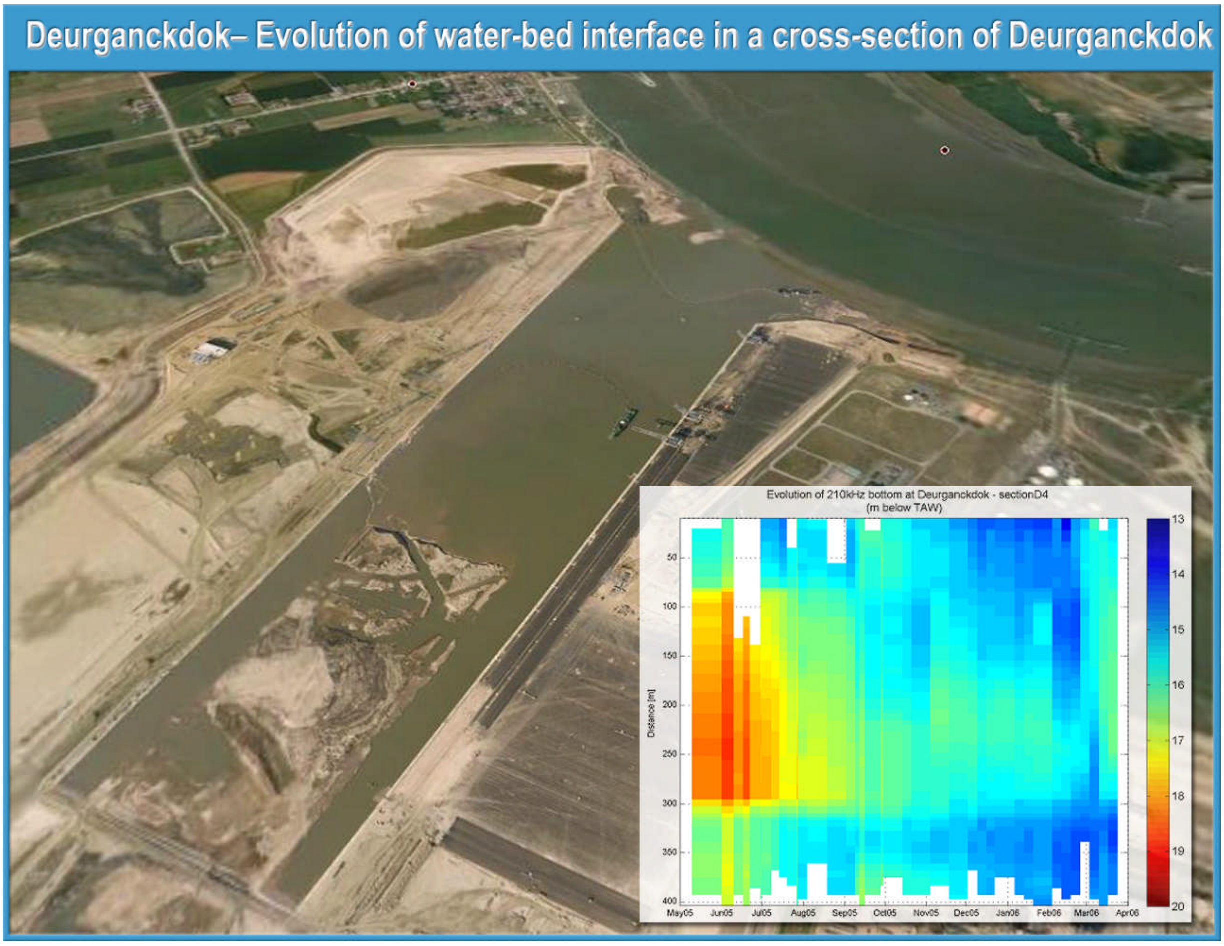
VLAAMSE OVERHEID

DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN
WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurganckdok 2: Opvolging en analyse aanslibbing

Bestek 16EB/05/04



Deelrapport 1.12 : Sediment balans 01/09/2007 – 31/12/2007

Report 1.12 : Sediment balance 01/09/2007 – 31/12/2007

23 September 2008

I/RA/11283/07.083/MSA

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GLOSSARY

BIS	Dredging Information System used in the Lower Sea Scheldt
d	Density of dredged sediment [kg/dm³]
DGD	Deurganckdok
HCBS	High Concentration Benthic Suspensions
M	mass of dry solids [ton]
ρ_s	density of the solid minerals [kg/dm³]
ρ_w	density of clear water [kg/dm³]
t_{0d}	Reference situation for densimetric analysis (empty dock)
t_{0e}	Reference situation for volumetric analysis (24 March 2006)
TDS	Ton of dry solids [ton]
V	volume of dredged sediment [m³]

1. INTRODUCTION

1.1. The assignment

This report is part of the set of reports describing the results of the long-term measurements conducted in Deurganckdok aiming at the monitoring and analysis of silt accretion. This measurement campaign is an extension of the study “Extension of the study about density currents in the Beneden Zeeschelde” as part of the Long Term Vision for the Scheldt estuary. It is complementary to the study ‘Field measurements high-concentration benthic suspensions (HCBS 2)’.

The terms of reference for this study were prepared by the ‘Departement Mobiliteit en Openbare Werken van de Vlaamse Overheid, Afdeling Waterbouwkundig Laboratorium’ (16EB/05/04). The repetition of this study was awarded to International Marine and Dredging Consultants NV in association with WL|Delft Hydraulics and Gems International on 10/01/2006. The project term was repeated with an extra year from April 2007 till March 2008, ‘Opvolging aanslibbing Deurganckdok’.

Waterbouwkundig Laboratorium– Cel Hydrometrie Schelde provided data on discharge, tide, salinity and turbidity along the river Scheldt and provided survey vessels for the long term and through tide measurements. Afdeling Maritieme Toegang provided maintenance dredging data. Agentschap voor Maritieme Dienstverlening en Kust – Afdeling Kust and Port of Antwerp provided depth sounding measurements.

The execution of the study involves a twofold assignment:

- Part 1: Setting up a sediment balance of Deurganckdok covering a period of one year, i.e. 04/2007 – 03/2008
- Part 2: An analysis of the parameters contributing to siltation in Deurganckdok

1.2. Purpose of the study

The Lower Sea Scheldt (Beneden Zeeschelde) is the stretch of the Scheldt estuary between the Belgium-Dutch border and Rupelmonde, where the entrance channels to the Antwerp sea locks are located. The navigation channel has a sandy bed, whereas the shallower areas (intertidal areas, mud flats, salt marshes) consist of sandy clay or even pure mud sometimes. This part of the Scheldt is characterized by large horizontal salinity gradients and the presence of a turbidity maximum with depth-averaged concentrations ranging from 50 to 500 mg/l at grain sizes of 60 - 100 μm. The salinity gradients generate significant density currents between the river and the entrance channels to the locks, causing large siltation rates. It is to be expected that in the near future also the Deurganckdok will suffer from such large siltation rates, which may double the amount of dredging material to be dumped in the Lower Sea Scheldt.

Results from the study may be interpreted by comparison with results from the HCBS and HCBS2 studies covering the whole Lower Sea Scheldt. These studies included through-tide measurement campaigns in the vicinity of Deurganckdok and long term measurements of turbidity and salinity in and near Deurganckdok.

The first part of the study focuses on obtaining a sediment balance of Deurganckdok. Aside from natural sedimentation, the sediment balance is influenced by the maintenance and capital dredging works. This involves sediment influx from capital dredging works in the Deurganckdok, and internal relocation and removal of sediment by maintenance dredging works. To compute a sediment balance an inventory of bathymetric data (depth soundings), density measurements of the deposited material and detailed information of capital and maintenance dredging works will be made up.

The second part of the study is to gain insight in the mechanisms causing siltation in Deurganckdok, it is important to follow the evolution of the parameters involved, and this on a long and short term basis (long term & through-tide measurements). Previous research has shown the importance of water exchange at the entrance of Deurganckdok is essential for understanding sediment transport between the dock and the Scheldt river.

1.3. Overview of the reports

1.3.1. Reports

Reports of the project 'Opvolging aanslibbing Deurganckdok' and 'Opvolging aanslibbing Deurganckdok 2' for the period April 2006 – March 2008 are summarized in Table 1-1.

Table 1-1: Overview of Deurganckdok Reports

Report	Description
Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.1	Sediment Balance: Three monthly report 1/4/2006 – 30/06/2006 (I/RA/11283/06.113/MSA)
1.2	Sediment Balance: Three monthly report 1/7/2006 – 30/09/2006 (I/RA/11283/06.114/MSA)
1.3	Sediment Balance: Three monthly report 1/10/2006 – 31/12/2006 (I/RA/11283/06.115/MSA)
1.4	Sediment Balance: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.116/MSA)
1.5	Annual Sediment Balance (I/RA/11283/06.117/MSA)
1.6	Sediment balance Bathymetry: 2005 – 3/2006 (I/RA/11283/06.118/MSA)
1.10	Sediment Balance: Three monthly report 1/4/2007 - 30/06/2007(I/RA/11283/07.081/MSA)
1.11	Sediment Balance: Two monthly report 1/7/2007 – 31/08/2007 (I/RA/11283/07.082/MSA)
1.12	Sediment Balance: Four monthly report 1/09/2007 – 31/12/2007 (I/RA/11283/07.083/MSA)
1.13	Sediment Balance: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/07.084/MSA)
1.14	Annual Sediment Balance (I/RA/11283/07.085/MSA)
Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP) & Calibrations	

Report	Description
2.1	Through tide measurement Siltprofiler 21/03/2006 Laure Marie (I/RA/11283/06.087/WGO)
2.2	Through tide measurement Siltprofiler 26/09/2006 Stream (I/RA/11283/06.068/MSA)
2.3	Through tide measurement Sediview spring tide 22/03/2006 Veremans (I/RA/11283/06.110/BDC)
2.4	Through tide measurement Sediview spring tide 27/09/2006 Parel 2 (I/RA/11283/06.119/MSA)
2.5	Through tide measurement Sediview neap tide (to be scheduled) (I/RA/11283/06.120/MSA)
2.6	Salinity-Silt distribution & Frame Measurements Deurganckdok 13/3/2006 – 31/05/2006 (I/RA/11283/06.121/MSA)
2.7	Salinity-Silt distribution & Frame Measurements Deurganckdok 15/07/2006 – 31/10/2006 (I/RA/11283/06.122/MSA)
2.8	Salinity-Silt distribution & Frame Measurements Deurganckdok 15/01/2007 – 15/03/2007 (I/RA/11283/06.123/MSA)
2.9	Calibration stationary equipment autumn (I/RA/11283/07.095/MSA)
2.10	Through tide measurement Siltprofiler winter (I/RA/11283/07.086/MSA)
2.11	Through tide measurement Salinity Profiling winter (I/RA/11283/07.087/MSA)
2.12	Through tide measurement Sediview winter (I/RA/11283/07.088/MSA)
2.13	Through tide measurement Sediview winter (I/RA/11283/07.089/MSA)
2.14	Through tide measurement Sediview winter (I/RA/11283/07.090/MSA)
2.15	Through tide measurement Siltprofiler (to be scheduled) (I/RA/11283/07.091/MSA)
2.16	Salt-Silt distribution Deurganckdok summer (21/6/2007 – 30/07/2007) (I/RA/11283/07.092/MSA)
2.17	Salt-Silt distribution & Frame Measurements Deurganckdok autumn (17/09/2007 - 10/12/2007) (I/RA/11283/07.093/MSA)
2.18	Salt-Silt distribution & Frame Measurements Deurganckdok winter (18/02/2008 - 31/3/2008) (I/RA/11283/07.094/MSA)
2.20	Calibration stationary & mobile equipment winter (I/RA/11283/07.096/MSA)
Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels	
3.1	Boundary conditions: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.127/MSA)
3.10	Boundary conditions: Three monthly report 1/4/2007 – 30/06/2007 (I/RA/11283/07.097/MSA)
3.11	Boundary conditions: Three monthly report 1/7/2007 – 30/09/2007 (I/RA/11283/07.098/MSA)

Report	Description
3.12	Boundary conditions: Three monthly report 1/10/2007 – 31/12/2007 (I/RA/11283/07.099/MSA)
3.13	Boundary conditions: Three monthly report 1/1/2008 – 31/03/2008 (I/RA/11283/07.100/MSA)
3.14	Boundary conditions: Annual report (I/RA/11283/07.101/MSA)
Analysis	
4.1	Analysis of Siltation Processes and Factors (I/RA/11283/06.129/MSA)
4.10	Analysis of Siltation Processes and Factors (I/RA/11283/07.102/MSA)

1.3.2. Measurement actions

Following measurements have been carried out during the course of this project:

1. Monitoring upstream discharge in the Scheldt river
2. Monitoring Salt and sediment concentration in the Lower Sea Scheldt taken from on permanent data acquisition sites at Lillo, Oosterweel and up- and downstream of the Deurganckdok.
3. Long term measurement of salt distribution in Deurganckdok.
4. Long term measurement of sediment concentration in Deurganckdok
5. Monitoring near-bed processes in the central trench in the dock, near the entrance as well as near the landward end: near-bed turbidity, near-bed current velocity and bed elevation variations are measured from a fixed frame placed on the dock's bed.
6. Measurement of current, salt and sediment transport at the entrance of Deurganckdok for which ADCP backscatter intensity over a full cross section are calibrated with the Sediview procedure and vertical sediment and salt profiles are recorded with the SiltProfiler equipment
7. Through tide measurements of vertical sediment concentration profiles -including near bed highly concentrated suspensions- with the SiltProfiler equipment. Executed over a grid of points near the entrance of Deurganckdok.
8. Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks
9. Monitoring dredging and dumping activities in the Lower Sea Scheldt

In situ calibrations were conducted on several dates (15 March 2006; 14/04/2006; 23/06/2006; 18/09/2006) to calibrate all turbidity and conductivity sensors (IMDC, 2006f & IMDC, 2007l).

1.4. Structure of the report

This report is the sediment balance of the Deurganckdok for the period of 01/09/2007 to 31/12/2007. The first chapter comprises an introduction. The second chapter describes the project. Chapter 3 describes the methodology. The measurement results and processed data are presented in Chapter 4, whereas chapter 5 gives a preliminary analysis of the data.

2. SEDIMENTATION IN DEURGANCKDOK

2.1. Project Area: Deurganckdok

Deurganckdok is a tidal dock situated at the left bank in the Lower Sea Scheldt, between Liefkenshoek and Doel. Deurganckdok has the following characteristics:

1. The dock has a total length of 2750 m and is 450 m wide at the Scheldt end and 400 m wide at the inward end of the dock
2. The bottom of Deurganckdok is provided at a depth of –17m TAW in the transition zones between the quay walls and the central trench. The bottom in the central trench is designed at –19 m TAW.
3. The quay walls reach up to +9m TAW

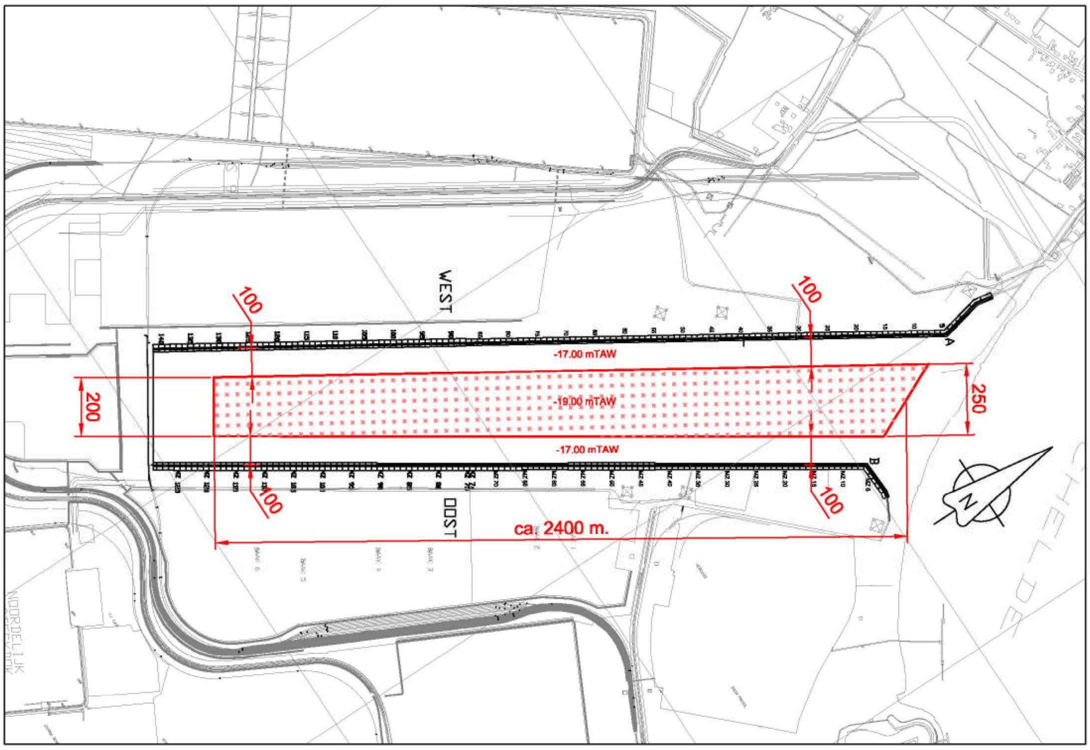

Figure 2-1: Overview of Deurganckdok

The dredging of the dock is performed in 3 phases. On 18 February 2005 the dike between the Scheldt and the Deurganckdok was breached. On 6 July 2005 Deurganckdok was officially opened. The second dredging phase was finalized a few weeks later. The first terminal operations have started since. In February 2007, the third dredging phase started and is planned to be finalised in 12 months time (by February 2008).

2.2. Overview of the studied parameters

The first part of the study aims at determining a sediment balance of Deurganckdok and the net influx of sediment. The sediment balance comprises a number of sediment transport modes: deposition, influx from capital dredging works, internal replacement and removal of sediments due to maintenance dredging (Figure 2-2).

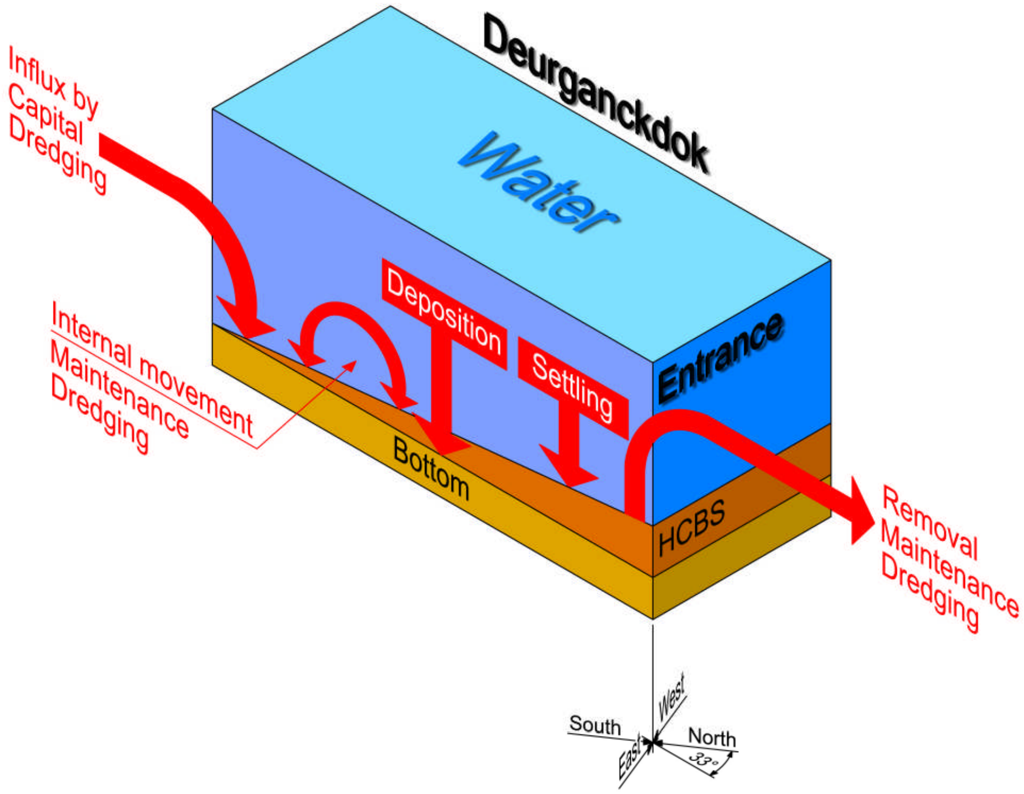

Figure 2-2: Elements of the sediment balance

A net deposition can be calculated from a comparison with a chosen initial condition t_0 (Figure 2-3). The mass of deposited sediment is determined from the integration of bed density profiles recorded at grid points covering the dock. Subtracting bed sediment mass at t_0 leads to the change in mass of sediments present in the dock (mass growth). Adding cumulated dry matter mass of dredged material removed since t_0 and subtracting any sediment influx due to capital dredging works leads to the total cumulated mass entered from the Scheldt river since t_0.

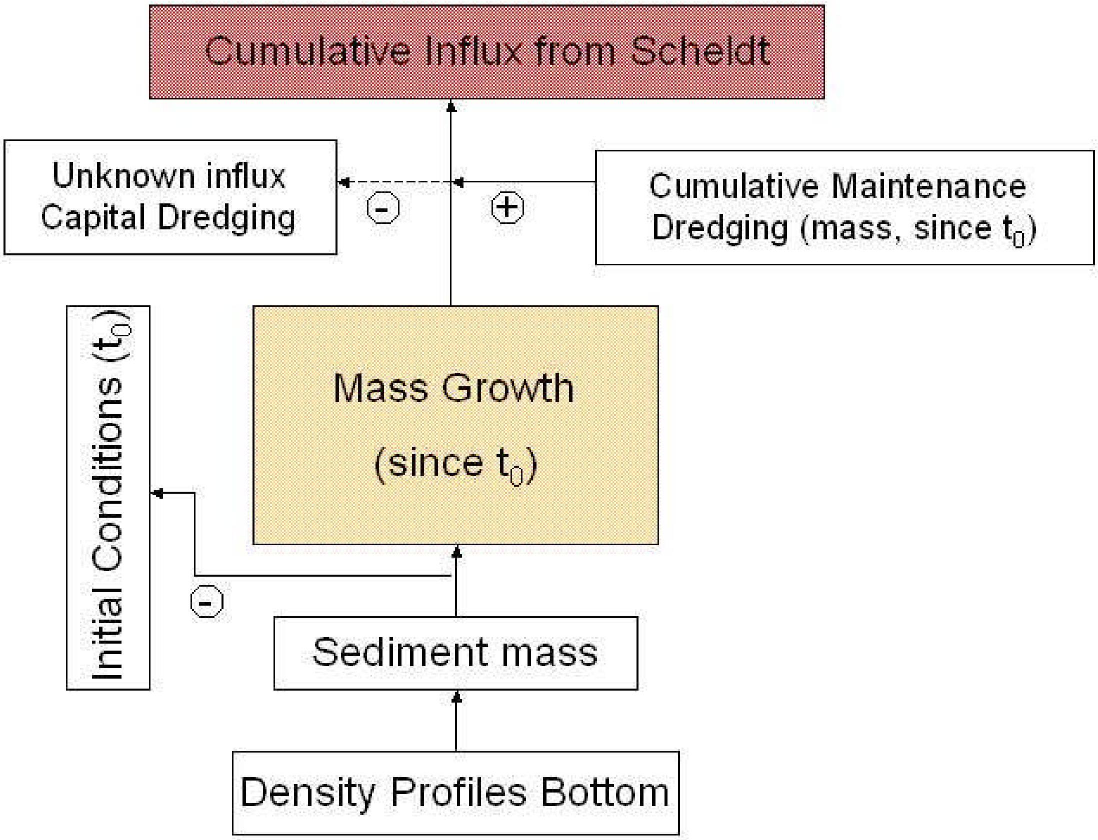

Figure 2-3: Determining a sediment balance

The main purpose of the second part of the study is to gain insight in the mechanisms causing siltation in Deurganckdok. The following mechanisms will be aimed at in this part of the study:

- Tidal prism, i.e. the extra volume in a water body due to high tide
- Vortex patterns due to passing tidal current
- Density currents due to salt gradient between the Scheldt river and the dock
- Density currents due to highly concentrated benthic suspensions

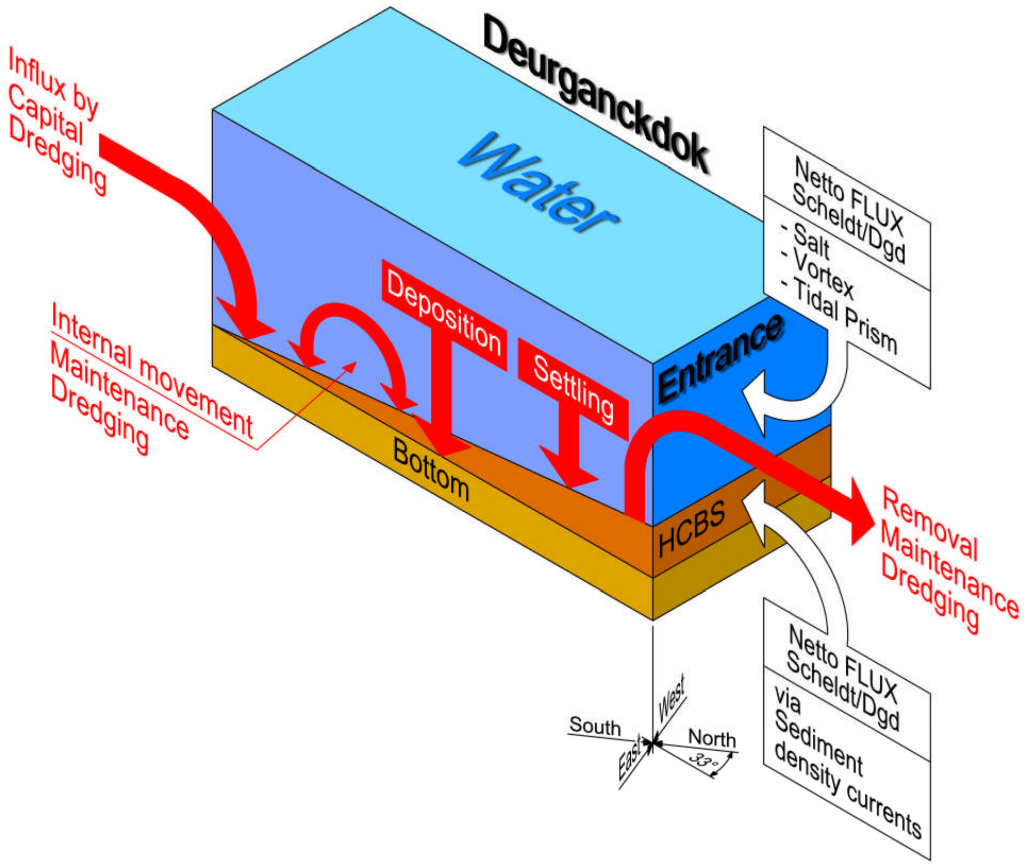

Figure 2-4: Transport mechanisms

These aspects of hydrodynamics and sediment transport have been landmark in determining the parameters to be measured during the project. Measurements will be focused on three types of timescales: one tidal cycle, one neap-spring cycle and seasonal variation within one year.

Following data are being collected to understand these mechanisms:

- Monitoring upstream discharge in the Scheldt river.
- Monitoring Salt and sediment concentration in the Lower Sea Scheldt at permanent measurement locations at Oosterweel, up- and downstream of the Deurganckdok.
- Long term measurement of salt and suspended sediment distribution in Deurganckdok.
- Monitoring near-bed processes (current velocity, turbidity, and bed elevation variations) in the central trench in the dock, near the entrance as well as near the current deflecting wall location.
- Dynamic measurements of current, salt and sediment transport at the entrance of Deurganckdok.
- Through tide measurements of vertical sediment concentration profiles -including near bed high concentrated benthic suspensions.
- Monitoring dredging activities at entrance channels towards the Kallo, Zandvliet and Berendrecht locks as well as dredging and dumping activities in the Lower Sea Scheldt.
- In situ calibrations were conducted on several dates to calibrate all turbidity and conductivity sensors.

3. MEASUREMENTS

3.1. Depth soundings

The client executes dual-frequency echo-sounder measurements every week to every three weeks. F. De Cock (Agentschap voor Maritieme Dienstverlening en Kust – Afdeling Kust) communicated that these measurements are carried out with a 210-33 kC Echo sounder using Qinsy software. The depth sounding measurements are executed in a grid configuration, consisting of sections perpendicular and parallel to the quay wall.

Table 3-1: Overview of the available depth soundings suitable for analysis 01/09/2007 – 31/12/2007

date	***type of measurement***	***signal***	***Source***
24/03/2006*	dual frequency 210-33 kHz	210	Afdeling Kust
5/09/2007	SILAS	210	
28/09/2007	dual frequency 210-33 kHz	210	Afdeling Kust
16/10/2007	SILAS	210	
7/11/2007	dual frequency 210-33 kHz	210	Afdeling Kust
16/11/2007	SILAS	210	
5/12/2007	SILAS	210	
13/12/2007	dual frequency 210-33 kHz	210	Afdeling Kust

*= reference situation depth soundings: t_{0e}

To calculate a sediment balance it is necessary to analyse the measurements in stationary situation, with no alteration in boundary conditions being dredging operations. Every period is characterized by a depth sounding measurement before (‘inpeiling’) and one after (‘uitpeiling’).

A number of analyses were done using the depth soundings in Table 3-1, originating from Afdeling Kust. The raw depth sounding data was processed in ESRI ArcGIS. The 210 kC signal is used in the following analyses as it gives an indication of the water-bed interface.

In addition, depth soundings could be derived from the SILAS density measurements too, see §3.2.2. As such, extra 210 kHz acoustic reflectance measurements became available as shown in Table 3-1.

A reference level was chosen from all depth sounding measurements, effectively the earliest most complete measurement. This turned out to be the measurement on 24 March 2006. This will be considered as a reference situation, initial condition t_{0e}.

A number of analyses were performed in ArcGIS 9 and a Matlab environment to produce maps, figures and tables with relevant information concerning elevation, elevation changes and volumetric growth (§4.2 to §4.4).

3.2. Density measurements

3.2.1. Navitracker

Navitracker was used to perform density measurements. Density measurements are necessary to calculate a sediment balance of dry weight of sediment per surface unit.

The Navitracker is a patented system to measure the density of fluid mud suspensions, by means of a gamma-density meter. It has been used by the Flemish authorities over 20 years to determine the nautical bed for the port of Zeebrugge.

The Navitracker system can be operated by a computer controlled winch to tow it through the mud (horizontal mode). The Navitracker is equipped with the following sensors:

- The Gamma ray density sensor, mounted on a fork-like tow fish, gives density information.
- The depth sensor gives information of the depth of the sensor.
- The position of the fish is calculated out of the length of the winch cable. Together with the position of the tow fish, following the density level, a dual frequency echo sounder is used to map the hard bottom and the top of the mud. With a speed of 2 to 3 knots, large areas can be covered.

For these measurements the Navitracker was used in a vertical profiling mode, with the probe in vertical position in order to penetrate the soft bottom. The vertical density profiler is used to measure density in thick mud layers with high densities.

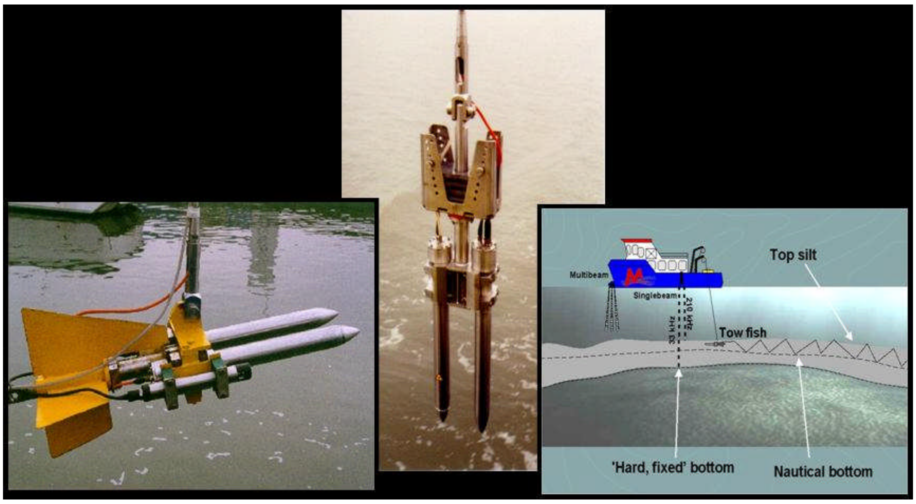

Figure 3-1: Navitracker

The Navitracker was calibrated in the laboratory for measuring high densities, formed by very dense water-mud mixtures. For this reason the Navitracker did not detect subtle variations in density caused by changes in salinity. The density deviated from 1.000 ton/m³ only in the presence of a high concentration of sediments.

The Navitracker has a sampling frequency of 10 measurements per second.

As a reference situation the empty dock will be used at the design depth. The design depths for the different zones are shown in Table 3-2. The different zones are described in §4.1.

Table 3-2: Reference Situation Density Measurements (t_{0d})

Zone	*Design Depth (mTAW)*
Central trench	-19
Berthing zones and transition zones to central trench	-17
Sill	-13.5
Transition sill to navigation channel	Not applicable

The resulting profiles were processed in a Matlab environment and visualized in Matlab and ESRI ArcGIS. Equal density layers were computed. Volume and density information was used to calculate masses of silt. All masses are given in ton of dry solids (TDS) characterized by a density of 2.65 kg/dm³. The water-bed interface is defined as the layer with a density of 1.03 kg/dm³.

In this measurement campaign, Navitracker density measurements have been performed on 5 September, 16 October, 16 November and 5 December 2007.

3.2.2. SILAS in combination with Echotrac MKIII

Whereas the Navitracker performs local measurements of the density, an Echotrac MKIII echo sounder is used in combination with the SILAS software to determine horizons of equal density. The echo sounder transmits an acoustic signal of 33 and 210 kHz. The echo of the 33 kHz signal is automatically interpreted by the SILAS software and identifies various reflections horizons or layers and density levels. From these, sediment mass between two subsequent layers can be determined. The sediment mass calculation method is briefly described as follows:

- SILAS is calibrated by the Navitracker measurements
- determine grids with depth of equal density plane: 1010, 1050, 1100, 1150, 1200 and 1250
- SILAS returns good SN-ratio until density of 1250; below this plane an average density based on available Navitracker data is used to calculate the mass
- calculation of mass in each layer based on the difference of plane depths and average layer density. For the bottom of the Deurganckdok, the design depth was used.

In this report, SILAS measurements were performed on the following dates: 5 September, 16 October, 16 November and 5 December 2007. The data analysis mainly focused on the feasibility of the technique to accurately measure densities and compute sediment masses from it. Therefore, results were critically evaluated against the Navitracker measurements as reference densities.

In addition, the 210 kHz acoustic signal was used to determine the depth level of the water-bed interface, similar to §3.1.

3.3. Maintenance Dredging Data

All maintenance dredging (except sweep beam) activities in Deurganckdok were collected in the BIS-system. This system gives a standardised output per week, that states the weight, volume and V'[1] removed/dumped in every 5*5m grid cell in the area. In case the density of the dredged sediment in the hopper bin is larger or equal to 1.6 kg/dm³, V' is equal to the volume in the bin. In case the density is smaller than 1.6 kg/dm³, V' is equal to the reduced volume which is defined as the volume the dredged sediment would have in case the density would be equal to 2 kg/dm³ (AWZ 2000). These dredged volumes are important to have an overall view on the sediment balance. Maintenance dredging occurred on 19 and 26 November 2007.

The available data on sweep beam activity is not collected in the BIS-system. However the mode of operation of the sweep beam is explained:

- On the sill (zone 1 & 2): the sediment is swept into the Lower Sea Scheldt
- Inside the dock: the sweep beam sweeps the berthing zones next to the quay walls and moves sediment into the central trench

Therefore an overview is given of where and when sweep beam dredger was working in Deurganckdok (DGD) or on the sill of Deurganckdok (sill DGD).

[1] V' = Reduced Volume

Table 3-3: Sweep beam Maintenance dredging activities in Deurganckdok and on the sill of Deurganckdok between September 2007 and December 2007 (source: Afdeling Maritieme Toegang)

From	***Till***	***Duration (days)***	***Location***
29/09/2007	29/09/2007	1	DGD
24/10/2007	24/10/2007	1	Sill DGD
5/11/2007	5/11/2007	1	DGD
13/11/2007	17/11/2007	5	Sill DGD + DGD
21/11/2007	24/11/2007	4	Sill DGD + DGD
12/12/2007	12/12/2007	1	Sill DGD
19/12/2007	19/12/2007	1	Sill DGD

An overview of the total dredged mass in all zones (BIS data) is provided in APPENDIX D. The sweep beam tracks are shown in APPENDIX D. The loggings of the sweep beam tracks show the position and depth of the rake. From the up-down position of the rake and the ship's direction, it is possible to identify whether the ship is sweeping sediment into the Scheldt or not. A thorough analysis of the obtained data revealed some problems though (IMDC, 2007d). For these reasons, the tracks will not be applied as such in this study. Only the sweep beam locations will be utilised in a qualitative way.

3.4. Capital Dredging Data

In February 2007, the 3rd phase of the capital dredging works was initiated. Topographic measurements on a regular grid were supplied by the contractor in order to follow up the capital dredging progress. For the period 01/09/2007 till 31/12/2007, progress data is available for the following dates:

- 3, 12, 18 and 25 September 2007;
- 4, 16, 24 and 30 October 2007;
- 26 November 2007;
- 3 December 2007

and are shown in APPENDIX E. Note that the design depth of the first half of the dock is presented and not the actual bathymetry.

These data allow studying the progress of the dredging works. In reference to 14 February 2007, i.e. before capital dredging started, the volume of removed sediment is calculated. In order to calculate the tide prism, the decadal tide data at Liefkenshoek was used, which resulted in a yearly averaged high and low tide level of 5.19 and 0.05 m TAW respectively.

4. SEDIMENT BALANCE ANALYSES

4.1. Project Area: (Sub)Zones and Sections

To calculate volumes and masses for the sediment balance of Deurganckdok it is necessary to subdivide it into 5 zones:

- Zone 1: Between the sill and the navigation channel in the Lower Sea Scheldt.
- Zone 2: Sill at entrance DGD designed at –13.5 m TAW.
- Zone 3: Central trench in DGD with a design depth at –19 m TAW (including slope to –17 m TAW)
- Zone 4: Transition between central trench and berthing zones with a design depth at –17.00 m TAW: on both (North (N) and South (Z)) sides of DGD (55 m wide).
- Zone 5: Berthing zones next to quay walls on both (North (N) and South (Z)) sides of DGD (40 m wide)

Zones 3, 4 and 5 are subdivided into subzones A, B, C, D and E. This is shown in Figure 4-1.

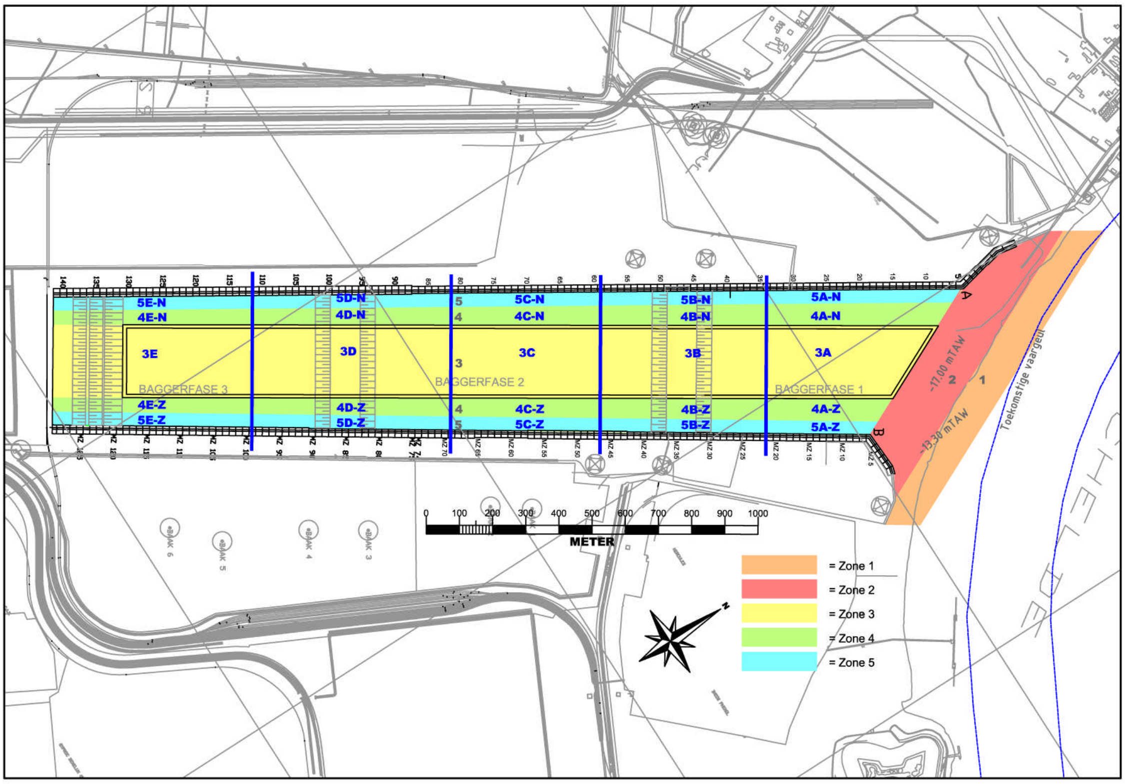

Figure 4-1: Deurganckdok: Zones and Subzones

Sections are defined for this whole area (Figure 4-2):

- D sections are oriented perpendicular to the quay walls inside the dock and parallel to the navigation channel outside the dock (sill and Scheldt). The origin of the sections is taken on the quay wall at the left bank (West side) looking outwards.
- L Sections are oriented along the centerline of the dock and run from the navigation channel towards the inland end of the dock, in anticipation of the realisation of the third phase of Deurganckdok. The origin is situated on the intersection between each L section and section D10.

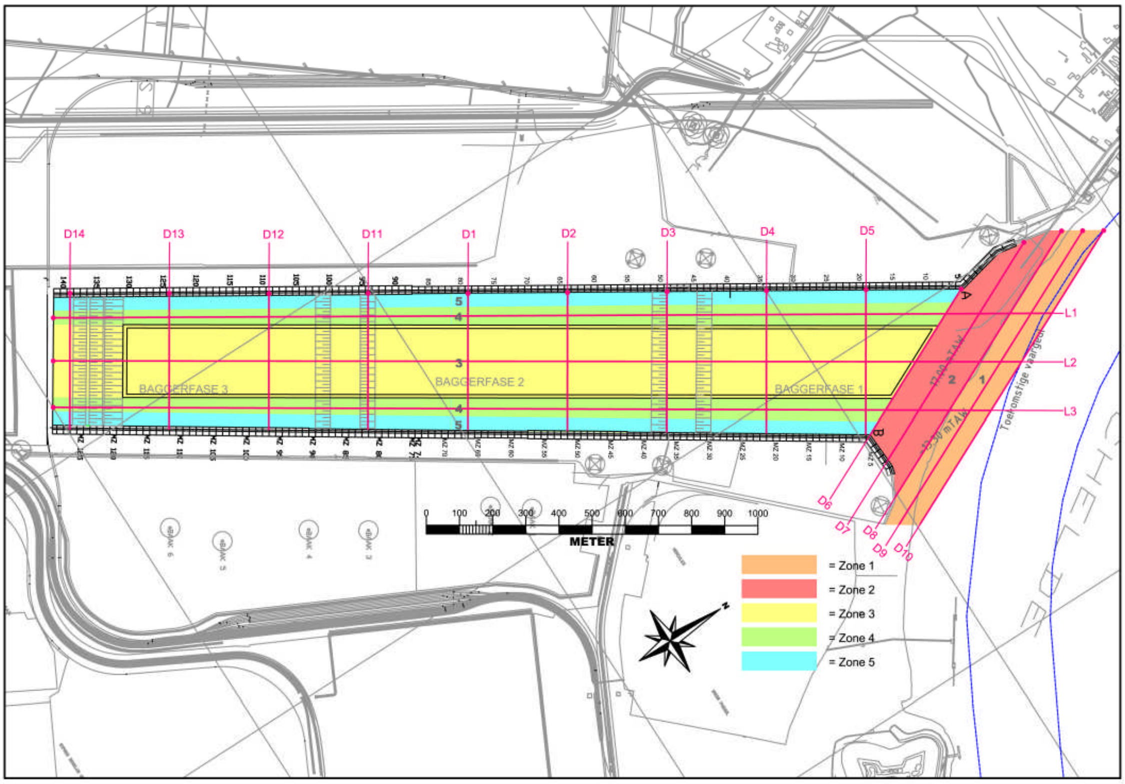

Figure 4-2: Deurganckdok: D and L Sections

The coordinates of these sections are given in Table 4-1.

Table 4-1: Coordinates of Sections [UTM ED50]

Name	***Origin***		***End***	
	Easting	***Northing***	***Easting***	***Northing***
D Sections				
D1	587773	5683253	588123	5683037
D2	587929	5683510	588283	5683290
D3	588084	5683767	588444	5683544
D4	588239	5684023	588604	5683797
D5	588394	5684280	588765	5684051
D6	588542	5684526	588772	5684062
D7	588521	5684761	588864	5684068
D8	588552	5684875	588972	5684027
D9	588585	5684930	589047	5683994
D10	588617	5684984	589081	5684047
D11	587615	5682997	587962	5682783
D12	587459	5682742	587802	5682529
D13	587300	5682487	587642	5682276
D14	587143	5682232	587482	5682023
L Sections				
L1	588748	5684720	587180	5682151
L2	588825	5684565	587290	5682082
L3	588901	5684410	587409	5682007

4.2. Depth of the water-bed interface (210 kC)

This is shown as a GIS grid map generated directly from the depth sounding data and is shown in APPENDIX A. An example is shown in Figure 4-3.

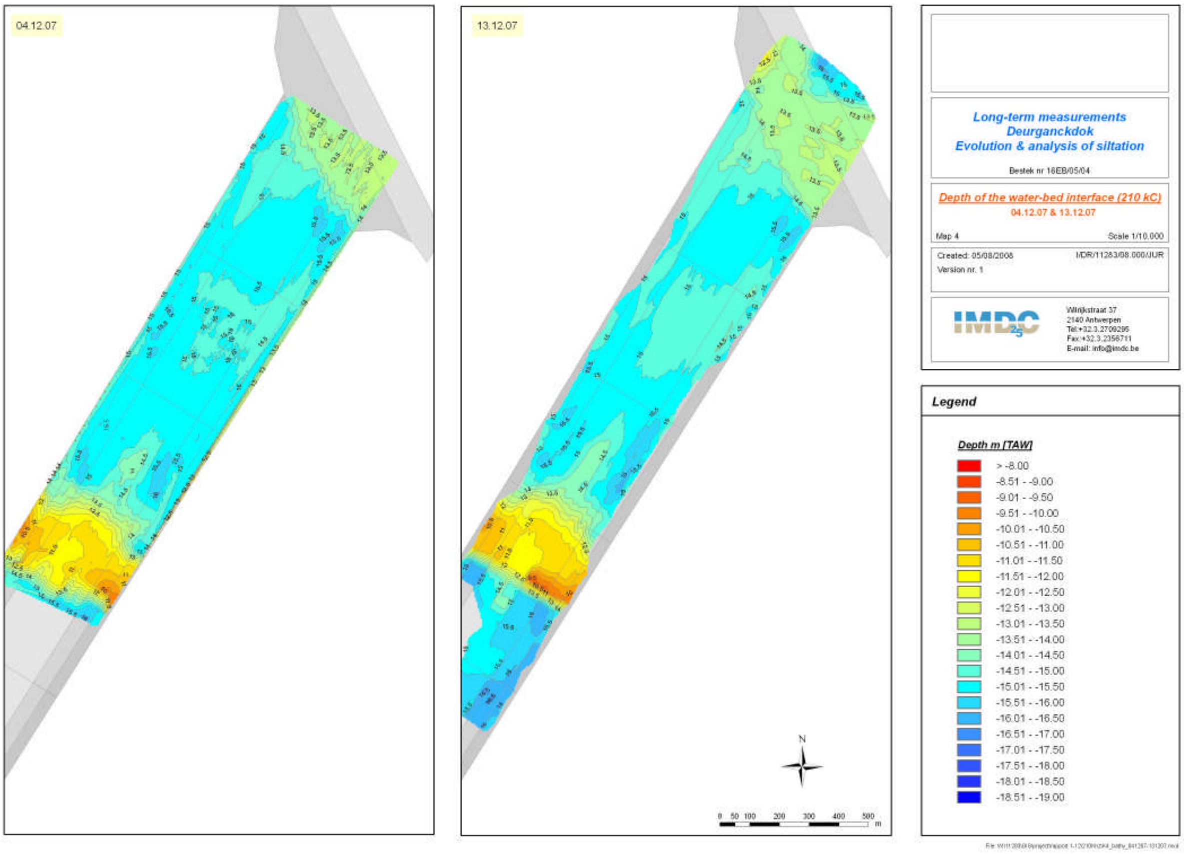

Figure 4-3: Example of a map showing depth of water-bed interface (210 kC) for 4/12/07 and 13/12/07

4.3. Evolution of water-bed interface (210 kC)

GIS grid maps show the difference charts for every depth sounding in relation to the reference situation (t_{0e}) and to the previous depth sounding (right). An example is shown in Figure 4-4.

The difference in depth between subsequent depth soundings for 210 kC measurements is also shown for all predefined sections. Graphs show a colour plot with Time in the X-axis, Distance to origin of section in the Y-axis and the depth of the top layer [m TAW] as a colour plot.

The origin for de the D sections is the northern quay wall. The origin of the L sections is the intersection between the L section with the Scheldt edge of zone 1. An example for sections is shown in Figure 4-5. The description of the sections is given in § 4.1.

Maps and graphs are shown in APPENDIX B.

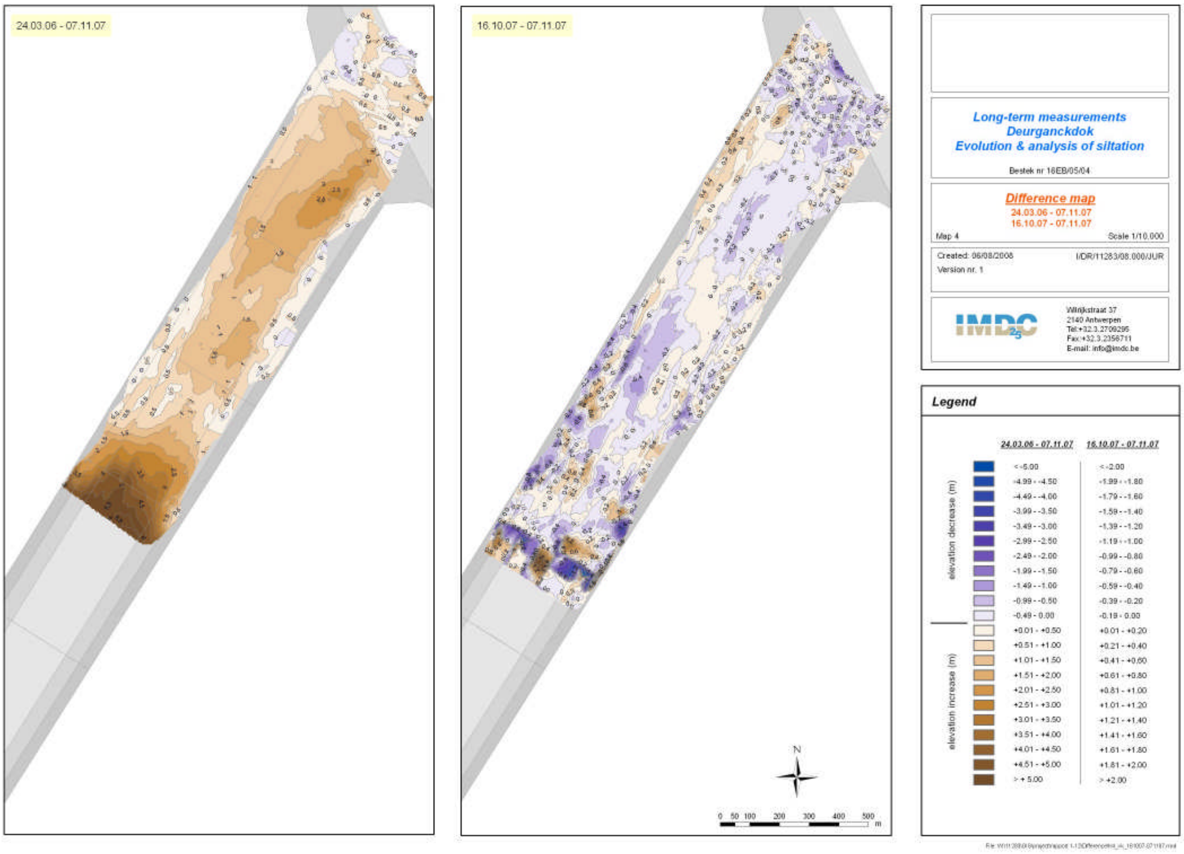

Figure 4-4: Difference charts of the depth sounding on 7/11/07: in reference to t_{0e} (left), and to the previous measurement (right) on 16/10/07

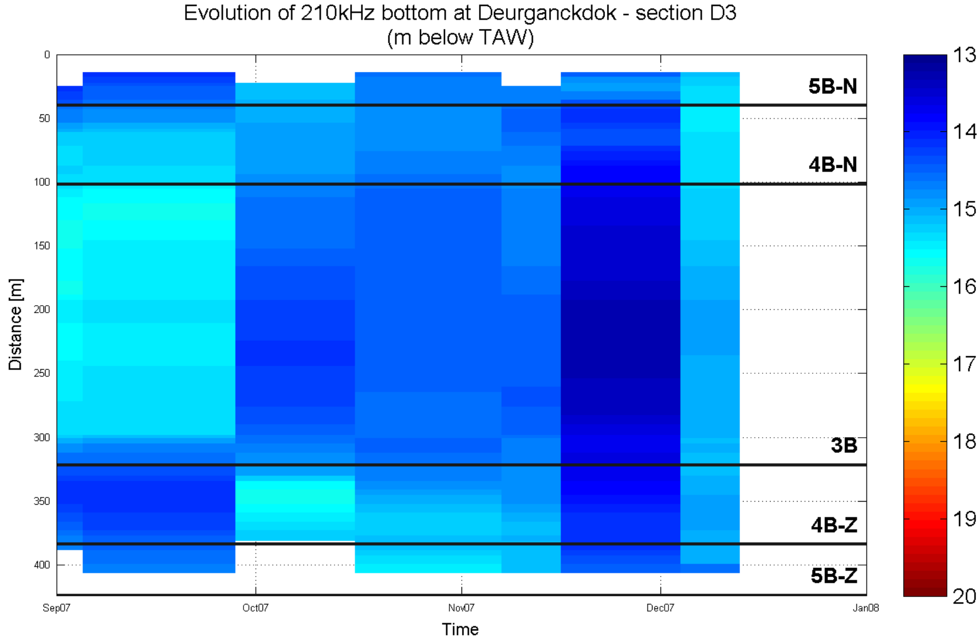

Figure 4-5: Graph of Evolution of the water-bed interface (210 kC) for section D5

4.4. Volumetric siltation rates [cm/day] in different zones and sections

A table with monthly average siltation rates for all (sub)zones is also given in APPENDIX C.

Graphs in APPENDIX C show two parameters:

- Average siltation rates [cm/day]: The average siltation rate is the difference in the depth of the water-bed interface and is calculated only for those zones and subzones that have at least a 50% surface area overlap between two subsequent depth soundings. This is done for all successive depth soundings. For each month an average siltation rate is calculated this way. It is shown in the plots as a bar and is positive for sedimentation and negative for erosion or removal.
- Cumulative bed level change [m]: an initial situation (t_0) is used as baseline. Starting from this reference level the evolution of the average bed level elevation is shown for the particular (sub)zone.

Dredging events from the BIS system are marked on each of these graphs. This is computed for all zones, subzones, sections and Deurganckdok as a whole. As an example we show siltation rate and cumulative bed level change for zone 3a in Figure 4-6.

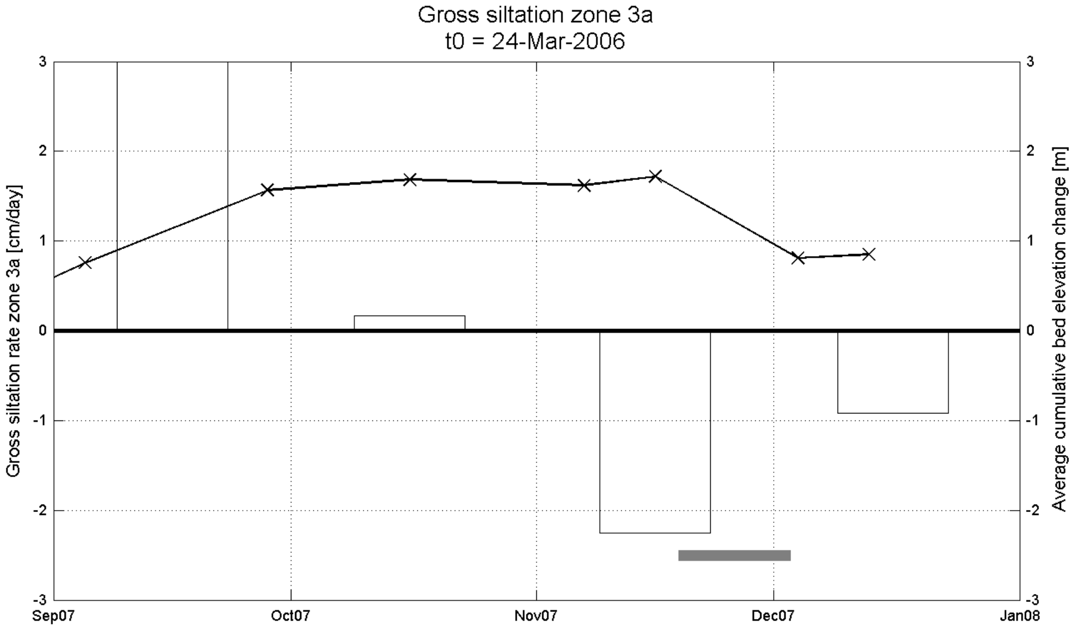

Figure 4-6: Volumetric siltation rate for zone 3a

4.5. Depth of water-bed interface (1.03 kg/dm³) and equal density layers

This analysis is based on density profile measurements from the Navitracker. Maps show the depth of water-bed interface and equal density layers (1.1, 1.2, 1.3 kg/dm³). The elevation of the water-bed interface is here defined as the depth at which the equipment encounters a density of 1.03 kg/dm³. This threshold is chosen since the maximum weight of salt and suspended sediment in the water column is estimated at 30 g/l, corresponding with a bulk density of about 1.03 kg/dm³. When the density passes this value, the equipment is assumed to reach the water-bed interface. The depth of the layers of constant density can be found in APPENDIX F, whereas APPENDIX G gives the density profiles for the different sections in Deurganckdok. An example for equal density layers in section D1 is given in Figure 4-7. An example of a map is given in Figure 4-8. The description of the sections is given in § 4.1.

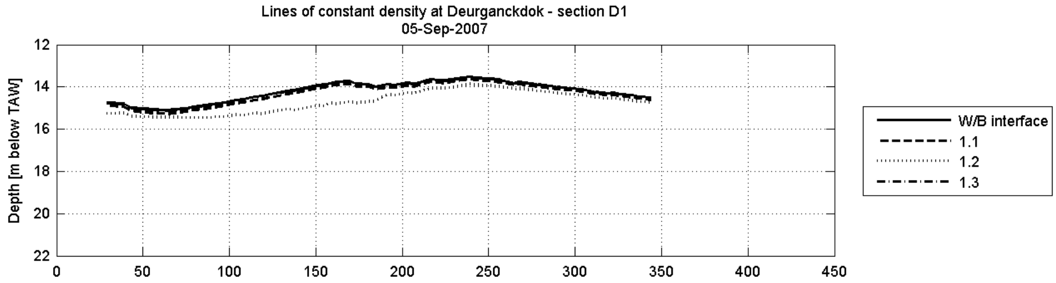

Figure 4-7: Depth of water-bed interface and equal density layers in section D1 on 5 September 2007

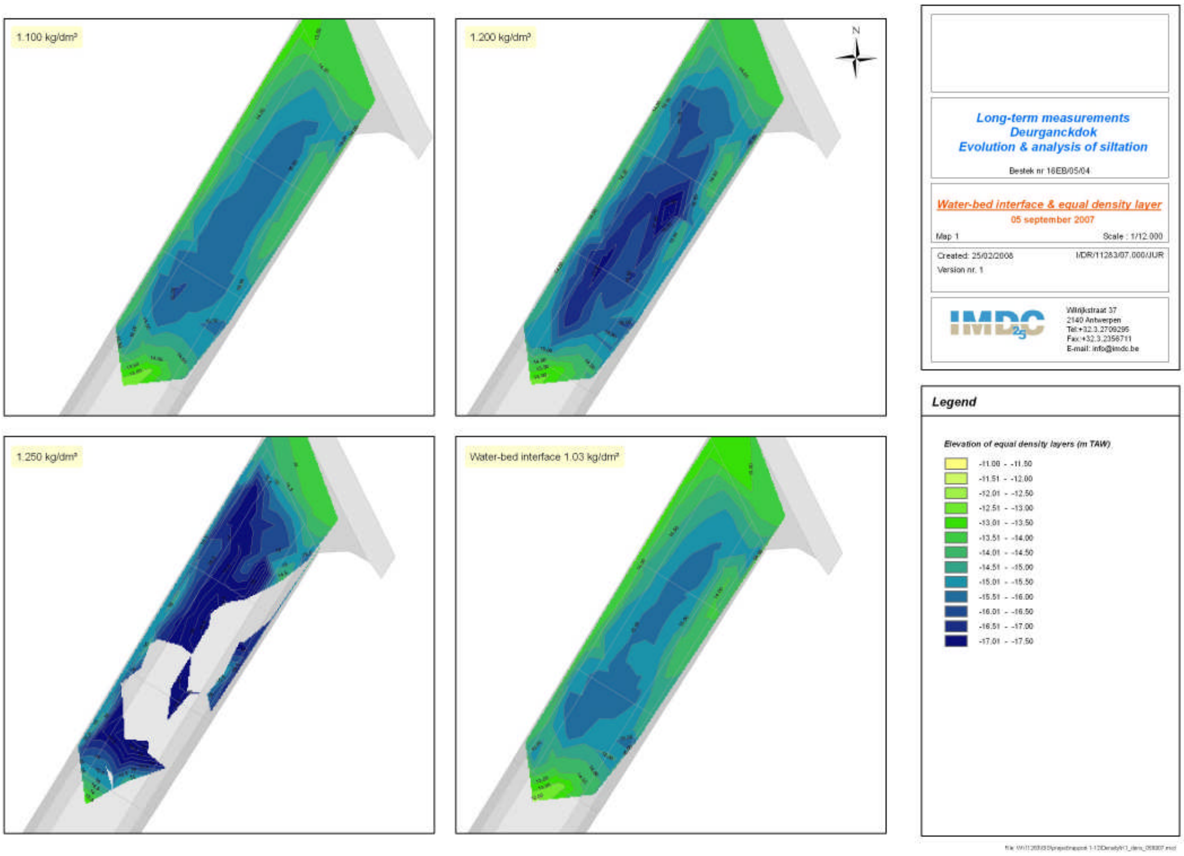

Figure 4-8: Map of the depth of the water-bed interface and equal density layers for 5/09/07

4.6. Evolution of water-bed interface and equal density layers elevation

The evolution of water-bed interface and equal density layers (1.1, 1.2 en 1.3 kg/dm³) are shown for all sections in APPENDIX H. The description of the sections is given in § 4.1.

All 4 density measurements are used for this comparison. Sections of four different planes of constant density are determined. These planes are determined by mapping the depths at which the specified densities have been encountered. For every measurement campaign the elevation of these planes across the sections has been plotted. An example is shown in Figure 4-9

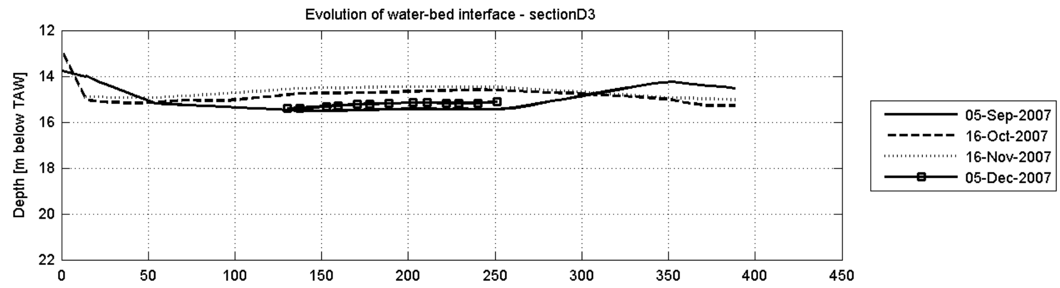

Figure 4-9: Graph of the evolution of 1.1 kg/dm³ plane in section D3

4.7. Measured mass maps

The measured mass in [TDS/m²] is calculated and visualized in maps for every measurement in reference to the empty dock at design depth (reference situation t_{0d}) (see §3.2). Every map is based on a density measurement.

These maps are shown in APPENDIX I.

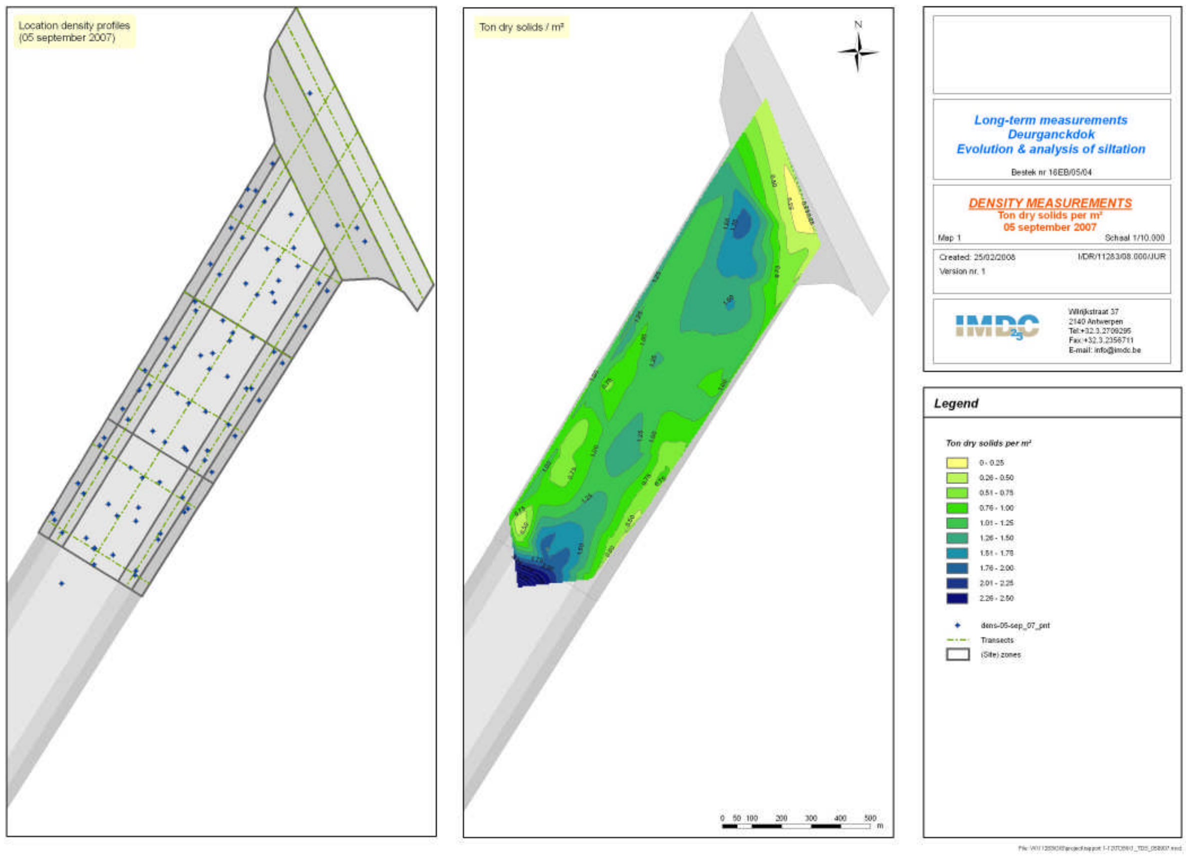

Figure 4-10: Map showing the location of the density profiles (left) and the calculation of TDS (right) on 5/09/07

4.8. Average net mass evolution

The average net mass growth [TDS/m²] in all zones and subzones is based on density profile measurements (measured sediment mass). The actual sediment mass present in the dock and measured by density profiling does not take the removed dredged material into account. The mass removed by dredging can be computed from BIS data (dredged material mass). Only the sediment dredged on locations for which the mass present in the bed could be measured is taken into account.

By adding measured mass to dredged material mass, the total accumulated mass and hence the growth can be shown (see Figure 4-11). In case this *total mass* can be computed for the complete dock (or a zone) for two subsequent measurements, an estimation of the net sediment flux into the dock (or zone) during the intermediate period is given by the difference of both total mass values. The net sediment flux into an area can also be defined as the net mass growth (kg/m² or Ton Dry Solids/m²). Division of the net mass growth of a zone by the number of days in between measurements leads to the averaged net mass growth rate.

Averaged net mass growth rate [kg/m²/day] is computed for each zone and subzone and is shown in APPENDIX J. An example is shown for zone 3B in Figure 4-12.

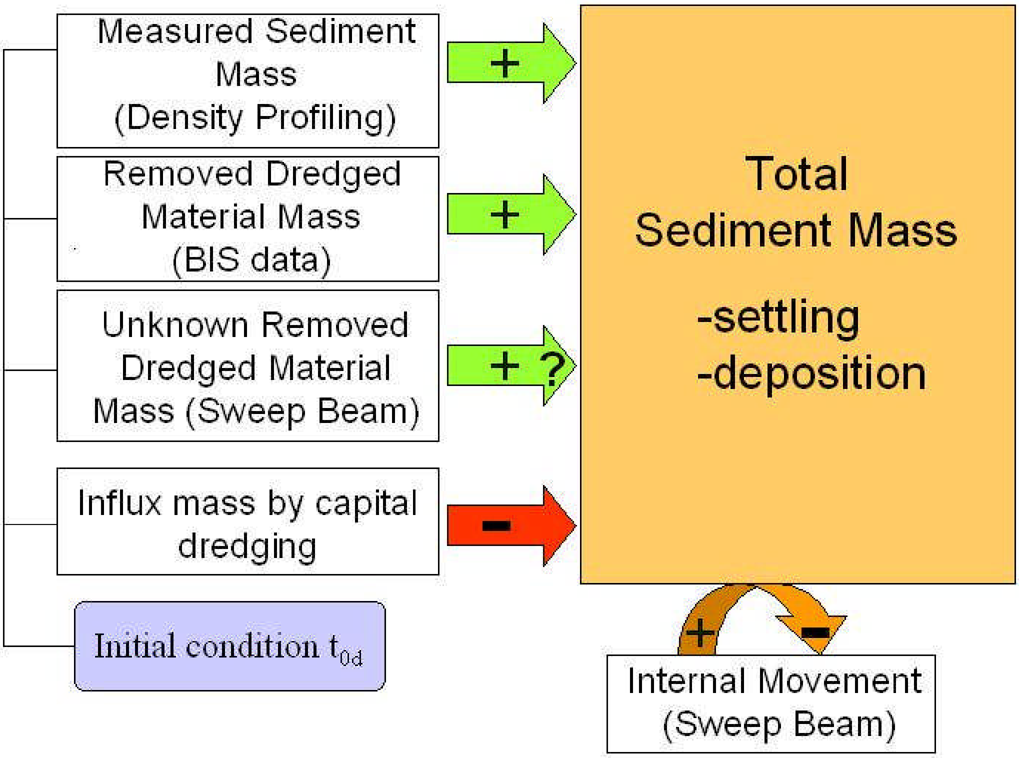

Figure 4-11: Flow chart with different elements contributing to total sediment mass for (sub)zones and total area

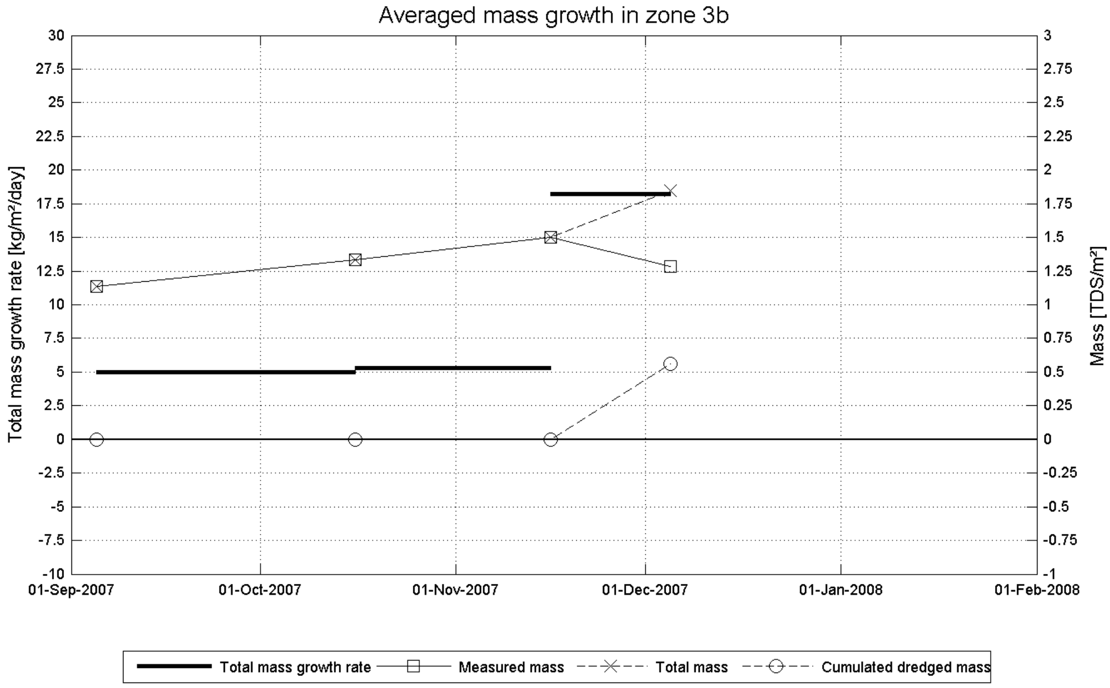

Figure 4-12: Example of averaged mass growth and mass evolution for subzone 3B

Clearly, the sediment mass balance is incomplete because sediment fluxes cannot be derived from the sweep beam data (of which no mass or volume information is available). Internal movements of sediment by the sweep beam (berthing zones to central trench) and removal of sediments from the sill into the Lower Sea Scheldt definitely influence the mass balance for (sub)zones and the total dock.

A table in APPENDIX J gives an overview for all zones and subzones for the following parameters, and this only if data is available for at least 50 % of this (sub)zone:

- Measured Sediment mass [TDS/m²]
- Dredged Material mass (absolute) [TDS]
- Total Sediment mass [TDS/m²]
- Growth rate [kg/m²/day]]
- Total area [ha]
- Covered area [ha]: area covered by density profiles
- Percent of zone covered [%]

4.9. Capital dredging works

Capital dredging data is used to compute the time evolution of the volume of dredged sediment. The volumetric change has been calculated in reference to 14 February 2007.

To compute the tide prism, it is necessary to have an idea about the total dock volume available for water storage during high and low tide. Therefore, the decadal tide data at Liefkenshoek was used and resulted in a yearly averaged high and low tide level of 5.19 and 0.05 m TAW respectively (AMT, 2003). In the operational part of the Deurganckdok (see Figure 4-13), the volume of exchanged water remains constant, and does not contribute to any change in tide prism, during the capital dredging works. For the remainder of the dock, topographic measurements were applied for the necessary calculations. An example of such a data set is shown in Figure 4-14.

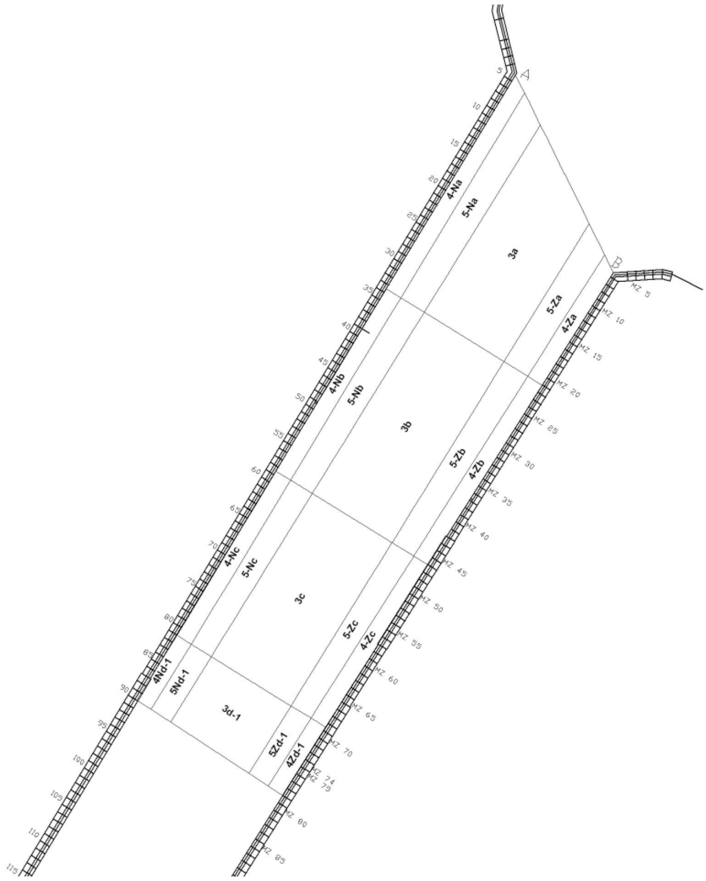

Figure 4-13: Operational part of Deurganckdok at the start of the 3rd phase of capital dredging works (Feb. 2007)

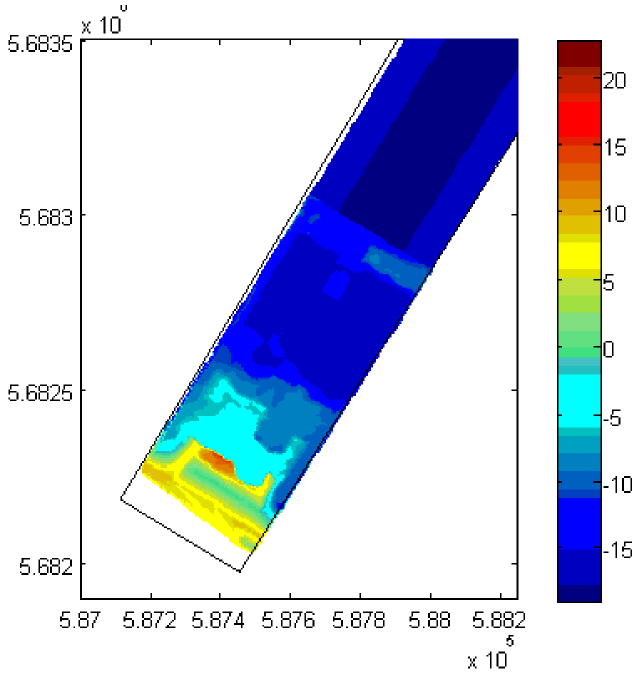

Figure 4-14: Depth of capital dredging (and design depth) on 16/10/2007

4.10. Evaluation of SILAS to measure sediment

This section aims at demonstrating the possibilities of the SILAS software in order to determine bulk densities and sediment mass accumulation. The sediment mass was therefore calculated using two different approaches:

- SILAS: echosouder-based software calculations;
- Navitracker: density-profile based calculations.

Results of this comparison can be found in the feasibility study note I/NO/11283/08.001/BOB (IMDC, 2008), and is included in APPENDIX L.

The performed work clearly illustrated that the SILAS is less appropriate for measuring densities of consolidated sediment layers. The SILAS seems to be incapable of distinguishing densities in Deurganckdok larger than 1.25 ton/m³. In these cases, the Navitracker device is preferred. However, the latter technique demands for a fine sampling grid to perform good sediment mass calculations.

In case of the project “Opvolging aanslibbing Deurganckdok 2”, Navitracker data is collected according to a dense measurement grid in Deurganckdock. In the entrance channels of different measured locks not enough Navitracker measurements were available to apply the Navitracker-based method to accurately perform mass calculations. The SILAS technique is therefore applied at these locations and is to be combined with an average sediment density derived from the Navitracker applicable to the depth range corresponding to densities larger than 1.25 ton/m³.

To conclude, the Navitracker-based method is preferred to the SILAS technique. However, a fine measurement grid should always be adopted.

5. PRELIMINARY ANALYSIS OF THE DATA

5.1. Volumetric analysis

Depth sounding data is processed to show the evolution of the average sediment volume per unit of surface, i.e. the average evolution of bed level as detected by a 210 kHz sounder. If more than 50% of the area of a (sub)zone is covered, an average siltation rate is calculated. For the period of September – December 2007, depth soundings were performed on 5 and 28 September, 16 October, 7 and 16 November, and 5 and 13 December. During these measurements, an adequate coverage was obtained during depth soundings, except for zone 1 and all subzones of E. Depending on the depth sounding date, some of subzones 5 are inadequately sampled as well.

The bathymetric measurements in APPENDIX A and the corresponding bathymetric difference maps in APPENDIX B show that the bed interface moves to decreasing depths in zones 3A and 3B from September to November. The water-bed interface level as deduced from the density measurements (see APPENDIX G and APPENDIX H) also indicated a steady bed level increase for this time period. This is demonstrated for two example locations in zones 3A and 3B as shown in Figure 5-1. The vertical density profiles in Figure 5-2 clearly show an increasing bed level.

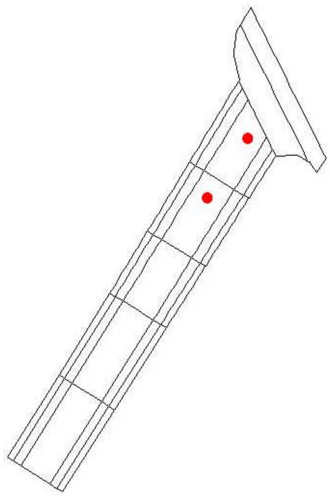

Figure 5-1: Example locations for investigating density profile time evolution

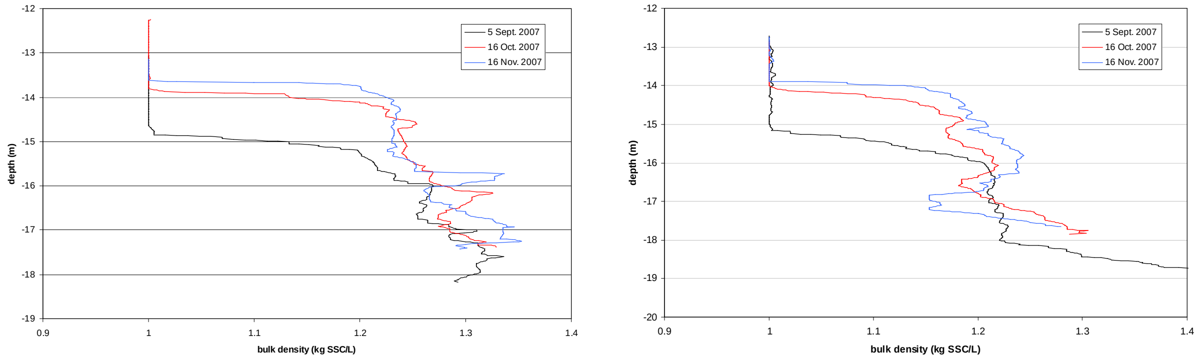

Figure 5-2: bulk density profiles in zones 3A (left) and 3B (right) for the following dates: 5 September, 16 October and 16 November 2007

From the maintenance dredging operation files, sediment removal from the central dock trench happened in the second half of November. This is also clearly observable in the bathymetric difference maps.

From the depth sounding data, volumetric siltation rates can be computed. APPENDIX C clearly shows a large monthly-averaged siltation rate in the central trench of the dock for September, in the order of 2.3 – 3.4 cm per day. This large value can be attributed to the dredging operation that took place prior to the depth sounding at the end of August. As a result, the solids rapidly accumulate in the deepened trench. Despite the fact that October is characterised by an undisturbed bed (no dredging), negative or only small positive siltation rates occur in the central trench. Similarly as above, the density measurements show much larger (densimetric) siltation rates (see §5.2). Instead, the northern berths (zones 4A-N, 4B-N and 4C-N) show positive volumetric siltation rates, generally being larger than those observed at the southern berths (zones 4A-Z, 4B-Z and 4C-Z). In zone 4A-N, a siltation rate of 1.32 cm per day occurred, which decreased when going further inside the dock. November showed negative monthly-based siltation rates because maintenance dredging occurred at the end of November.

Averaged over zones A, B and C (see Figure 5-3), the order of magnitude of the observed undisturbed siltation rates (for September) is around 1.4 cm/day. Note that this siltation rate is much larger than the one observed for the period July-August 2007, where a value of 0.3 cm/day was found (IMDC, 2007h).

A table with siltation rates per month and for all cross sections, longitudinal sections and subzones is given in a table in APPENDIX C.

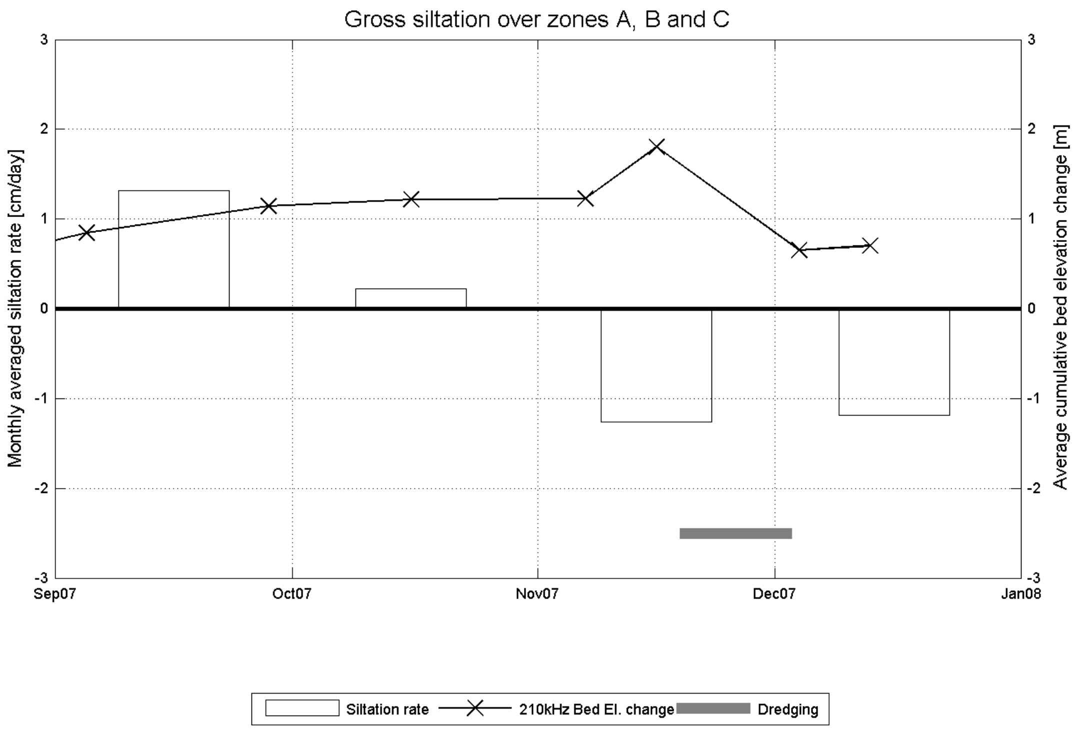

Figure 5-3: Monthly averaged siltation rate for the present measurement period (September - December 2007)(BOTTOM) (t_{0e} : 24/03/2006)

Capital dredging started in February 2007 in order to deepen the remainder of the Deurganckdok to its design depth (Figure 5-4). In this respect, Table 5-1 summarizes the time evolution of removed sediment by capital dredging. From the table, it is calculated that more than 0.38 million m³ sediment/month is dredged for the period September-December 2007.

Whereas the period July-August led to a tide prism increase of 375.4 10³ m³, the present period of September until December 2007 resulted in an increase of 1286.4 10³ m³ (Table 5-2).

Table 5-1: Calculated volume removed by capital dredging in reference to 14 February 2007

Date	***Dredged volume from capital dredging works*** **(reference time: 14 Feb. 2007)** ***(10³ m³)***
03/04/2007	1571.5
08/05/2007	2392.6
18/06/2007	3229.5
25/07/2007	3658.0
31/07/2007	3574.3
06/08/2007	3720.0
28/08/2007	4261.8
3/09/2007	4396.9
12/09/2007	4525.0
18/09/2007	4564.7
25/09/2007	4724.7
4/10/2007	4843.0
16/10/2007	5087.1

24/10/2007	5276.4
30/10/2007	5383.6
26/11/2007	5325.1
3/12/2007	5548.2

Table 5-2: Calculated tide prism during capital dredging operations at Deurganckdok

Date	***Tide prism (10^3 m^3)***
start 3th phase	3441.4
26/03/2007	4482.7
03/04/2007	4626.4
08/05/2007	4720.8
18/06/2007	4858.1
25/07/2007	4938.7
31/07/2007	4987.1
06/08/2007	5037.5
28/08/2007	5096.1
3/09/2007	4186.4
12/09/2007	5076.7
18/09/2007	5082.3
25/09/2007	5089.0
4/10/2007	5074.8
16/10/2007	5082.1
24/10/2007	5156.5
30/10/2007	5151.5
26/11/2007	5155.6
3/12/2007	5144.7

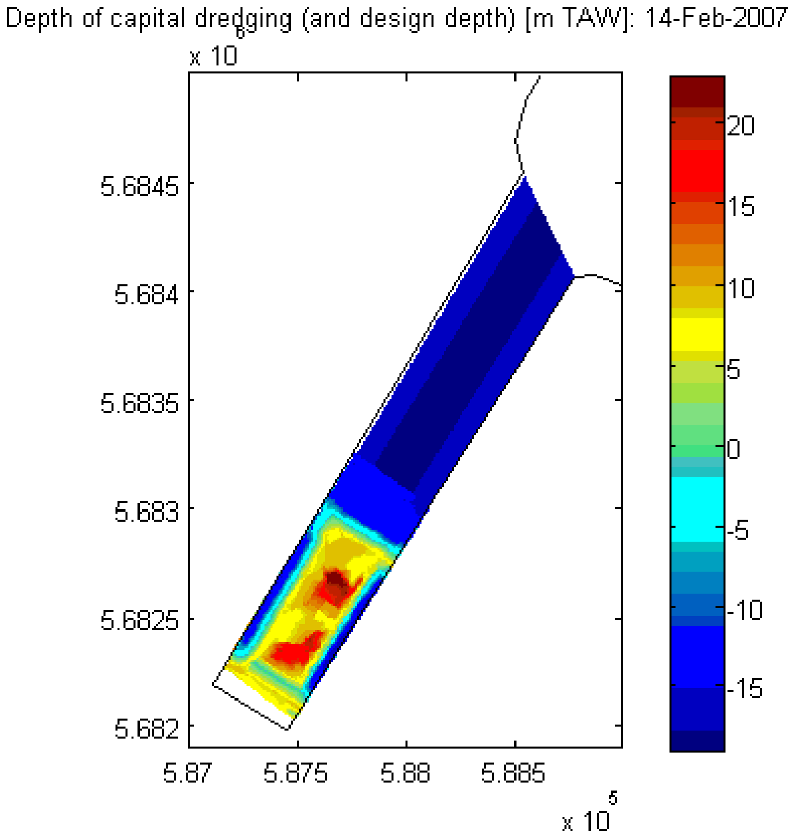

Figure 5-4: Depth before capital dredging works started from the dockside in February 2007 (for the operational part of the dock, the design depth is showed)

5.2. Densimetric analysis

BIS data revealed that hopper maintenance dredging took place the second half of November and lasted two consecutive weeks. Approximately 247x10³ TDS was dredged in total of which 73% originated from zones 3A, 3B and 3C. Each of these zones contributed between 18 and 30%. Other important zones were 4A-N, 4B-N and 4B-Z which all contributed for more than 5% each to the total amount of dredged solids.

Sweep beam maintenance dredging took place both on the sill and along the commercial berth zones A and B. Minor sweep beam actions occurred sporadically and spread in time. The two major sweep beam dredgings took place prior to each hopper maintenance dredging operation. Whereas the northern commercial berths were intensely dredged on 16 November, both northern and southern berths were dredged on 22 November. The sill was dredged on these dates as well.

Vertical density profiles have been numerically integrated to calculate the mass of dry solids above a reference plane for each zone (i.e. the design depth of Deurganckdok t_{0d} (see §2.1)). This data availability also enables the use of the densimetric dredging data, cf. BIS data, in the mass balance calculations. Total sediment mass is only calculated for locations where both density profile and dredging information are available. Adding up both leads to the total sediment mass as shown in APPENDIX J. Results show a mass growth rate in the central trench (zones 3A, 3B and 3C) in the range of 2 to 8 kg/m²/day for the period September – mid-November. The second half of November, intense dredging (both hopper and sweep beam) took place. A rapid accumulation with sediments therefore only results in a minor decrease of the measured sediment mass in the central trench by early December (see APPENDIX J). As a result, large growth rates in the order of 13 – 18 kg/m²/day are obtained in zones 3B and 3C. For the period August – December 2005, calculated growth rates were in the range of 4 – 7.5 kg/m²/day (IMDC, 2006a). From these data and the dredging data, it is observed that the actual increase of growth rate is proportional to the amount of dredged sediment mass.

Zones 4N-A, 4N-B and 4N-C, and their southern equivalents, generally showed negative growth rates for the period September-October. At first glance, this decrease of total mass is attributed to the local sweep beam actions occurring at the end of September. However, these are only limited to the southern quay zones. Further, the evolution of the equal density planes as recorded in section D3 and D4 (APPENDIX H) also demonstrate some mass removal. For the period mid-October – mid-November, growth rates in zones 4N and 4Z show an average value of approximately 3.6 kg/m²/day. With respect to these zones, the actual growth rates are slightly larger than those reported for October-December 2005, i.e. 3.2 kg/m²/day (IMDC, 2006a).

An overview of the total mass settled over time, for all zones that have been covered for at least 85%, is shown in Table 5-3 and Table 5-4. Exceptions are zones 3B and 3C on 5 December. Here, coverages between 50 and 60% are obtained. From these figures, it is concluded that between early September and mid-October about 51x10³ tons of dry solids have settled in zones 3 and 4, subzones A, B and C. Between mid-October and mid-November about 64x10³ tons of dry solids have settled in the same area. Instead, the period between mid-November and early December is characterised by an amount of 62x10³ tons of dry solids, which is only located in zones 3B and 3C. The larger amount of settled mass in December is not only attributed to the intense dredging of this area but is also strongly dependent on the not entirely covered area by density measurements. Only the central part of the dock trench has been measured so an extrapolation to the entire zones 3A till 3C could result in a mass overestimation.

Subdividing per subzone (Table 5-4), it is concluded that the settled mass in subzones A (nearest to river) is larger than the settled mass in subzones B which, on its turn, is larger than the one calculated for subzone C. This confirms the hypothesis of a gradual decrease in siltation with distance from the Scheldt river.

Table 5-3: Total sediment mass (measured + dredged, in 10³ TDS) in some zones

zone	05-Sep-07	16-Oct-07	16-Nov-07	05-Dec-07
3a	139	171	191	
3b	125	147	165	204
3c	126	139	144	168
4Na	42	38	44	
4Nb	30	27	29	
4Nc	19	20	21	
4Za	25	21	26	
4Zb	29	24	28	
4Zc	19	19	20	

Table 5-4: Mass settled per subzone in zones 3 and 4 (measured + dredged, in 10³ TDS)

subzone	05-Sep-07 / 16-Oct-07	16-Oct-07 / 16-Nov-07	16-Nov-07 / 05-Dec-07
A	24	31	
B	14	25	38
C	12	9	24

6. REFERENCES

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AWZ (2000): Baggerwerken 2000, Westerschelde en Zeeschelde

IMDC (2006a) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.6 Sediment balance Bathymetry: 2005 – 3/2006 (I/RA/11283/06.118/MSA)

IMDC (2006b) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.1 Through tide measurement SiltProfiler 21/03/2006 Laure Marie (I/RA/11283/06.087/WGO).

IMDC (2006c) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.3 Through tide measurement Sediview spring tide 22/03/2006 Veremans (I/RA/11283/06.110/BDC)

IMDC (2006d) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.4 Through tide measurement Sediview spring tide 27/09/2006 Parel 2 (I/RA/11283/06.119/MSA).

IMDC (2006e) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.6 Salt-Silt distribution & Frame Measurements Deurganckdok 13/3/2006 – 31/05/2006 (I/RA/11283/06.121/MSA).

IMDC (2007a) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.1 Sediment Balance: Three monthly report 1/4/2006 – 30/06/2006 (I/RA/11283/06.113/MSA)

IMDC (2007b) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.2 Sediment Balance: Three monthly report 1/7/2006 – 30/09/2006 (I/RA/11283/06.114/MSA)

IMDC (2007c) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.3 Sediment Balance: Three monthly report 1/10/2006 – 31/12/2006 (I/RA/11283/06.115/MSA)

IMDC (2007d) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.4 Sediment Balance: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.116/MSA)

IMDC (2007e) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.5 Annual Sediment Balance (I/RA/11283/06.117/MSA)

IMDC (2007f) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.2 Through tide measurement SiltProfiler 26/09/2006 Stream (I/RA/11283/06.068/MSA)

IMDC (2007g) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.5 Through tide measurement Sediview neap tide (to be scheduled) (I/RA/11283/06.120/MSA)

IMDC (2007h) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.7 Salt-Silt distribution & Frame Measurements Deurganckdok 15/07/2006 – 31/10/2006 (I/RA/11283/06.122/MSA)

IMDC (2007i) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.8 Salt-Silt distribution & Frame Measurements Deurganckdok 15/01/2007 – 15/03/2007 (I/RA/11283/06.123/MSA)

IMDC (2007j) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 3.1 Boundary conditions: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.127/MSA)

IMDC (2007k) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 3.2 Boundary conditions: Annual report (I/RA/11283/06.128/MSA)

IMDC (2007g) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 6.2 Summer Calibration and Final Report (I/RA/11291/06.093/MSA)

IMDC (2007h). Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.11 Sediment Balance: Two monthly report 1/7/2007 – 31/08/2007 (I/RA/11283/07.082/MSA).

IMDC (2008). Feasibility study of echo sounding to determine fluid mud density profiles (I/NO/11283/08.001/BOB).

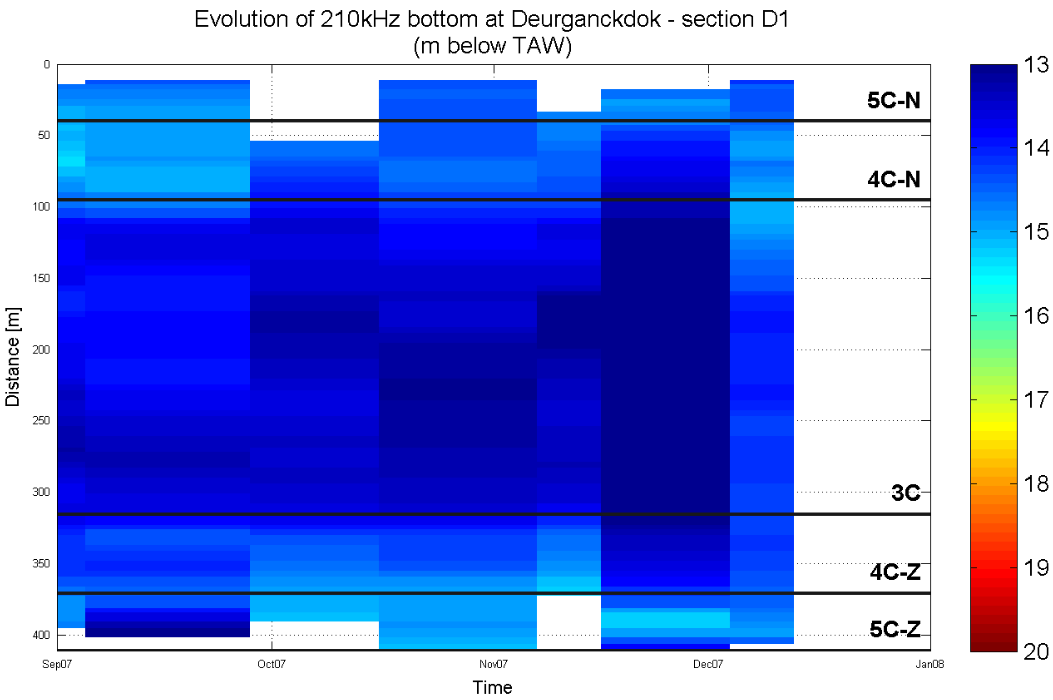
APPENDIX A. DEPTH OF THE WATER-BED INTERFACE (210 KC)

APPENDIX B. EVOLUTION OF DEPTH OF WATER-BED INTERFACE (210 KC)

B.1 Difference maps

B.2 Bed elevation evolution per section

Long-term monitoring siltation Deurganckdok	
Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

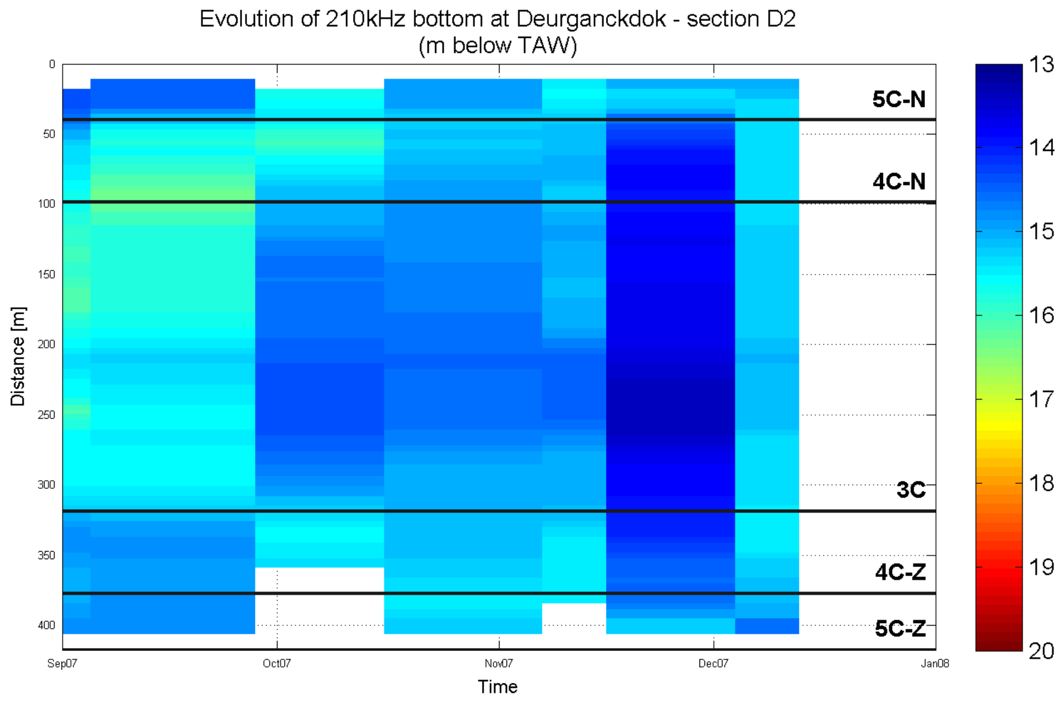


Data Processed by: IMDC

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



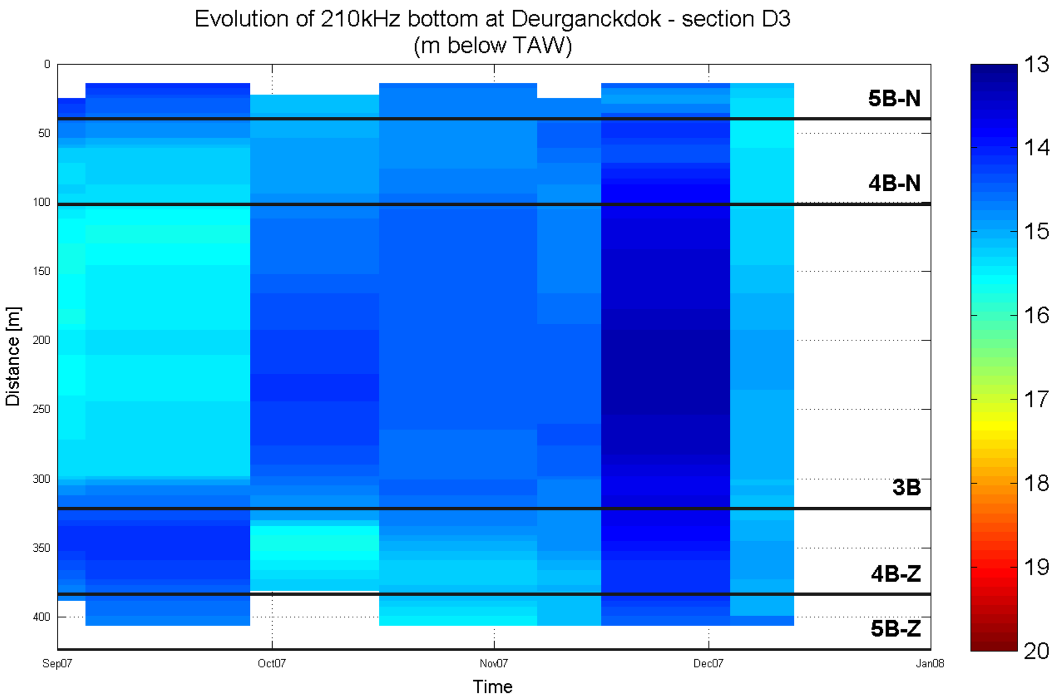
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



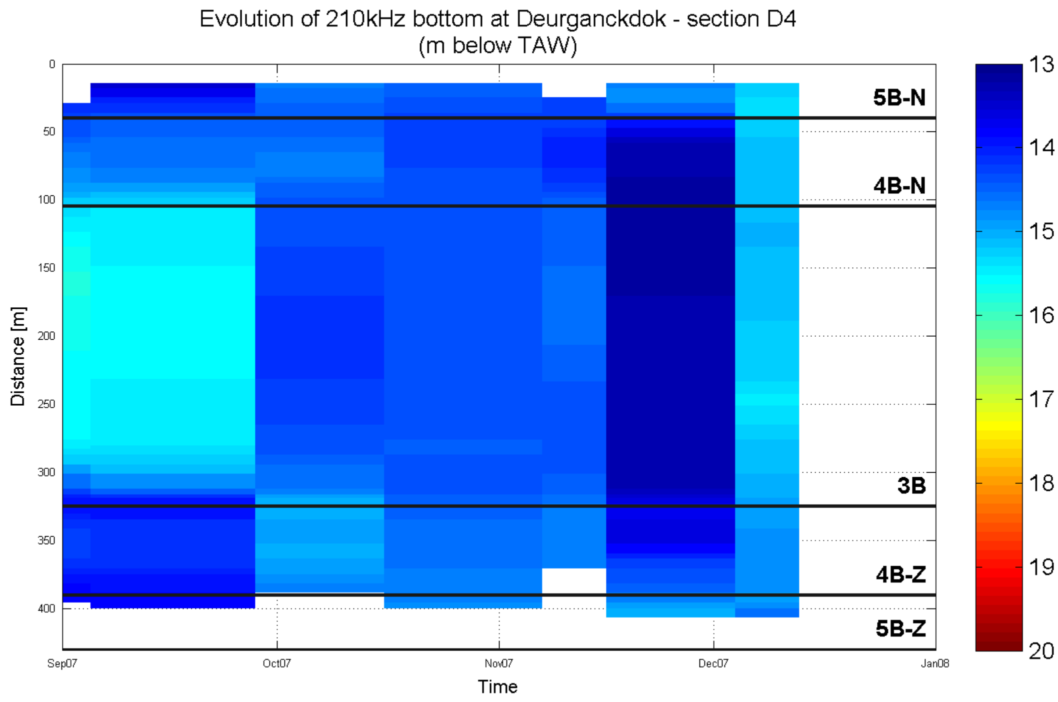
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



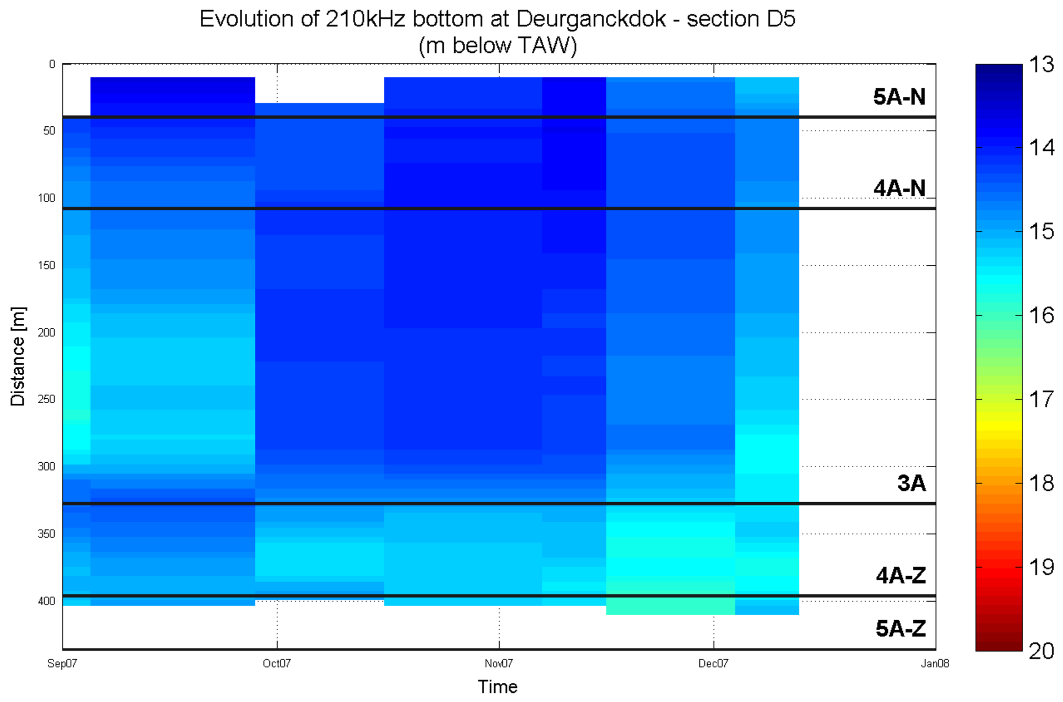
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



Data Processed by:

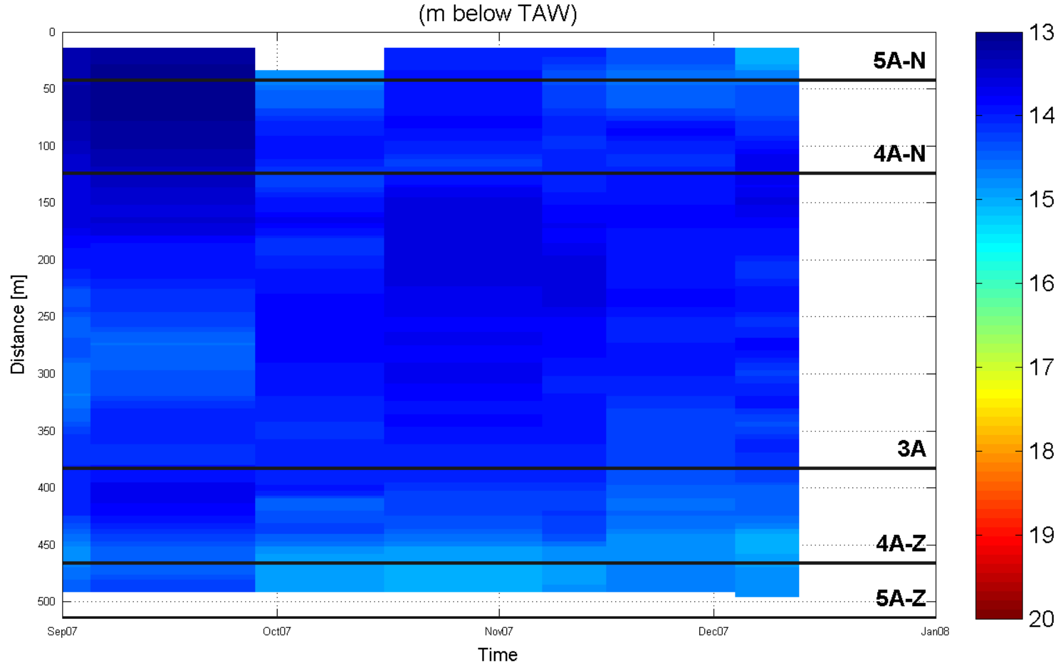
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section D6
(m below TAW)



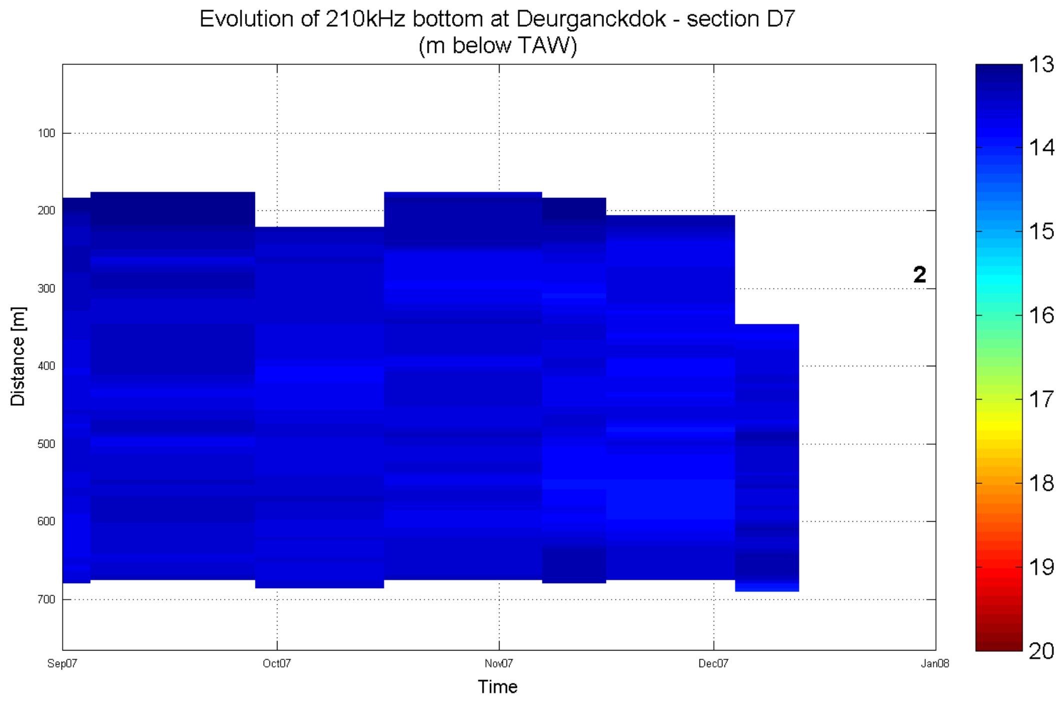
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



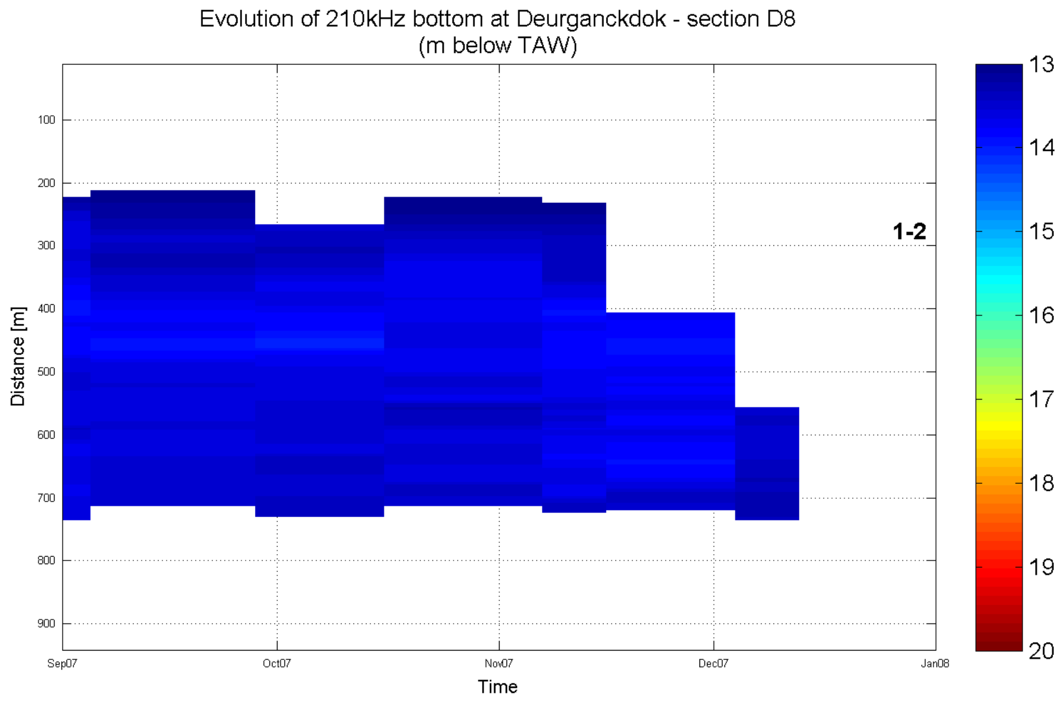
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



Data Processed by:

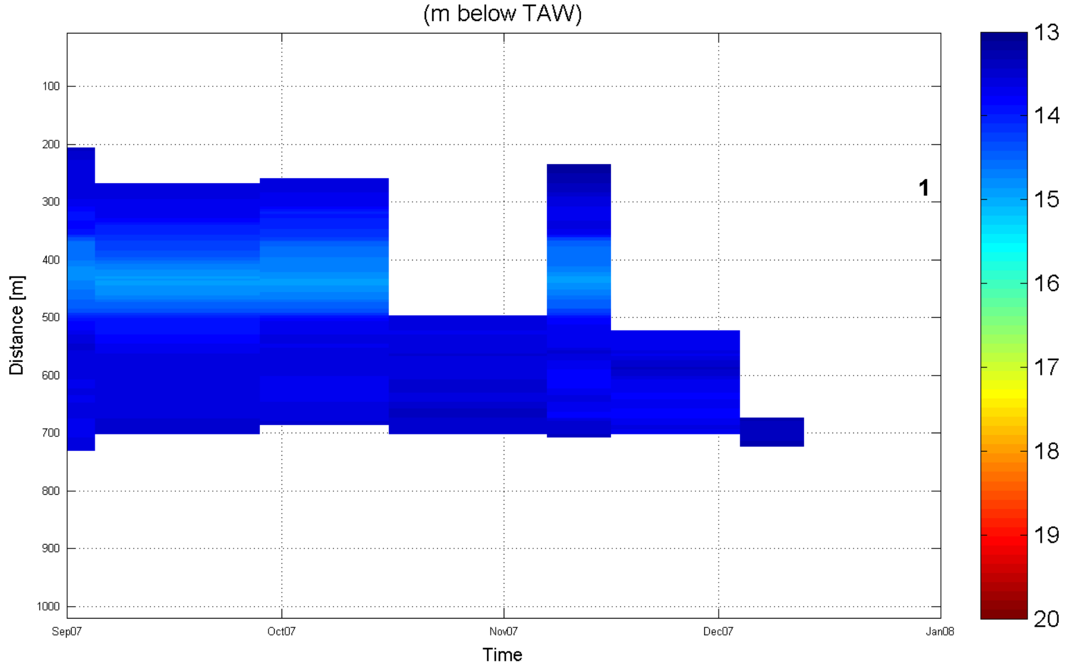
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section D9
(m below TAW)



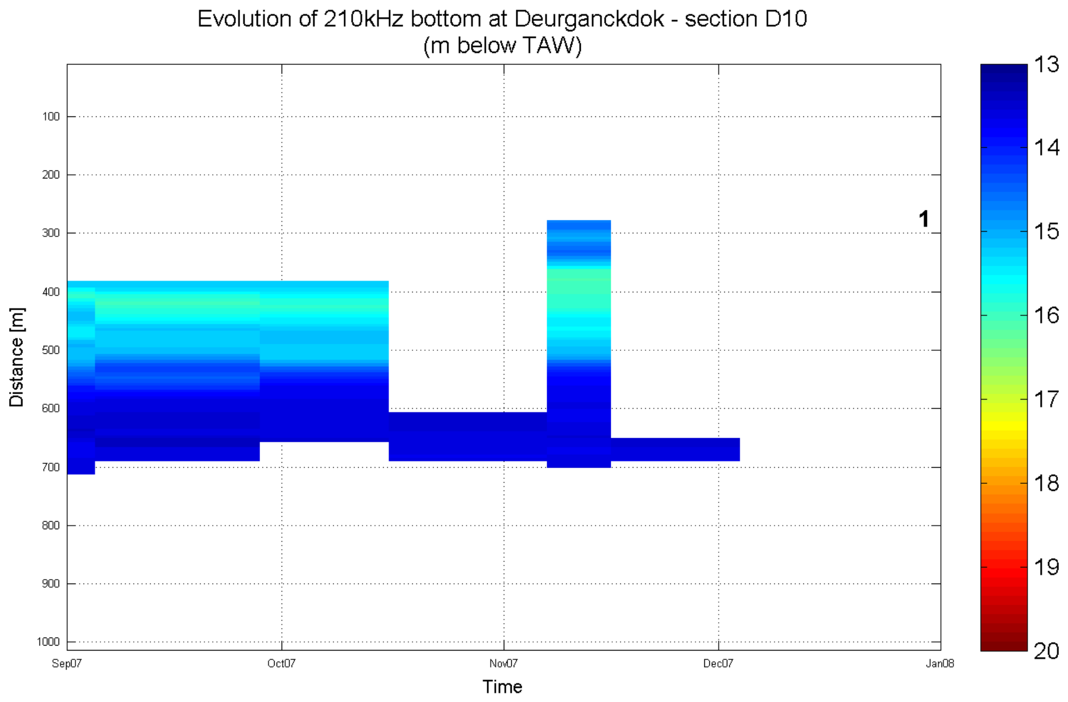
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



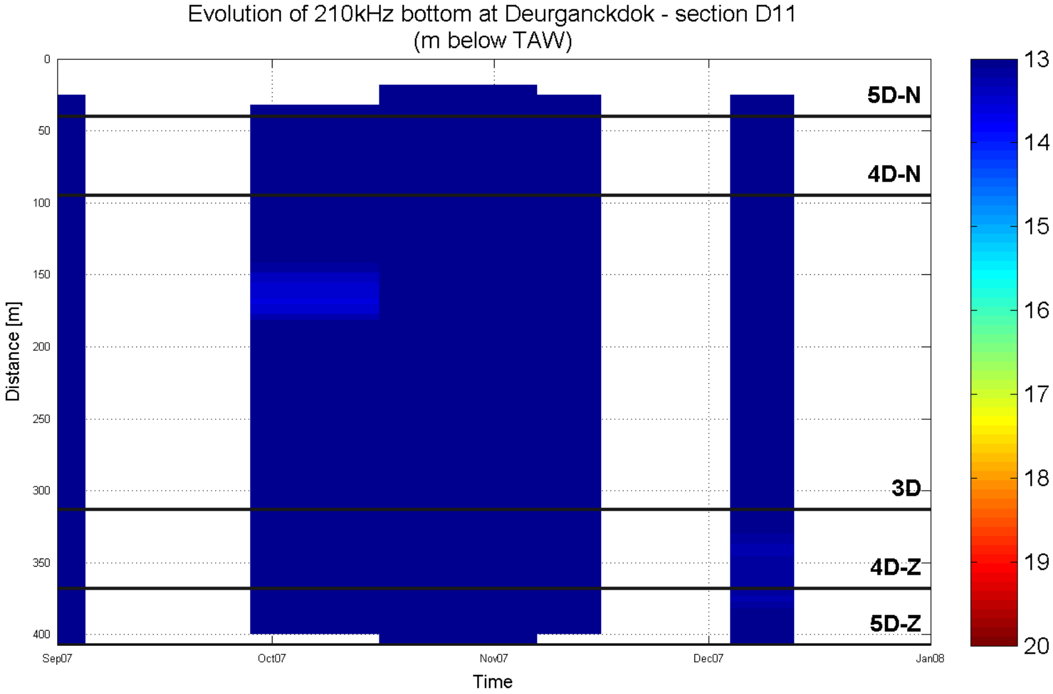
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



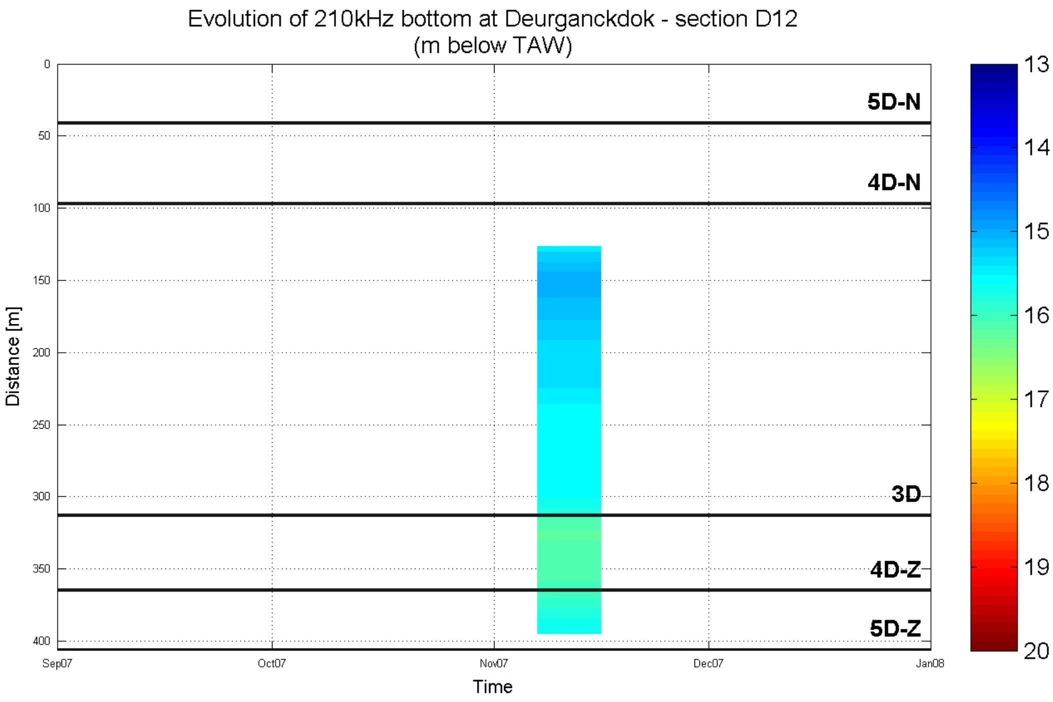
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



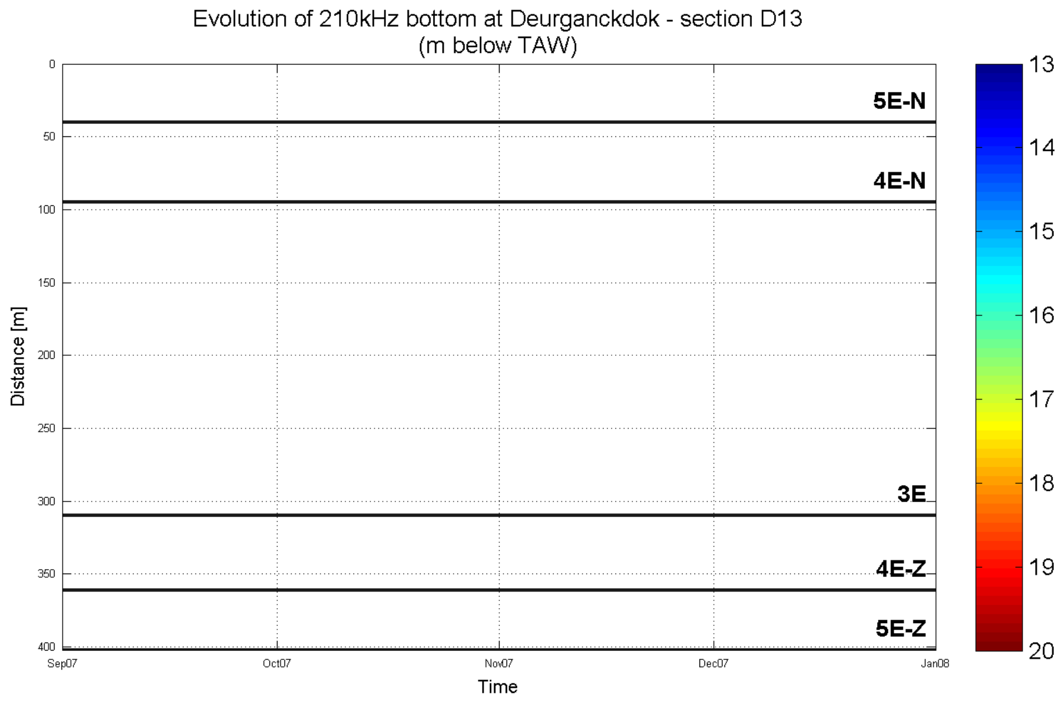
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



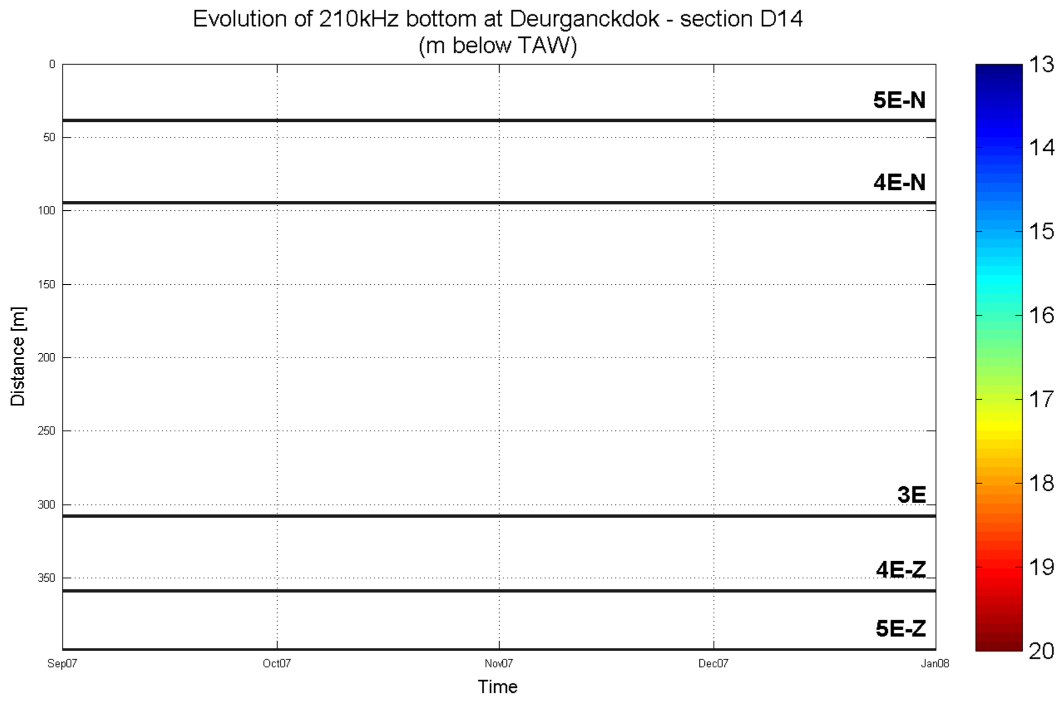
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

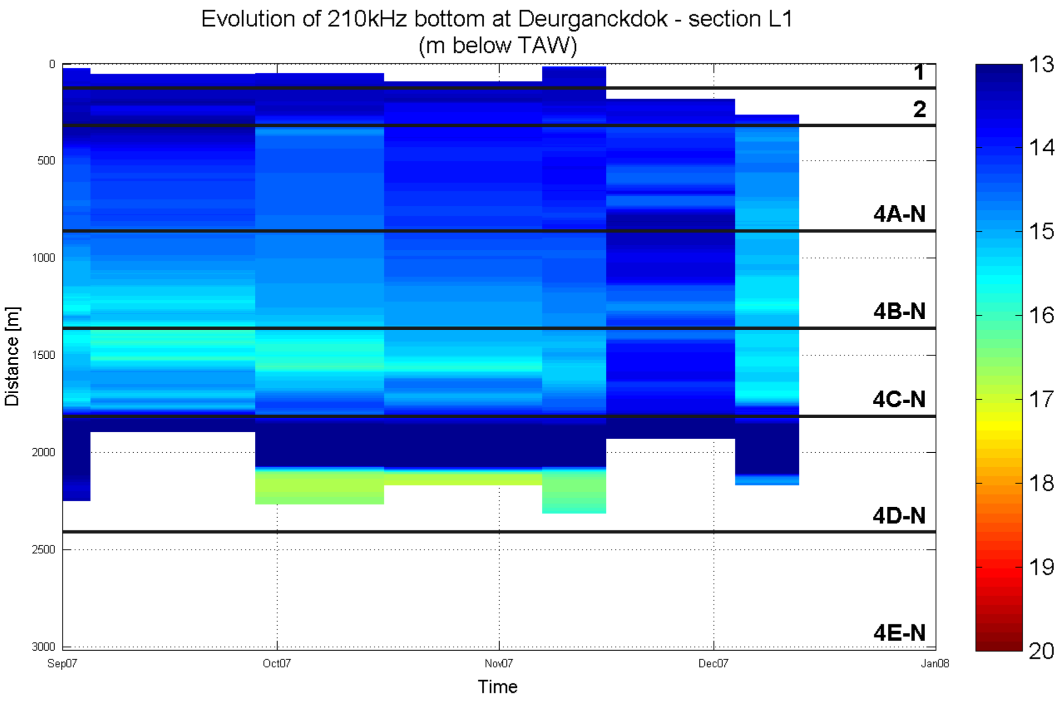


Data Processed by:

In association with :

I/RA/11283/07.083/MSA

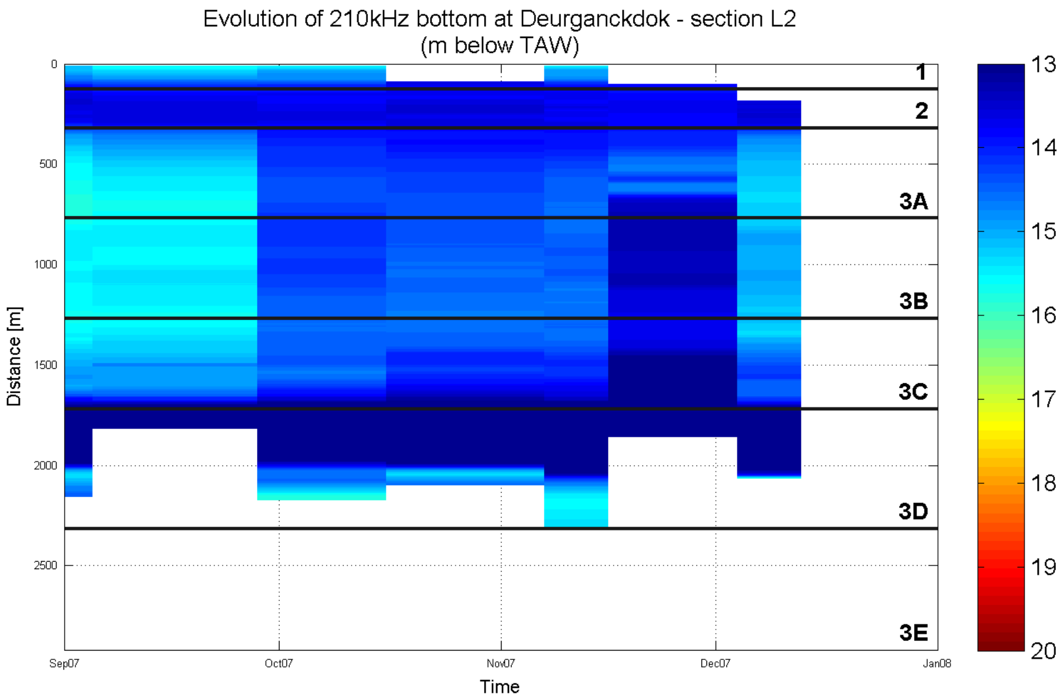
Long-term monitoring siltation Deurganckdok	
Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



	Data Processed by: In association with : I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD



Data Processed by:

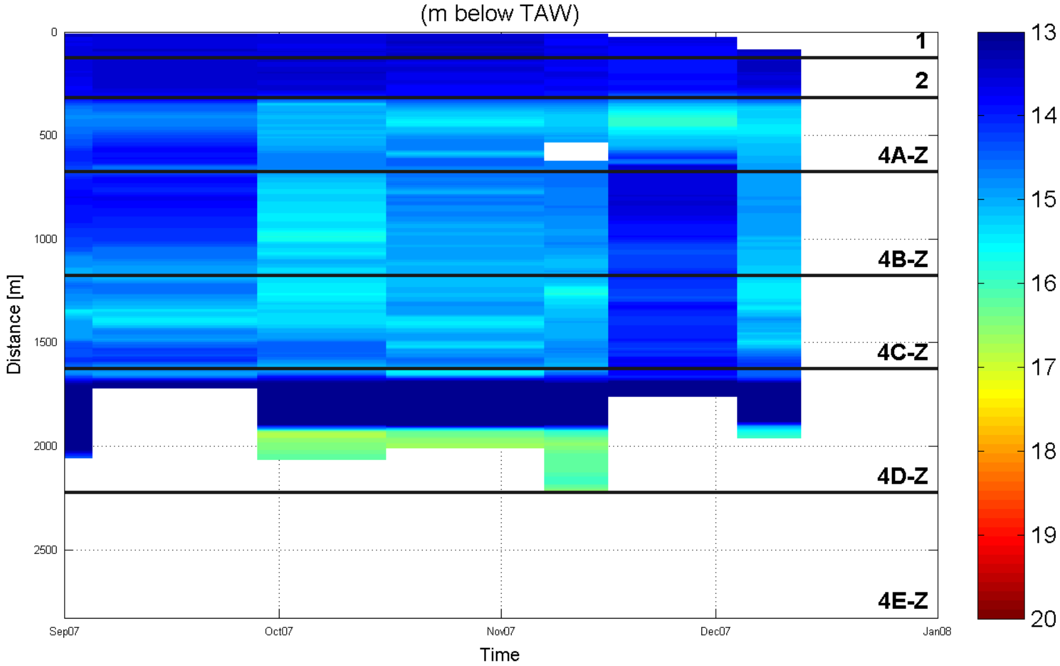
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom	Equipment(s): 210kHz depth sounder
	Location: DGD

Evolution of 210kHz bottom at Deurganckdok - section L3
(m below TAW)



Data Processed by:

In association with :

I/RA/11283/07.083/MSA

APPENDIX C.

VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS

C.1 Siltation rates (tabular)

Siltation rates in cm/day

1/ Per zone

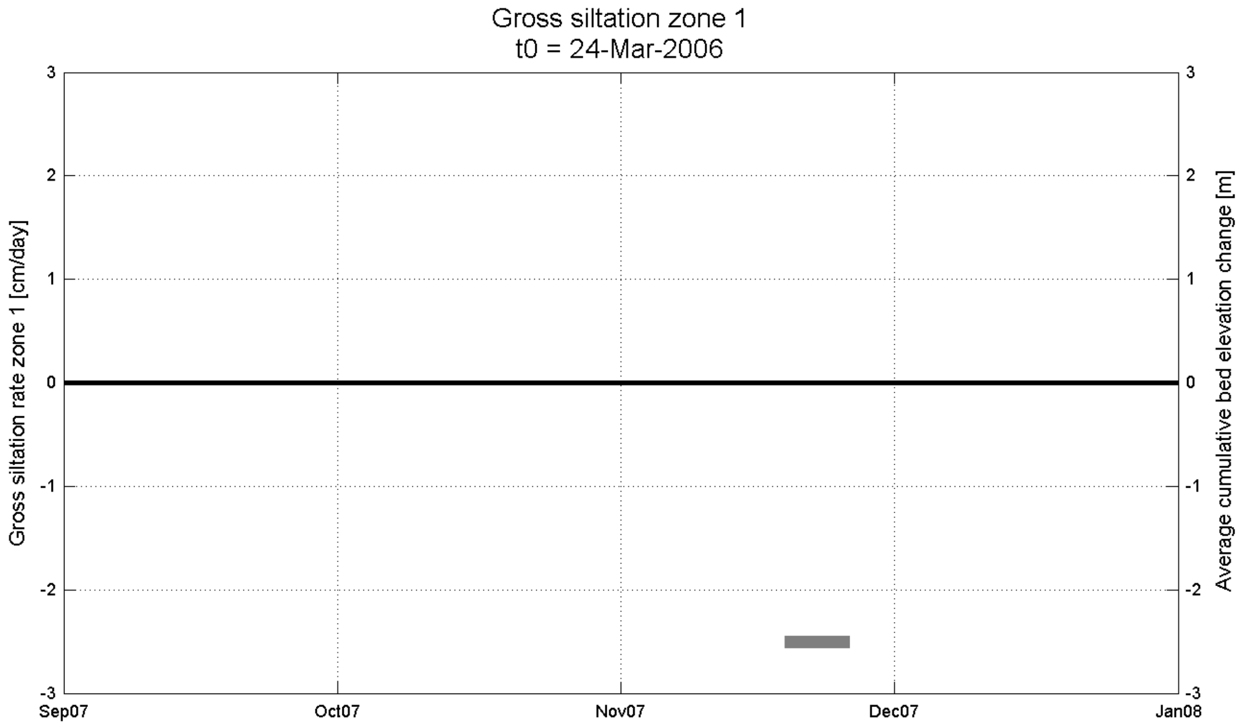
	Sept/07	Oct/07	Nov/07	Dec/07
1	-	-	-	-
2	0.058	-0.333	-0.084	0.15
3a	3.301	0.166	-2.257	-0.918
3b	3.425	-0.326	-0.883	-1.639
3c	2.311	0.111	-1.17	-2.019
3d	-	-	-	-
3e	-	-	-	-
4Na	-0.892	1.324	-2.587	0.402
4Nb	0.269	0.801	-1.437	-0.411
4Nc	0.333	0.428	-0.345	-2.341
4Nd	-	-	-	-
4Ne	-	-	-	-
4Za	-1.725	0.545	-1.3	0.219
4Zb	-2.867	0.865	0.114	-0.767
4Zc	-1.227	0.136	0.343	-4.095
4Zd	-	-	-	-
4Ze	-	-	-	-
5Na	-	-0.525	-3.082	0.894
5Nb	-	-0.666	-1.617	-0.822
5Nc	-0.762	-1.296	0.489	-0.575
5Nd	-	-	-	-
5Ne	-	-	-	-
5Za	-	-	-	-
5Zb	-	-	-	-
5Zc	-	-	-	-
5Zd	-	-	-	-

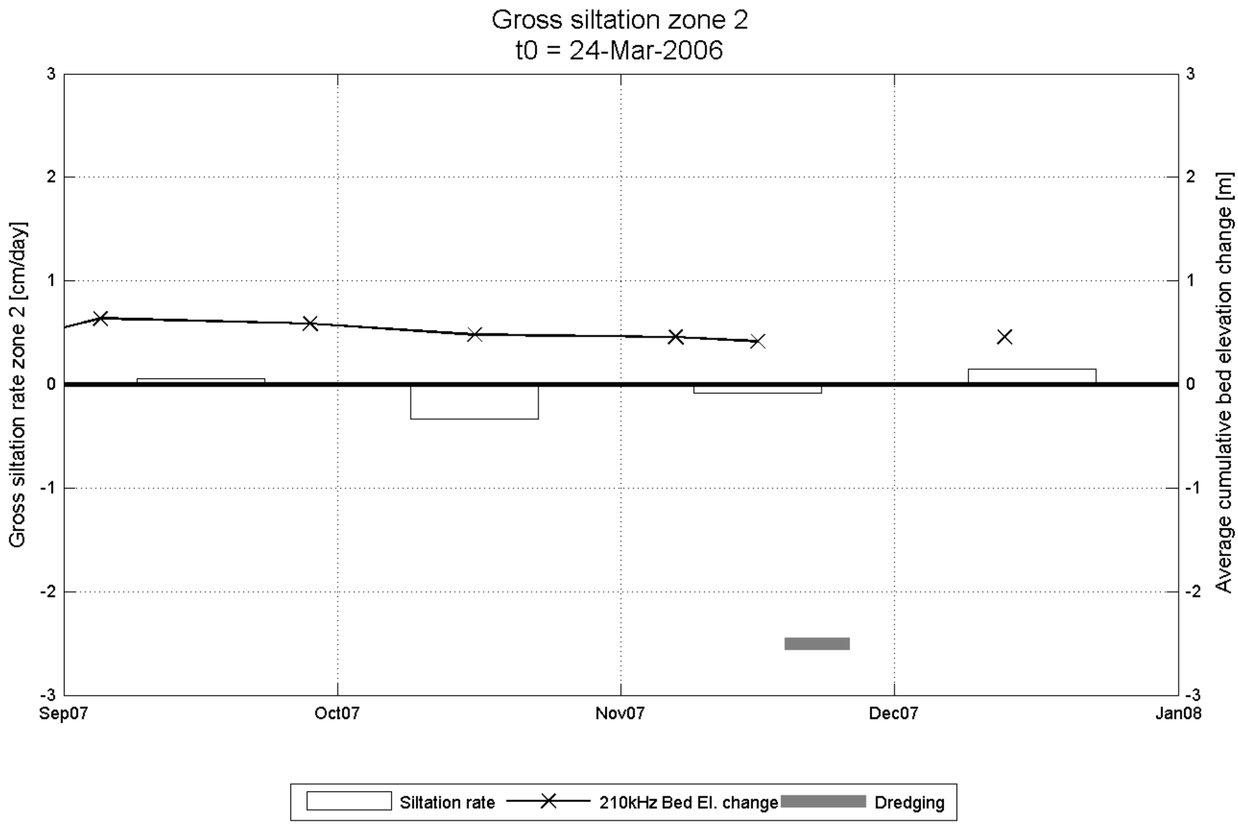
2/ Per section

	Sept/07	Oct/07	Nov/07	Dec/07
D1	0.933	-0.021	-1.259	-0.415
D2	1.743	-0.102	-0.249	-2.157
D3	1.333	0.147	-0.815	-0.638
D4	2.045	0.146	-1.527	-0.992
D5	1.665	0.394	-2.639	0.574
D6	-0.334	0.161	-0.645	0.394
D7	-0.05	-0.272	-0.102	0.337
D8	0.263	-0.097	-0.039	0.001
D9	-	-	-	-
D10	-	-	-	-
D11	-	-	-	-
D12	-	-	-	-
D13	-	-	-	-
D14	-	-	-	-
L1	-0.147	0.835	-0.821	-1.655
L2	2.812	0.021	-0.611	-1.834
L3	-1.486	0.407	0.053	-0.889

C.2 Water-bed interface evolution for all zones

Long-term monitoring siltation Deurganckdok	
Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

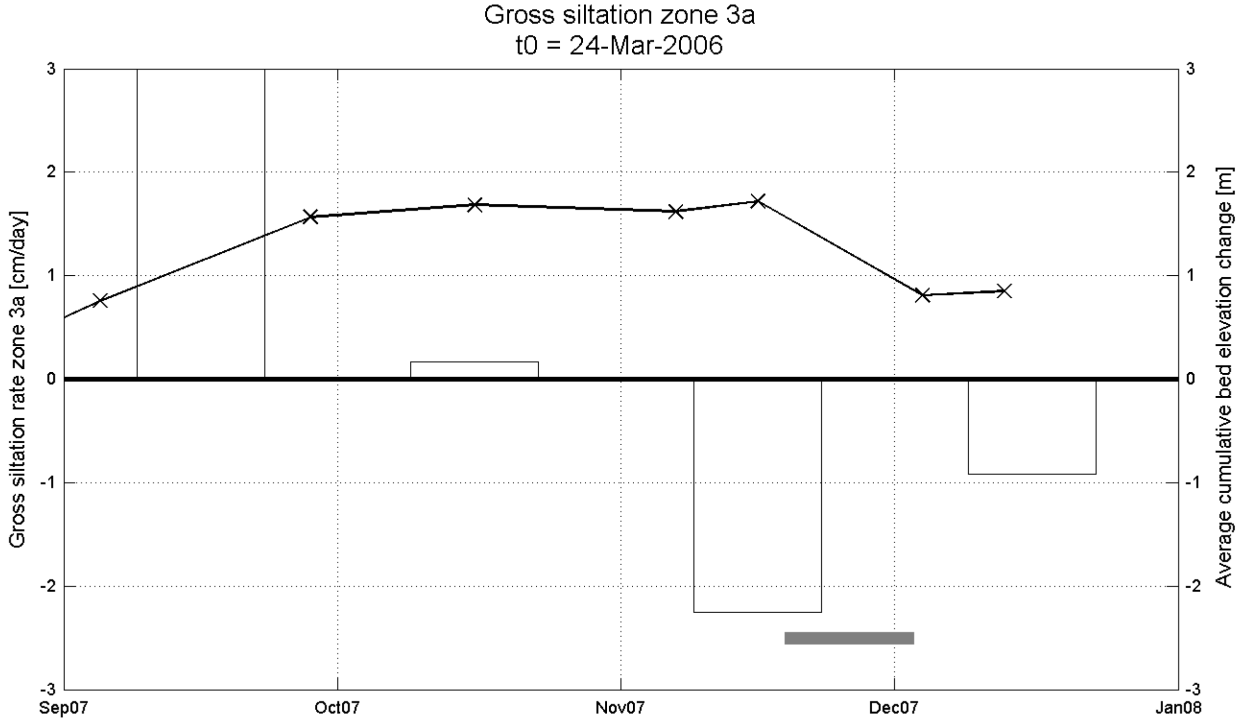
Data Processed by:

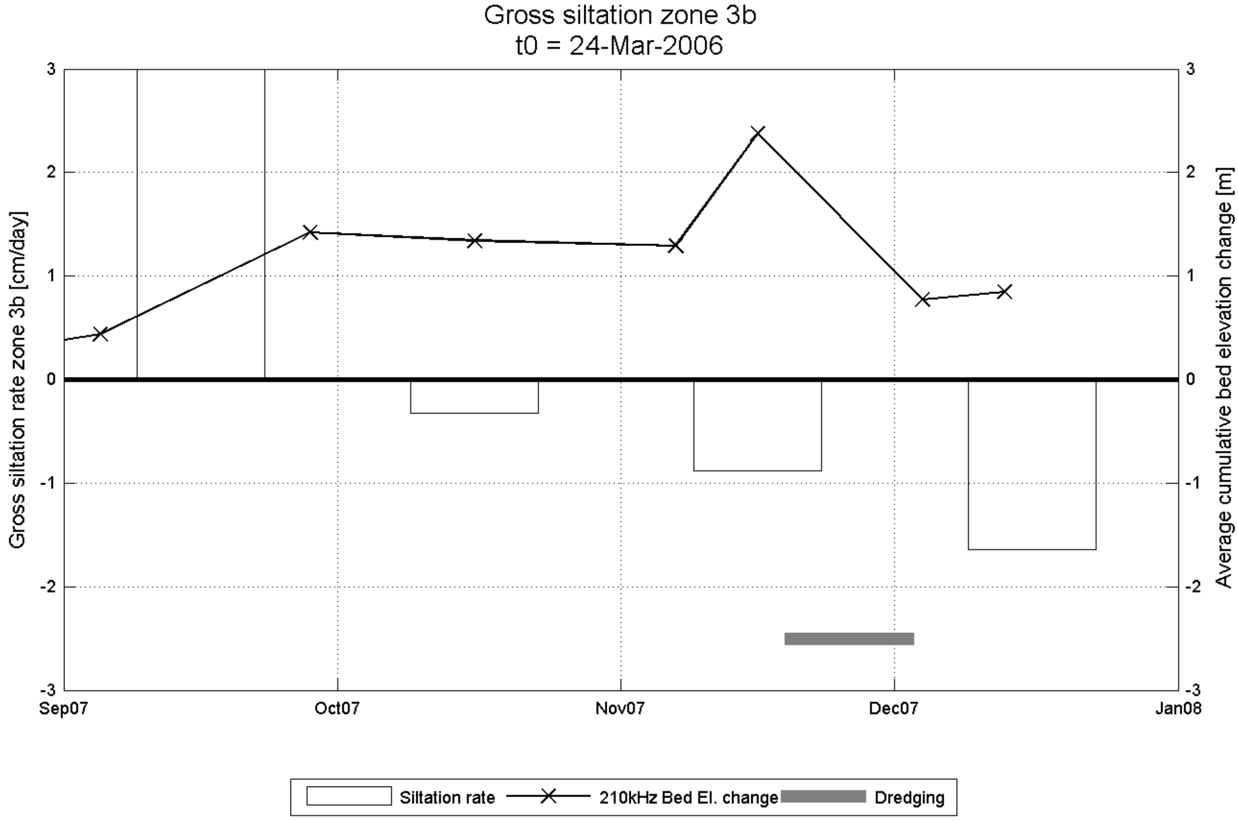
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

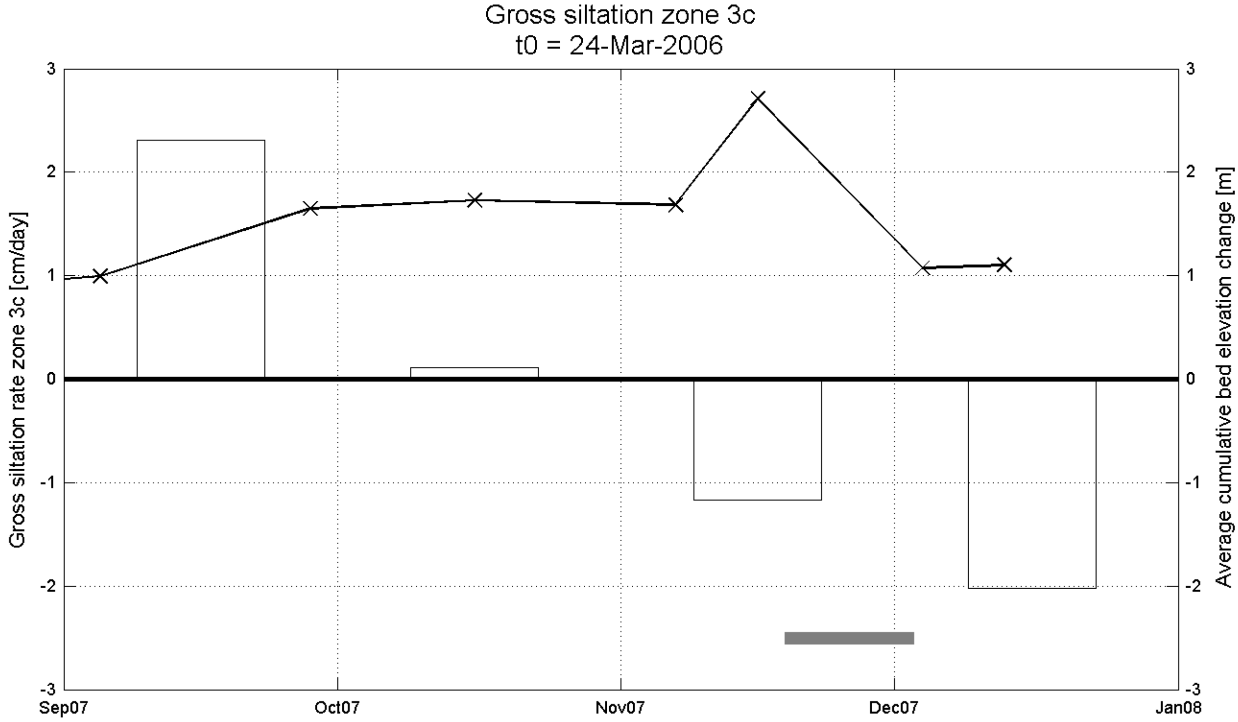
Data Processed by: IMDC

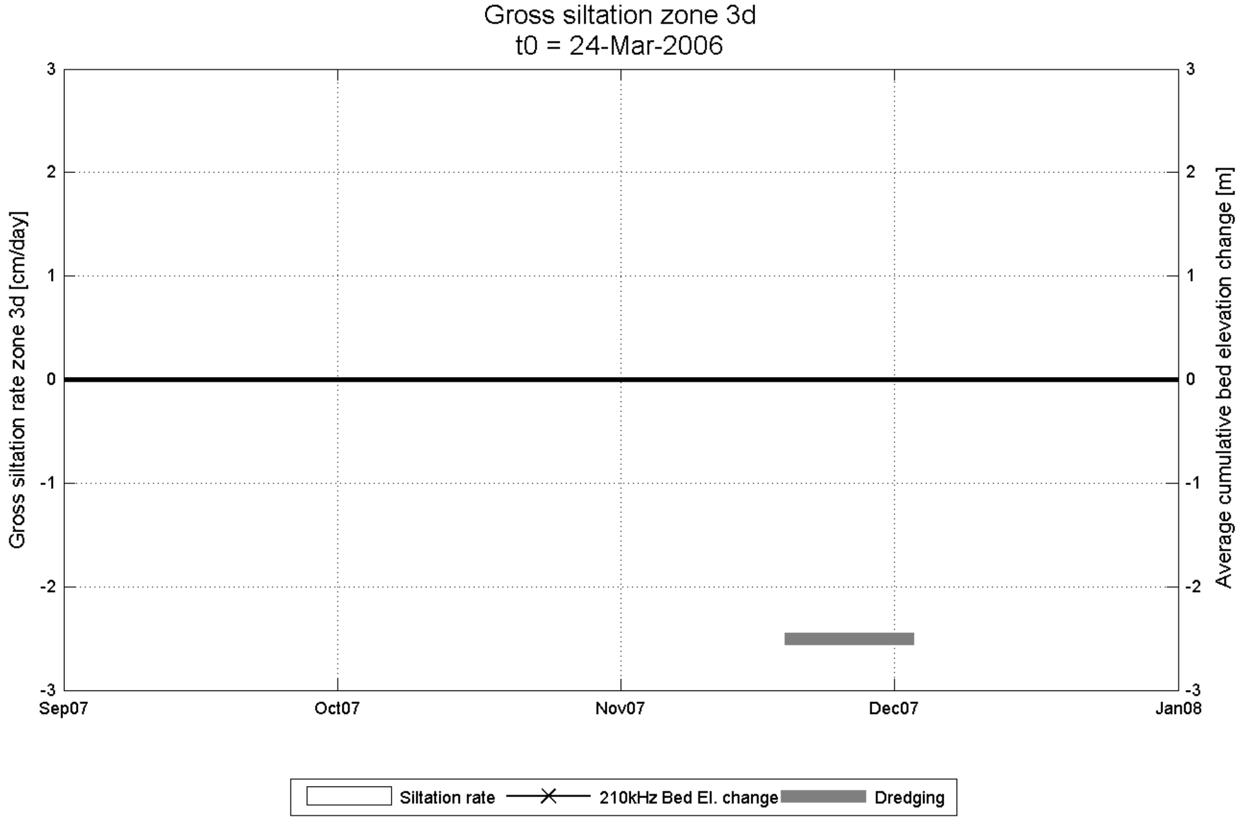
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

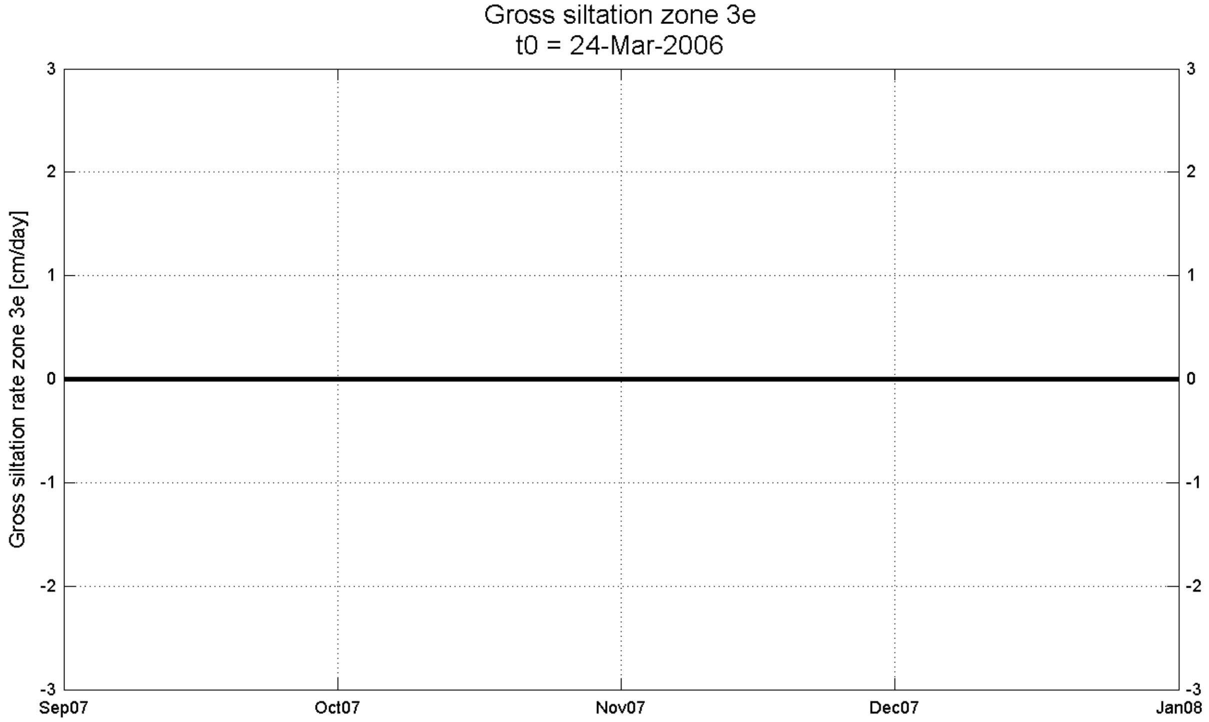
Data Processed by: IMDC

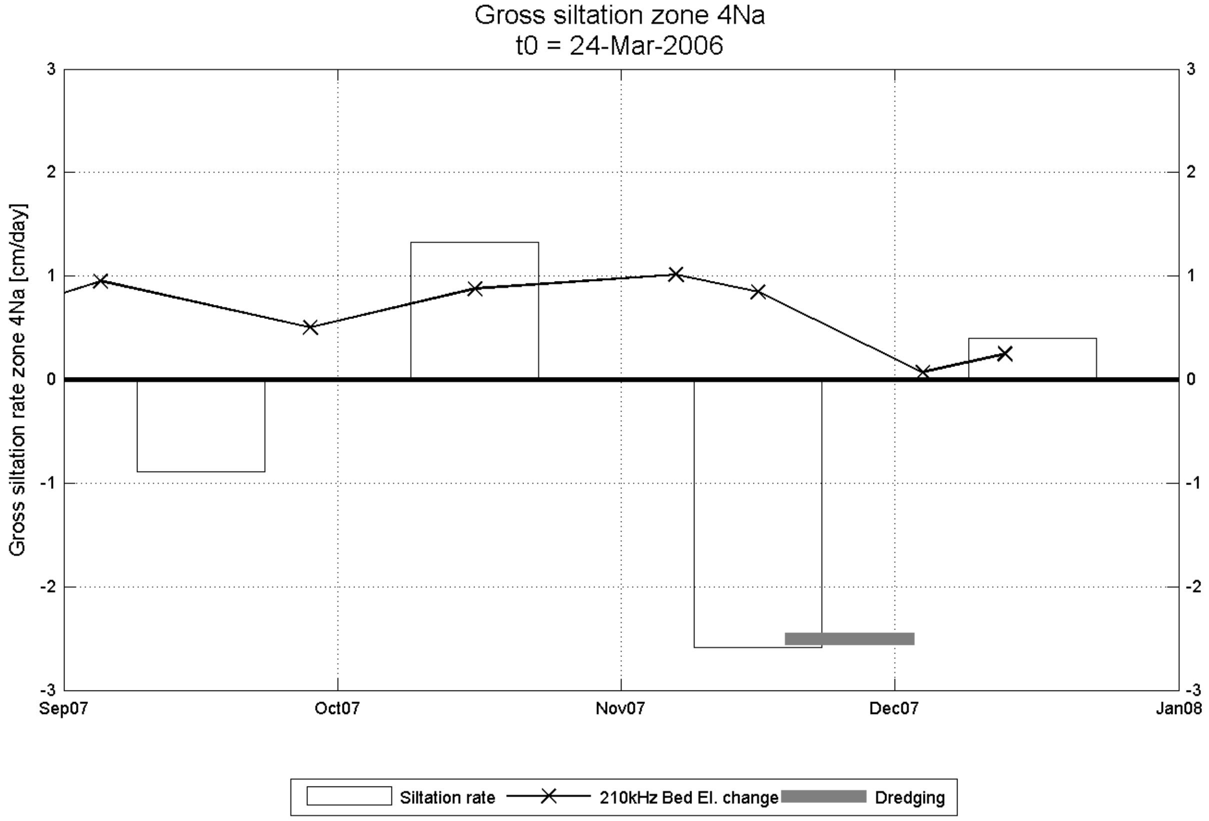
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





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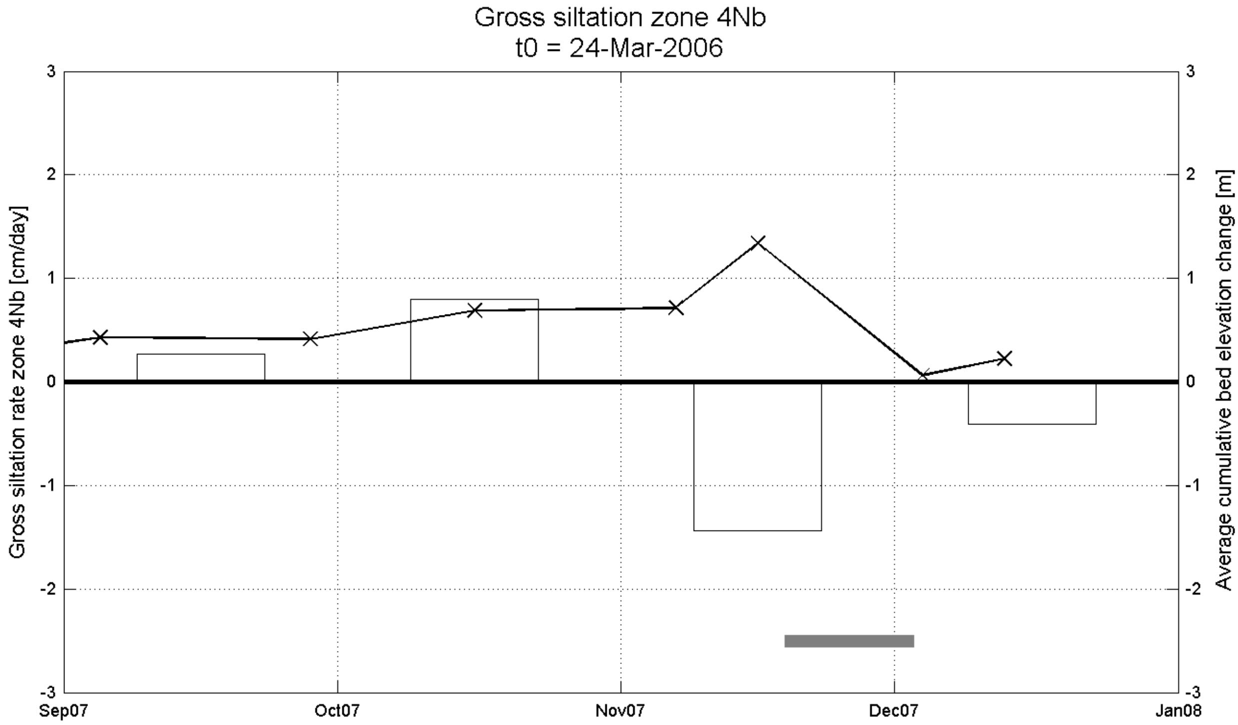
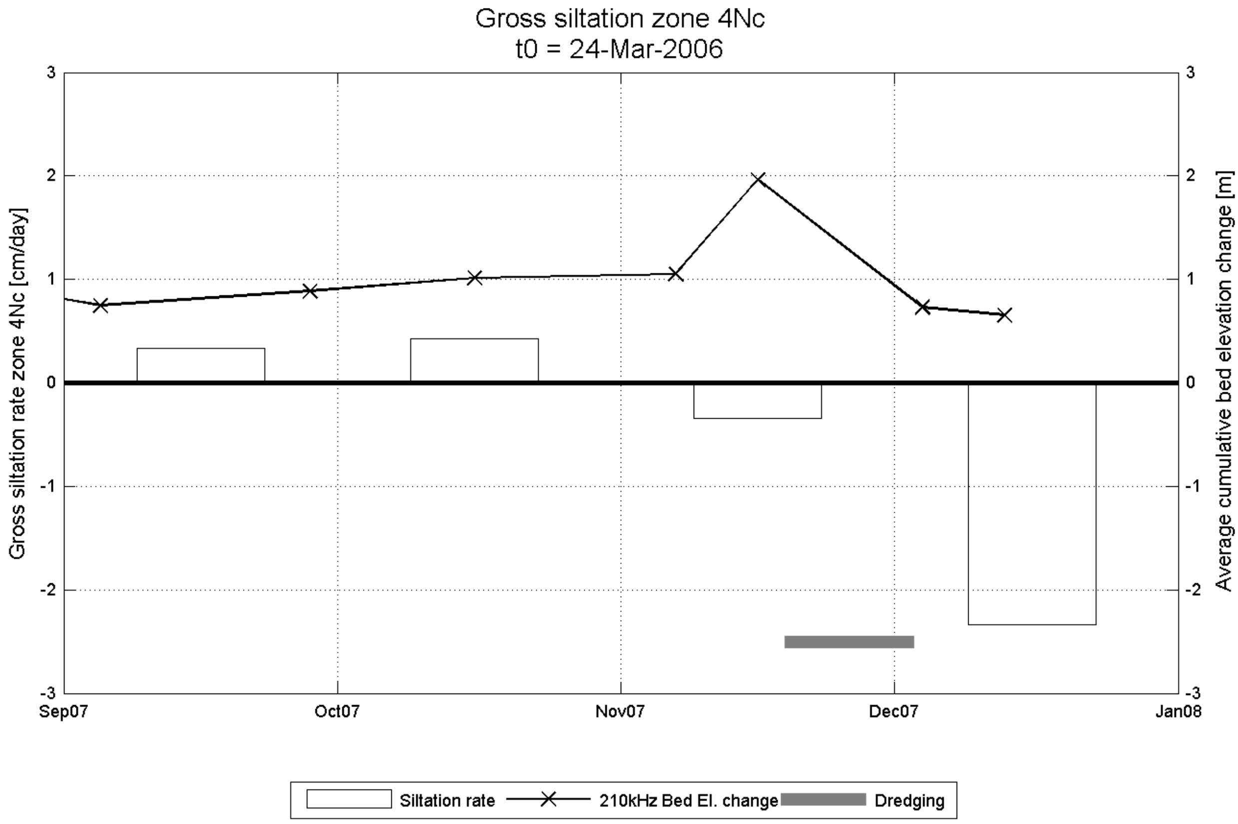
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





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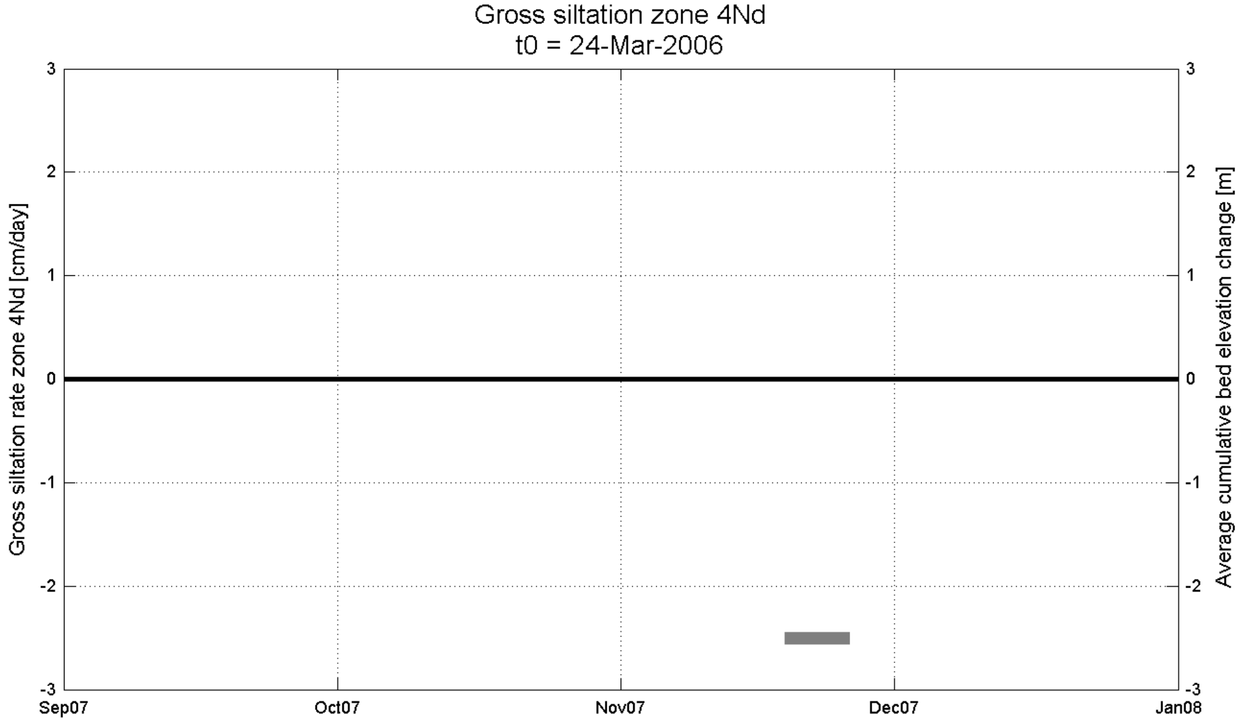
Data Processed by:

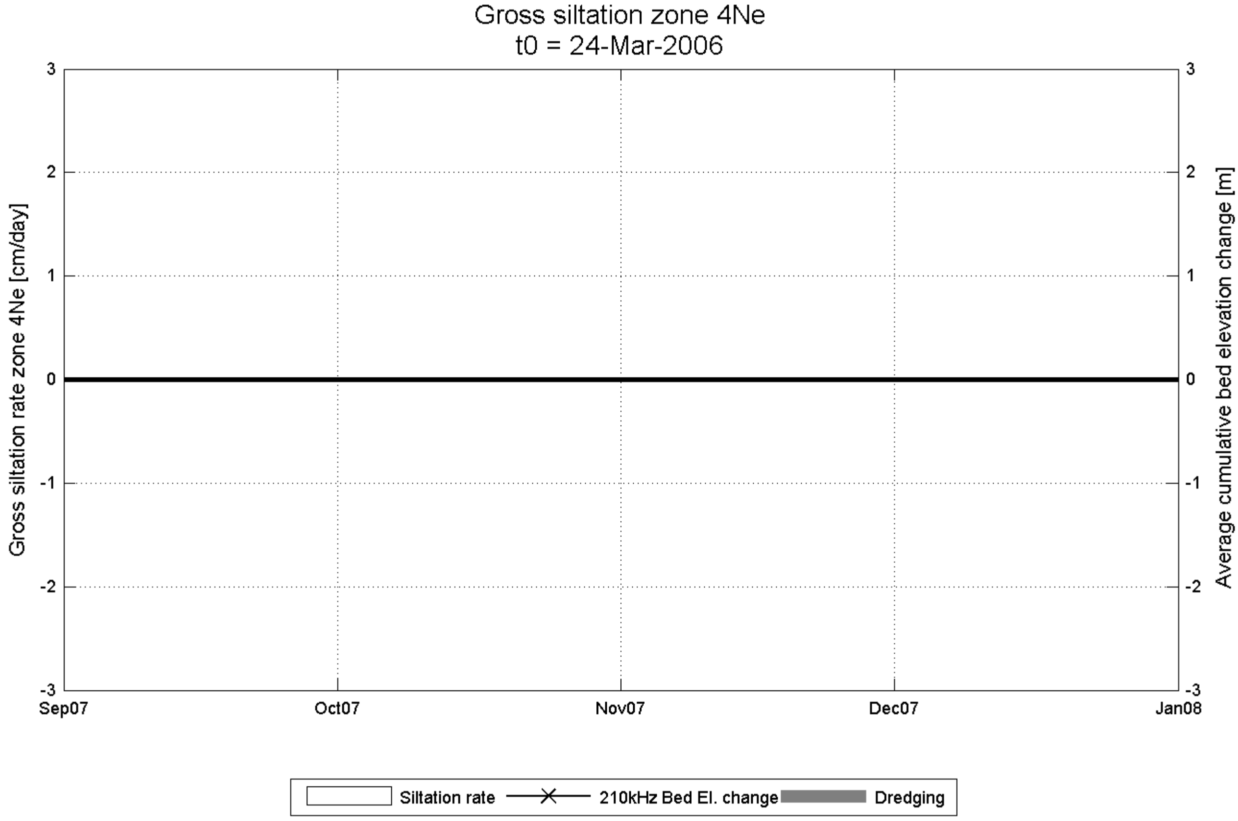
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





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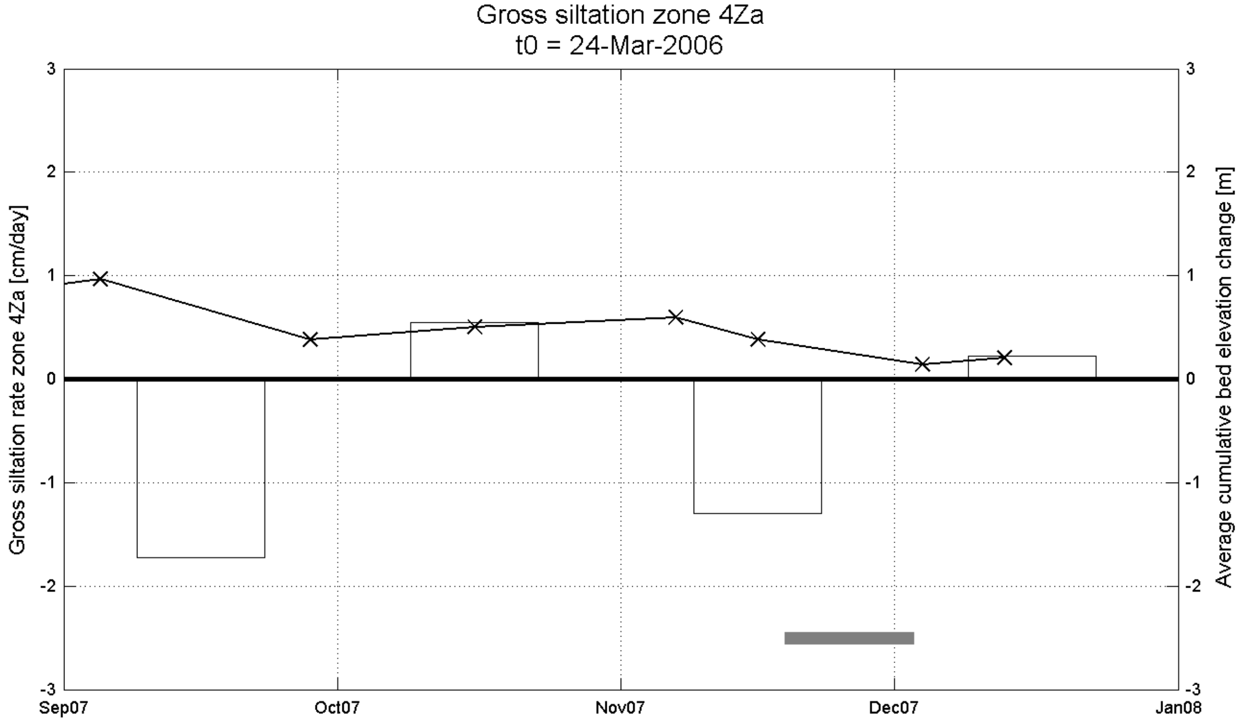
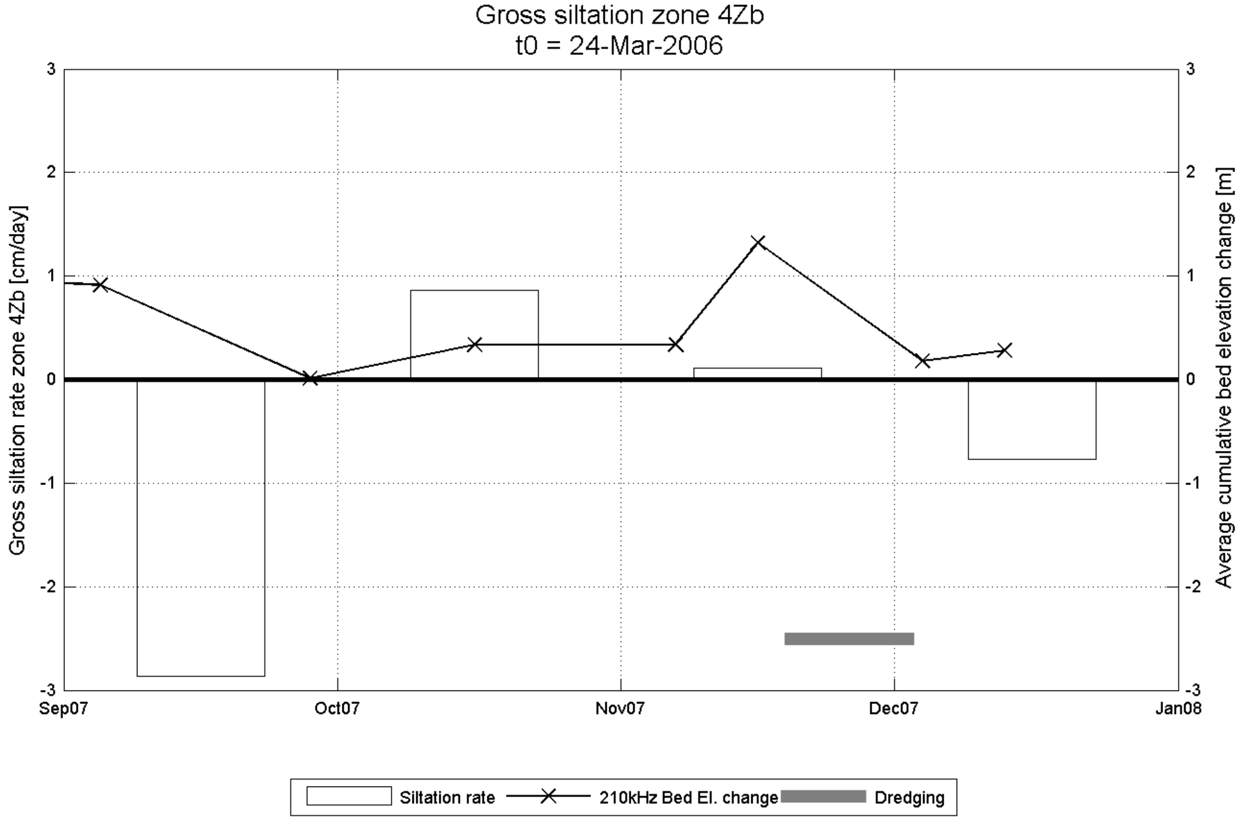
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

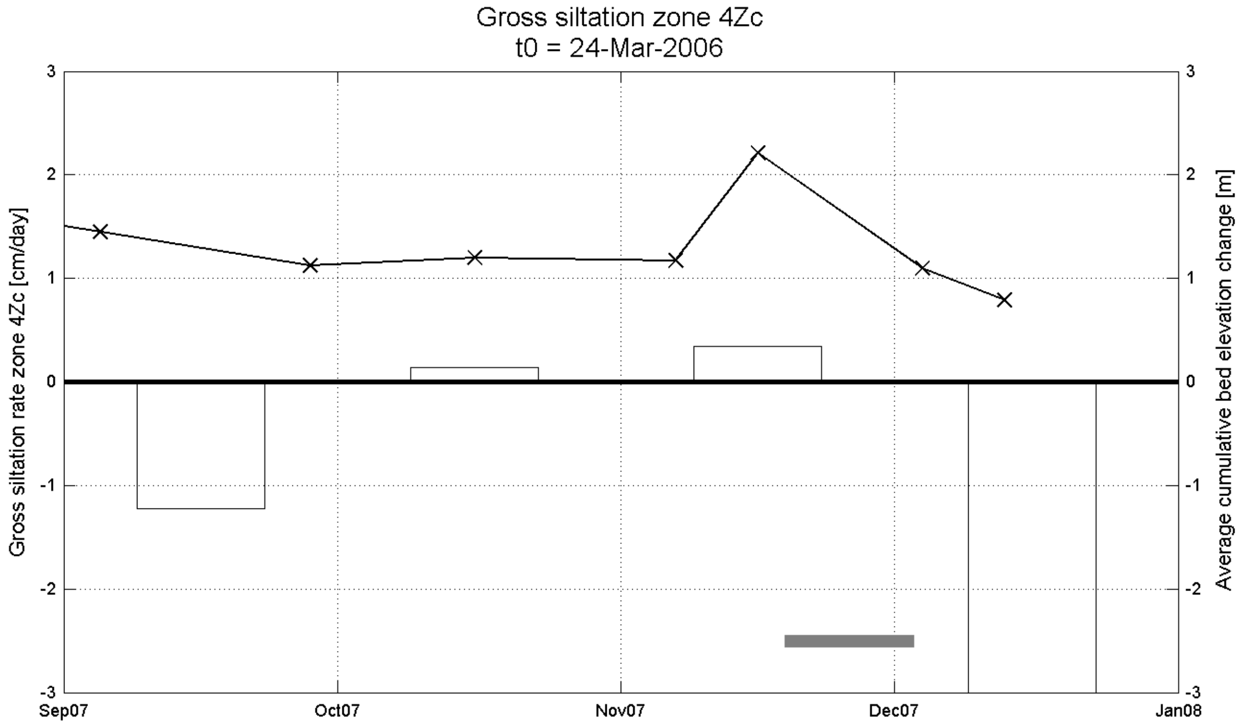
Data Processed by: IMDC

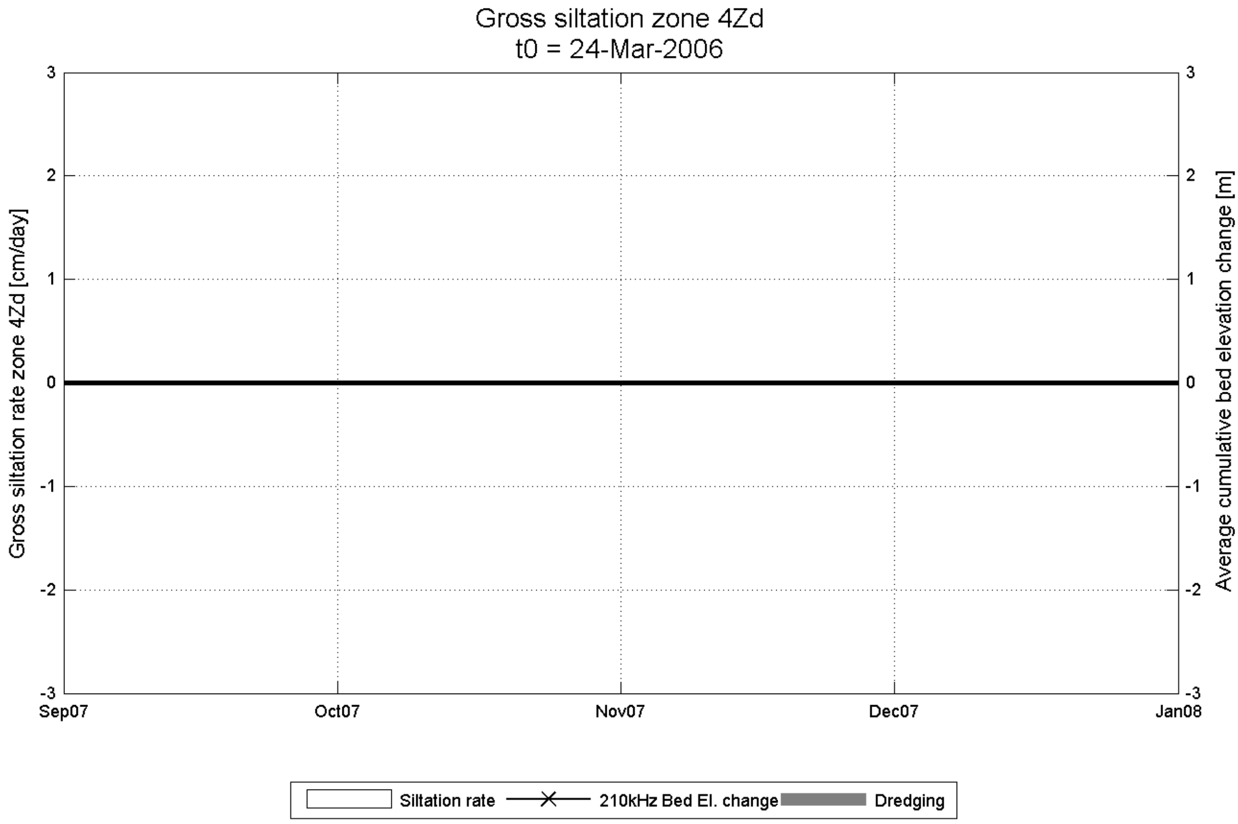
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

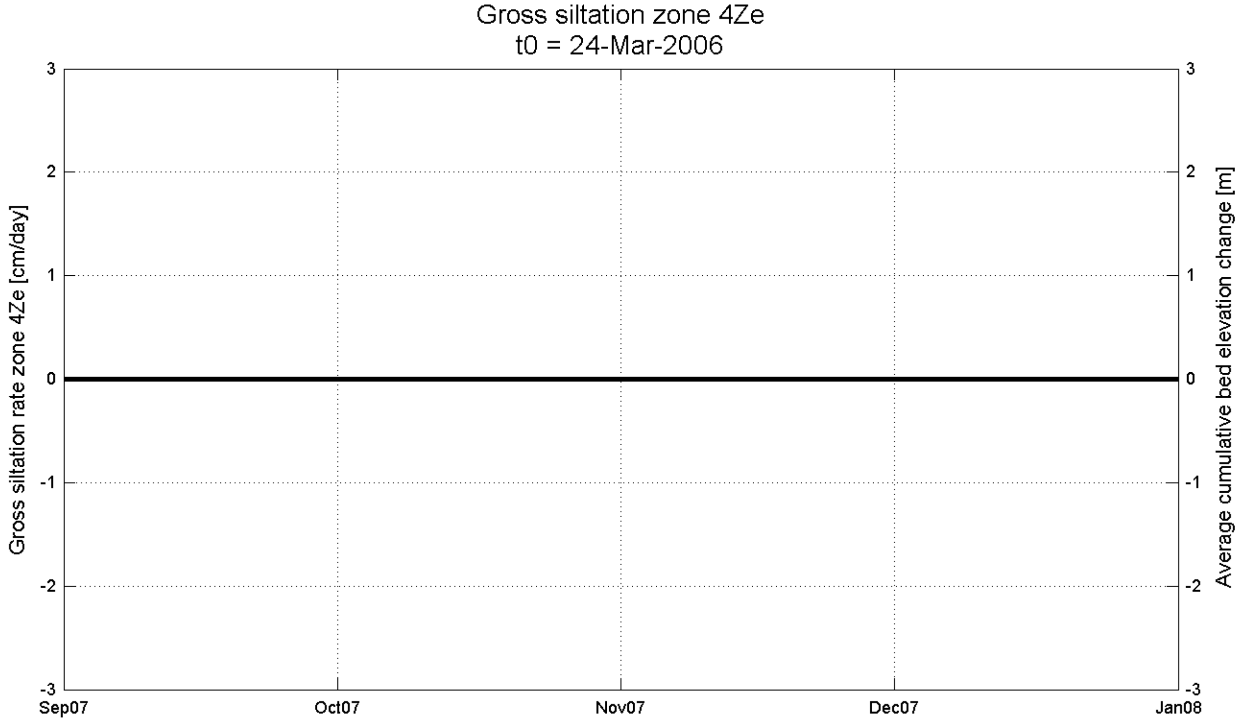


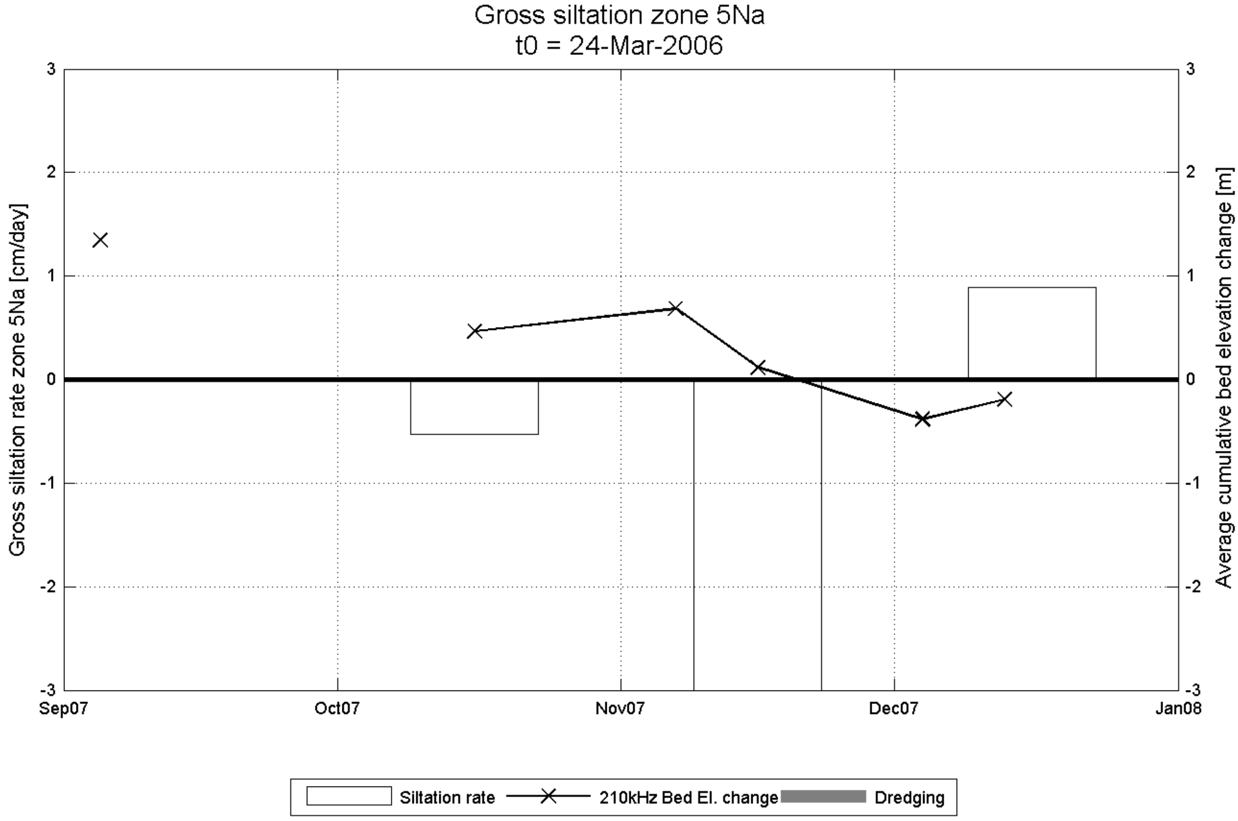


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

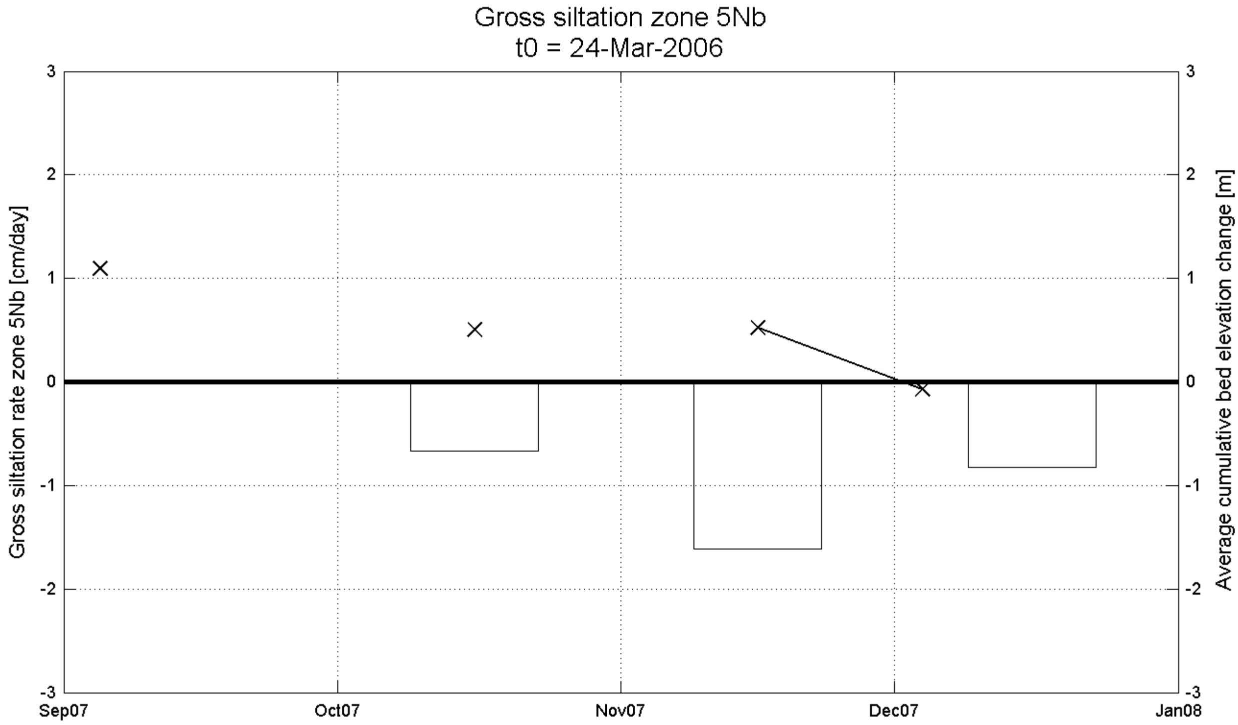
Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

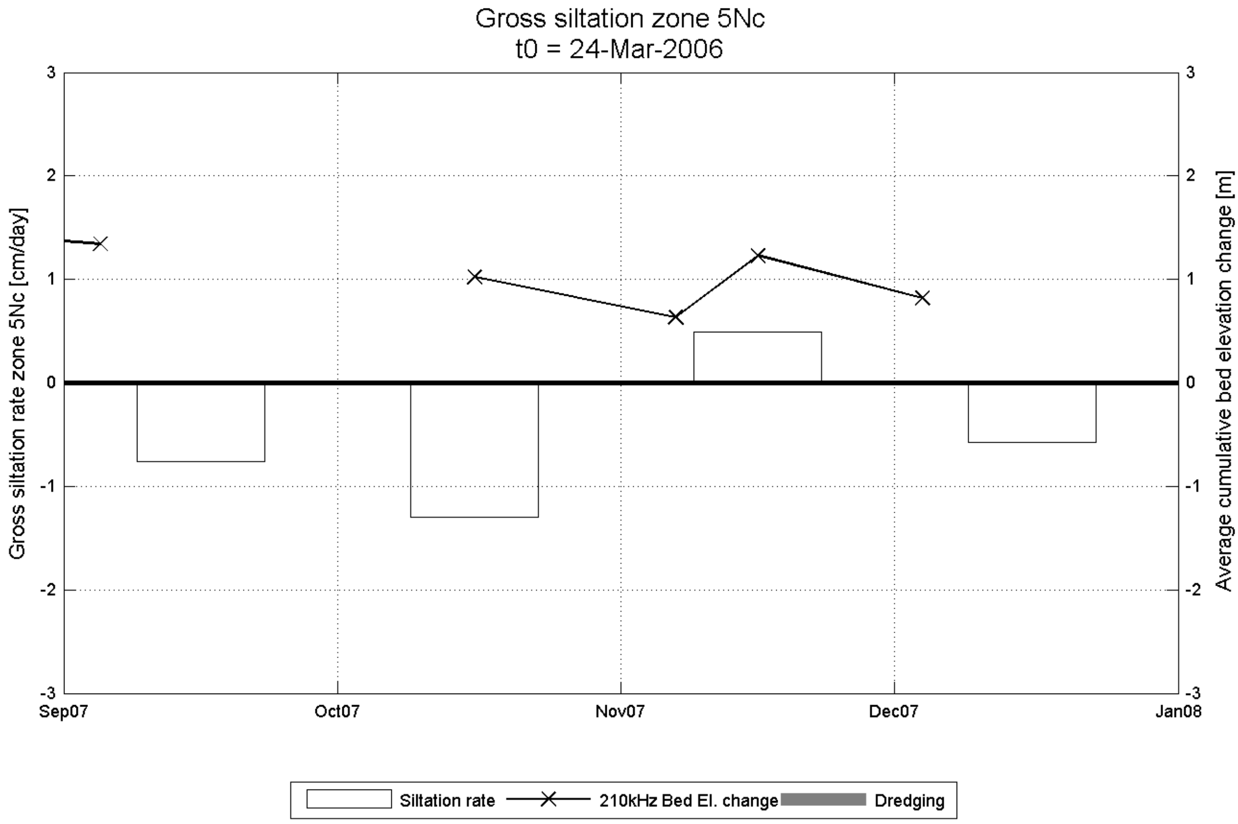




Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

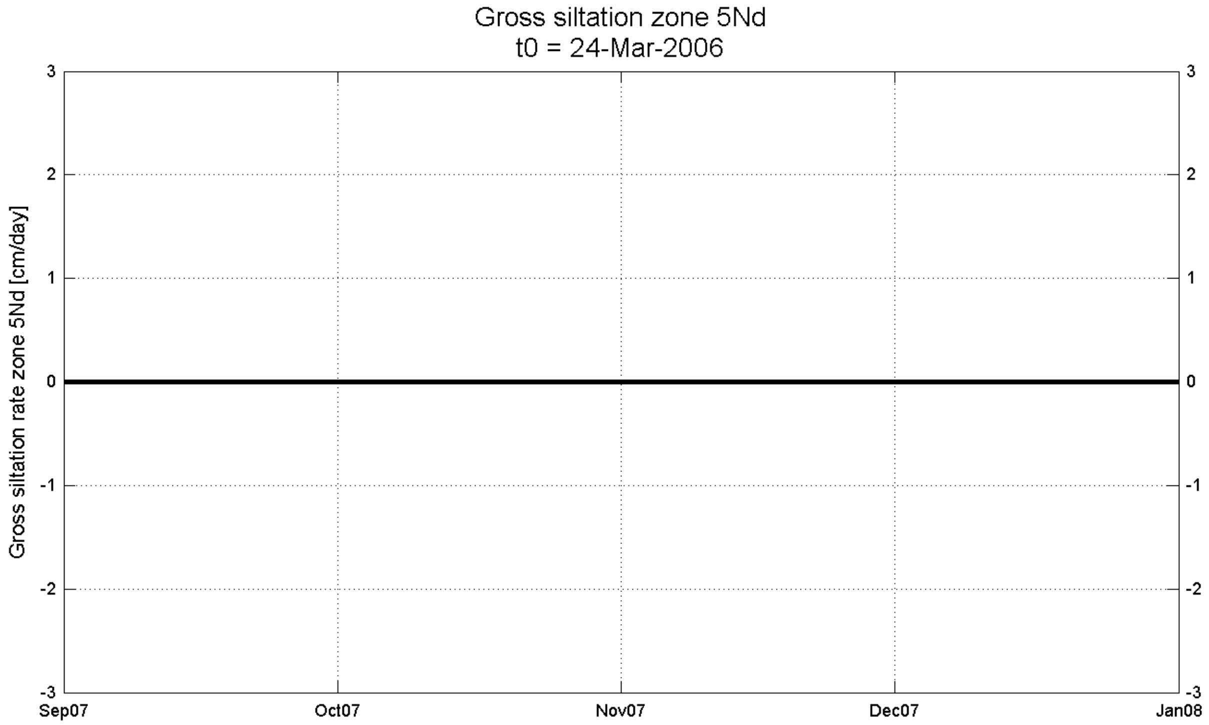
Data Processed by:

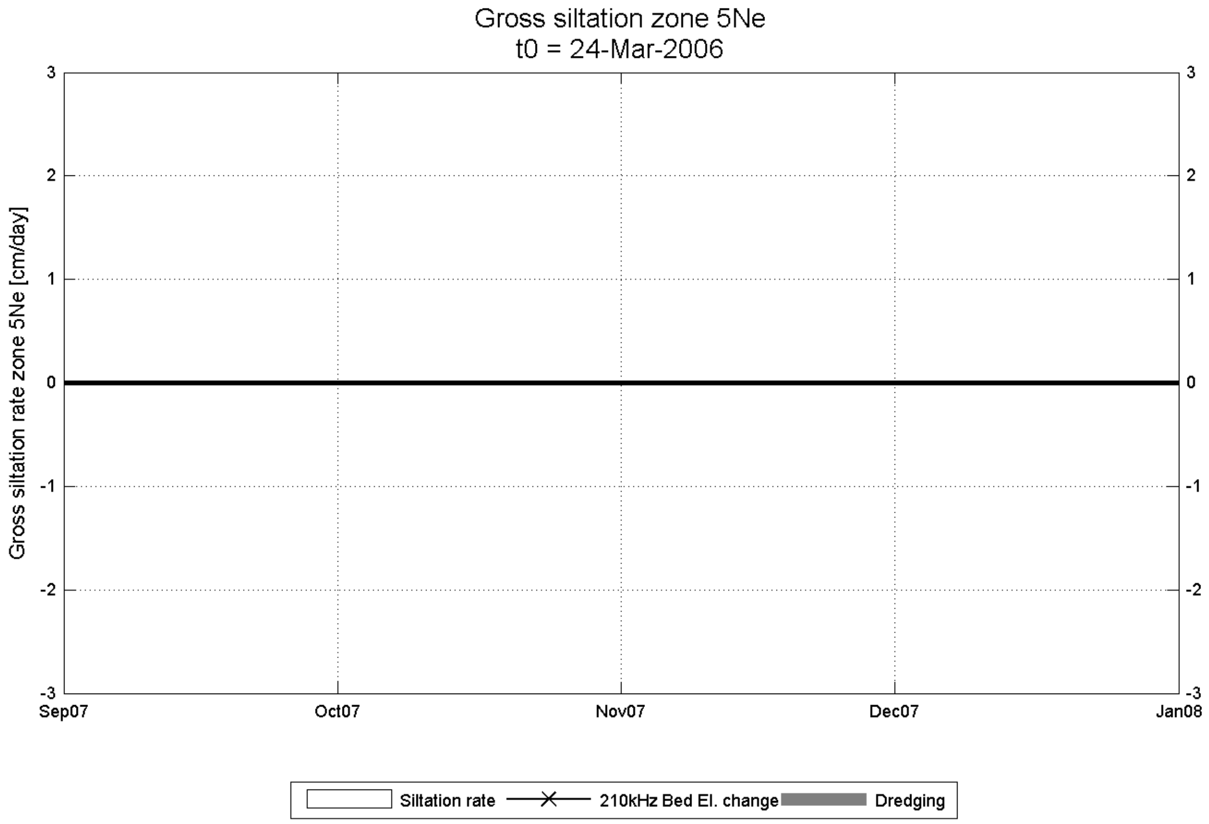
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

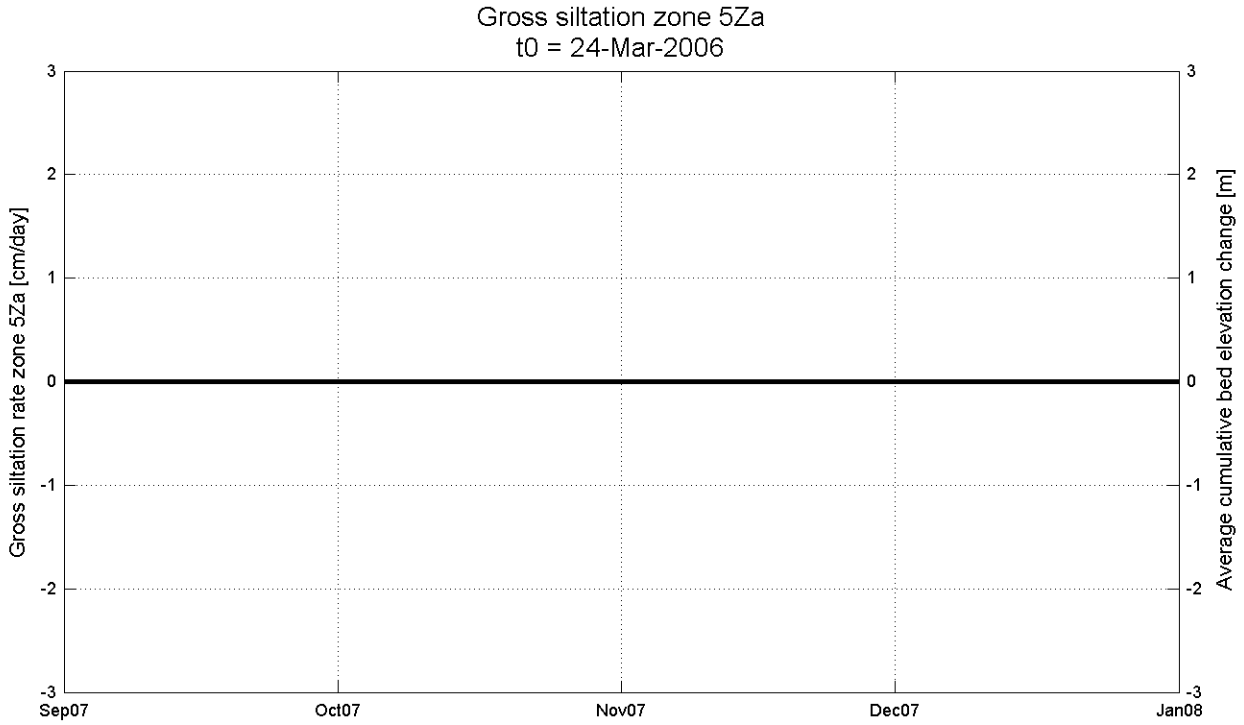
Data Processed by: IMDC

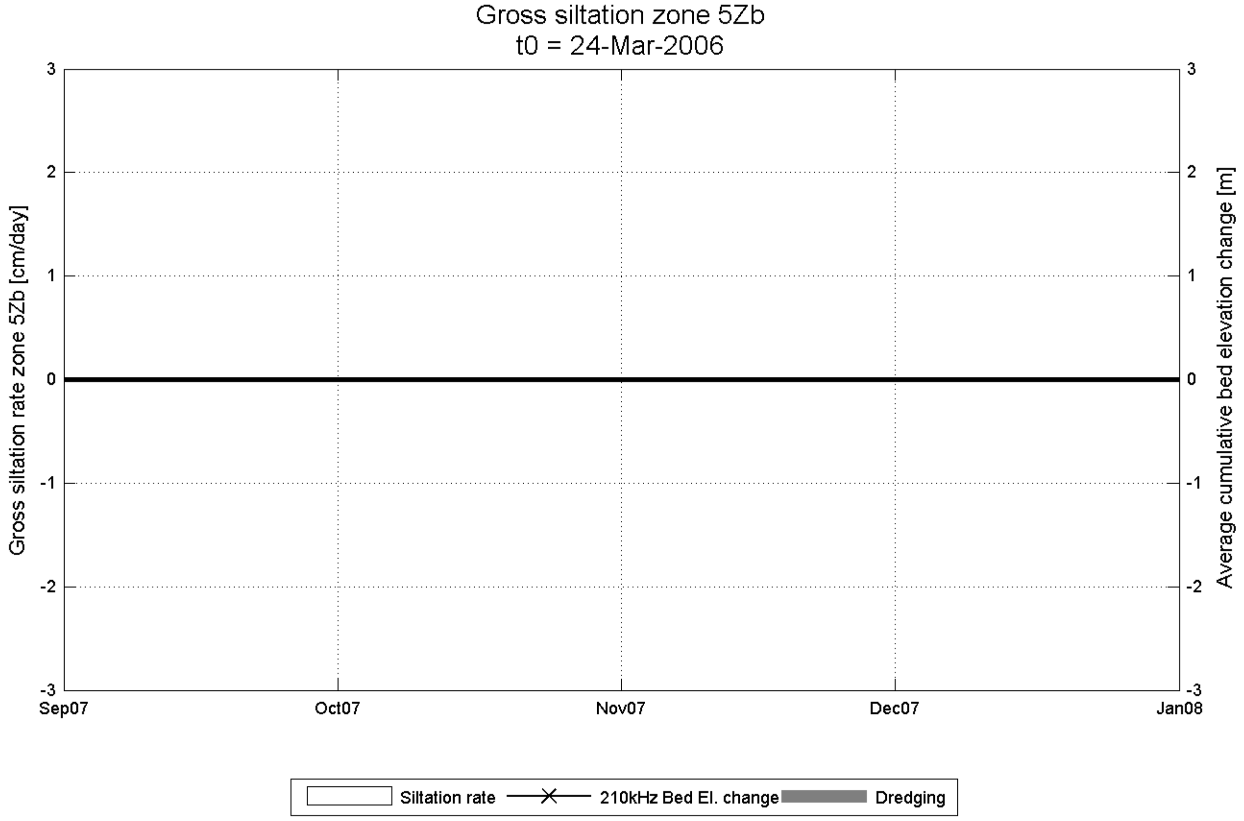
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

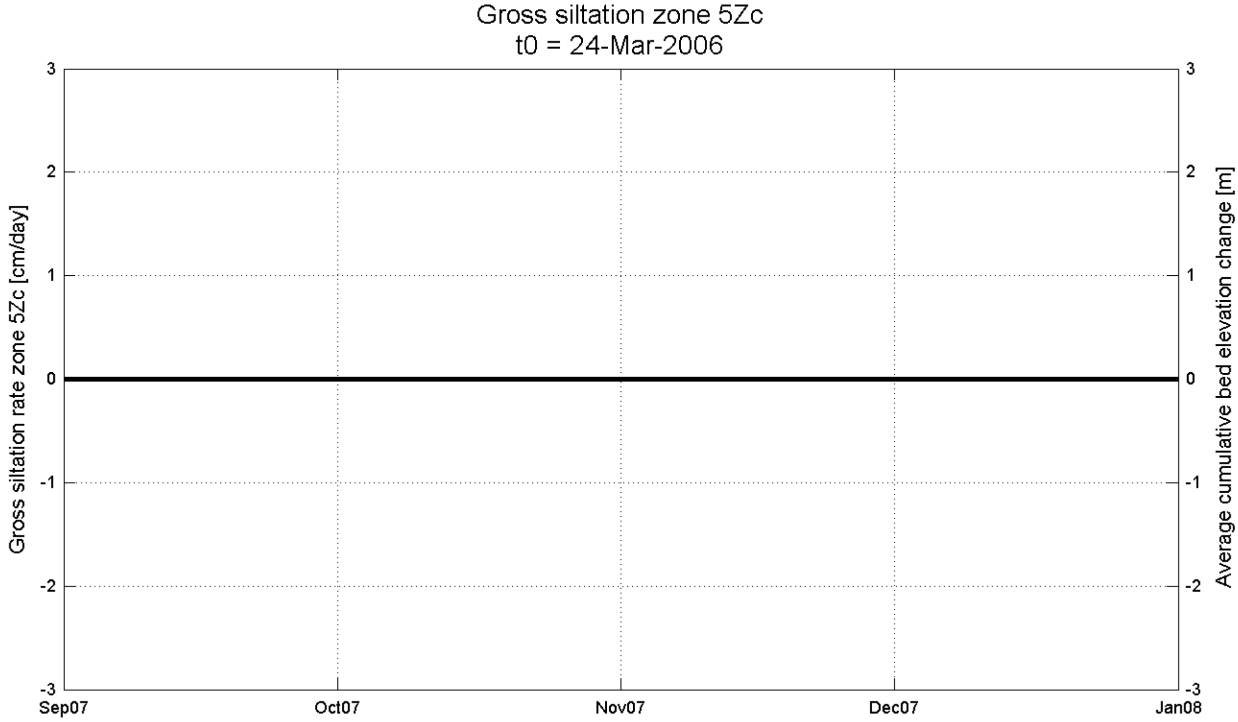
Data Processed by: IMDC

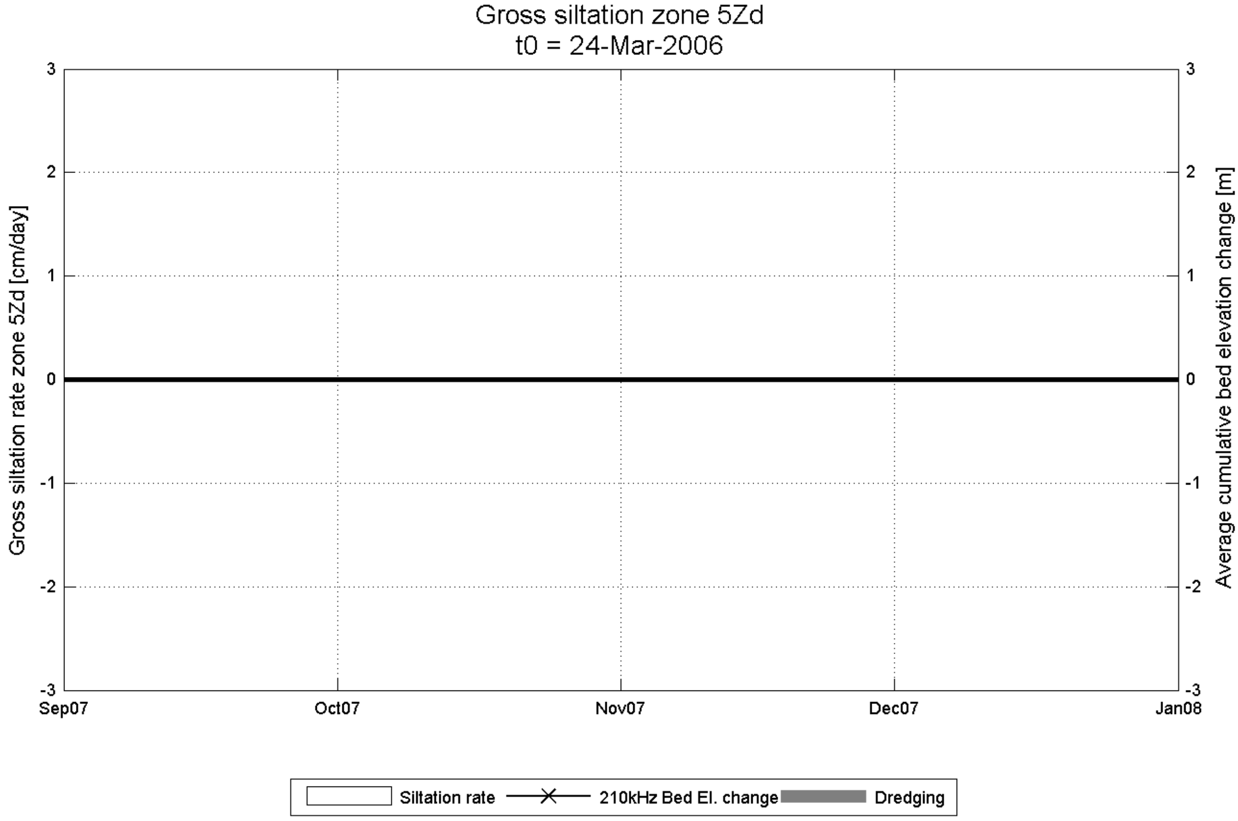
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

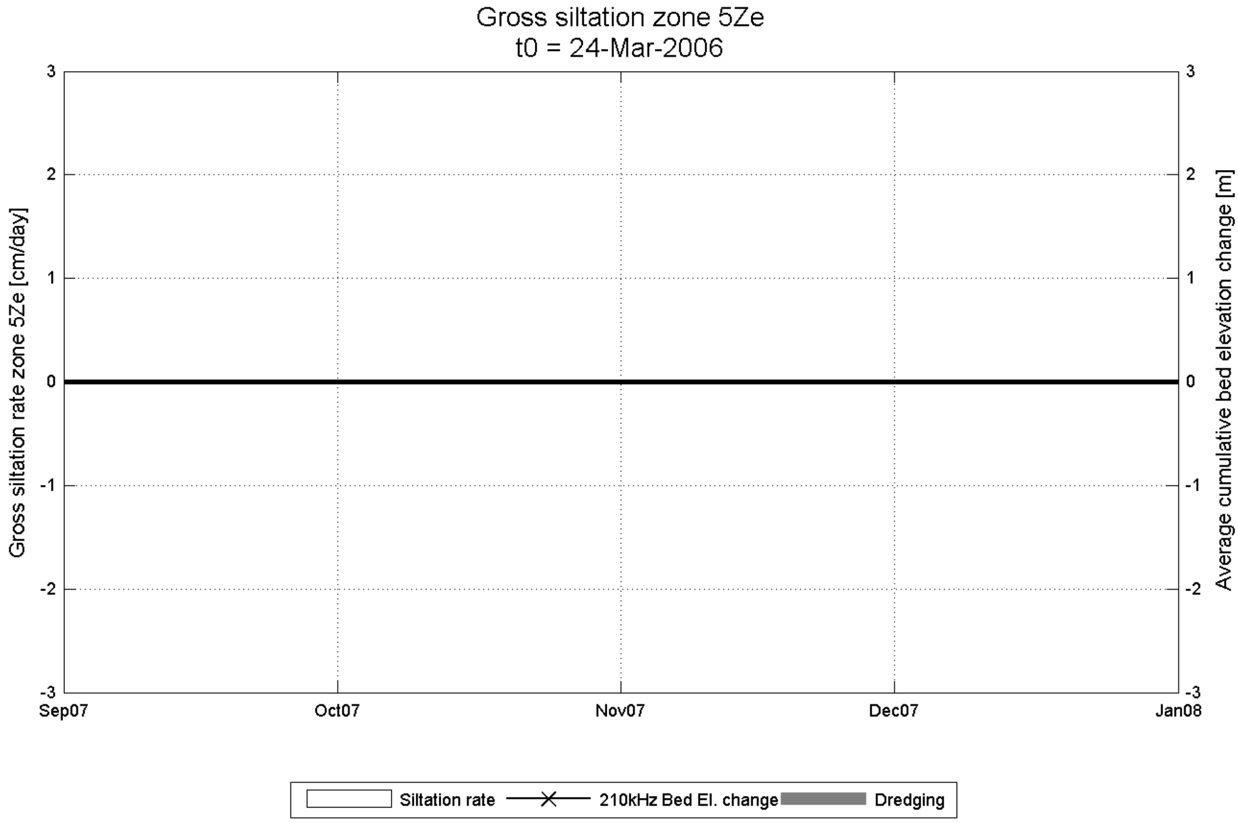
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 24-Mar-2006

Data Processed by: IMDC

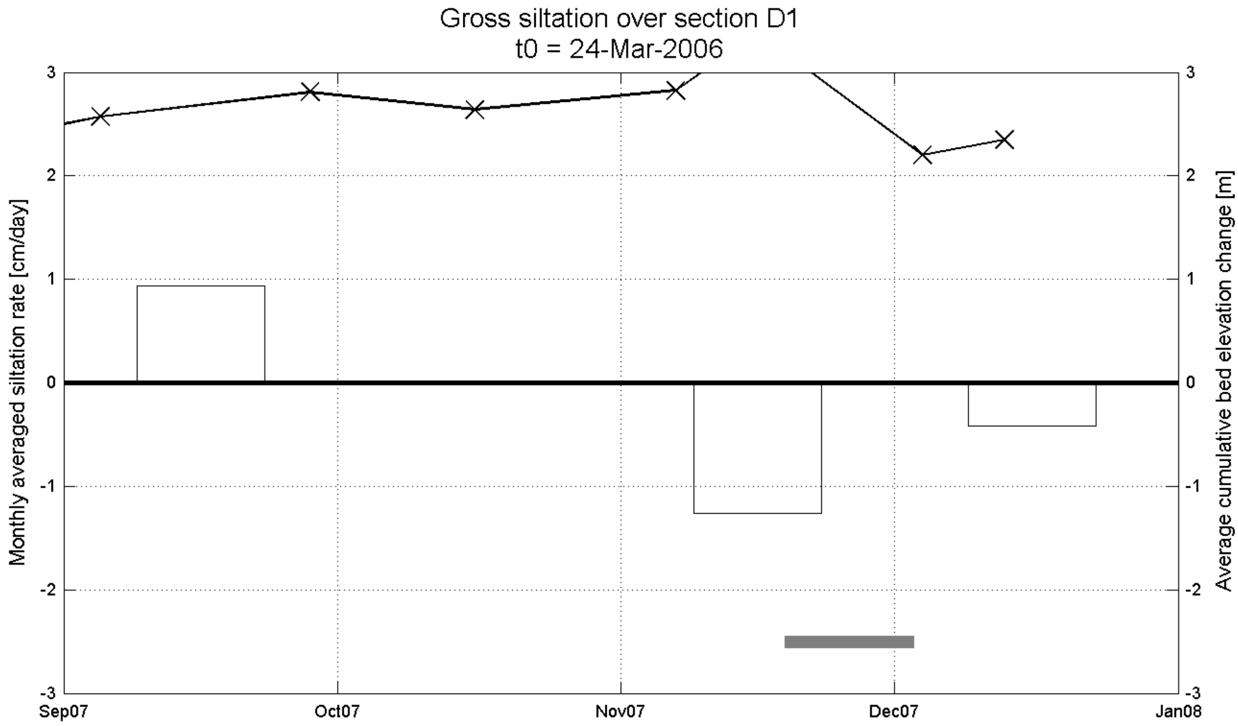
In association with :

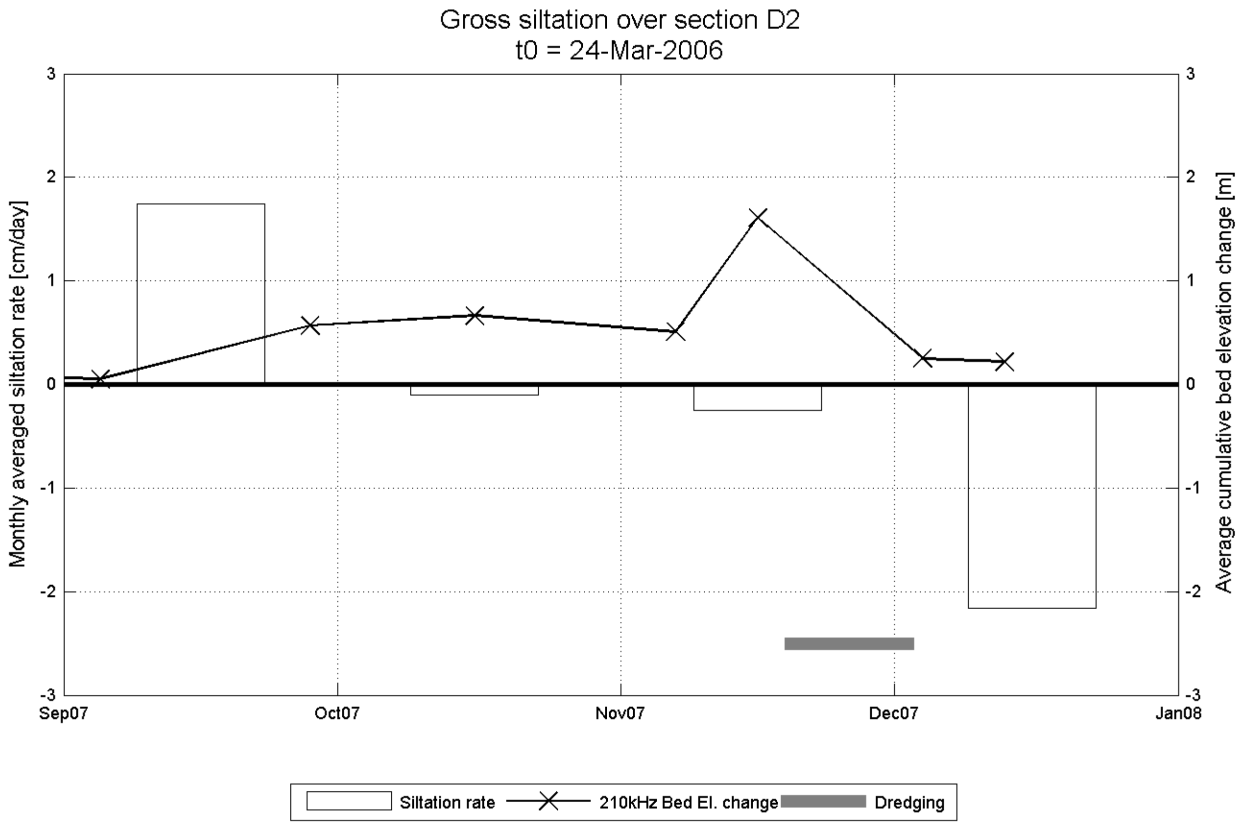
I/RA/11283/07.083/MSA

C.3 Water-bed interface evolution for all sections

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

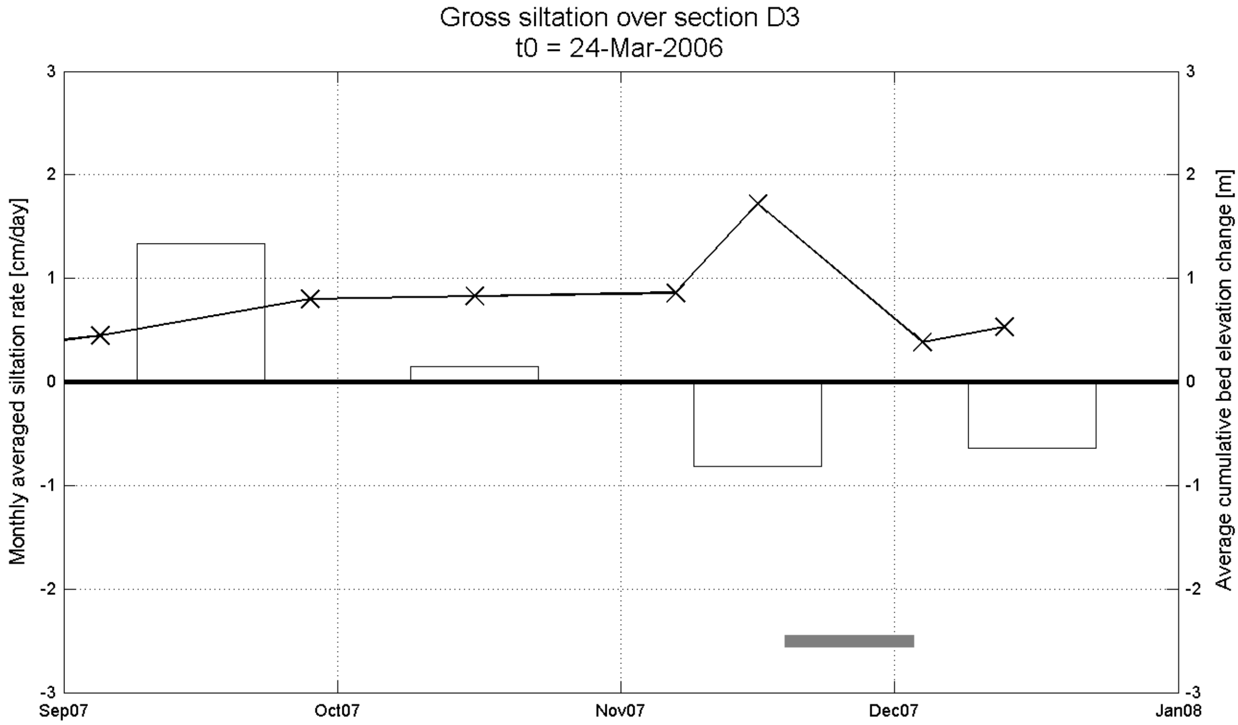
Data Processed by:

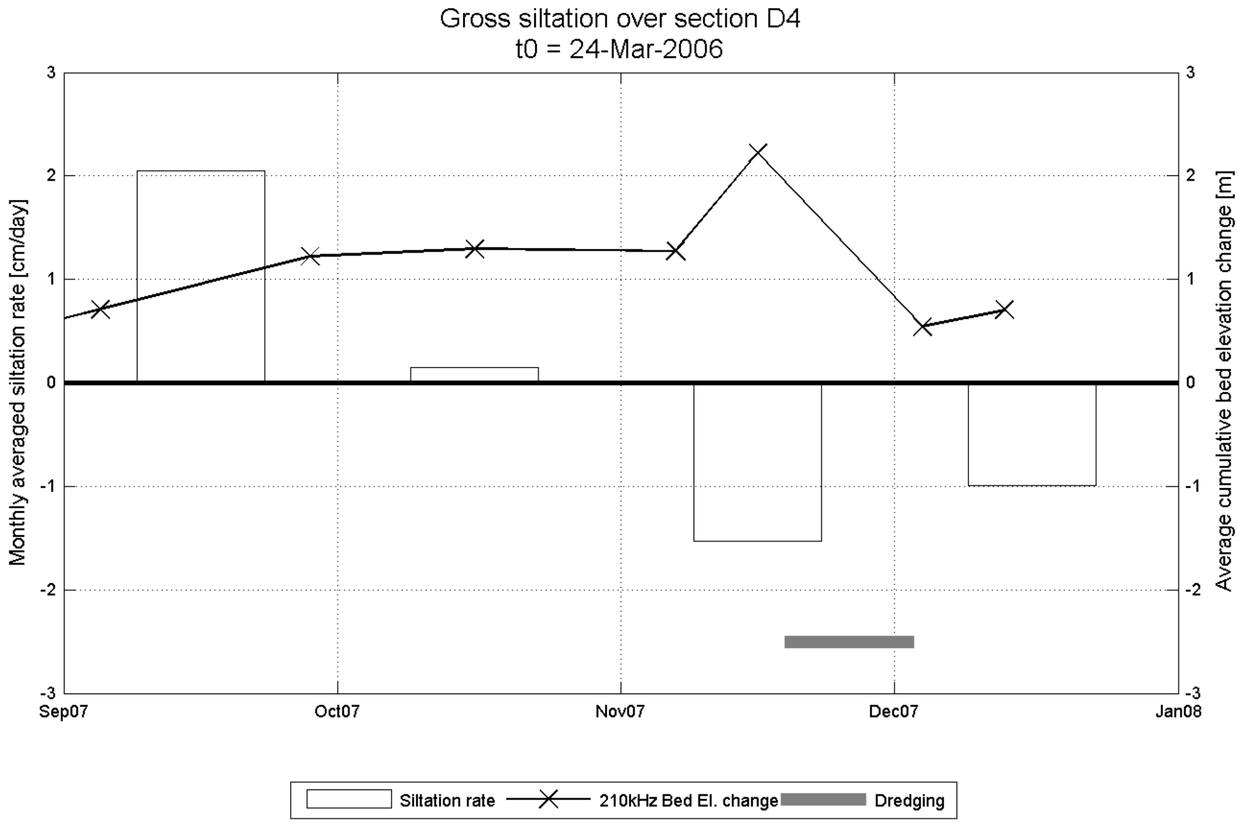
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



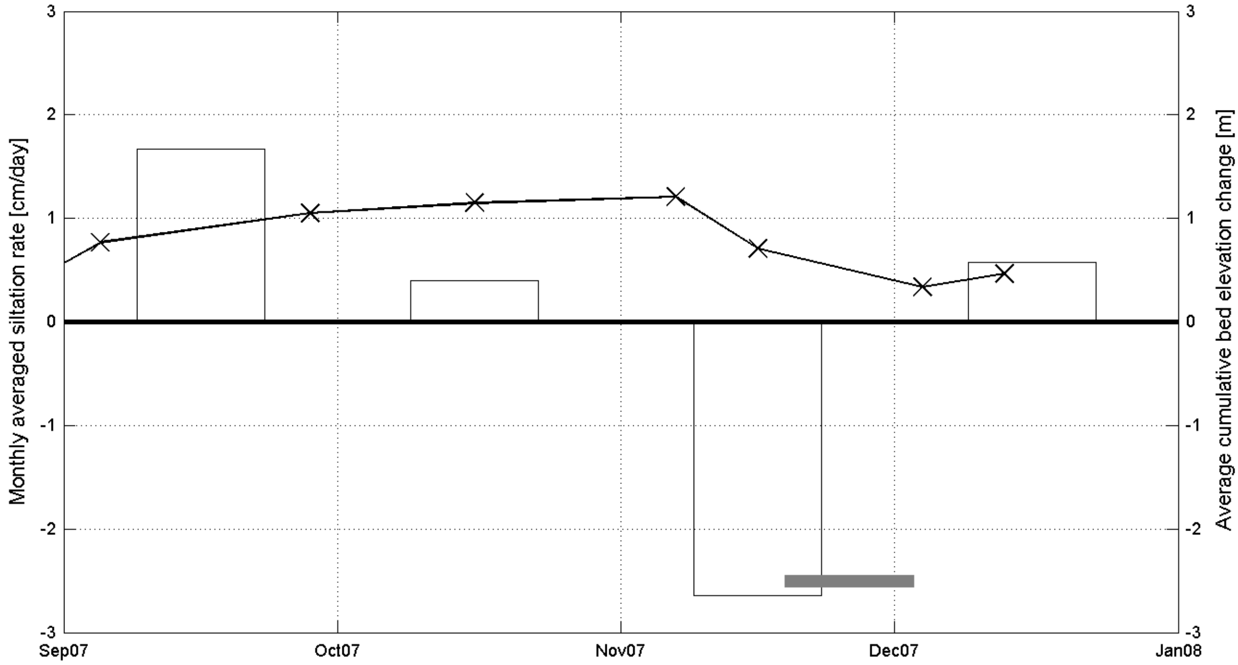


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

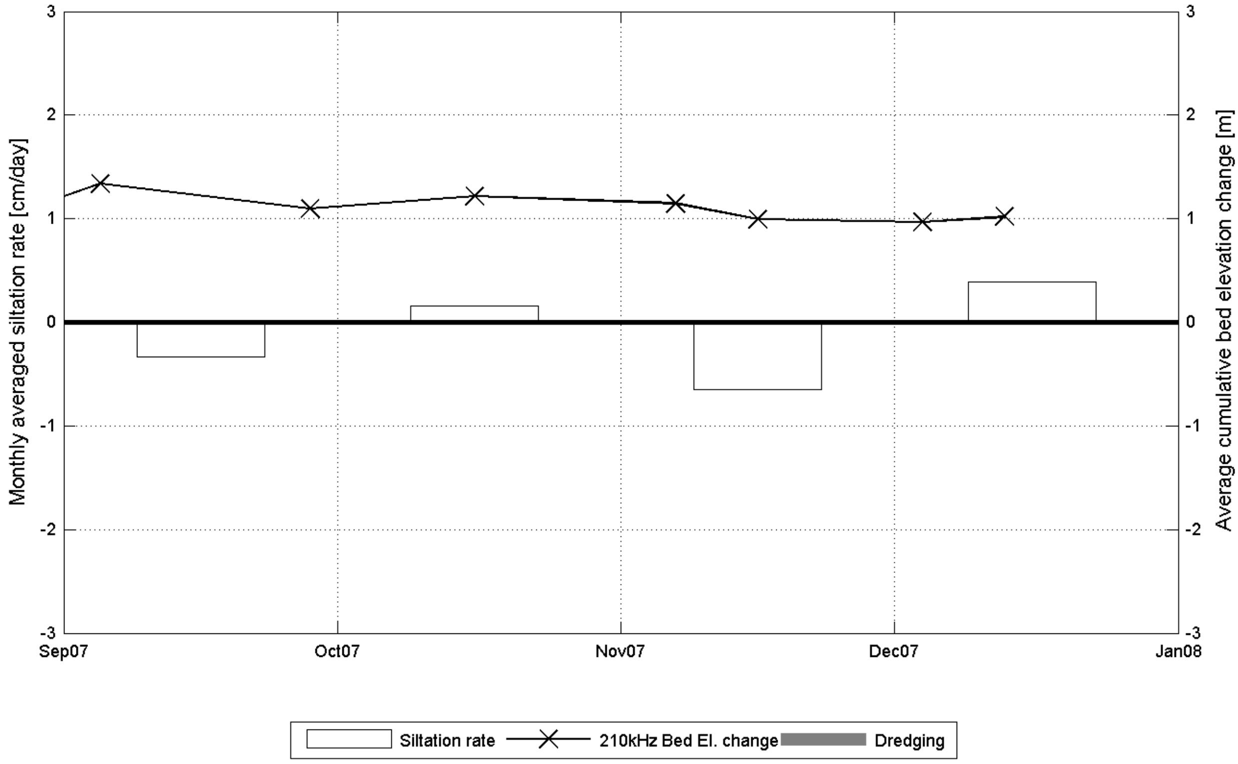
Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

Gross siltation over section D5
t0 = 24-Mar-2006



Gross siltation over section D6
t0 = 24-Mar-2006



Reference level: depth sounding 24-Mar-2006

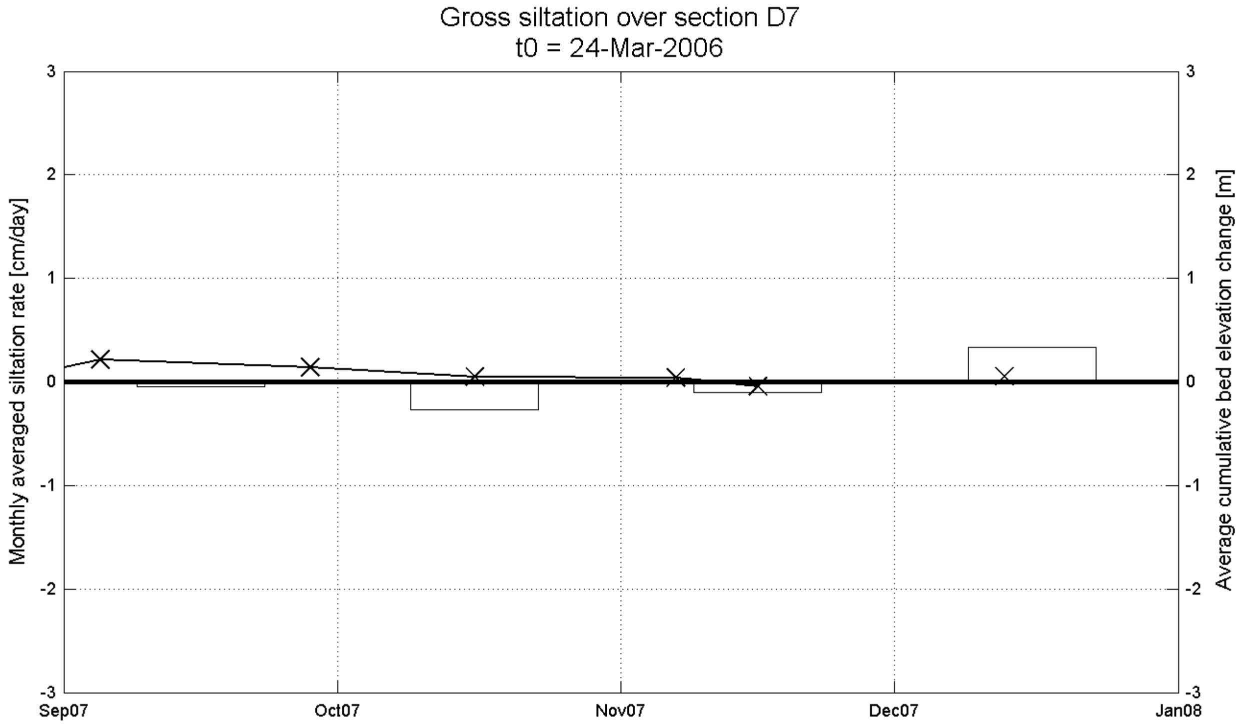
Data Processed by: IMDC

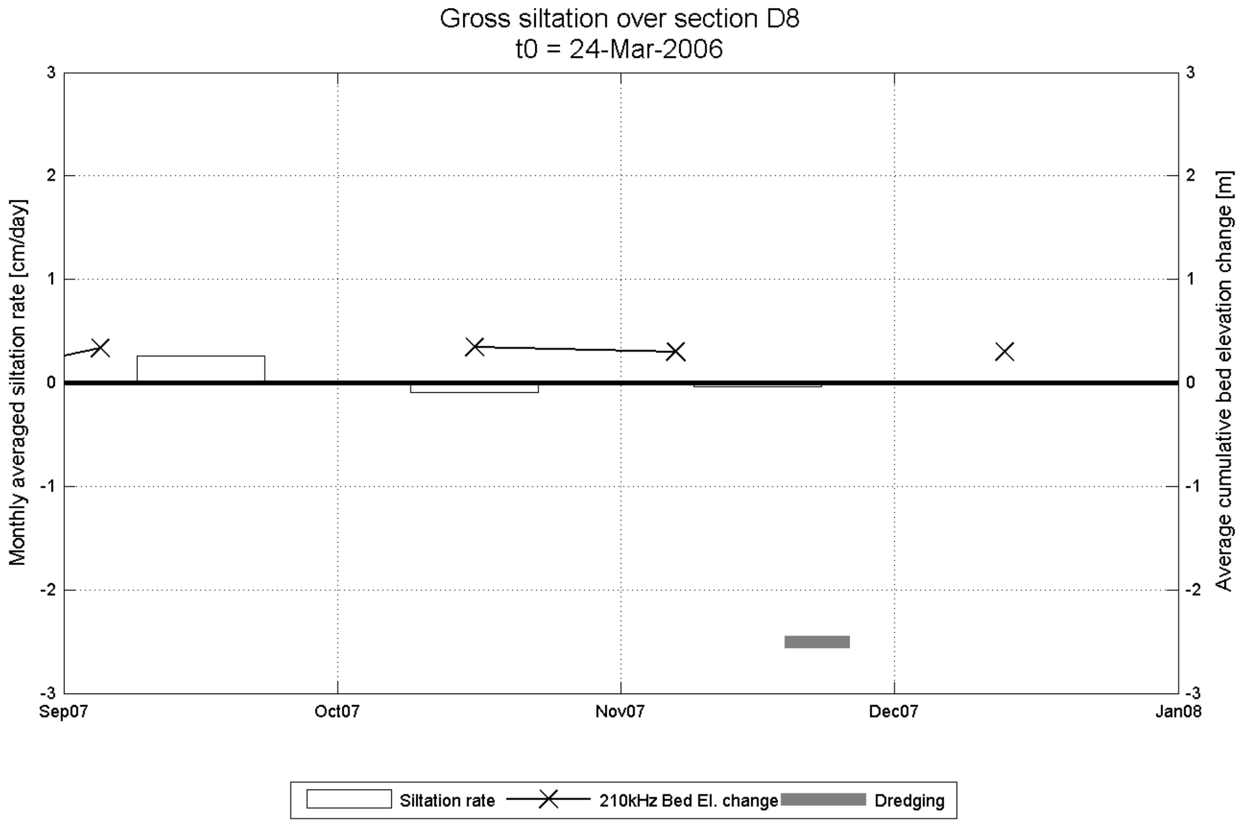
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

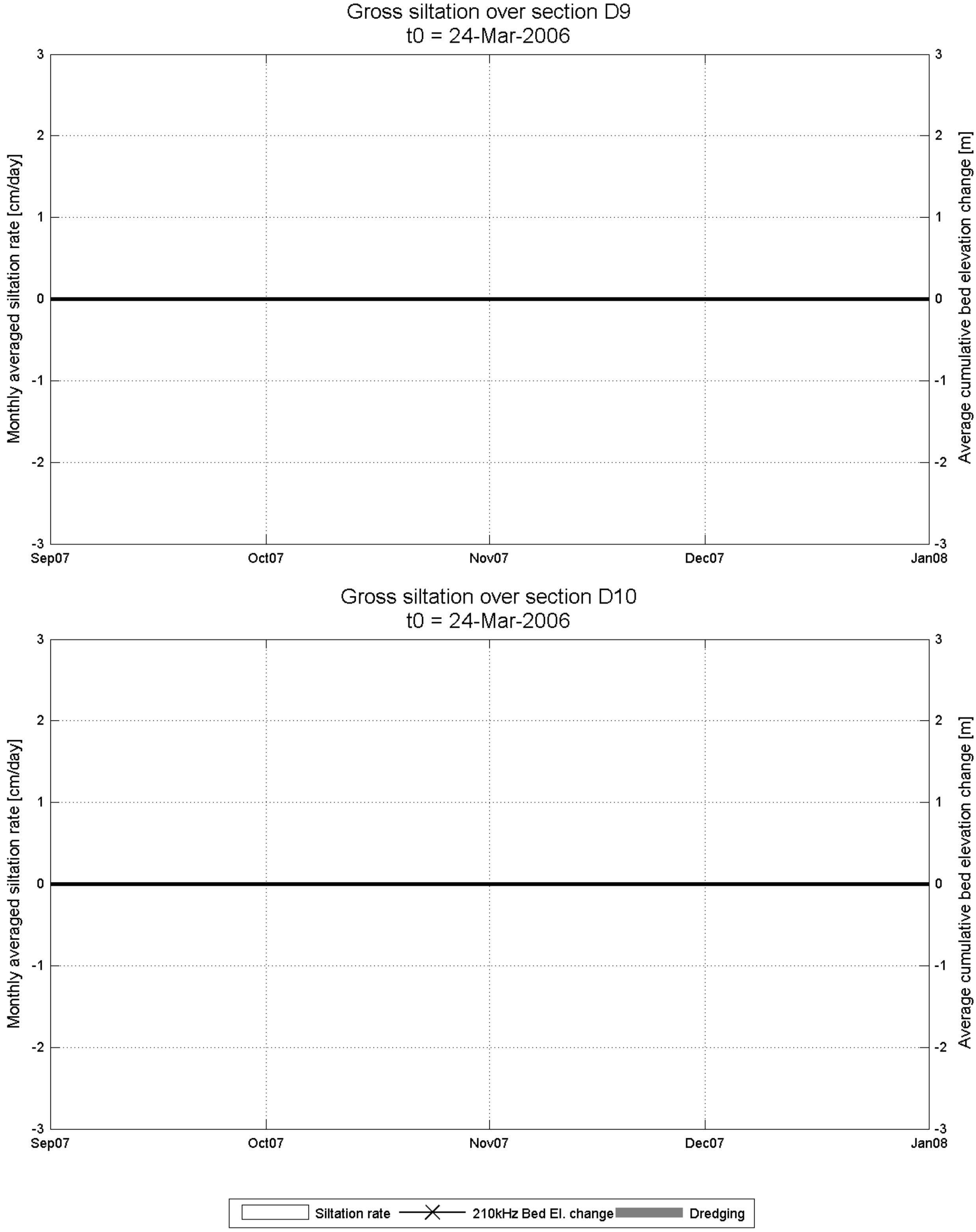
Data Processed by: IMDC

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 24-Mar-2006

Data Processed by:

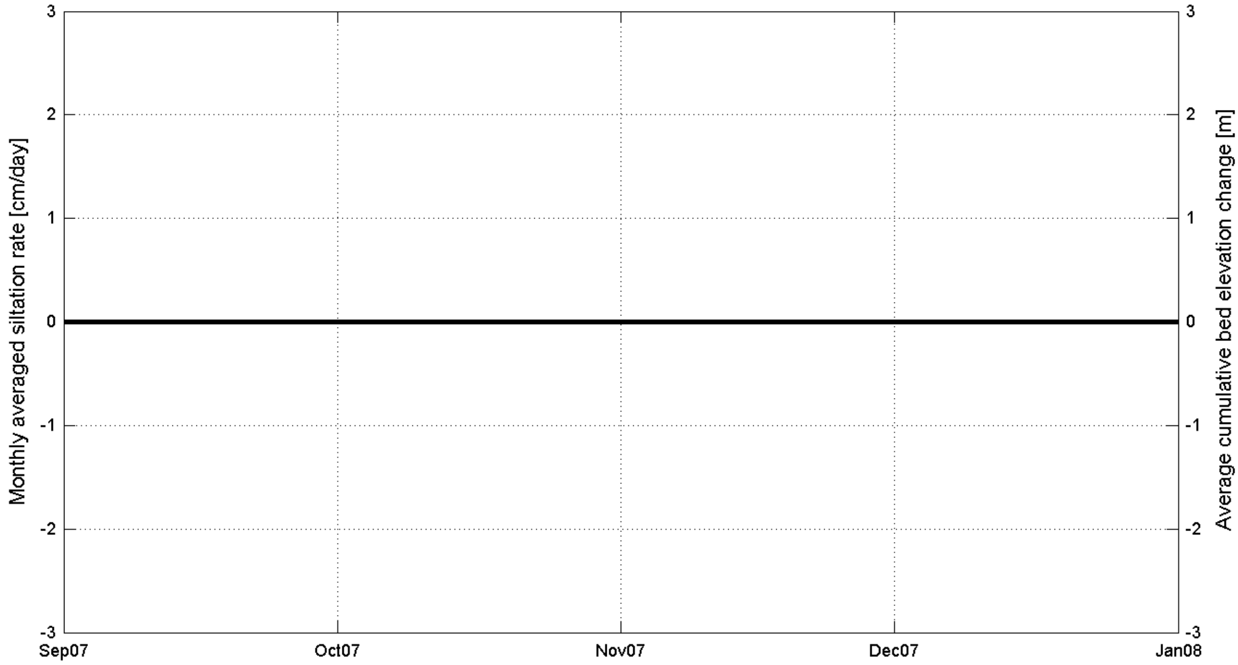
In association with :

I/RA/11283/07.083/MSA

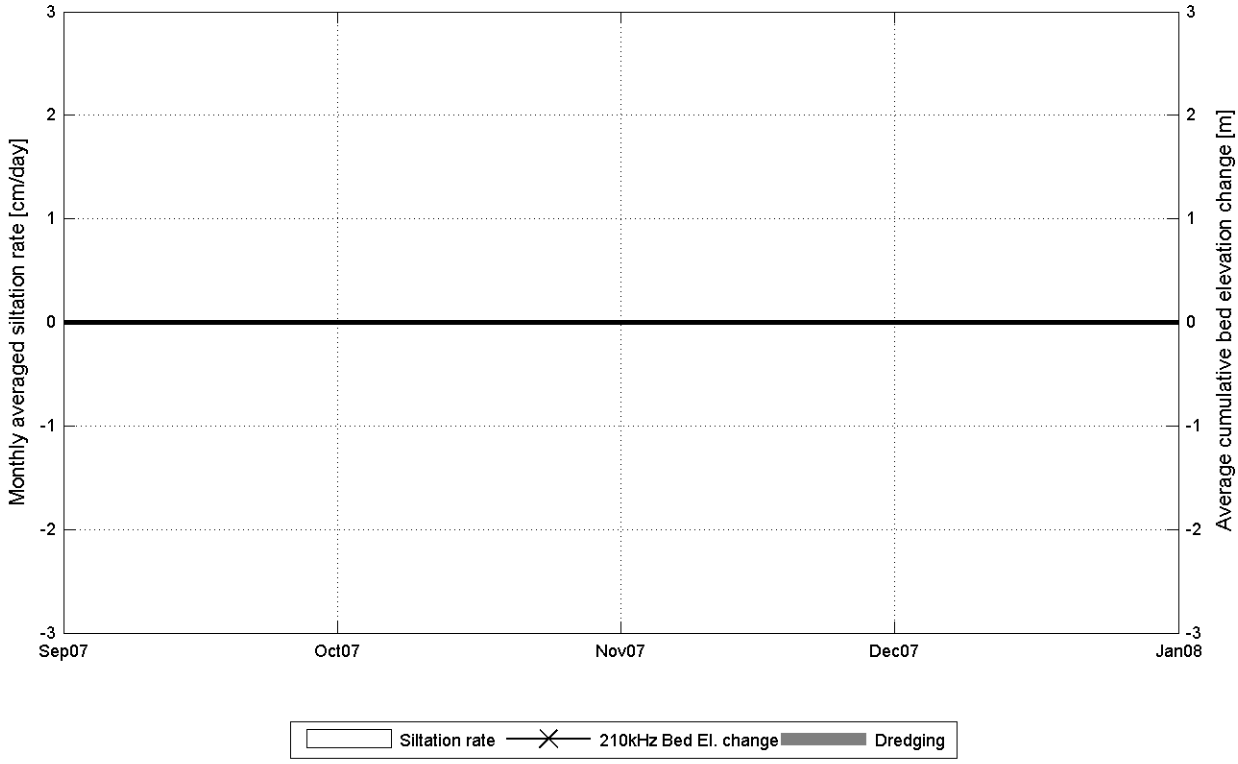
Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

Gross siltation over section D11
t0 = 24-Mar-2006



Gross siltation over section D12
t0 = 24-Mar-2006



Reference level: depth sounding 24-Mar-2006

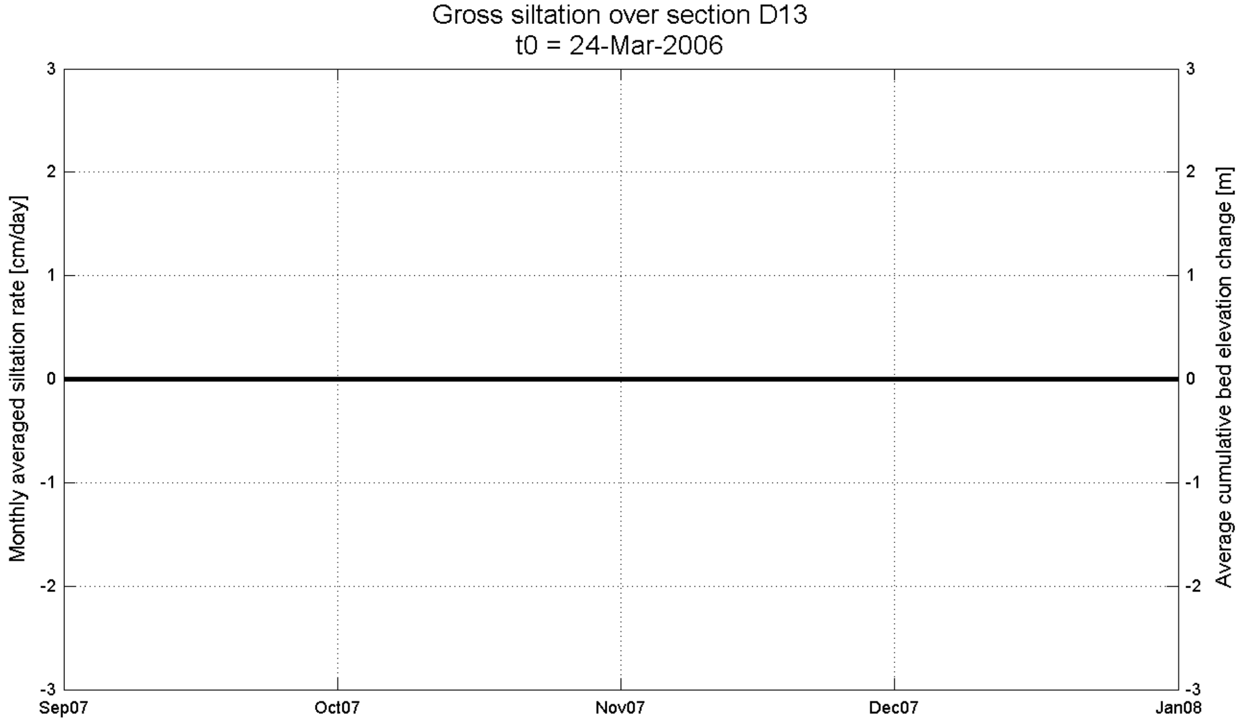
Data Processed by: IMDC

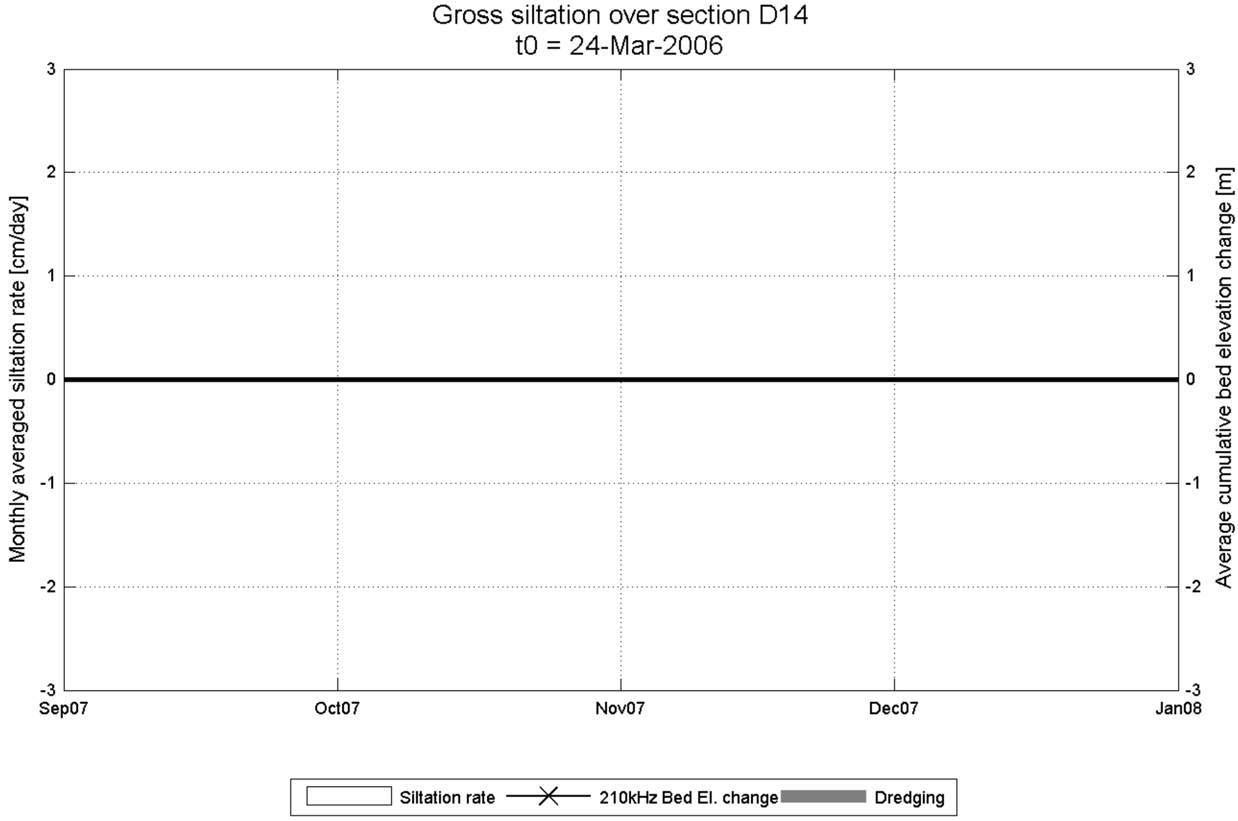
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

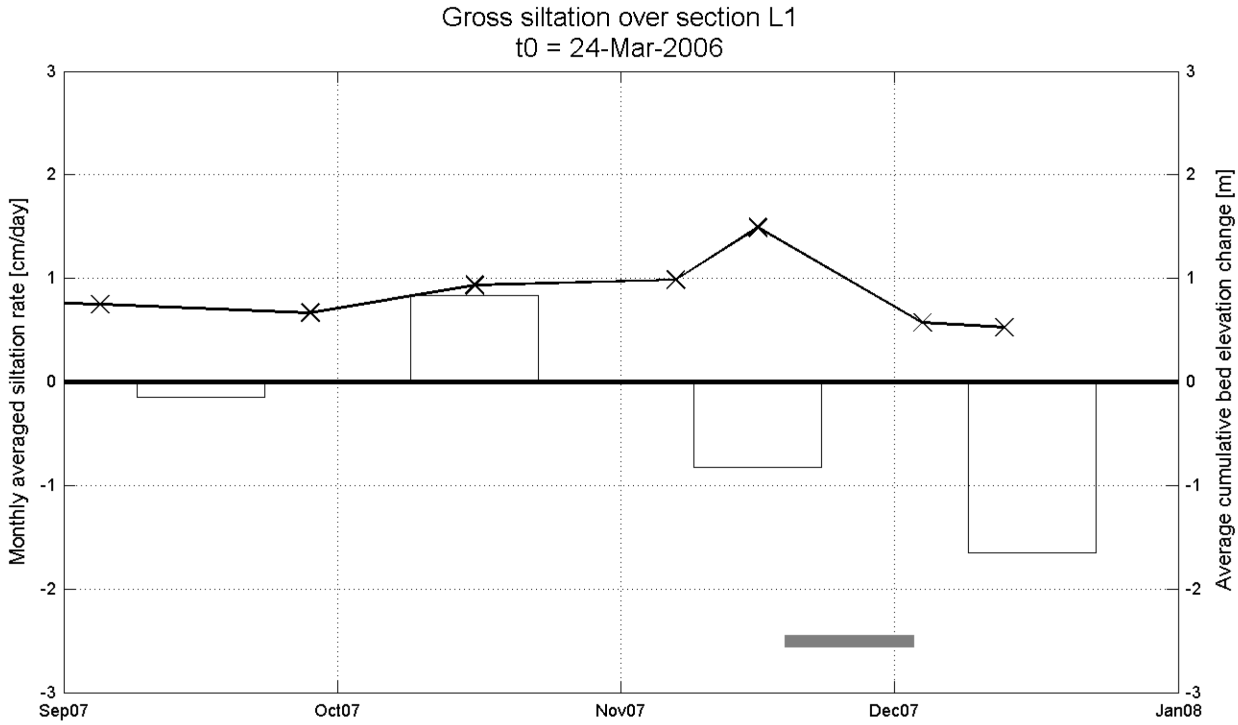
Data Processed by: IMDC

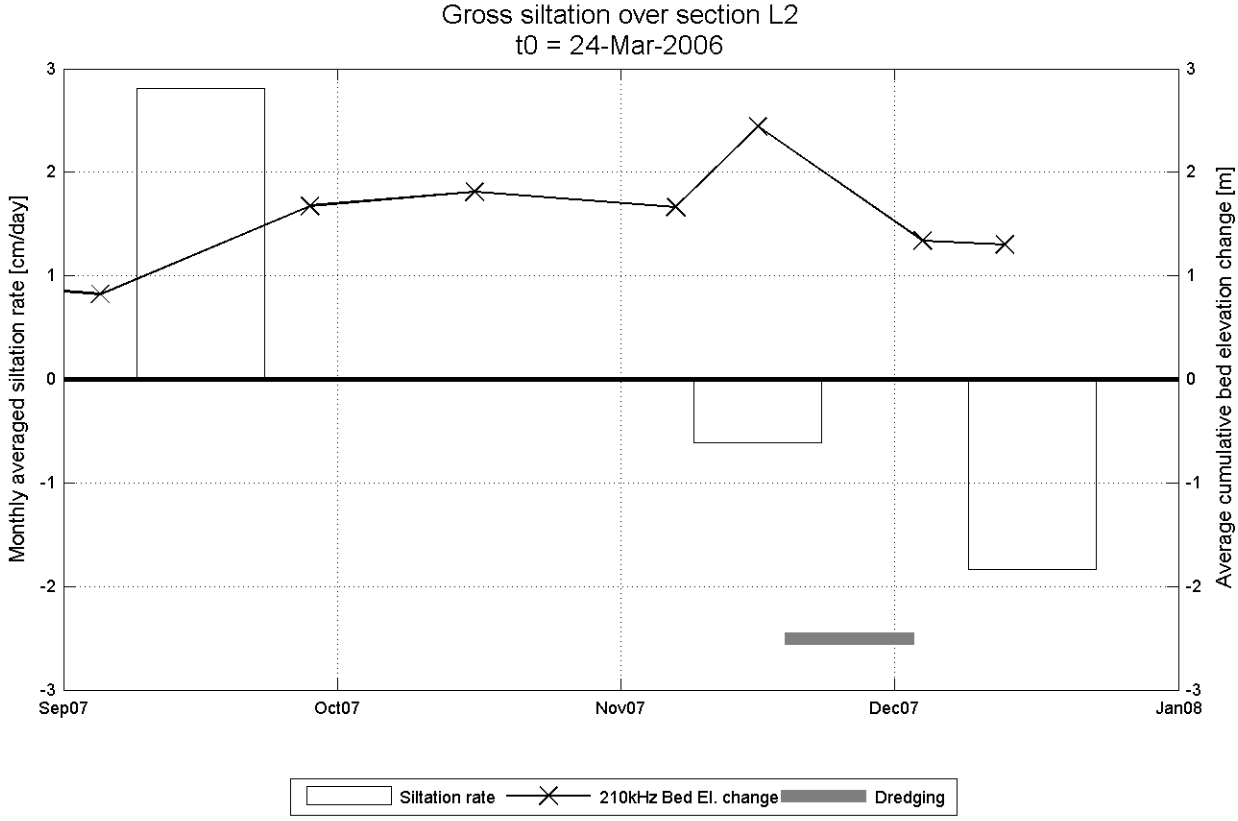
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD





Reference level: depth sounding 24-Mar-2006

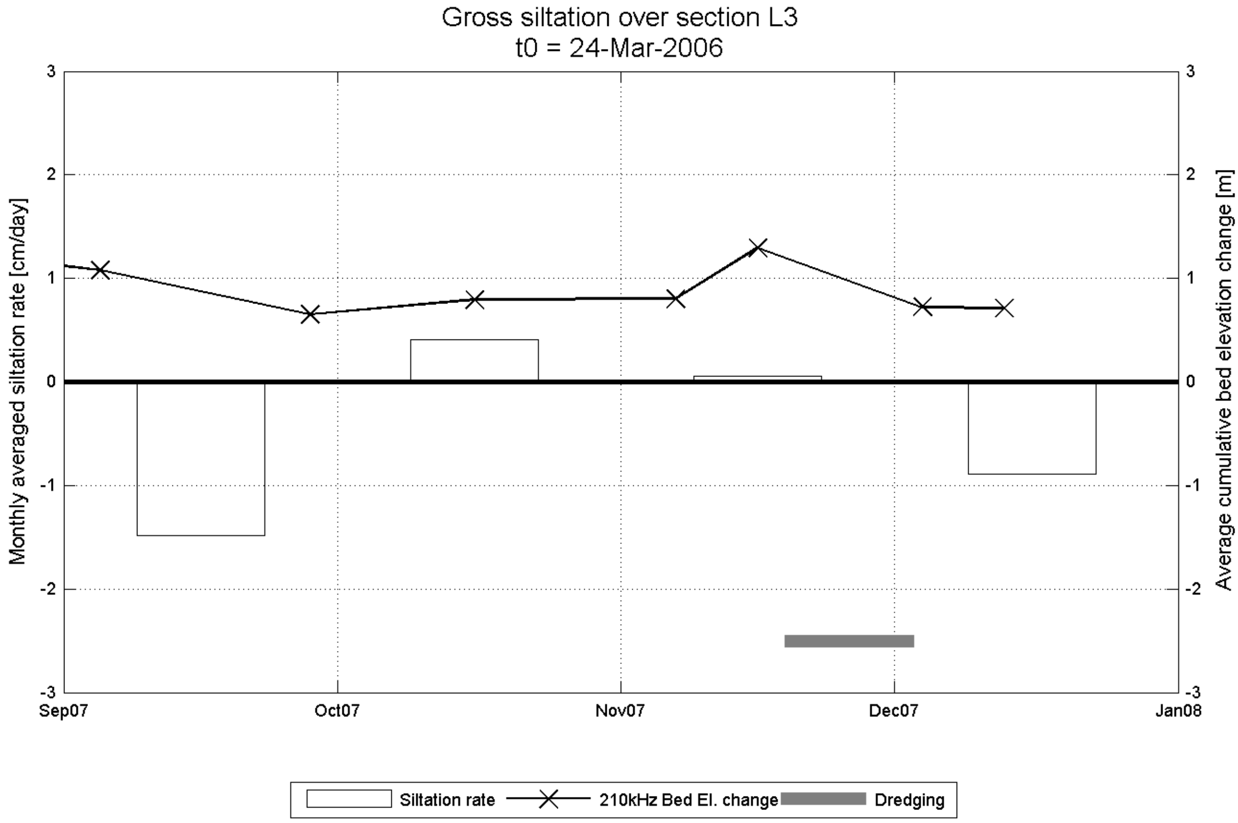
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Siltation height / monthly gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 24-Mar-2006

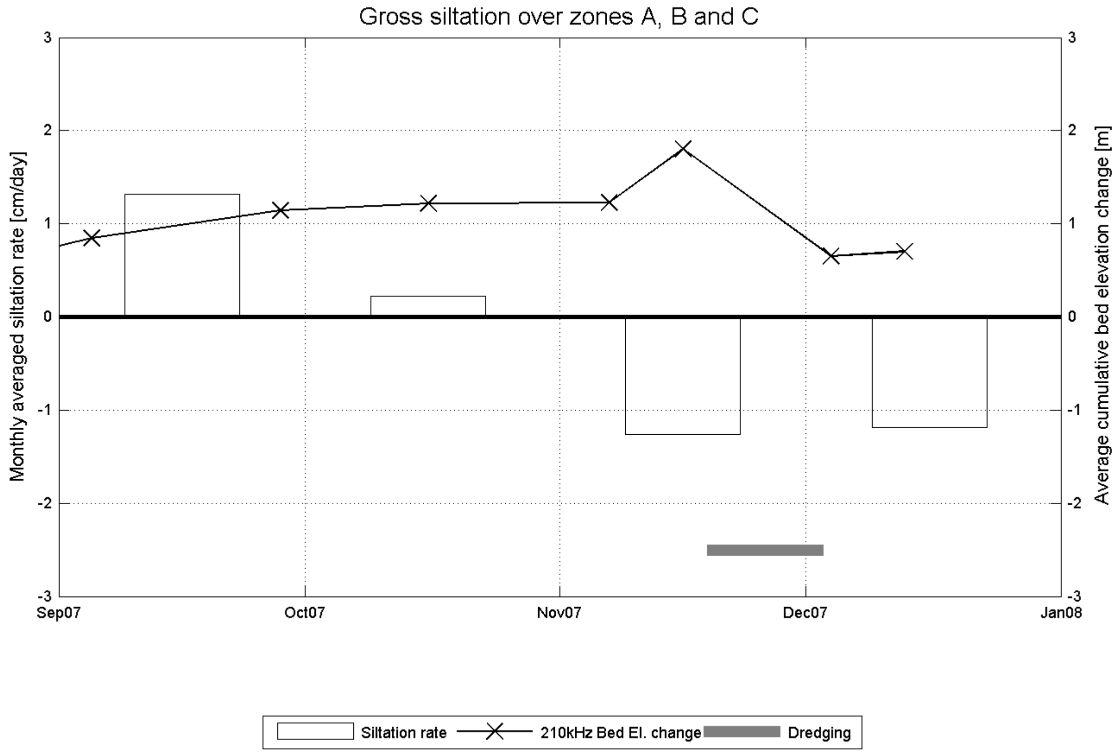
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

C.4 Siltation rate complete Deurganckdok

Long-term monitoring siltation Deurganckdok	
Siltation height / monthly siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Gross siltation for zones 3A/3B/4A/4B/5A/5B
Reference level: depth sounding 24-Mar-2006

Data Processed by:

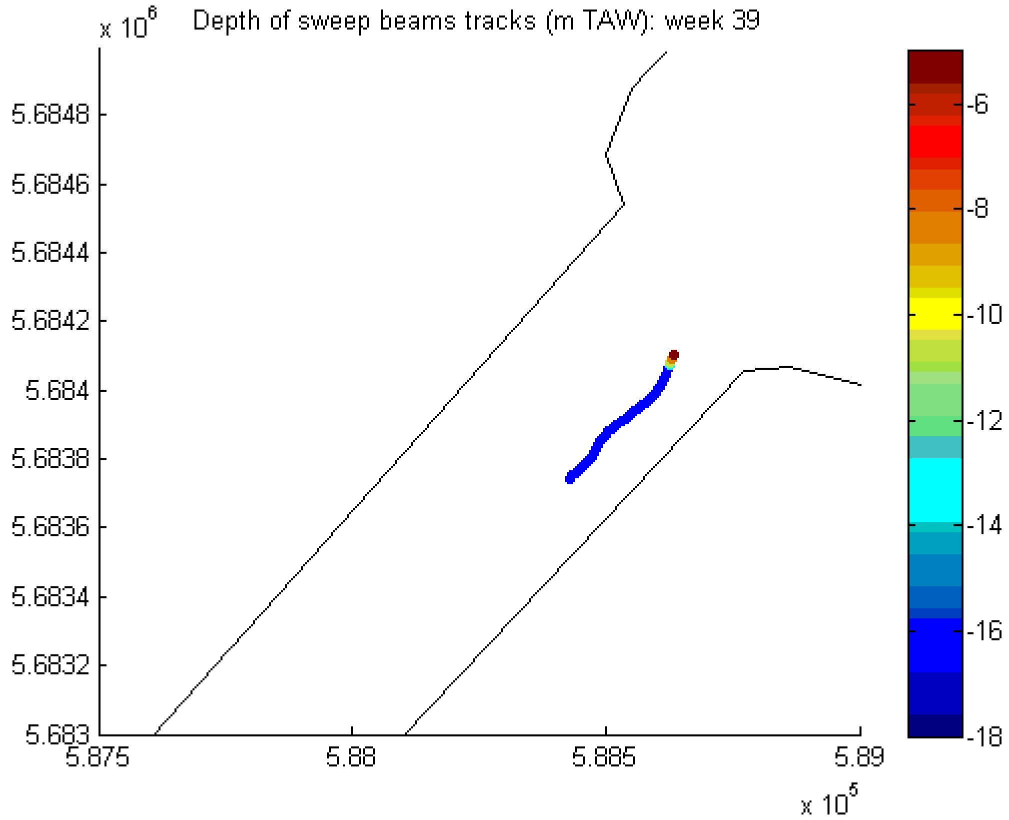
In association with :

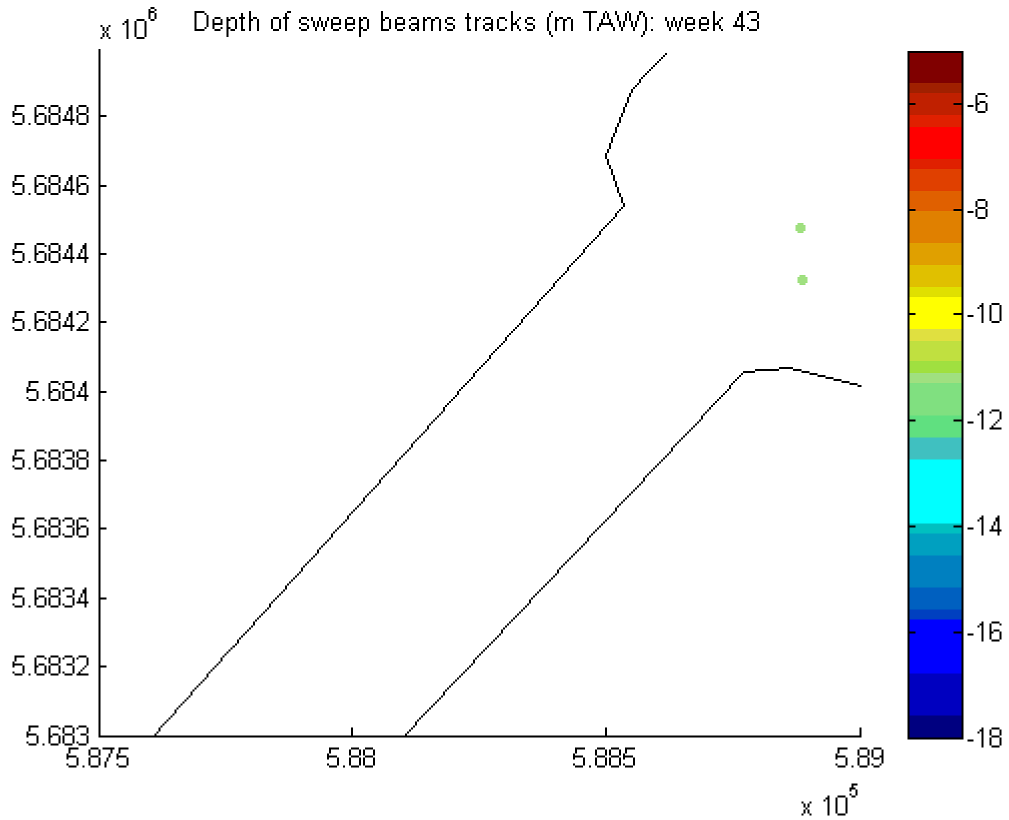
I/RA/11283/07.083/MSA

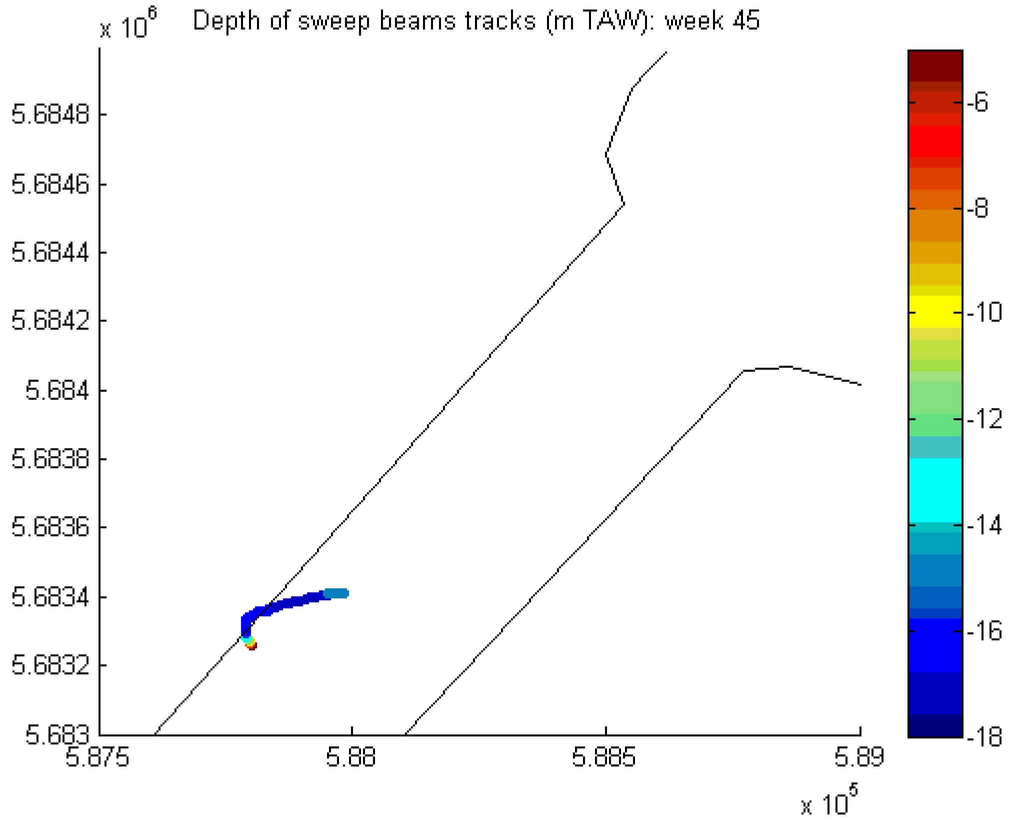
APPENDIX D.

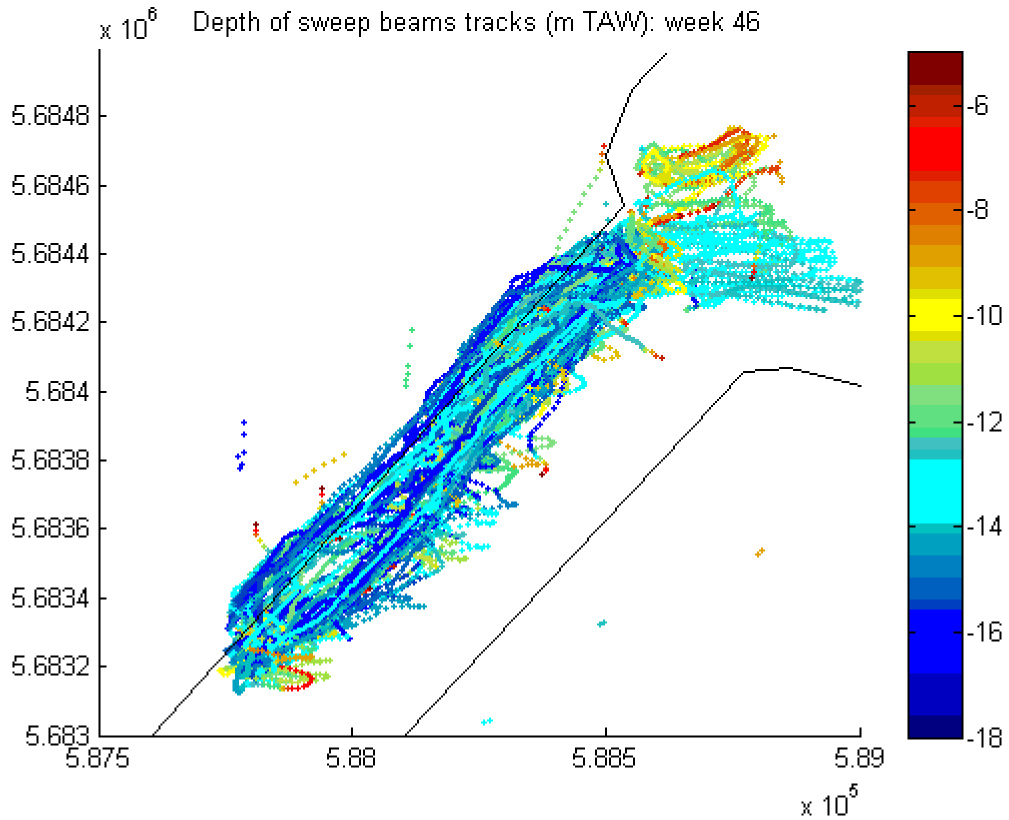
SWEEP BEAM TRACKS

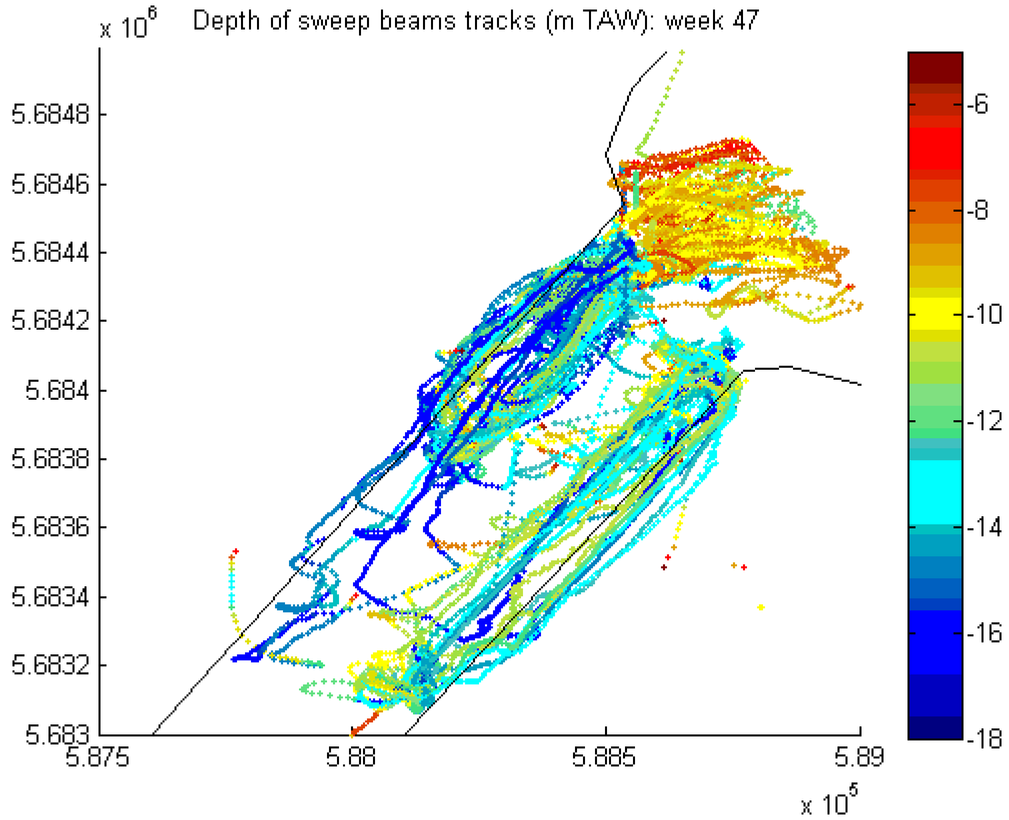
D.1 Depth of sweep beam tracks

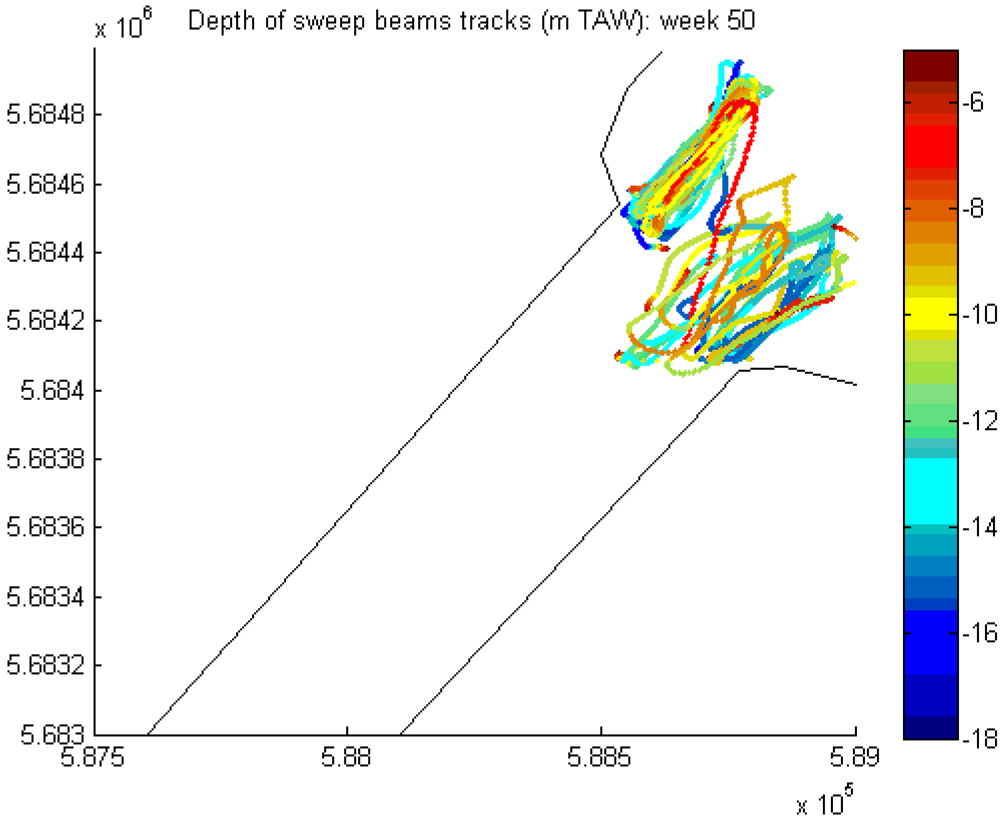

Depth of sweep beams tracks (m TAW): week 39
x 10^6
5.6848
5.6846
5.6844
5.6842
5.684
5.6838
5.6836
5.6834
5.6832
5.683
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

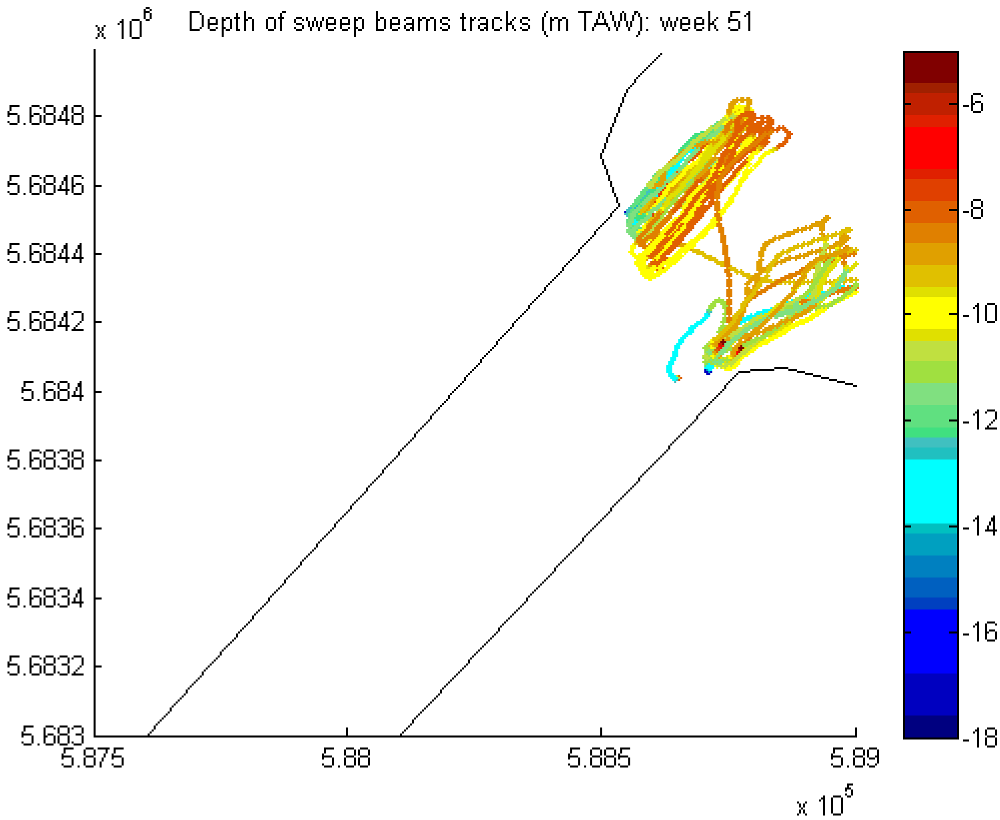

Depth of sweep beams tracks (m TAW): week 43
x 10^6
5.6848
5.6846
5.6844
5.6842
5.684
5.6838
5.6836
5.6834
5.6832
5.683
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18


Depth of sweep beams tracks (m TAW): week 45
x 10^6
5.6848
5.6846
5.6844
5.6842
5.684
5.6838
5.6836
5.6834
5.6832
5.683
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18


Depth of sweep beams tracks (m TAW): week 46
x 10^6
5.6848
5.6846
5.6844
5.6842
5.684
5.6838
5.6836
5.6834
5.6832
5.683
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

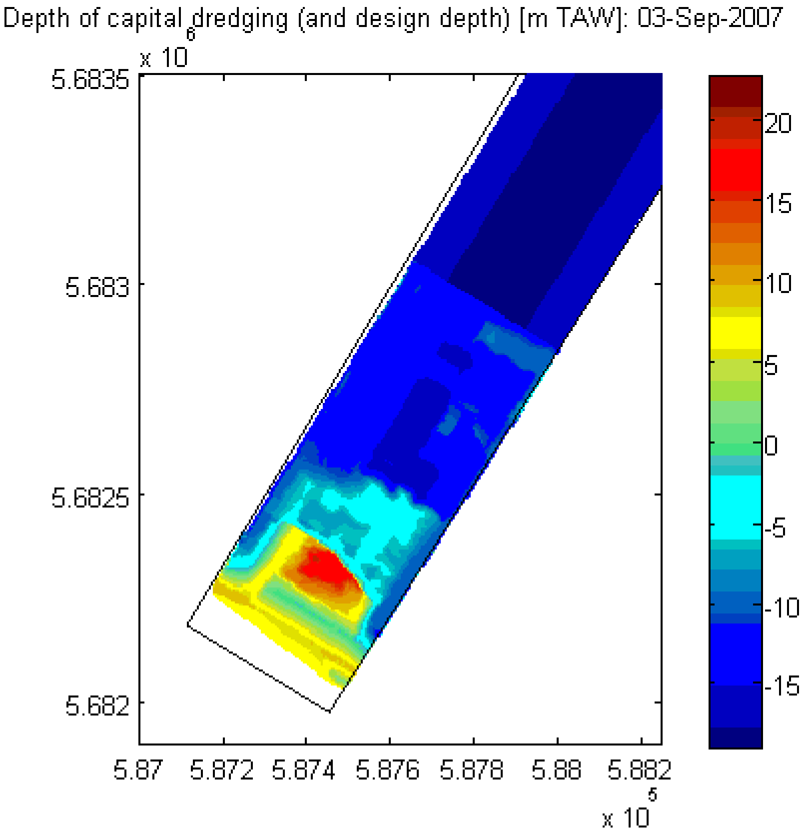

Depth of sweep beams tracks (m TAW): week 47
x 10^6
5.6848
5.6846
5.6844
5.6842
5.684
5.6838
5.6836
5.6834
5.6832
5.683
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

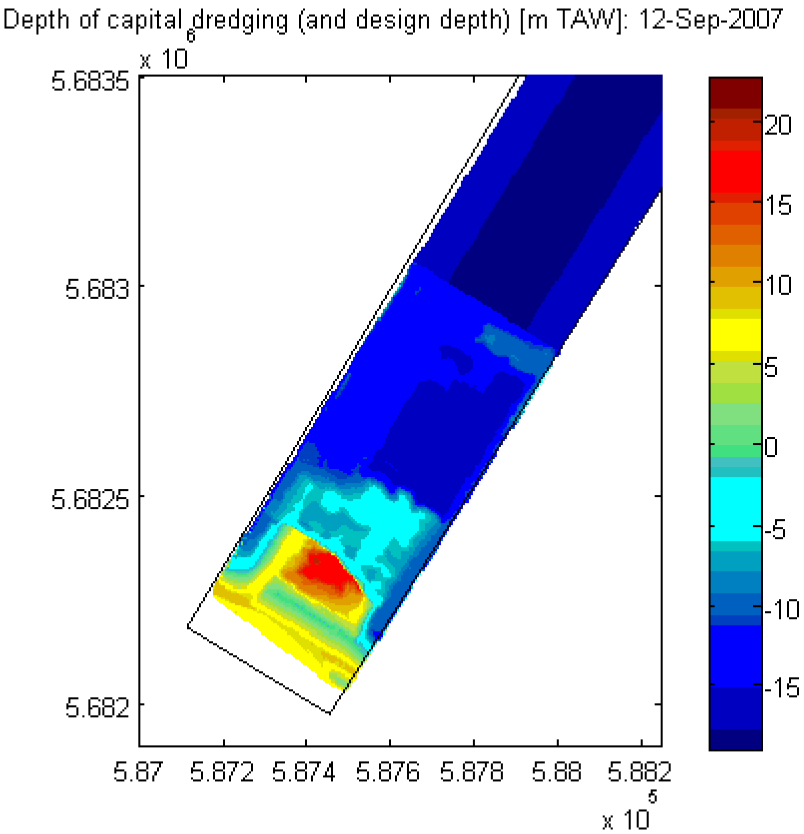

Depth of sweep beams tracks (m TAW): week 50
x 10^6
5.6848
5.6846
5.6844
5.6842
5.684
5.6838
5.6836
5.6834
5.6832
5.683
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

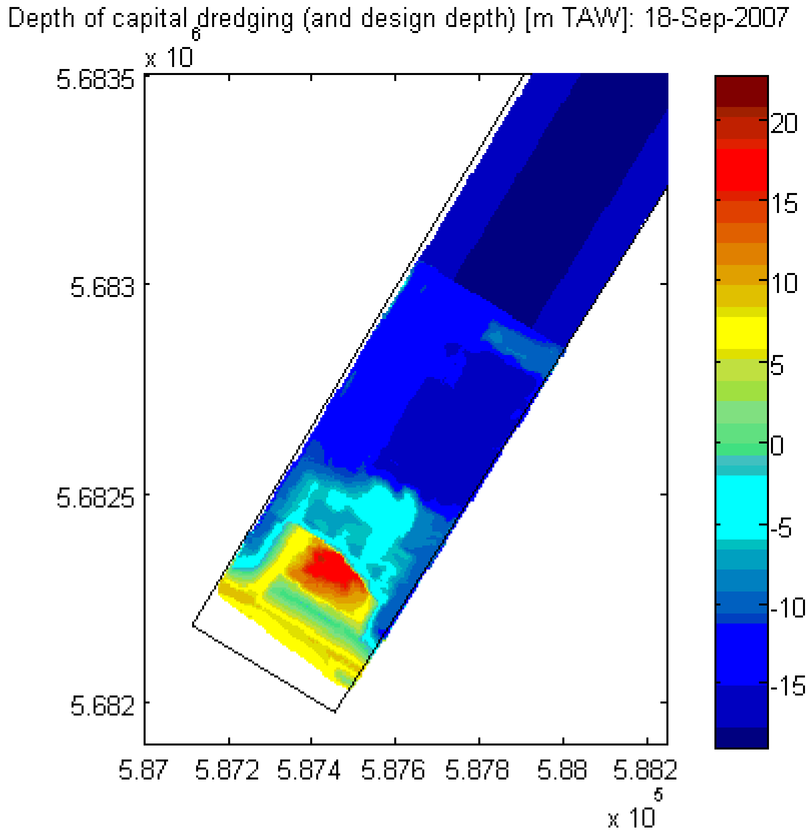

Depth of sweep beams tracks (m TAW): week 51
x 10^6
5.6848
5.6846
5.6844
5.6842
5.684
5.6838
5.6836
5.6834
5.6832
5.683
5.875
5.88
5.885
5.89
x 10^5
-6
-8
-10
-12
-14
-16
-18

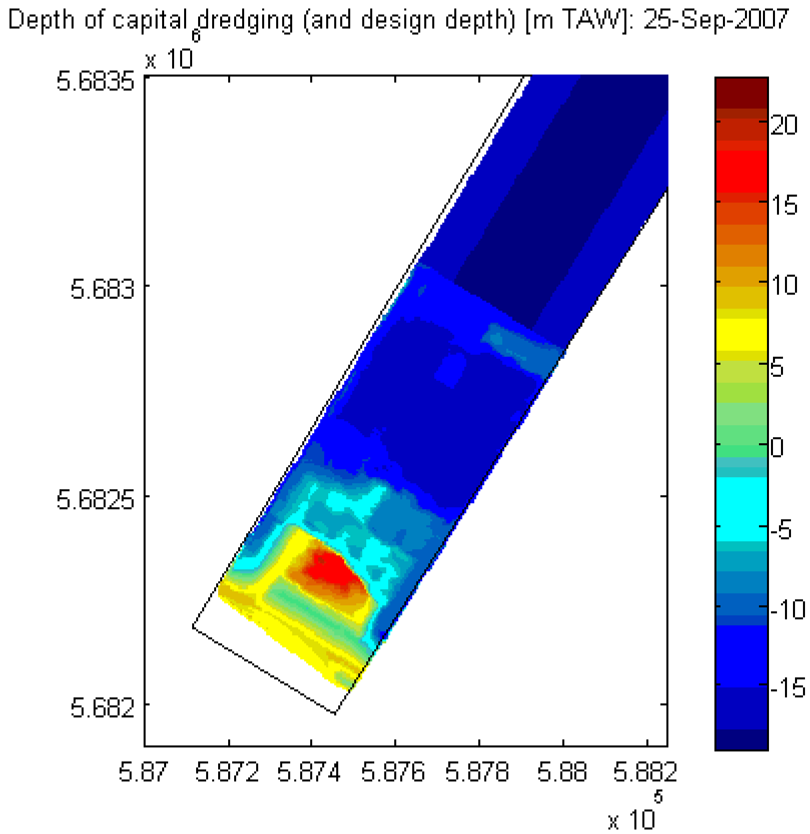
APPENDIX E.

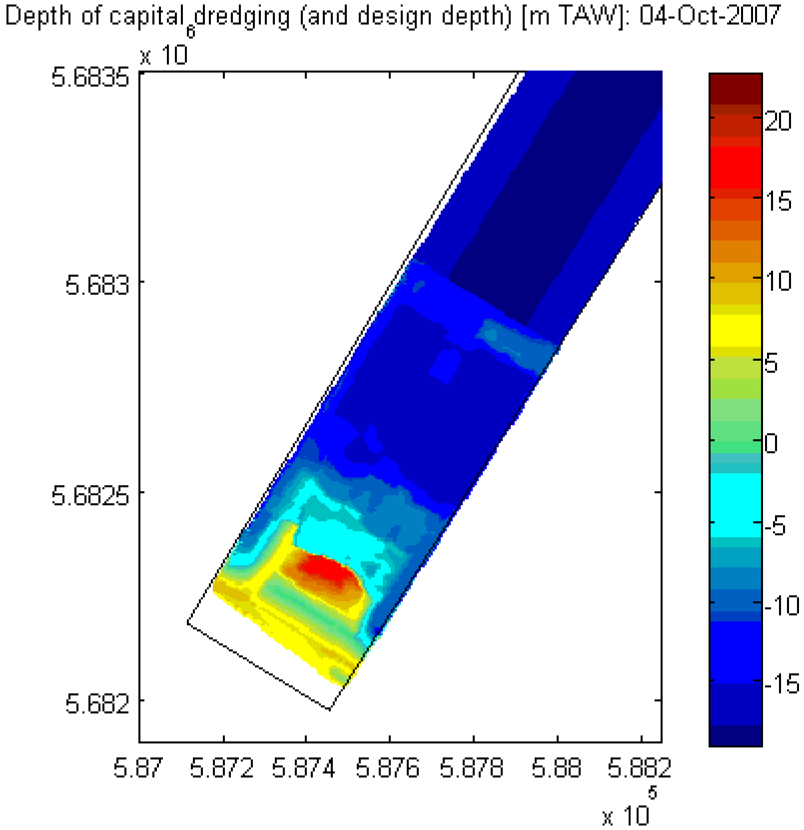
CAPITAL DREDGING PROGRESS

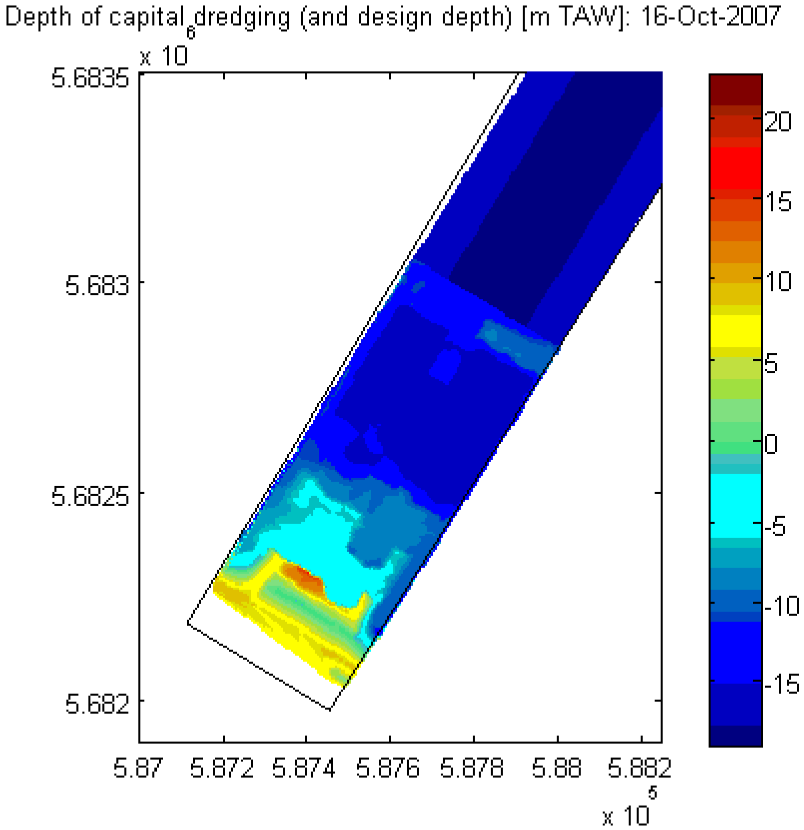

Depth of capital dredging (and design depth) [m TAW]: 03-Sep-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87
5.872
5.874
5.876
5.878
5.88
5.882
x 10^5
20
15
10
5
0
-5
-10
-15

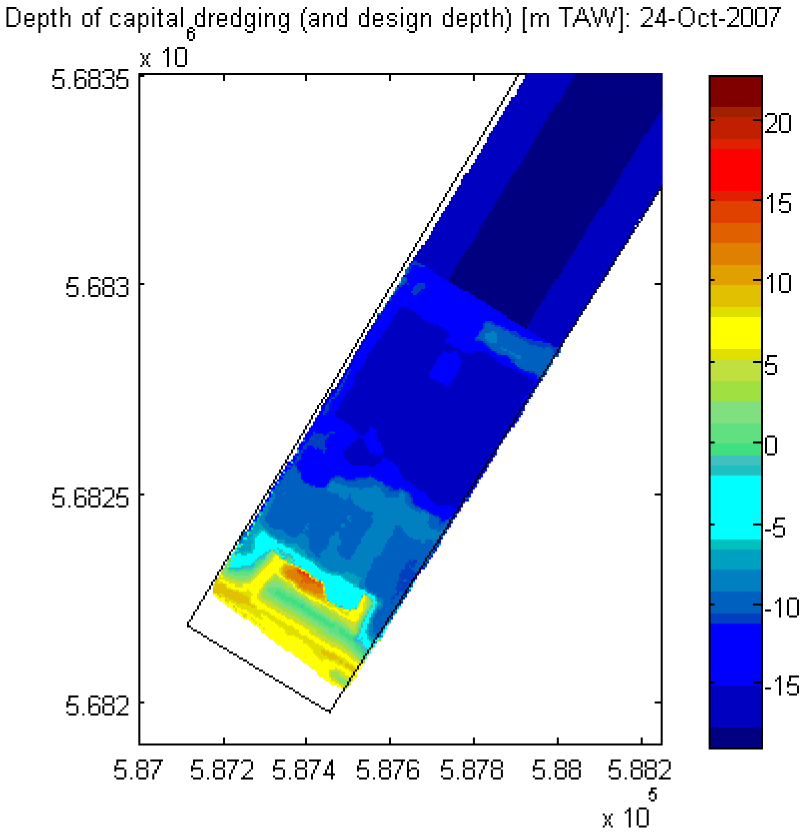

Depth of capital dredging (and design depth) [m TAW]: 12-Sep-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87
5.872
5.874
5.876
5.878
5.88
5.882
x 10^5
20
15
10
5
0
-5
-10
-15

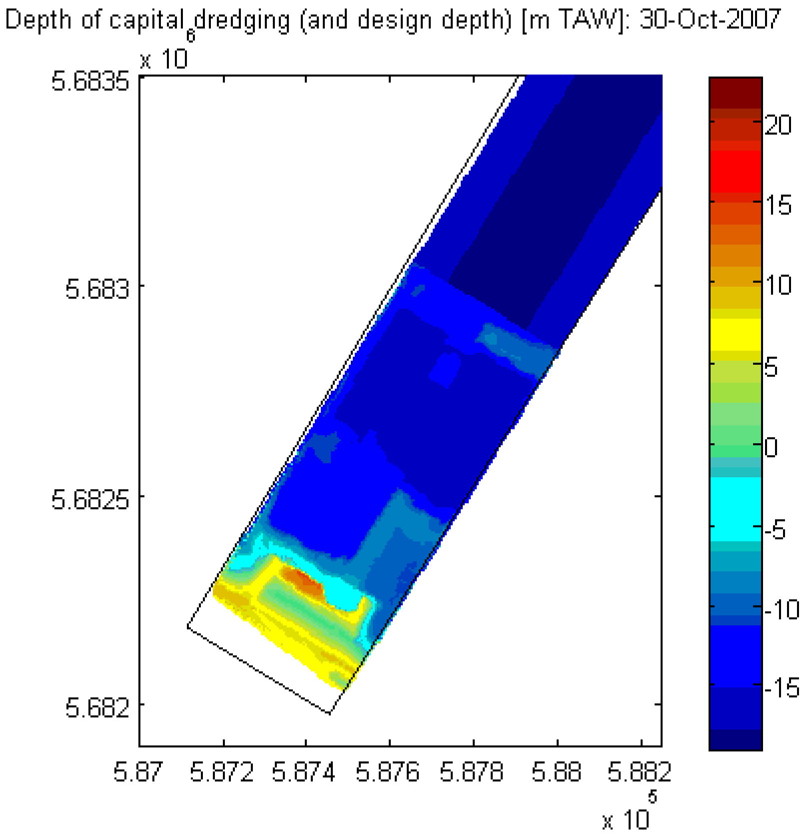

Depth of capital dredging (and design depth) [m TAW]: 18-Sep-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87 5.872 5.874 5.876 5.878 5.88 5.882
x 10^5
20
15
10
5
0
-5
-10
-15

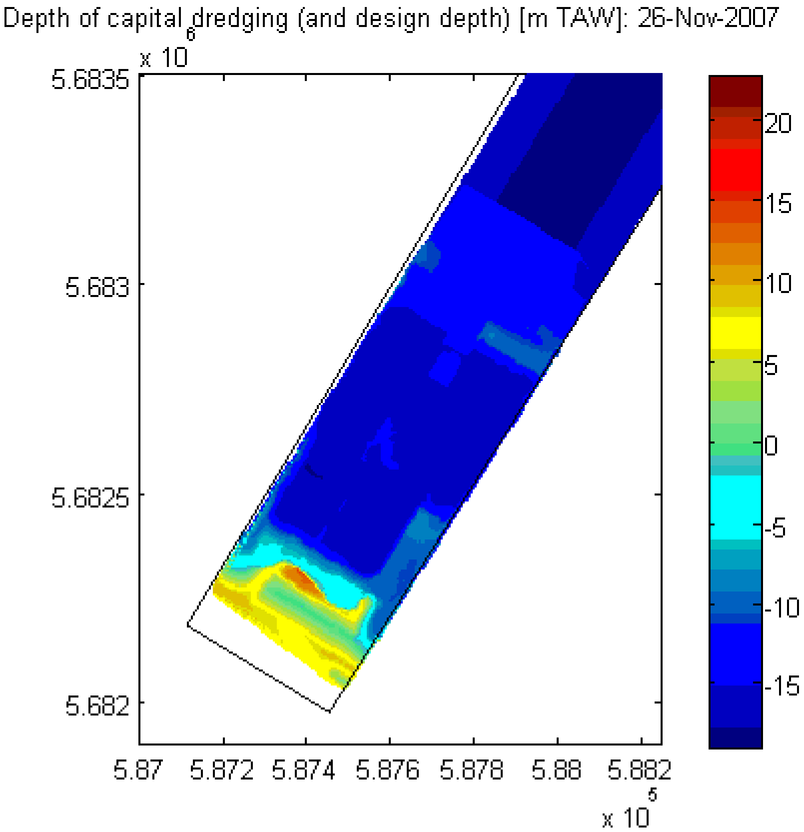

Depth of capital dredging (and design depth) [m TAW]: 25-Sep-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87 5.872 5.874 5.876 5.878 5.88 5.882
x 10^5
20
15
10
5
0
-5
-10
-15

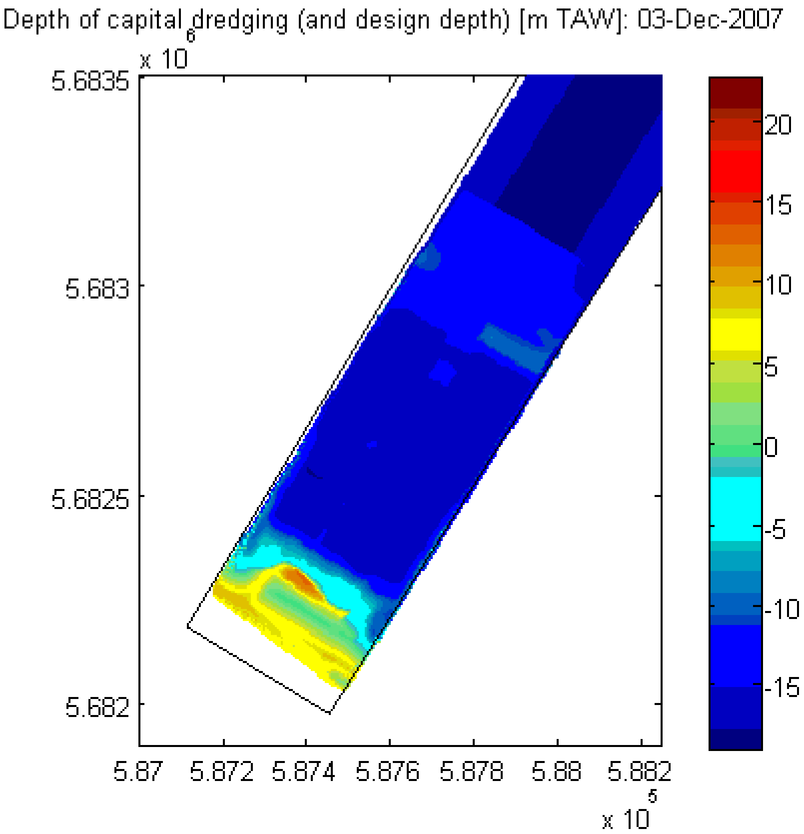

Depth of capital dredging (and design depth) [m TAW]: 04-Oct-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87
5.872
5.874
5.876
5.878
5.88
5.882
x 10^5
20
15
10
5
0
-5
-10
-15


Depth of capital dredging (and design depth) [m TAW]: 16-Oct-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87
5.872
5.874
5.876
5.878
5.88
5.882
x 10^5
20
15
10
5
0
-5
-10
-15


Depth of capital dredging (and design depth) [m TAW]: 24-Oct-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87
5.872
5.874
5.876
5.878
5.88
5.882
x 10^5
20
15
10
5
0
-5
-10
-15


Depth of capital dredging (and design depth) [m TAW]: 30-Oct-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87
5.872
5.874
5.876
5.878
5.88
5.882
x 10^5
20
15
10
5
0
-5
-10
-15


Depth of capital dredging (and design depth) [m TAW]: 26-Nov-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87
5.872
5.874
5.876
5.878
5.88
5.882
x 10^5
20
15
10
5
0
-5
-10
-15


Depth of capital dredging (and design depth) [m TAW]: 03-Dec-2007
x 10^6
5.6835
5.683
5.6825
5.682
5.87
5.872
5.874
5.876
5.878
5.88
5.882
x 10^5
20
15
10
5
0
-5
-10
-15

APPENDIX F.

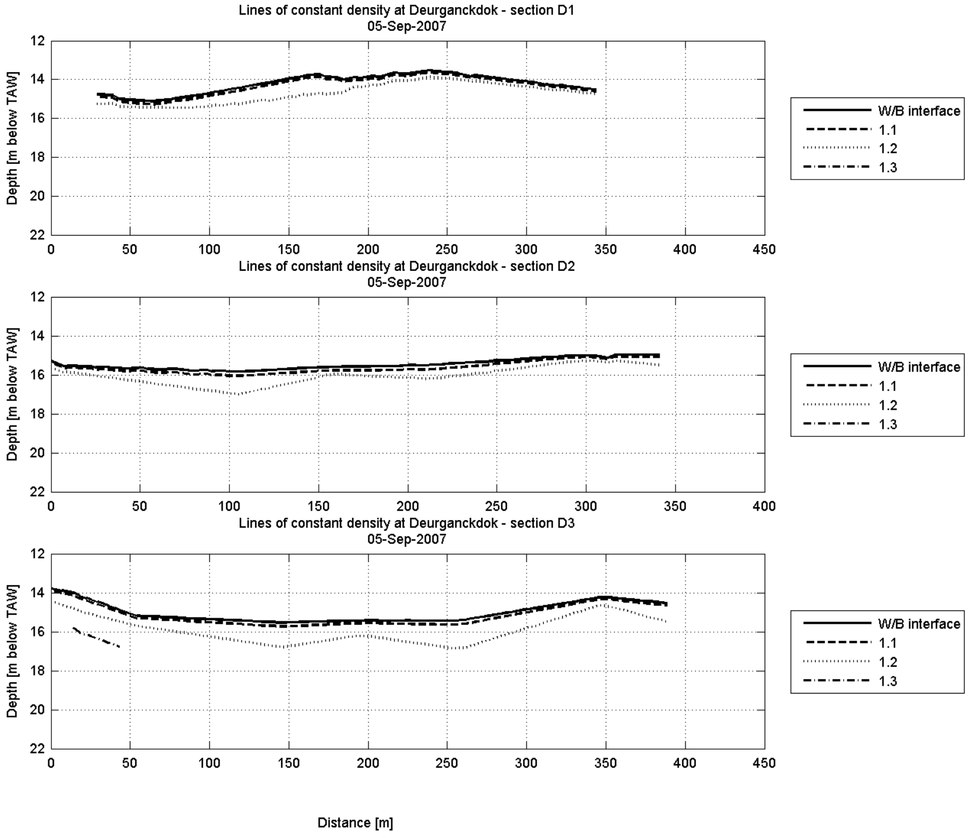
DEPTH OF WATER-BED INTERFACE AND EQUAL DENSITY LAYERS

APPENDIX G.

DEPTH OF PLANES OF CONSTANT DENSITY

G.1 Measurements September 5th 2007

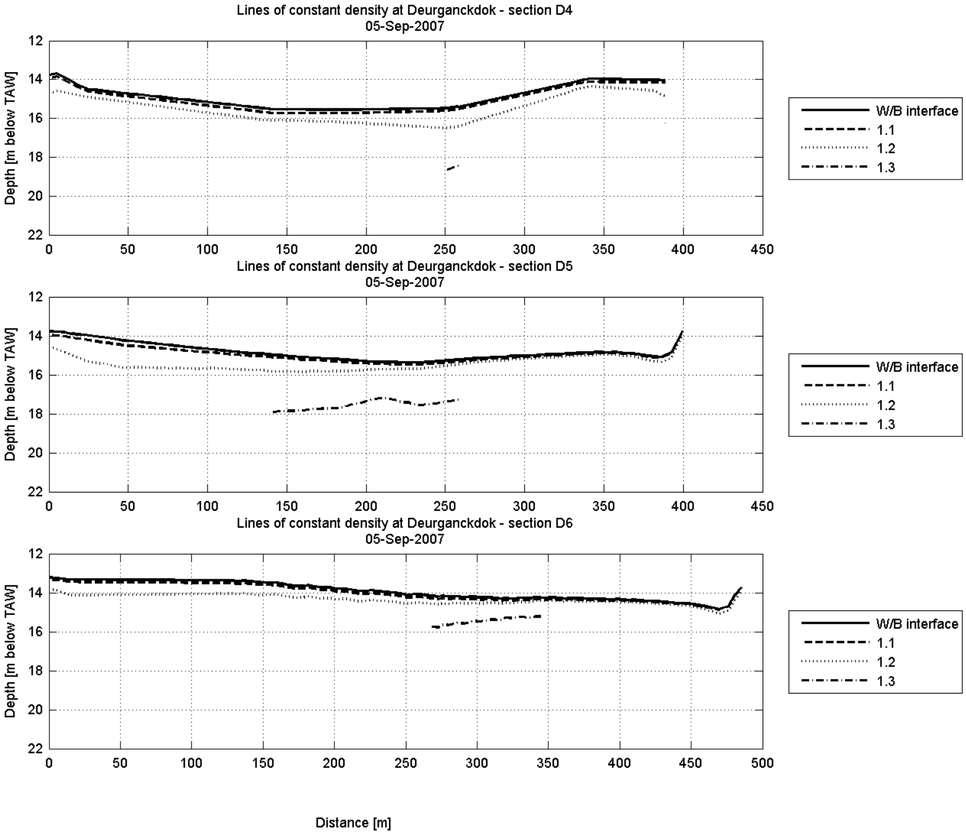
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :

I/RA/11283/07.083/MSA

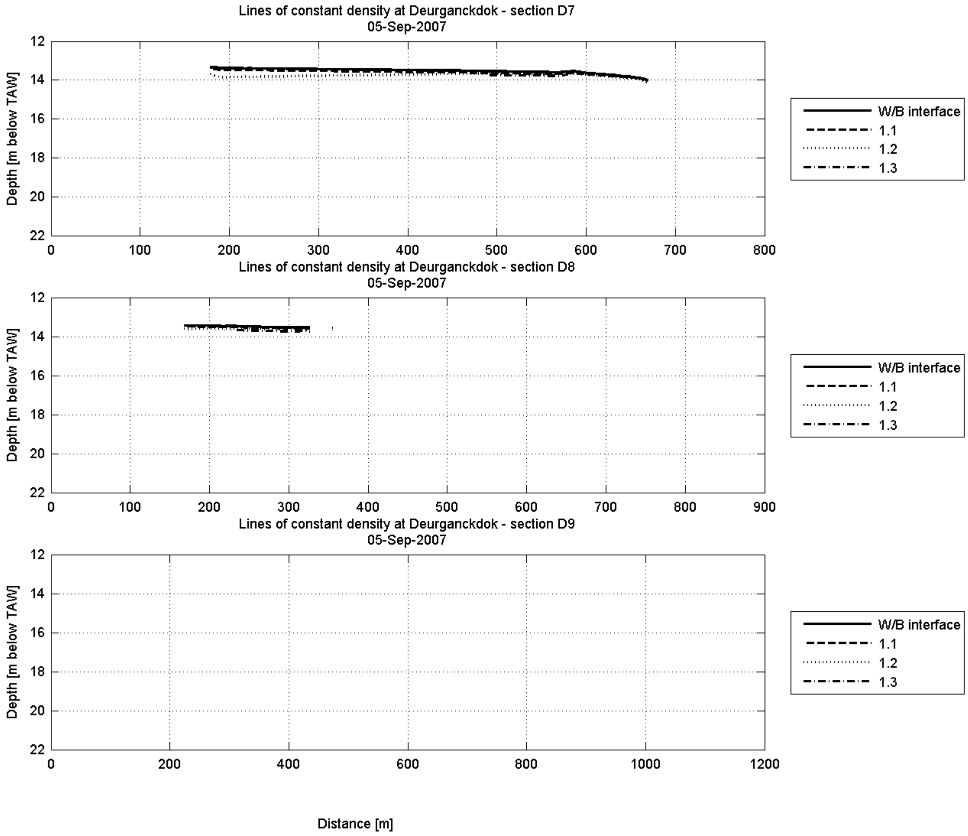
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



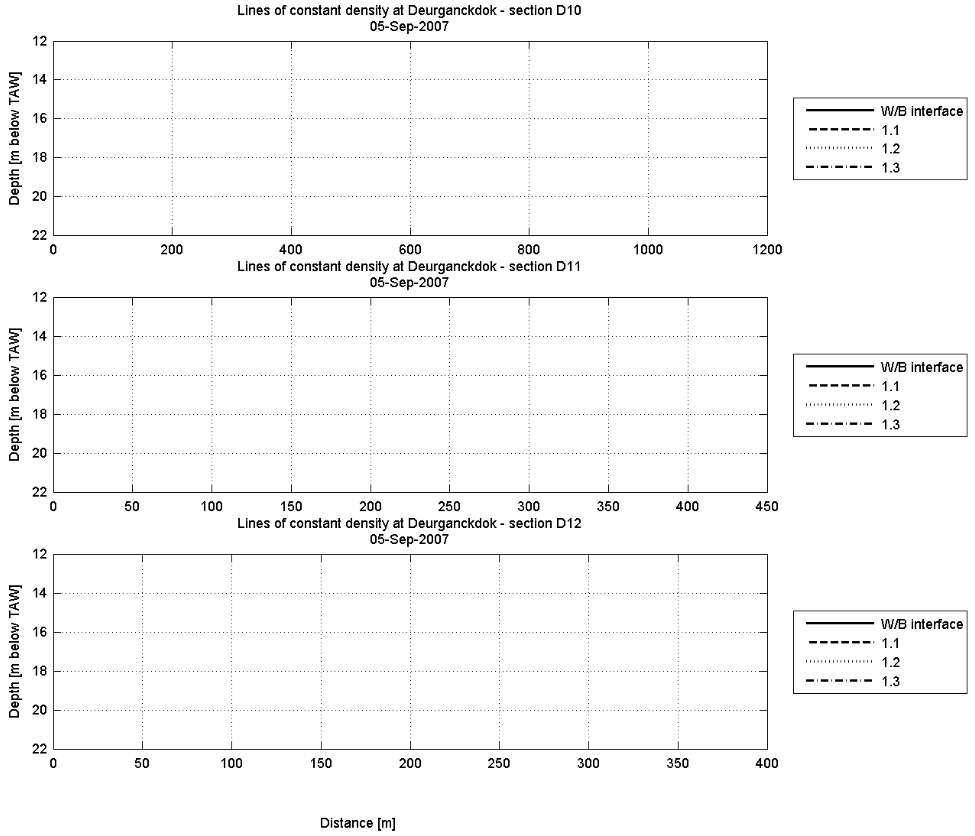
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD

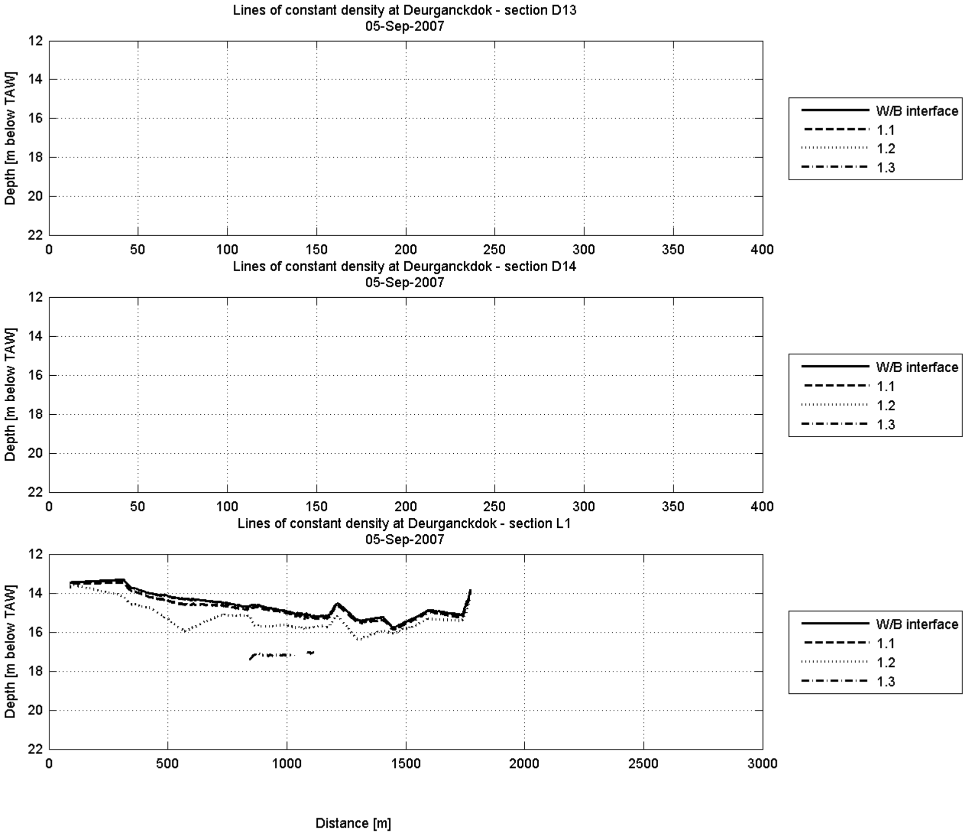


Data Processed by:

In association with :

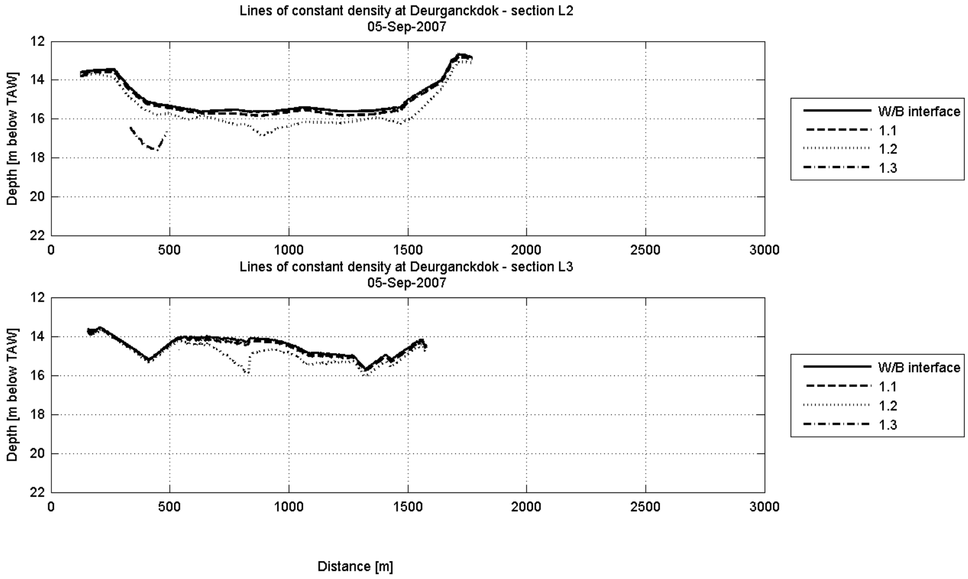
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



	Data Processed by: In association with : I/RA/11283/07.083/MSA

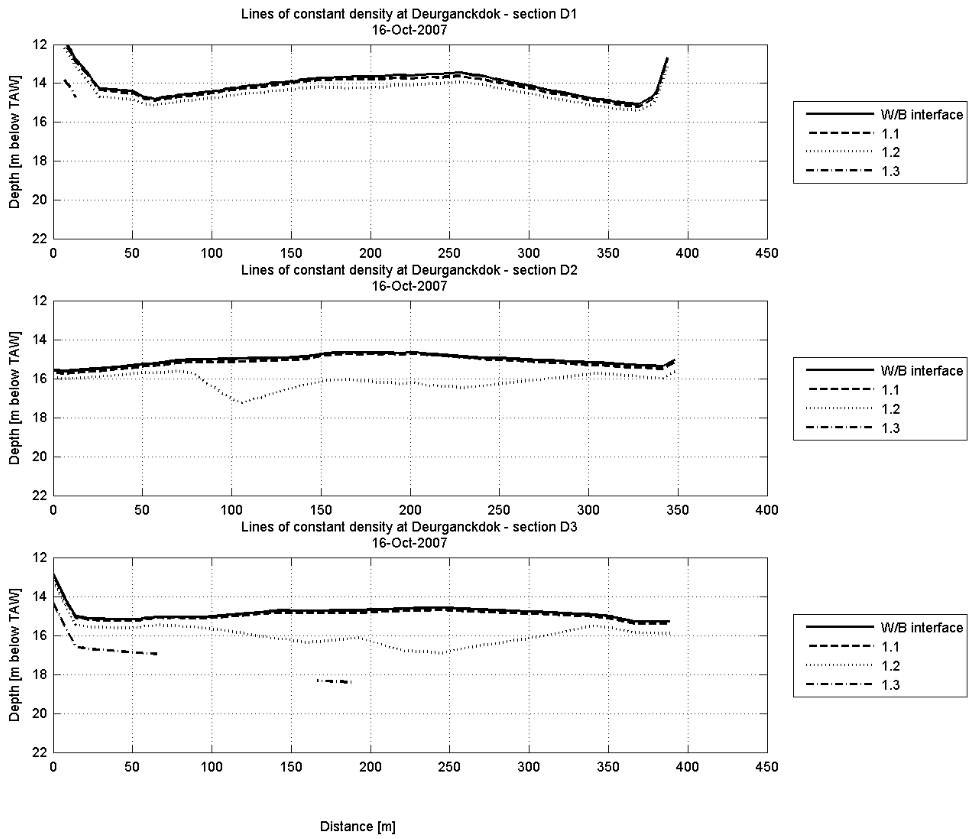
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

G.2 Measurements October 16th 2007

Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



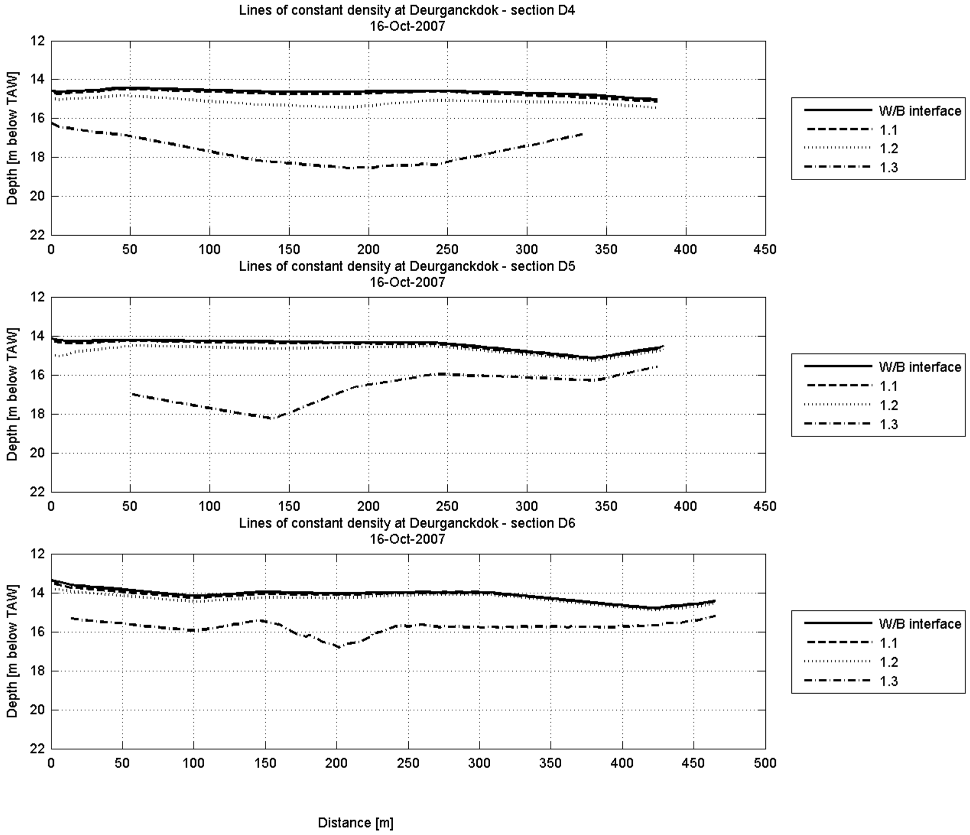
Data Processed by: IMDC

In association with :

I/RA/11283/07.083/MSA

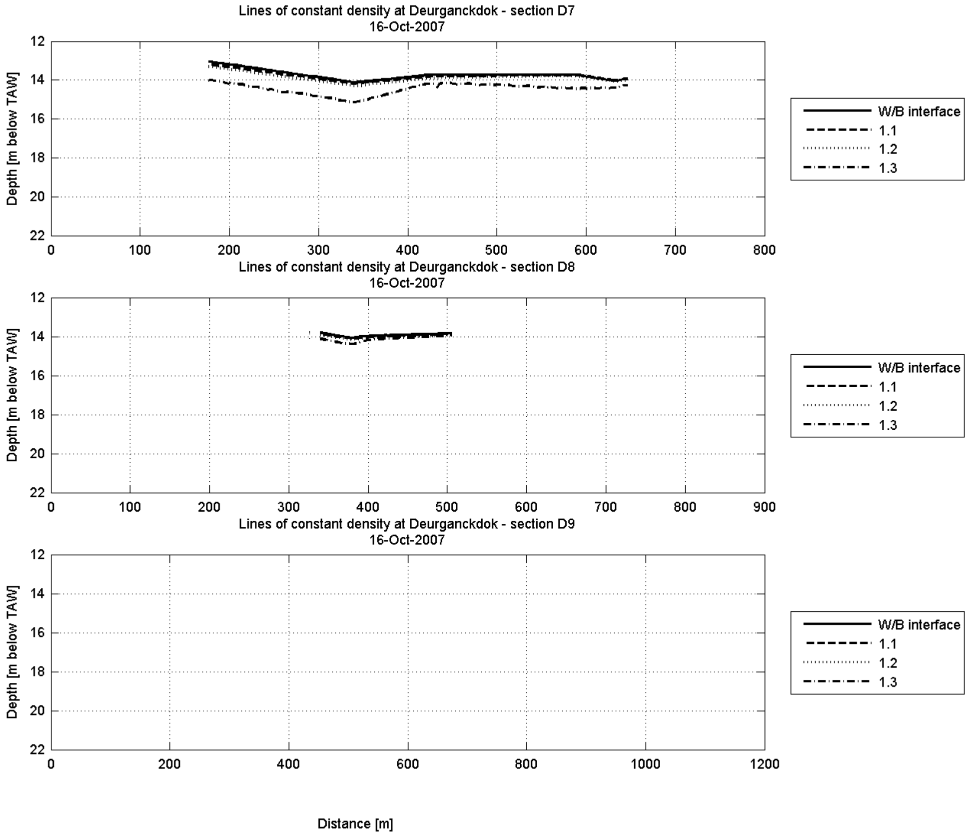
Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



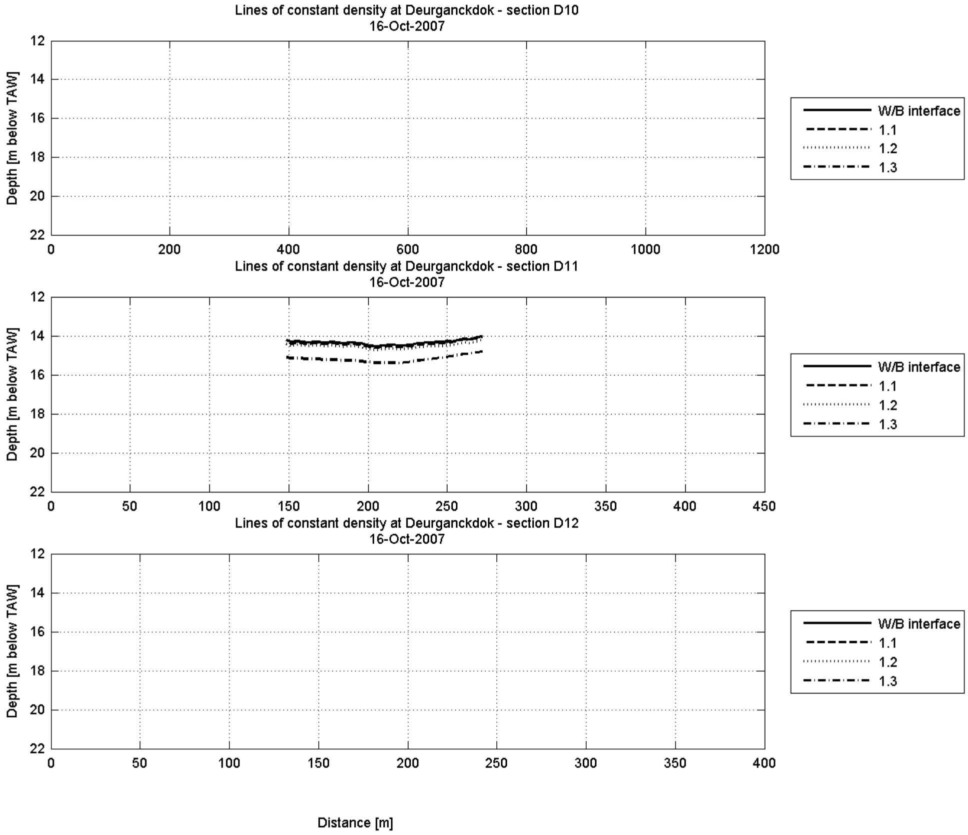
Data Processed by: IMDC
In association with :
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD

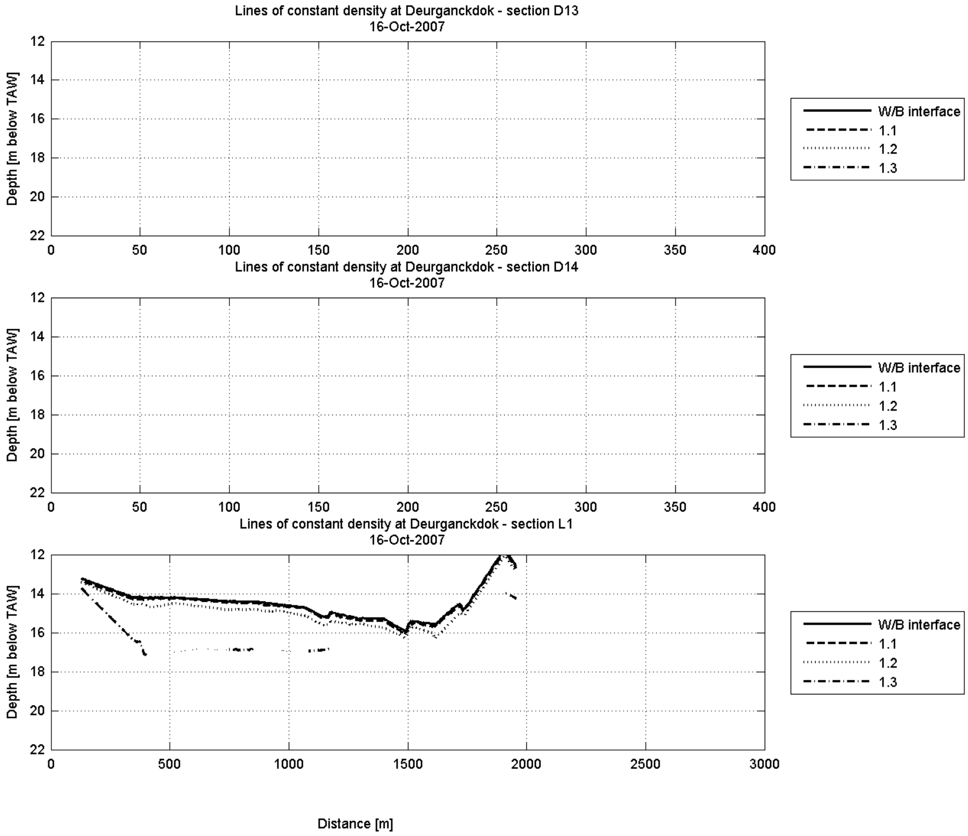


Data Processed by:
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD

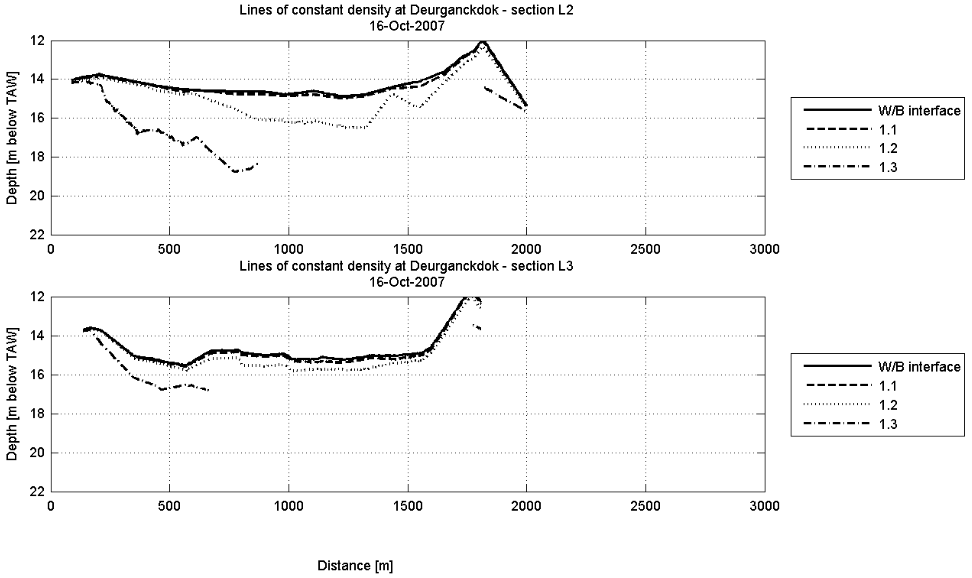


Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD

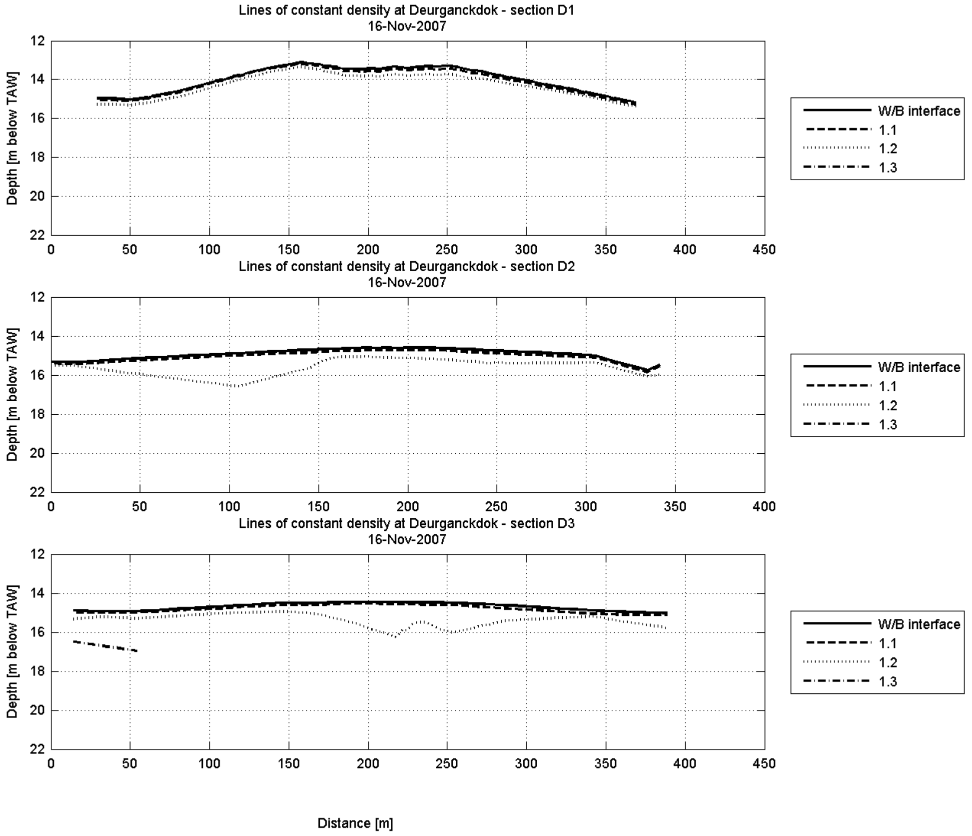


	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

G.3 Measurements November 16th 2007

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD

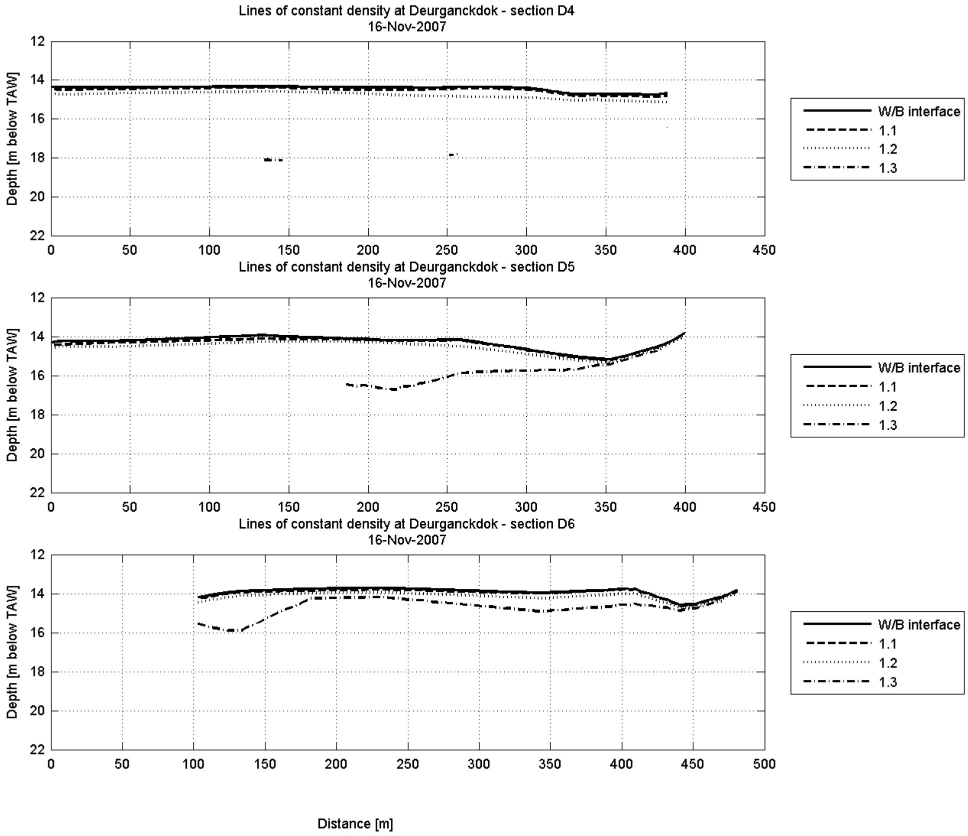


Data Processed by:
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

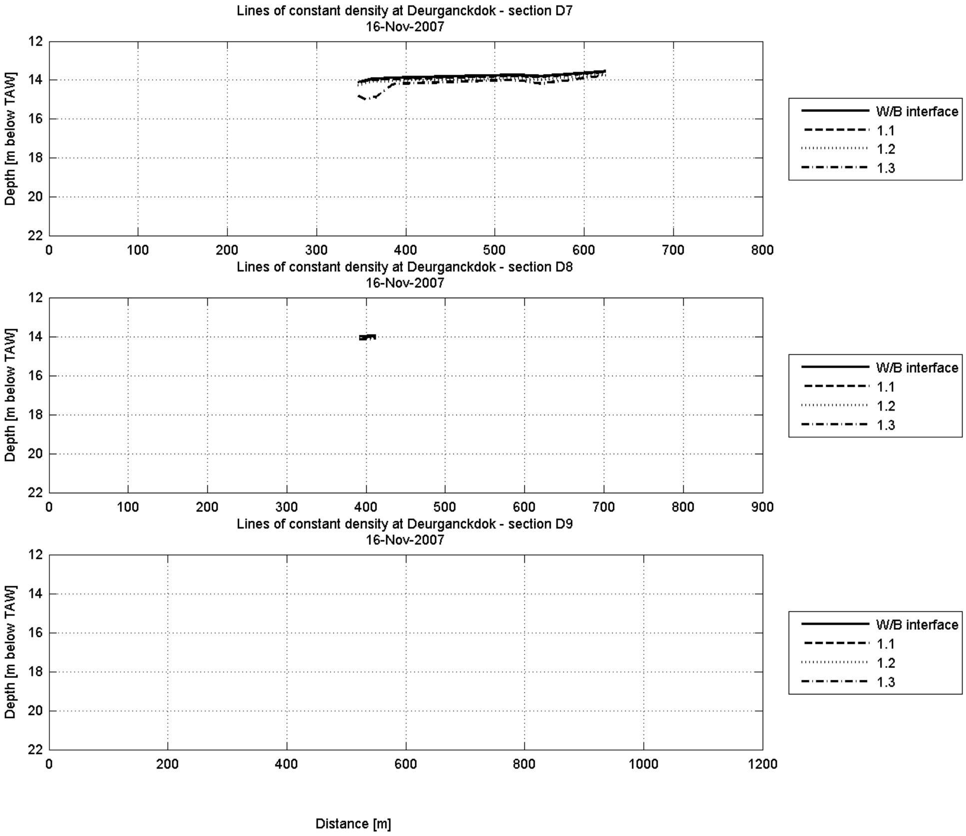
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :

I/RA/11283/07.083/MSA

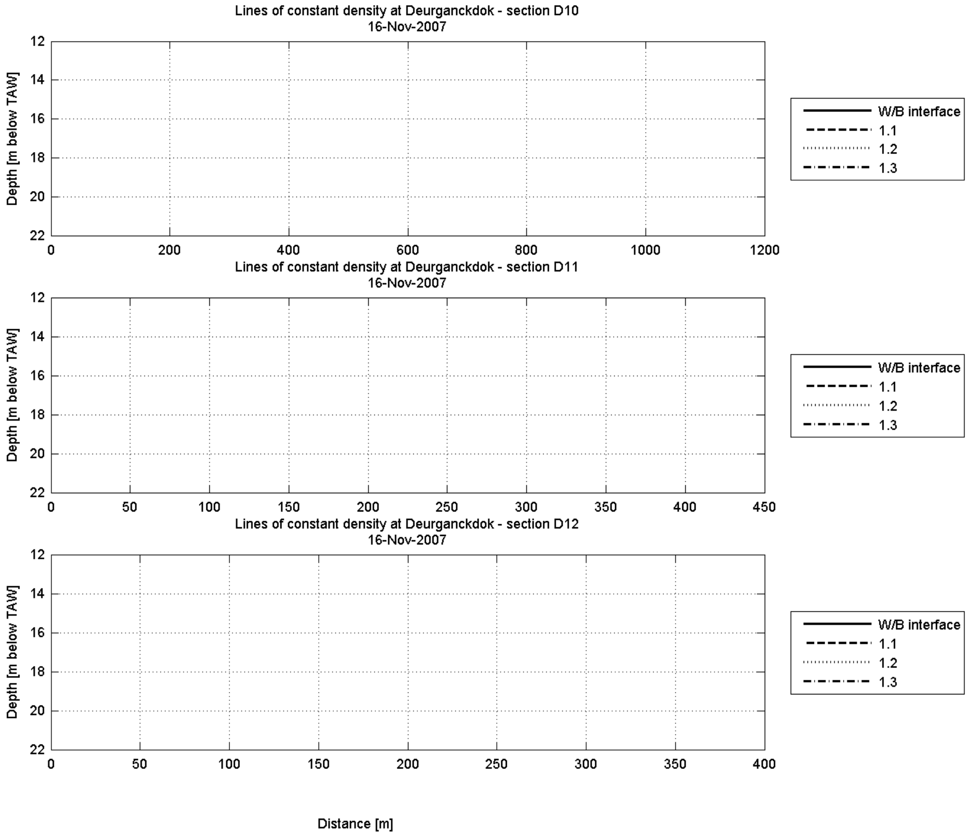
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

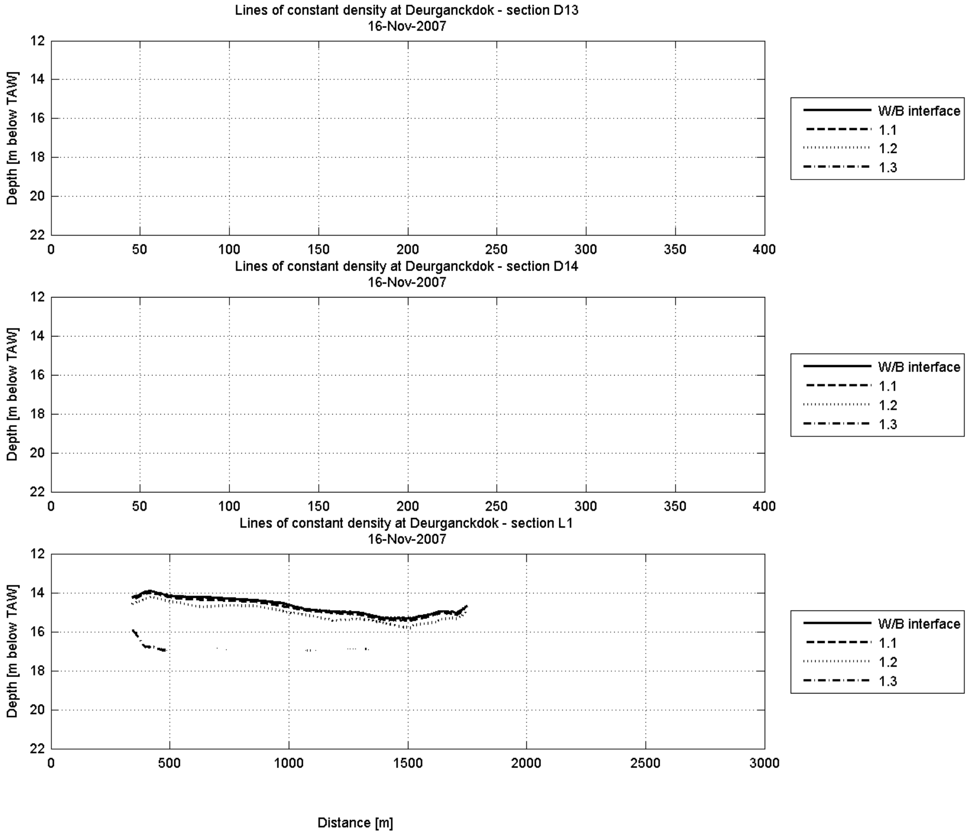
Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.083/MSA

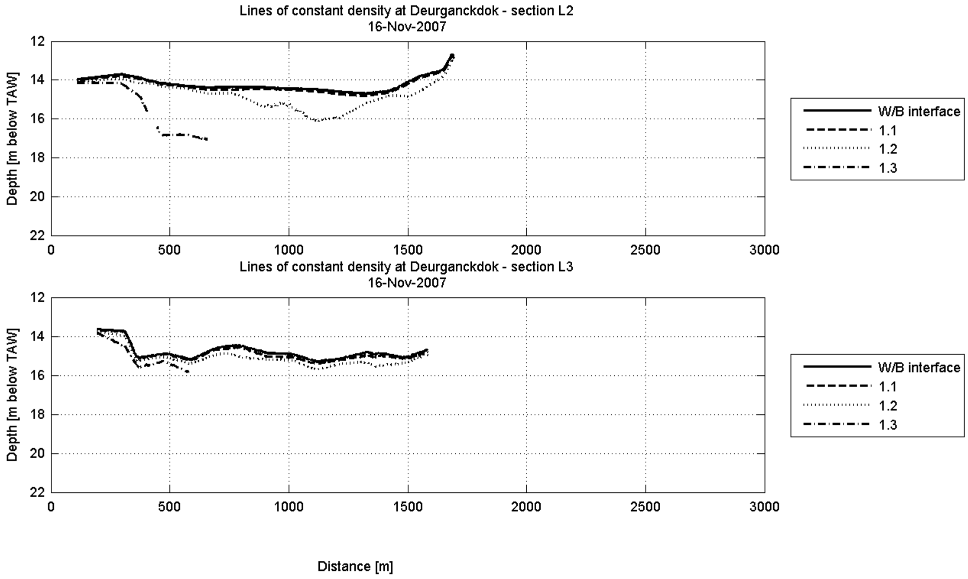
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with :
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

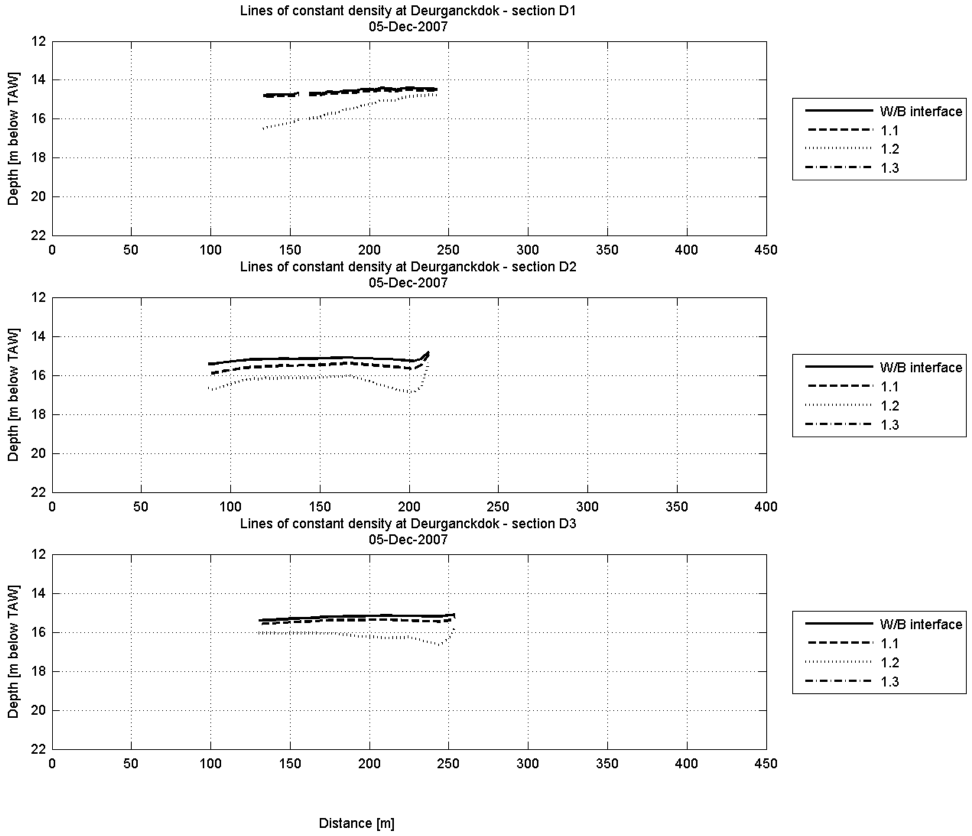
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with :
I/RA/11283/07.083/MSA

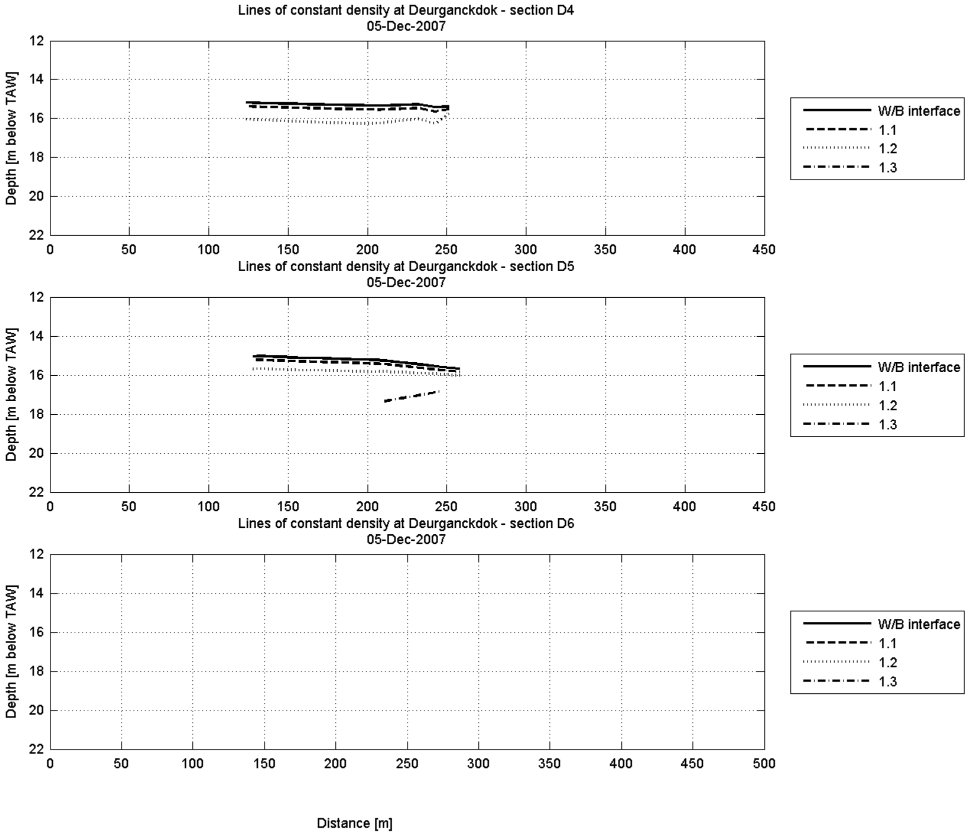
G.4 Measurements December 5th 2007

Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

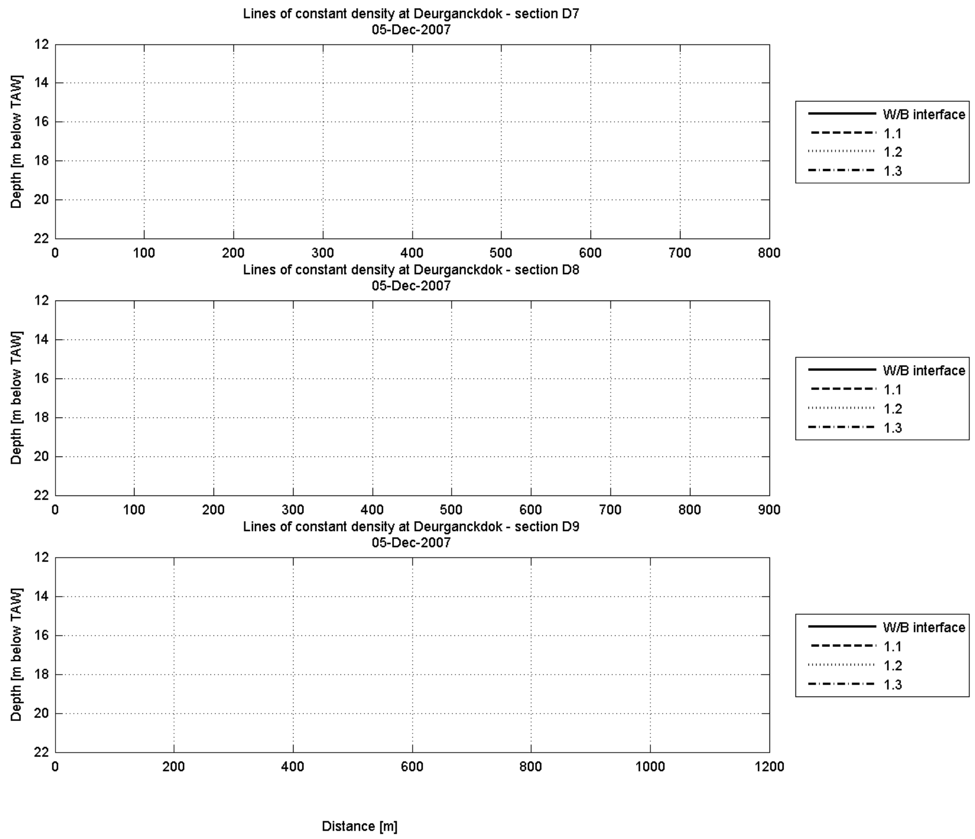
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :

I/RA/11283/07.083/MSA

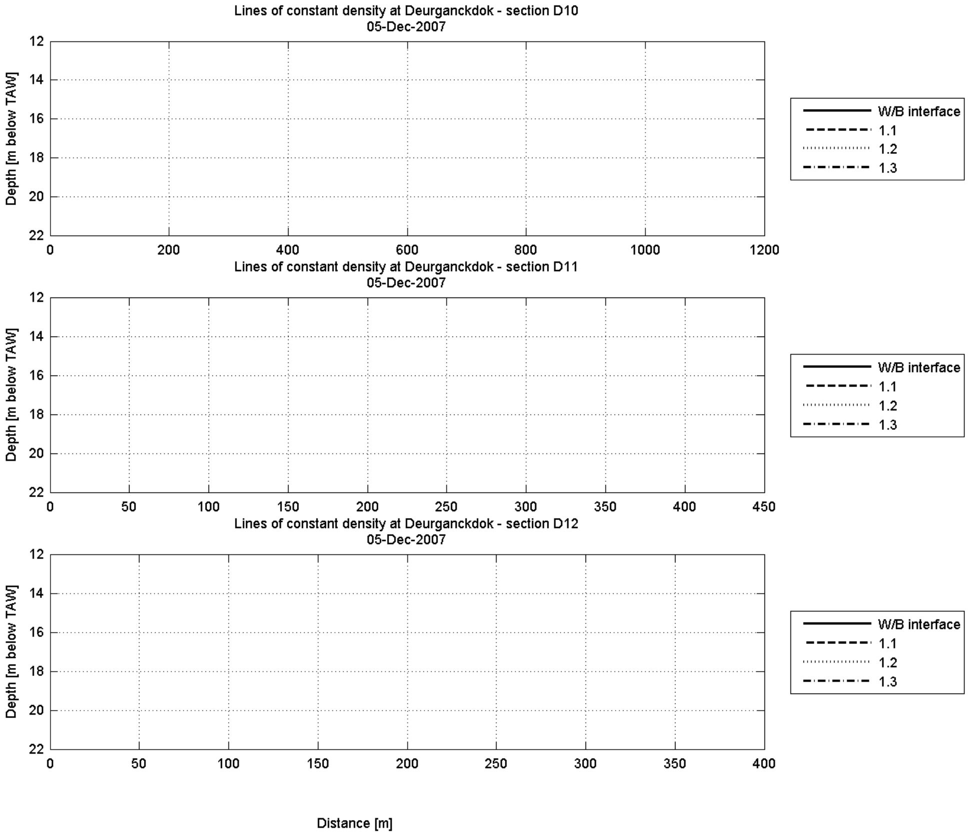
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



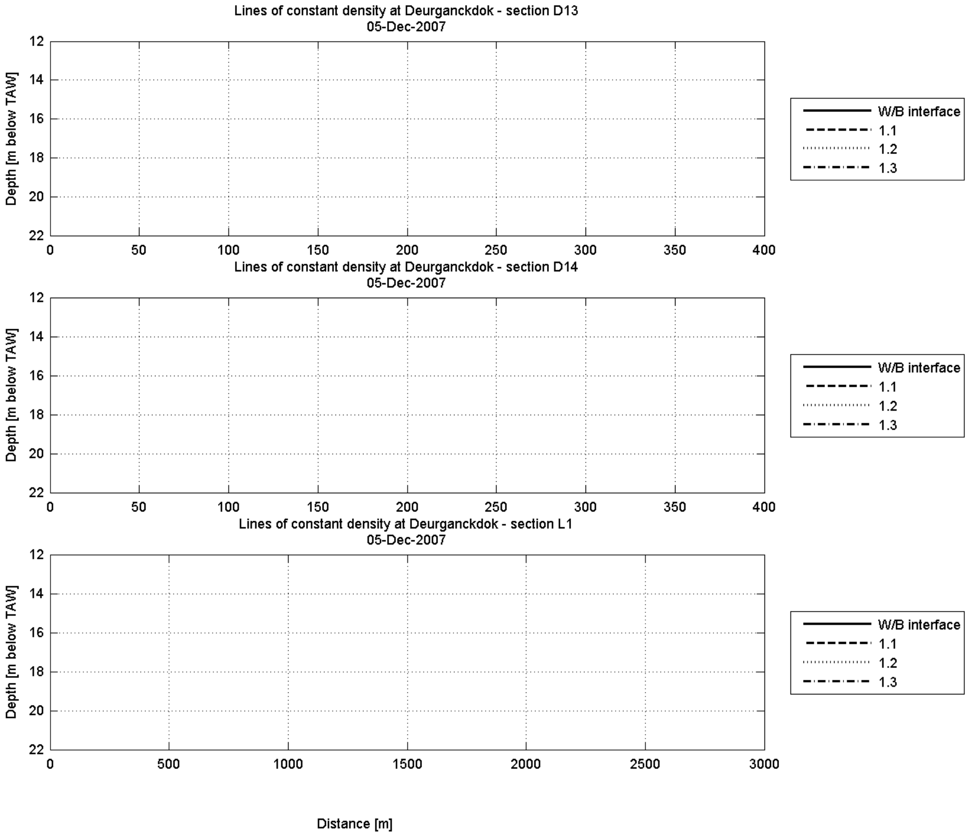
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



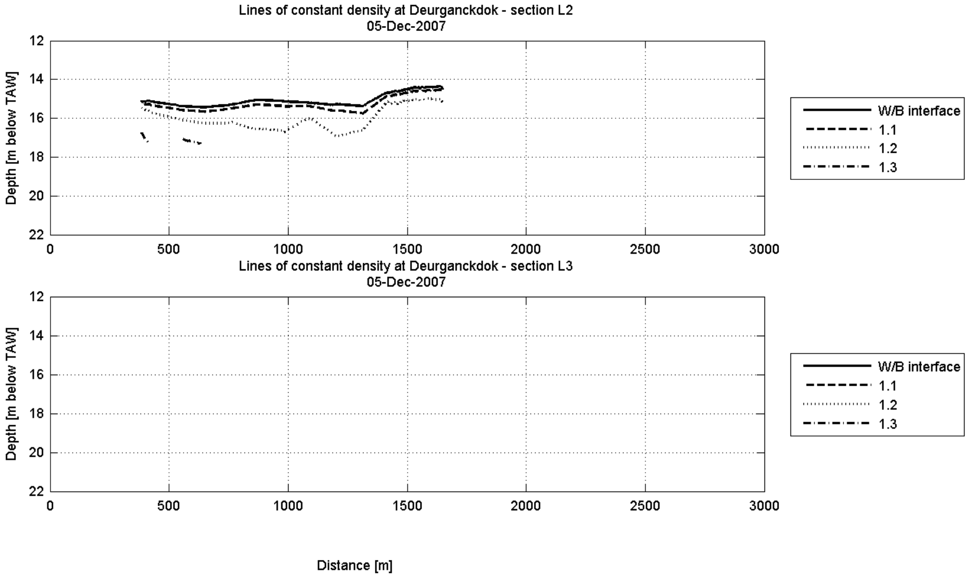
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:

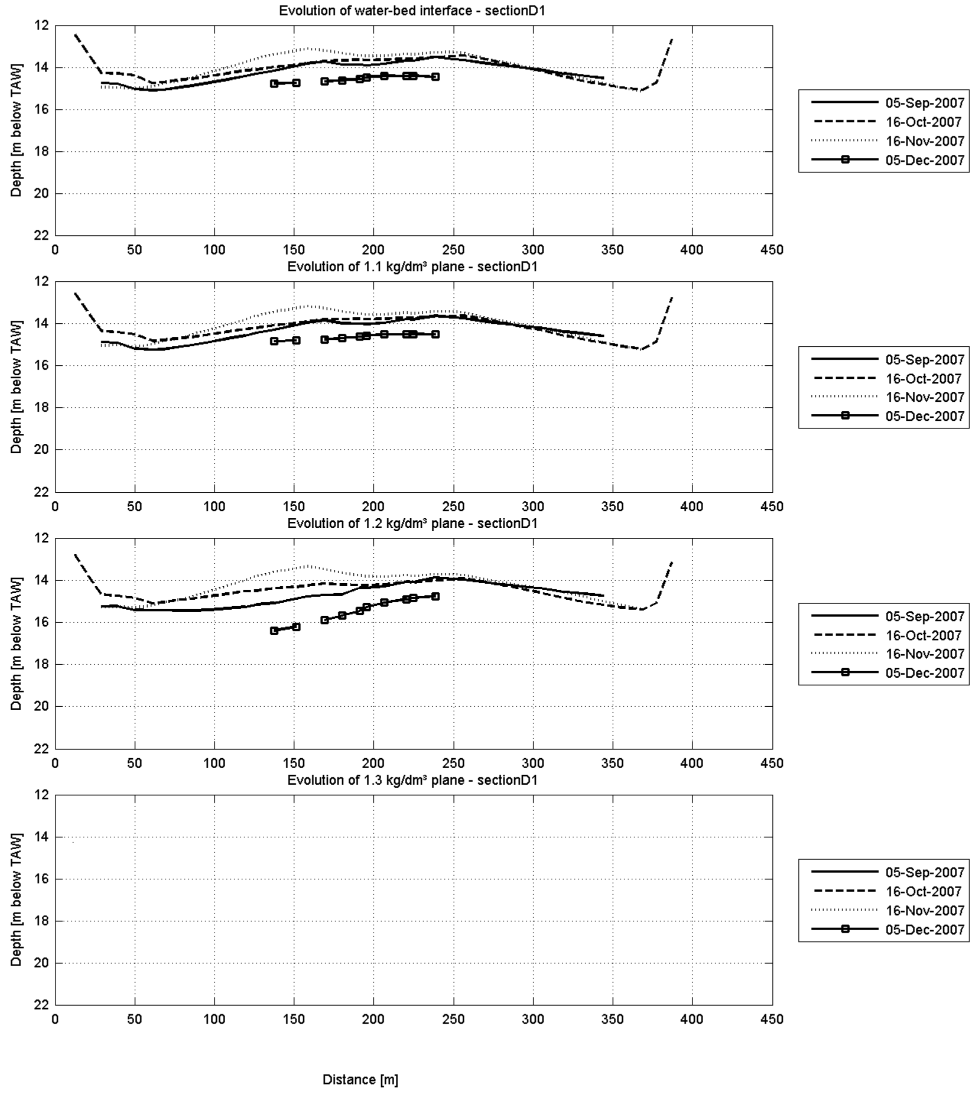
In association with :

I/RA/11283/07.083/MSA

APPENDIX H.

DEPTH EVOLUTION OF PLANES OF CONSTANT DENSITY

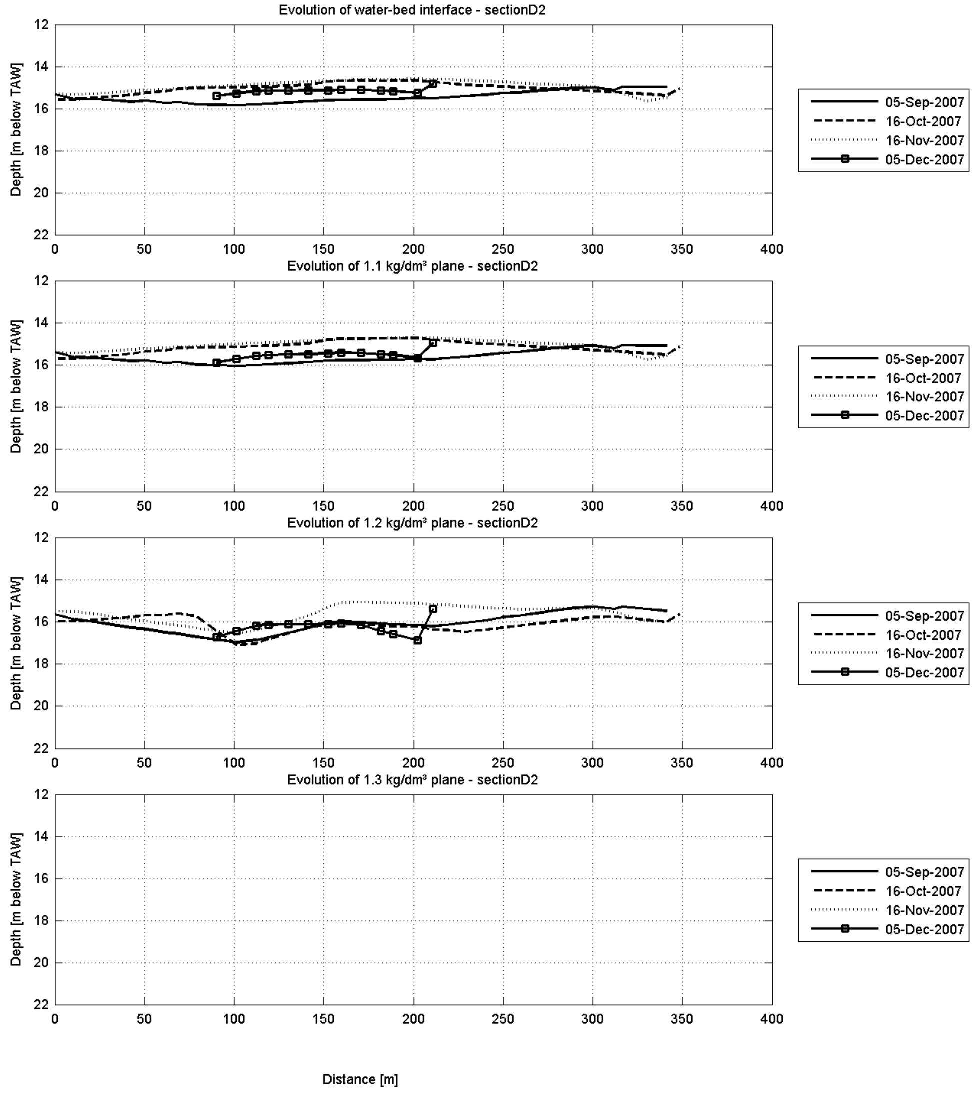
Long-term monitoring siltation Deurganckdok	
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with :
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD

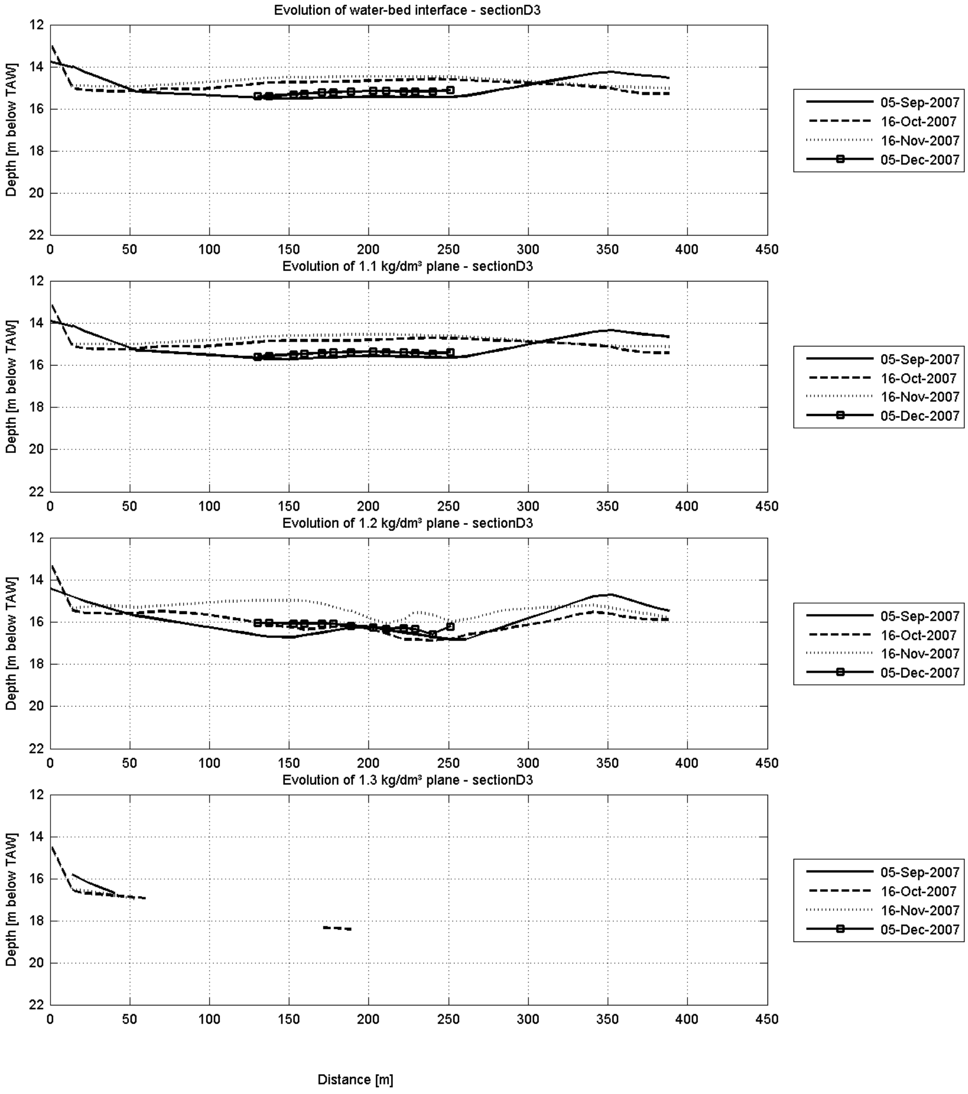


Data Processed by:

In association with :

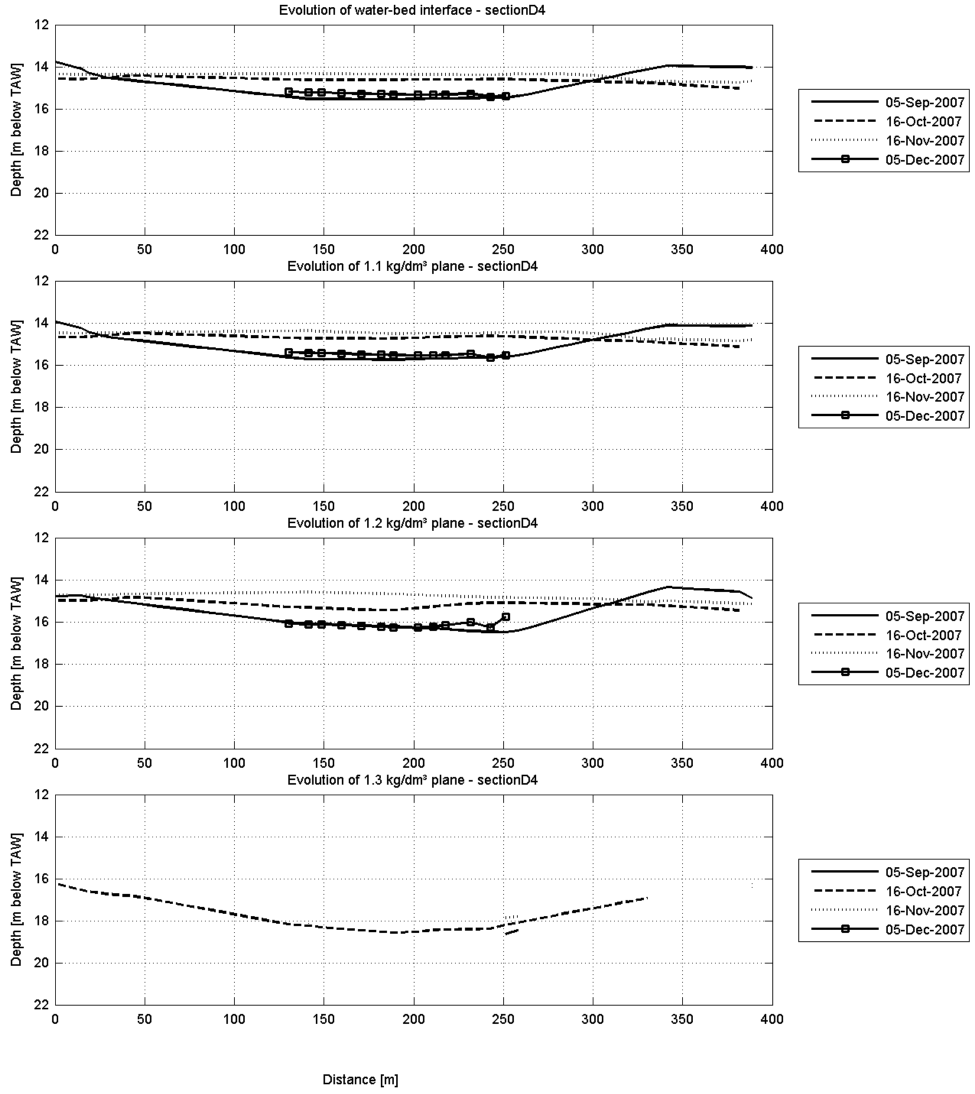
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

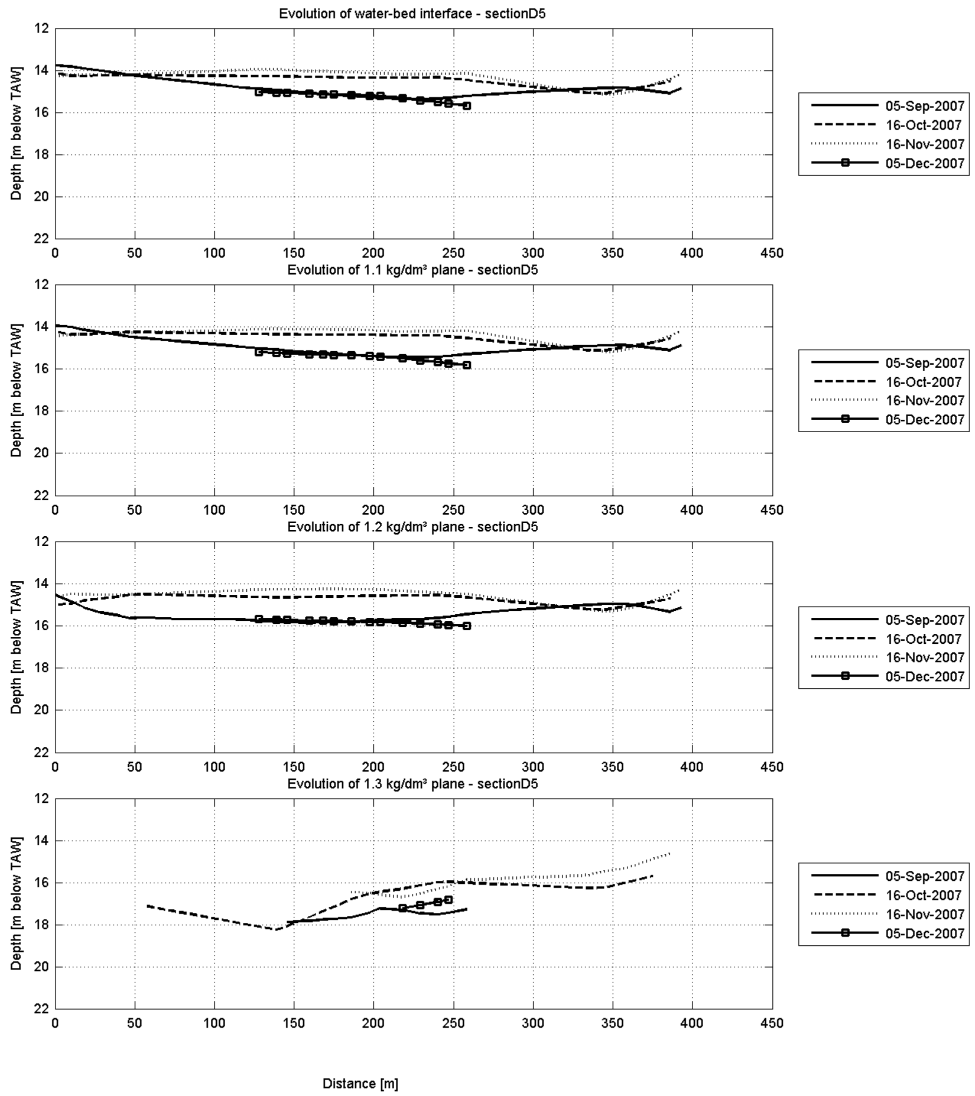
Long-term monitoring siltation Deurganckdok	
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



	Data Processed by: In association with : I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



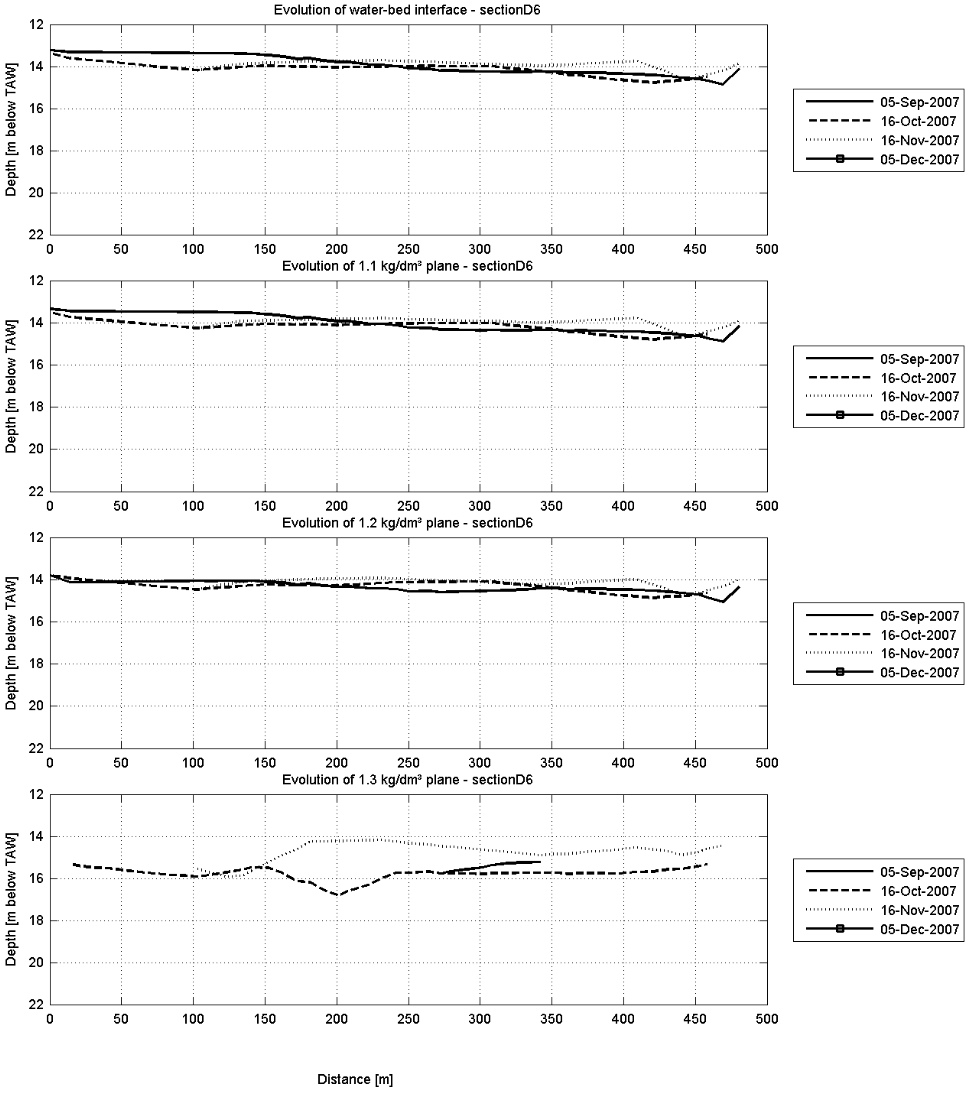
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

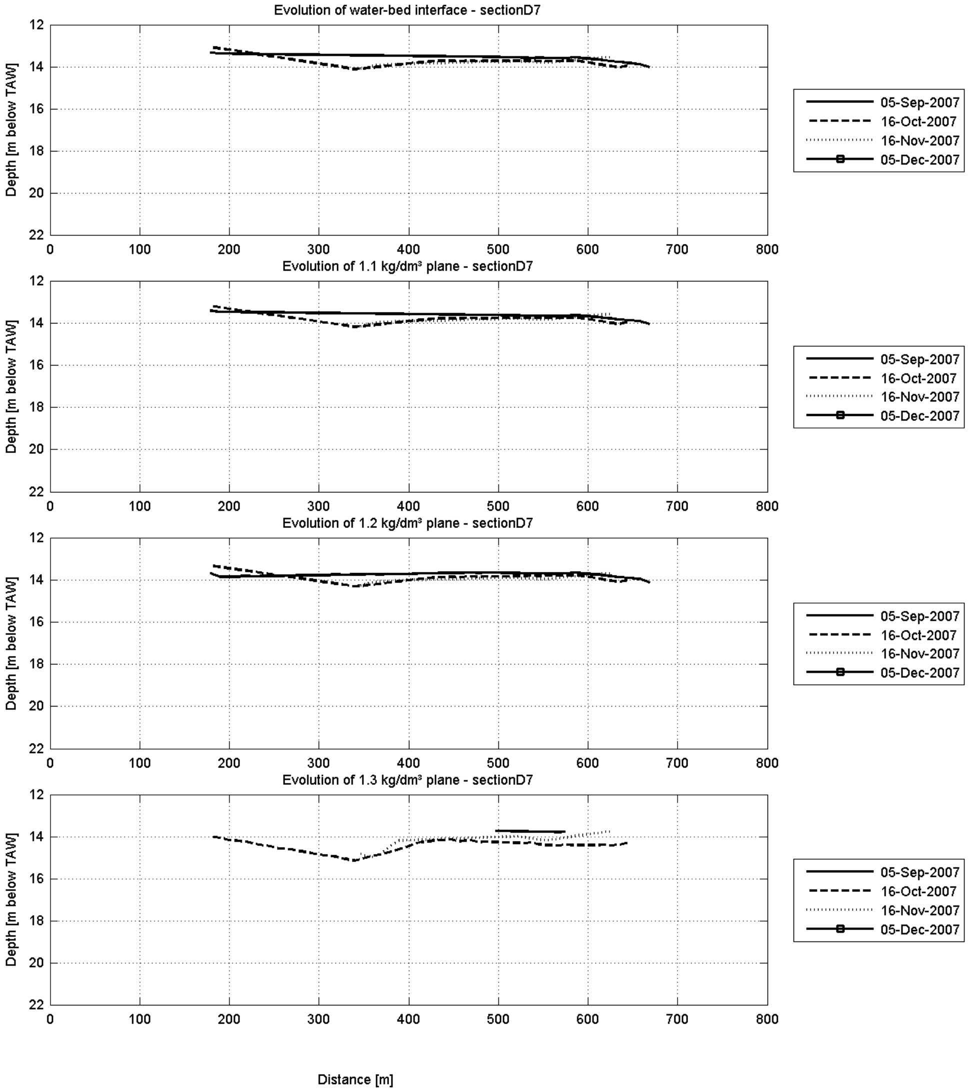
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :

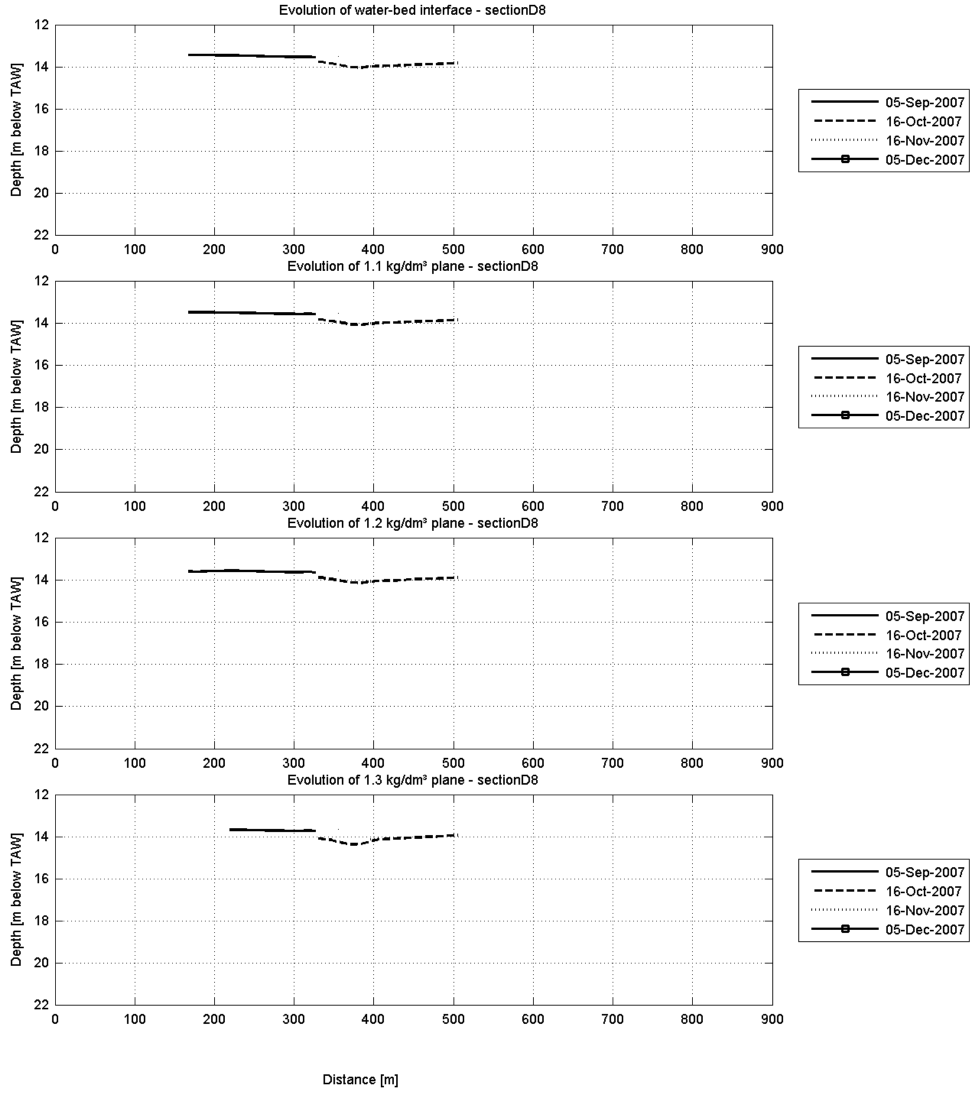
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

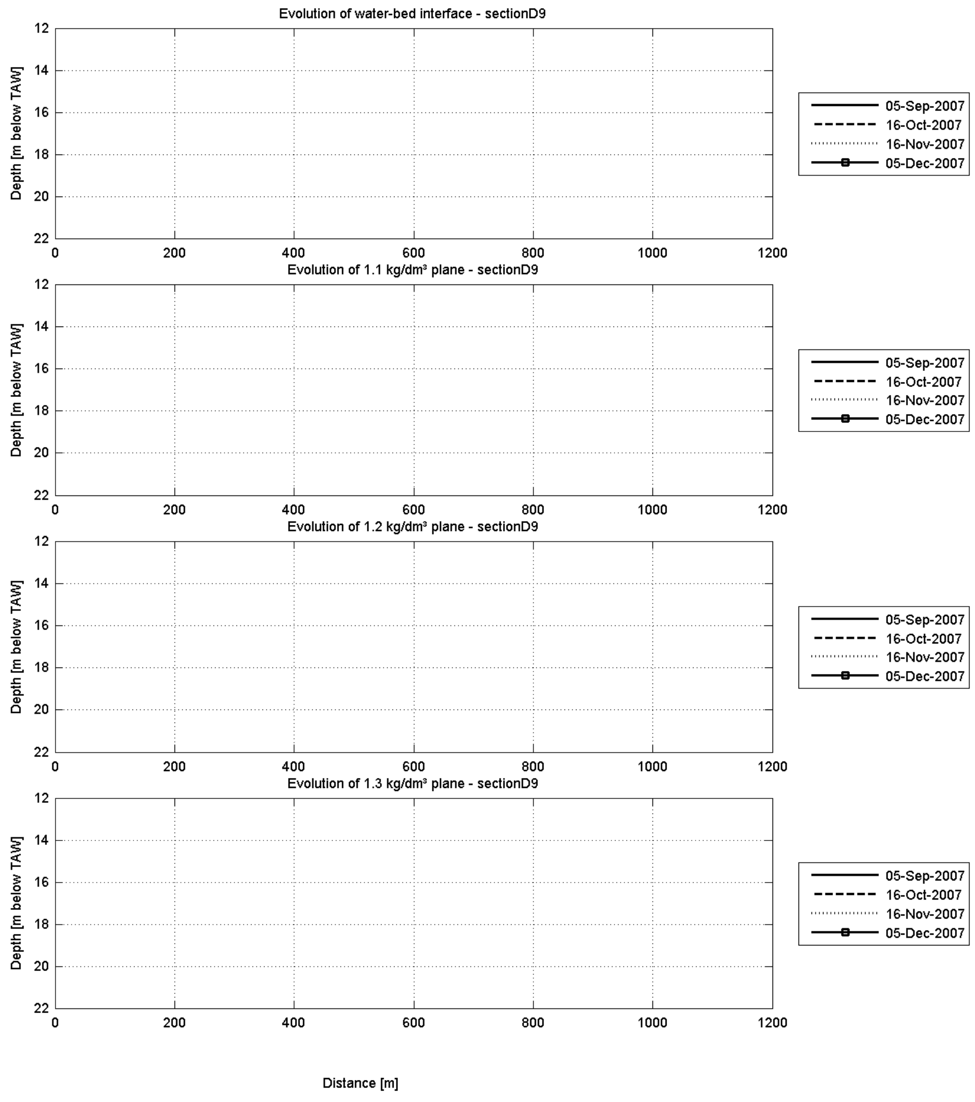
Long-term monitoring siltation Deurganckdok	
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



	Data Processed by: IMDC In association with : I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

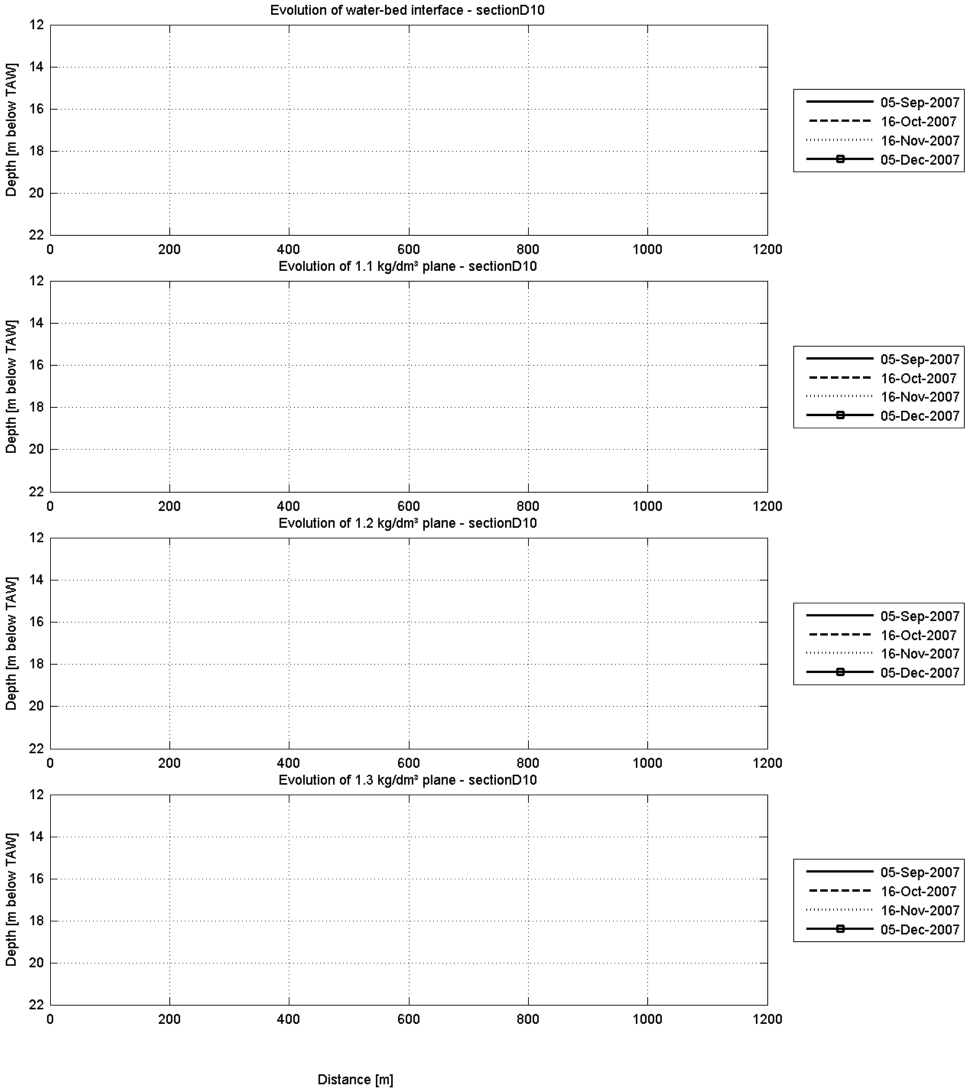
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :

I/RA/11283/07.083/MSA

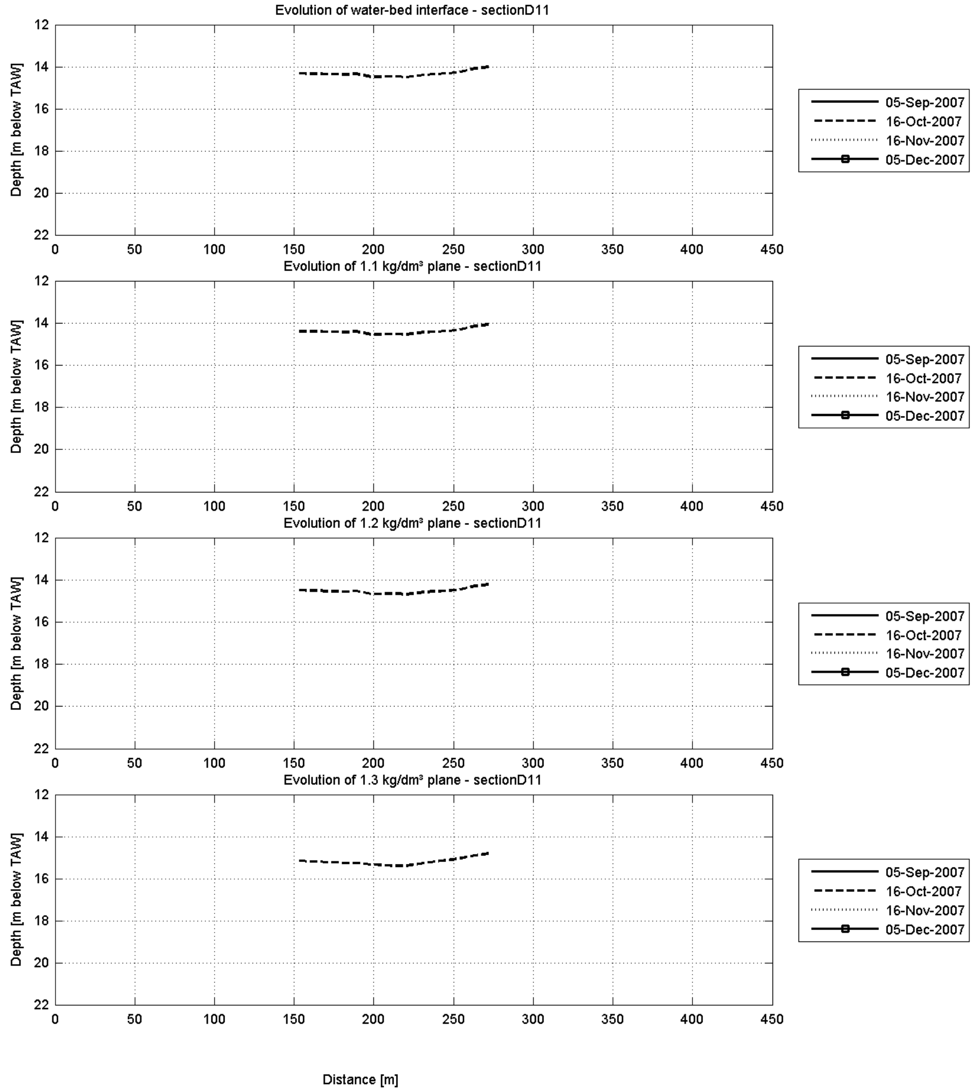
Long-term monitoring siltation Deurganckdok	
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with : WL | delft hydraulics, GEMS International

I/RA/11283/07.083/MSA

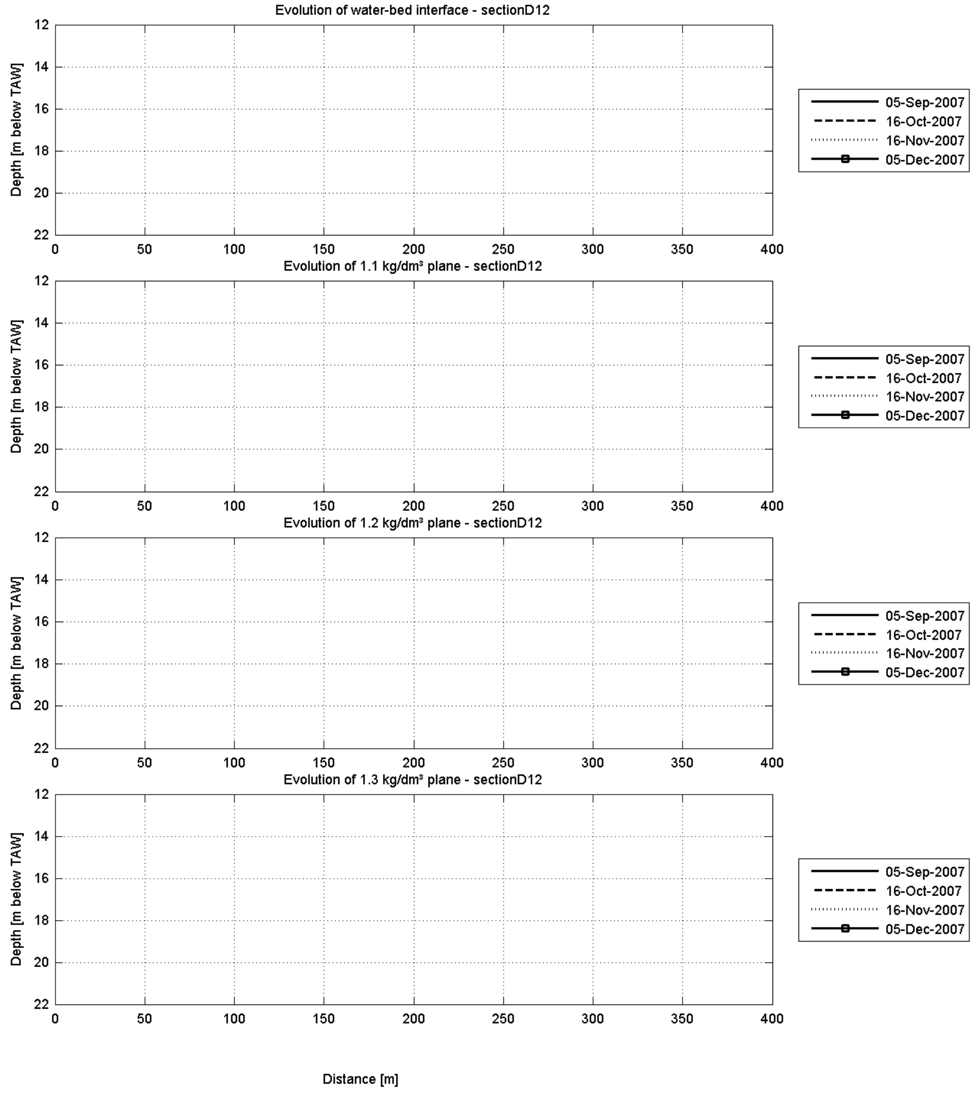
Long-term monitoring siltation Deurganckdok	
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

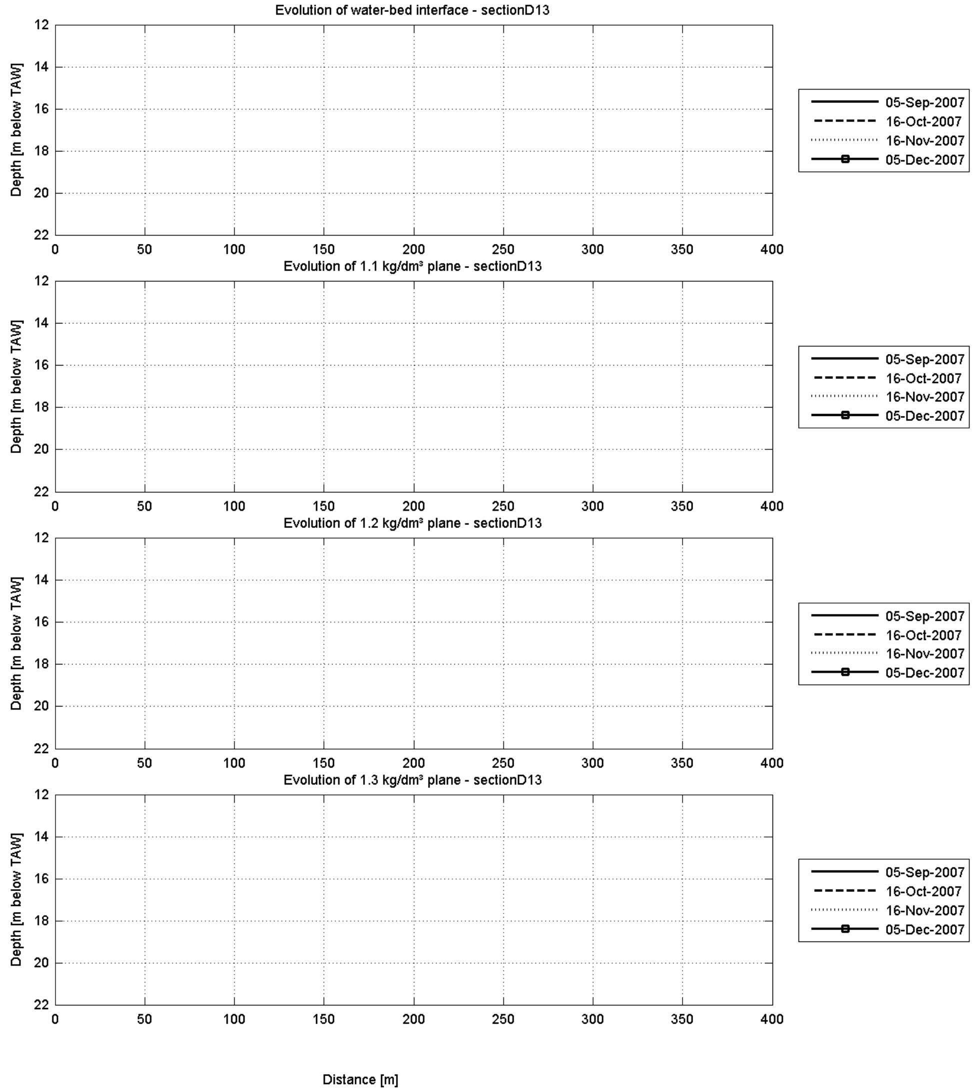
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



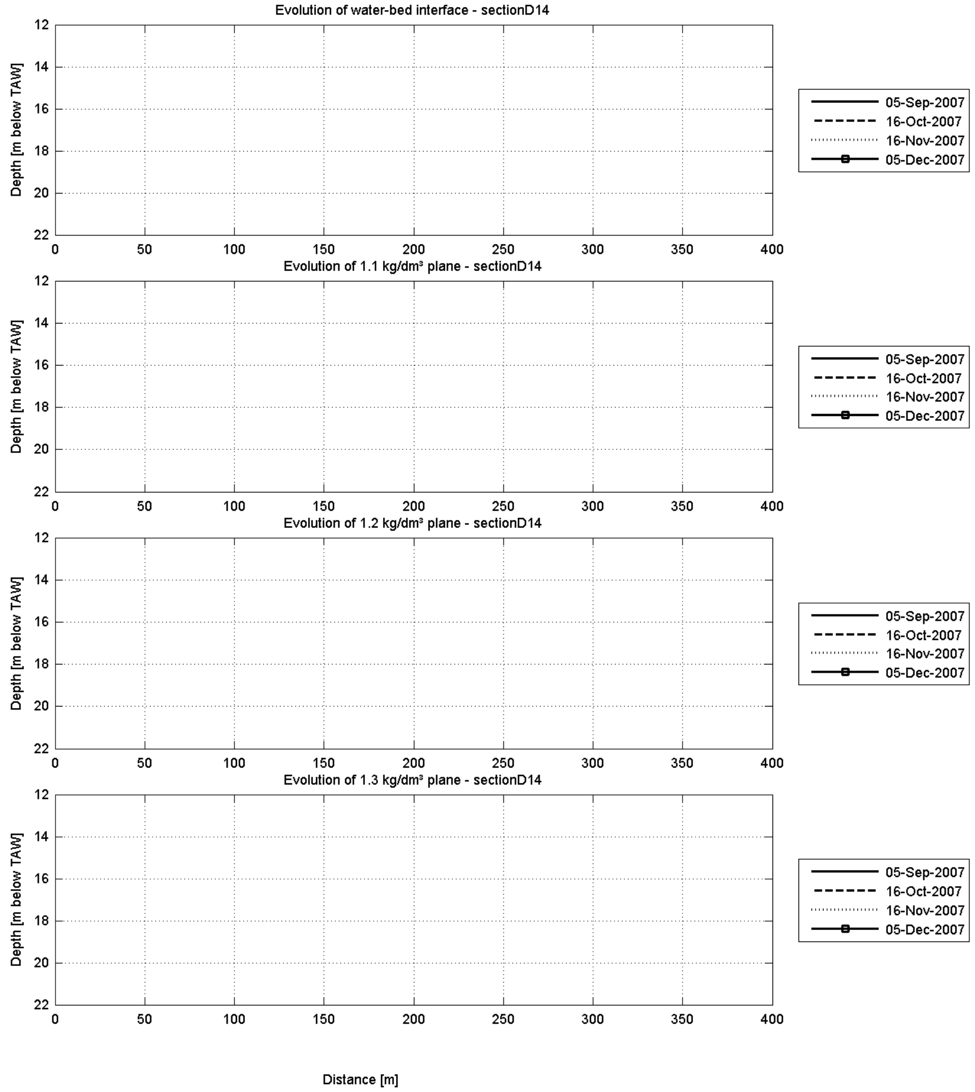
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

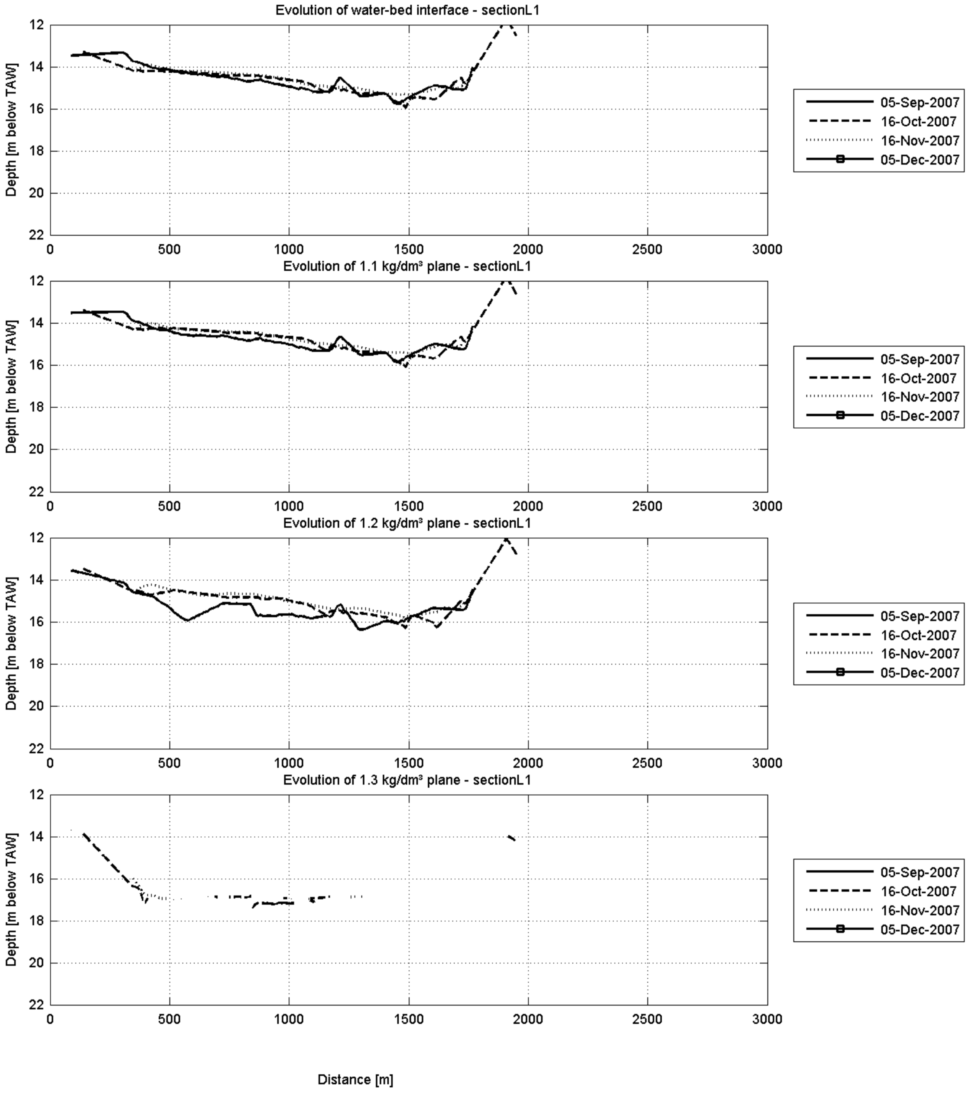
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



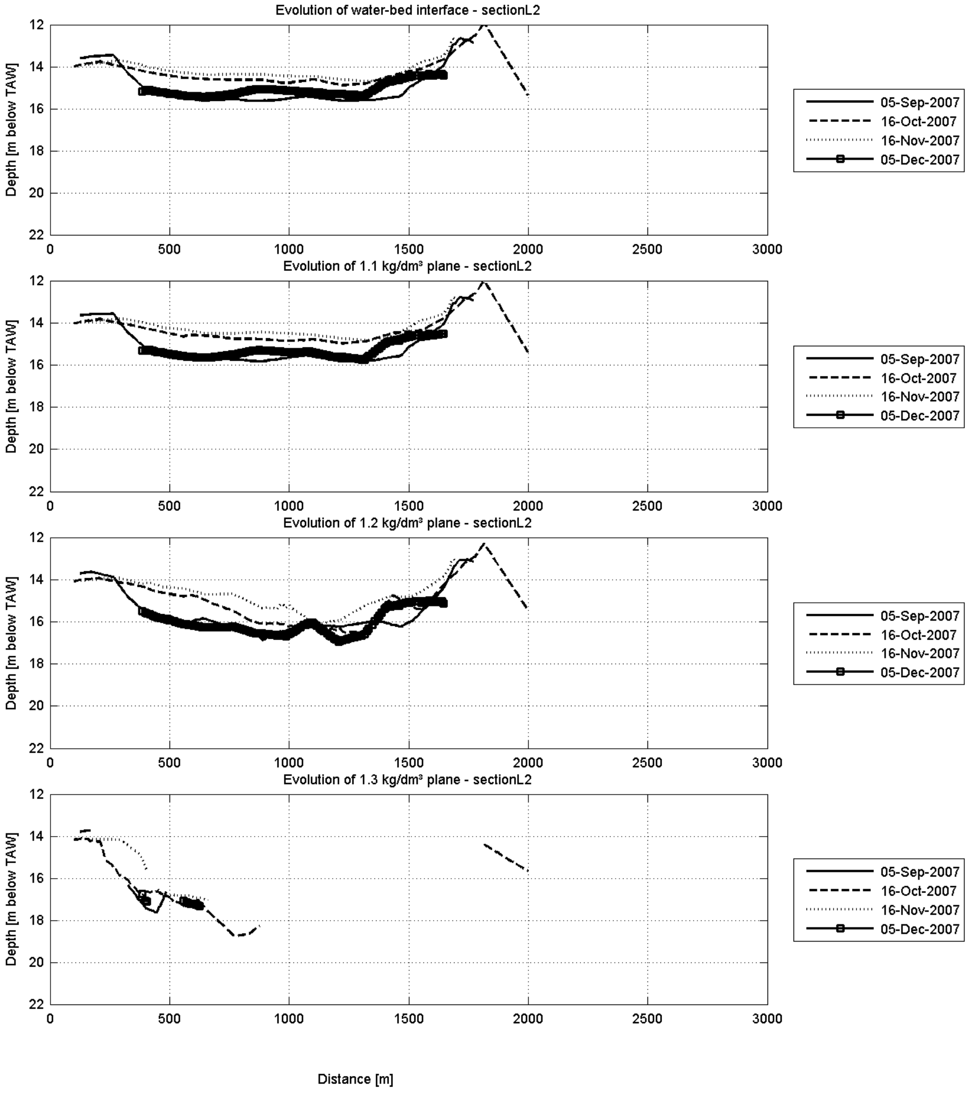
Data Processed by: IMDC

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

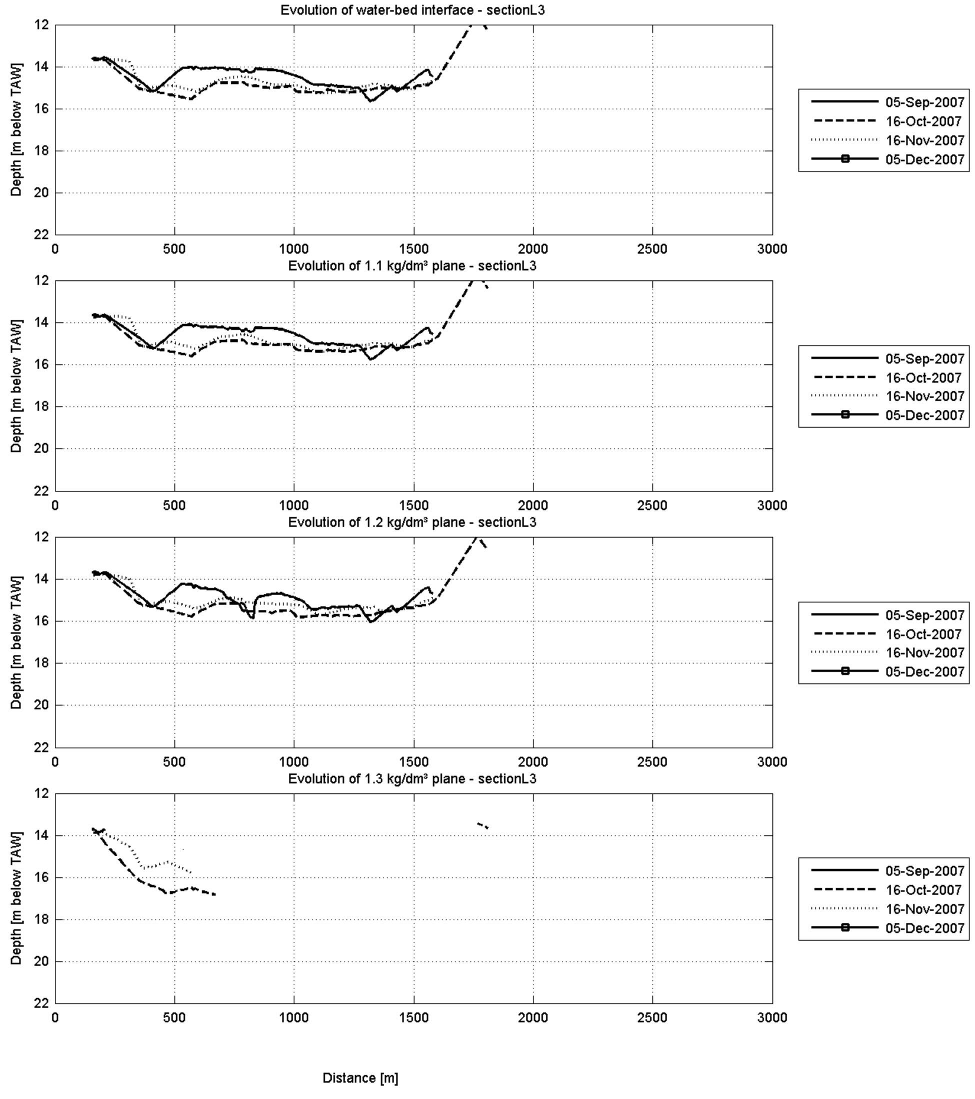
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Evolution of planes of constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC

In association with : WL | delft hydraulics, GEMS International

I/RA/11283/07.083/MSA

APPENDIX I.

SEDIMENT MASS DISTRIBUTION IN DEURGANCKDOK

APPENDIX J.

AVERAGE MASS GROWTH AND GROWTH RATE

J.1 Tabular results

Measured Mass (TDS/m²)				

	05-Sep-07	**16-Oct-07**	**16-Nov-07**	**05-Dec-07**
1	-	-	-	-
2	0.522	0.58	-	-
3a	1.405	1.73	1.937	-
3b	1.133	1.337	1.5	1.286
3c	1.278	1.399	1.463	1.261
3d	-	-	-	-
3e	-	-	-	-
4Na	1.167	1.036	1.196	-
4Nb	0.951	0.86	0.942	-
4Nc	0.744	0.763	0.817	-
4Nd	-	-	-	-
4Ne	-	-	-	-
4Za	1.019	0.877	1.055	-
4Zb	0.929	0.767	0.91	-
4Zc	0.743	0.74	0.786	-
4Zd	-	-	-	-
4Ze	-	-	-	-
5Na	1.237	0.881	-	-
5Nb	1.135	0.902	-	-
5Nc	0.893	1.113	-	-
5Nd	-	-	-	-
5Ne	-	-	-	-
5Za	0.82	-	0.842	-
5Zb	0.904	0.609	0.724	-
5Zc	-	0.586	-	-
5Zd	-	-	-	-
5Ze	-	-	-	-
Area mean	1.085	1.243	1.315	1.332

**Cumulative dredged mass in covered area (TDS) ------------				
	05-Sep-07	**16-Oct-07**	**16-Nov-07**	**05-Dec-07**
1	0	0	0	28
2	0	0	0	30
3a	0	0	0	83520
3b	0	0	0	65578
3c	0	0	0	50508
3d	0	0	0	565
3e	0	0	0	0
4Na	0	0	0	16984
4Nb	0	0	0	13912
4Nc	0	0	0	9459
4Nd	0	0	0	14
4Ne	0	0	0	0
4Za	0	0	0	10803
4Zb	0	0	0	16330
4Zc	0	0	0	6739
4Zd	0	0	0	0
4Ze	0	0	0	0
5Na	0	0	0	0
5Nb	0	0	0	0
5Nc	0	0	0	0
5Nd	0	0	0	0
5Ne	0	0	0	0
5Za	0	0	0	0
5Zb	0	0	0	0
5Zc	0	0	0	0
5Zd	0	0	0	0
5Ze	0	0	0	0
Total	0	0	0	274469

Growth rate (kg/m²/day)			
	05-Sep-2007 / 16-Oct-2007	**16-Oct-2007 / 16-Nov-2007**	**16-Nov-2007 / 05-Dec-2007**
1	-	-	-
2	1.41	-	-
3a	7.91	6.69	-
3b	4.97	5.29	18.21
3c	2.95	2.04	12.72
3d	-	-	-
3e	-	-	-
4Na	-3.19	5.14	-
4Nb	-2.22	2.65	-
4Nc	0.46	1.74	-
4Nd	-	-	-
4Ne	-	-	-
4Za	-3.47	5.74	-
4Zb	-3.94	4.61	-
4Zc	-0.06	1.49	-
4Zd	-	-	-
4Ze	-	-	-
5Na	-8.69	-	-
5Nb	-5.69	-	-
5Nc	5.37	-	-
5Nd	-	-	-
5Ne	-	-	-
5Za	-	-	-
5Zb	-7.19	3.73	-
5Zc	-	-	-
5Zd	-	-	-
5Ze	-	-	-
Mean	3.86	2.33	33.71

**Total cumulative mass(TDS/m²) ------------				
	05-Sep-07	**16-Oct-07**	**16-Nov-07**	**05-Dec-07**
1	-	-	-	-
2	0.522	0.58	-	-
3a	1.405	1.73	1.937	-
3b	1.133	1.337	1.5	1.846
3c	1.278	1.399	1.463	1.704
3d	-	-	-	-
3e	-	-	-	-
4Na	1.167	1.036	1.196	-
4Nb	0.951	0.86	0.942	-
4Nc	0.744	0.763	0.817	-
4Nd	-	-	-	-
4Ne	-	-	-	-
4Za	1.019	0.877	1.055	-
4Zb	0.929	0.767	0.91	-
4Zc	0.743	0.74	0.786	-
4Zd	-	-	-	-
4Ze	-	-	-	-
5Na	1.237	0.881	-	-
5Nb	1.135	0.902	-	-
5Nc	0.893	1.113	-	-
5Nd	-	-	-	-
5Ne	-	-	-	-
5Za	0.82	-	0.842	-
5Zb	0.904	0.609	0.724	-
5Zc	-	0.586	-	-
5Zd	-	-	-	-
5Ze	-	-	-	-
Mean	1.085	1.243	1.315	1.956

Covered Area (ha) ------------				
	05-Sep-07	**16-Oct-07**	**16-Nov-07**	**05-Dec-07**
1	0.16	0.19	0.01	0
2	7.57	7.33	4.23	0
3a	9.87	9.87	9.87	4.83
3b	10.99	10.99	10.99	6.42
3c	9.88	9.91	9.67	5.02
3d	1.11	5.68	0	0
3e	0	0	0	0
4Na	3.64	3.64	3.28	0
4Nb	3.12	3.12	3.12	0
4Nc	2.51	2.57	2.42	0
4Nd	0.03	0.99	0	0
4Ne	0	0	0	0
4Za	2.42	2.42	2.42	0
4Zb	3.12	3.12	3.12	0
4Zc	2.26	2.59	2.4	0
4Zd	0	1.09	0	0
4Ze	0	0	0	0
5Na	1.9	1.9	0.67	0
5Nb	1.68	1.57	0.84	0
5Nc	1.29	1.33	0.66	0
5Nd	0	0.41	0	0
5Ne	0	0	0	0
5Za	0.98	0.63	0.94	0
5Zb	1.05	1.06	1.05	0
5Zc	0.26	0.96	0.5	0
5Zd	0	0.34	0	0
5Ze	0	0	0	0
Total	63.82	71.69	56.17	16.27

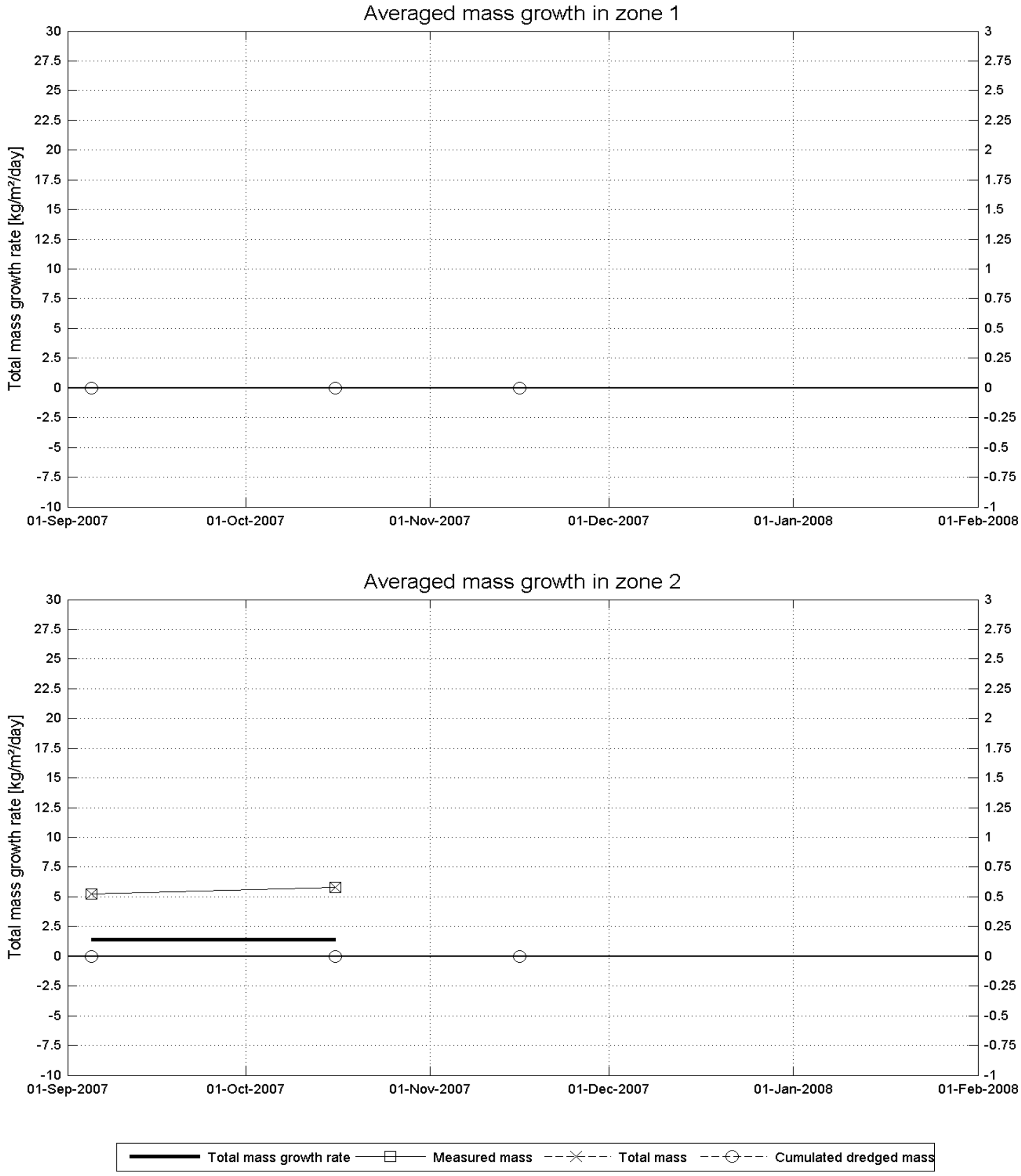
****Percent of zone covered**

	05-Sep-07	16-Oct-07	16-Nov-07	05-Dec-07
1	1	2	0	0
2	61	59	34	0
3a	100	100	100	49
3b	100	100	100	58
3c	100	100	98	51
3d	9	44	0	0
3e	0	0	0	0
4Na	100	100	90	0
4Nb	100	100	100	0
4Nc	97	100	94	0
4Nd	1	30	0	0
4Ne	0	0	0	0
4Za	100	100	100	0
4Zb	100	100	100	0
4Zc	87	100	93	0
4Zd	0	34	0	0
4Ze	0	0	0	0
5Na	83	83	29	0
5Nb	84	79	42	0
5Nc	71	73	37	0
5Nd	0	17	0	0
5Ne	0	0	0	0
5Za	75	48	72	0
5Zb	53	53	52	0
5Zc	15	53	28	0
5Zd	0	14	0	0
5Ze	0	0	0	0
Mean	49	55	43	6

J.2 For each zone

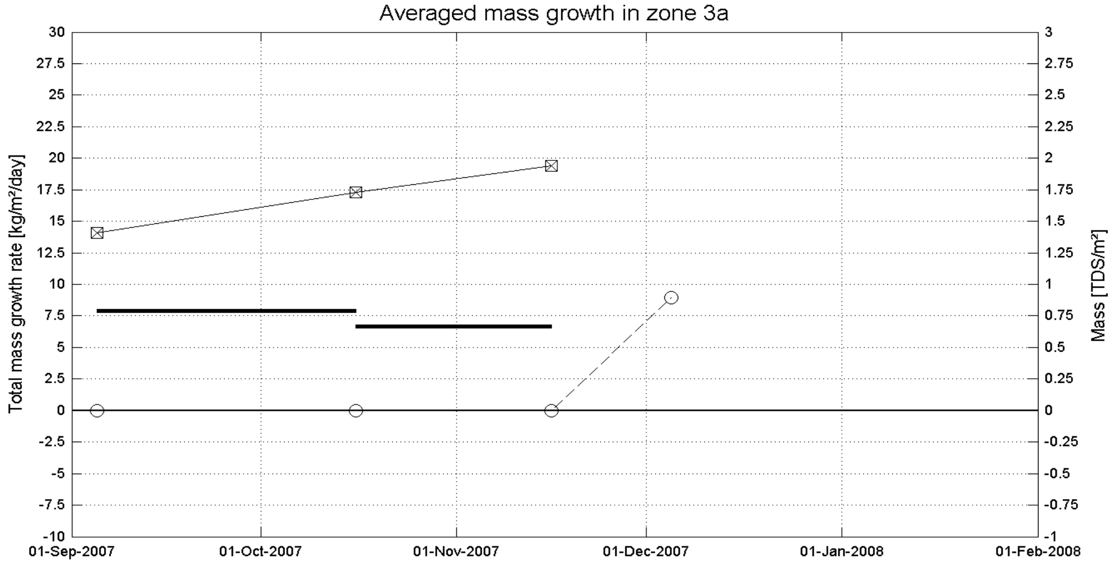
Long-term monitoring siltation Deurganckdok

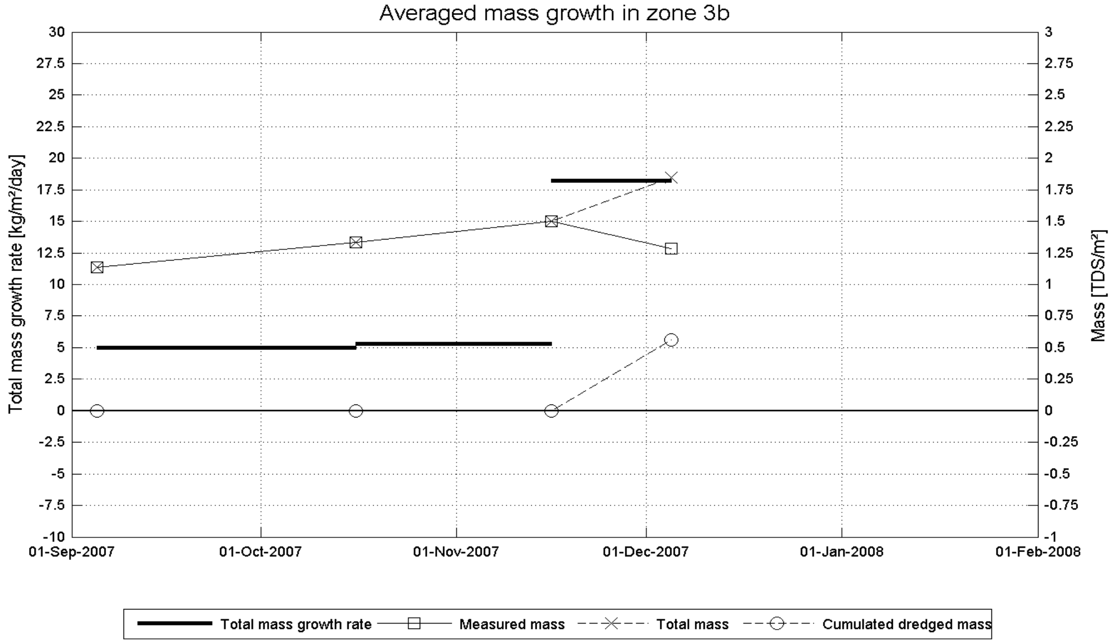
Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC In association with : WL | delft hydraulics, GEMS International I/RA/11283/07.083/MSA

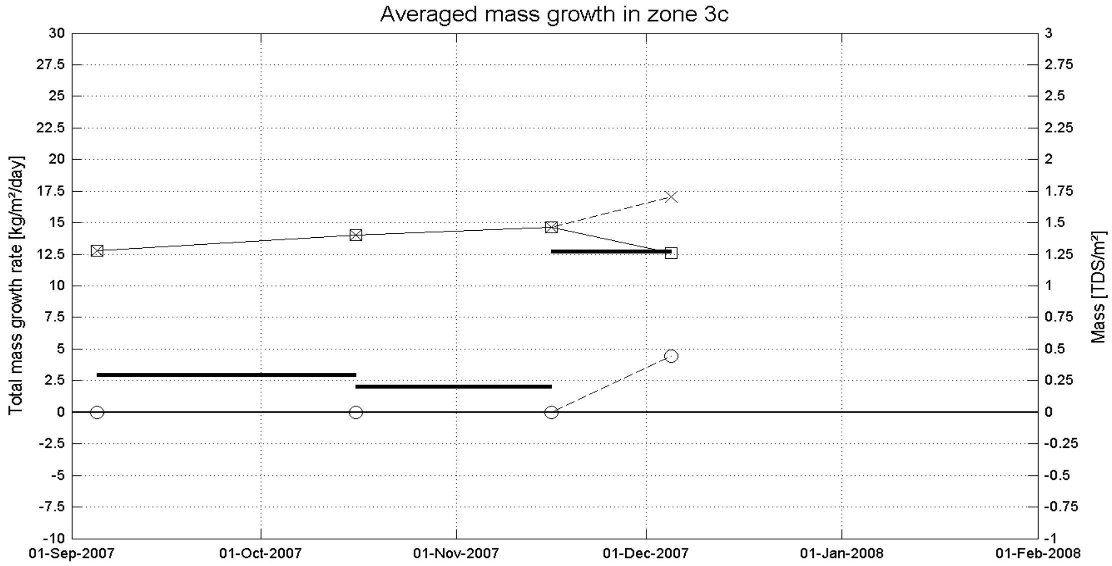
Long-term monitoring siltation Deurganckdok	
Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

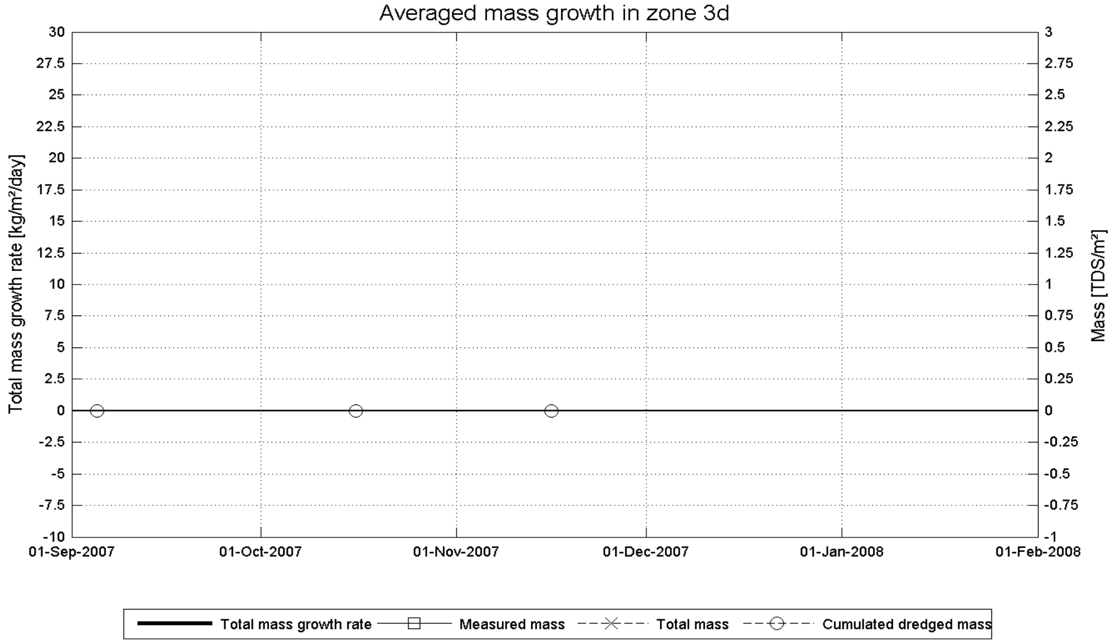




	Data Processed by: In association with : I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD





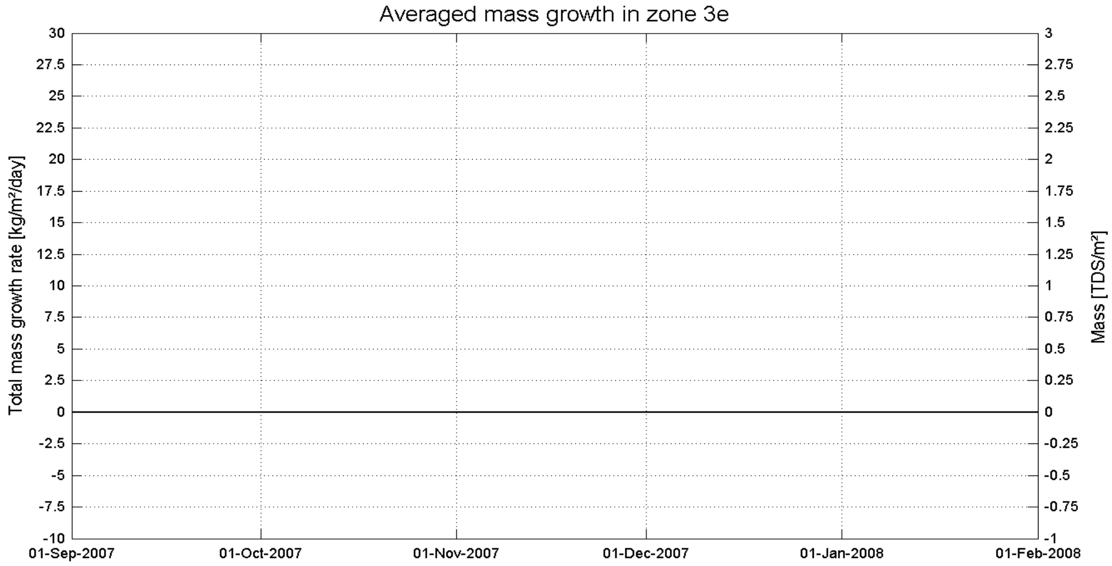
Data Processed by:

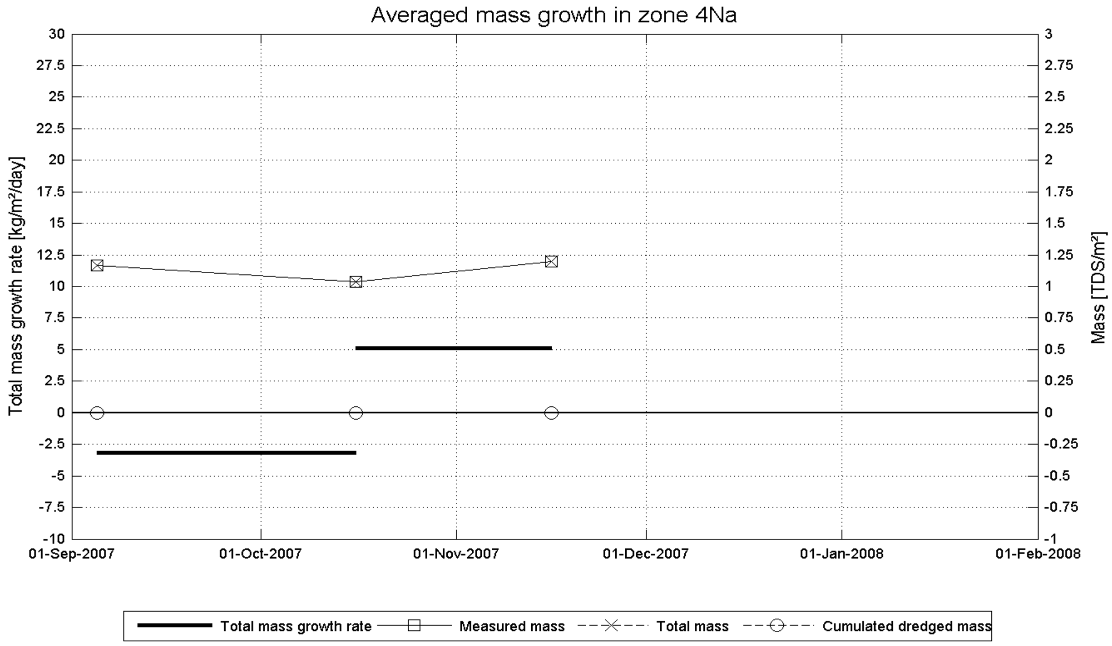
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



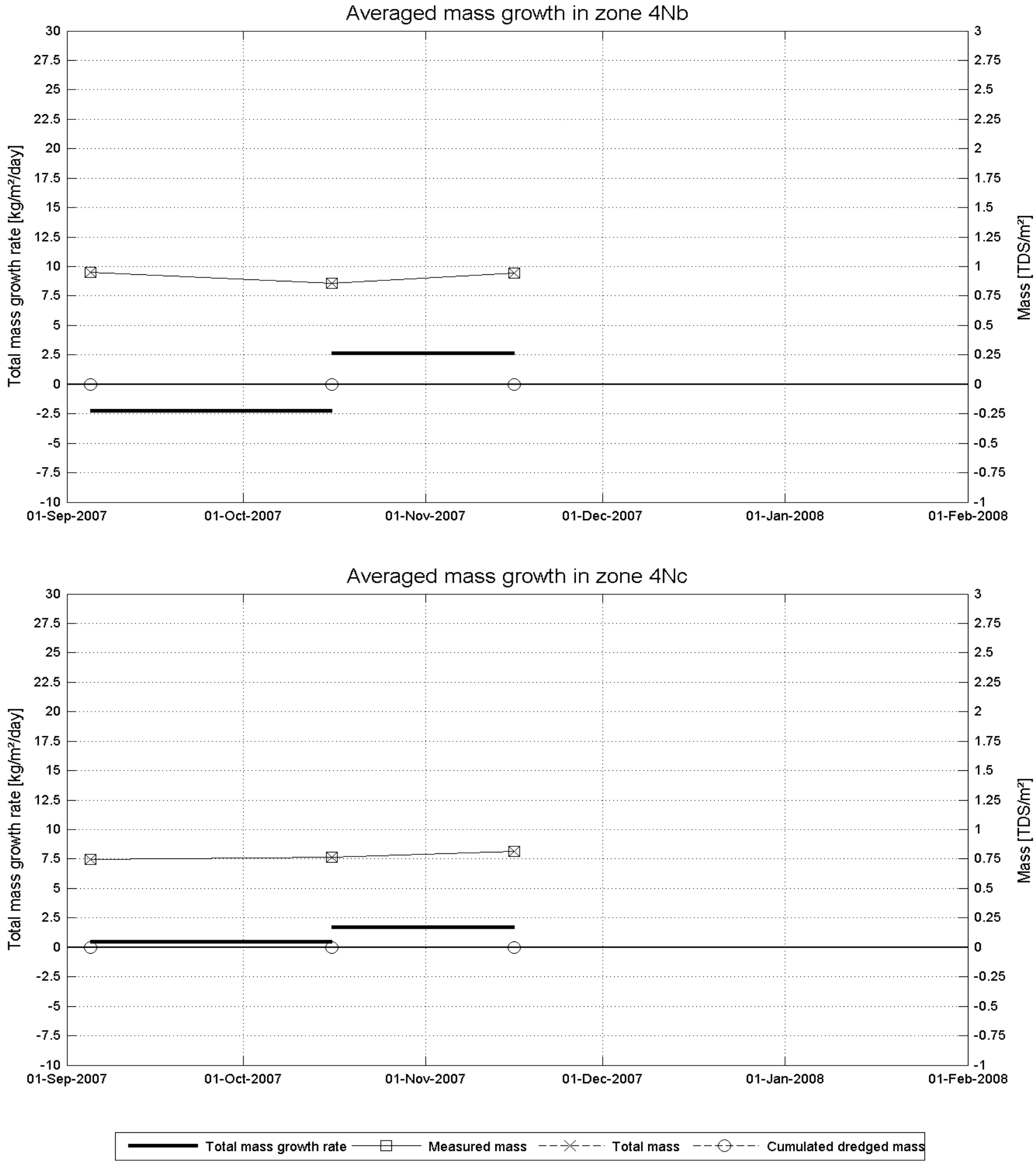


Data Processed by:

In association with :

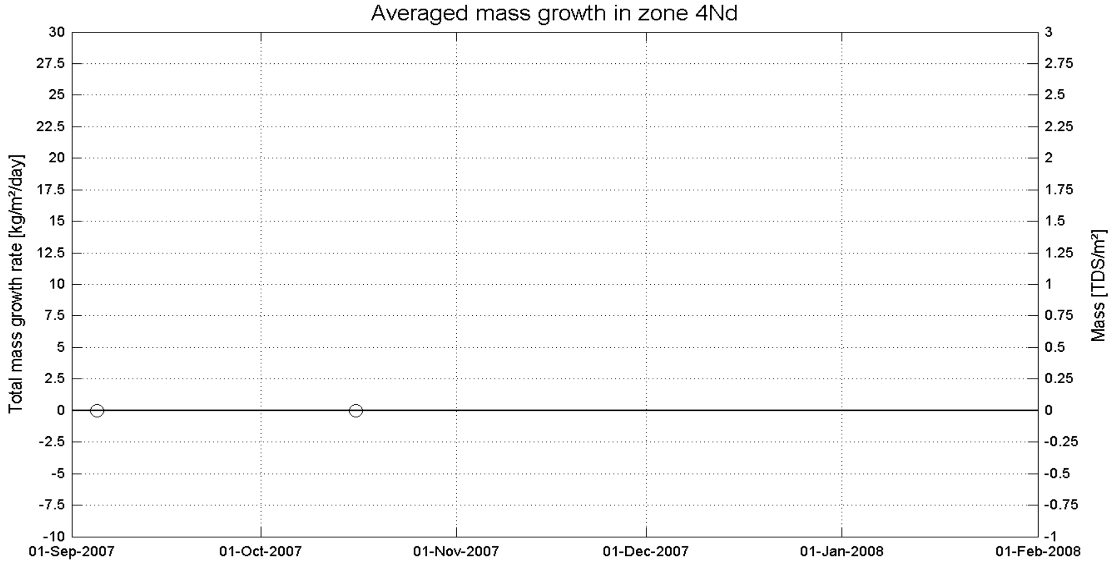
I/RA/11283/07.083/MSA

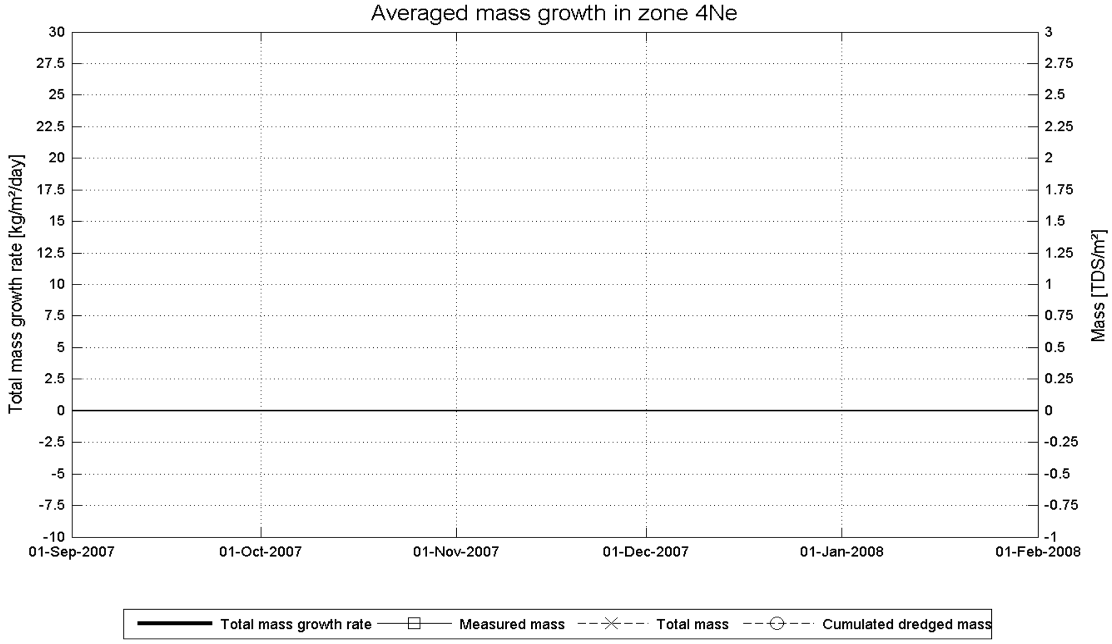
Long-term monitoring siltation Deurganckdok	
Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



	Data Processed by: IMDC In association with : WL delft hydraulics, GEMS International I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



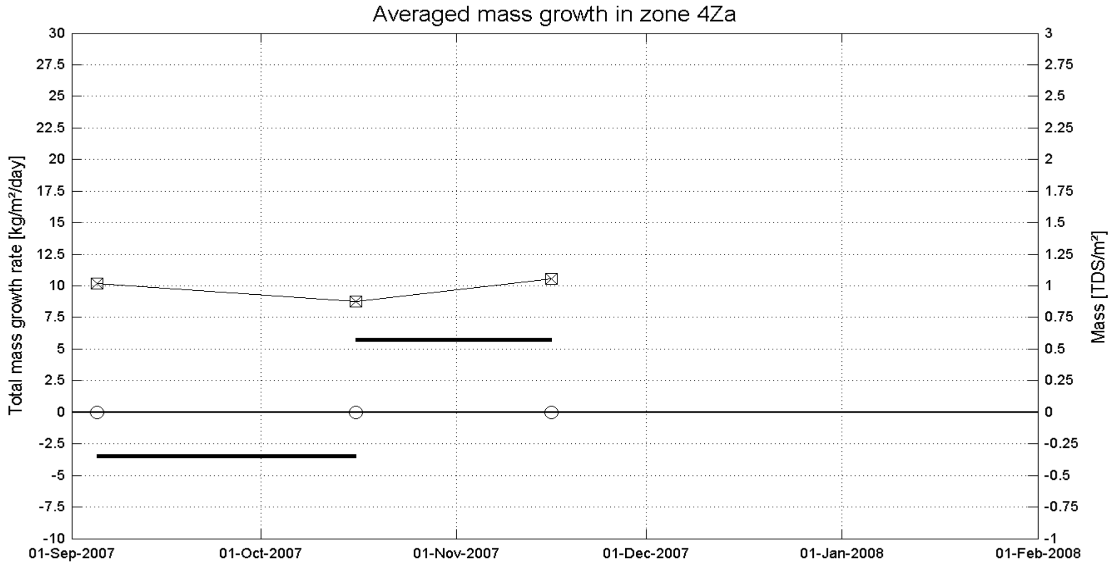


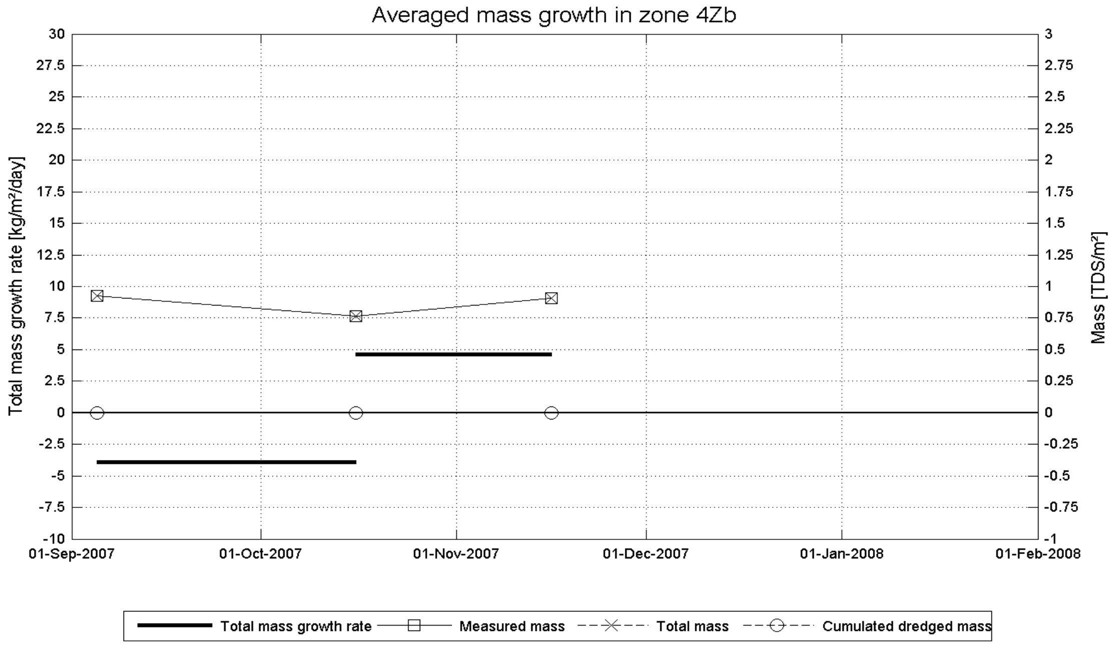
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD





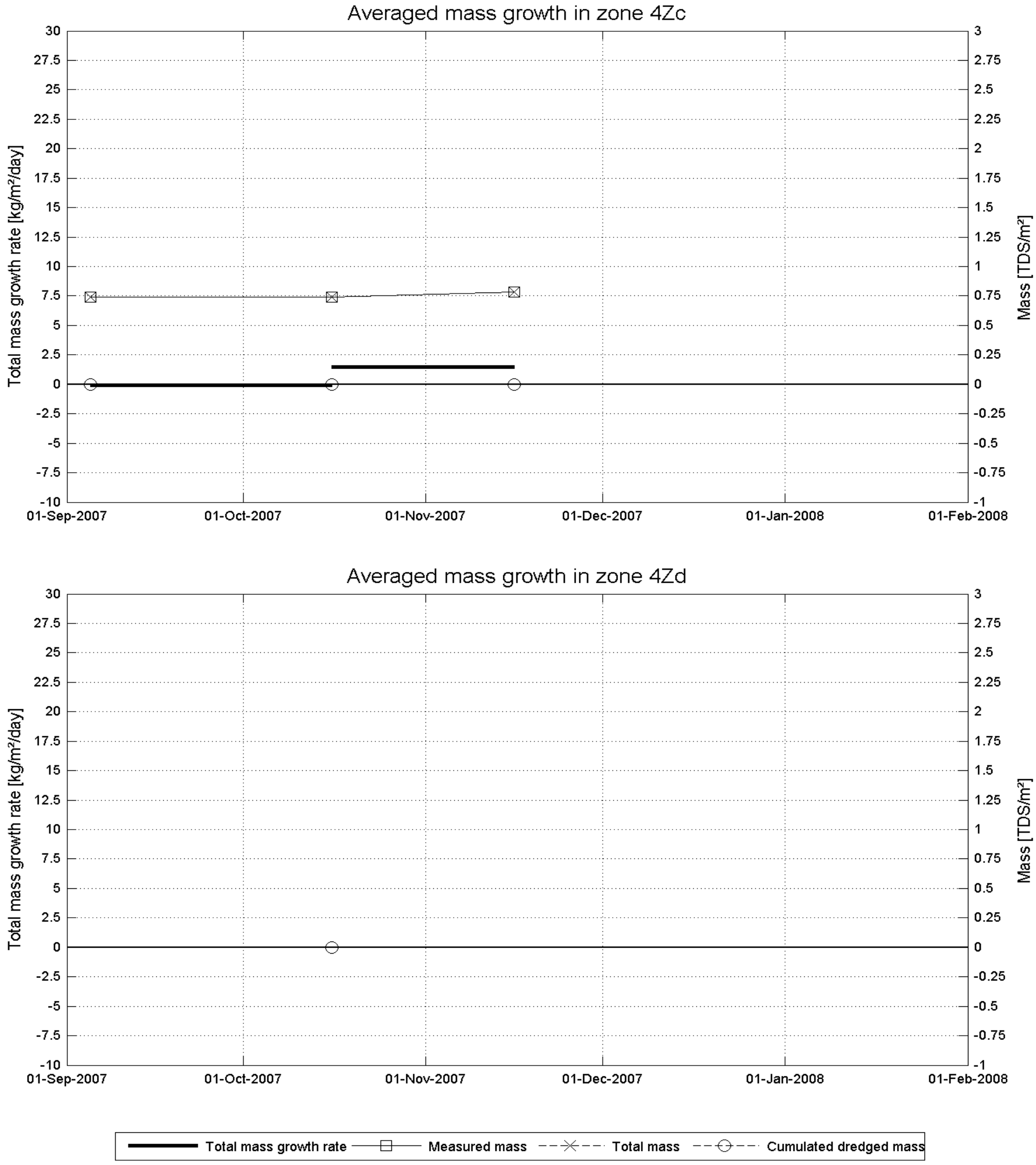
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

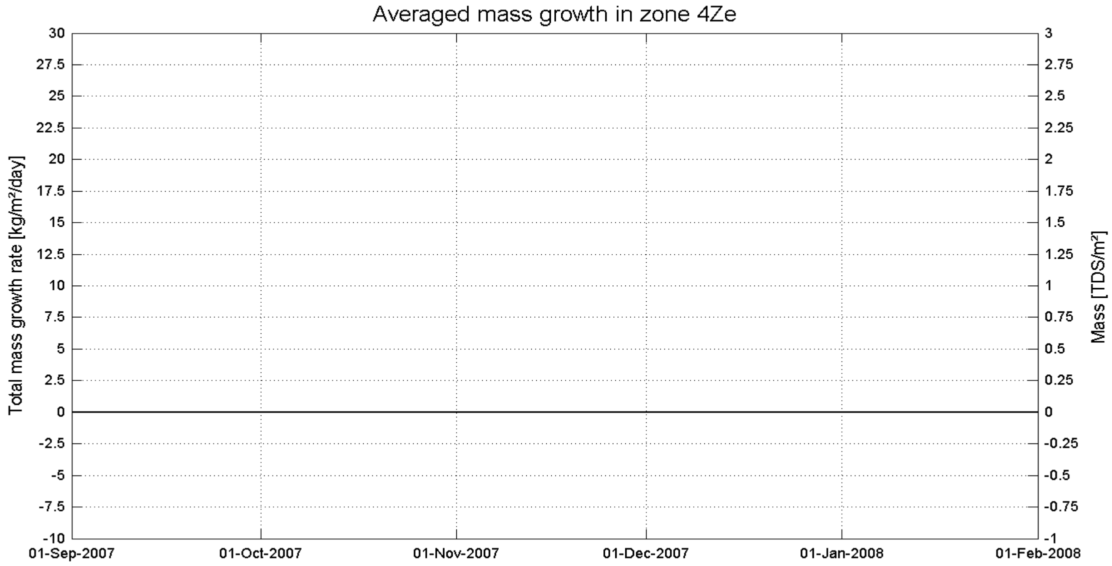


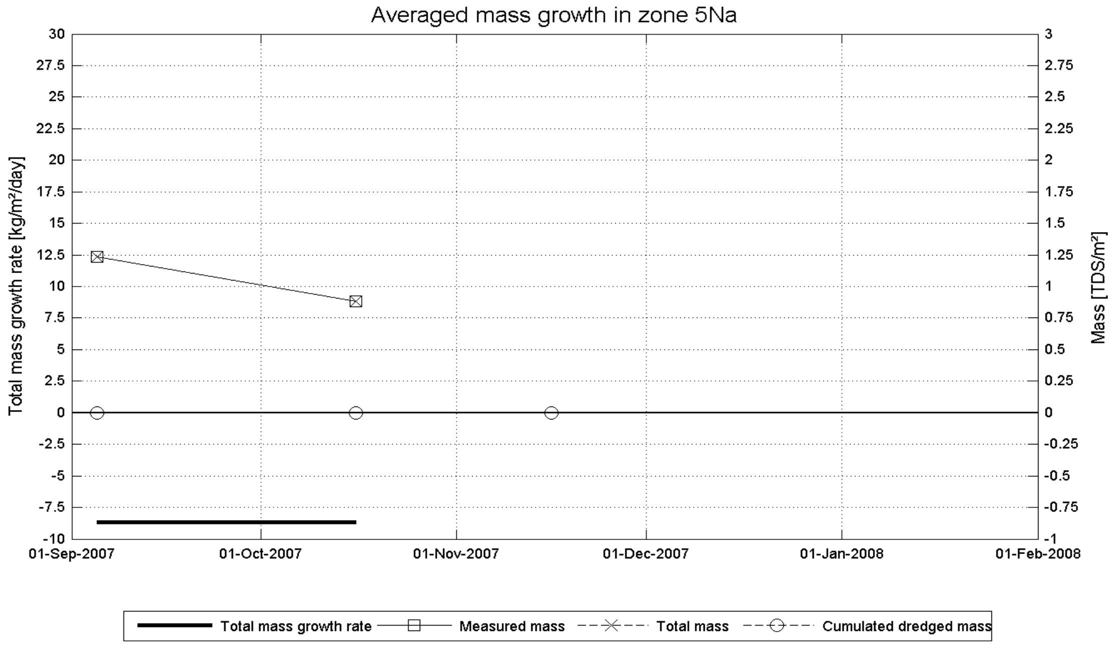
Data Processed by: IMDC

In association with : WL | delft hydraulics, GEMS International

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



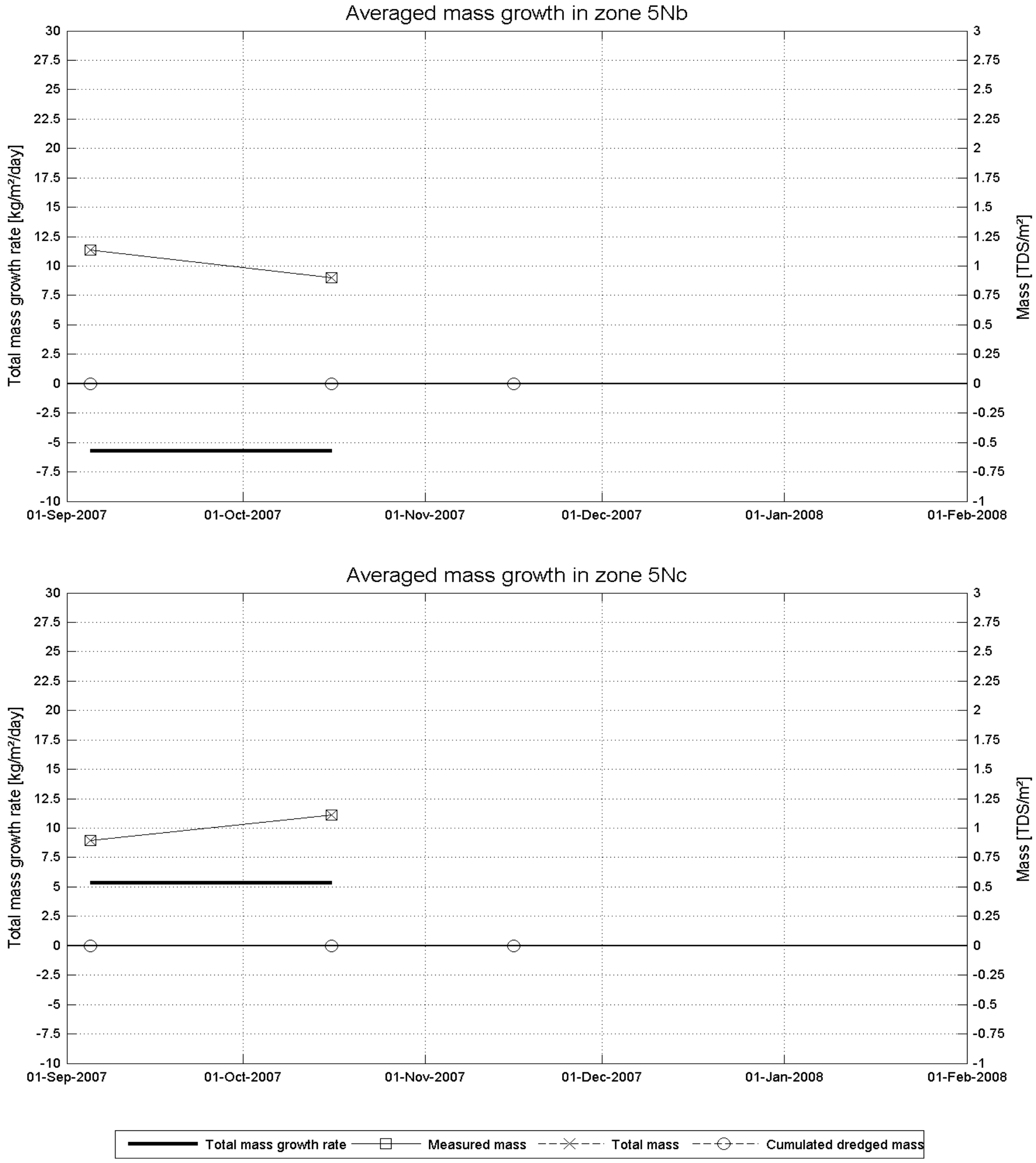


Data Processed by: IMDC

In association with : WL | delft hydraulics, GEMS International

I/RA/11283/07.083/MSA

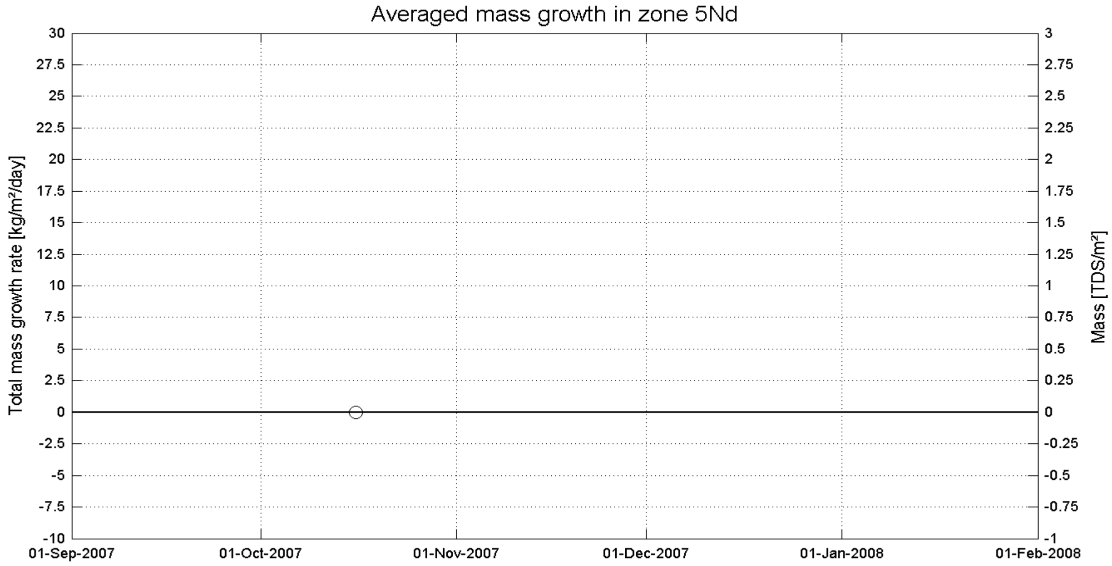
Long-term monitoring siltation Deurganckdok	
Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

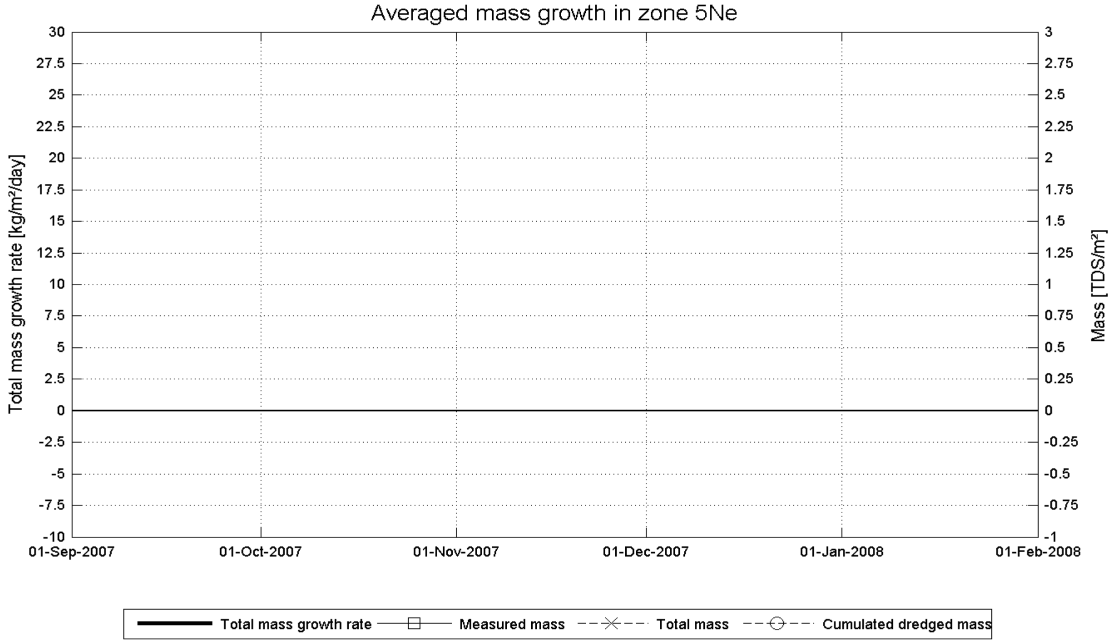


Data Processed by:
In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok	
Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

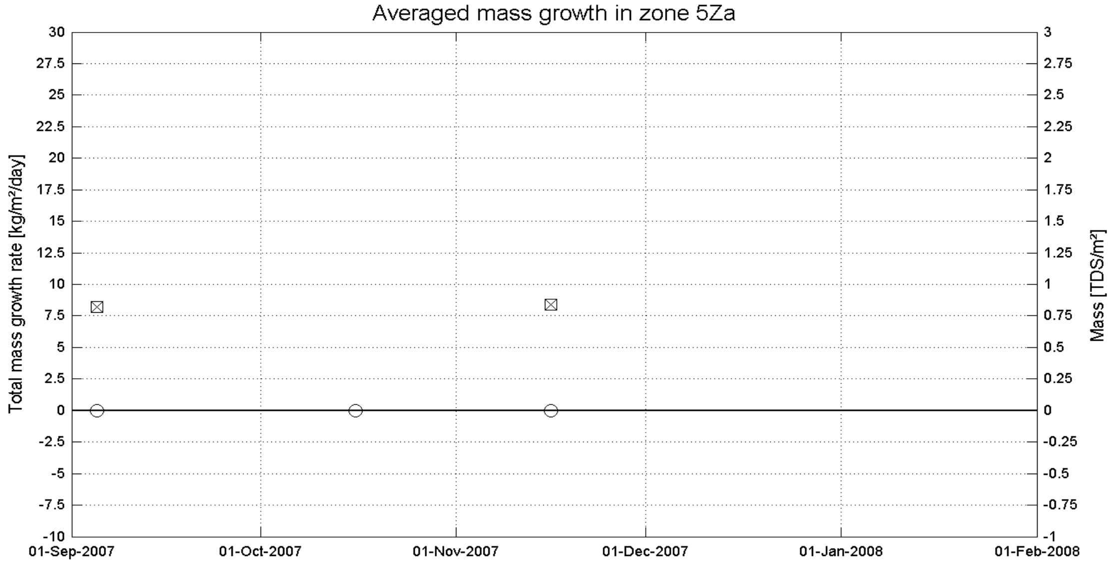


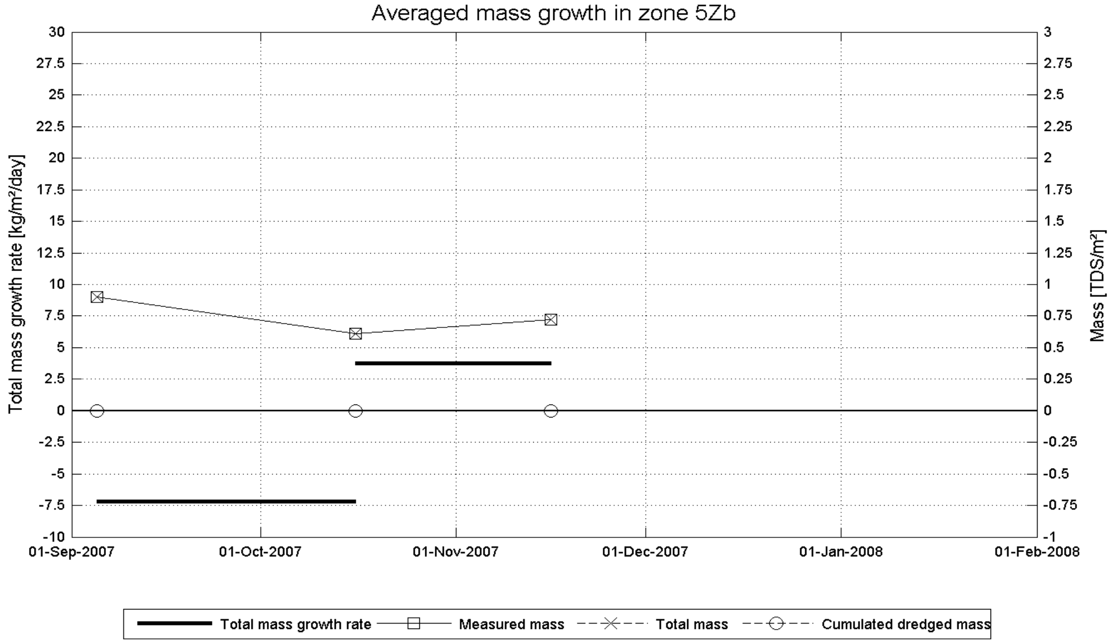


	Data Processed by: In association with : I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD

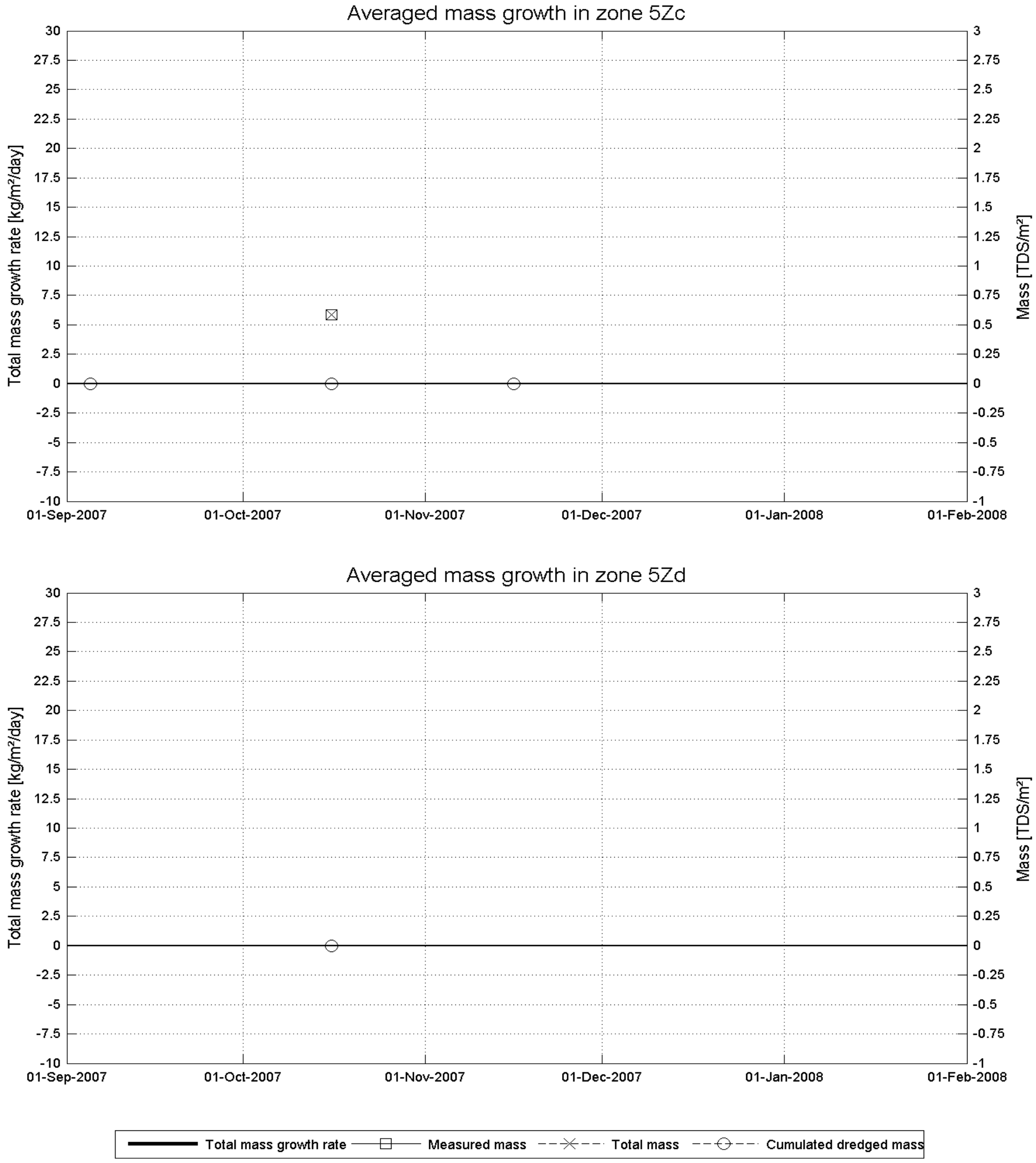




	Data Processed by: In association with : I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



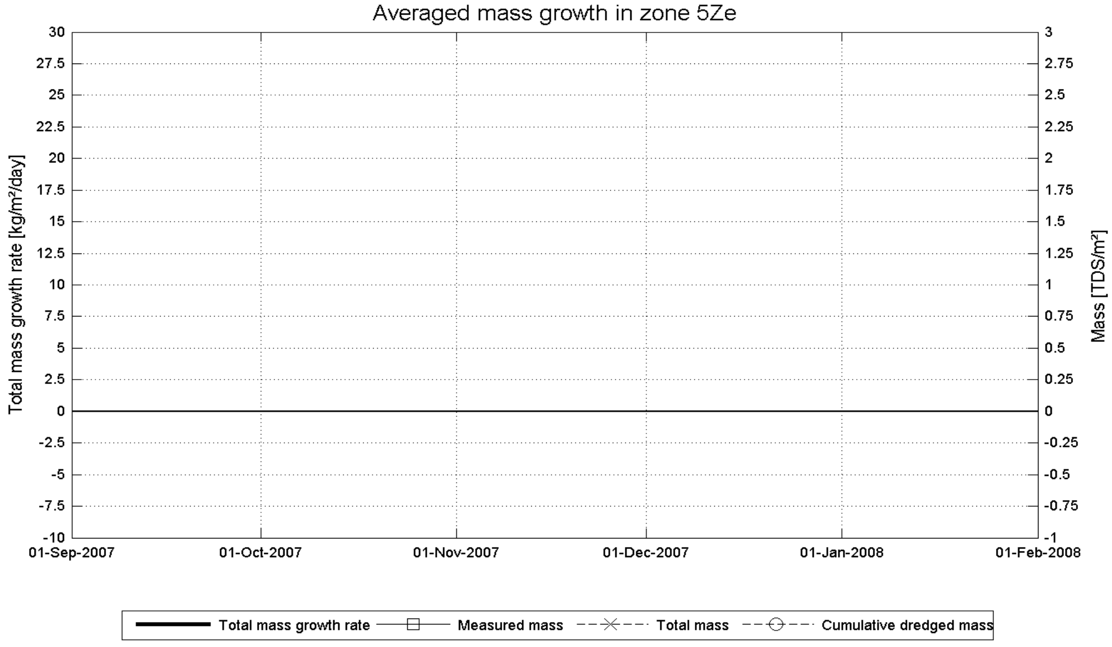
Data Processed by:

In association with :

I/RA/11283/07.083/MSA

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:

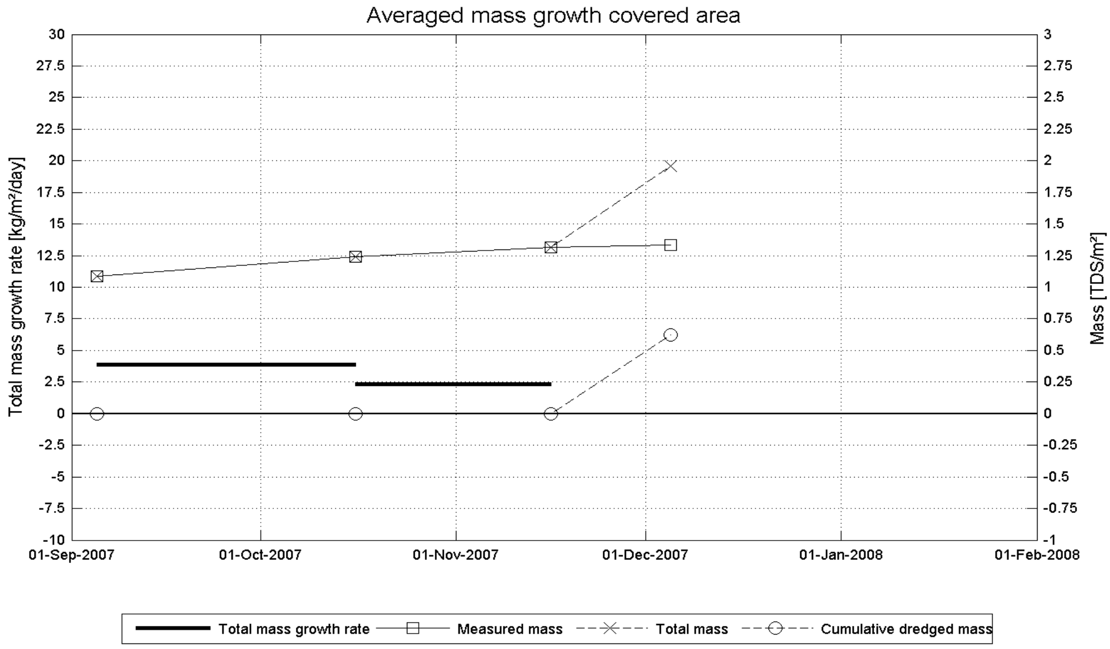
In association with :

I/RA/11283/07.083/MSA

J.3 For complete Deurganckdok

Long-term monitoring siltation Deurganckdok

Measured/Dredged/Total Mass	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:

In association with :

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APPENDIX K.

DREDGING DATA

***Total dredged mass in covered area per week (TDS)**		
	19 November 07	***26 November 07***
ZONE	***25 November 07***	***2 December 07***
1	28	0
2	30	0
3a	40406	43114
3b	45720	19857
3c	38674	11835
3d	470	95
3e	0	0
4Na	5662	11322
4Nb	6984	6928
4Nc	5861	3598
4Nd	14	0
4Ne	0	0
4Za	7480	3323
4Zb	12214	4116
4Zc	4699	2040
4Zd	0	0
4Ze	0	0
5Na	0	0
5Nb	0	0
5Nc	0	0
5Nd	0	0
5Ne	0	0
5Za	0	0
5Zb	0	0
5Zc	0	0
5Zd	0	0
5Ze	0	0
Total	168243	106227

APPENDIX L.

FEASIBILITY STUDY OF ECHO SOUNDING TO DETERMINE FLUID MUD DENSITY PROFILES

NOTA

Datum :	25/01/07
Aan:	AMT, WL Borgerhout
Auteur:	BOB/JME/MBO
Documentref	I/NO/11283/08.001/BOB
naam vh document :	K:\PROJECTS\11\11283 - Opvolging aanslibbing dgd\10-Rap\DGD2\NO08001_comparison between Navitracker and Silas_v10.doc

Betreft: 11283 – Feasibility study of echo sounding to determine fluid mud density profiles

INHOUDSTAFEL

1. INTRODUCTION

Bulk density measurements are important in two ways. Firstly, for ship traffic it is essential to know the nautical bottom as this determines the maximum allowable draught. This parameter depends on the local fluid mud density. Secondly, density measurements are important to study sediment transport phenomena. The measurements may reveal how much sediment mass has been deposited at a specific location, e.g. a dock or an entrance channel. Hence, not only the fluid mud density needs to be known but the deeper more consolidated sediment should be accounted for as well.

In this report, a feasibility study is performed on the analysis of echo sounding data in order to determine vertical density profiles. Traditionally, the Flemish authorities determine the bulk density by (gamma-) radioactive techniques. The device determines high-resolution vertical profiles but at discrete location in the horizontal plane only. Large ship transport costs for measuring in the Deurganckdok allow sampling on a coarse grid. The radioactive probe also poses difficulties with respect to administrative permits.

For this reason, the feasibility of an echo sounder to determine bulk densities has been investigated. Its advantages are:

- the absence of any radioactive source;
- an almost continuous sampling resulting in a very fine horizontal sampling grid.

Because the attenuation of an acoustical signal is used, measured densities largely depend on the in situ parameters. A calibration of the device is therefore necessary.

Below, the echo sounding method is shortly presented, together with the traditional gamma-radioactive techniques, as they will be used in this report.

1.1. Gamma-radioactive method

The Navitracker device (Figure 1-1) is a patented system to measure the density of fluid mud suspensions, by means of a gamma-density meter. It has been used by the Flemish authorities for more than 20 years to determine the nautical bed of the port of Zeebrugge.
The Navitracker system can be operated by a computer-controlled winch to tow it through the mud (horizontal mode). The Navitracker is equipped with the following sensors:

- the Gamma-ray density sensor, mounted on a fork-like tow fish, returning density information.
- the depth sensor gives information on the depth of the sensor.
- the position of the fish is calculated out of the length of the winch cable. Together with the position of the tow fish, following the density level, a dual frequency echo sounder is used to map the hard bottom and the top of the mud. With a speed of 2 to 3 knots, large areas can be covered.

For these measurements the Navitracker was used in a vertical profiling mode though, with the probe in vertical position in order to penetrate the soft bottom. The vertical density profiler is used to measure densities of thick mud layers with high densities. Examples of such profiles for Deurganckdok are shown in Figure 1-2.

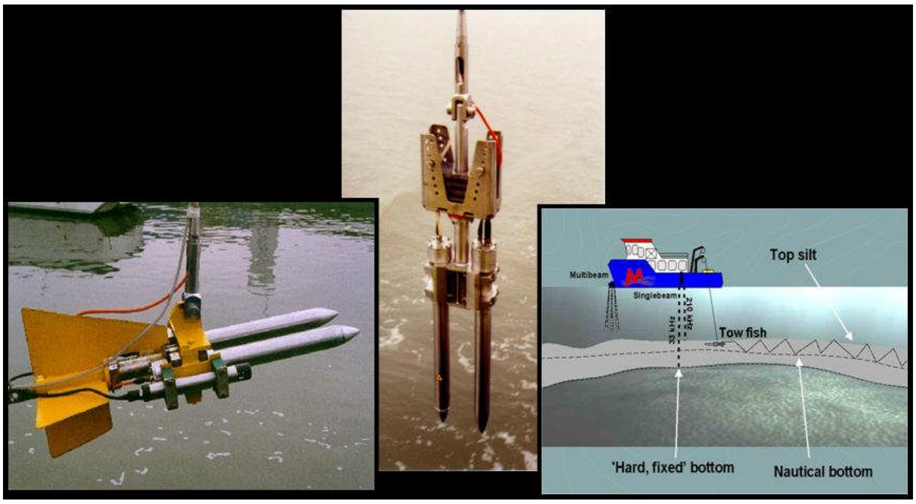


Figure 1-1: Navitracker

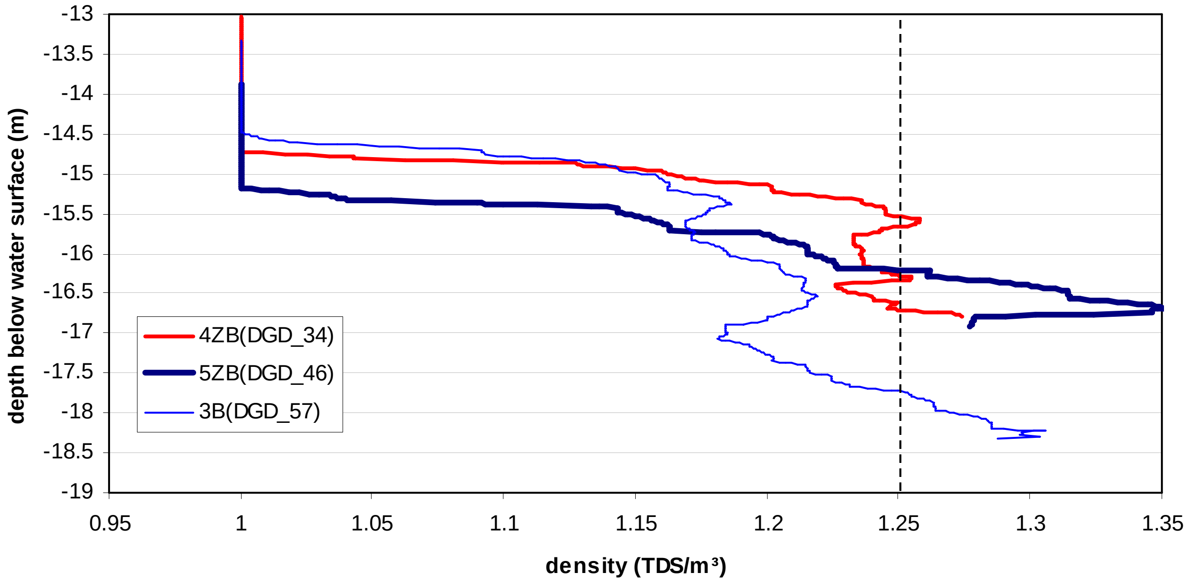


Figure 1-2: Examples of density profiles in Deurganckdok (16 October 2007)

The Navitracker was calibrated in the laboratory for measuring high densities, formed by very dense water-mud mixtures. For this reason, the Navitracker did not detect subtle variations in density caused by changes in salinity. The measured density therefore deviated from 1 ton/m³ only in the presence of a high concentration of sediments.
The Navitracker has a sampling frequency of 10 measurements per second.

1.2. Echo sounder technique

Whereas the Navitracker performs local measurements of the density, an Echotrac MKIII echo sounder is used in combination with the SILAS software to determine horizons of equal density. The echo sounder transmits an acoustic signal of 33 and 210 kHz. The echo of the 33 kHz signal is automatically interpreted by the SILAS software and identifies various reflections horizons or layers with corresponding density levels.
In order to relate the echo signal to the local density, calibration data is needed. In this exercise, the Navitracker data set was used for this.

2. AIM OF THE STUDY

This report aims at demonstrating the possibilities of the SILAS software, in combination with an echo sounder, in order to determine bulk densities and sediment mass accumulation.

3. METHOD

As mentioned, the echo sounder / SILAS needs to be calibrated prior to any density calculations. Seen the research work already performed on the sediment balance in the Deurganckdok, it was decided to perform Navitracker measurements in the dock on a rather fine sampling grid. These data were subsequently used for the calibration of the echo sounder by means of the SILAS software. Results between the gamma radiation method and echo sounder were critically evaluated with respect to sediment mass accumulations.

In a second stage, the entrance channel near the Kallo sluice was considered. The same exercise was done, but less (Navitracker) density samples were available for the calibration. Here, the advantage of the echo sounder / SILAS system with respect to its large (horizontal) spatial resolution is investigated. Again, sediment mass measurements based on the two measurement techniques are compared.

The sediment mass calculation method for both techniques can be briefly described as follows:

- Navitracker
    - o vertical integration of sediment mass according to measured density profiles to obtain TDS/m² at measurement locations
    - o interpolation of local sediment mass to zone areas

- SILAS
    - o SILAS is calibrated by the Navitracker measurements
    - o grids with depth of equal density plane: 1010, 1050, 1100, 1150, 1200 and 1250
    - o SILAS returns good SN-ratio until density of 1250; below this plane an average density based on available Navitracker data is used to calculate the mass
    - o calculation of mass in each layer based on difference of plane depths and average layer density:
        1. DGD: bottom = design depth
        2. Kallo: bottom = -14 m TAW for navigation channel (depth of maintenance dredging = -11 m GLLWS) and –9 m TAW for side areas – based on maximum depth of Navitracker measurements

The sediment mass will be calculated in several zones in both Deurganckdok and the Kallo lock. The zones are specified in Figure 3-1 and Figure 3-2.

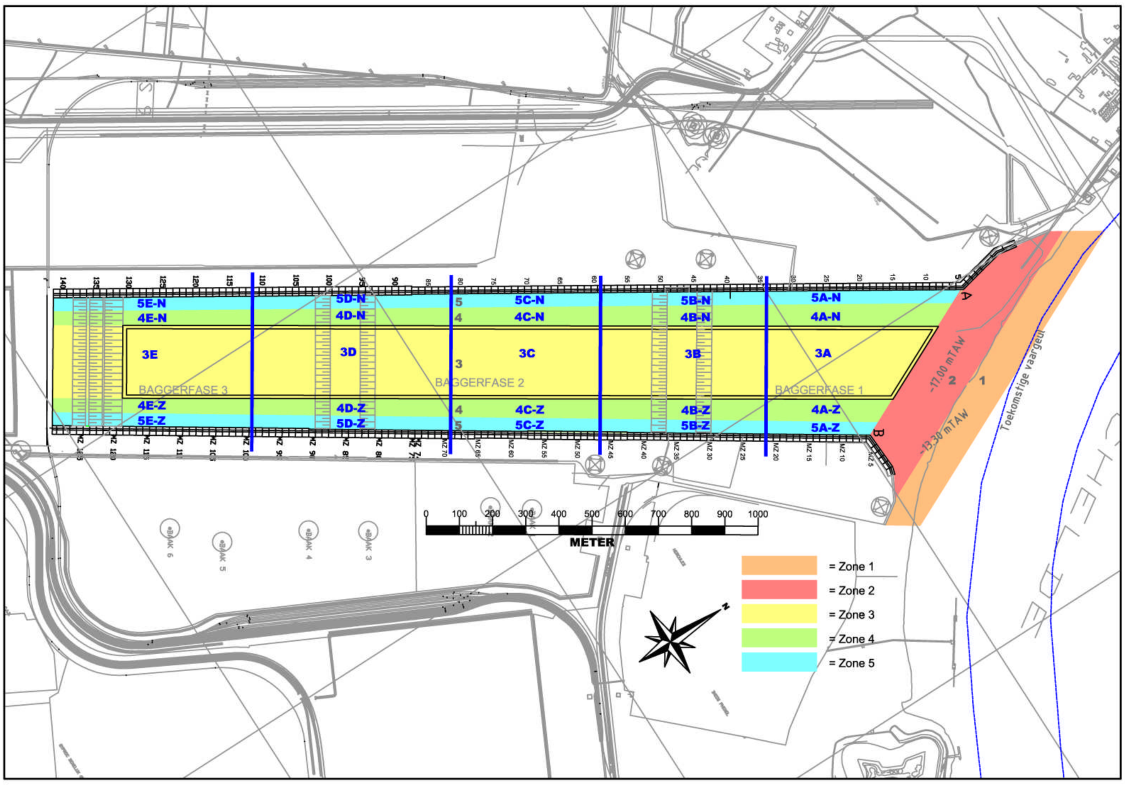


Figure 3-1: Zones and subzones in Deurganckdok

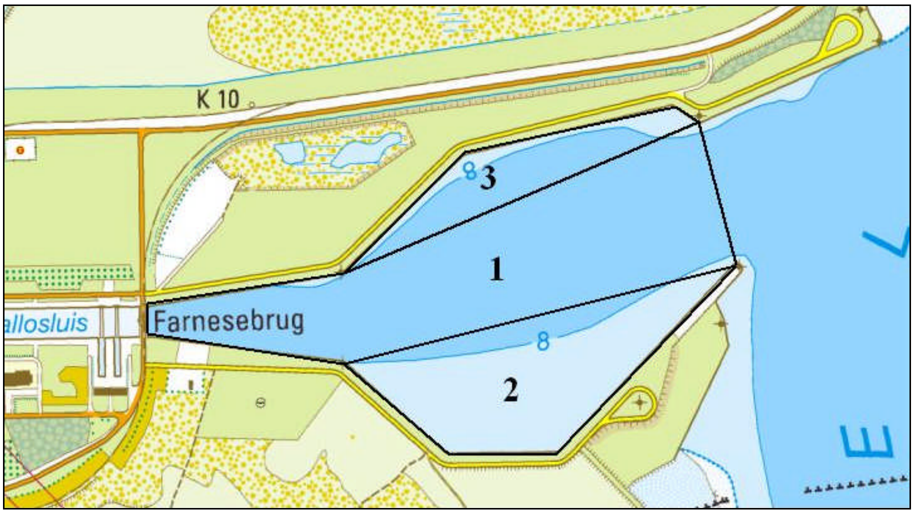


Figure 3-2: Zones in the navigation channel of Kallo lock

4. RESULTS AND DISCUSSION

The discussion of the results consists of three topics, i.e.

- the SILAS calibration;
- a comparison between the sediment mass calculations by Navitracker and SILAS; and
- the advantages and disadvantages of the two sediment mass estimations.

4.1. SILAS calibration

The SILAS calibration determines a vertical density profile based on the Navitracker samples. The SILAS software needs only three density measurements at different depths to perform the calibration of the local SILAS parameters. Examples of this calibration exercise are given in Annex 1. As observed, the calibrated density profiles not always correctly fit the measurements. Some large local discrepancies may occur. This may obviously result in differences in sediment mass calculations. The examples also show that densities larger than 1250 kg/m³ are described by means of heterogeneity coefficients, which are difficult to estimate.

Because SILAS needs to be calibrated, its frequency is very important as it is tedious and expensive. In this respect, Table 4-1 summarizes the four calibration parameters for different locations (Deurganckdok, navigation channel of Kallo lock, Boudewijn lock and Zandvliet lock) and dates. These sets of parameters were determined independent from each other. Some small differences exist between the different measurement campaigns, but trials show that the average values do not give any significant difference in the spatial distribution (vertical and horizontal) of densities.

Table 4-1: Calibration parameters of the SILAS for the different measurement locations and dates

location	measurement date	Ainv	Absorption	Heterogenity	Heterogenity starting dens
DGD	23/07/2007	307.92	0.35	0.65	1200
DGD	5/09/2007	359.88	0.35	0.65	1150
DGD	16/10/2007	297.93	0.35	1.05	1200
toegang Kallosluis	4/09/2007	304.14	0.35	0.65	1150
toegang Kallosluis	15/10/2007	260.43	0.35	1.05	1200
toegang Boudewijnsluis	4/09/2007	244.1	0.35	1.05	1200
toegang Zandvlietsluis	6/09/2007	258.86	0.3	0.6	1200
Averages		*290*	*0.34*	*0.81*	*1186*

4.2. Sediment mass calculations

The results of the sediment mass calculations can be found in Annex 2. The sediment masses were determined for different zones in both Deurganckdok and the navigation channel of the Kallo lock. Two measurement campaigns were performed for each location in order to discover some trends:

- Deurganckdok: 5 September 2007 (campaign 1; immediately after maintenance dredging) and 16 October 2007 (campaign 2)
- Navigation channel Kallo lock: 4 September 2007 (campaign 1) and 15 October 2007 (campaign 2)

The following conclusions can be drawn from the measurements (only those zones are considered with a 100% area coverage by the Navitracker):

- in general, the SILAS method returns a larger global mass in comparison to the Navitracker for the zones 3 in Deurganckdok; less mass is found for zones 4;
- the sediment mass difference between the two measurement methods for the zones changes between the different measurement campaigns, but the trend of maintaining the ratio of differences within one measurement campaign remains;

An in-depth comparison has been made between the densities in Deurganckdok as measured by the Navitracker and the SILAS. In this respect, Figure 4-1 and Figure 4-2 show some Navitracker density profiles in two zones for the central trench and near the quays respectively. Additionally, the top bed level (density of 1.01 ton/m³) and the maximum measurement depth (density of 1.25

ton/m³) measured by the SILAS are given in the figures as well. Densities larger than 1.25 ton/m³ are not measured and the sediment mass below this depth is estimated by an averaged density from the Navitracker. Whereas the Navitracker measures the local density from top till “bottom”, the SILAS only scans a part of the sediment bed depth (Figure 4-3). The remainder is estimated based on an average density from the Navitracker. Clearly, the sediment mass calculated/measured by the SILAS is only a small fraction in comparison with the estimated (consolidated) mass. Significant errors therefore may occur on the calculated sediment mass accumulation in the different zones in the dock.

From these preliminary results, it is clear that the SILAS is less efficient in measuring densities in consolidated sediment layers with values more than 1.25 ton/m³. It is however a useful device for:

- tracking the nautical bottom with great ease and large horizontal resolution (e.g. Westerschelde)
- determining the density profiles in areas without sharp density interfaces (e.g. harbour of Zeebrugge)

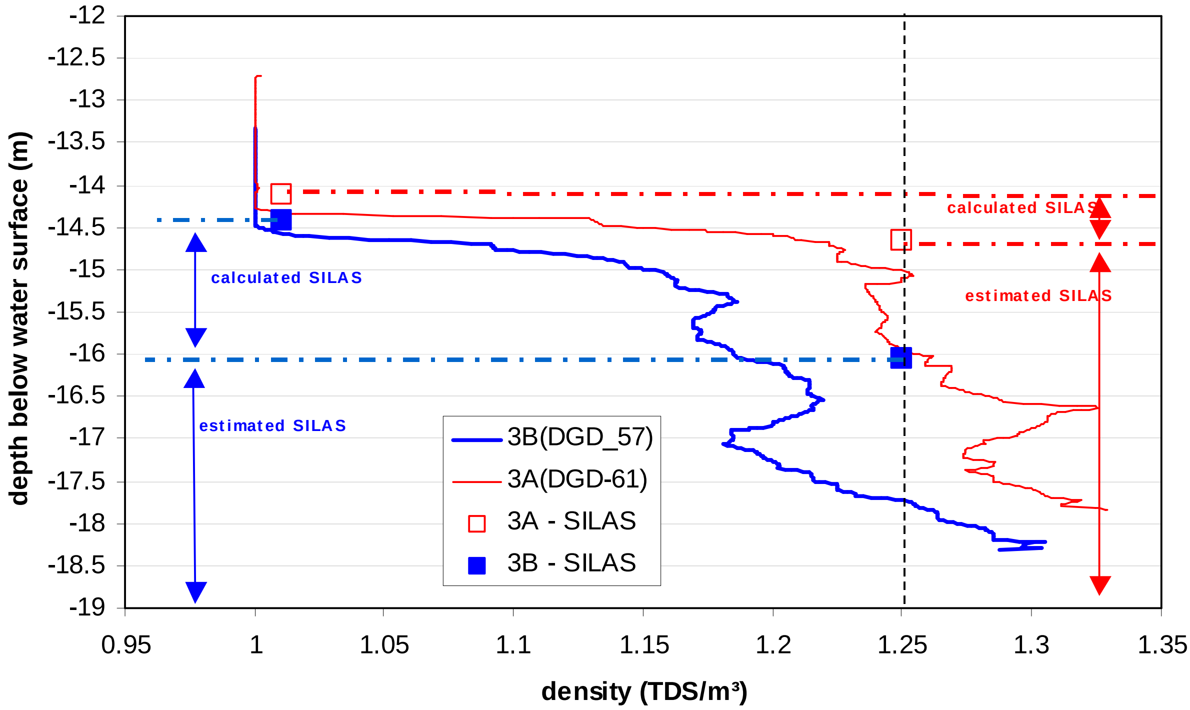


Figure 4-1: Densities measured in the central trench of Deurganckdok by Navitracker (profiles) and SILAS (densities of 1.01 ton/m³ (top bed) and 1.25 ton/m³)

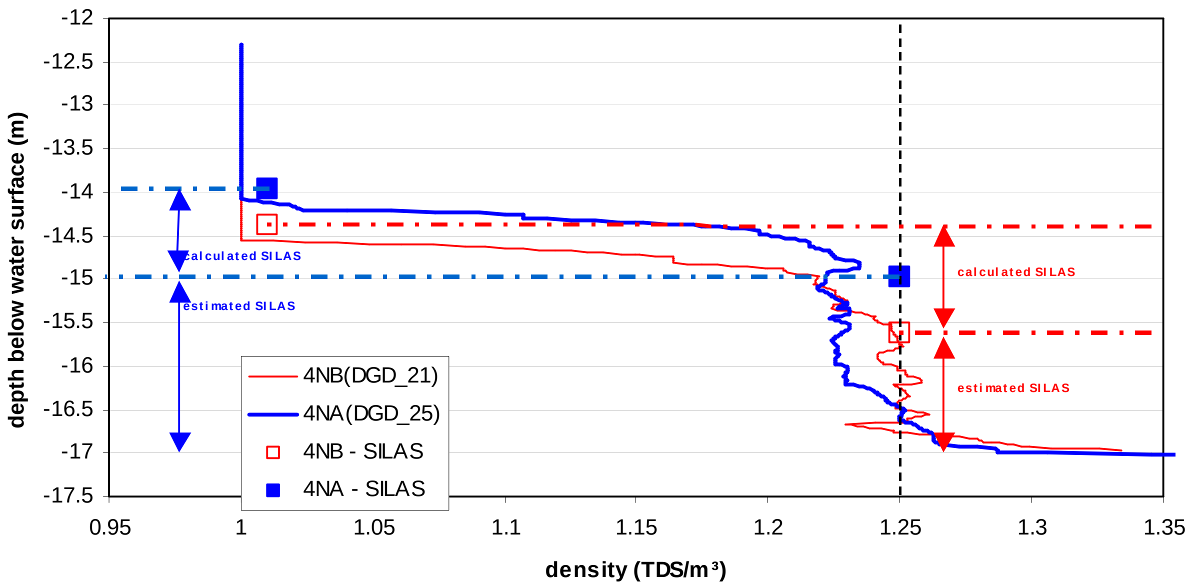


Figure 4-2: Densities measured near the quays of Deurganckdok by Navitracker (profiles) and SILAS (densities of 1.01 ton/m³ (top bed) and 1.25 ton/m³)

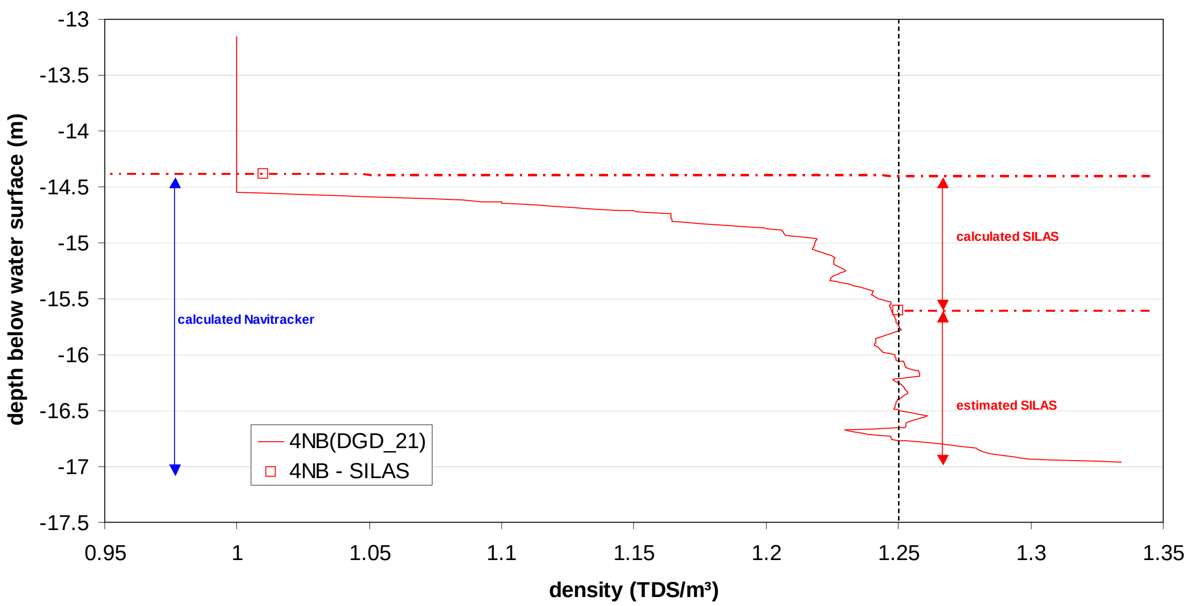


Figure 4-3: Comparison of measured/estimated fraction of the density profile between the Navitracker and the SILAS

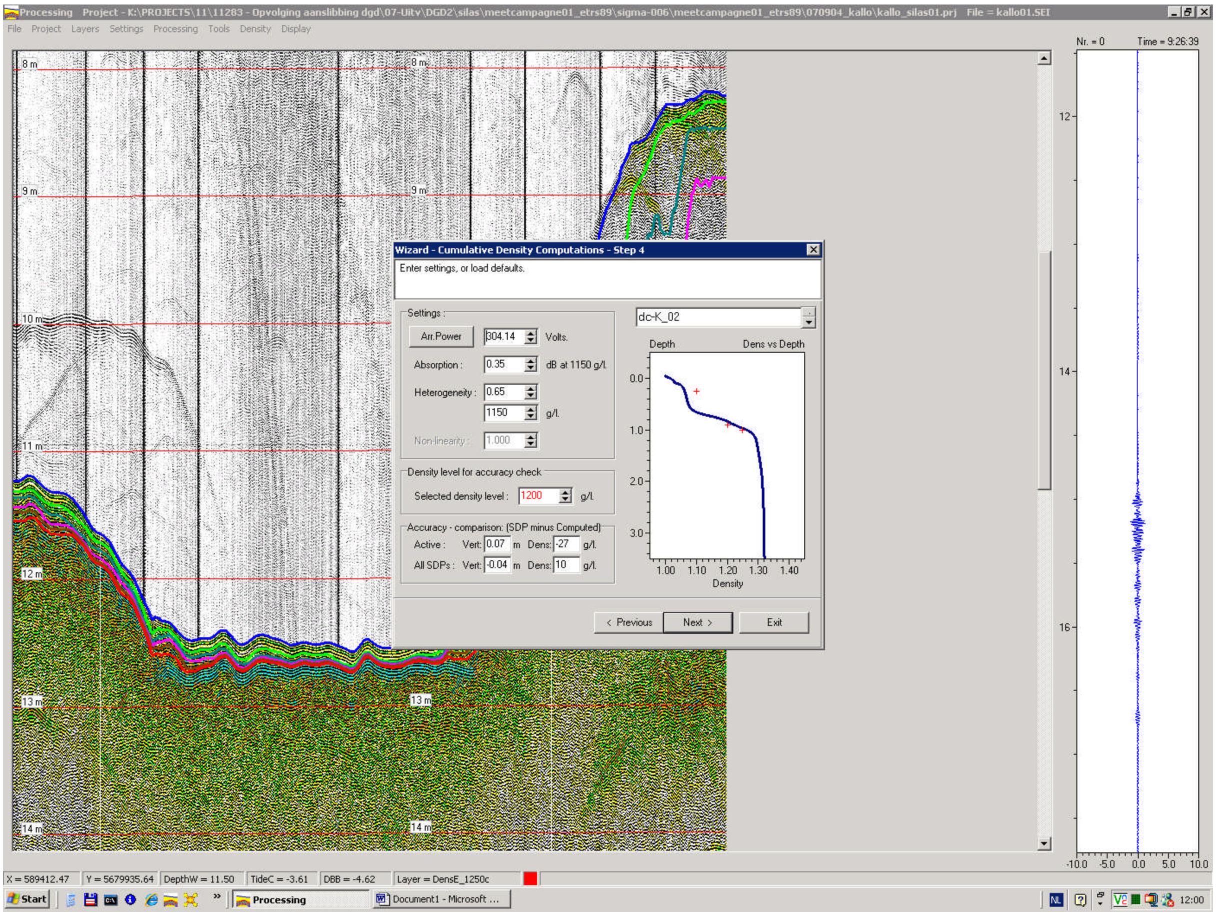
5. CONCLUSIONS

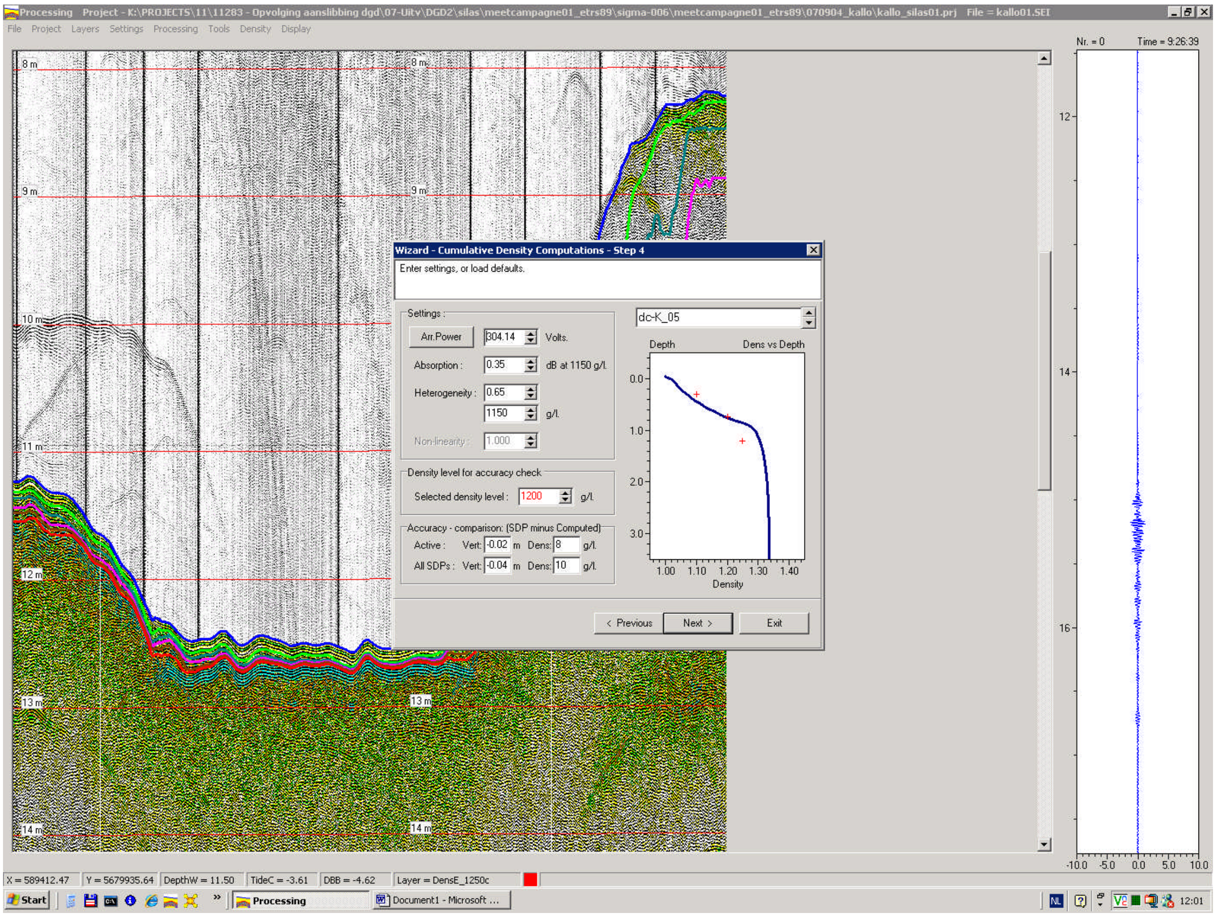
The performed work in this report illustrates that the SILAS is less appropriate for measuring densities of consolidated sediment layers. Less confident measurement data are collected for densities more than 1.25 ton/m³. In these cases, the Navitracker device should be preferred. However, the device demands for a fine sampling grid to perform good sediment mass calculations.

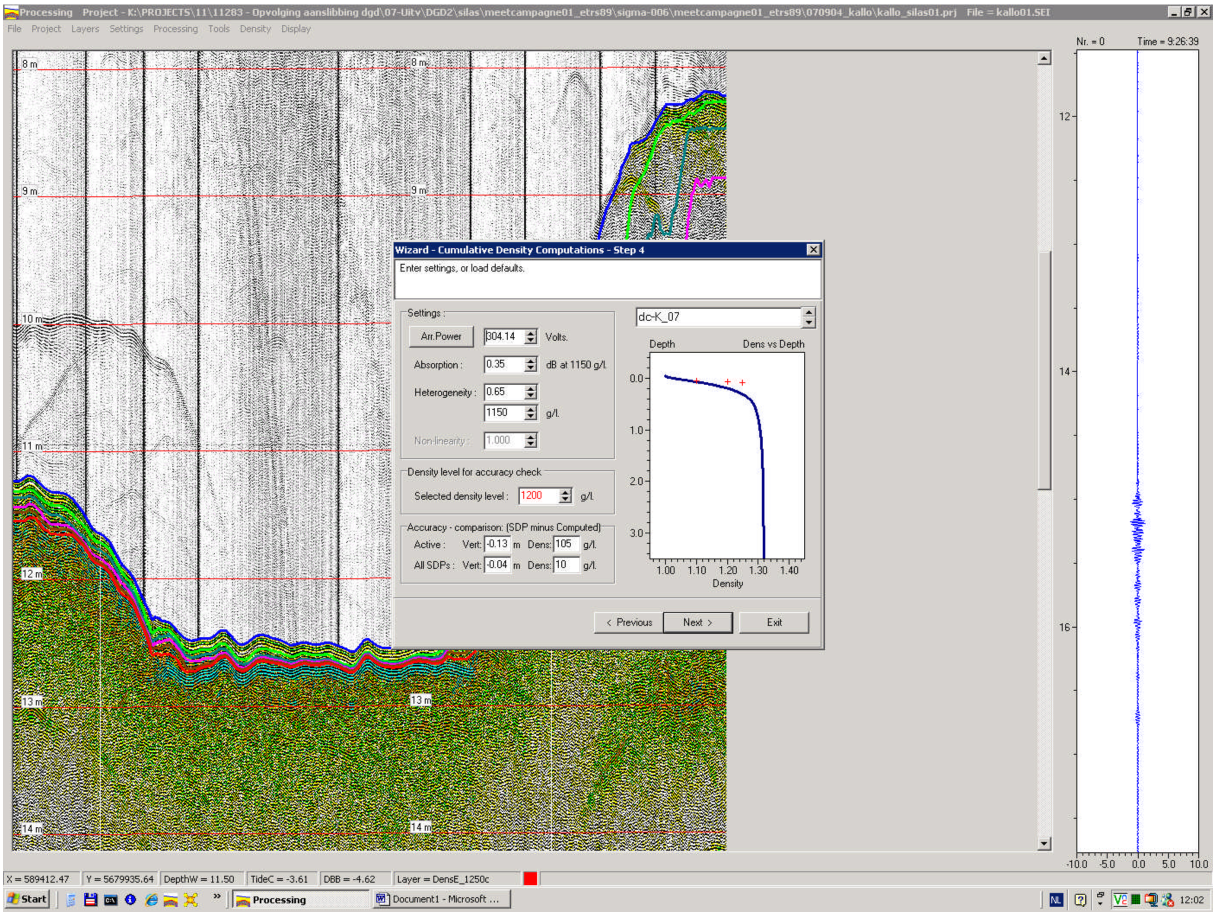
In case of the project “Deurganckdok 2”, Navitracker data is collected according to a dense measurement grid in Deurganckdock. Here, good sediment mass estimations can be performed. However, the entrance channels of the different measured locks do not show enough Navitracker measurements to accurately perform mass calculations. The SILAS technique is therefore

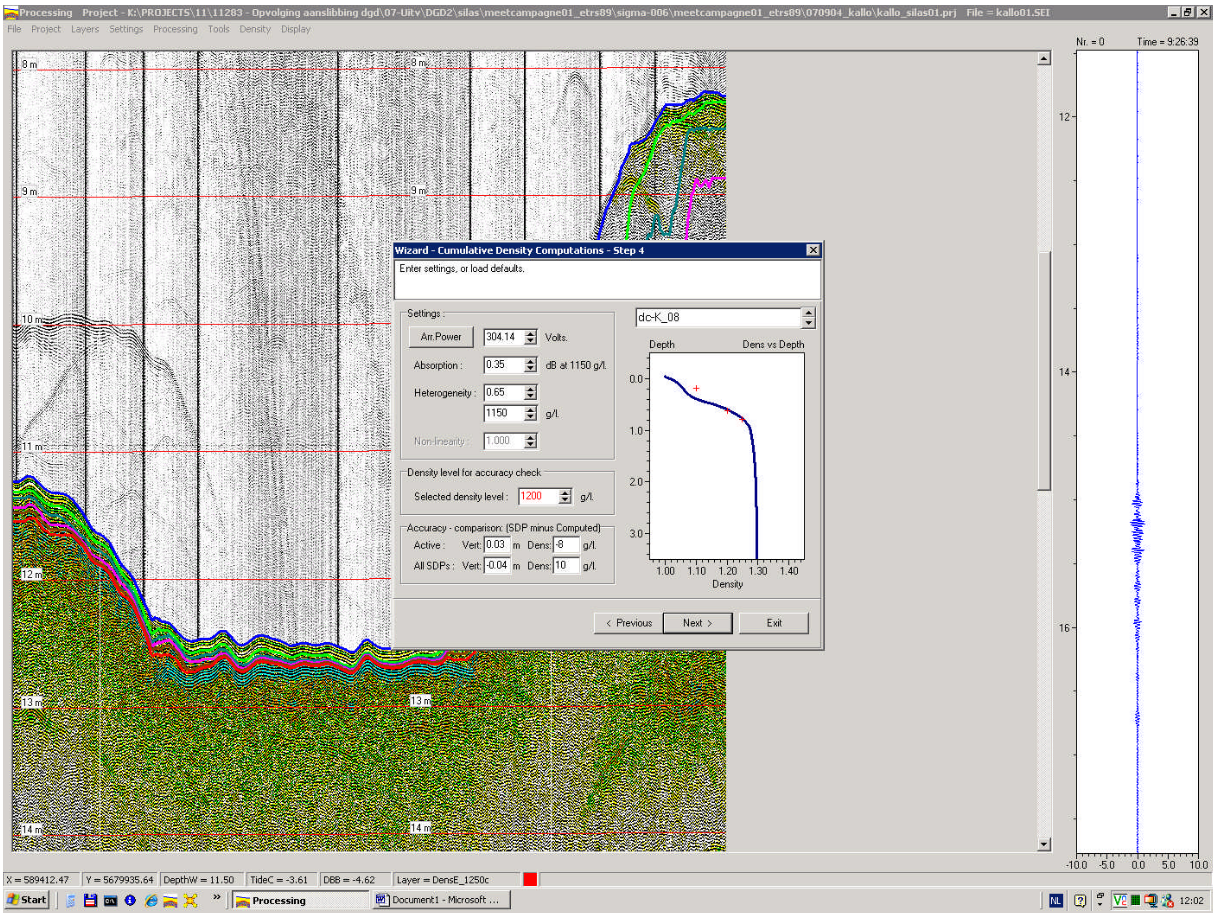
preferred and is to be combined with an average sediment density from the Navitracker applicable to the depth range corresponding to densities larger than 1.25 ton/m³.
For future upcoming sediment mass calculations (both Deurganckdok and entrance channels) it is suggested to perform Navitracker measurements according to a fine sampling grid.

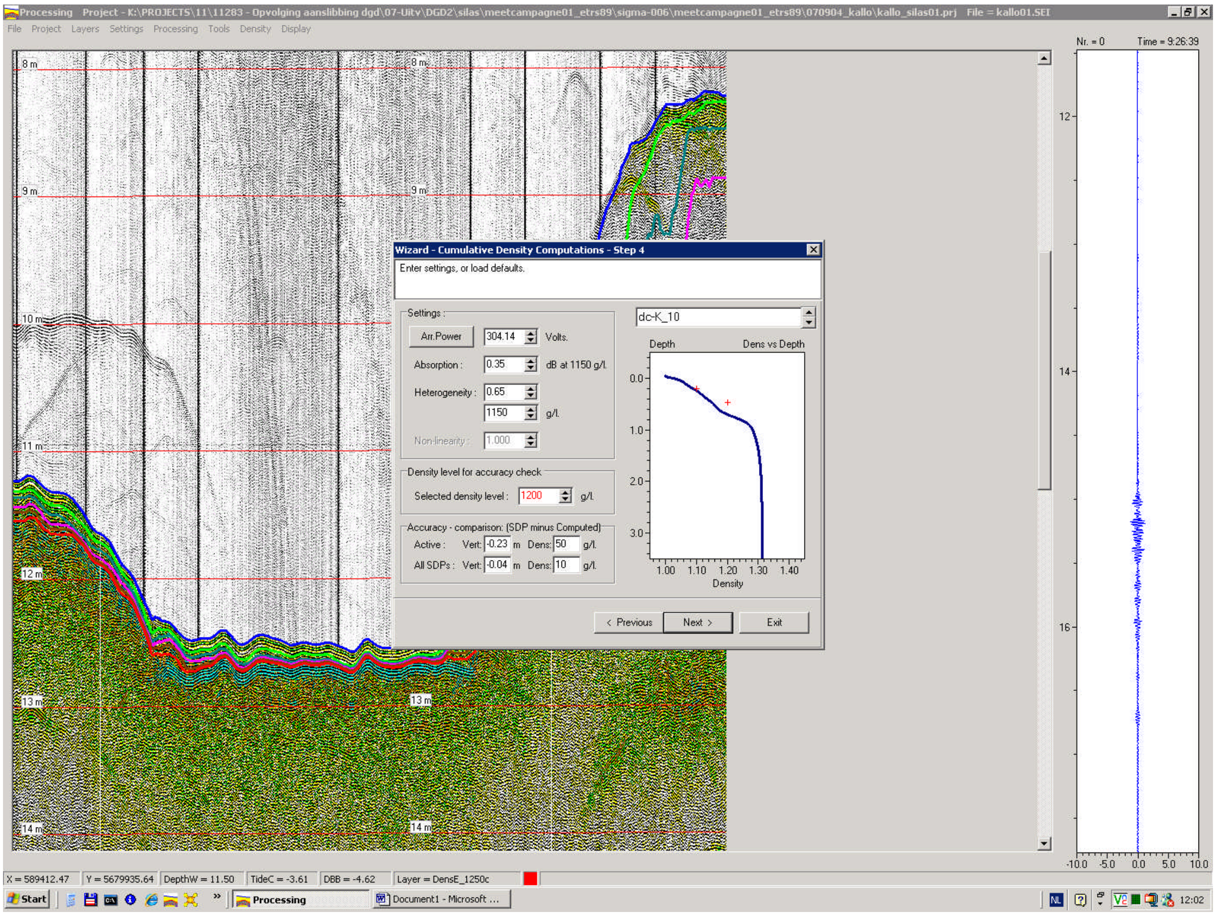
Annex 1:
Examples of calibrated SILAS density profiles










Wizard - Cumulative Density Computations - Step 4
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Settings :
Arr.Power
304.14
Volts.
Absorption :
0.35
dB at 1150 g/l.
Heterogeneity :
0.65
1150
g/l
Non-linearity :
1.000
Density level for accuracy check
Selected density level :
1200
g/l
Accuracy - comparison: (SDP minus Computed)
Active : Vert: -0.23 m Dens: 50 g/l
All SDPs : Vert: -0.04 m Dens: 10 g/l
dc-K_10
Depth
Dens vs Depth
Density
< Previous
Next >
Exit
X = 589412.47
Y = 5679935.64
DepthW = 11.50
TideC = -3.61
DBB = -4.62
Layer = DensE_1250c
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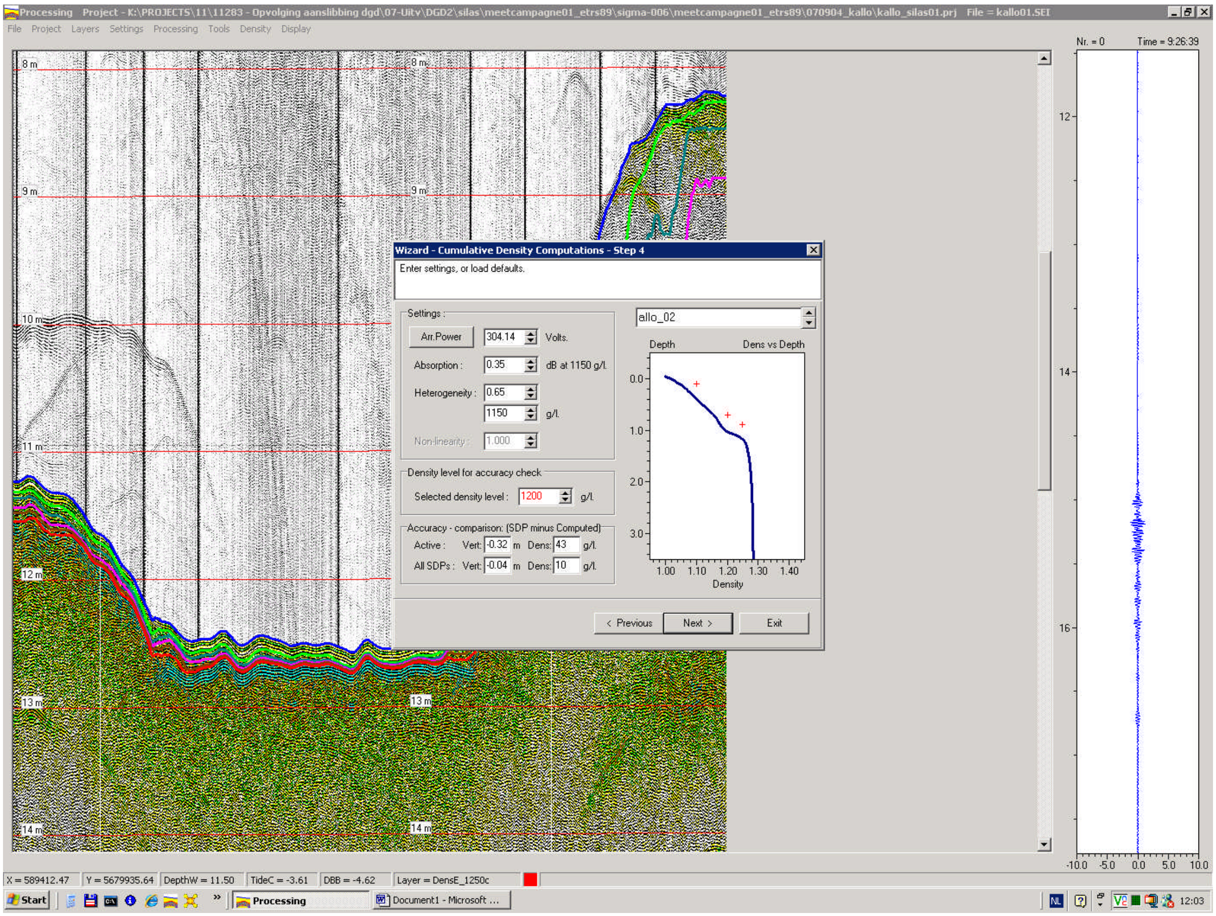
Processing
Document1 - Microsoft ...
12:02


Wizard - Cumulative Density Computations - Step 4
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Settings :
Arr.Power
304.14
Volts.
Absorption :
0.35
dB at 1150 g/l.
Heterogeneity :
0.65
1150
g/l
Non-linearity :
1.000
Density level for accuracy check
Selected density level :
1200
g/l
Accuracy - comparison: (SDP minus Computed)
Active : Vert: -0.32 m Dens: 43 g/l
All SDPs : Vert: -0.04 m Dens: 10 g/l
allo_02
Depth
Dens vs Depth
Density
< Previous
Next >
Exit
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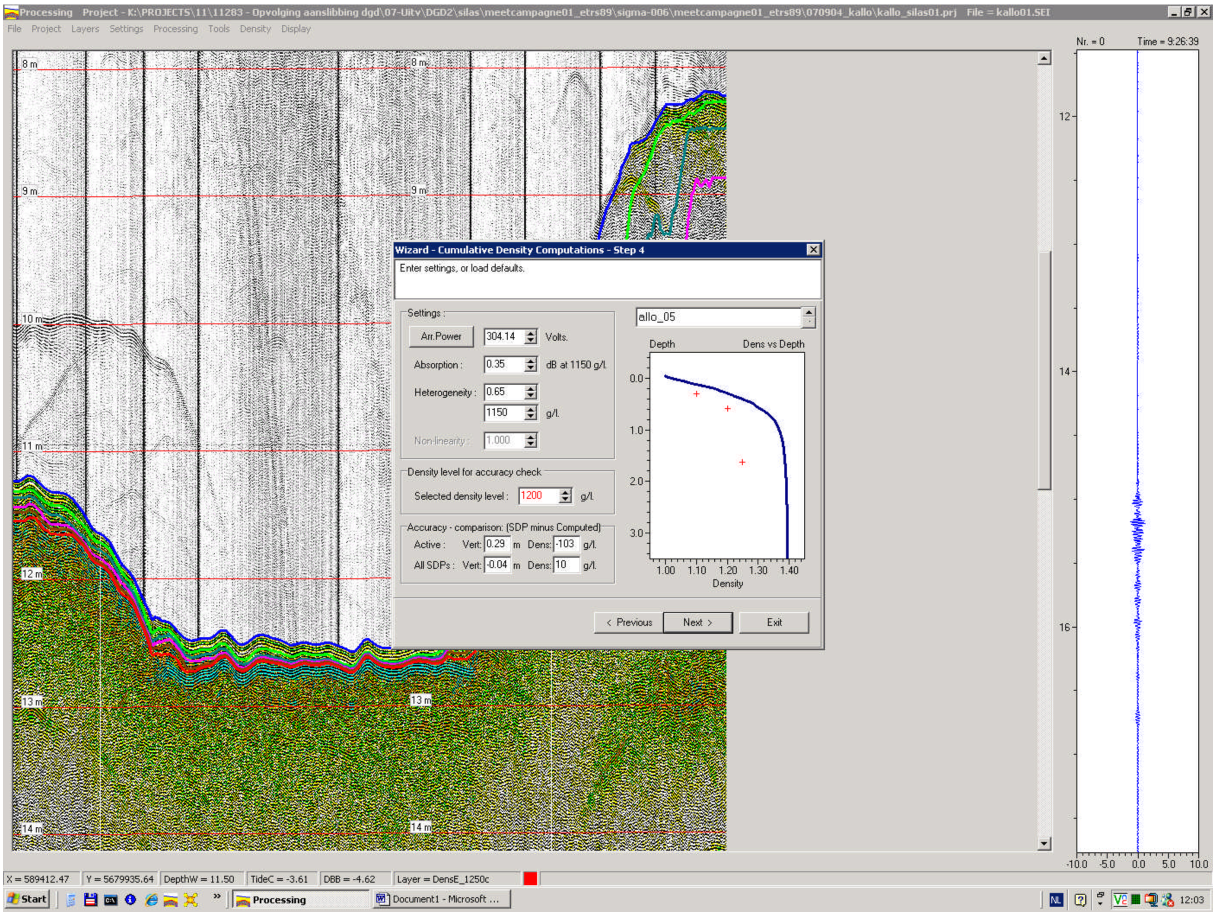

Annex 2:
Calculated sediment mass per zone

meetcampagne 1: DGD (5 Sept. 2007)

	Navitracker			Silas	ratio of Silas to Navitracker
zones	covered area (ha)	% coverage	mass (TDS)	mass (TDS)	
1	0.16	1		4255.7	
2	7.57	61	43073.3	12899.4	
3a	9.87	100	157821.3	145789.5	0.92
3b	10.99	100	141880.9	137926.5	0.97
3c	9.88	100	139308	139679.2	1.00
3d	1.11	9		59891.5	
3e					
4Na	3.64	100	44844.8	28367.4	0.63
4Nb	3.12	100	31855.2	22793.3	0.72
4Nc	2.51	97	20632.2	14909.9	0.72
4Nd	0.03	1		376.1	
4Ne					
4Za	2.42	100	29475.6	11365.9	0.39
4Zb	3.12	100	34132.8	14871.3	0.44
4Zc	2.26	87	20543.4	20539.8	1.00
4Zd				329.1	
4Ze					
5Na	1.9	83	27360	31762	1.16
5Nb	1.68	84	22226.4	20867.2	0.94
5Nc	1.29	71	13828.8	15313.9	1.11
5Nd				279.8	
5Ne					
5Za	0.98	75	9956.8	25931.6	2.60
5Zb	1.05	53	11613	26630.8	2.29
5Zc	0.26	15		1457.6	
5Zd				189.8	
5Ze					
TOTAL			748552.5	736427.3	0.98

meetcampagne 1: Kallo (4 Sept. 2007)

	Navitracker			Silas	ratio of Silas to Navitracker
zones	covered area (ha)	% coverage	mass (TDS)	mass (TDS)	
1	15.07	80	231324.5	144034.9	0.62
2	4.16	47		63029.4	
3	1.88	48		37637.2	

meetcampagne 2: DGD (16 Oct. 2007)

	Navitracker			Silas	ratio of Silas to Navitracker
zones	**covered area (ha)**	**% coverage**	**mass (TDS)**	**mass (TDS)**	
1	0.19	2		2526.3	
2	7.33	59	49037.7	8510.6	0.17
3a	9.87	100	194833.8	205551.9	1.06
3b	10.99	100	169026.2	193230.9	1.14
3c	9.91	100	155190.6	164085.6	1.06
3d	5.68	44		204440	
3e					
4Na	3.64	100	46046	23939.7	0.52
4Nb	3.12	100	33134.4	17828.4	0.54
4Nc	2.57	100	22102	14013.4	0.63
4Nd	0.99	30		1681.7	
4Ne					
4Za	2.42	100	27684.8	10465.8	0.38
4Zb	3.12	100	29452.8	12072.4	0.41
4Zc	2.59	100	22636.6	9286.9	0.41
4Zd	1.09	34		1315.2	
4Ze					
5Na	1.9	83	20330	40542	1.99
5Nb	1.57	79	18102.1	29523.7	1.63
5Nc	1.33	73	17050.6	19029.2	1.12
5Nd	0.41	17		26864.4	
5Ne					
5Za	0.63	48		21607.2	
5Zb	1.06	53	8755.6	25519.9	2.91
5Zc	0.96	53	7372.8	19040.5	2.58
5Zd	0.34	14		20991.9	
5Ze					
TOTAL			820756	1072067.6	1.31

meetcampagne 2: Kallo (15 Oct. 2007)

	Navitracker			Silas	ratio of Silas to Navitracker
zones	**covered area (ha)**	**% coverage**	**mass (TDS)**	**mass (TDS)**	
1	13.73	73	206361.9	170138	0.82
2	5.29	60	68928.7	67984.9	0.99
3	2.7	69	47277	39509.3	0.84