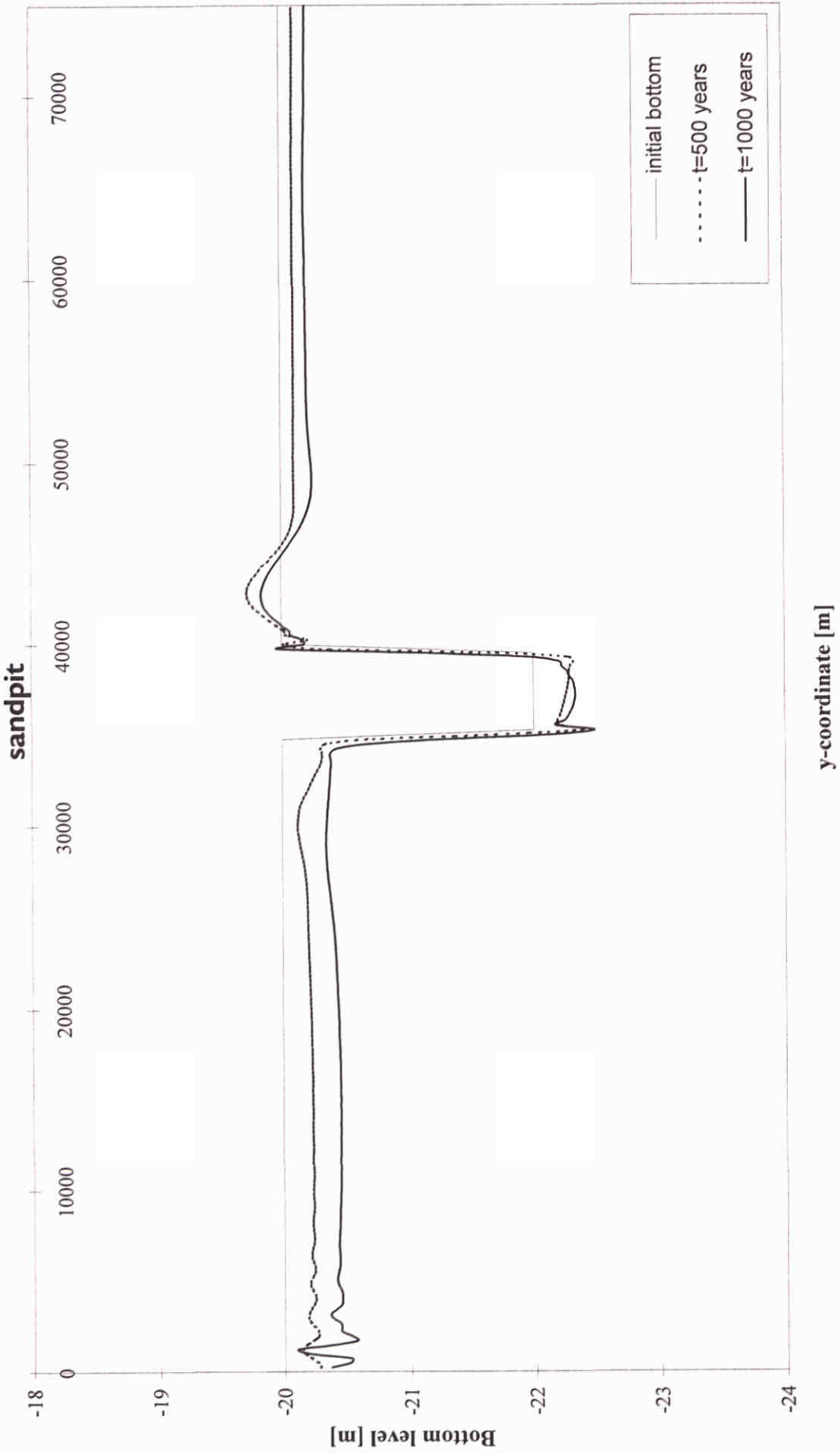
Parallel, 22 m deep $10 \times 5 \text{ km}^2$ sandpit

Morphological results after 1000 years

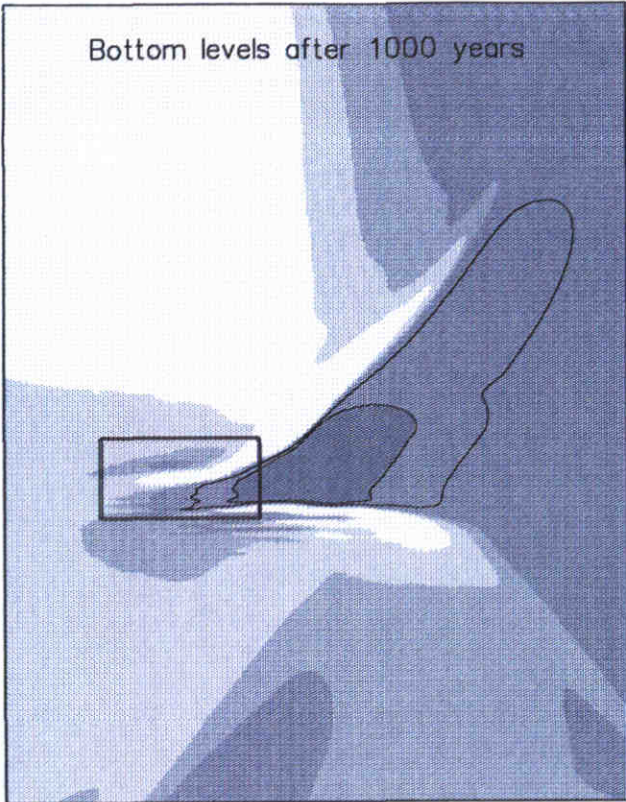
Figuur 8.23b: Bottom levels in the center longitudinal section of parallel, 22 m deep 10x5 km² sandpit



Figuur 8.23c: Bottom levels in the center cross-section of parallel, 22 m deep $10 \times 5 \text{ km}^2$ sandpit

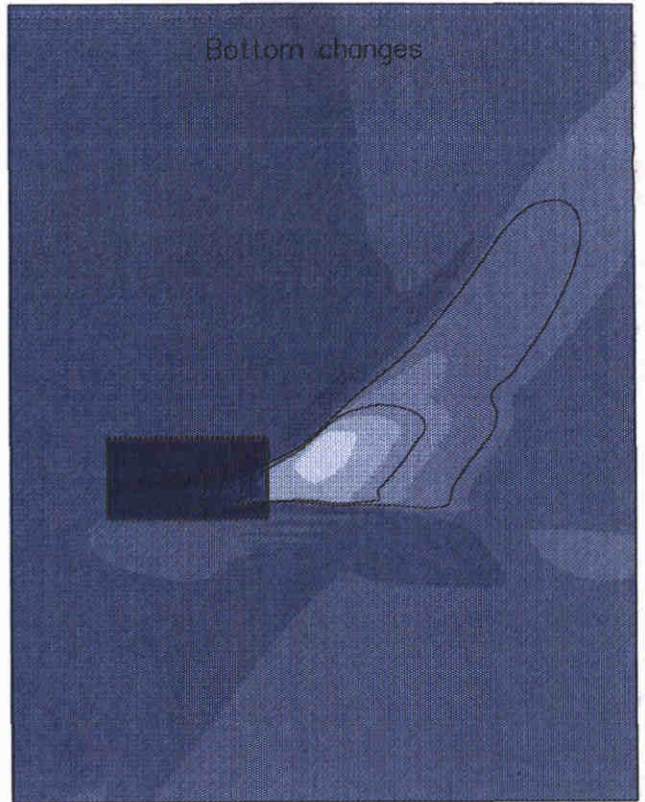


Bottom levels after 1000 years



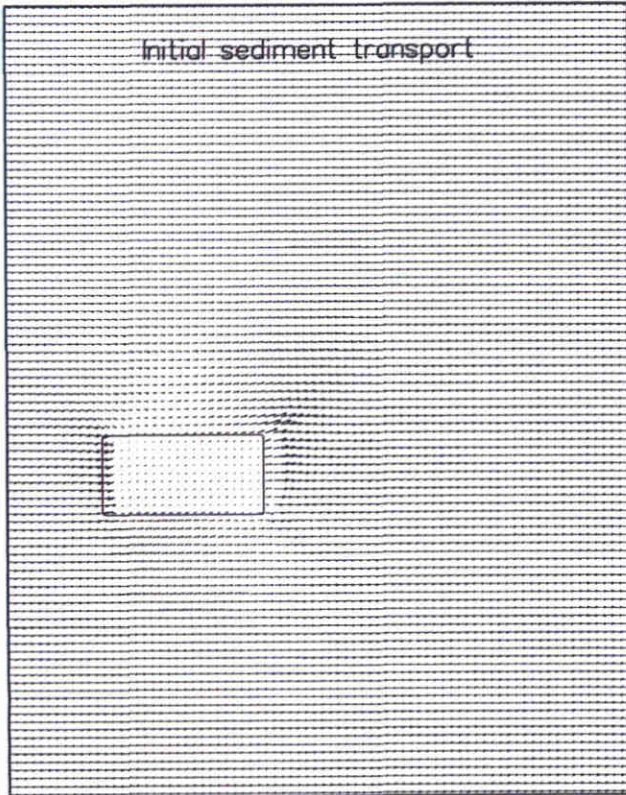
- <19.5
- <20.0
- <20.5
- <25.0
- <29.5
- <30.0
- <30.5
- >30.5

Bottom changes



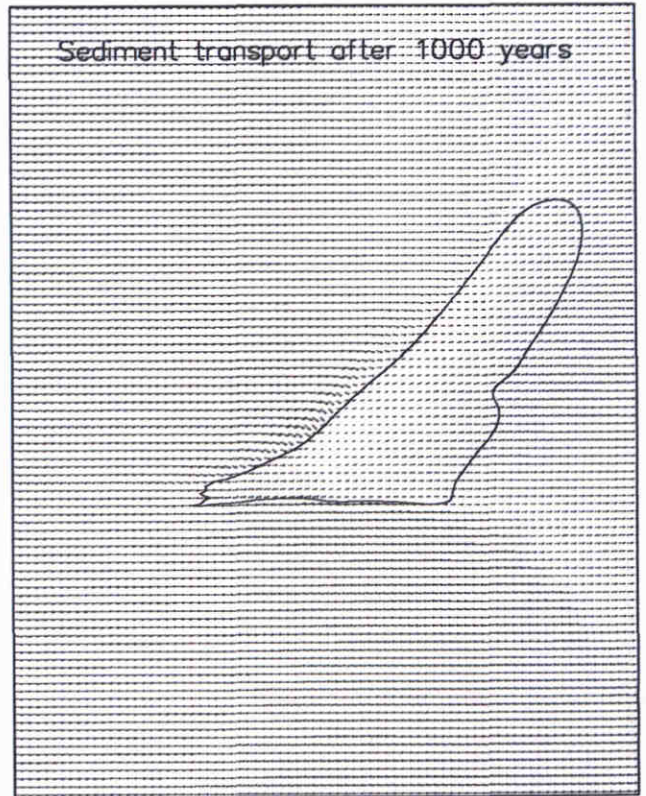
- <-10.0
- <-8.0
- <-6.0
- <-4.0
- <-2.0
- <0.0
- <2.0
- <4.0
- <6.0
- <8.0
- <10.0
- >10.0

Initial sediment transport



→ $1.0 \cdot 10^{-5} \text{ m}^2/\text{s}$

Sediment transport after 1000 years

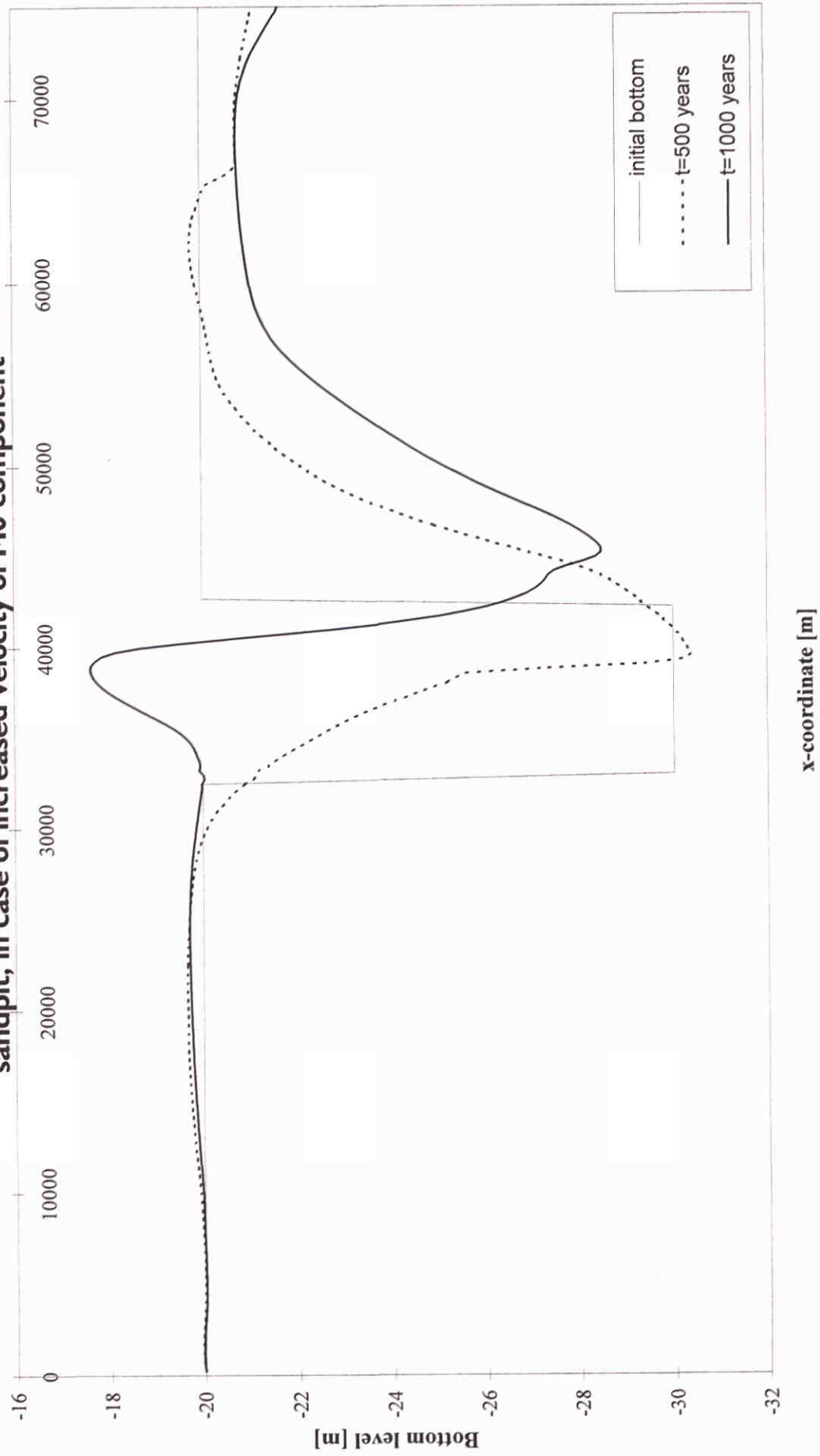


Bottom levels and changes [m]; sediment transport [m^2/s]

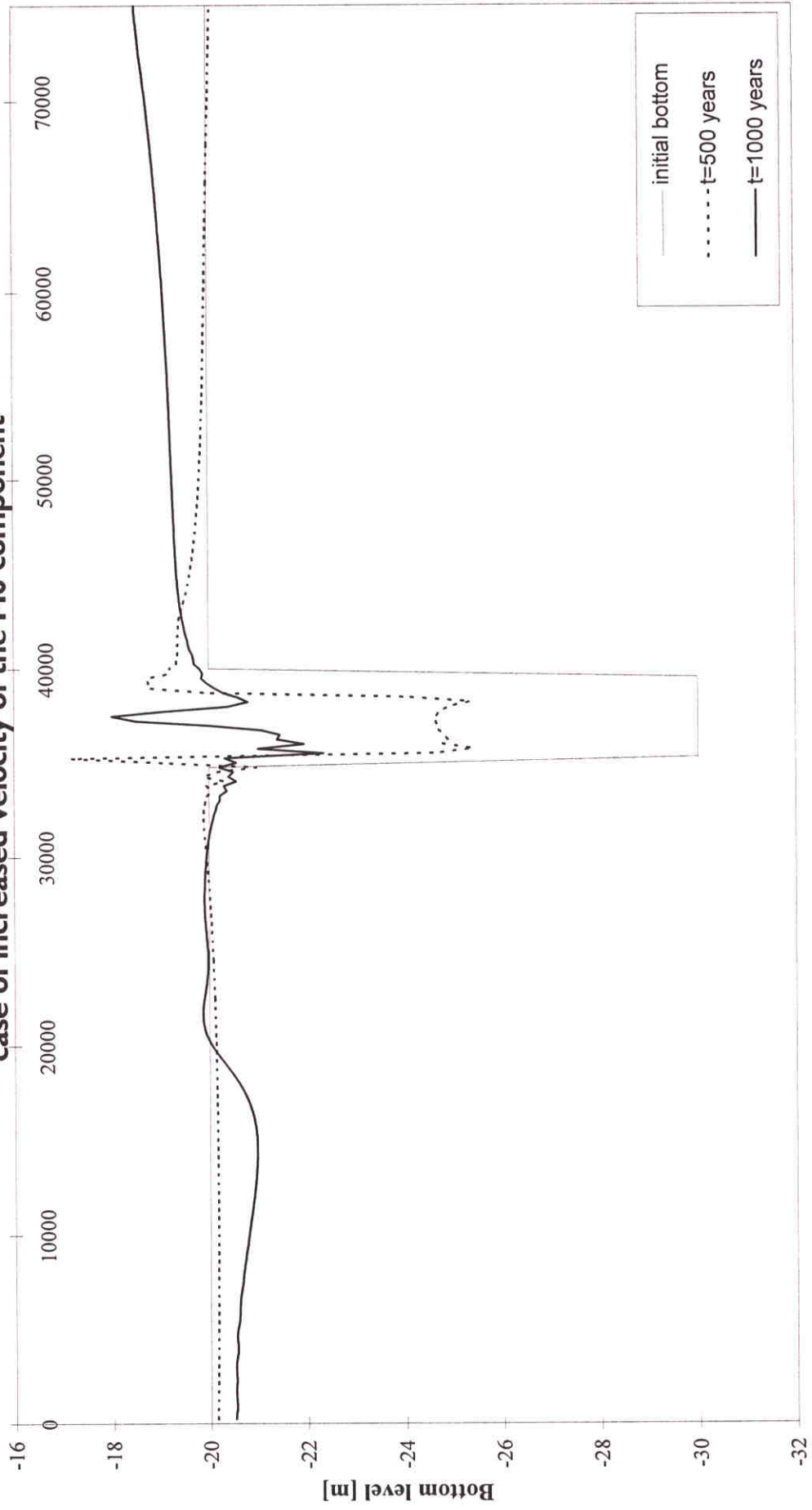
Parallel $10 \times 5 \text{ km}^2$ sandpit; variant with increased MO velocity

Morphological results after 1000 years

Figure 8.24b: Bottom levels in the center longitudinal section of a parallel $24 \times 5 \text{ km}^2$ sandpit, in case of increased velocity of M0 component

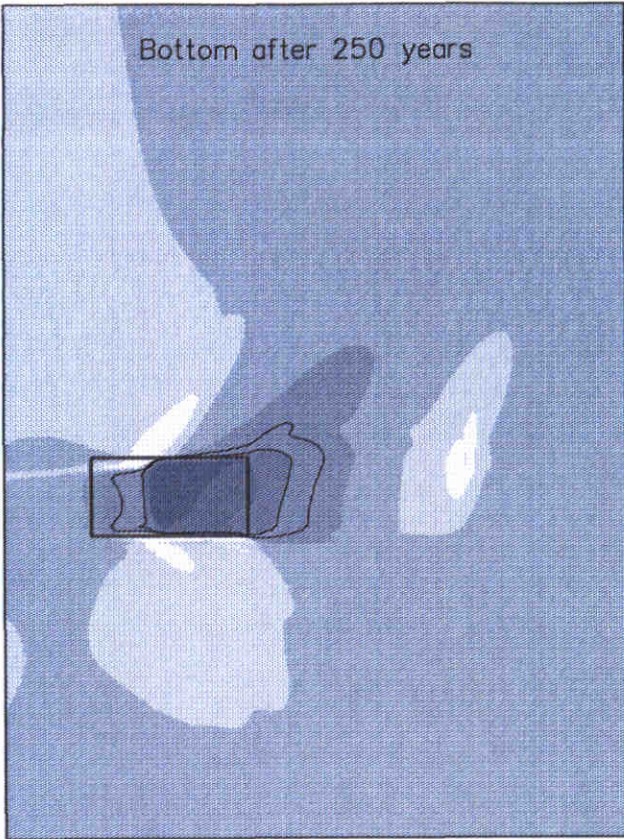


Figuur 8.24c: Bottom levels in the center cross-section of a parallel $10 \times 5 \text{ km}^2$ sandpit, in case of increased velocity of the M0 component

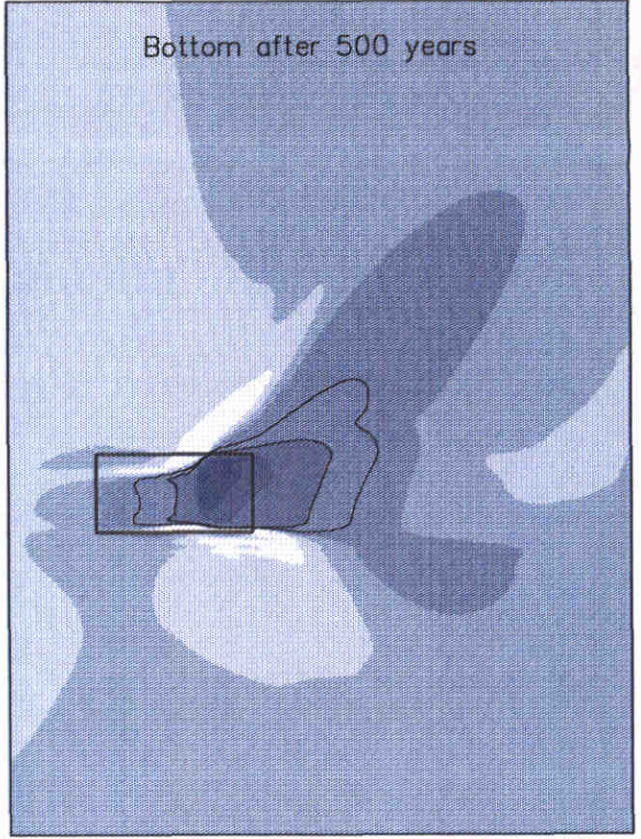


y-coordinate [m]

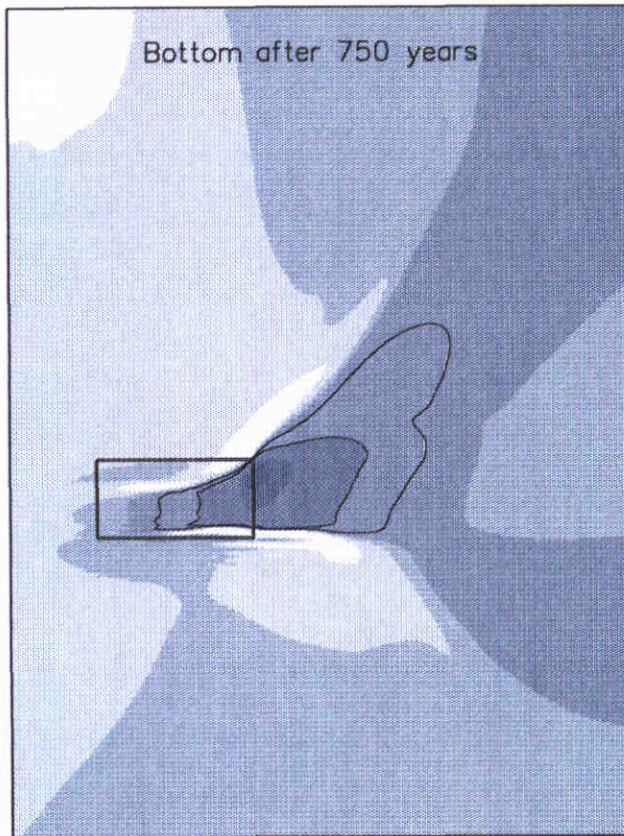
Bottom after 250 years



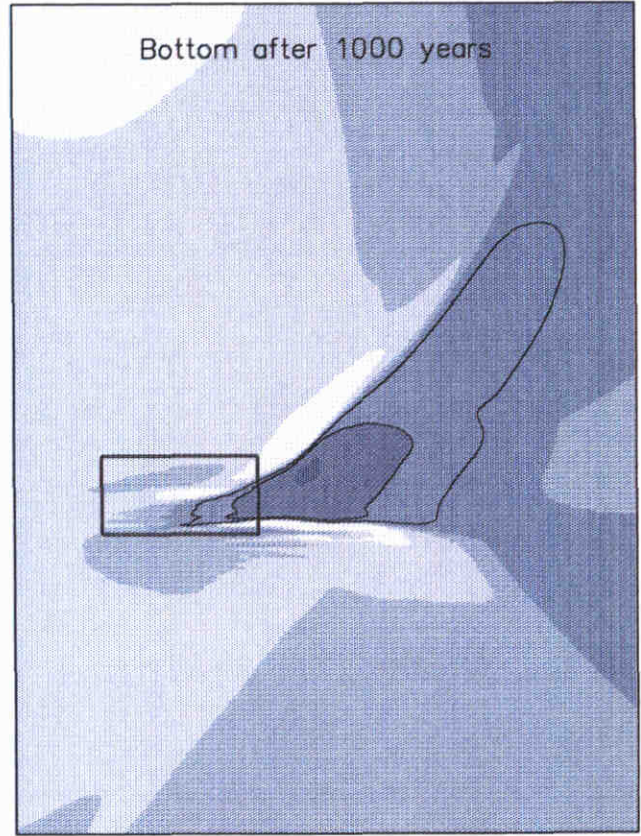
Bottom after 500 years



Bottom after 750 years



Bottom after 1000 years

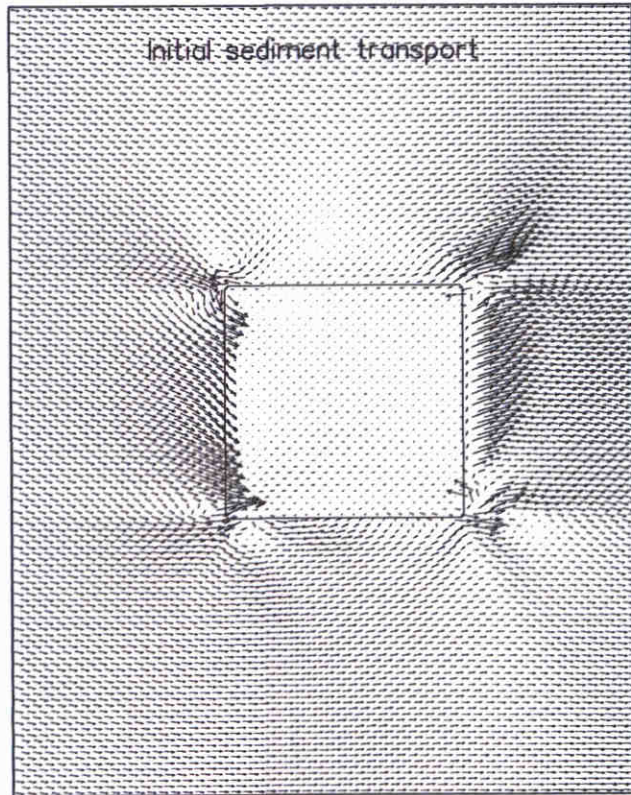
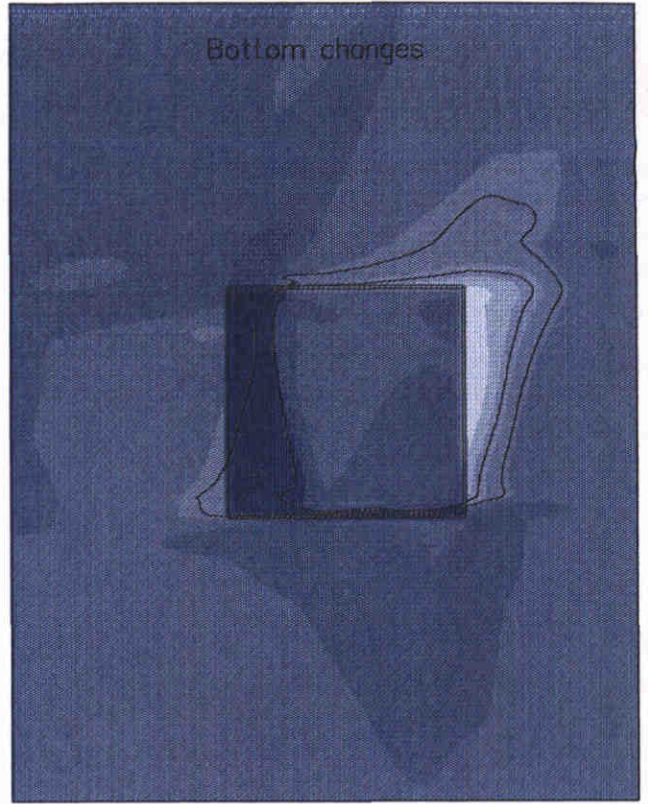
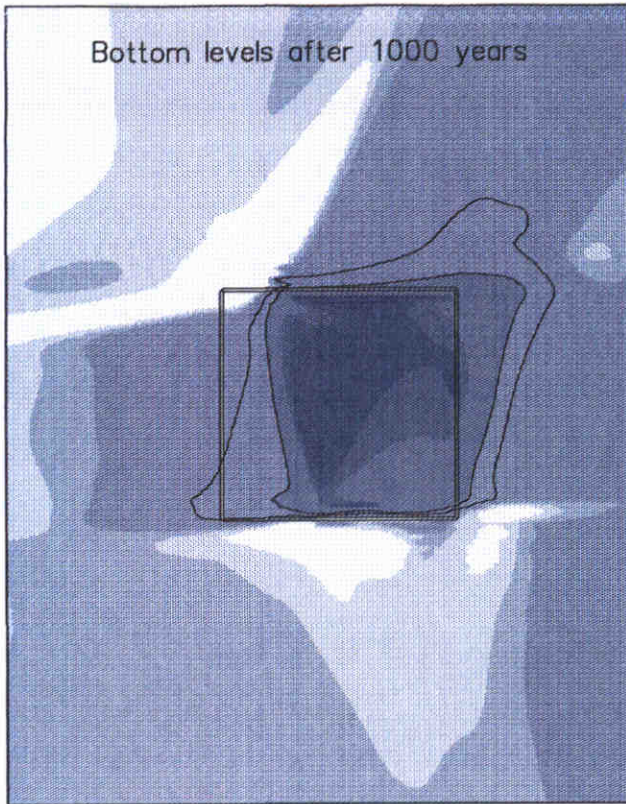


<19.0
 <21.0
 <29.0
 <31.0
 <20.0
 <25.0
 <30.0
 >31.0

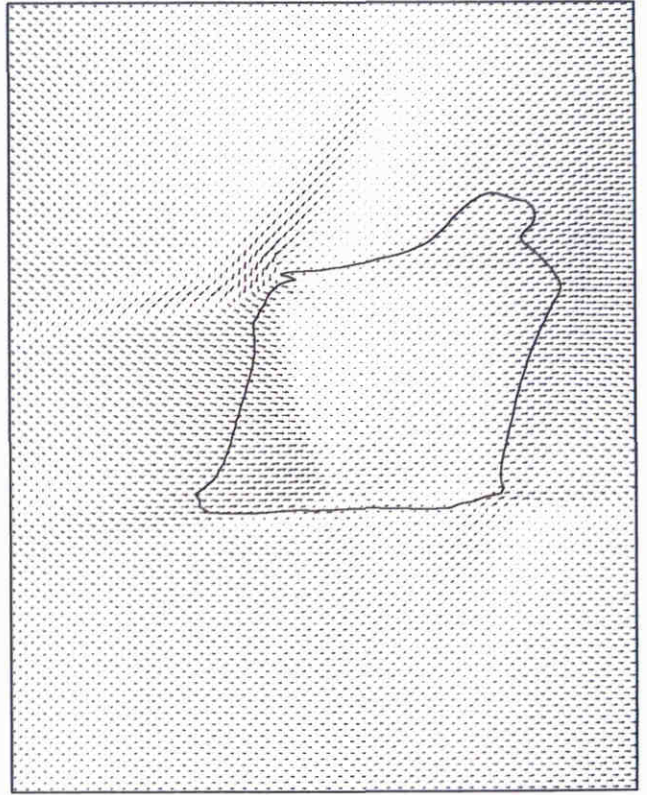
Bottom levels [m]

Parallel 10x5 km² sandpit; velocity variant

Morphological development in time



→ $2.0 \cdot 10^{-6} \text{ m}^2/\text{s}$



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

+45 degrees rotated $10 \times 10 \text{ km}^2$ sandpit

Morphological results after 1000 years

Figure 8.26b: Bottom levels in the center longitudinal section of a parallel $10 \times 10 \text{ km}^2$ sandpit

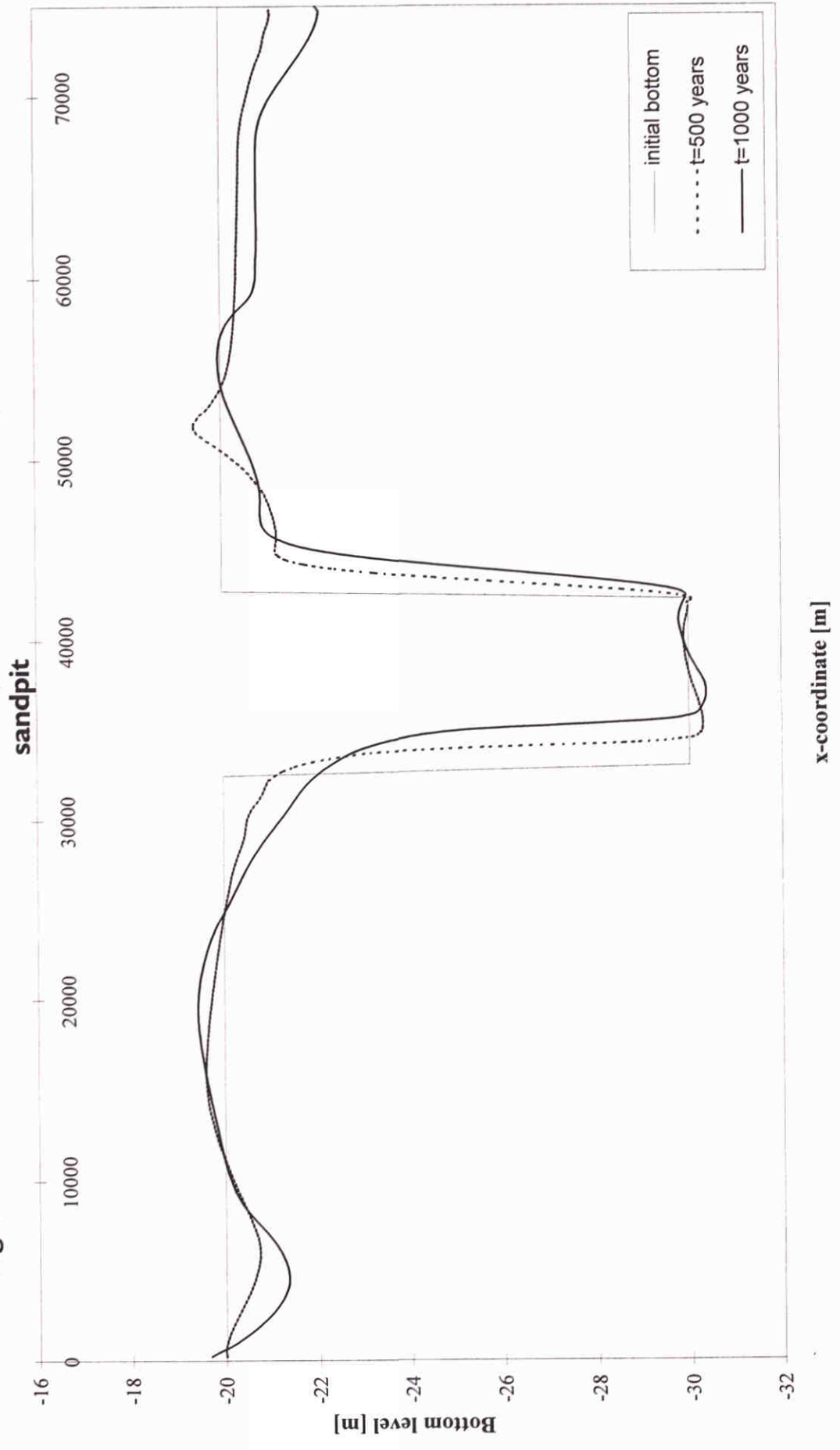
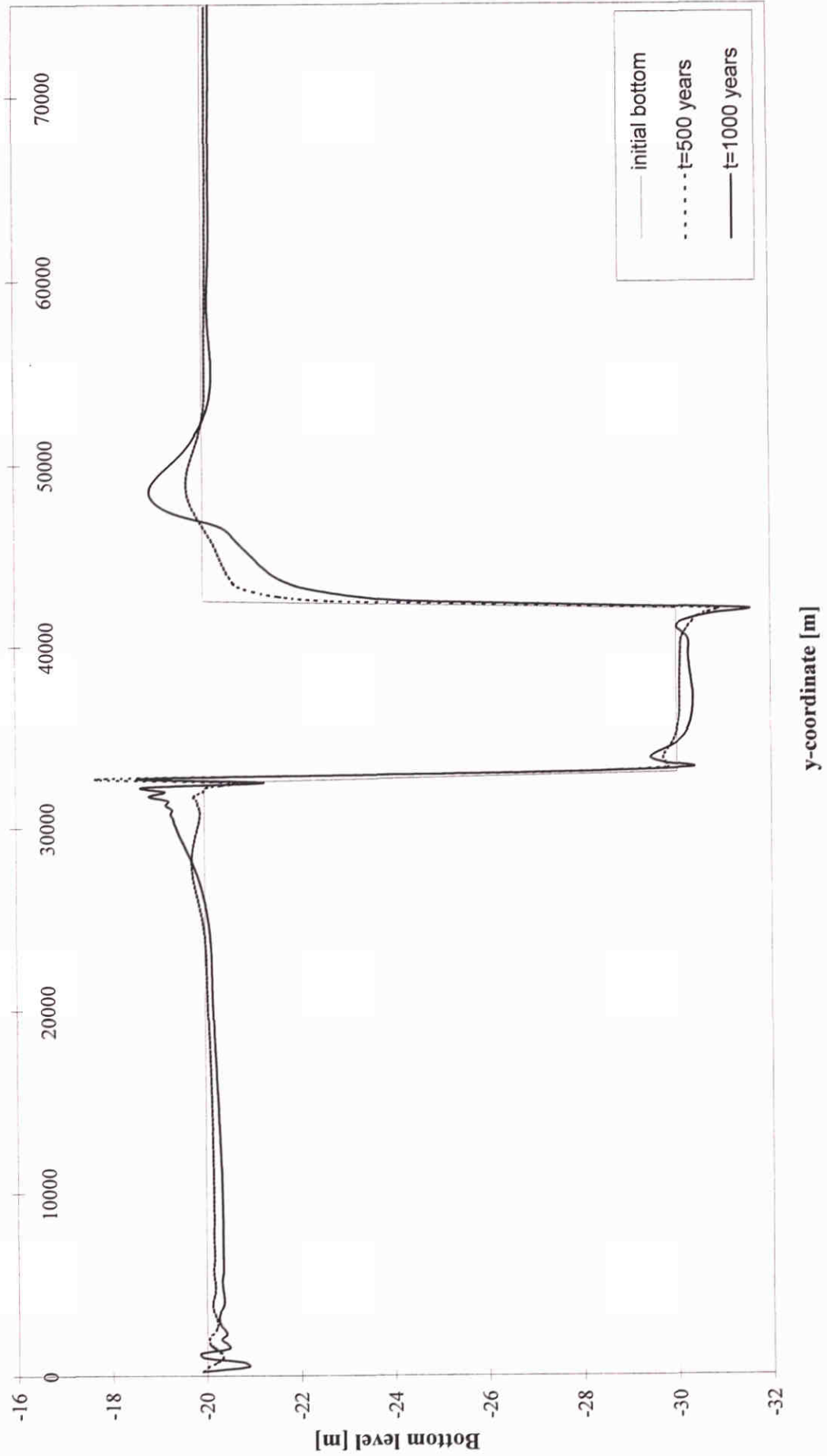
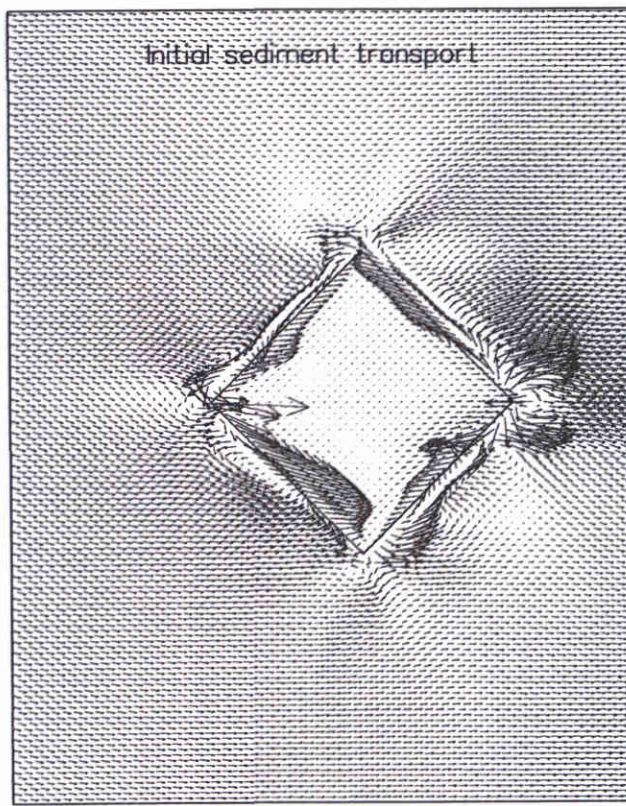
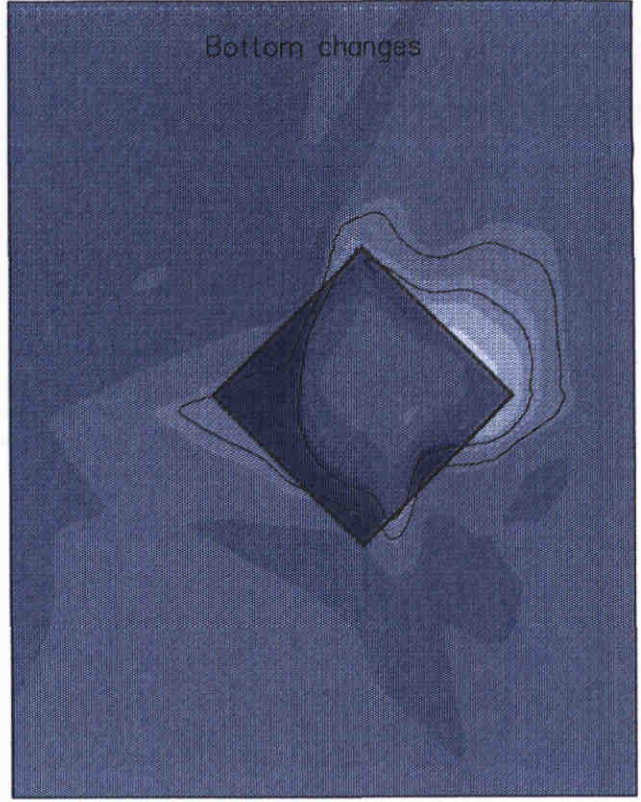
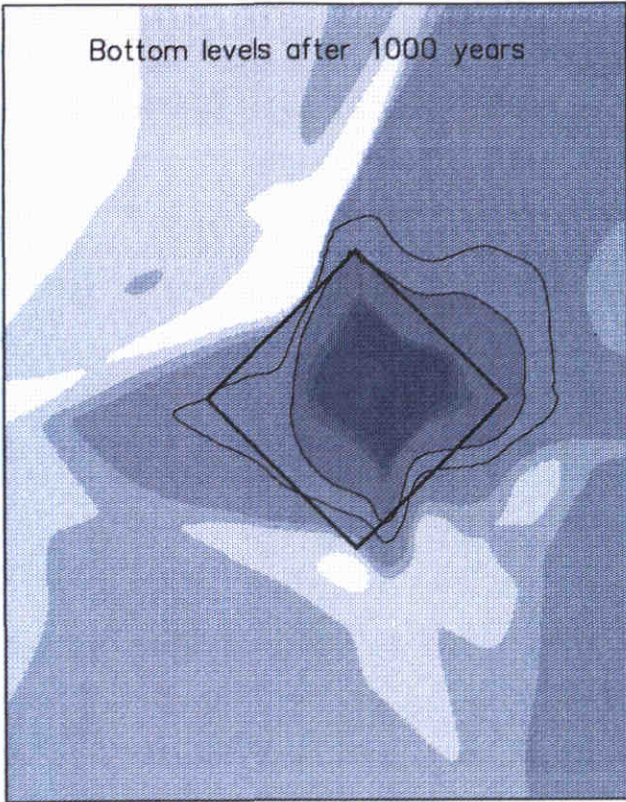
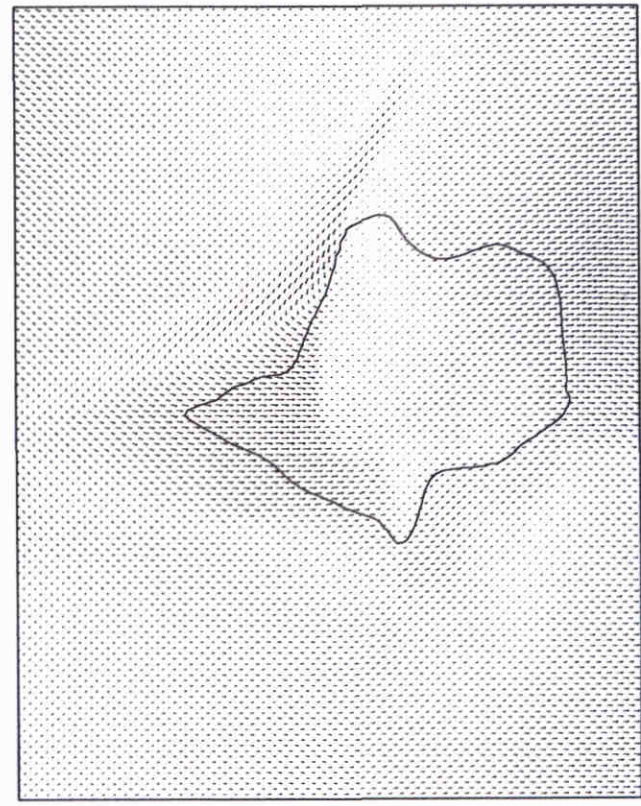


Figure 8.26c: Bottom levels in the center cross-section of a parallel $10 \times 10 \text{ km}^2$ sandpit





→ $2.0 \cdot 10^{-6} \text{ m}^2/\text{s}$



Bottom levels and changes [m]; sediment transport [m^2/s]
 +45 degrees rotated $10 \times 10 \text{ km}^2$ sandpit
 Morphological results after 1000 years

Figure 8.27b: Bottom levels in the longitudinal section of a +45° rotated 10x10 km² sandpit

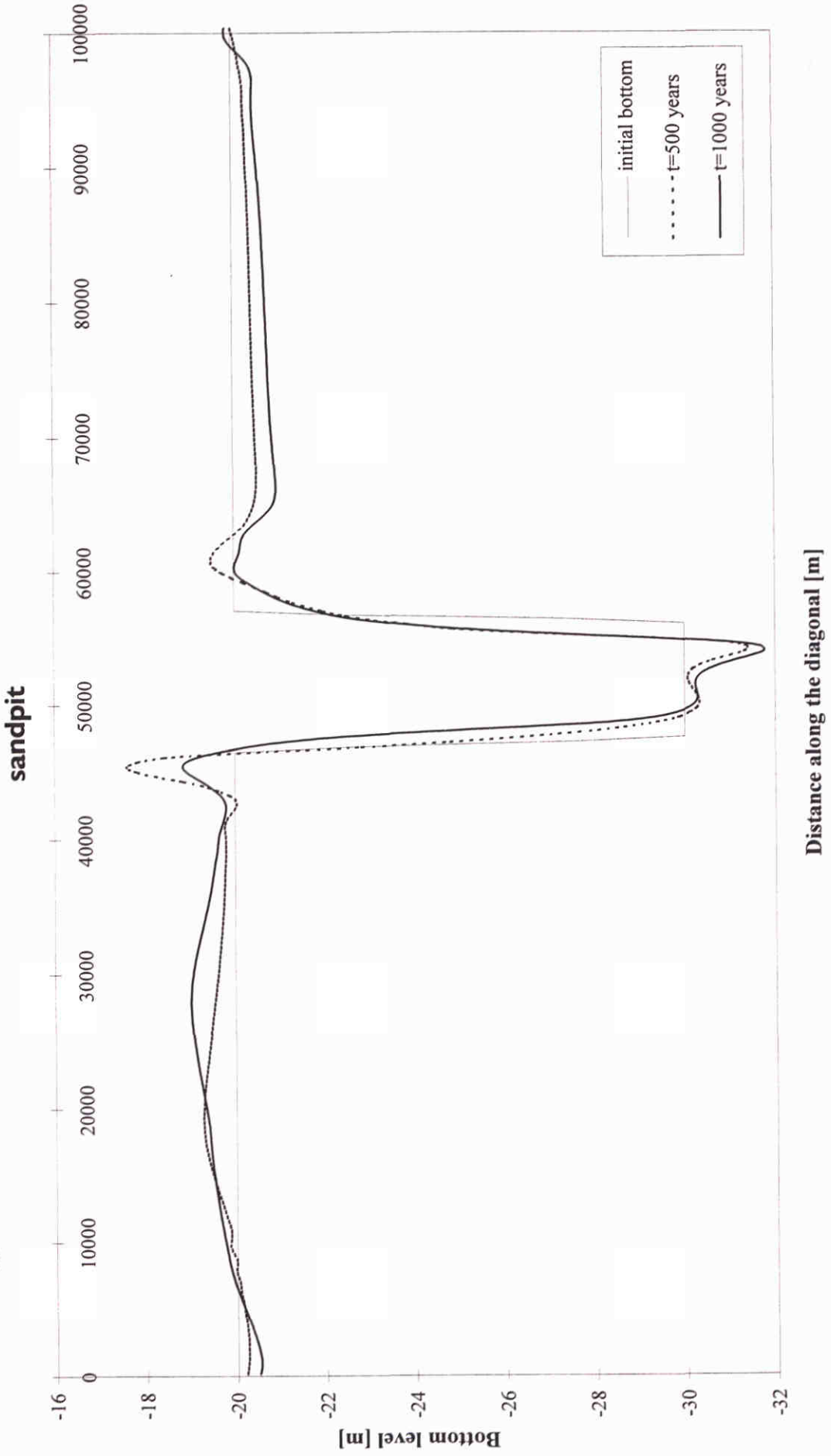
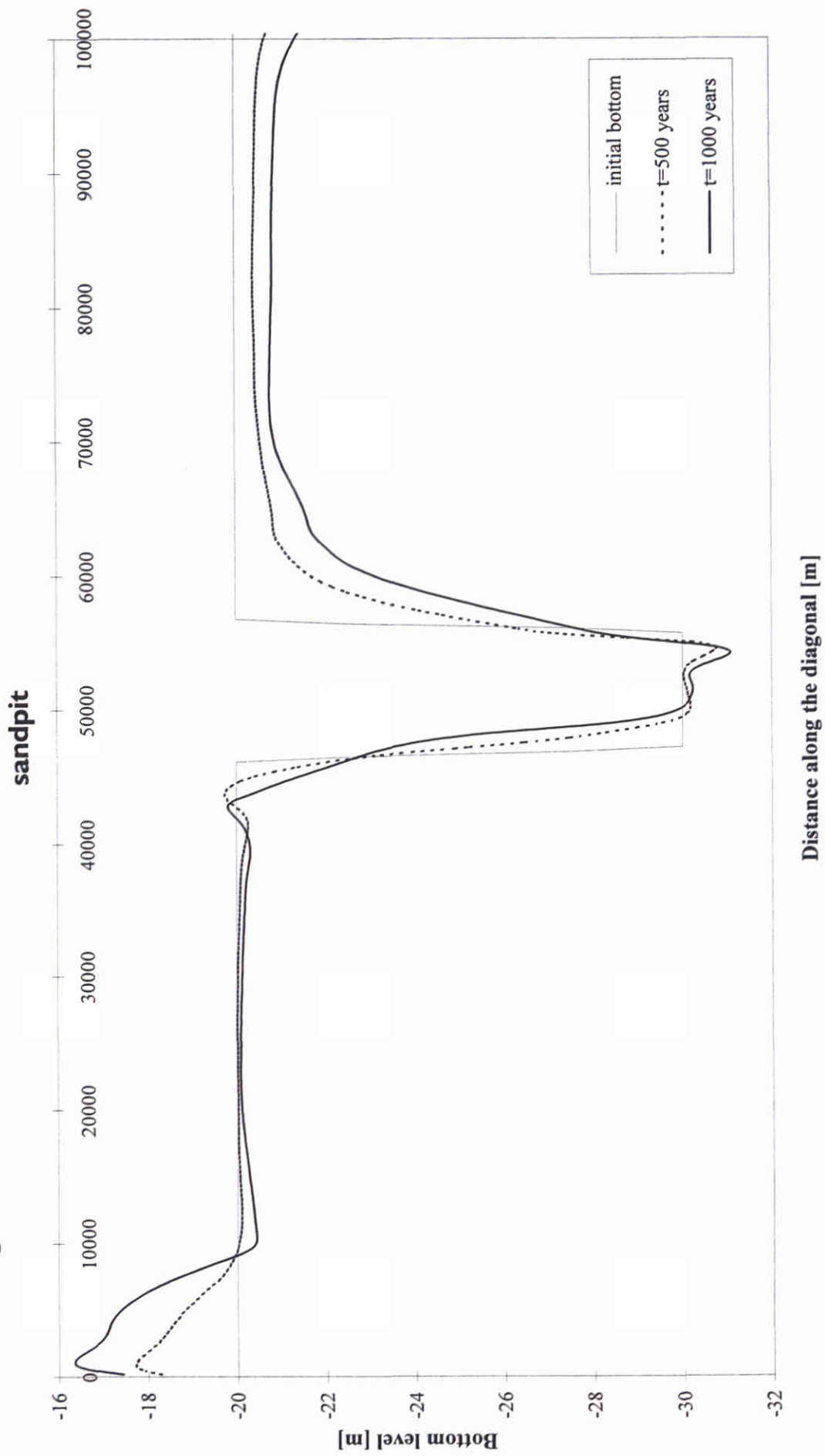
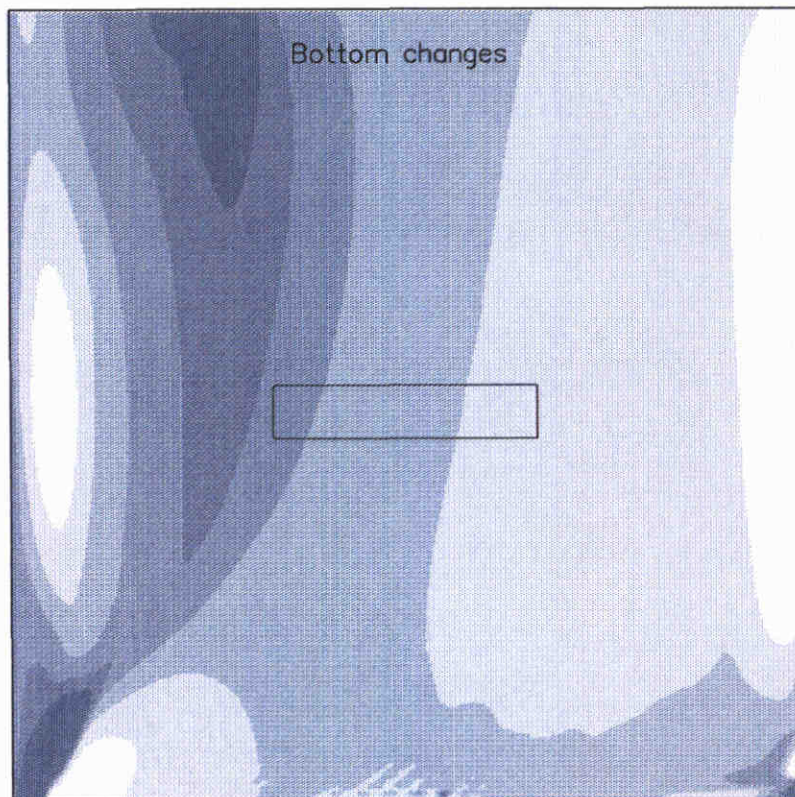
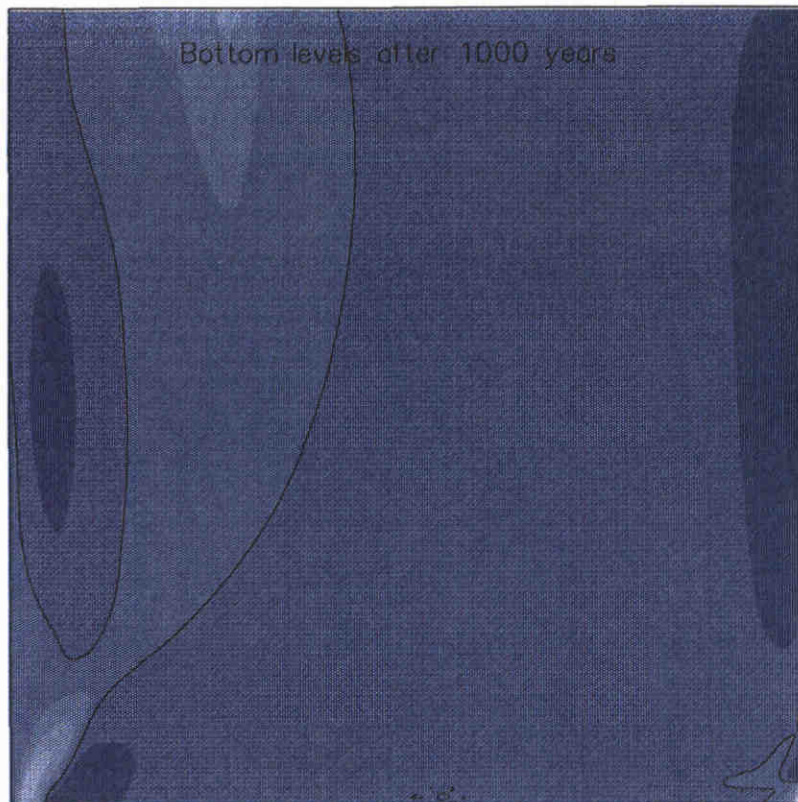


Figure 8.27c: Bottom levels in the center cross-section of a +45° rotated 10x10 km² sandpit

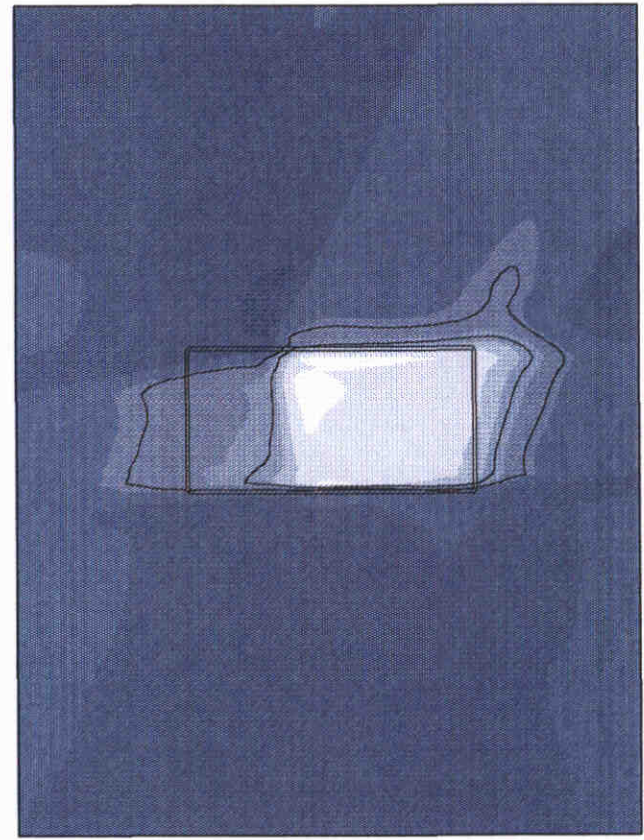
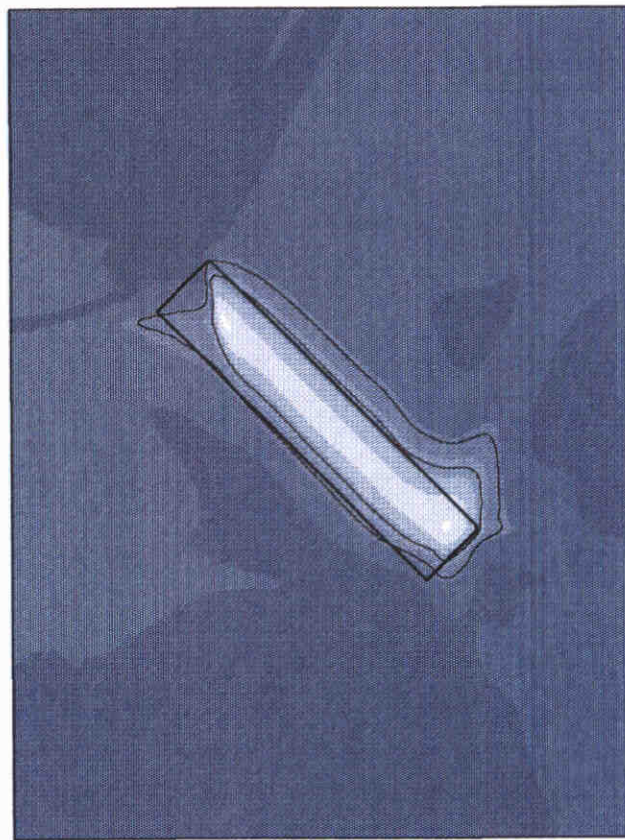
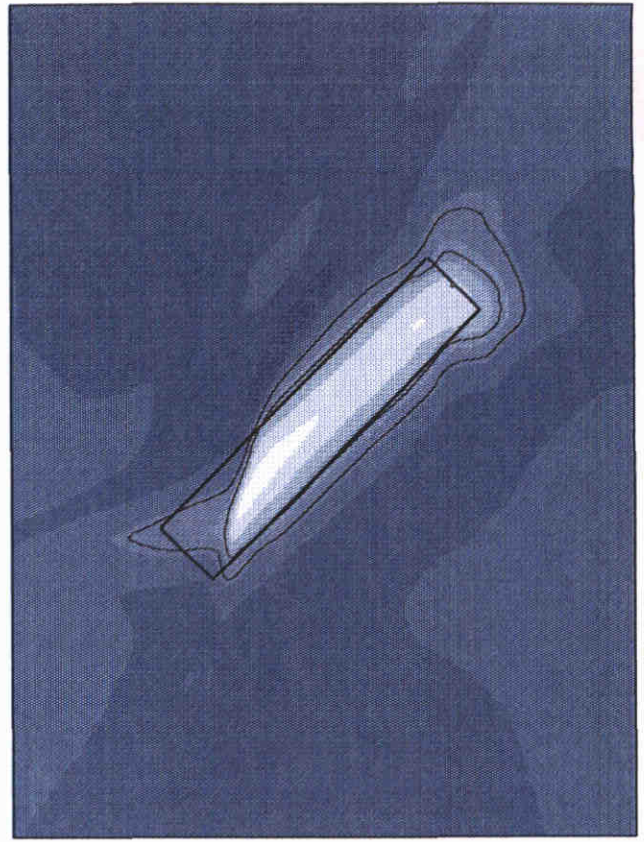
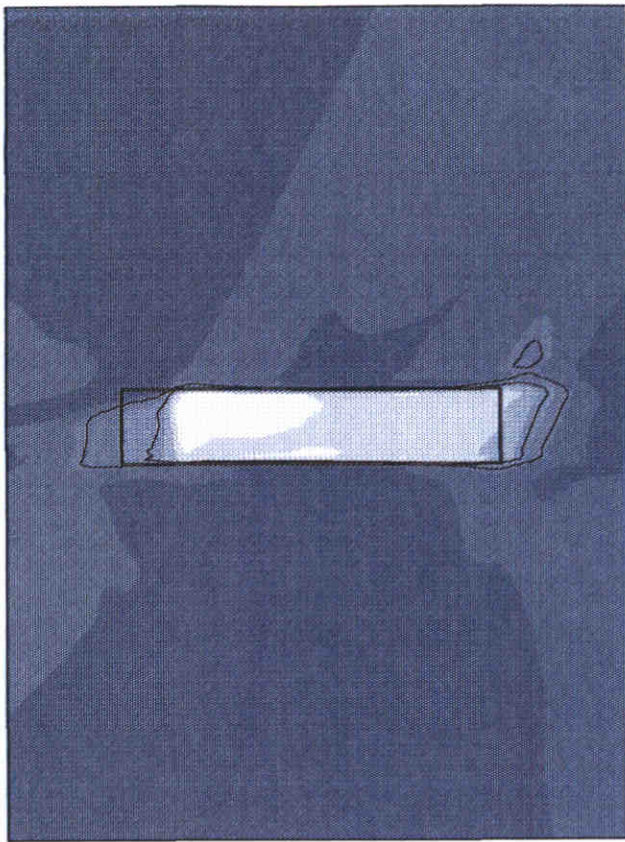




Bottom levels and changes [m]

Flat bottom without a sandpit

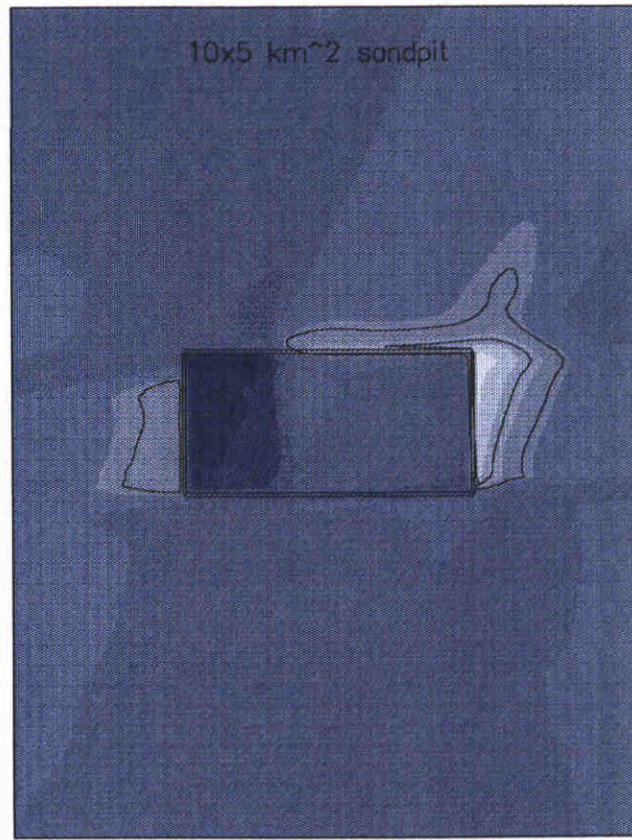
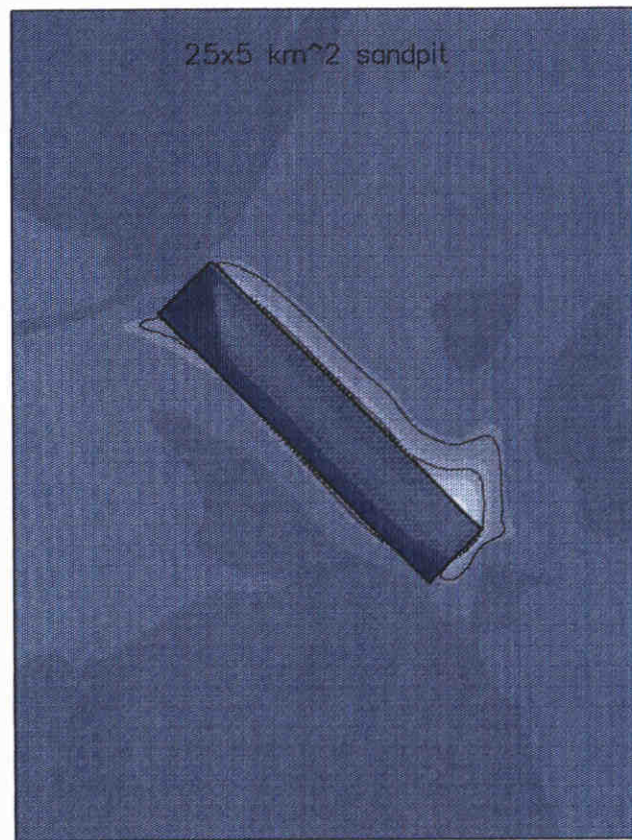
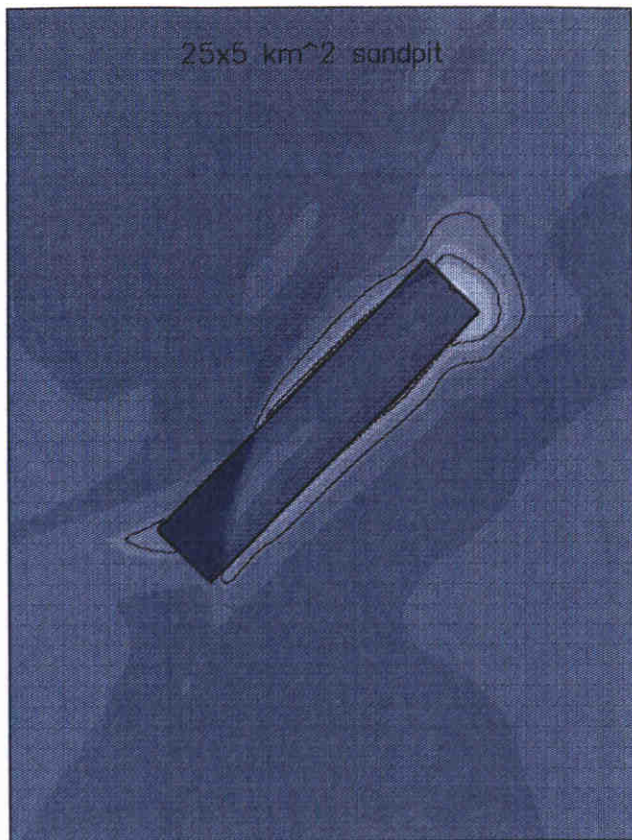
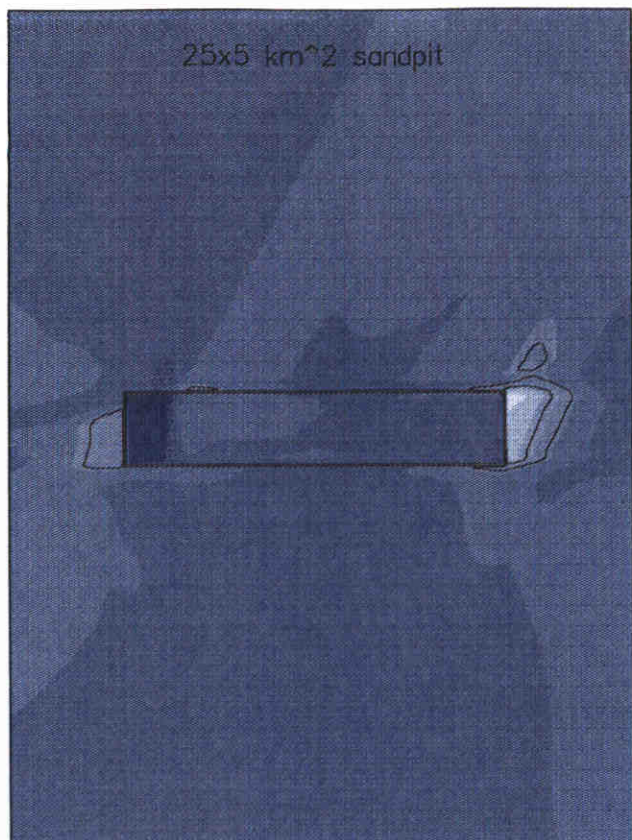
Morphological results after 1000 years



Bottom levels [m] with respect to undisturbed sea bottom

Correction for the influence of the boundary conditions

Morphological results after 1000 years



Bottom changes [m]

Correction for the influence of the boundary conditions

Morphological results after 1000 years



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