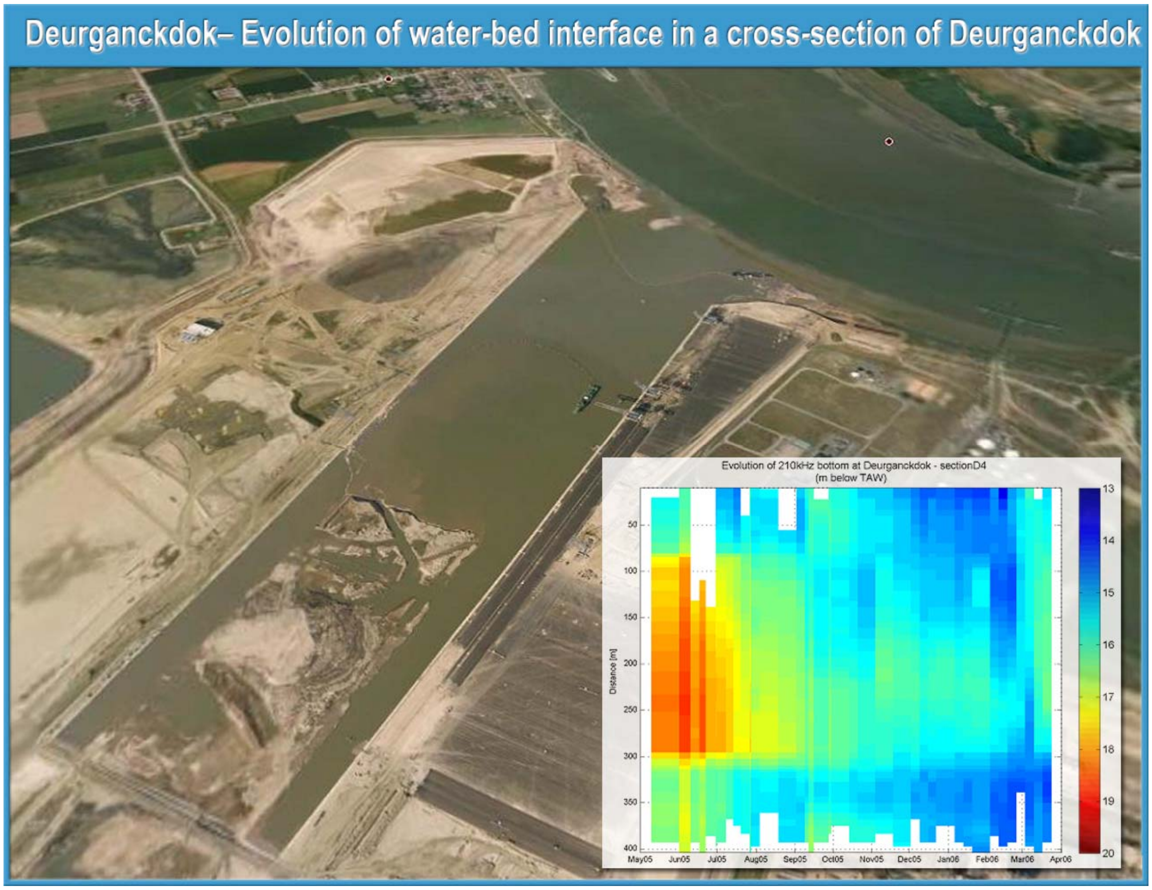
VLAAMSE OVERHEID

DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN
WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurganckdok 2: Opvolging en analyse aanslibbing

Bestek 16EB/05/04



Deelrapport 1.14 : **Sediment jaarbalans 01/04/2007 – 31/03/2008**

Report 1.14: **Annual sediment balance 01/04/2007 – 31/03/2008**

19 February 2009

I/RA/11283/07.085/MSA

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Document Control Sheet

Document Identification

Title:	Report 1.14: Annual sediment balance 01/04/2007 – 31/03/2008
Project:	Langdurige metingen Deurganckdok 2: Opvolging en analyse aanslibbing
Client	Waterbouwkundig Laboratorium
File reference:	I/RA/11283/07.085/MSA
File name	K:\PROJECTS\11\11283 - Opvolging aanslibbing dgd\10-Rap\DGD2\1_14_RA07085_AnnualBal0708\RA07085_AnnualBal_0708_v20_TAW.doc

Revisions

Version	Date	Author	Description
2.0	19/02/2009	BOB/JME	Final
1.0	13/10/2008	BOB/JME	Concept

Distribution List

Name	# ex.	Company/authorities	Position in reference to the project
Joris Vanlede	7	Waterbouwkundig Laboratorium	Client
Frederik Roose	3	afdeling Maritieme Toegang	Client

Approval

Version	Date	Author	Project manager	Commissioner
2.0	19/02/2009	BOB/JME	MSA	MSA
1.0	13/10/2008	BOB/JME	MSA	MSA

TABLE OF CONTENTS

1. INTRODUCTION 1

1.1. THE ASSIGNMENT 1
1.2. PURPOSE OF THE STUDY 1
1.3. OVERVIEW OF THE REPORTS 2
1.3.1. Reports 2
1.3.2. Measurement actions 4
1.4. STRUCTURE OF THE REPORT 4

2. SEDIMENTATION IN DEURGANCKDOK 6

2.1. PROJECT AREA: DEURGANCKDOK 6
2.2. OVERVIEW OF THE STUDIED PARAMETERS 7

3. MEASUREMENTS 10

3.1. DEPTH SOUNDINGS 10
3.2. DENSITY MEASUREMENTS 11
3.3. MAINTENANCE DREDGING DATA 12
3.4. CAPITAL DREDGING DATA 13
3.5. OVERVIEW OF ACTIVITIES AND PROCESSES 14

4. SEDIMENT BALANCE ANALYSES 15

4.1. PROJECT AREA: (SUB)ZONES AND SECTIONS 15
4.2. DEPTH OF THE WATER-BED INTERFACE (210 KC) 17
4.3. EVOLUTION OF WATER-BED INTERFACE (210 KC) 18
4.4. VOLUMETRIC SILTATION RATES [CM/DAY] IN DIFFERENT ZONES AND SECTIONS 20
4.5. AVERAGE NET MASS EVOLUTION 20

5. DATA ANALYSIS 23

5.1. INTRODUCTION 23
5.2. VOLUMETRIC SILTATION RATES 25
5.2.1. Gross yearly averaged siltation rate 25
5.2.2. Natural siltation rate 26
5.3. DENSIMETRIC SILTATION RATE 27
5.3.1. Dredged sediment mass 27
5.3.2. Vertical density profiles 28
5.3.3. Densimetric growth rate 28
5.3.4. Total deposited mass 29

6. SEDIMENT MASS BALANCE: LIMITATIONS 31

7. CONCLUSIONS 32

8. REFERENCES 33

APPENDICES

APPENDIX A. DEPTH OF THE WATER-BED INTERFACE (210 KC) 35
APPENDIX B. EVOLUTION OF DEPTH OF WATER-BED INTERFACE (210 KC) 37
APPENDIX C. VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS 58
APPENDIX D. DEPTH OF PLANES OF CONSTANT DENSITY 88
APPENDIX E. AVERAGE MASS GROWTH AND GROWTH RATE 131
APPENDIX F. DREDGING DATA 160

LIST OF TABLES

TABLE 1-1: OVERVIEW OF DEURGANCKDOK REPORTS 2
TABLE 3-1: OVERVIEW OF THE AVAILABLE DEPTH SOUNDINGS SUITABLE FOR ANALYSIS 01/01/2008 – 31/03/200810
TABLE 3-2: REFERENCE SITUATION DENSITY MEASUREMENTS (T_{0D})........ 12
TABLE 3-3: SWEEP BEAM MAINTENANCE DREDGING ACTIVITIES IN DEURGANCKDOK AND ON THE SILL OF DEURGANCKDOK FOR THE PERIOD MARCH 2007-2008 (SOURCE: AFDELING MARITIEME TOEGANG) 13
TABLE 3-4: OVERVIEW OF MEASUREMENTS AND DREDGING ACTIVITIES IN THE DEURGANCKDOK 14
TABLE 4-1: COORDINATES OF SECTIONS [UTM ED50] 17
TABLE 5-1: GROSS YEARLY AVERAGED SILTATION RATES FOR EVERY ZONE 25
TABLE 5-2: NATURAL SILTATION RATES OBTAINED FROM UNDISTURBED MEASUREMENT PERIODS 27
TABLE 5-3: AMOUNTS OF DREDGED MASS PER ZONE AND DREDGING PERIOD 28
TABLE 5-4: TOTAL SEDIMENT MASS (MEASURED + DREDGED, IN 10³ TDS) IN SOME ZONES 29
TABLE 5-5: MASS SETTLED PER SUBZONE IN ZONES 3 AND 4 (MEASURED + DREDGED, IN 10³ TDS) 30

LIST OF FIGURES

FIGURE 2-2: ELEMENTS OF THE SEDIMENT BALANCE 7
FIGURE 2-3: DETERMINING A SEDIMENT BALANCE 8
FIGURE 2-4: TRANSPORT MECHANISMS 9
FIGURE 3-1: NAVITRACKER 11
FIGURE 4-1: DEURGANCKDOK: ZONES AND SUBZONES 15
FIGURE 4-2: DEURGANCKDOK: D AND L SECTIONS 16
FIGURE 4-3: DEPTH OF WATER-BED INTERFACE (210 KHZ) FOR 27/04/2007 AND 13/03/2008........ 18
FIGURE 4-4: DIFFERENCE CHART OF THE DEPTH SOUNDING ON 13/03/08, IN REFERENCE TO 27/04/2007........ 19
FIGURE 4-5: GRAPH OF EVOLUTION OF THE WATER-BED INTERFACE (210 KC) FOR SECTION D5 19
FIGURE 4-6: VOLUMETRIC SILTATION RATE FOR ZONE 3A 20
FIGURE 4-7: FLOW CHART WITH DIFFERENT ELEMENTS CONTRIBUTING TO TOTAL SEDIMENT MASS FOR (SUB)ZONES AND TOTAL AREA 21
FIGURE 4-8: EXAMPLE OF AVERAGED MASS GROWTH AND MASS EVOLUTION FOR SUBZONE 3B 22
FIGURE 5-1: DIFFERENCE BETWEEN NATURAL AND GROSS (VOLUMETRIC) SILTATION RATE 24
FIGURE 5-2: PRINCIPLE OF TOTAL DEPOSITED SEDIMENT MASS CALCULATED FROM THE MEASURED MASS M_{MEAS} AND DREDGED MASS M_{DREDGE} 24

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 1/1/2008 – 31/03/2008 (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 to calibrate all turbidity and conductivity sensors (IMDC, 2006f & IMDC, 2007l).

1.4. Structure of the report

This report presents the annual sediment balance of the Deurganckdok for the period of 01/04/2007 to 31/03/2008. The first chapter comprises an introduction. The second chapter describes the project. Chapter 3 deals with the collected data over the one-year measurement period, whereas the method of data processing is presented in Chapter 4. Chapter 5 gives an analysis of the one-year dataset. Finally, Chapter 6 will discuss some limitations of the actual data set and recommendations to make a sediment mass balance of the dock possible.

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

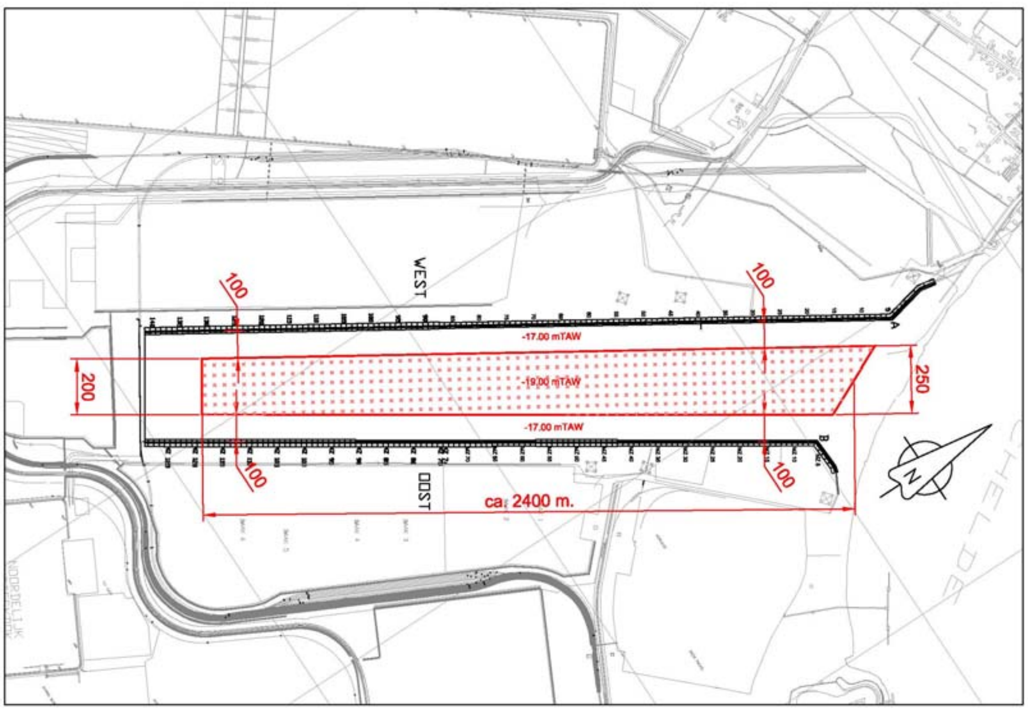


Figure 2-1: Overview of Deurganckdok

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 finalised 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).

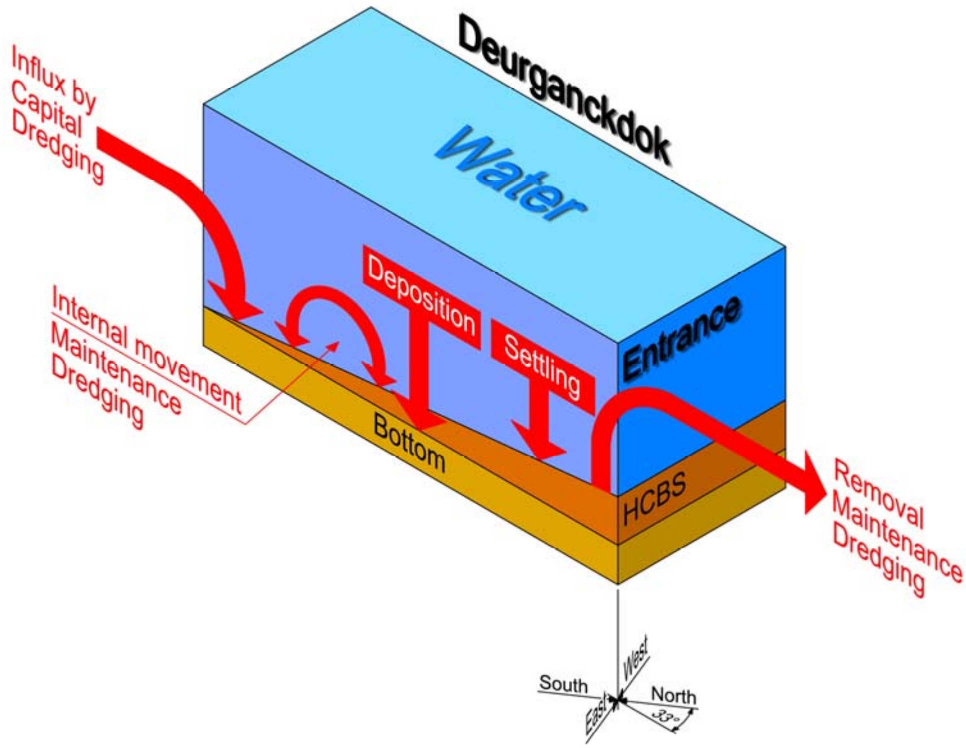


Figure 2-2: Elements of the sediment balance

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.

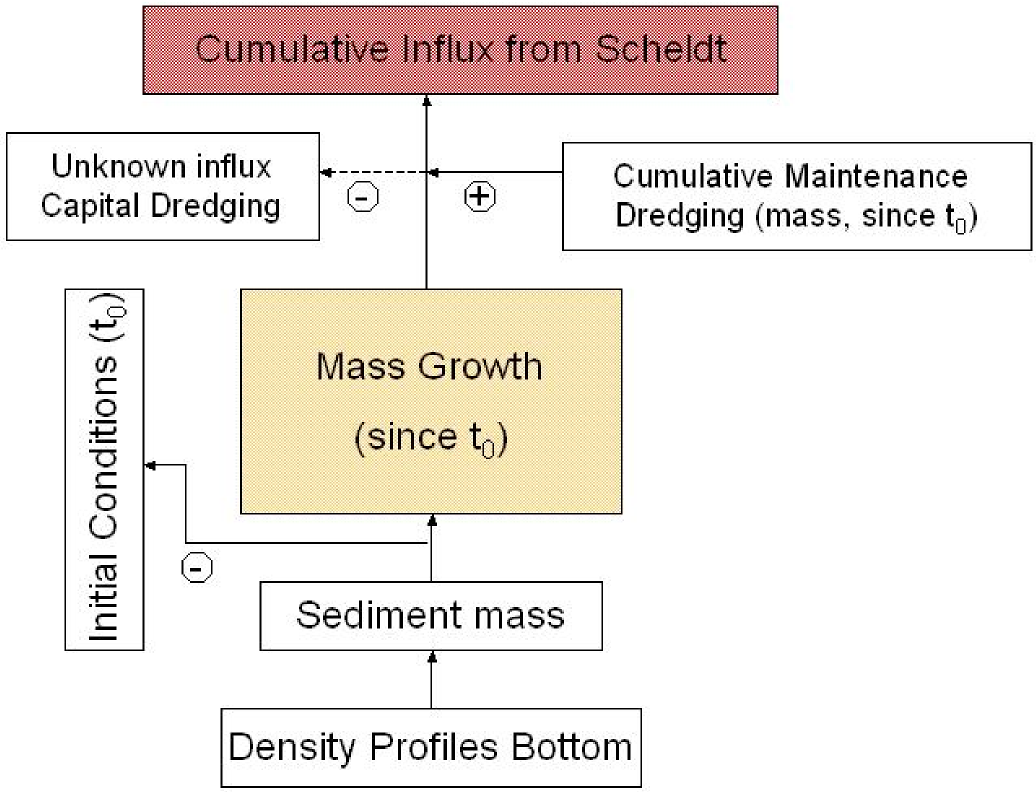


Figure 2-3: Determining a sediment balance

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

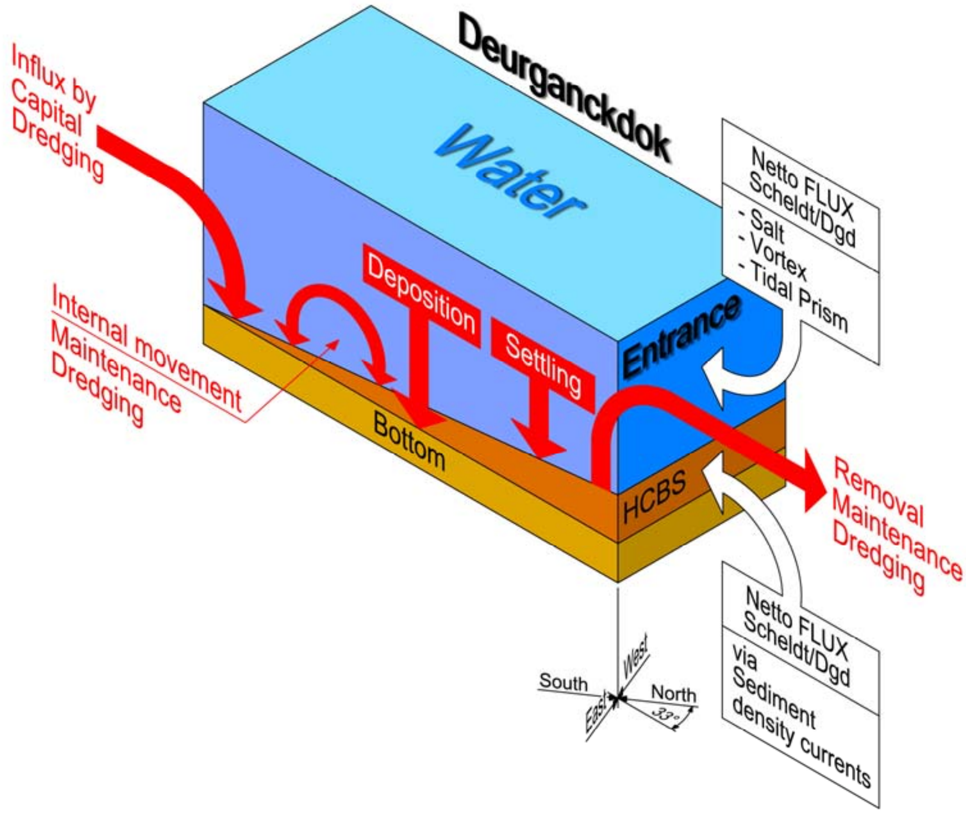


Figure 2-4: Transport mechanisms

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.

Additional depth soundings could be derived from performed SILAS density measurements too. As such, extra 210 kHz acoustic reflectance measurements became available as shown in Table 3-1.

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 01/01/2008 – 31/03/2008

date	type of measurement	signal	Source
24/03/2006*	dual frequency 210-33 kHz	210	Afdeling Kust
27/04/2007	dual frequency 210-33 kHz	210	Afdeling Kust
23/05/2007	dual frequency 210-33 kHz	210	Afdeling Kust
22/06/2007	dual frequency 210-33 kHz	210	Afdeling Kust
27/07/2007	dual frequency 210-33 kHz	210	Afdeling Kust
31/08/2007	dual frequency 210-33 kHz	210	Afdeling Kust
5/09/2007	SILAS – 210 kHz	210	
28/09/2007	dual frequency 210-33 kHz	210	Afdeling Kust
16/10/2007	SILAS – 210 kHz	210	
7/11/2007	dual frequency 210-33 kHz	210	Afdeling Kust
16/11/2007	SILAS – 210 kHz	210	
5/12/2007	SILAS – 210 kHz	210	
13/12/2007	dual frequency 210-33 kHz	210	Afdeling Kust
8/01/2008	dual frequency 210-33 kHz	210	Afdeling Kust
11/01/2008	dual frequency 210-33 kHz	210	Afdeling Kust
25/01/2008	dual frequency 210-33 kHz	210	Afdeling Kust
15/02/2008	dual frequency 210-33 kHz	210	Afdeling Kust
13/03/2008	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.

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

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 the following dates:

- 5 September 2007;
- 16 October 2007;
- 16 November 2007;
- 5 December 2007;
- 24 January 2008; and
- 22 February 2008.

~~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. An overview of the total dredged mass in all zones (BIS data) is provided in APPENDIX F.

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

- 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 in Table 3-3 of where and when a sweep beam dredger was working in Deurganckdok (DGD) or on the sill of Deurganckdok (sill DGD) for the period March 2007-2008.

[1] V' = Reduced Volume

Table 3-3: Sweep beam maintenance dredging activities in Deurganckdok and on the sill of Deurganckdok for the period March 2007-2008 (source: Afdeling Maritieme Toegang)

From	*Till*	*Duration (days)*	*Location*
2/04/2007	7/04/2007/2007	5	Sill DGD + DGD
11/04/2007	14/04/2007	3	Sill DGD + DGD
16/04/2007	16/04/2007	1	Sill DGD
23/04/2007	28/04/2007	5	Sill DGD + DGD + CKN
2/05/2007	2/05/2007	1	Sill DGD
7/05/2007	7/05/2007	1	Sill DGD
14/05/2007	16/05/2007	3	Sill DGD + comm quays
21/05/2007	26/05/2007	5	Sill DGD + DGD + CKN
29/05/2007	2/06/2007	5	Sill DGD + DGD + CKN
4/06/2007	4/06/2007	1	Sill DGD
12/06/2007	16/06/2007	4	Sill DGD
18/06/2007	23/06/2007	5	Sill DGD
25/06/2007	25/06/2007	1	Sill DGD
2/07/2007	2/07/2007	1	Sill DGD
12/07/2007	12/07/2007	1	Sill DGD
16/07/2007	16/07/2007	1	Sill DGD
24/07/2007	24/07/2007	1	Sill DGD
1/08/2007	1/08/2007	1	Sill DGD
6/08/2007	6/08/2007	1	Sill DGD
16/08/2007	17/08/2007	2	Sill DGD
20/08/2007	25/08/2007	5	Sill DGD + small part of commercial berths north and south
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
7/01/2008	7/01/2008	1	Sill DGD
11/01/2008	11/01/2008	1	Sill DGD + commercial quays
14/01/2008	16/01/2008	3	Sill DGD
21/01/2008	23/01/2008	3	Sill DGD + DGD
28/01/2008	28/01/2008	1	Sill DGD
30/01/2008	30/01/2008	1	Sill DGD
1/02/2008	1/02/2008	1	Sill DGD
4/02/2008	5/02/2008	2	Sill DGD + northern commercial quays
3/03/2008	3/03/2008	1	Sill DGD

~~3.2.~~3.4. Capital Dredging Data

In February 2007, the 3^{rd} 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 March 2007-2008, progress data is only available for the following dates:

- 3 April 2007;
- 2, 8 and 21 May 2007;
- 6 and 18 June 2007;
- 25 and 31 July 2007;
- 6 and 28 August 2007;
- 3, 12, 18 and 25 September 2007;
- 4, 16, 24 and 30 October 2007;
- 26 November 2007;
- 3 December 2007; and
- 8 February 2008.

The last date is the date of completion of the capital dredging works.

The 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.

~~3.3.~~3.5. Overview of activities and processes

To facilitate the data analysis in Chapter 5, Table 3-4 gives an overview of all conducted measurements and human interferences on the natural siltation in the dock. This makes it possible to identify periods of undisturbed siltation of specific zones in the dock, i.e. without any dredging operations. In this way, it is possible to distinguish between the "natural" siltation and "gross" siltation; the latter indicates that human interferences are included in the measurement results too. This is especially important for the determination of the natural volumetric siltation rate, as discussed in §5.2.

Table 3-4~~3-4~~: Overview of measurements and dredging activities in the Deurganckdok

	April 07		May 07		June 07		July 07		August 07		September 07	
activity	1 - 15	16 - 30	1 - 15	16 - 31	1 - 15	16 - 30	1 - 15	16 - 31	1 - 15	16 - 31	1 - 15	16 - 30
depth sounding												
density measurements												
maintenance dredging												
sweep beam dredging - sill												
sweep beam dredging - commercial quays												
capital dredging												

	October 07		November 07		December 07		January 08		February 08		March 08	
activity	1 - 15	16 - 31	1 - 15	16 - 30	1 - 15	16 - 31	1 - 15	16 - 31	1 - 15	16 - 28	1 - 15	16 - 31
depth sounding												
density measurements												
maintenance dredging												
sweep beam dredging - sill												
sweep beam dredging - commercial quays												
capital dredging												

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.

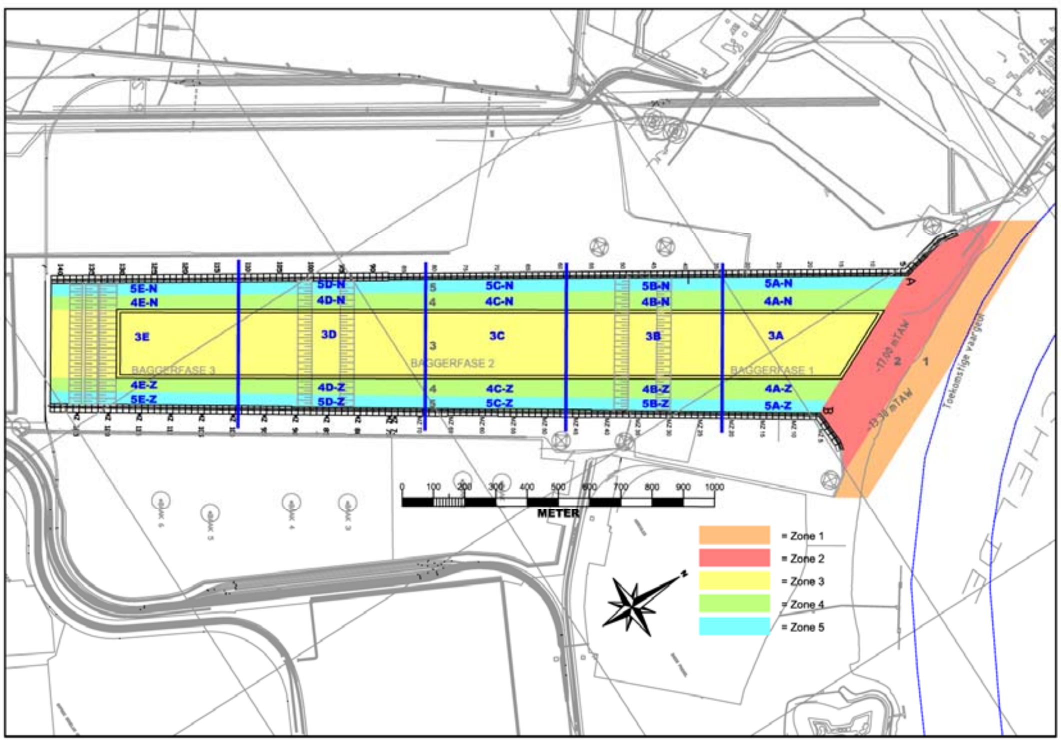


Figure 4-1: Deurganckdok: Zones and Subzones

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.

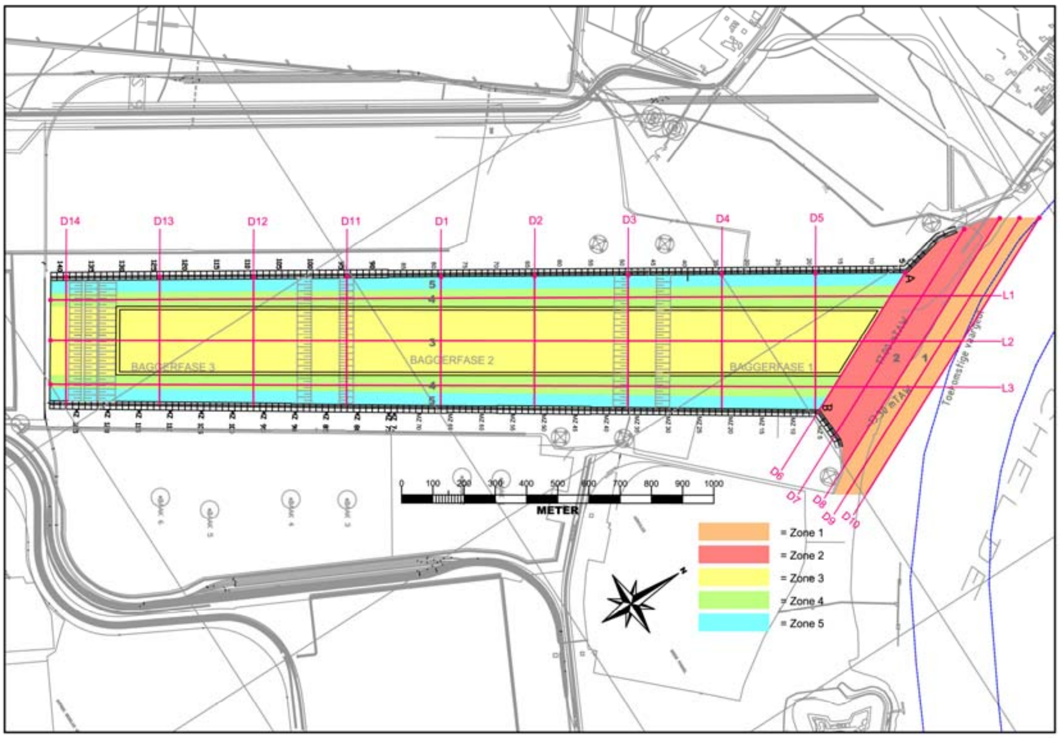


Figure 4-2: Deurganckdok: D and L Sections

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. The initial and final bathymetries are shown in Figure 4-3, and the enlarged format can be found in APPENDIX A. Only these depth soundings are considered in this report because the annual trend is aimed at. All other collected depth sounding dataset can be found in IMDC (2007m, 2007n, 2008a, 2008b).

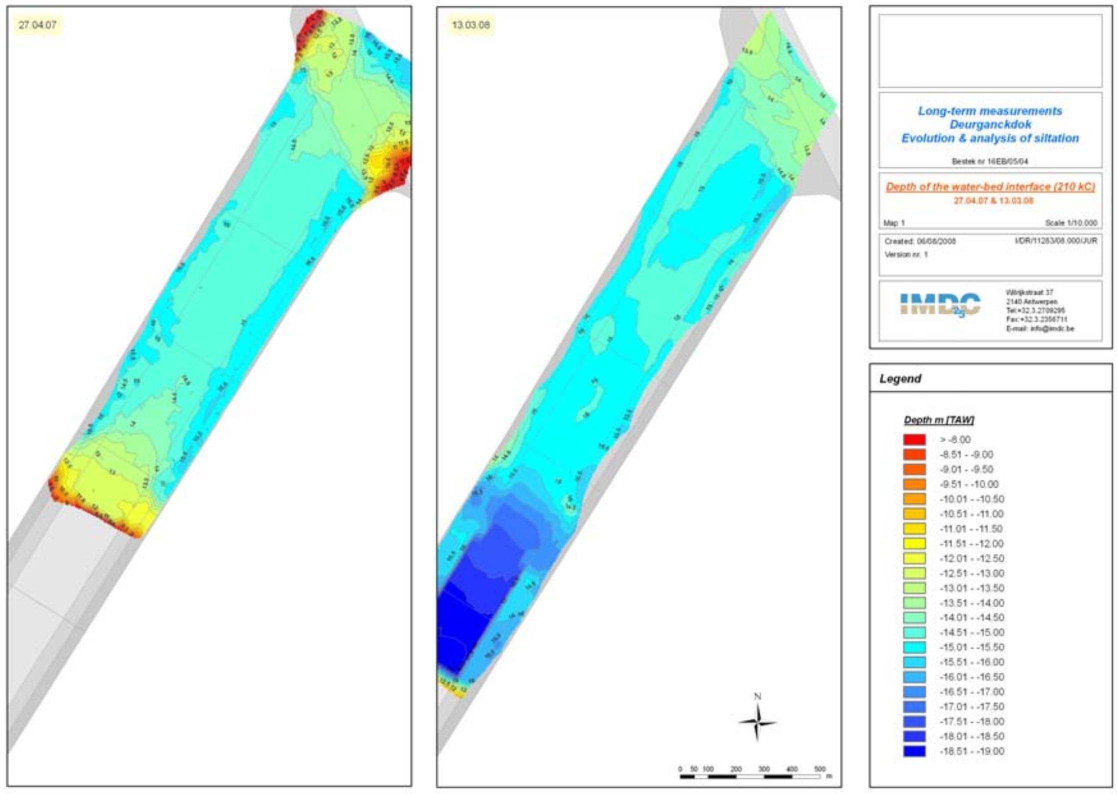


Figure 4-3: Depth of water-bed interface (210 kHz) for 27/04/2007 and 13/03/2008

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

GIS grid maps show the difference charts for every depth sounding in relation to a reference situation. Figure 4-4 shows such a difference chart covering the period of one year. Note that intermediate difference charts can be found in IMDC (2007m, 2007n, 2008a, 2008b).

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.

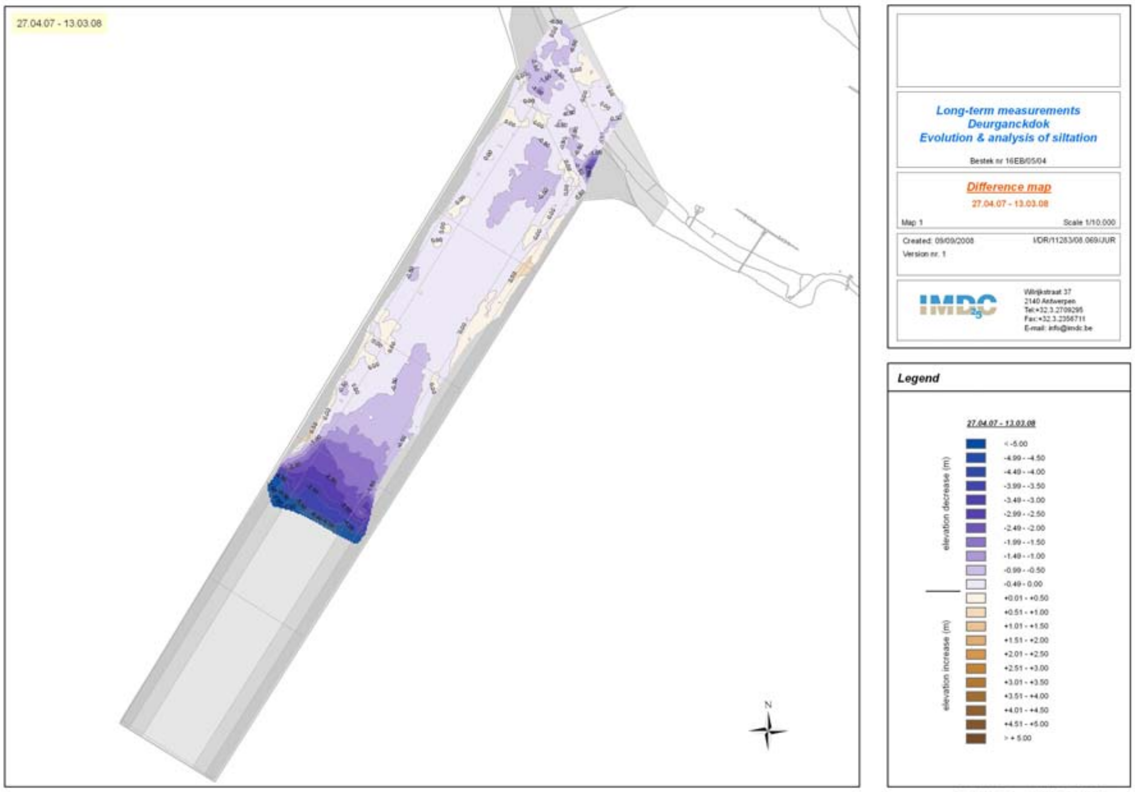


Figure 4-4: Difference chart of the depth sounding on 13/03/08, in reference to 27/04/2007

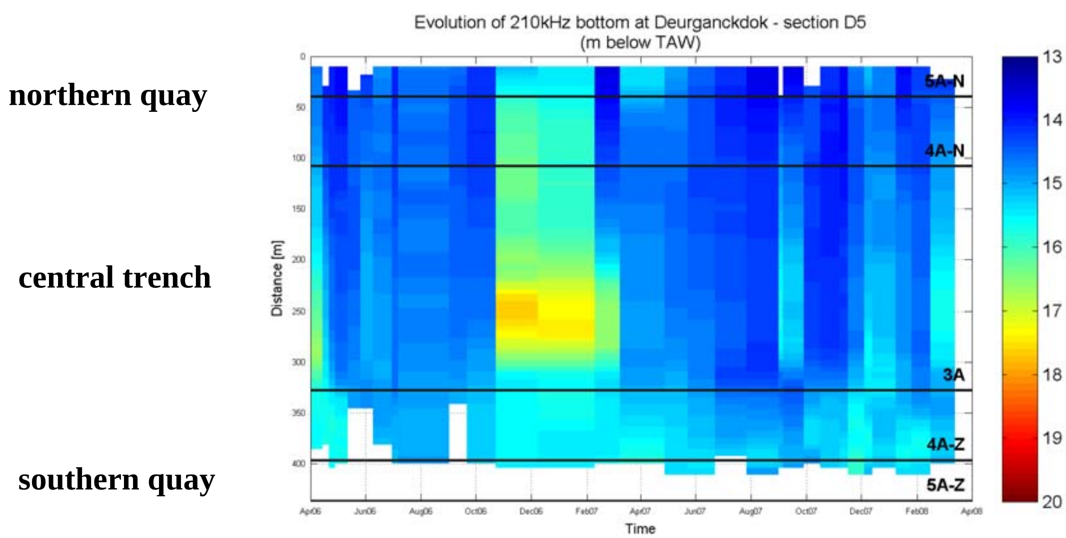


Figure 4-5: Graph of Evolution of the water-bed interface (210 kC) for section D5

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

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

Graphs in APPENDIX C show two parameters:

- Gross siltation rates [cm/day]: The gross 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. It is shown in the plots as a bar and is positive for sedimentation and negative for erosion or sediment removal.
- Cumulative bed level change [m]: an initial situation (t_{0e}) 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.

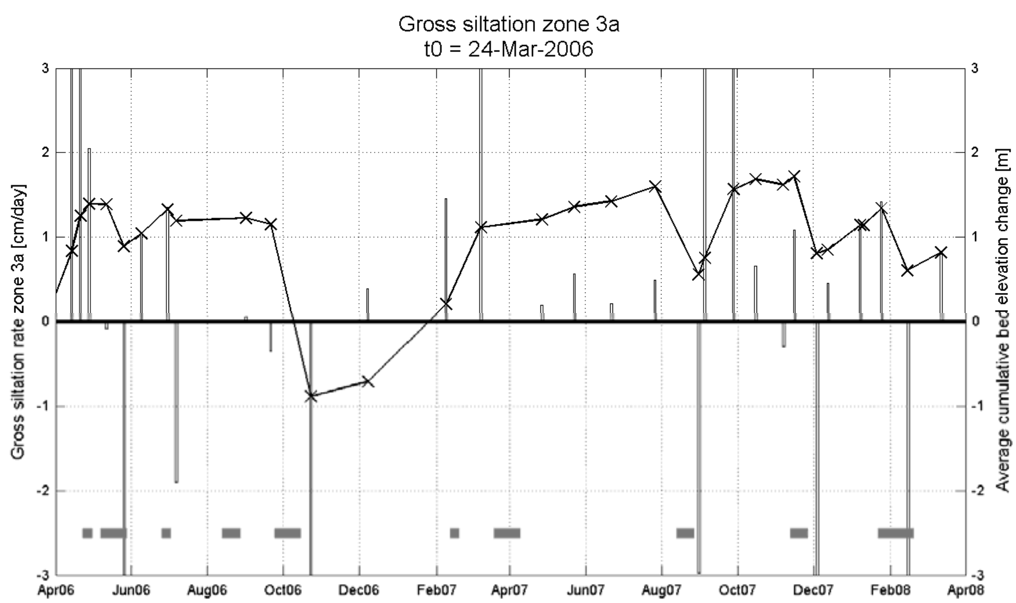


Figure 4-6: Volumetric siltation rate for zone 3a

4.5. Average net mass evolution

This analysis is based on density profile measurements from the Navitracker. The measured mass in [TDS/m²] is subsequently calculated for every measurement in reference to the empty dock at design depth (reference situation t_{0d}) (see §3.2). 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 zones spatially covered for 50% and more by density measurements are considered for sediment mass calculations. Unmeasured parts of these zones retrieve a value for the calculations (in order to close the mass balance of the zone), being the average mass per square meter based on the actual density measurements of the considered zone.

By adding measured mass to dredged material mass, the total accumulated mass and hence the growth can be shown (see Figure 4-7). 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 E. An example is shown for zone 3B in Figure 4-8.

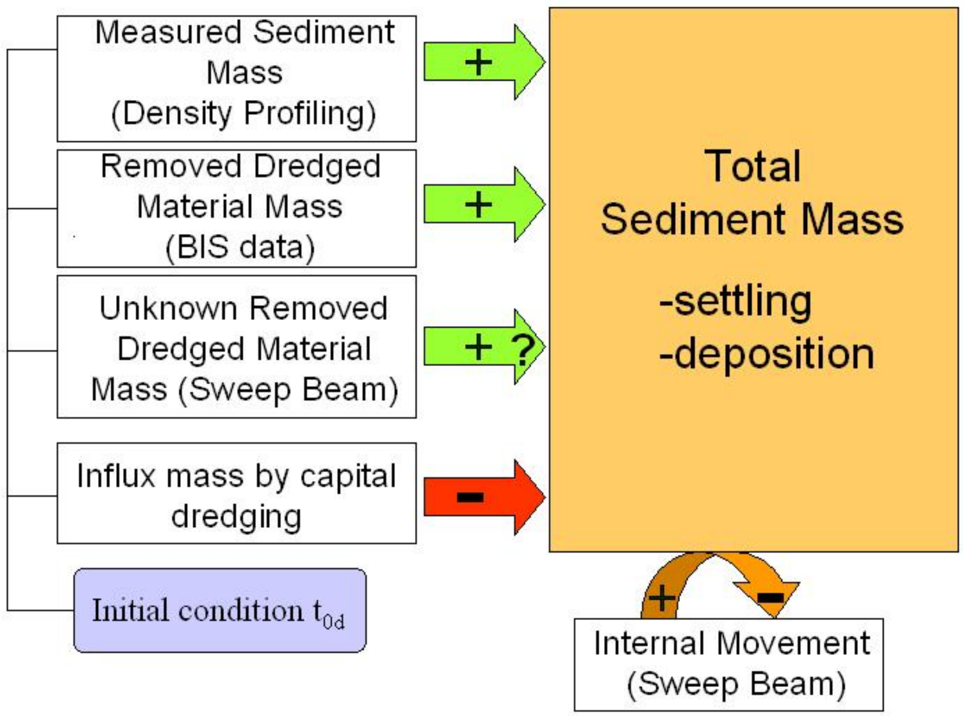


Figure 4-7: Flow chart with different elements contributing to total sediment mass for (sub)zones and total area

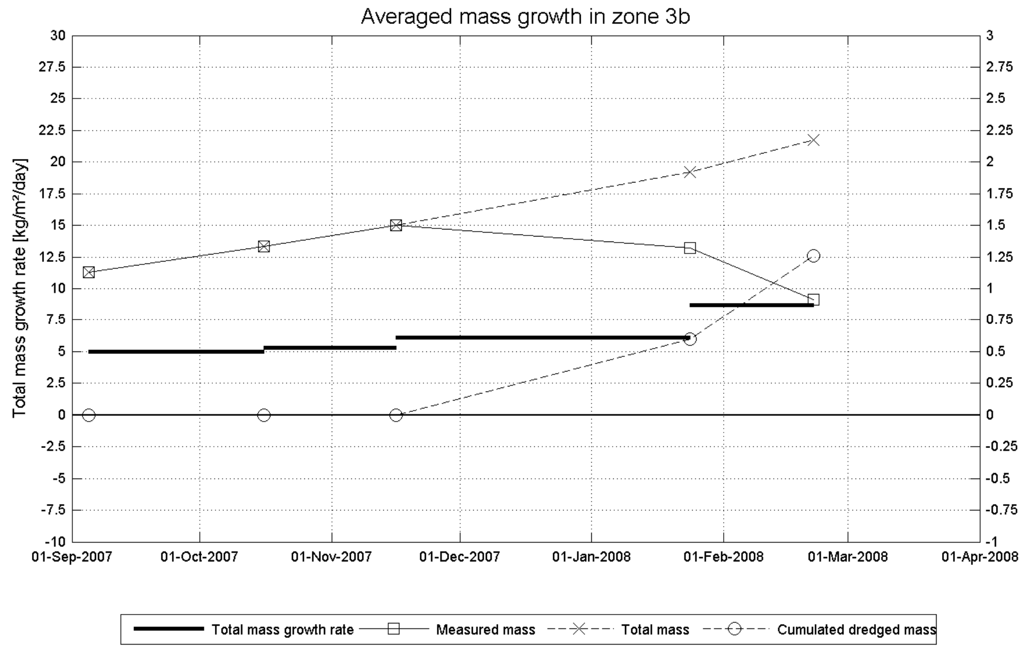


Figure 4-8: Example of averaged mass growth and mass evolution for subzone 3B

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 E 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 [%]

5. DATA ANALYSIS

5.1. Introduction

This chapter discusses the measurements on a yearly basis. Three-monthly trends that are already covered in previous reports are not dealt with, cf. IMDC (2007m, 2007n, 2008a, 2008b). Instead, more long-term evolutions are focused, or evolutions and phenomena bridging these three-monthly periods.

With respect to the data analysis and its interpretation, it is important to keep in mind the different contributing terms in the sediment mass balance of each defined zone in the Deurganckdok:

$$\frac{dM_s}{dt} = R_{siltation} - R_{erosion} \pm R_{sweepbeam} - R_{maintenance} \pm R_{capitaldredging}$$

with:

- M_s = local amount of sediment mass [TDS]
- $R_{siltation}$ = sediment mass flux from siltation [TDS/day]
- $R_{erosion}$ = sediment erosive flux [TDS/day]
- $R_{sweepbeam}$ = mass flux from sweep beam dredging operations [TDS/day]
- $R_{maintenance}$ = mass flux from maintenance dredging [TDS/day]
- $R_{capital\ dredging}$ = mass flux from capital dredging [TDS/day]

It is important to note that observations of bed level changes (from depth soundings and density measurements) refer to the gross effect of all contributing terms. Strictly seen, the siltation rate is only observed when no other process takes place at a specific location. With respect to the erosive flux, it is expected that flow velocities and shear forces are so low that erosion can be neglected from the mass balance.

The siltation in Deurganckdok can in fact be described in both a volumetric and a densimetric manner. The sediment volume is difficult to interpret because sediment volume is not conservative, i.e. sedimentation and consolidation increases the local sediment concentration. Sediment mass is therefore a better way of studying the siltation in the dock. However, due to the vast amount of depth soundings performed in this study and their additional information to density measurements, it is interesting to look at these data too.

Firstly, the 'volumetric siltation rate' is computed from the temporal bed level change as obtained from the depth soundings. Because different processes result in these observations, it is crucial to understand what is meant by the computed 'volumetric siltation rate'. For that reason, some definitions are considered important for the data interpretation:

- natural siltation rate: is computed from a time period in which only siltation occurs and no other process;
- gross siltation rate: is computed from a time period in which other processes occur besides the natural siltation;

The difference between these two definitions is schematised in Figure 5-1. Note that the gross siltation rate may also be larger than the natural one due to e.g. sweep beam activities, which may import sediment into the considered dock zone.

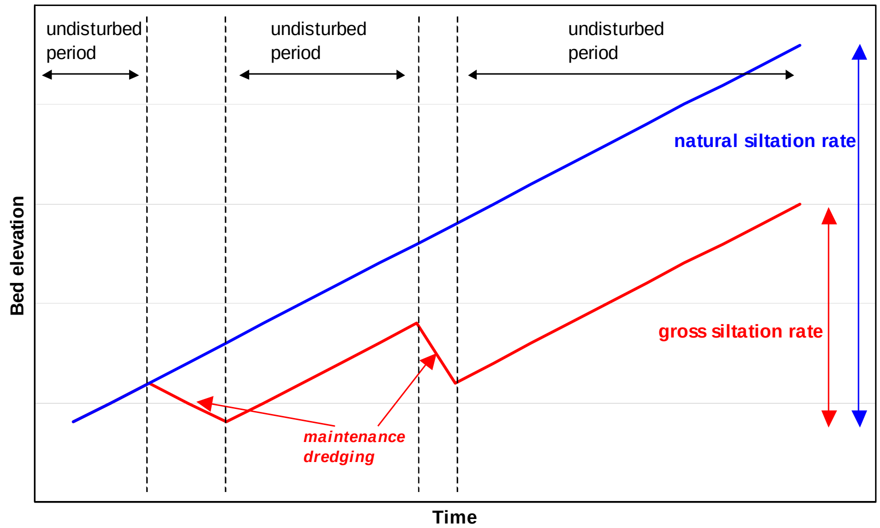


Figure 5-1: difference between natural and gross (volumetric) siltation rate

Secondly, the sediment mass distribution and its temporal evolution are studied. Here, densimetric growth rates can be calculated for the different dock zones. Because dredged mass are known, the sediment mass settled in a specific time frame can be computed, similar to the volumetric siltation rate as shown in Figure 5-1. Hence, according to Figure 5-2, the total sediment mass deposition rate (i.e. the densimetric growt rate) is to be computed as:

$$R_{siltation} = \frac{M_{meas,2} - M_{meas,2} + M_{dredge}}{t_2 - t_1}$$

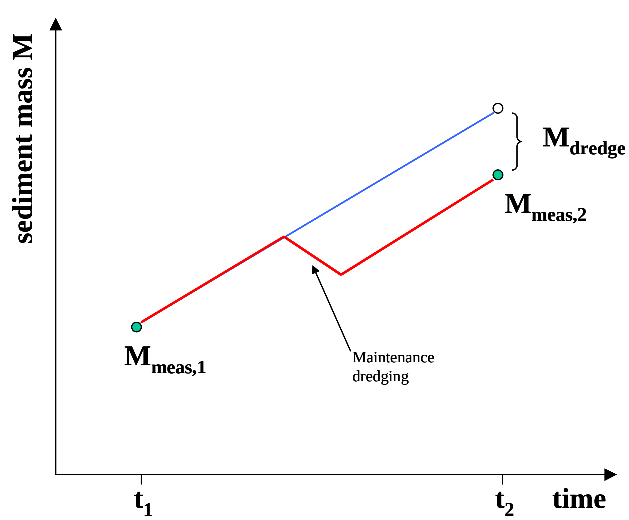


Figure 5-2: Principle of total deposited sediment mass calculated from the measured mass M_{meas} and dredged mass M_{dredge}

Seen the nature of collected data and their relation to the sediment balance, the chapter below will discuss the following topics:

- changes in elevation of the water-bed interface, i.e. the volumetric siltation rate;
- the accumulation of sediment mass in the dock, i.e. the densimetric siltation rate; and
- the dredged sediment mass.

5.2. Volumetric siltation rates

Depth sounding data was processed to show the evolution of the bed level as detected by the 210 kHz sounder. If more than 50% of the area of a (sub)zone was covered, an average bed level change was calculated. These data can be found in APPENDIX C.

Below, the natural and the gross yearly averaged siltation rates are discussed.

5.2.1. Gross yearly averaged siltation rate

To compute a gross yearly averaged siltation rate for every zone of the dock, the raw depth soundings are used because monthly averaged values may entail too large estimation errors. This is inherent to the way the monthly estimates were computed. Here, the subsequent bed level measurements are used to compute the gross siltation rate. This gross siltation rate is valid for the time period between these subsequent depth soundings. As a consequence, effects from dredging activities are included in these results. The obtained siltation rates therefore refer to a *gross* yearly averaged siltation rate. The results are shown in Table 5-1, which indicates that, in general, gross siltation rates are very small and negative. The mean gross siltation rate measured –0.08 cm/day, averaged over zones A, B and C. The temporal evolution of the sediment bed level indeed indicates that the levels observed in March 2008 are smaller than those of April 2007. In contrast, subzone D showed very large negative siltation rates, i.e. a large sediment withdrawal occurred here. In the period January – March 2008, the sediment plug in subzone D was dredged away hence resulting in a strong bed deepening.

Table 5-1~~5-1~~: gross yearly averaged siltation rates for every zone

ZONE	gross yearly averaged siltation rate [cm/day]
2	-0.50
3a	-0.12
3b	-0.07
3c	-0.51
3d	-2.69
4Na	-0.03
4Nb	-0.06
4Nc	-0.09
4Za	-0.02
4Zb	0.04
4Zc	-0.12
4Zd	-2.16
5Na	-0.11
5Nb	-0.01
5Nc	0.05

ZONE	*gross yearly averaged siltation rate [cm/day]*
5Nd	-1.09
5Za	0.02
5Zb	0.08
5Zc	-0.08
5Zd	-2.03

5.2.2. Natural siltation rate

The observed siltation rates are the result of many processes of which the natural siltation is only one. Human interferences such as maintenance and sweep beam dredging indeed largely influence the sediment balance of the dock. Whereas the maintenance dredging removes sediment from the dock, sweep beam dredging along the quays simply relocates the sediment towards the central trench (where it is removed by a subsequent maintenance dredging operation).

Quantifying the natural siltation is important as it determines the necessary dredging frequency. To do so, it is essential to identify undisturbed periods where no human interferences took place. From the observed bed elevation trend during such a period, the natural siltation rate can be calculated. Remark that siltation rates depend on local bathymetric and hydrodynamic conditions. Hence, it is important to acknowledge that calculated siltation rates cannot be generalised. However, the calculations return an order of magnitude for the siltation rates and allow the investigation of any spatial distribution of this process variable.

When investigating the siltation in zones A - C (cf. APPENDIX C.4), three periods can be identified being undisturbed by maintenance dredging, i.e.

- Period 1: 27/4/2007 – 27/7/2007;
- Period 2: 31/8/2007 – 16/11/2007; and
- Period 3: 4/12/2007 – 25/1/2008.

For the selection of these periods it was also imposed that minimally three consecutive bed level measurements were available for the calculation of the natural siltation rate.

Comparing Table 5-1 with Table 5-2 reveals that the natural siltation rate is larger than the gross yearly averaged siltation rate. This is simply due to the absence of dredging activities. Table 5-2 also clearly indicates that natural siltation rates in the central trench and observed in Period 1 are significantly smaller than those of the subsequent periods. This can be attributed to the intensity of dredging. Periods 1 and 3 showed dredging activities two weeks prior to the time periods of analysis, whereas Period 2 experienced dredging just before the measurements. However, in the case of Period 3 almost triple the amount of sediments was dredged in comparison to Period 1. As a result, the initial bed level in the central trench was almost one meter lower for Period 3; it is therefore assumed that the trench acted as a sediment trap in which sediment rapidly accumulated and resulted in larger siltation rates compared to Period 1. Siltation rates in Period 2 were however much larger compared to the subsequent period although dredging intensity was much lower. Here, dredging happened right before the measurement and the effect of dredging was therefore more pronounced in the measurements in terms of rapid siltation. Such a rapid siltation period had already gone by in case of Period 3 and, as such, its effect could not be observed in the measurements.

Table 5-2 also indicates that the natural siltation rate decreased when going from the sill to the back-end of the dock. A gradient in the transverse direction was not so clear although such a transverse trend could be observed in the period April 2006 – March 2007 (IMDC, 2007e). The absolute values of siltation rates as calculated in IMDC (2007e) are larger than those of Periods 1 and 2.

In 2004, sediment transport simulations of the Deurganckdok were performed in order to investigate natural siltation rates (IMDC, 2004). The applied mathematical model indicated that the first one third of the dock, near the Scheldt, was characterised with a siltation rate of 1.4 cm/day and decreased when going more inside the dock. This spatial trend of siltation rates inside the dock is similar to the present observations.

Further, the hydrodynamic sediment transport model returned an estimation of the sedimentation volume to be dredged annually. It was calculated at approximately 4.3 million m^3/year if the sediment is dredged immediately (at a bulk density of around 1.15 kg/l) after sedimentation. This results in an area-averaged mean volume of 3.4 m^3/m^2.year to be dredged. The actual observations return a value of 1.27, 5.1 and 1.8 m^3/m^2.year when using the natural siltation rates for Periods 1, 2 and 3 respectively.

Obviously, the absolute values differ because of model assumptions, e.g. the fully constructed dock was considered in the simulations whereas the observations are related to a partly constructed dock. Clearly, an absolute comparison between the simulation study and the actual measurements is not applicable. However, the order of magnitude and the trends are quite similar.

Table 5-2~~5-2~~: natural siltation rates obtained from undisturbed measurement periods

ZONE	**Natural siltation rates [cm/day]**		
	27/4/07 - 27/7/07	**31/8/07 - 16/11/07**	**4/12/07 - 25/1/08**
3a	0.42	2.46	1.02
3b	0.15	2.12	0.45
3c	0.16	1.67	0.20
4Na	0.99	0.18	0.90
4Nb	0.42	0.7	0.49
4Nc	0.04	0.41	0.39
4Za	0.73		0.36
4Zb	0.60		
4Zc	0.28		

5.3. Densimetric siltation rate

The volumetric siltation rate, computed from 210 kHz depth sounding profiles, does not reveal the amount of mass that settled. Information on the consolidation process remains unknown too. For that reason, a densimetric analysis is performed as well. Below, both the dredging and the sediment mass accumulation in the dock are discussed.

5.3.1. Dredged sediment mass

From the BIS data (see APPENDIX F), it can be concluded that almost 955,000 TDS was dredged over the entire measurement period. This is approximately 14.5% more sediment mass withdrawn from the dock in comparison with the corresponding measurement period of 2006-2007 (IMDC, 2007e). According to Table 5-3, intense weekly dredging occurred in the second half of November

2007 and the end of January 2008 during which 39% of the annual total amount was removed from the dock. These weeks of intense dredging were characterised by dredged masses of more than 100,000 TDS per week. When the geographical distribution of dredged mass in the Deurganckdok is considered, it is observed that 77% of the total mass originated from zones 3A, 3B and 3C, being the central trench of the dock. Subzones 3D, 4NA and 4NB each contributed 4% and more to the total dredged amount.

Table 5-3: Amounts of dredged mass per zone and dredging period

	Total dredged mass in covered area per week (TDS)												
	02-Apr-07	09-Apr-07	20-Aug-07	27-Aug-07	19-Nov-07	26-Nov-07	28-Jan-08	04-Feb-08	11-Feb-08	18-Feb-08	03-Mar-08		
ZONE	09-Apr-07	14-Apr-07	25-Aug-07	01-Sep-07	24-Nov-07	01-Dec-07	03-Feb-08	10-Feb-08	17-Feb-08	24-Feb-08	09-Mar-08	Total (TDS)	%
1	0	0	141	28	28	0	0	0	0	0	0	196	0.0
2	57	23	1140	177	30	0	72	0	268	0	0	1767	0.2
3a	3111	23207	46059	27635	40406	43114	29277	24258	35827	4033	0	276927	29.0
3b	7854	36043	28619	28630	45720	19857	24791	32056	22571	1099	0	247239	25.9
3c	7213	16162	25493	21020	38674	11835	22477	17659	24994	959	20665	207151	21.7
3d	0	0	2	0	470	95	162	52	274	0	43945	45001	4.7
3e	0	0	0	0	0	0	0	0	0	0	0	0	0.0
4Na	25	435	8759	4198	5662	11322	4564	5226	3524	54	0	43770	4.6
4Nb	60	427	7704	3772	6984	6928	5206	4737	1838	0	0	37656	3.9
4Nc	127	141	3396	2108	5861	3598	2659	3765	1440	27	2176	25297	2.7
4Nd	0	0	0	0	14	0	0	0	0	0	8042	8056	0.8
4Ne	0	0	0	0	0	0	0	0	0	0	0	0	0.0
4Za	0	143	359	3	7480	3323	4483	1118	2009	13	0	18930	2.0
4Zb	0	69	14	61	12214	4116	5141	2847	646	0	0	25109	2.6
4Zc	0	0	0	28	4699	2040	1947	1525	445	0	2305	12990	1.4
4Zd	0	0	0	0	0	0	0	0	0	0	4048	4048	0.4
4Ze	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Na	0	0	3	0	0	0	0	0	0	0	0	3	0.0
5Nb	0	0	29	0	0	0	68	0	0	0	0	98	0.0
5Nc	0	0	19	0	0	0	0	7	0	0	0	26	0.0
5Nd	0	0	0	0	0	0	0	0	0	0	26	26	0.0
5Ne	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Za	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Zb	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Zc	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Zd	0	0	0	0	0	0	0	0	0	0	2	2	0.0
5Ze	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Total	**18447**	**76649**	**121738**	**87660**	**168243**	**106227**	**100846**	**93251**	**93837**	**6185**	**81209**	**954291**	
%	**1.9**	**8.0**	**12.8**	**9.2**	**17.6**	**11.1**	**10.6**	**9.8**	**9.8**	**0.6**	**8.5**		

5.3.2. Vertical density profiles

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. Adding up both leads to the total sediment mass as shown in Table 5-4. Note however that density measurements were only available between September 2007 and February 2008. Hence, a complete annual sediment mass balance could not be made. Further on, the measurement of 5 December 2007 covered a small area of the dock allowing an analysis for only subzones 3A-C.

As shown in APPENDIX E, measured sediment masses changed in time due to dredging. With the absence of any dredging activities, the mass growth rate showed a rather linear trend. Dredging activities in the time period of analysis however resulted in a large increase of mass growth rate, which presumably is to be related to a rapid siltation of the lowered bed.

5.3.3. Densimetric growth rate

Results show a mass growth rate in the central trench (zones 3A, 3B and 3C) in the range of 11 to 20 kg/m²/day for the period November – December 2007 and January – February 2008. These numbers are much larger in comparison to the other measurement periods. In the latter period without any dredging activities, total sediment mass growth rates approximately ranged between 2 and 8 kg/m²/day in the central trench. This significant difference can be attributed to a combination of the two dredging processes, i.e. hopper and sweepbeam maintenance dredging. Whereas sweepbeam operations result in an artificial influx of sediment in the central trench, the continuous hopper maintenance dredging in this period leads to a lower bed level and, therefore, to a possible more rapid siltation. Finally, density measurements performed in the period August – December 2005 resulted in a sediment mass growth of 3 – 7 kg/m²/day in zones 3A and 3B, which is very similar to the results obtained for the period September – November 2008.

It was also observed that zones along the quays generally showed negative growth rates for the period September – October 2007. Sweepbeam actions were only limited recorded at the southern quay and, therefore, could not result in the observed lowering of equidensity planes of APPENDIX D. Between mid-October 2007 and mid-January 2008, the measured growth rates were of the same order of magnitude for both the northern and southern quay zones, except for the southern quay zones in the period of January-February 2008 that showed larger values. With respect to these zones, the actual growth rates were slightly larger than those reported for October-December 2005, i.e. 3.2 kg/m²/day (IMDC, 2006a). From mid-January on, the 4Z-zones were generally characterised by larger growth rates (up to more than 12 kg/m²/day). The large growth rate of 12.4 kg/m²/day in zone 4Z-A may have been due to the hopper dredging; also here the lowering of the bed level possibly resulted in a rapid siltation.

5.3.4. Total deposited mass

An overview of the total mass settled over time, for all subzones of 3, 4N and 4B that have been covered for at least 85%, is shown in Table 5-4 and Table 5-5. An exception to this is zone 4Z-A. Here, a coverage of 68% is obtained. Additionally, total masses are given for subzones of zone 5 too of which the zone coverage was more than 50%. For these subzones, the coverage never exceeded 85%.

From these figures, it is concluded that the maximum amount of settled sediment occurred in the periods November – January and January – February, and was located in zone 3A. Subdividing per subzone (Table 5-5), it is concluded that the settled mass in subzones A (nearest to river) is generally larger than the settled mass in subzone B. This confirms the hypothesis of a gradual decrease in siltation with distance from the Scheldt river.

Table 5-4: Total sediment mass (measured + dredged, in 10³ TDS) in some zones

	05-Sep-07	16-Oct-07	16-Nov-07	5-Dec-07	24-Jan-08	22-Feb-08
3a	139	171	192		252	313
3b	125	147	165	208	211	247
3c	126	138	144	175	177	219
3d						122
4Na	43	38	44		54	64
4Nb	29	27	29		40	44
4Nc	19	20	21		31	35
4Nd						28
4Za	25	21	26		33	47
4Zb	29	24	29		40	46
4Zc	19	19	20		22	27
4Zd						26

	05-Sep-07	16-Oct-07	16-Nov-07	5-Dec-07	24-Jan-08	22-Feb-08
5Na	29	20			20	
5Nb	23	18			14	
5Nc	16	20				
5Za	11		11		9	
5Zb	18	12	14		14	
5Zc		11				
Total	651	675	695		917	1218

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

	settled mass (10³ TDS)				
	05-Sep-2007 / 16-Oct-2007	**16-Oct-2007/ 16-Nov-2007**	**16-Nov-2007/ 24-Jan-2008**	**24-Jan-2008 / 22-Feb-2008**	**Total**
subzone A	24	41	45	77	187
subzone B	15	33	40	66	153
subzone C	12	12	23	79	126
Total	51	86	108	221	

6. SEDIMENT MASS BALANCE: LIMITATIONS

As mentioned in Chapter 1, the aim of this study is twofold. Firstly, setting up the sediment balance of the Deurganckdok is focused. Secondly, the mechanisms causing siltation in the dock are to be investigated. The latter is the subject of other reports (see §1.3.1), and the confrontation of both the sediment balance and the siltation contributing factors for the period 2007-2008 will be dealt with in Report 4.10 “Analysis of Siltation Processes and Factors” (I/RA/11283/07.102/MSA).

The actual report aims at quantifying the different processes that contribute to the sediment balance in order to compute the sediment influx from the Scheldt. The different contributions are schematically shown in Figure 2-2 and the sediment balance equation is to be found in §5.1.

In Chapter 5 it became clear that the sediment mass balance could only be set up for the period September 2007 – February 2008. This was simply due to the fact that density measurements were not available for the first half of the one-year covering measurement campaign. However, the present results return more information though with respect to the siltation process inside the dock. Different processes of the sediment transport have been considered densimetrically, such as:

- maintenance dredging;
- capital dredging;
- settling and consolidation (measured indirectly by the local sediment densities)

Only one process has been inadequately described, i.e. the sweep beam actions. Although the depth of the rake or plough and its location is known, it seems difficult to estimate the transport capacity of it. The question indeed remains whether the rake introduces a momentum so the sediment flows in the direction of the rake movement, or the rake pushes the sediment. The sweep beam data has therefore only been used for data interpretation.

Another remark on the sediment mass balance is related to accuracy. The trend of calculated total sediment mass (measured + dredged) in the dock (cf. Appendix E.4) shows a decrease in the period January – February. This is unrealistic because both dredged and measured sediment masses are used in the calculations, and flow velocities are considered as too small to induce bed erosion. Hence, an increase of sediment mass in time would be expected. The discrepancy is assumed to be related to:

- uncertainties on the BIS data and density measurements;
- inaccuracies introduced by the horizontal and vertical interpolation between de density measurement points to obtain a 3D spatial distribution of densities.

Note however that these uncertainties exist on every calculation of sediment mass.

7. CONCLUSIONS

The available data consisted of dredging (maintenance and sweep beam) data, depth soundings and density measurements. Whereas depth soundings were available for the one-year duration of the measurement campaign, density data could only be collected for the period September 2007 till February 2008. Different interesting features, related to both volumetric and densimetric siltation, could be identified:

- the dock (zones A, B and C) showed a mean gross siltation rate of –0.08 cm/day;
- natural siltation rates were determined for three time periods, all unaffected by external disturbances. Siltation rates varied between 0.5 and 2.5 cm/day. These differences can be related to the presence, or not, of intense dredging prior to the measurements. The initial bed level therefore may have a possible impact on the volumetric siltation rates. The resulting volumetric flux measured between 1.27 and 5.1 $m^3/m^2/year$;
- 955,000 TDS was dredged during the one-year measurement campaign, being 13% more sediment mass withdrawal from the dock in comparison with the corresponding measurement period of 2006-2007. 77% of the total mass originated from zones 3A, 3B and 3C, being the central trench of the dock;
- the sediment mass growth rate in the central trench (zones 3A, 3B and 3C) varied in the range of 2 and 8 $kg/m^2/day$ for the period September – December 2007. These numbers were much larger in the period of November – December 2007 and January – February 2008 where dredging occurred. In these periods, total sediment mass growth rates ranged between 11 and 20 $kg/m^2/day$ in the central trench;
- siltation rate decreased when going from the sill to the back-end of the dock;
- both volumetric siltation rates and mass growth rates indicated that rapid silation occurs after a period of dredging.

This report aimed at setting up the annual sediment balance of the Deurganckdok by quantifying all contributing factors such as dredging, sedimentation and sediment accumulation. From the resulting balance, sediment accumulation could be calculated and, hence, the sedimentation of the dock. Only the consideration of the local effect of the sweep beam maintenance dredging on the mass balance remains difficult to consider quantitatively.

8. REFERENCES

AMT(2003). Intern rapport, Getij-informatie Scheldebekken 1991-2000.

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 (2007l) 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)

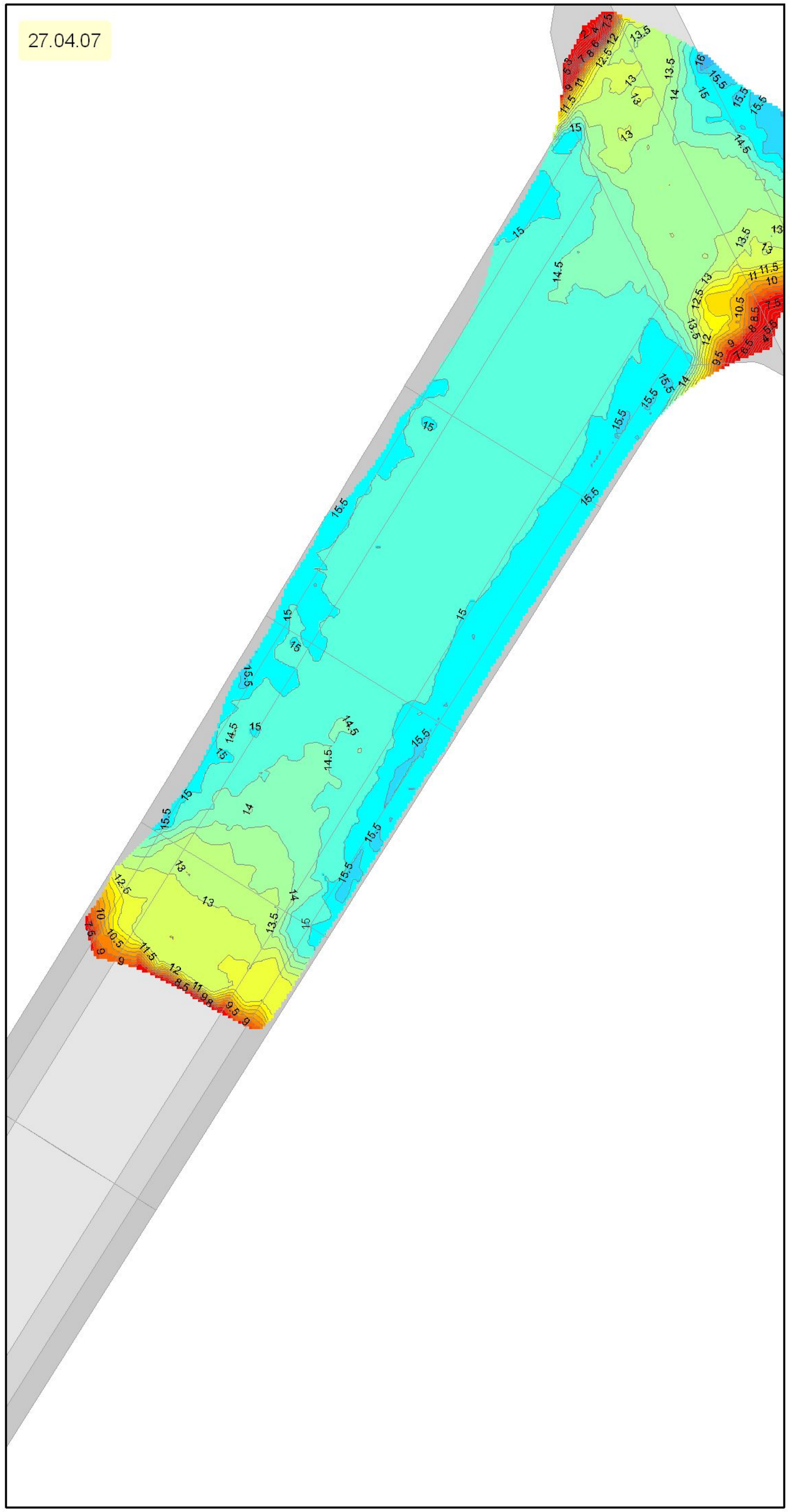
IMDC (2007m). Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.10 Sediment Balance: Three-monthly report 1/4/2007 – 30/06/2007 (I/RA/11283/07.081/MSA).

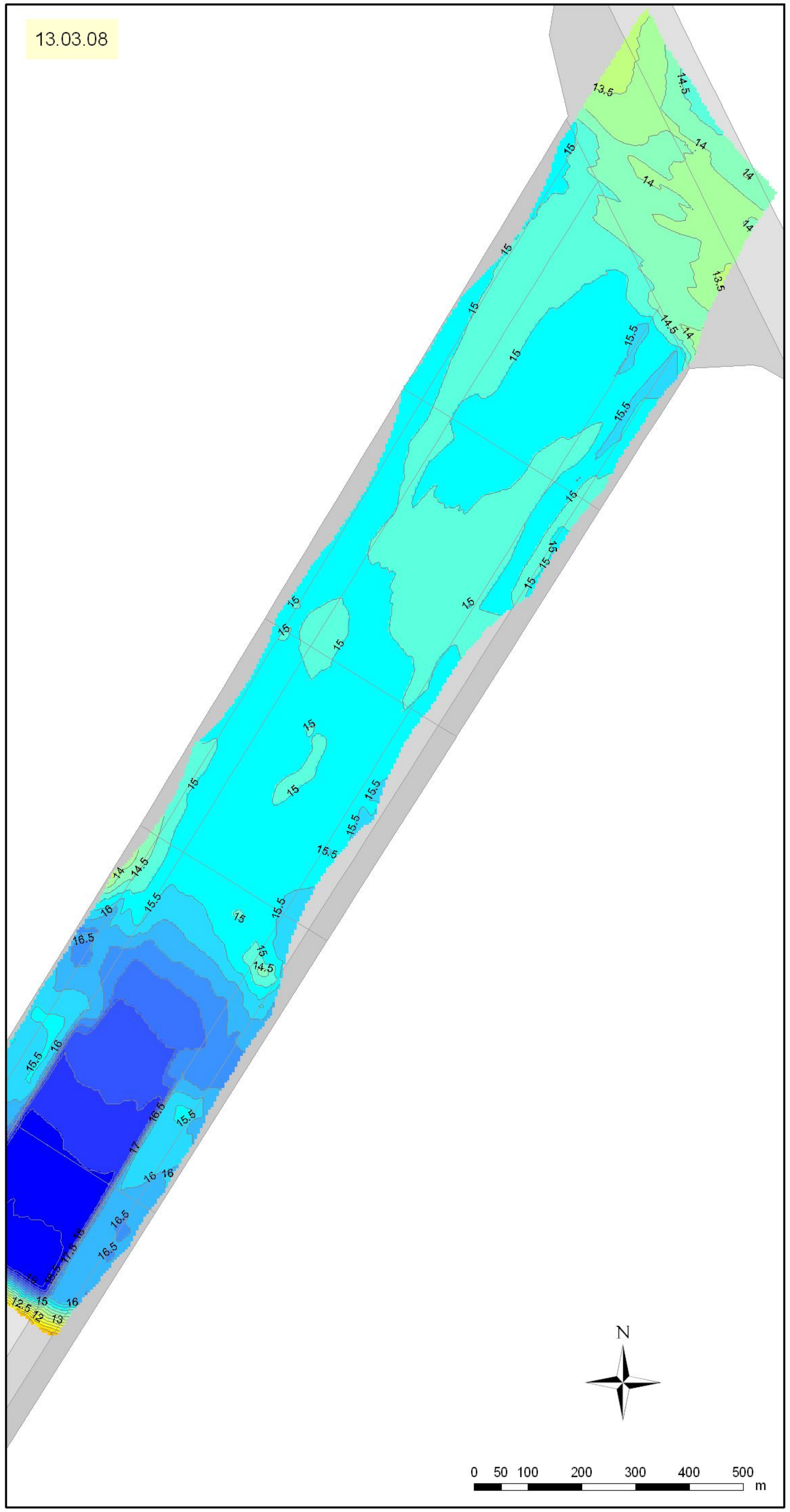
IMDC (2007n). Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.11 Sediment Balance: Two-monthly report 1/7/2007 – 31/08/2007 (I/RA/11283/07.082/MSA).

IMDC (2008a). Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.12 Sediment Balance: Four-monthly report 1/9/2007 – 31/12/2007 (I/RA/11283/07.083/MSA).

IMDC (2008b). Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.13 Sediment Balance: Three-monthly report 1/1/2008 – 31/03/2008 (I/RA/11283/07.084/MSA).

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





Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

Depth of the water-bed interface (210 kC)

27.04.07 & 13.03.08

Map 1 Scale 1/10.000

Created: 06/08/2008 I/DR/11283/08.000/JUR

Version nr. 1

IMDC

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2140 Antwerpen
Tel:+32.3.2709295
Fax:+32.3.2356711
E-mail: info@imdc.be

Legend

Depth m [TAW]

- > -8.00
- -8.51 - -9.00
- -9.01 - -9.50
- -9.51 - -10.00
- -10.01 - -10.50
- -10.51 - -11.00
- -11.01 - -11.50
- -11.51 - -12.00
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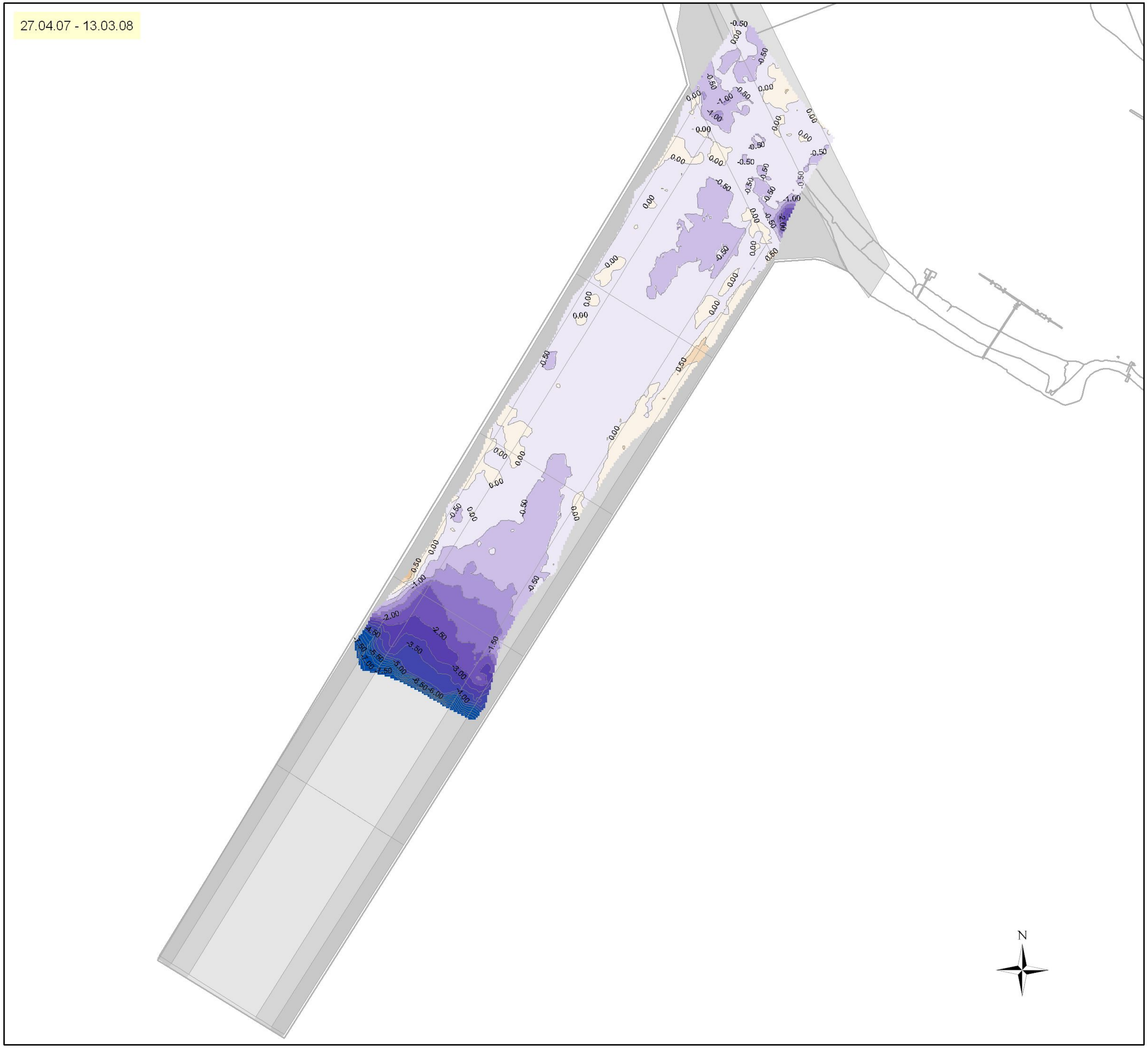
- -16.51 - -17.00
- -17.01 - -17.50
- -17.51 - -18.00
- -18.01 - -18.50
- -18.51 - -19.00

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

B.1 Difference maps



Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map

27.04.07 - 13.03.08

Map 1 Scale 1/10.000

Created: 09/09/2008 I/DR/11283/08.069/JUR
Version nr. 1

IMDC 25

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Fax:+32.3.2356711
E-mail: info@imdc.be

Legend

27.04.07 - 13.03.08

elevation decrease (m)

- < -5.00
- -4.99 - -4.50
- -4.49 - -4.00
- -3.99 - -3.50
- -3.49 - -3.00
- -2.99 - -2.50
- -2.49 - -2.00
- -1.99 - -1.50
- -1.49 - -1.00
- -0.99 - -0.50
- -0.49 - 0.00

elevation increase (m)

- +0.01 - +0.50
- +0.51 - +1.00
- +1.01 - +1.50
- +1.51 - +2.00
- +2.01 - +2.50
- +2.51 - +3.00
- +3.01 - +3.50
- +3.51 - +4.00
- +4.01 - +4.50
- +4.51 - +5.00
- > + 5.00

File: W:\11283\GIS\project\rapport 1-14\210Khz\K1_vk_270407-130308.mxd

B.2 Bed elevation evolution per section

Long-term monitoring siltation Deurganckdok

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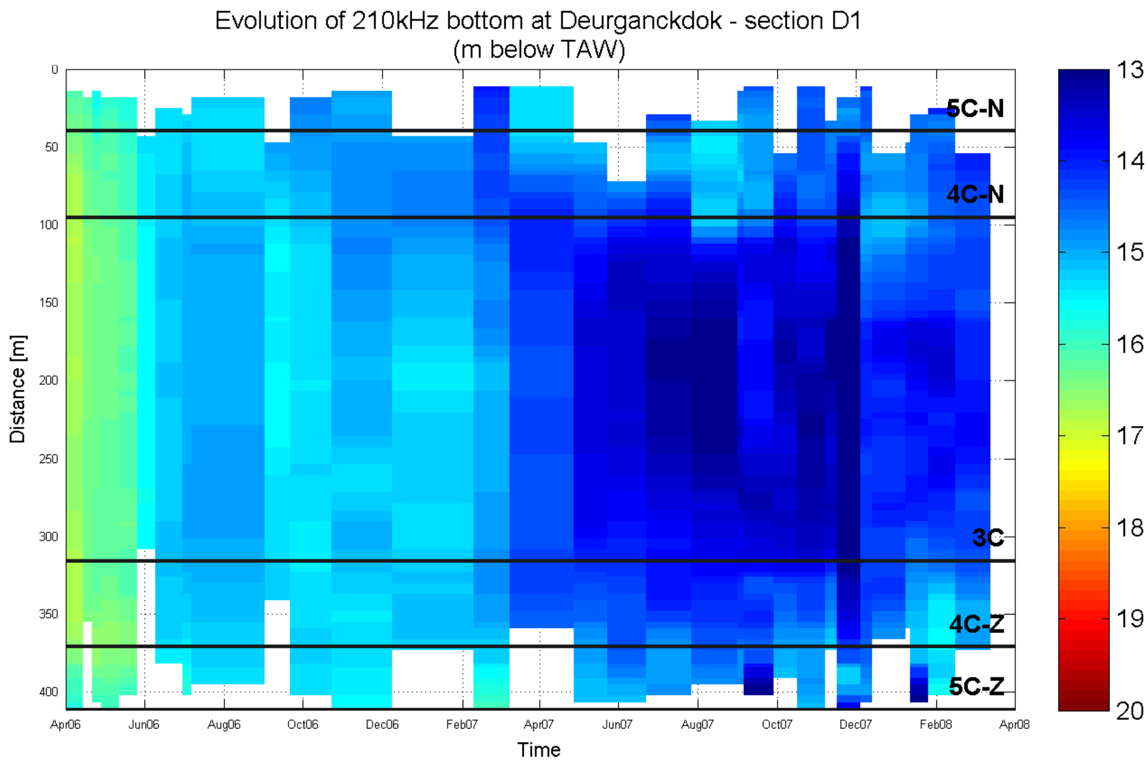

Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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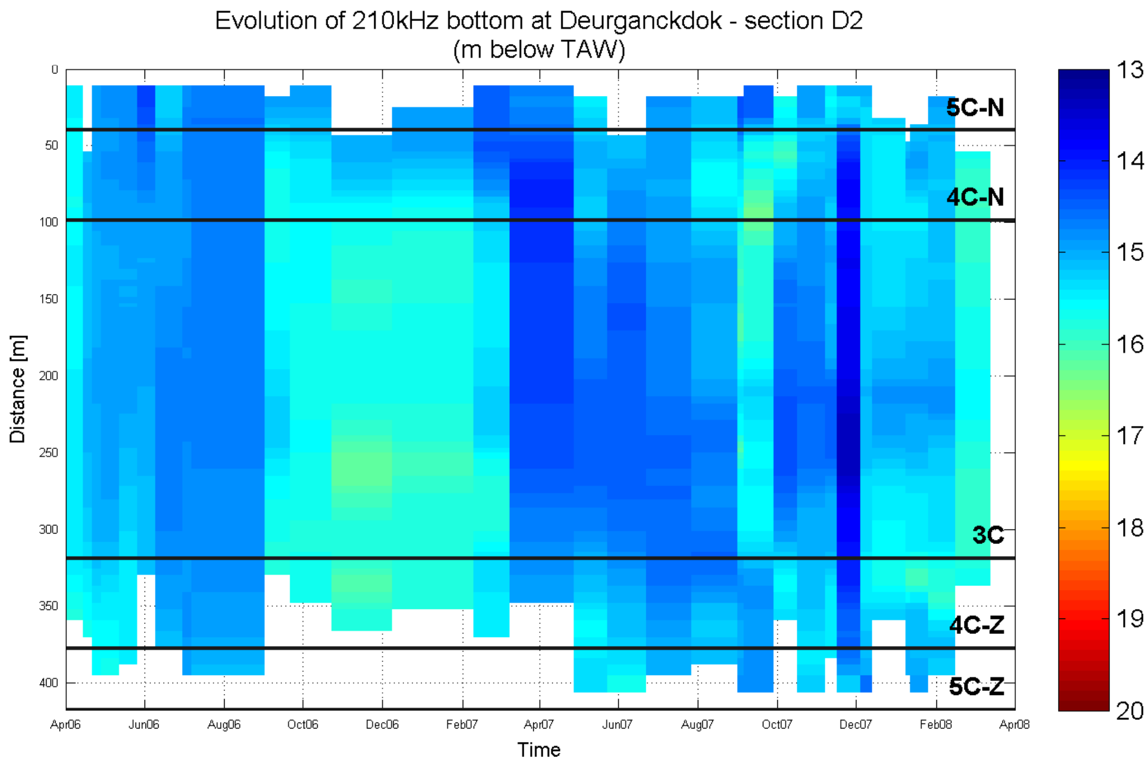


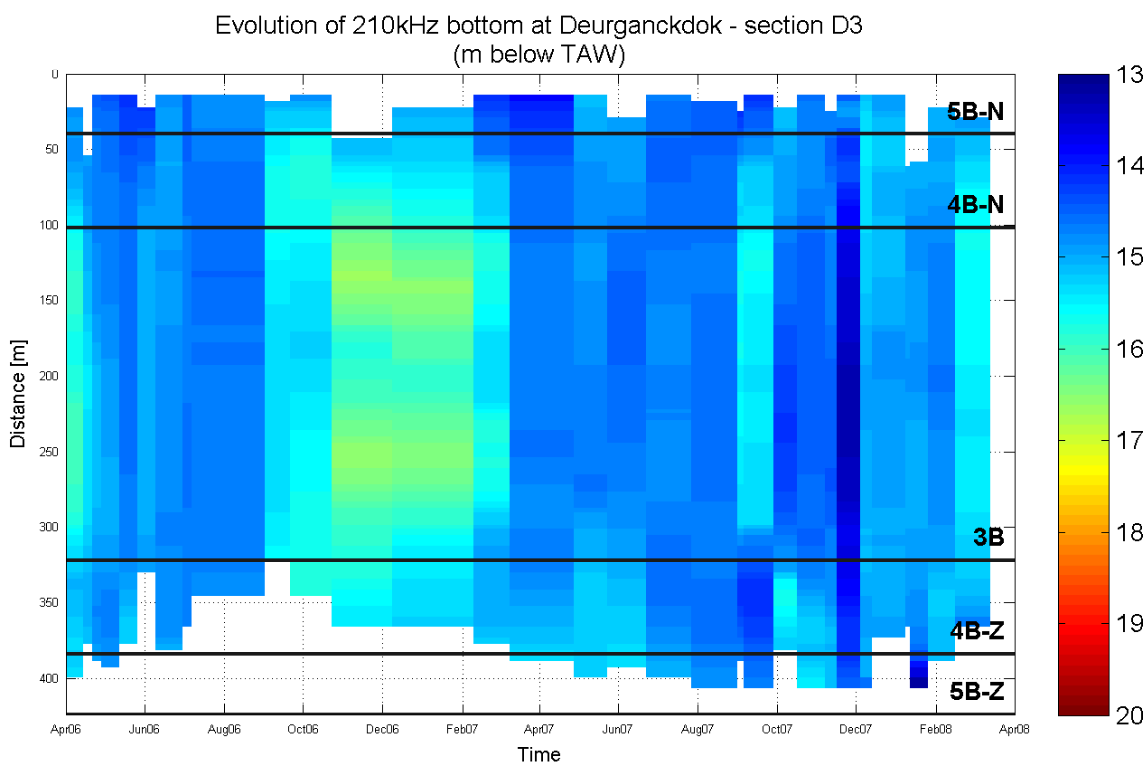
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



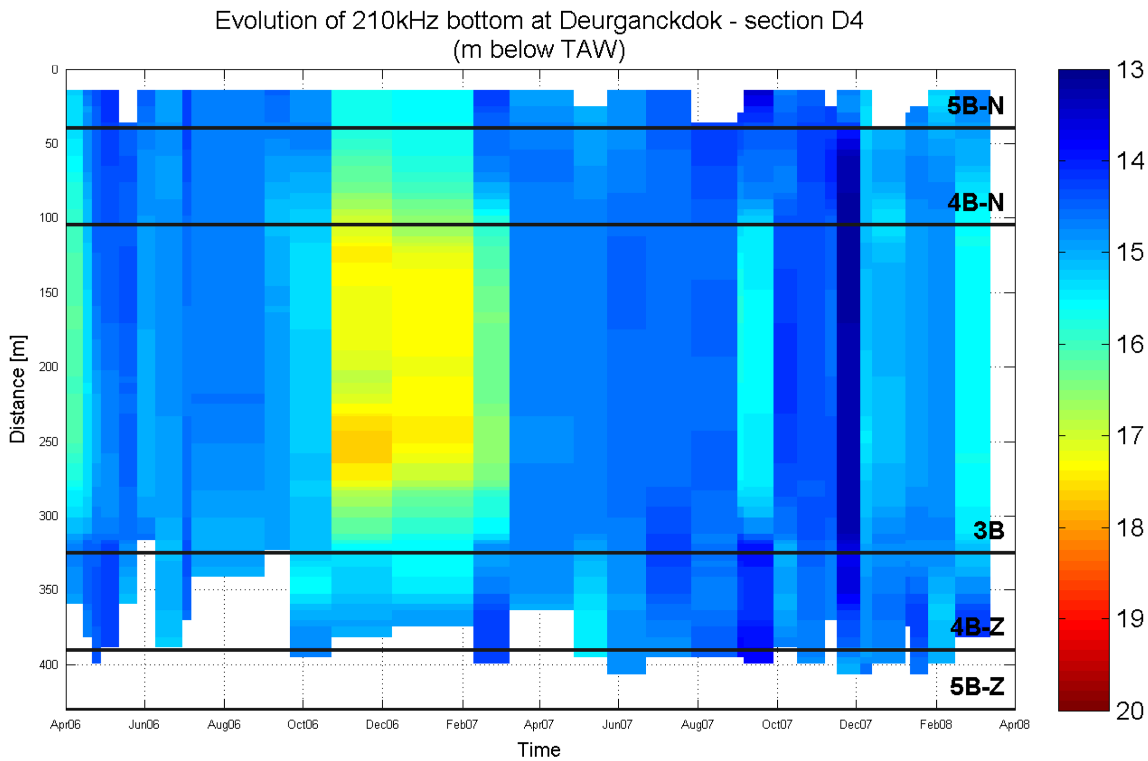
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



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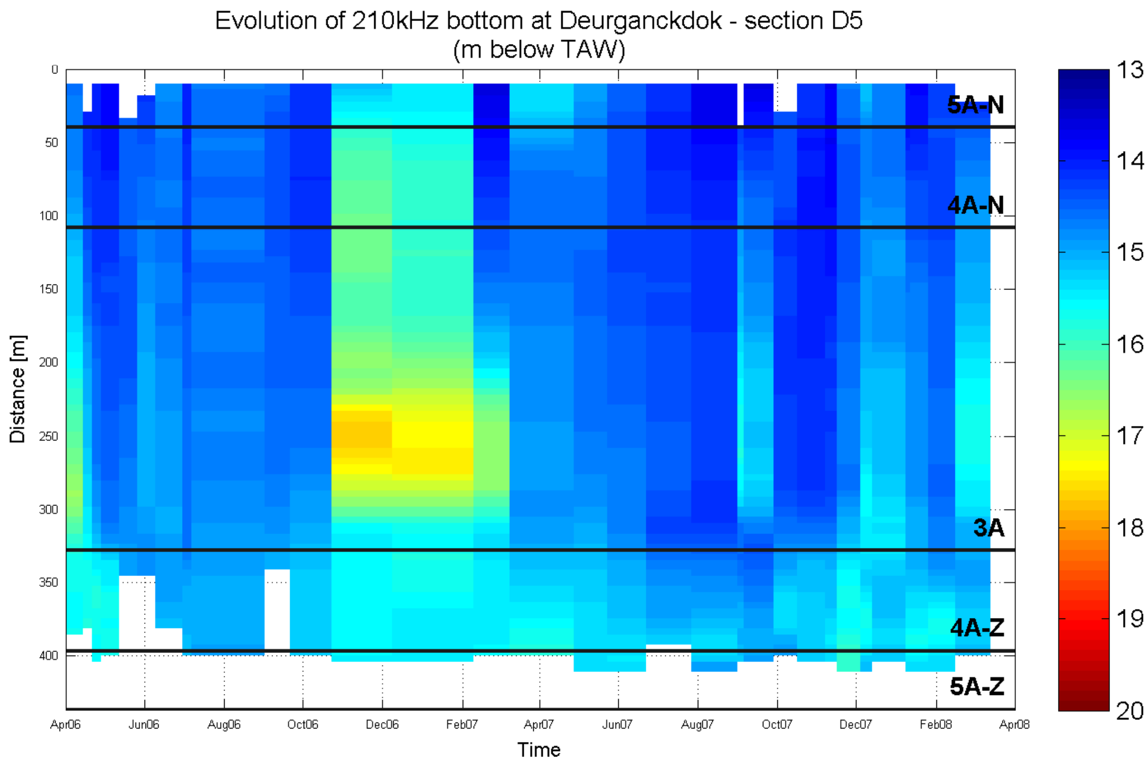
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



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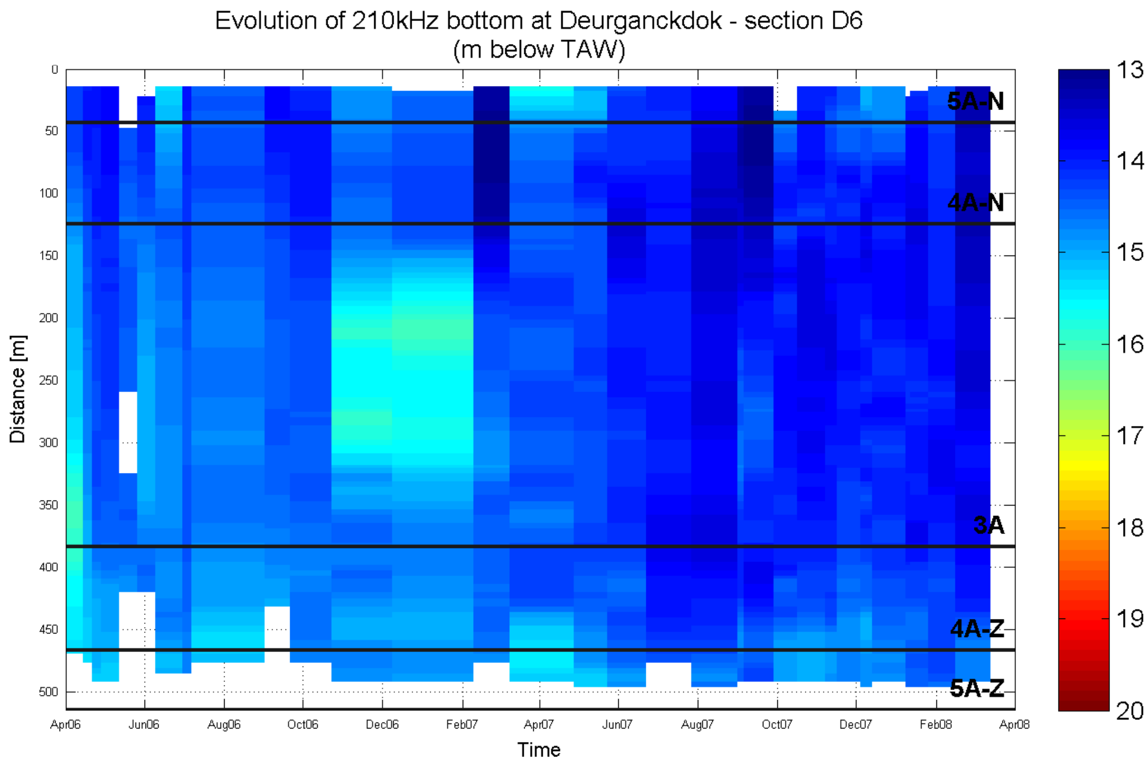
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



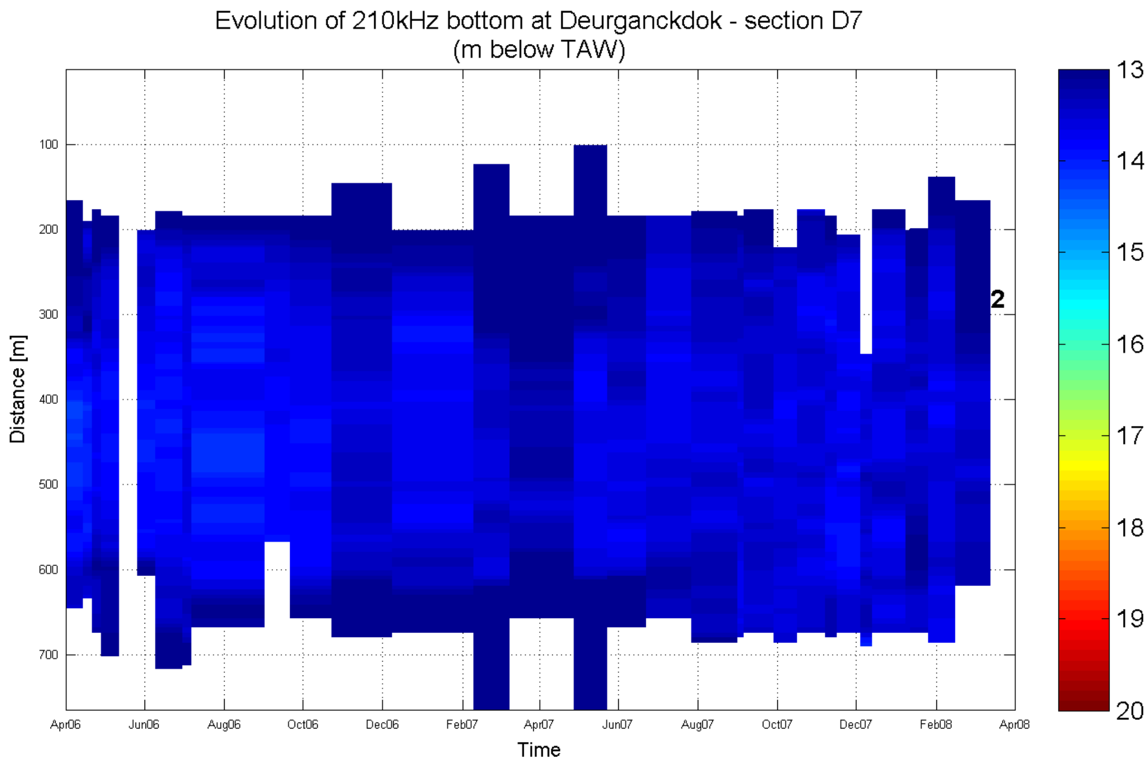
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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

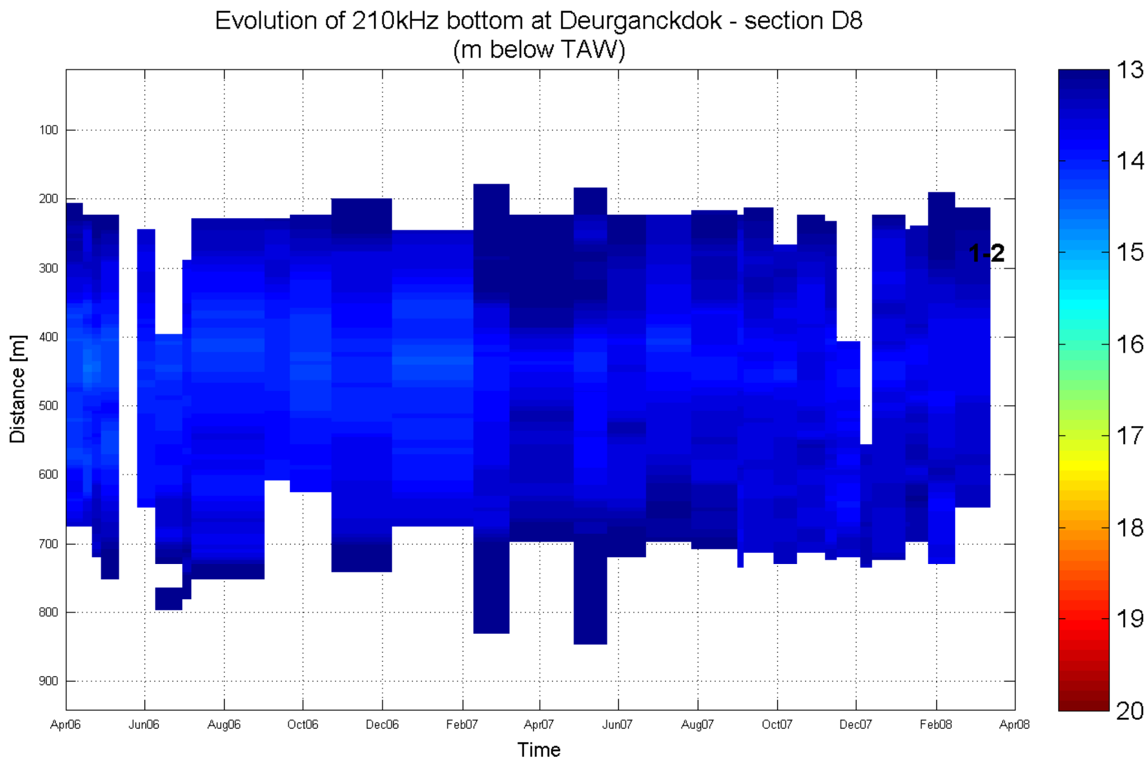


Data Processed by:

In association with :

I/RA/11283/07.085/MSA

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



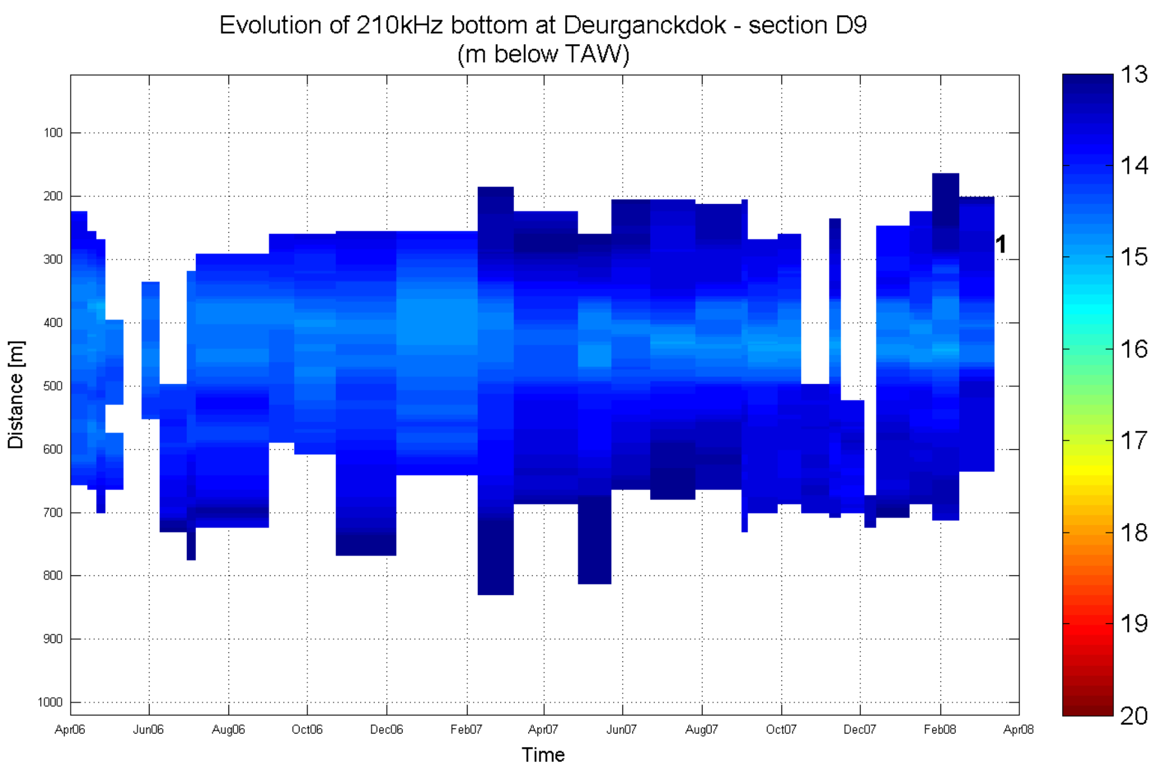
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



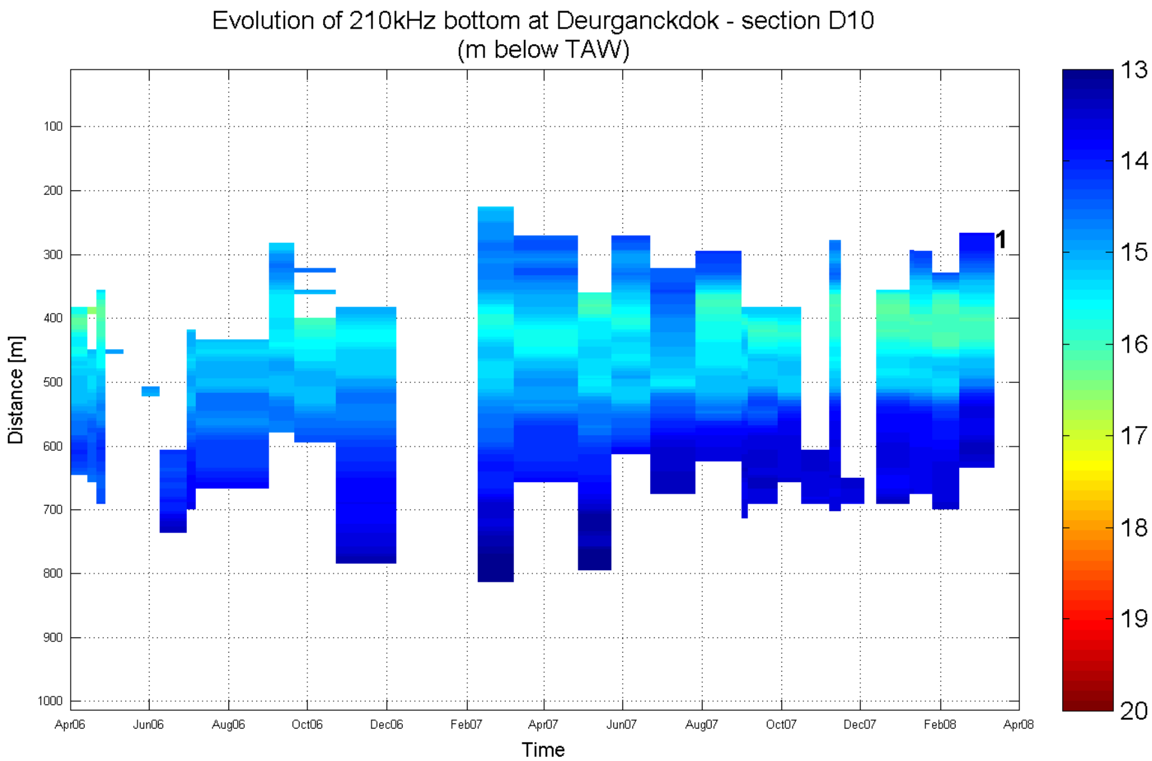
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



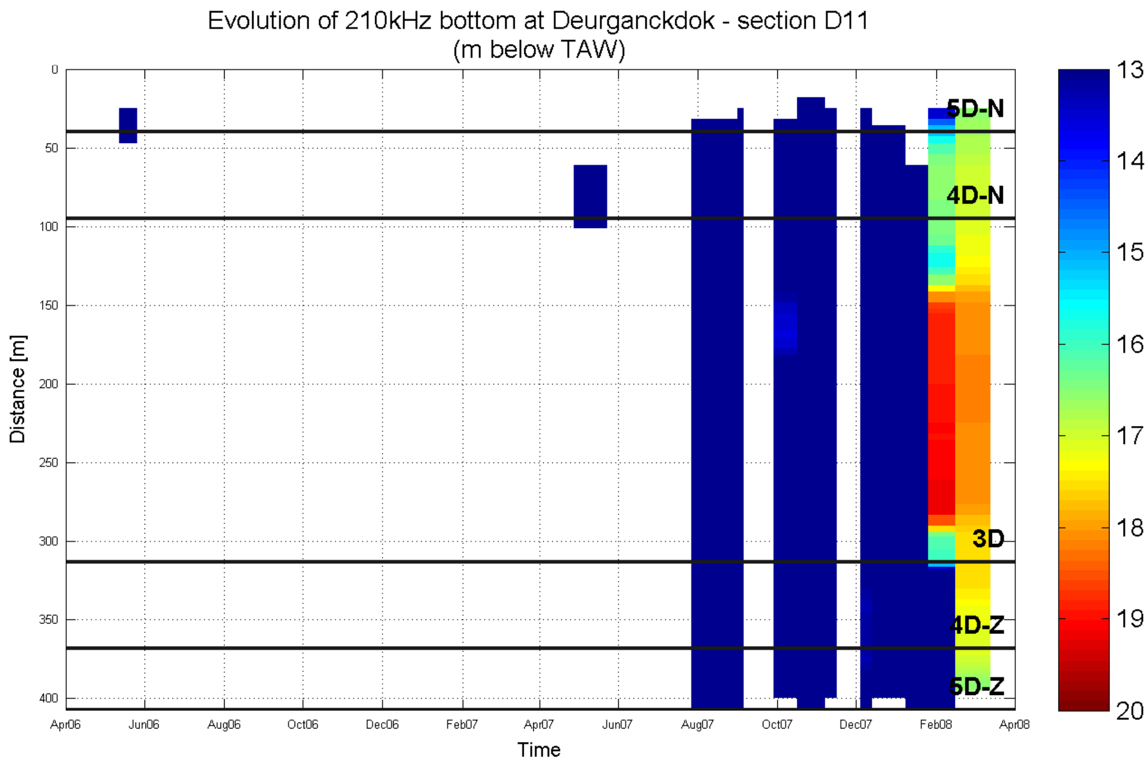
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



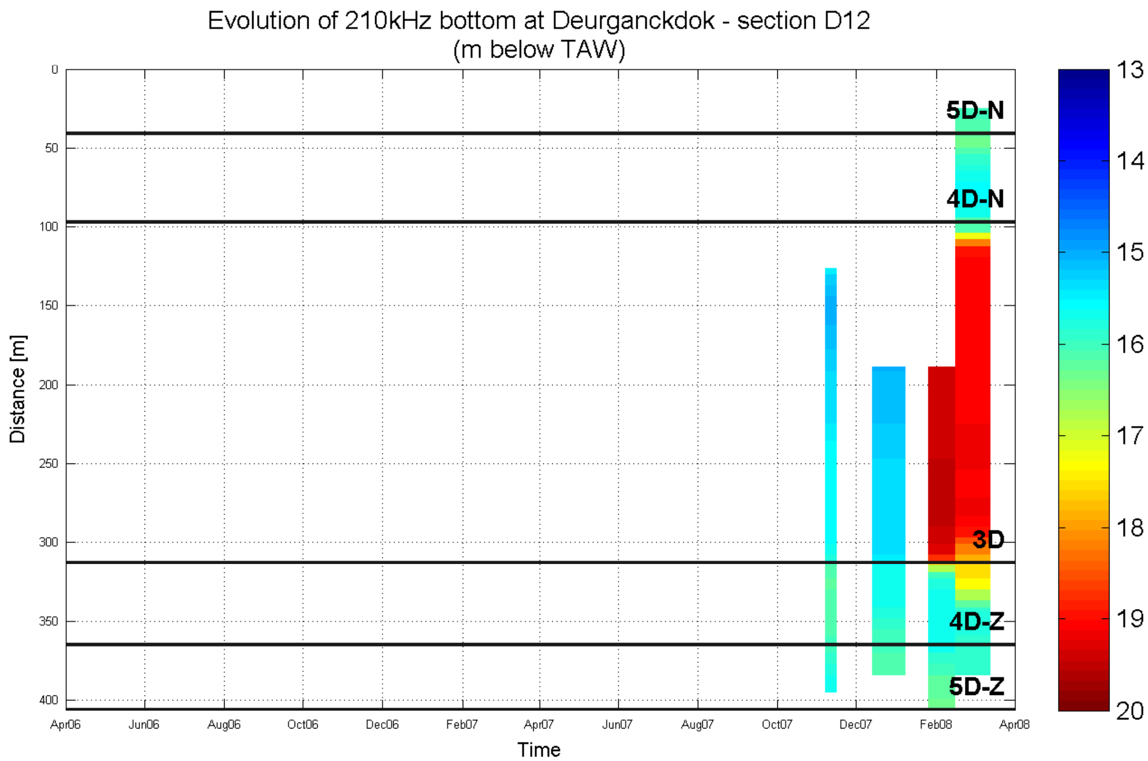
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



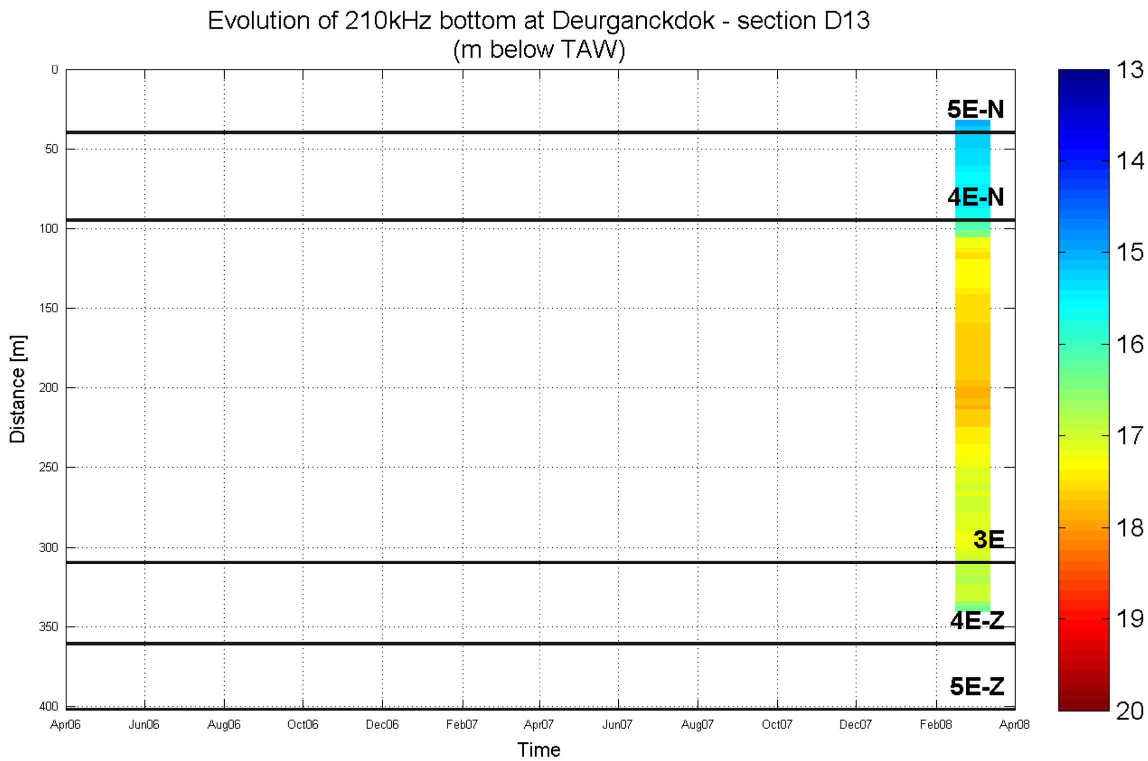
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



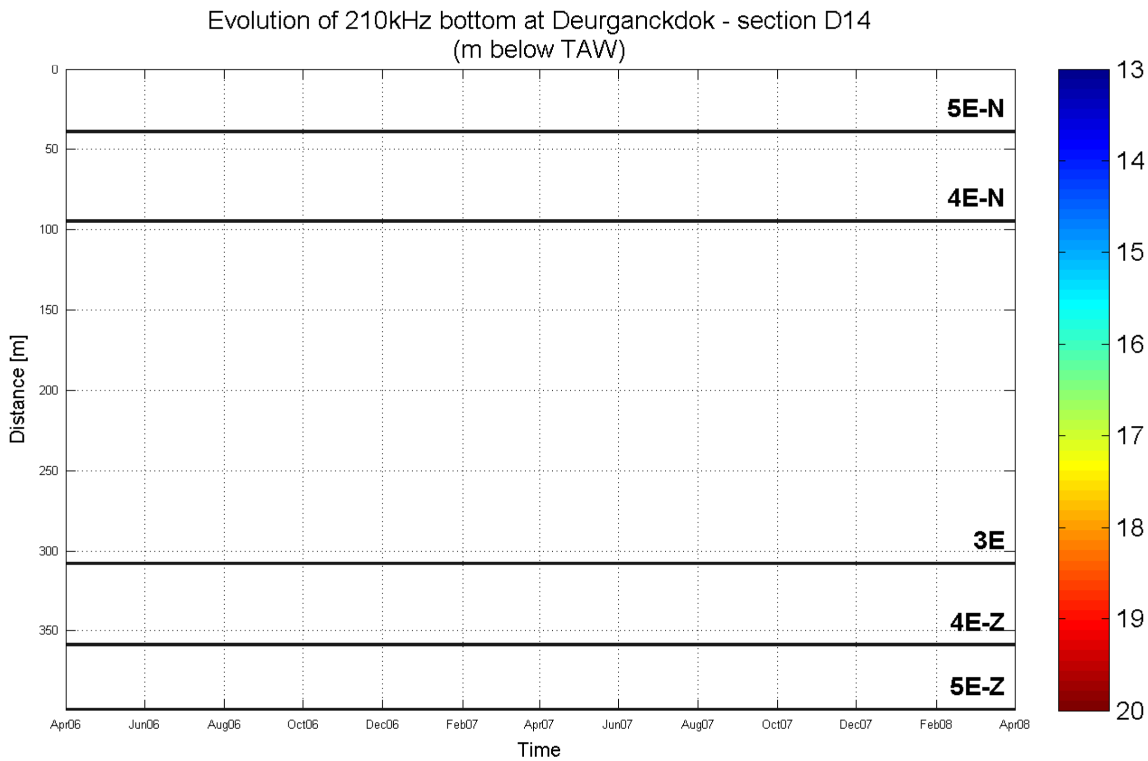
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



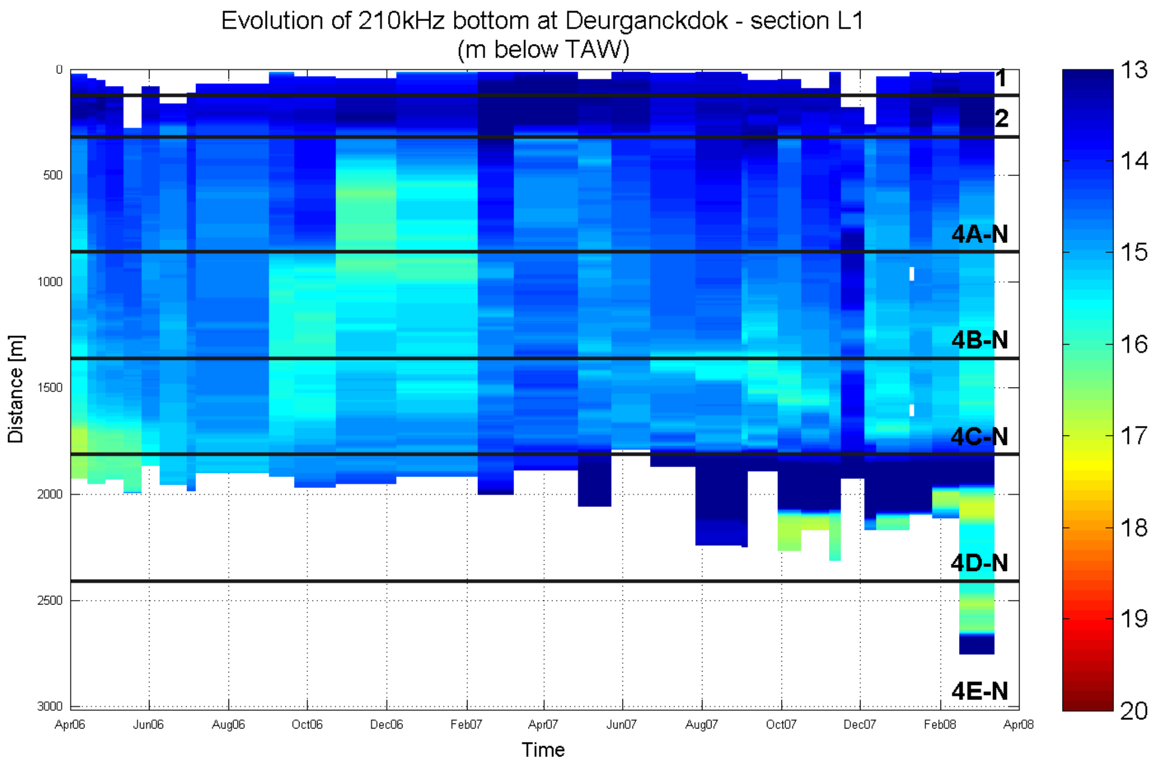
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



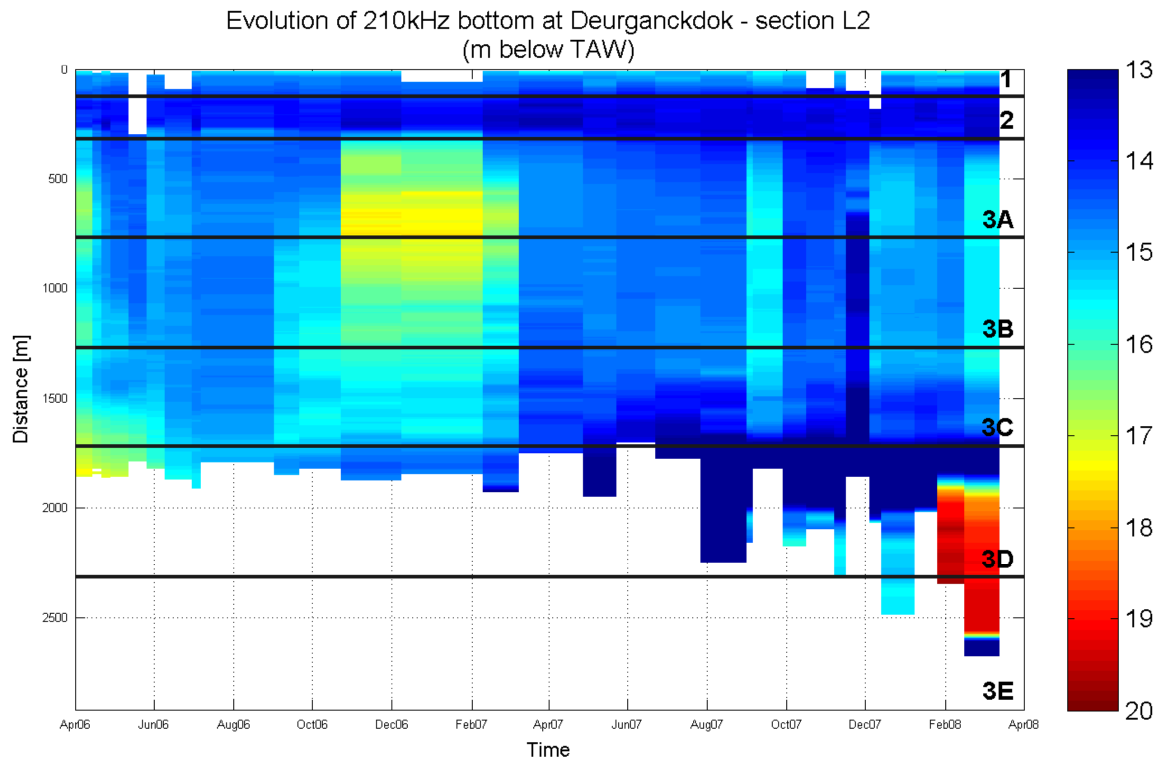
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



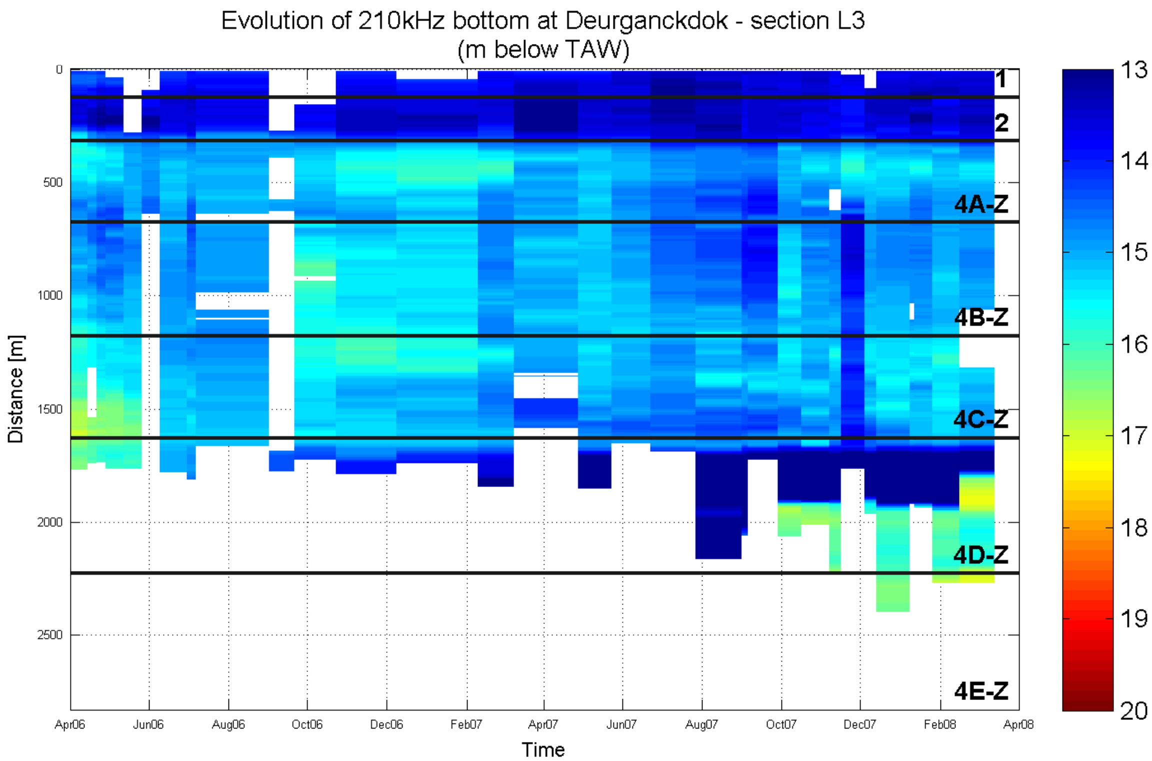
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



Data Processed by:

In association with :

I/RA/11283/07.085/MSA

APPENDIX C.

VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS

C.1 Siltation rates (tabular)

Siltation rates in cm/day computed from subsequent depth soundings (no monthly averaged values)

1. Per zone

	27-Apr-2007	23-May-2007	22-Jun-2007	27-Jul-2007	31-Aug-2007	5-Sep-2007	28-Sep-2007	16-Oct-2007	7-Nov-2007	16-Nov-2007	4-Dec-2007	13-Dec-2007	8-Jan-2008	11-Jan-2008	25-Jan-2008	15-Feb-2008	13-Mar-2008
1	0.1														-0.168		
2	1.826	-3.703	-0.756	0.404	-0.35	2.792	-0.706	-0.013	-0.174	-1.681		0.657	0.692	0.121	-0.373	1.128	-2.836
3a	0.197	0.57	0.214	0.494	-2.978	4.028	3.519	0.663	-0.3	1.085	-5.045	0.457	1.125	-0.01	1.421	-3.508	0.795
3b	-0.259	0.532	-0.263	0.208	-2.45	1.437	4.275	-0.435	-0.223	12.059	-8.913	0.786	0.206	-0.062	0.804	-3.331	2.036
3c	-0.24	0.665	0.22	0	-2.411	0.616	2.848	0.45	-0.207	11.416	-9.107	0.344	0.452	0.01	-0.312	-2.003	0.112
3d					-3.458		-2.777	3.96	-4.342		5.39	-10.922	5.771	-0.473	-35.45	0.259	-1.159
3e																	
4Na	-0.001	1.45	0.638	0.954	-0.923	3.148	-1.954	2.082	0.621	-1.844	-4.317	2.018	2.15	-0.113	-1.92	-0.415	-1.2
4Nb	-0.884	0.599	0.557	0.176	-1.19	1.254	-0.067	1.532	0.109	6.987	-7.102	1.813	0.864	0.545	-1.083	-1.392	0.722
4Nc	-0.753	0.037	0.038	-0.427	-0.536	-1.464	0.597	0.699	0.174	10.156	-6.852	-0.747	1.091	0.145	-0.142	-0.986	0.535
4Nd					0.498		-5.015	4.586	-3.925		6.515	-5.266			-3.426	-4.258	-2.321
4Ne																	
4Za	-0.367	1.117	0.875	0.309	0.235	1.162	-2.675	0.738	-0.01	-0.93	-1.361	0.745	0.85	-0.001	-0.732	0.149	-1.01
4Zb	-0.298	0.578	1.17	0.128	1.059	-0.076	-3.816	1.641	-0.028	10.919	-6.221	1.299	0.392	-0.566	-1.81	0.516	-0.439
4Zc	-0.872	0.77	0.604	-0.359	0.292	-1.156	-1.337	0.329	-0.067	11.118	-5.983	-2.891	0.079	-0.026	-0.557	0.935	-0.865
4Zd					-2.694		-4.689	2.999	-4.959		5.471	-11.802		6.544	-14.573	-6.711	-1.952
4Ze																	
5Na		0.733	1.349	1.378		1.04		-2.577	1.379	-5.822	-2.897	3.337			0.777		-1.405
5Nb	-1.697		1.025			0.832		-1.89		1.119	-4.393						
5Nc			0.355	-0.863	1.356	0.492		-0.811	-1.673	6.988	-2.367				0.456		
5Nd				-1.009	0.761			0.655	-2.821		3.24					-4.124	-1.508
5Ne																	
5Za	-0.814	1.211	-0.109	0.617	0.612	3.633	-2.47	0.35		-0.186	0.031	-1.155	0.895	4.65	-2.968	2.952	-2.751
5Zb	-0.097	0.256	1.161	0.195		1.041		-1.8	0.281	6.114	-0.475			1.051	-6.169		
5Zc	-0.486	0.329	1.123	-0.245	0.49	15.563		-2.963		0.955	2.518			-0.079	-7.23		
5Zd					-1.854			-2.885	-3.264						-0.147		-4.181
5Ze																	

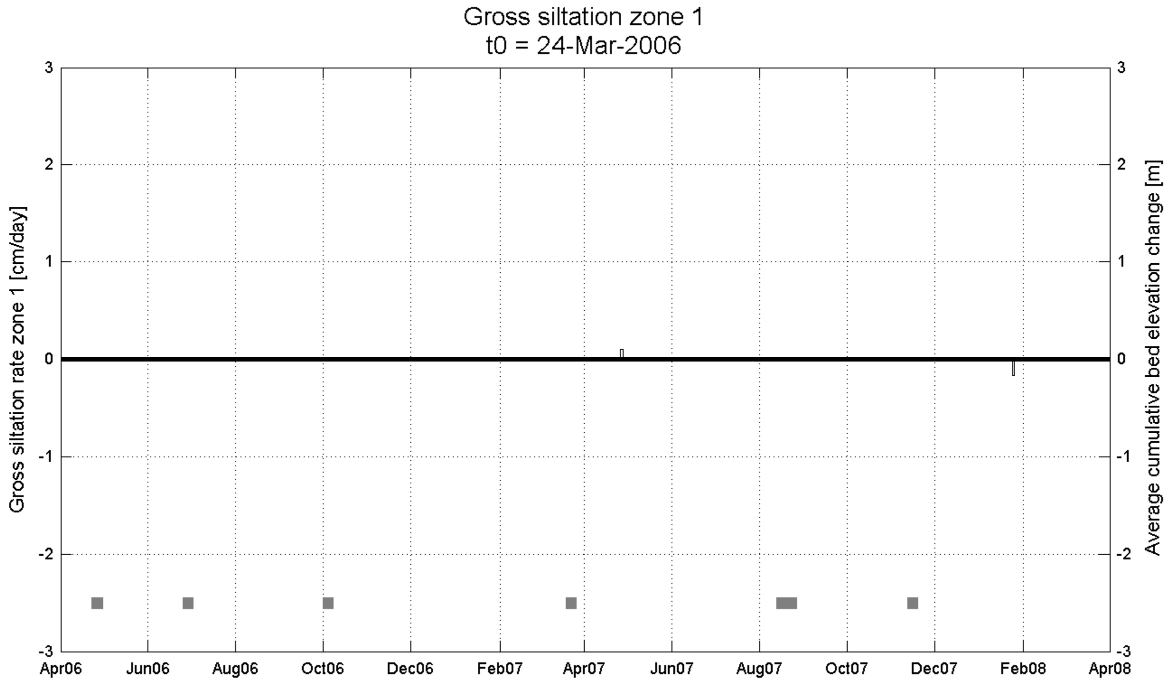
2. Per section

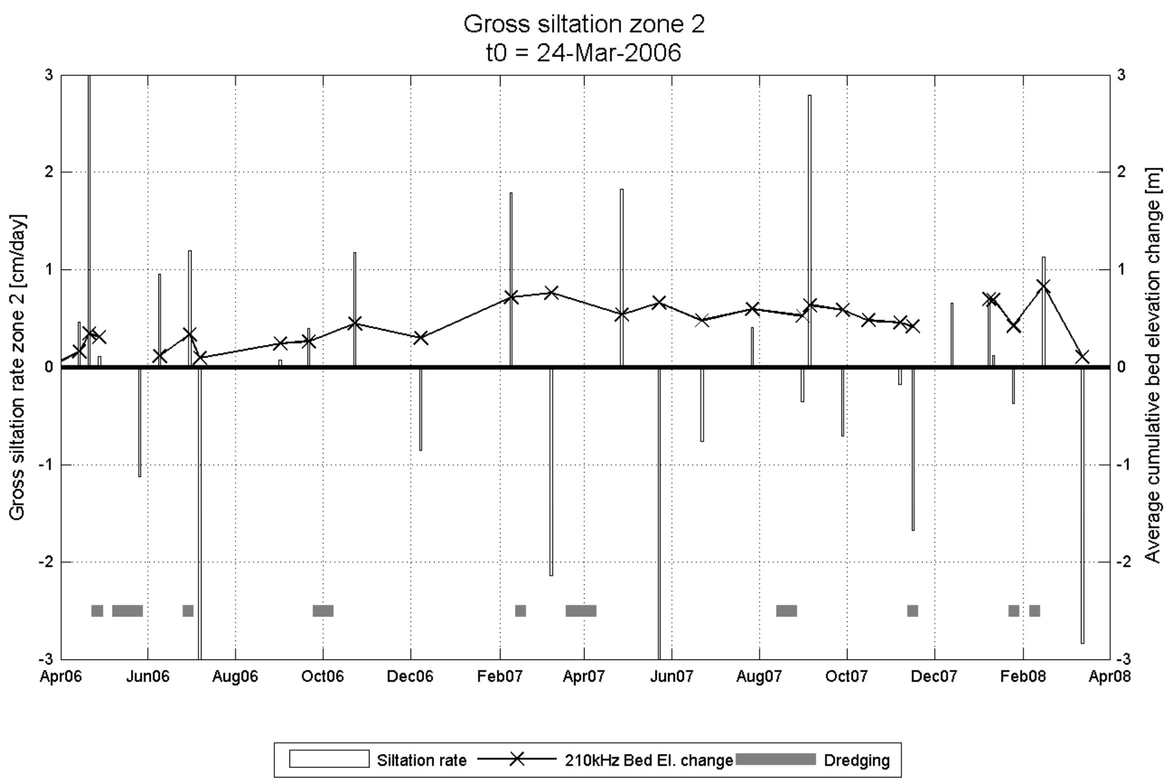
	27-Apr-2007	23-May-2007	22-Jun-2007	27-Jul-2007	31-Aug-2007	5-Sep-2007	28-Sep-2007	16-Oct-2007	7-Nov-2007	16-Nov-2007	4-Dec-2007	13-Dec-2007	8-Jan-2008	11-Jan-2008	25-Jan-2008	15-Feb-2008	13-Mar-2008
D1	0.648	0.733	0.242	-0.104	-0.589	1.858	0.791	-0.488	0.419	7.113	-6.481	0.311	0.056	1.222	-0.572	0.521	-3.536
D2	-1.025	0.692	-0.057	-0.654	-1.2	0.053	1.962	0.28	-0.607	11.53	-6.831	-0.846	0.317	0.287	0.055	-2.693	2.3
D3	-0.497	0.383	0.375	0.239	-1.494	1.982	1.363	0.108	0.139	9.229	-6.913	0.976	0.272	5.222	-0.784	-2.392	1.44
D4	-0.259	0.735	0.403	0.104	-1.363	2.586	1.644	0.359	-0.047	9.222	-8.164	0.994	0.735	1.558	-1.06	-1.869	0.825
D5	0.277	0.676	0.811	0.348	-2.173	6.599	0.994	0.685	0.229	-5.753	-1.656	1.276	1.121	0.156	0.655	-2.271	-0.107
D6	0.27	1.285	0.451	0.637	-0.74	3.102	-1.328	0.861	-0.265	-1.569	-0.191	0.647	0.727	-0.089	-0.534	1.752	-3.01
D7	2.037	-4.688	-1	0.328	-0.219	2.523	-0.783	0.108	-0.105	-1.501		0.582	0.894	0.38	0.178	0.661	-2.833
D8	0.501	-3.852		-0.186	-0.49	2.587		-0.047	-0.333			0.094			0.595		
D9	0.047				-0.456										0.118		
D10																	
D11					1.146		-4.438	5.505	-2.634		-1.062	17.657	-0.687	2.292	-35.423	-8.95	2.332
D12												0.33			-5.876	1.052	1.764
D13																	2.994
D14																	
L1	0.076	-0.605	0.313	1.087	-0.581	-5.513	-0.552	1.915	-0.274	4.951	-3.753	0.247	1.52	-0.691	-3.061	-1.108	-1.455
L2	0.408	-0.337	0.17	2.029	-3.332	-3.041	3.68	0.83	-0.829	8.036	-5.217	-1.582	0.881	-0.047	-7.98	-1.672	-0.493
L3	-0.048	-0.288	0.916	1.87	-0.487	-6.429	-1.519	1.134	-0.926	5.895	-2.318	-2.388	1.662	-0.913	-2.932	-0.971	-1.417

C.2 Water-bed interface evolution for all zones

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

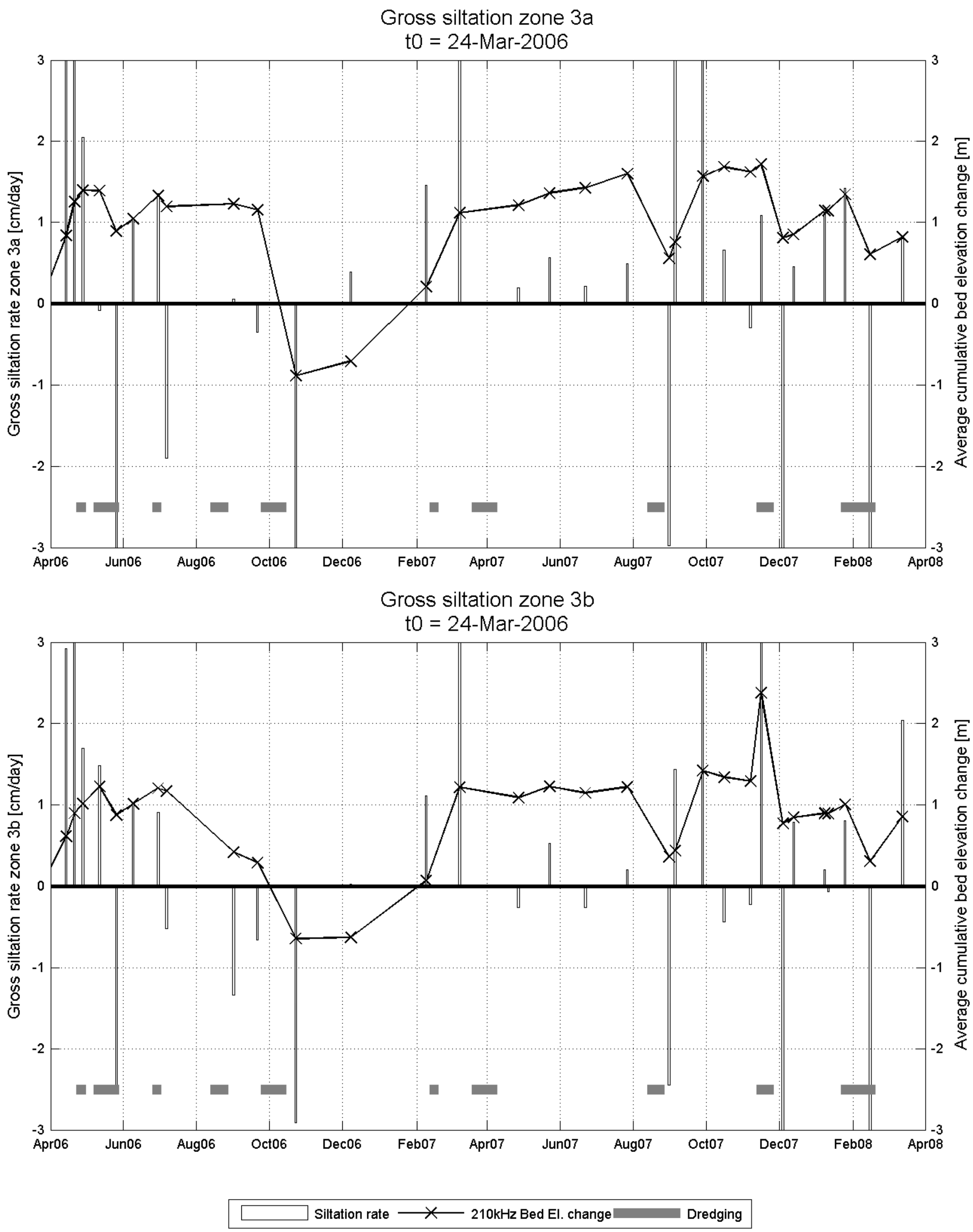
Data Processed by: IMDC

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

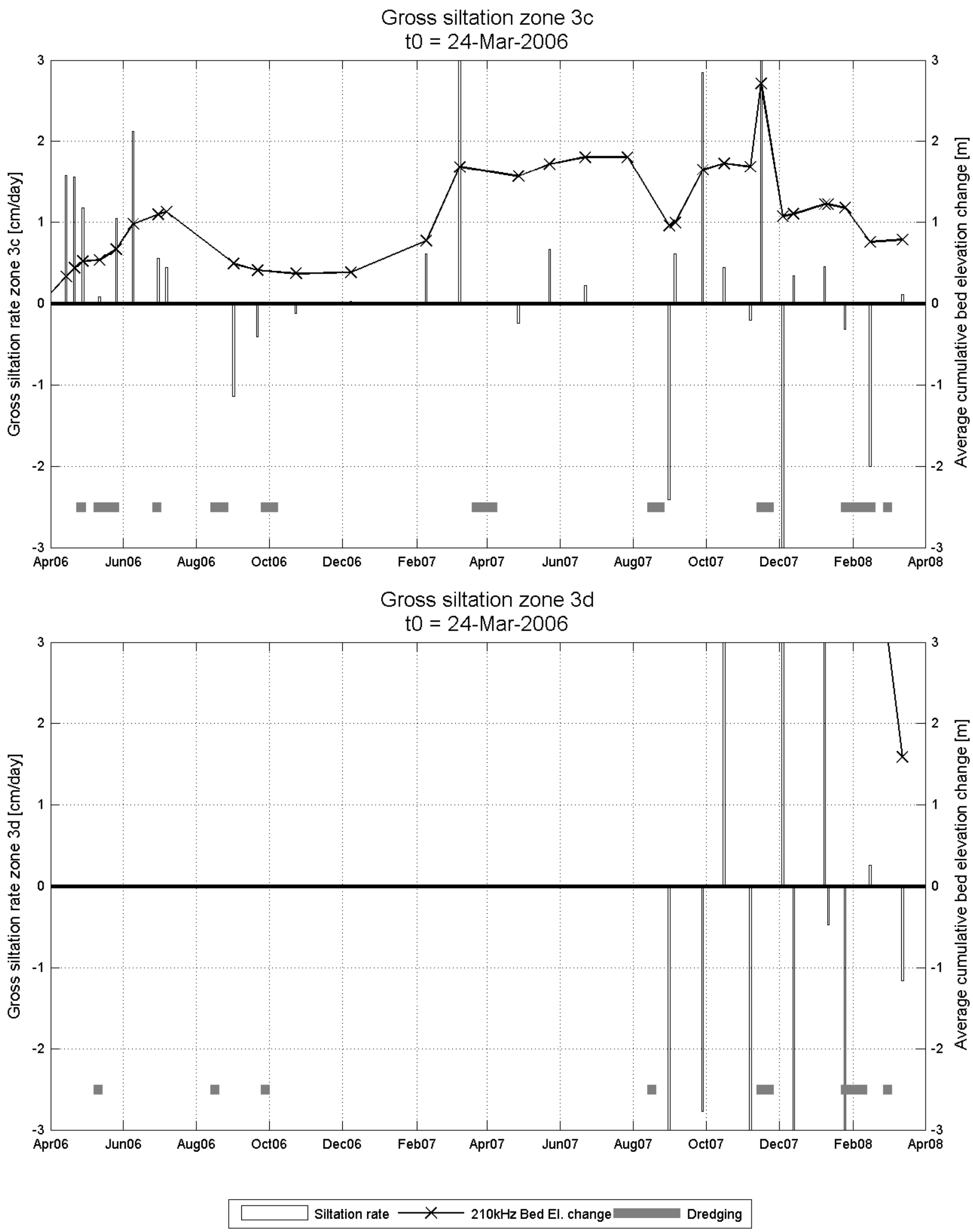
Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD



Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : WL delft hydraulics, GEMS International I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

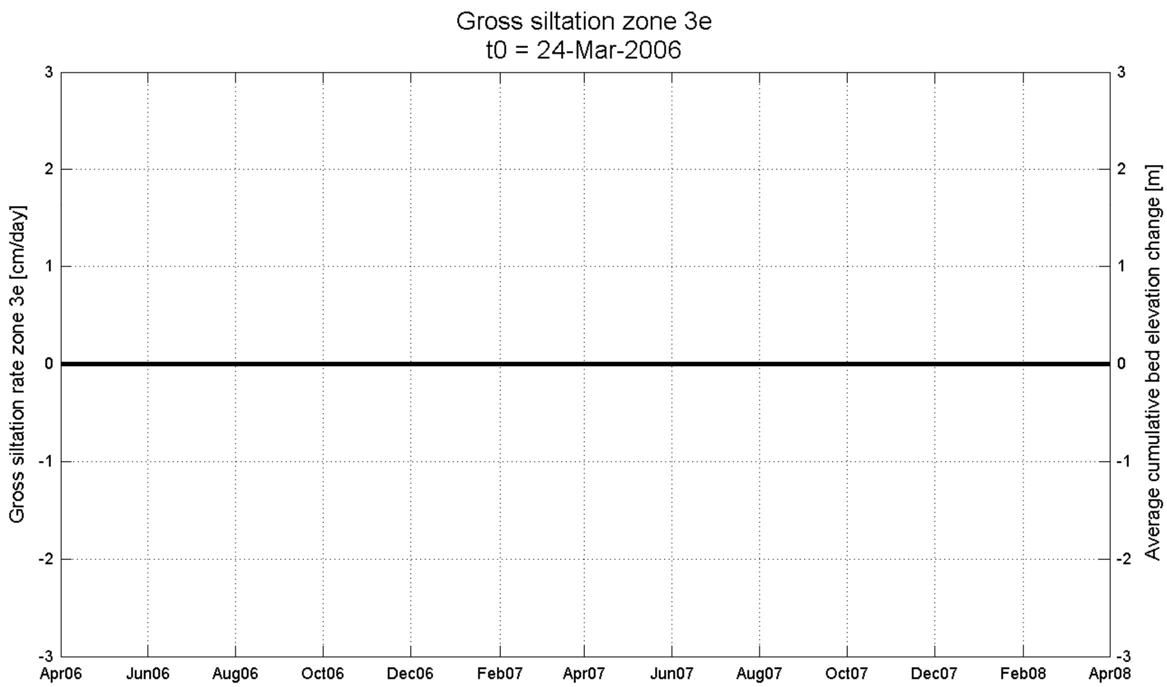
Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

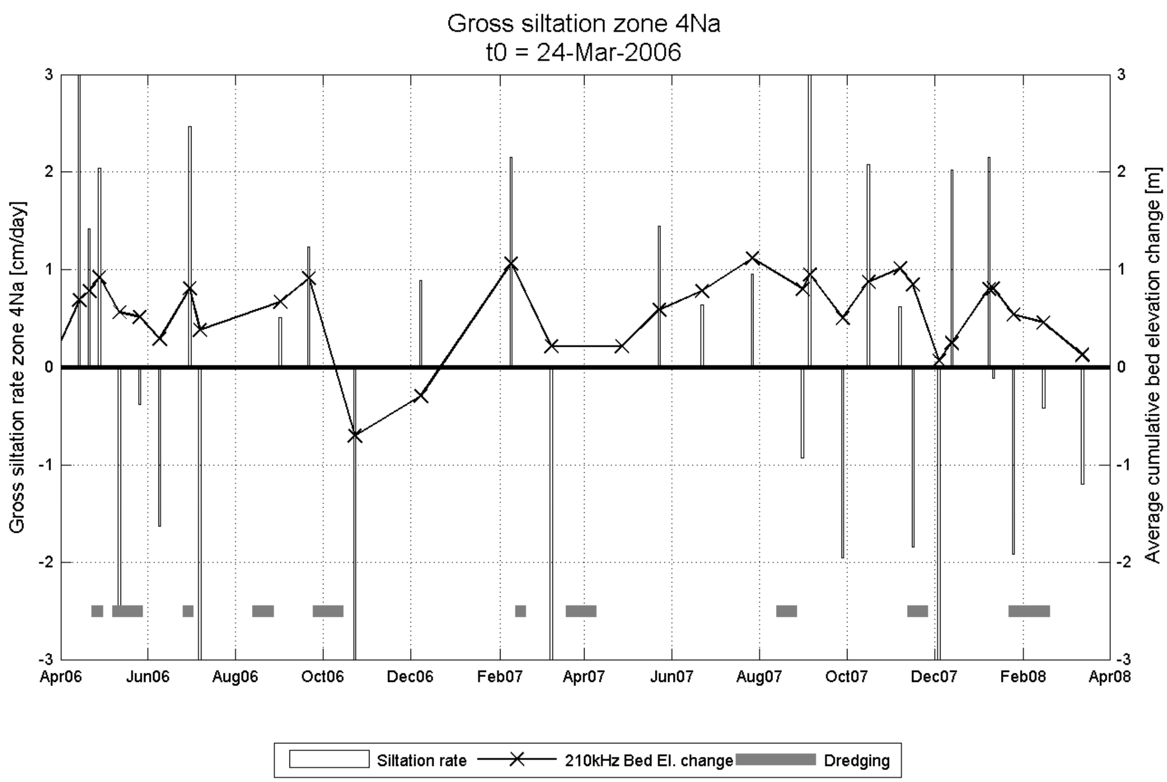


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : WL / delft hydraulics, GEMS International I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

Data Processed by: IMDC

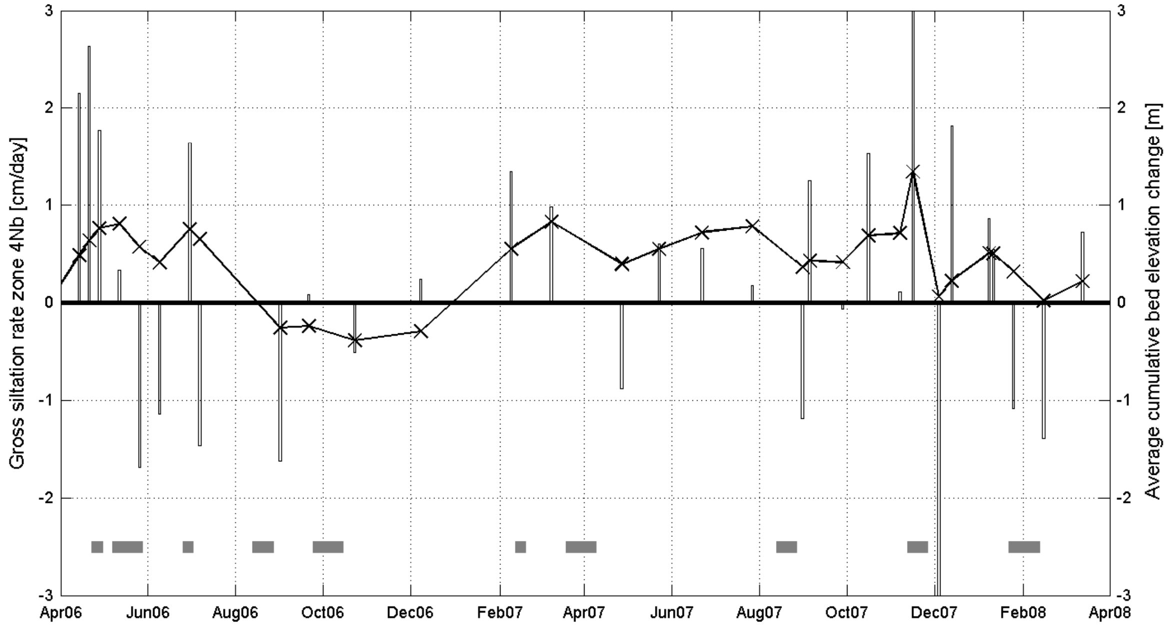
In association with :

I/RA/11283/07.085/MSA

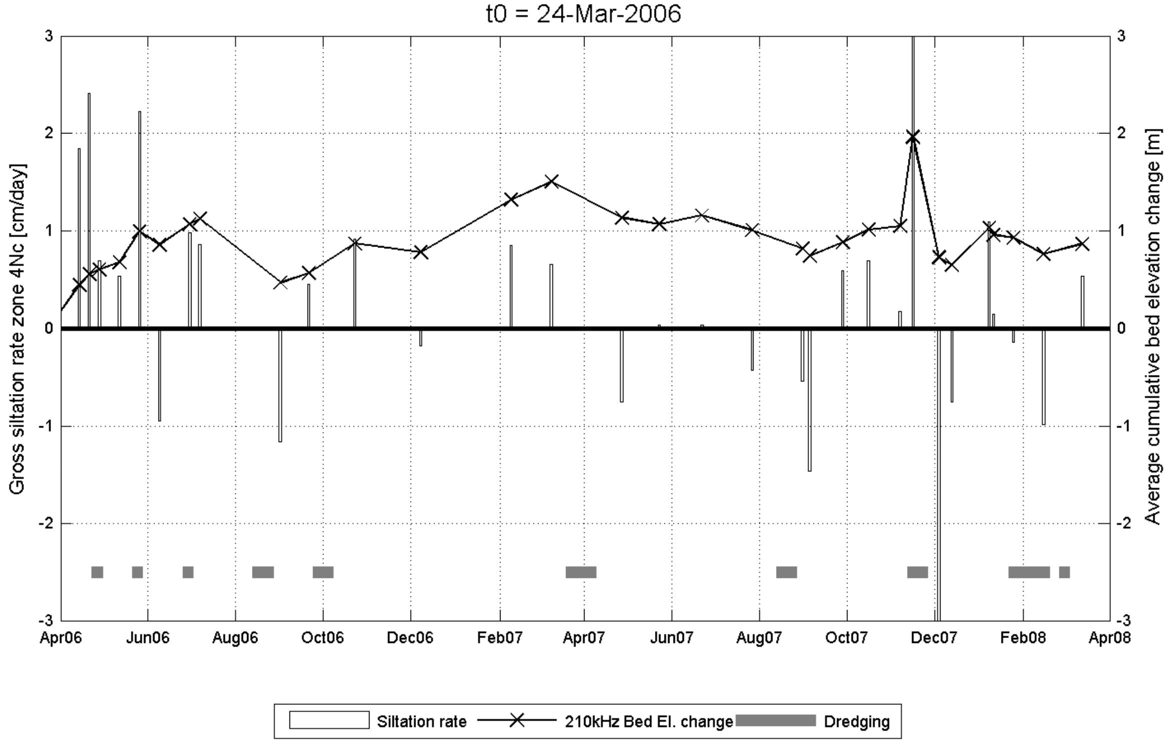
Long-term monitoring siltation Deurganckdok

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

Gross siltation zone 4Nb
t0 = 24-Mar-2006



Gross siltation zone 4Nc
t0 = 24-Mar-2006



Reference level: depth sounding 24-Mar-2006

Data Processed by: IMDC

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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

Gross siltation zone 4Nd
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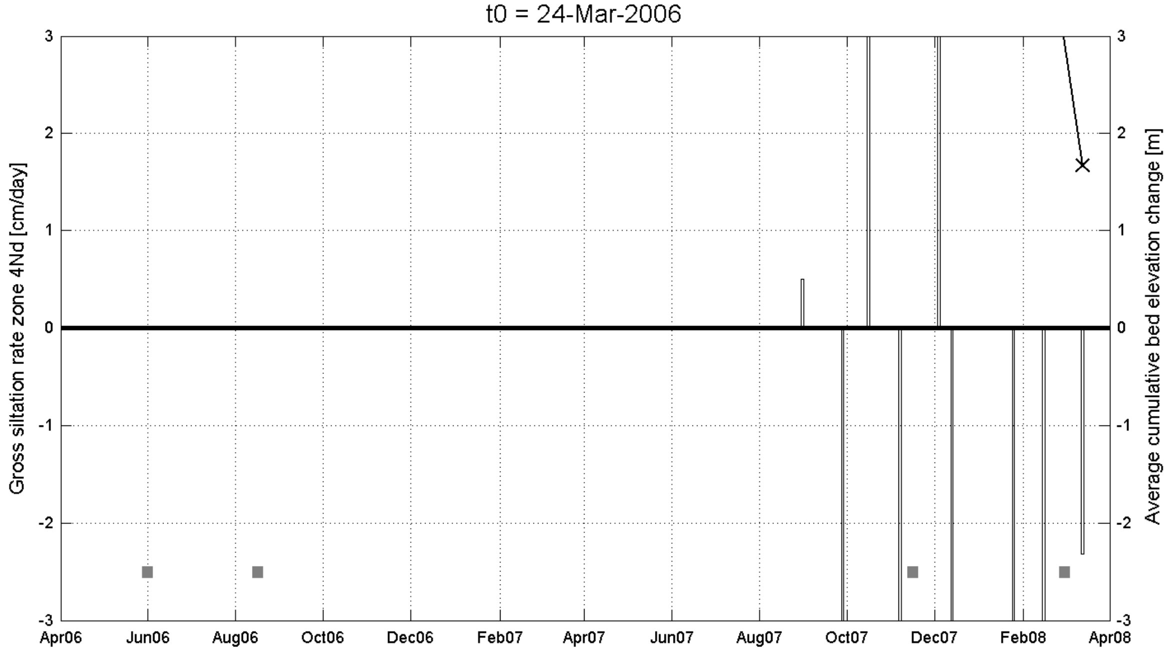

Gross siltation zone 4Ne
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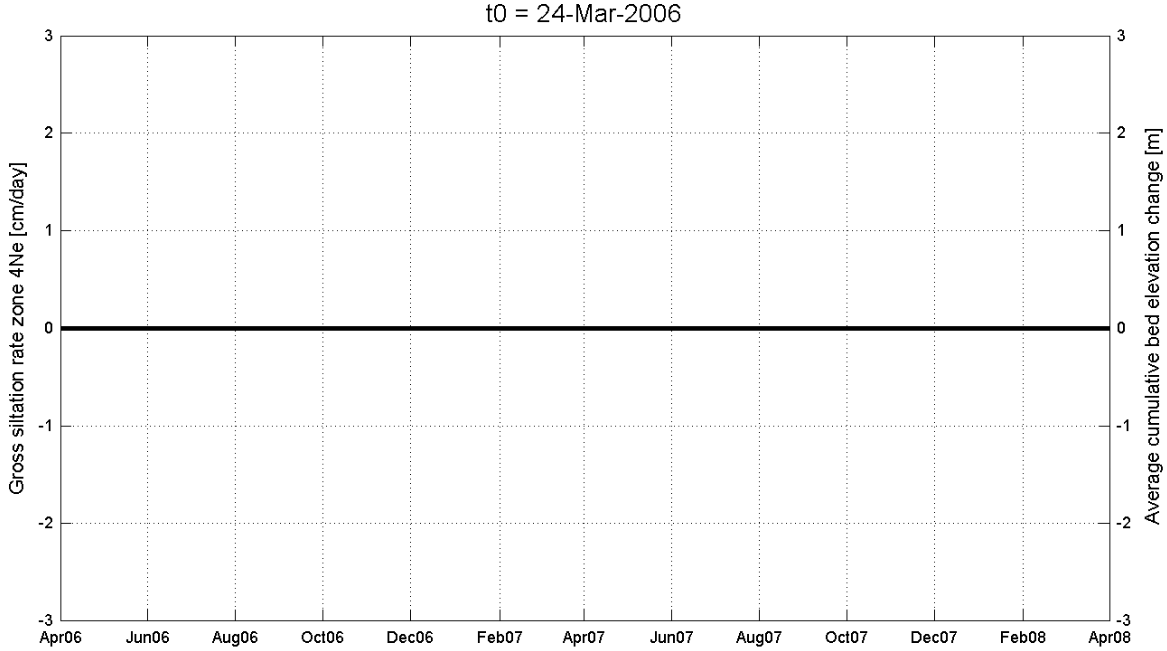


Siltation rate — 210kHz Bed El. change — Dredging

Reference level: depth sounding 24-Mar-2006

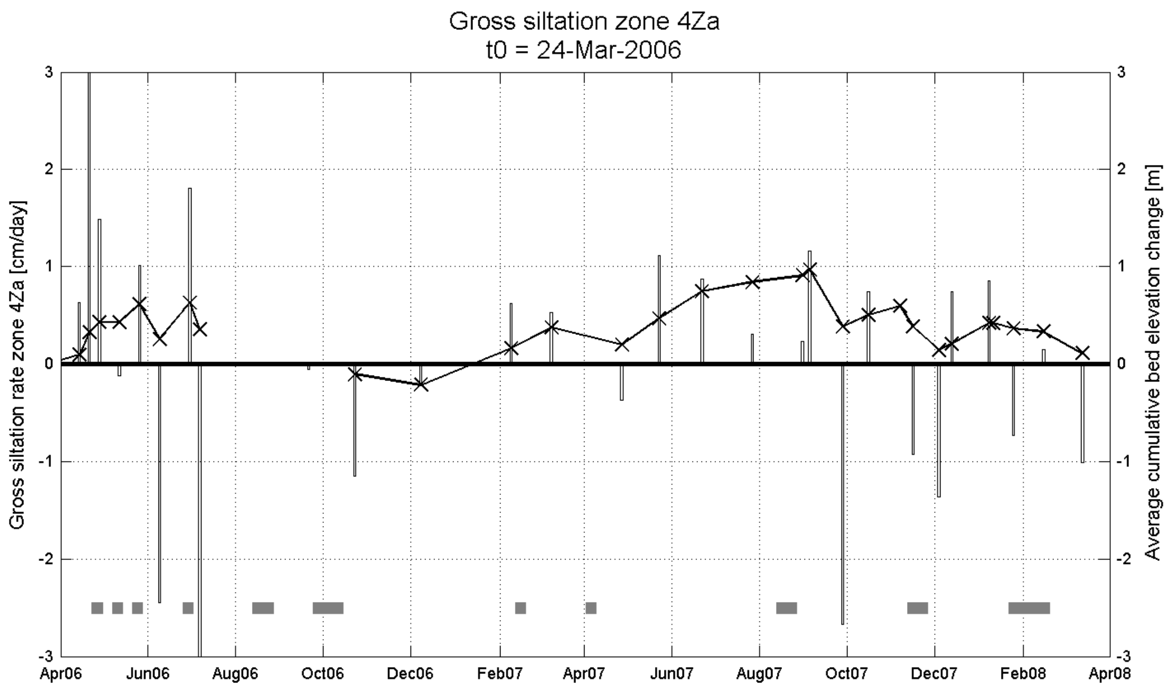
Data Processed by:

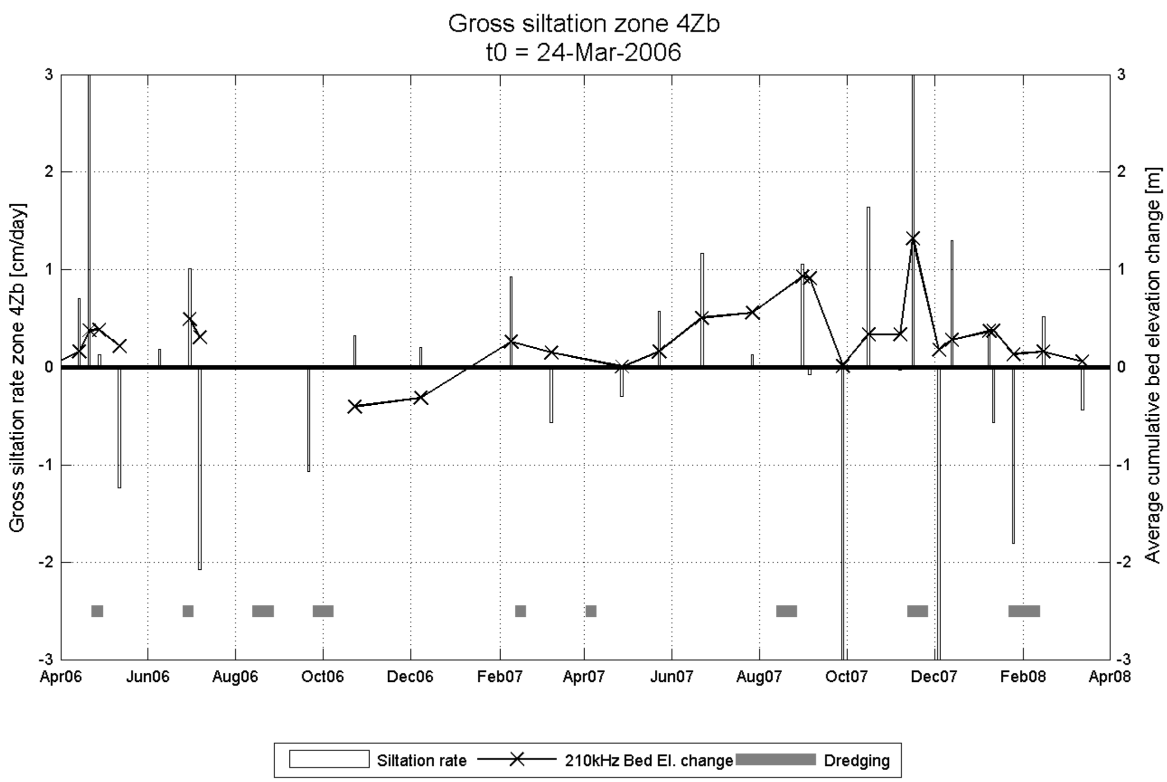
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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

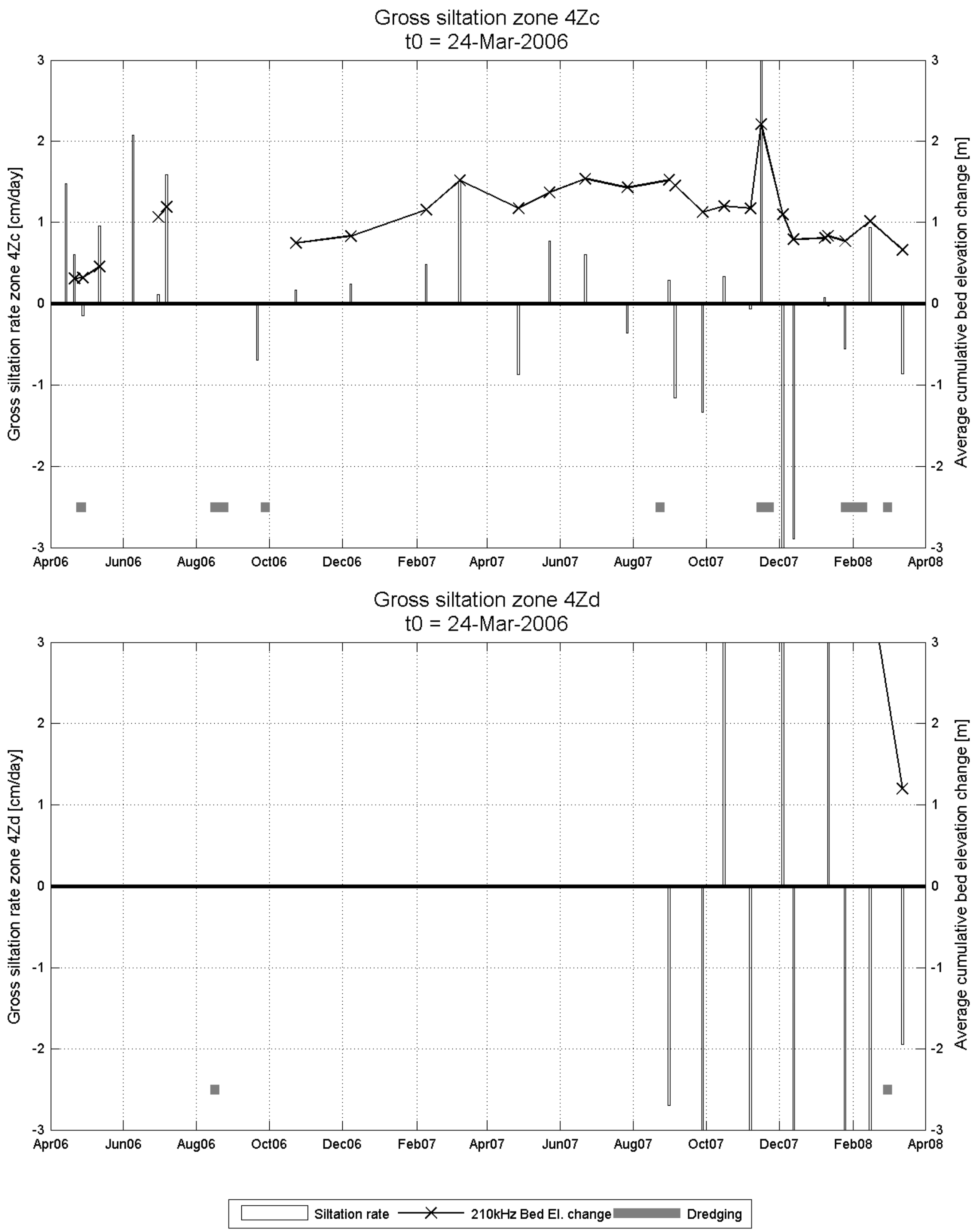




Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

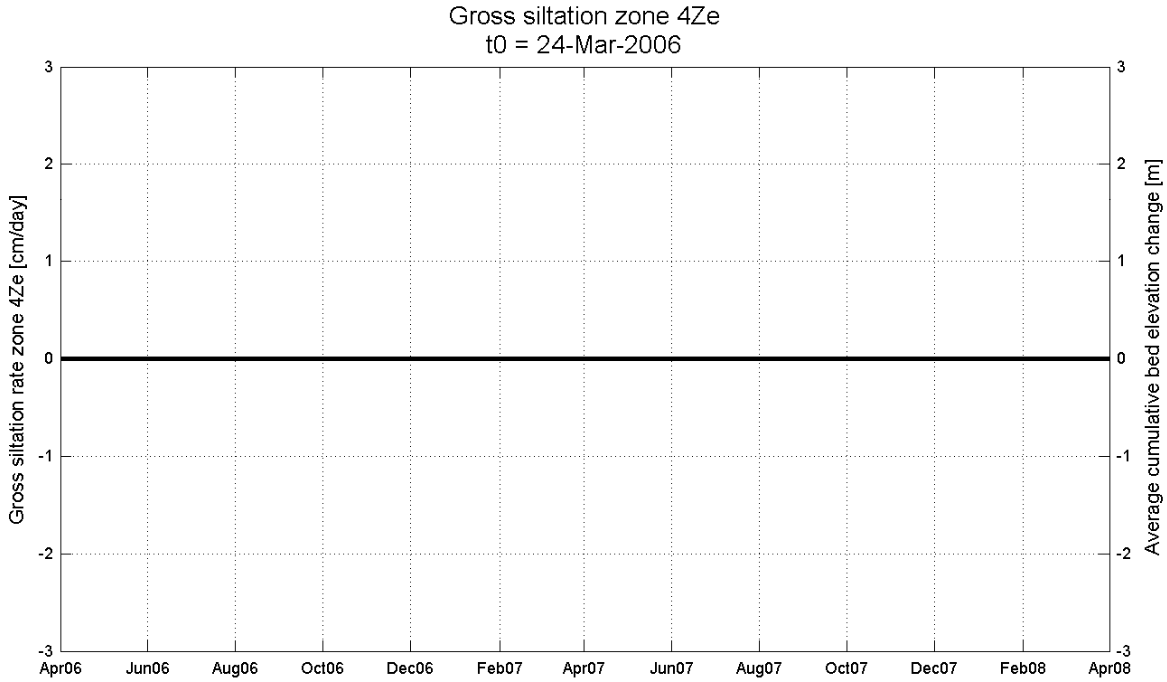
Siltation height / gross siltation rate	Equipment(s): 210kHz depth sounder
	Location: DGD

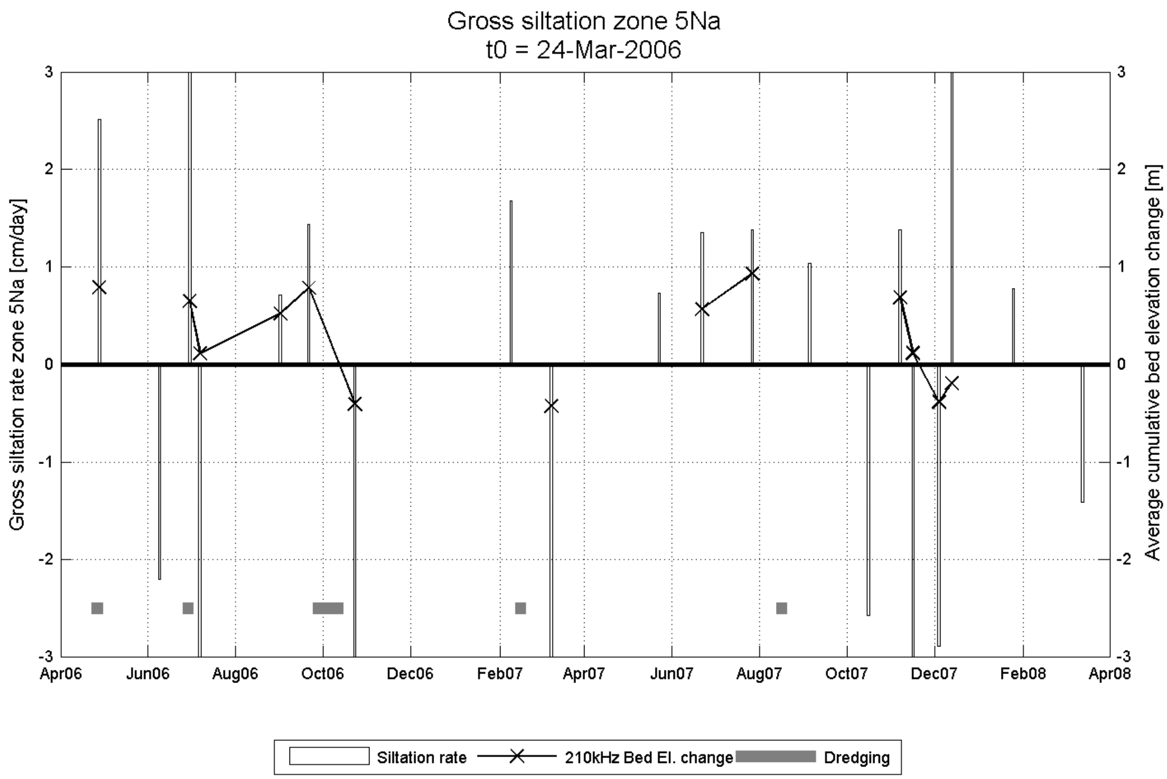


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : wl | delft hydraulics, GEMS International I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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

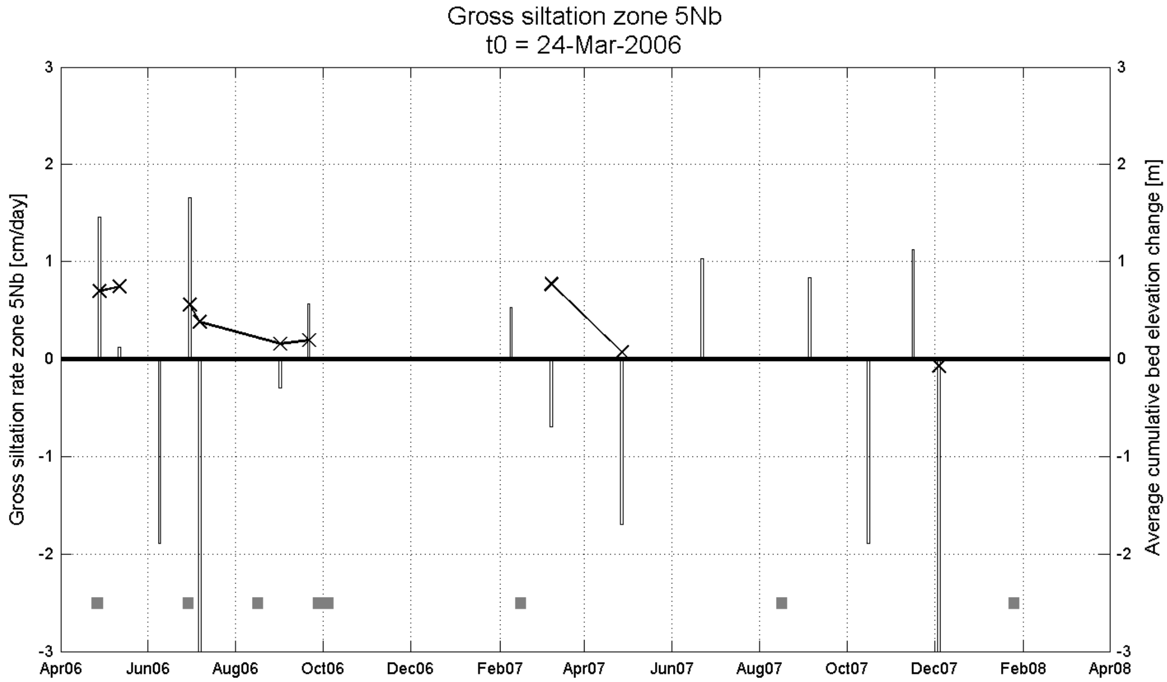


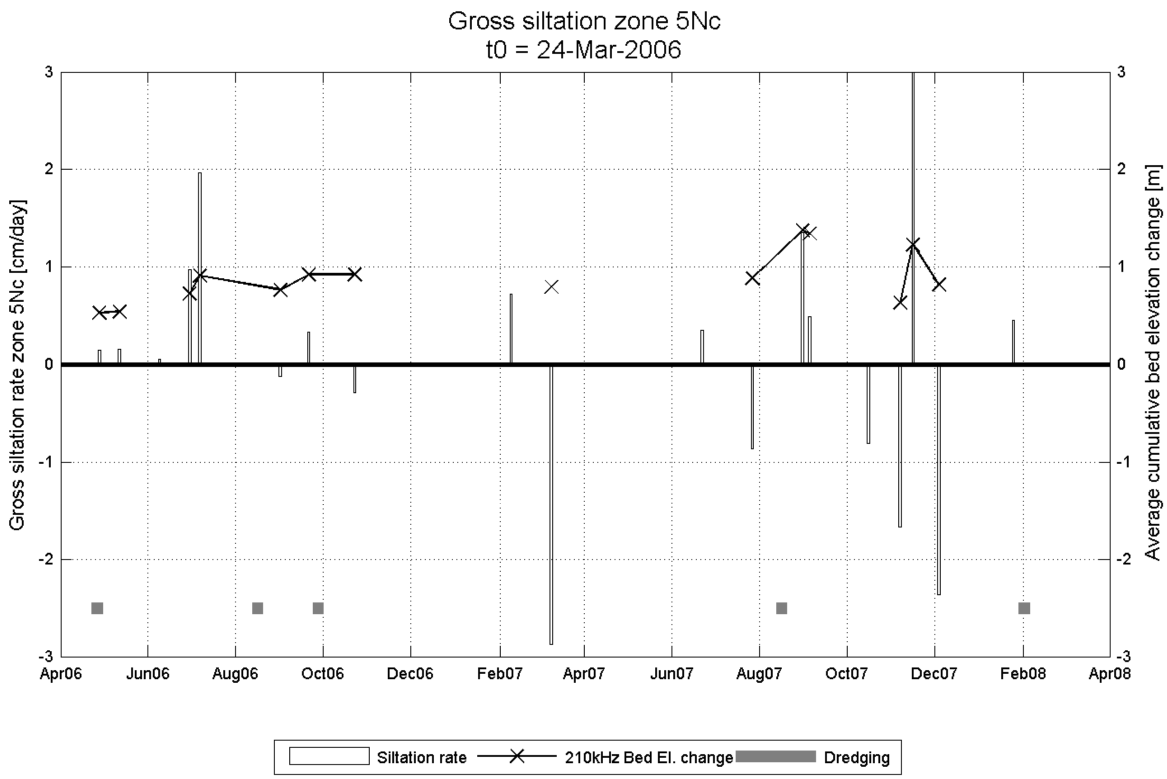


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

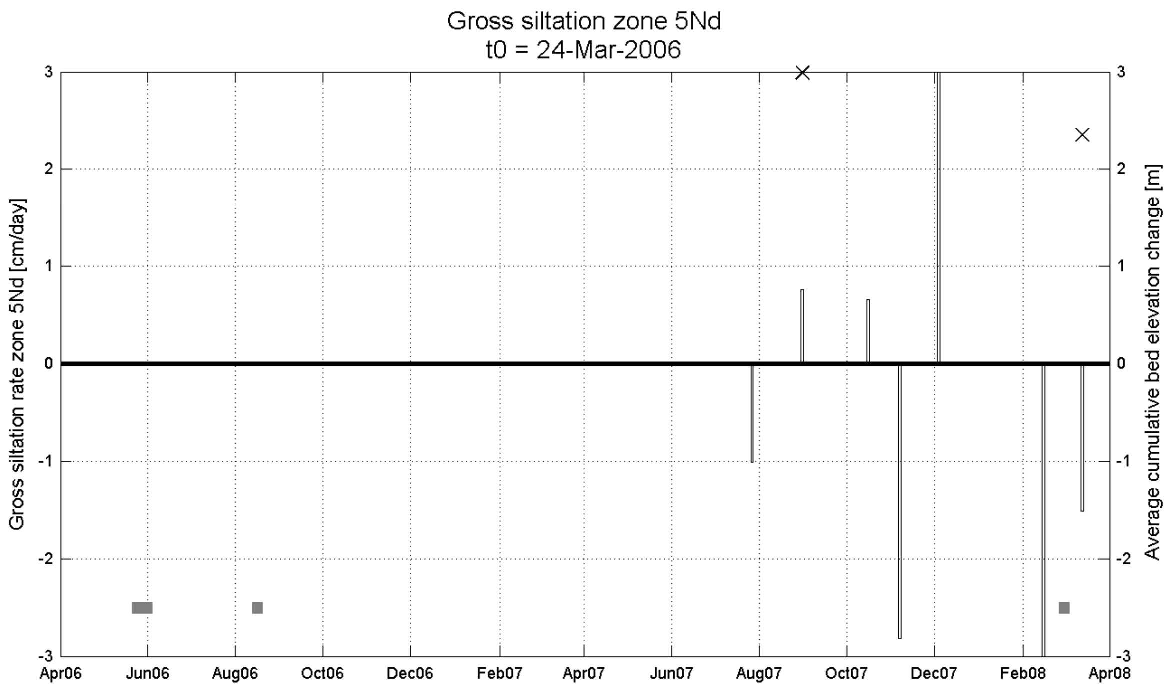
Data Processed by: IMDC

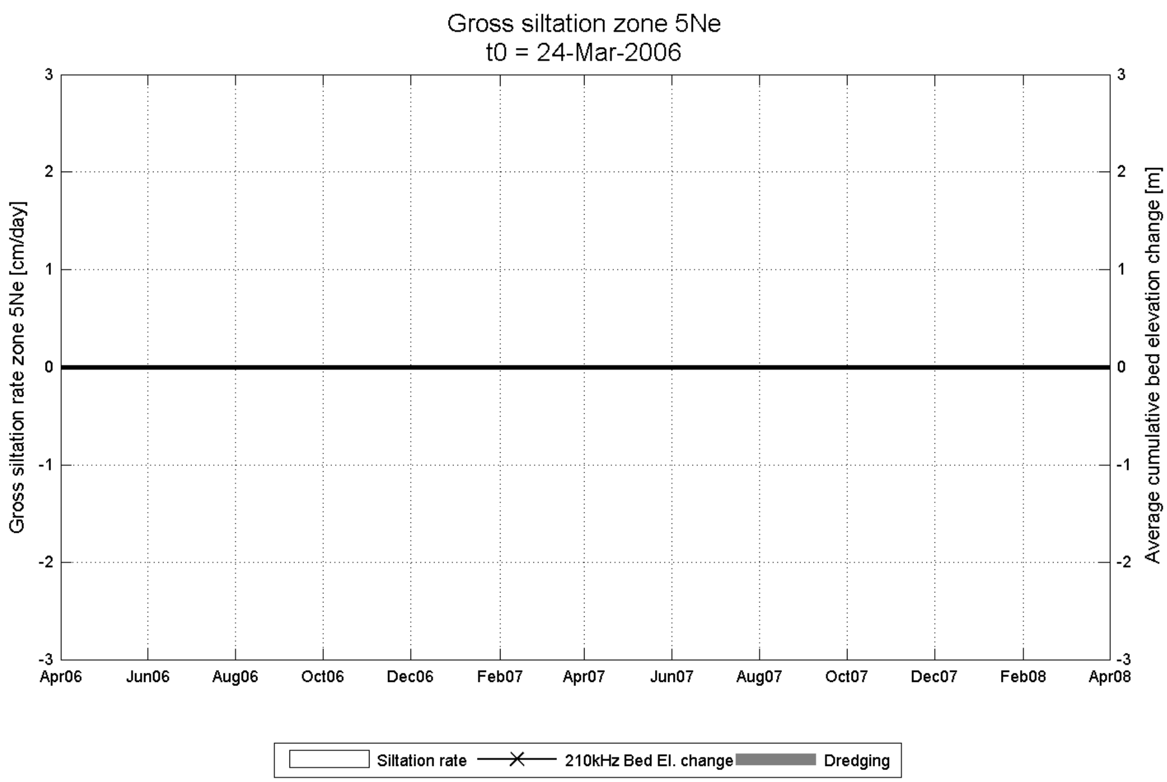
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

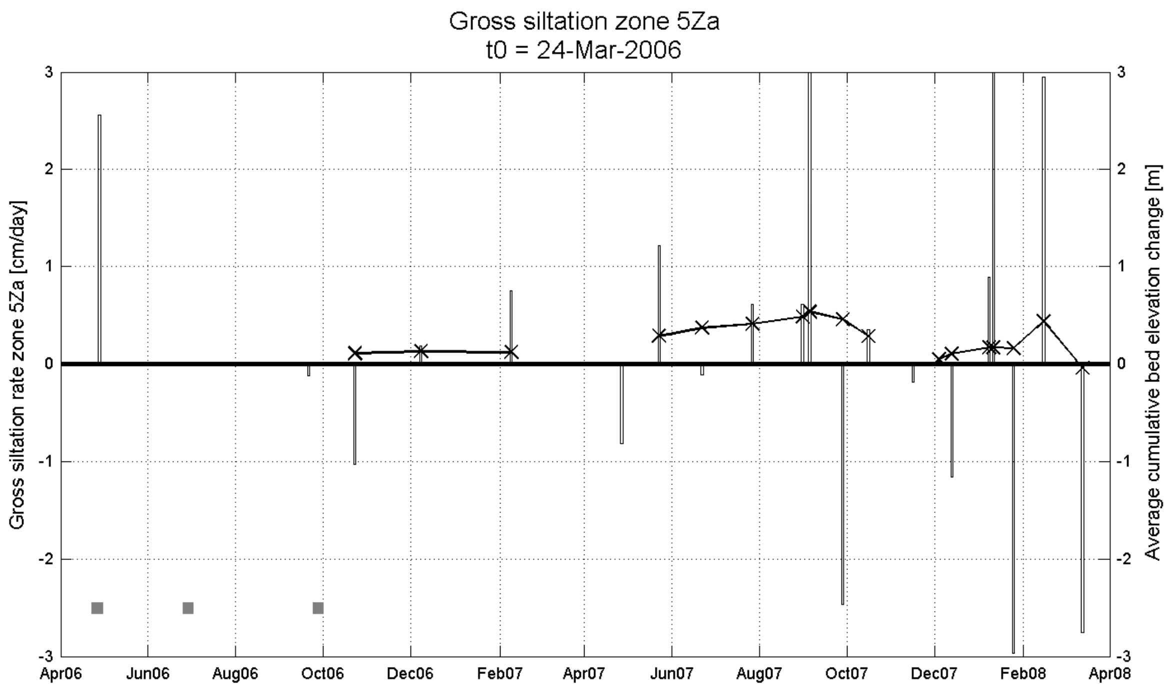
Data Processed by:

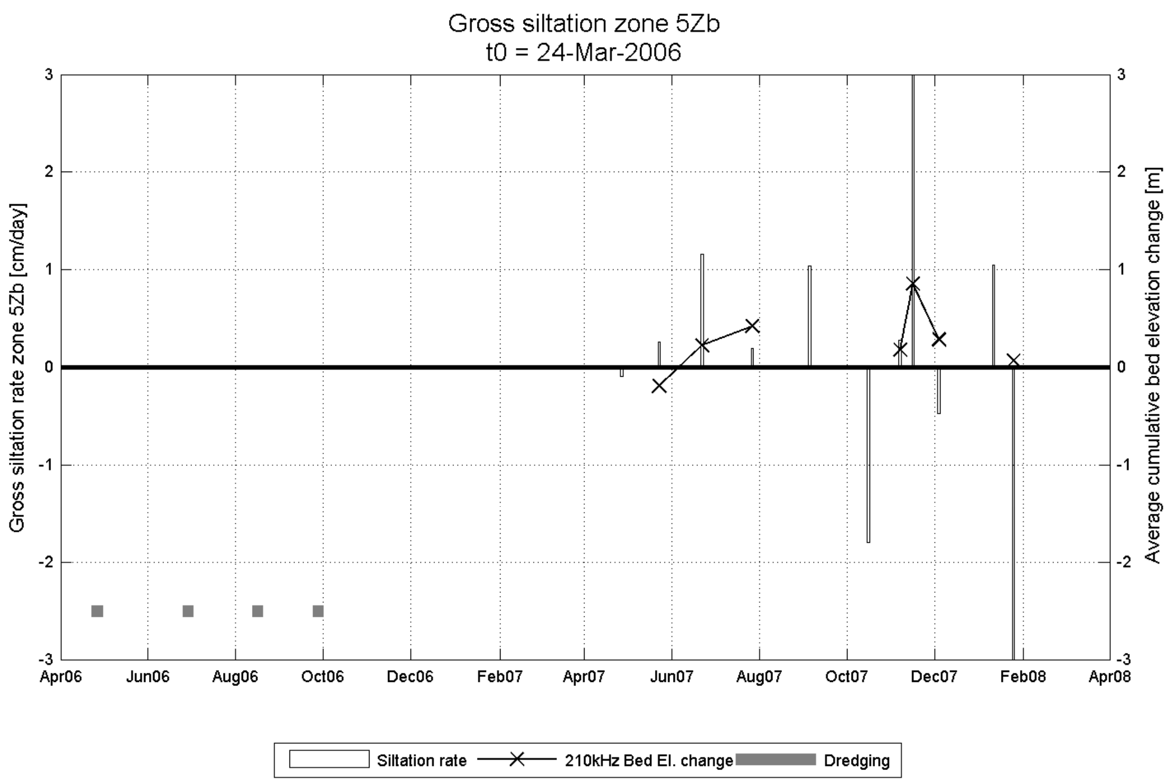
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

Data Processed by: IMDC

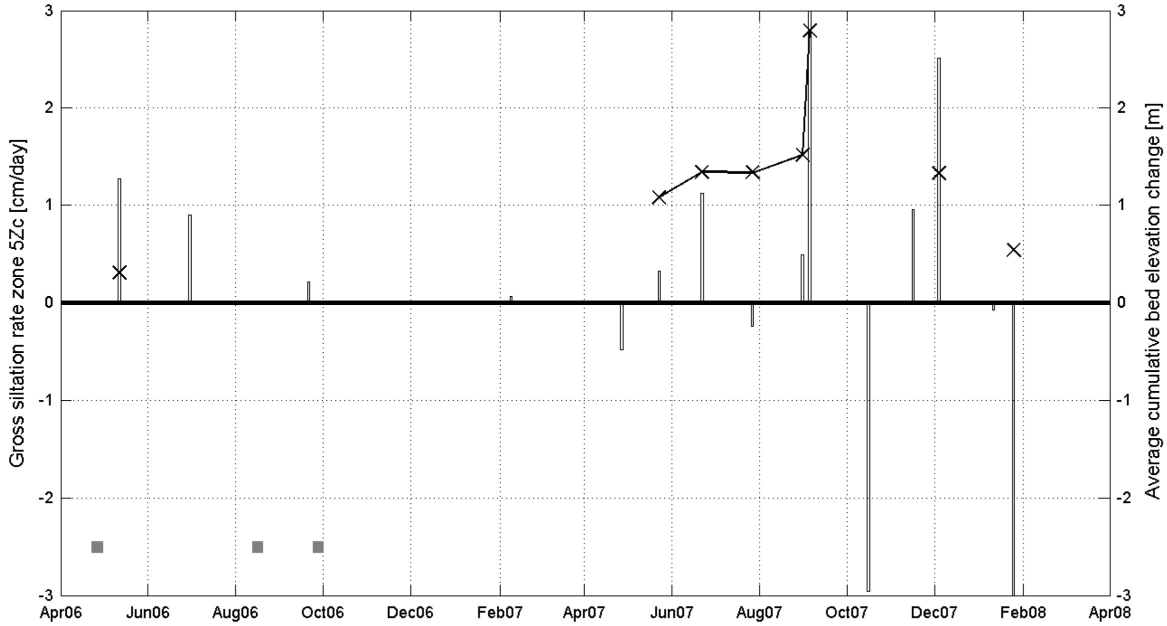
In association with :

I/RA/11283/07.085/MSA

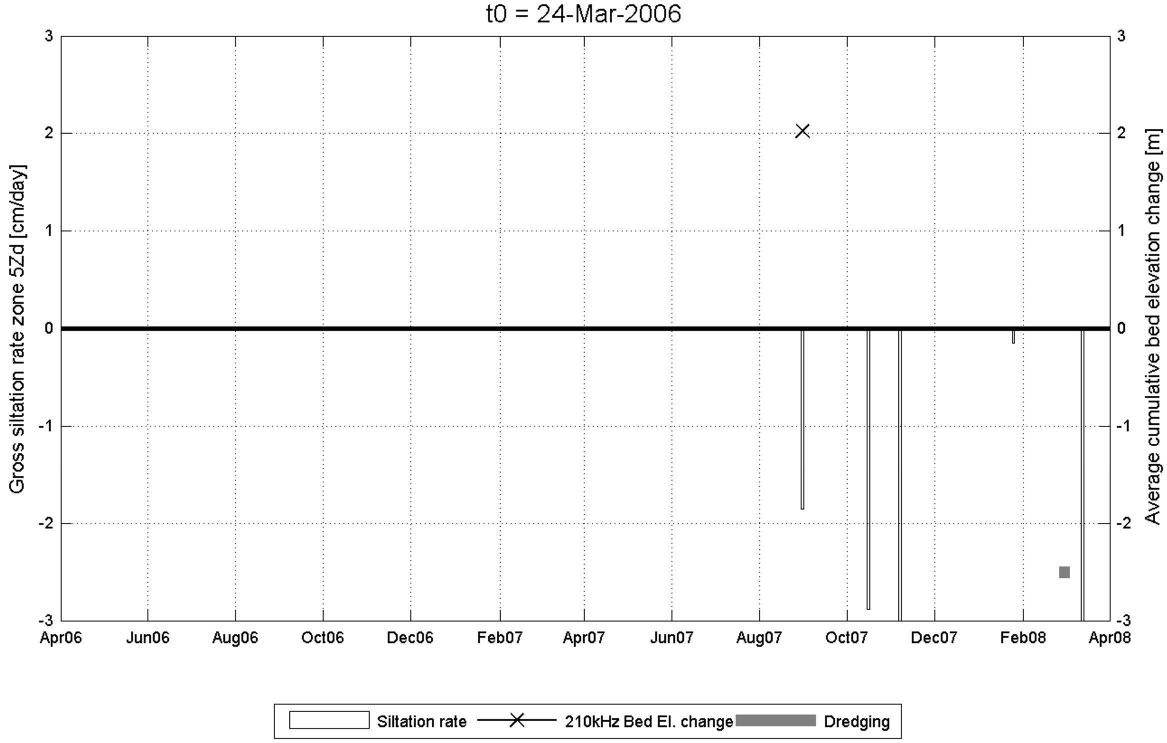
Long-term monitoring siltation Deurganckdok

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

Gross siltation zone 5Zc
t0 = 24-Mar-2006



Gross siltation zone 5Zd
t0 = 24-Mar-2006



Reference level: depth sounding 24-Mar-2006

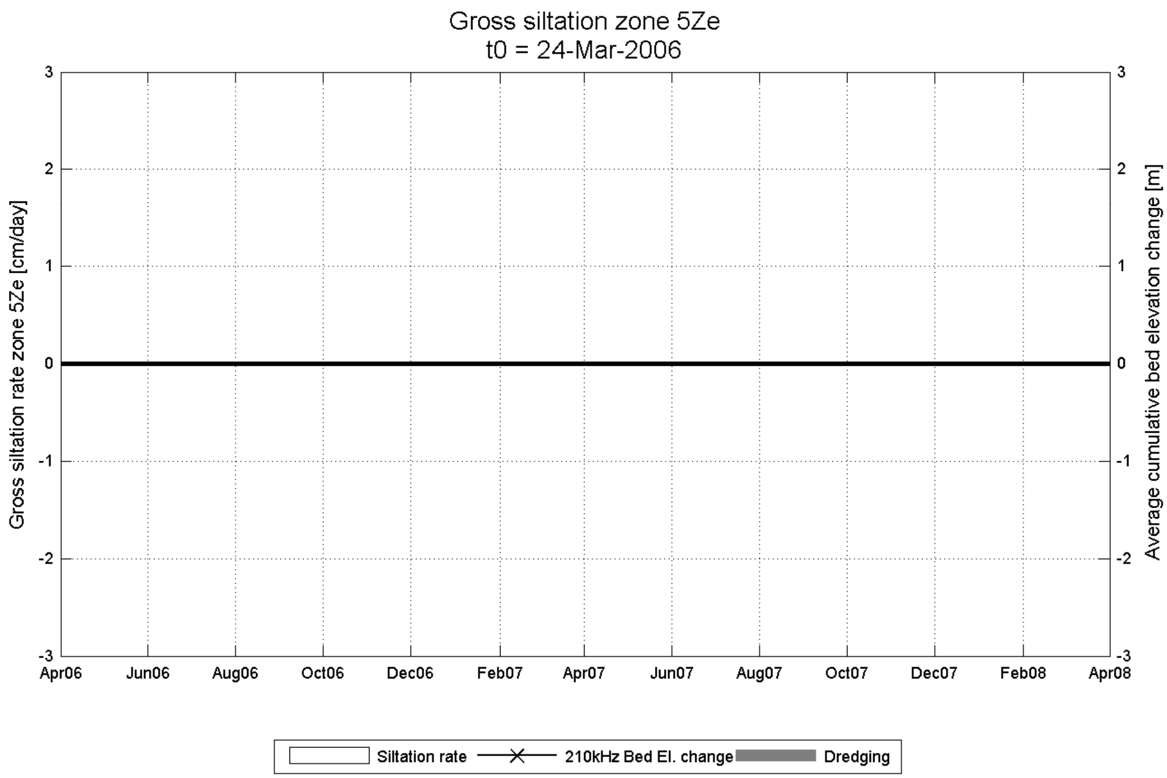
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



Reference level: depth sounding 24-Mar-2006

Data Processed by: IMDC

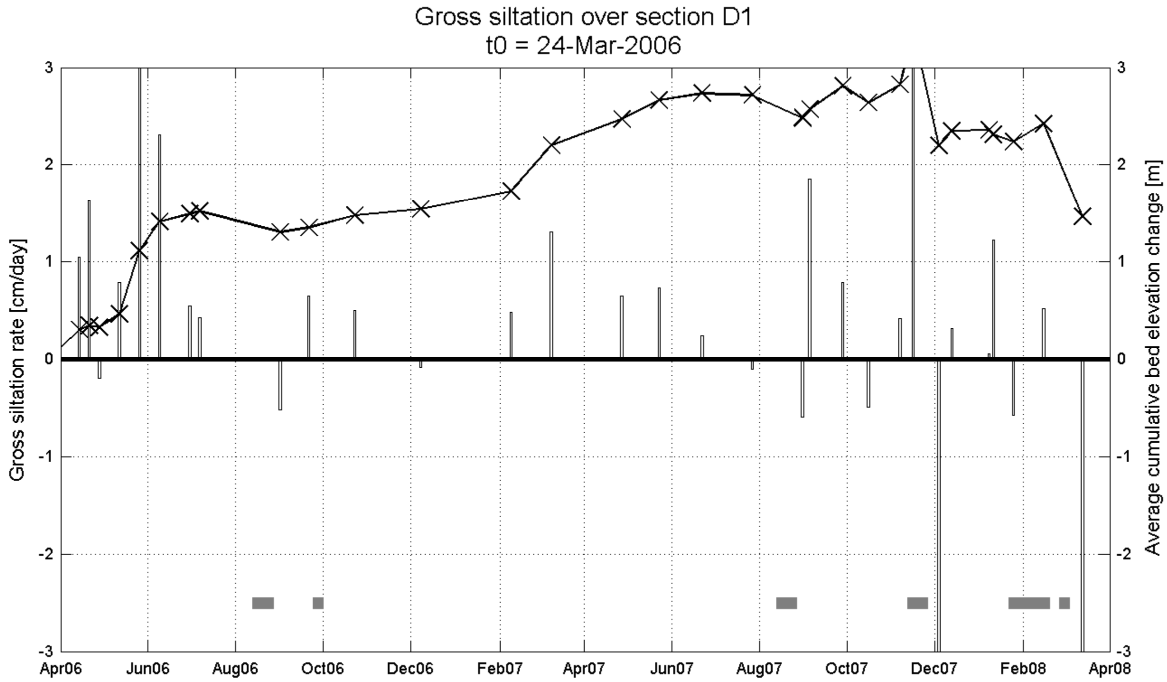
In association with :

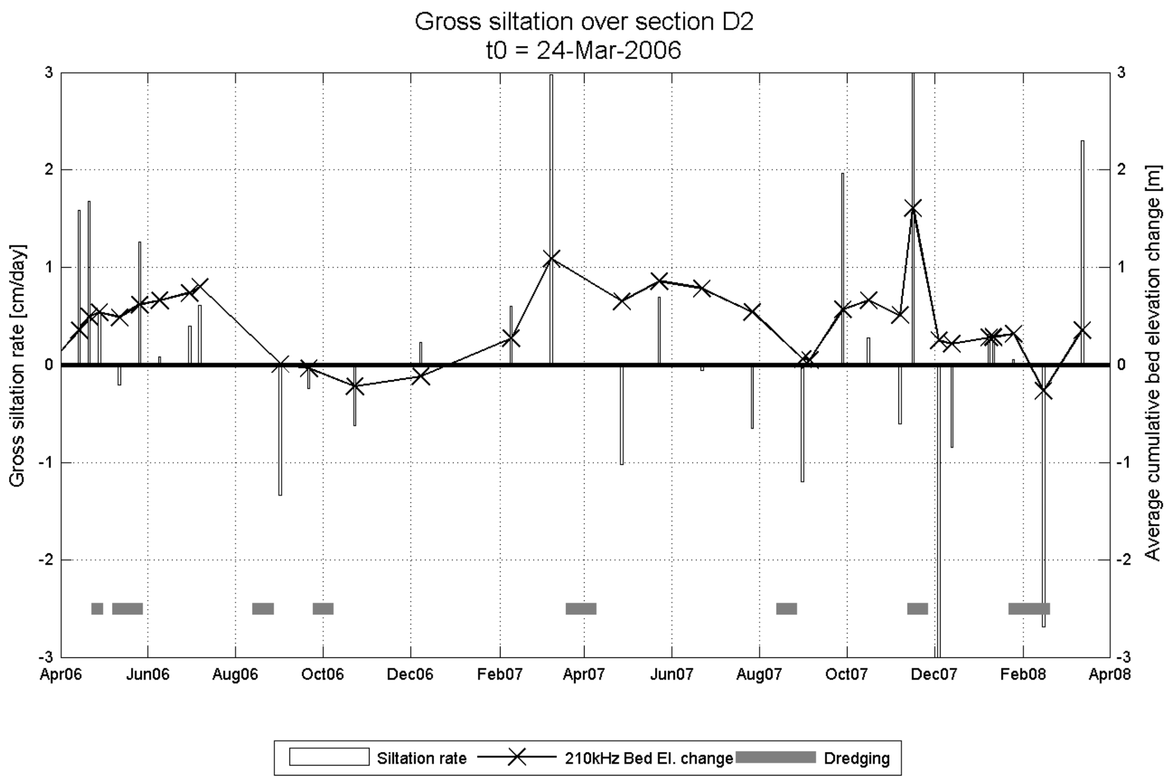
I/RA/11283/07.085/MSA

C.3 Water-bed interface evolution for all sections

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

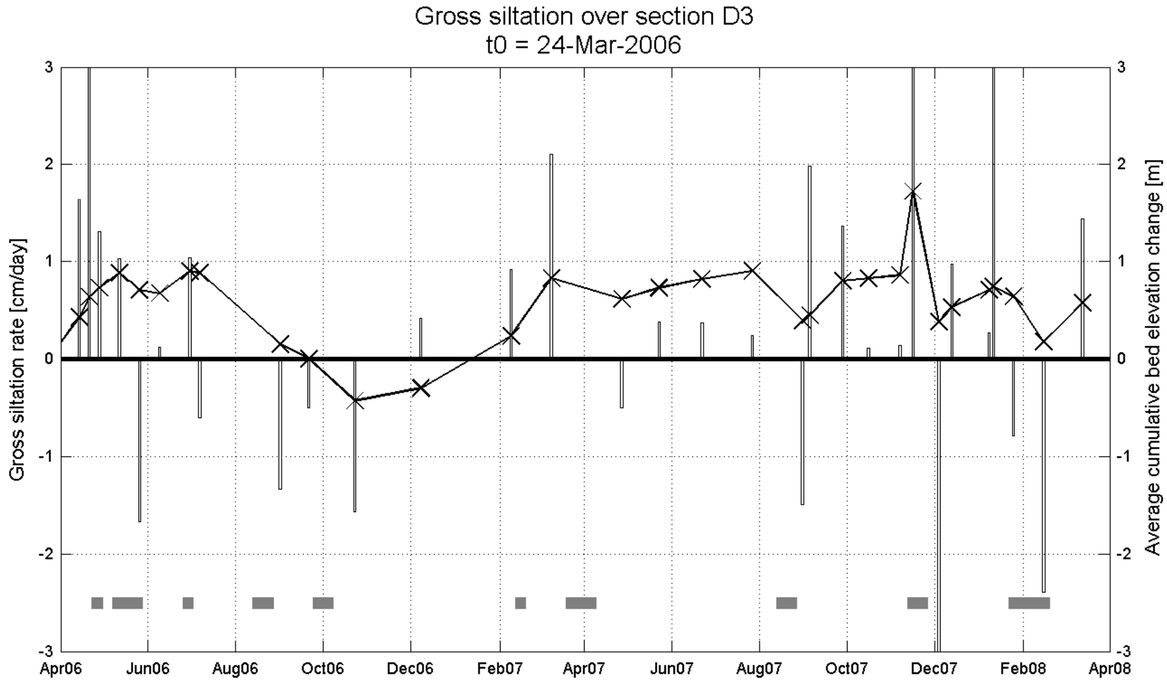
Data Processed by: IMDC

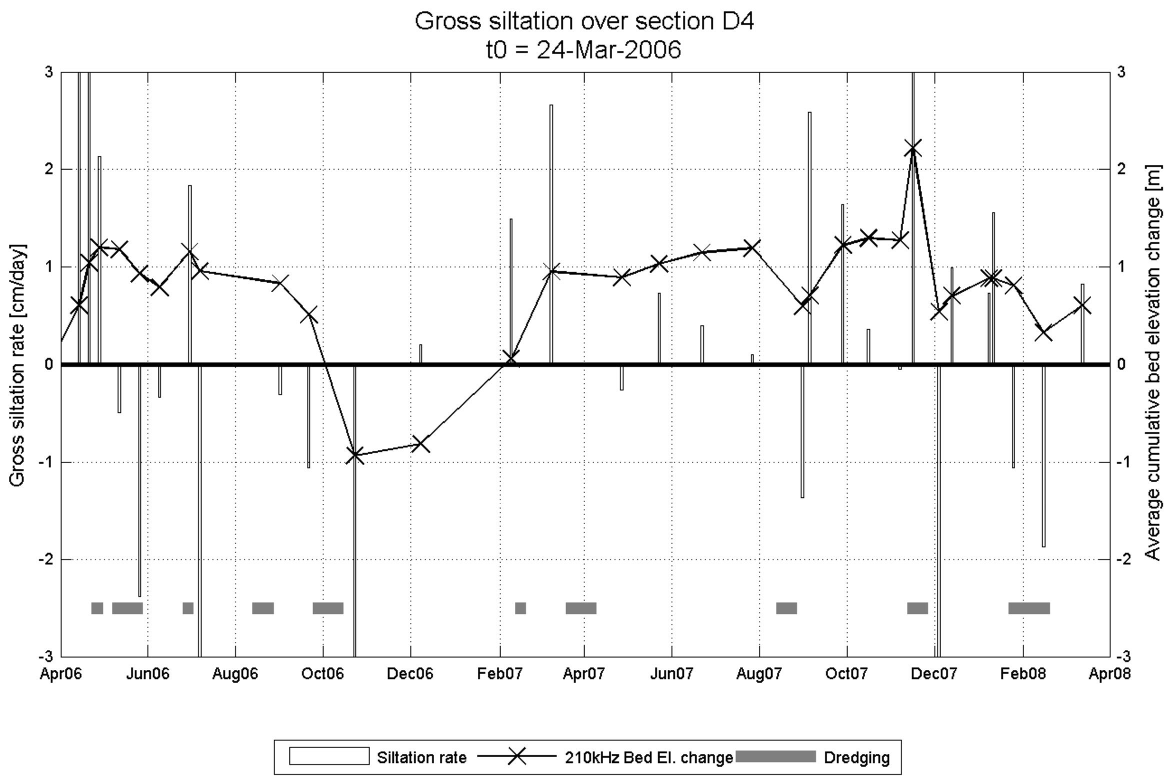
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

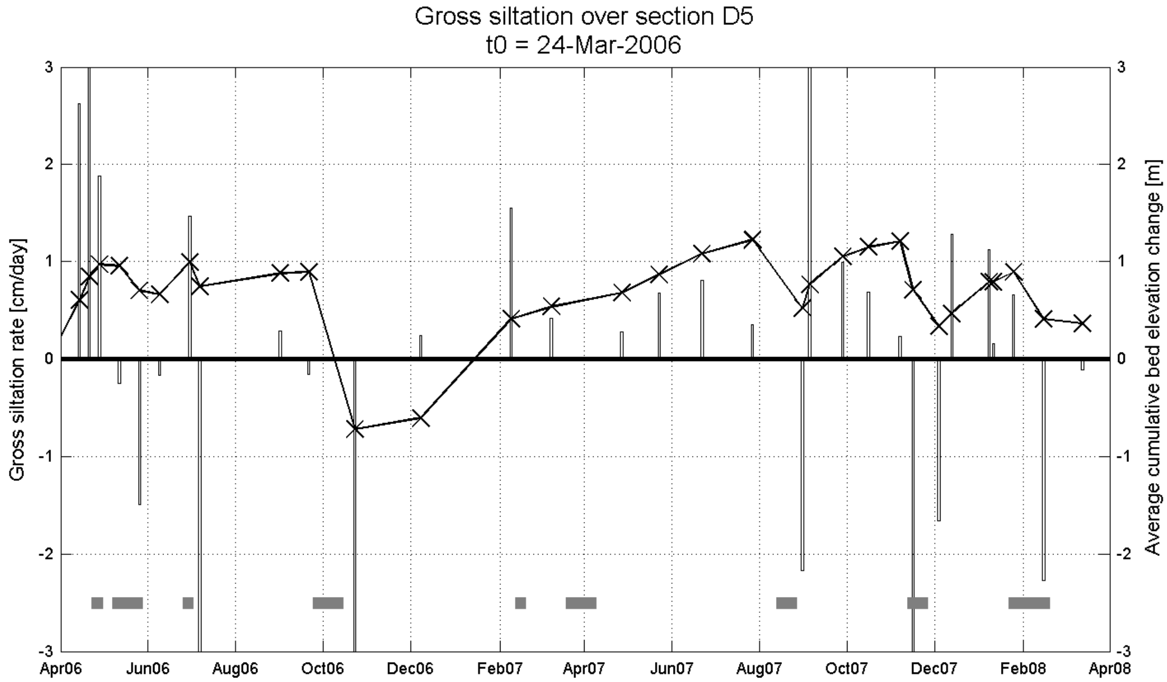
Data Processed by:

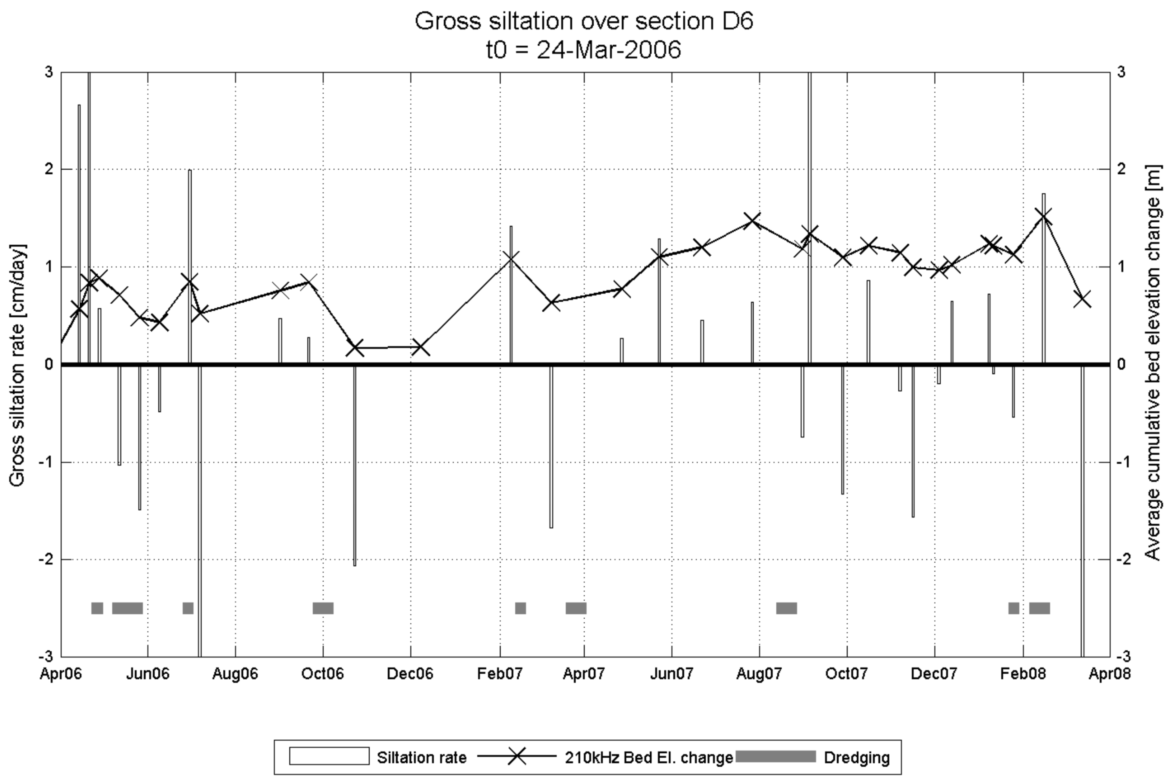
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

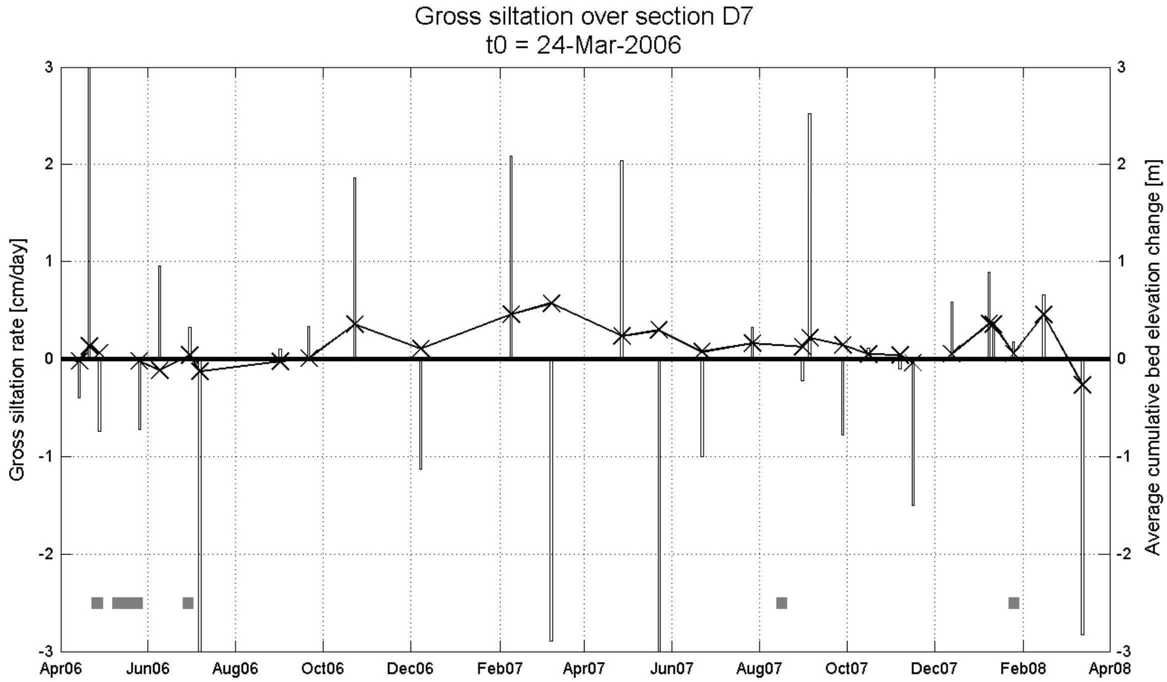
Data Processed by:

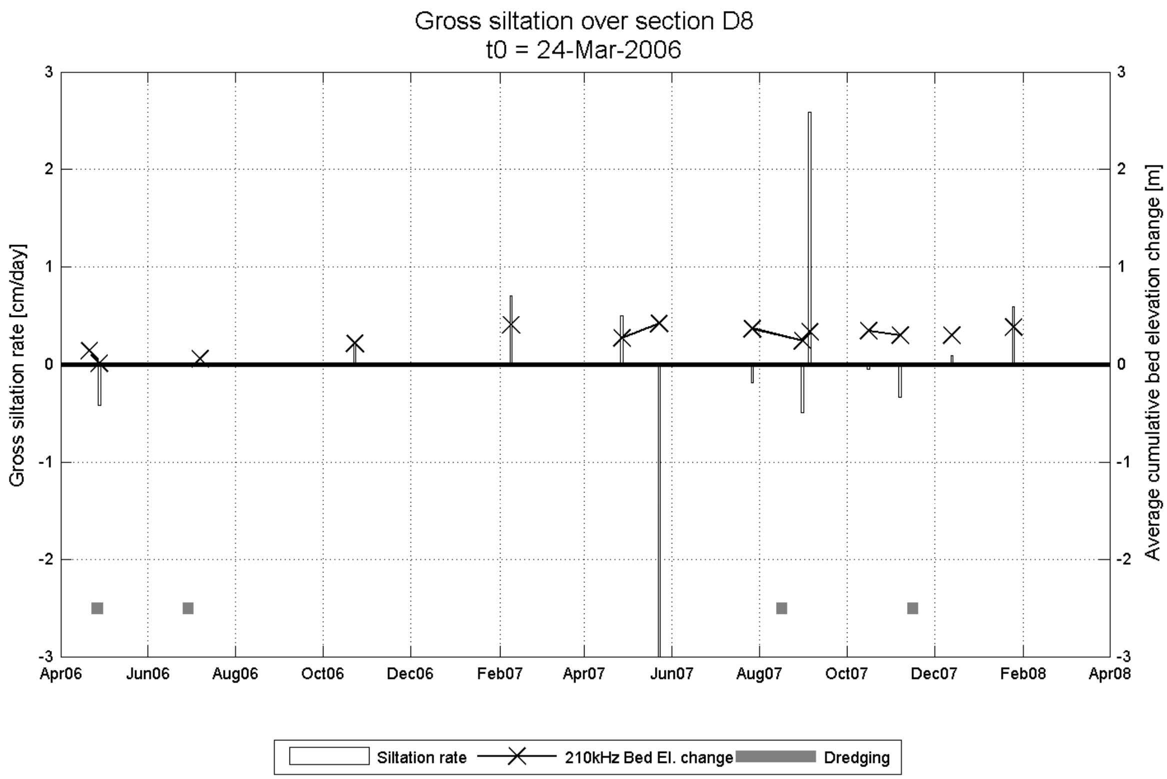
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

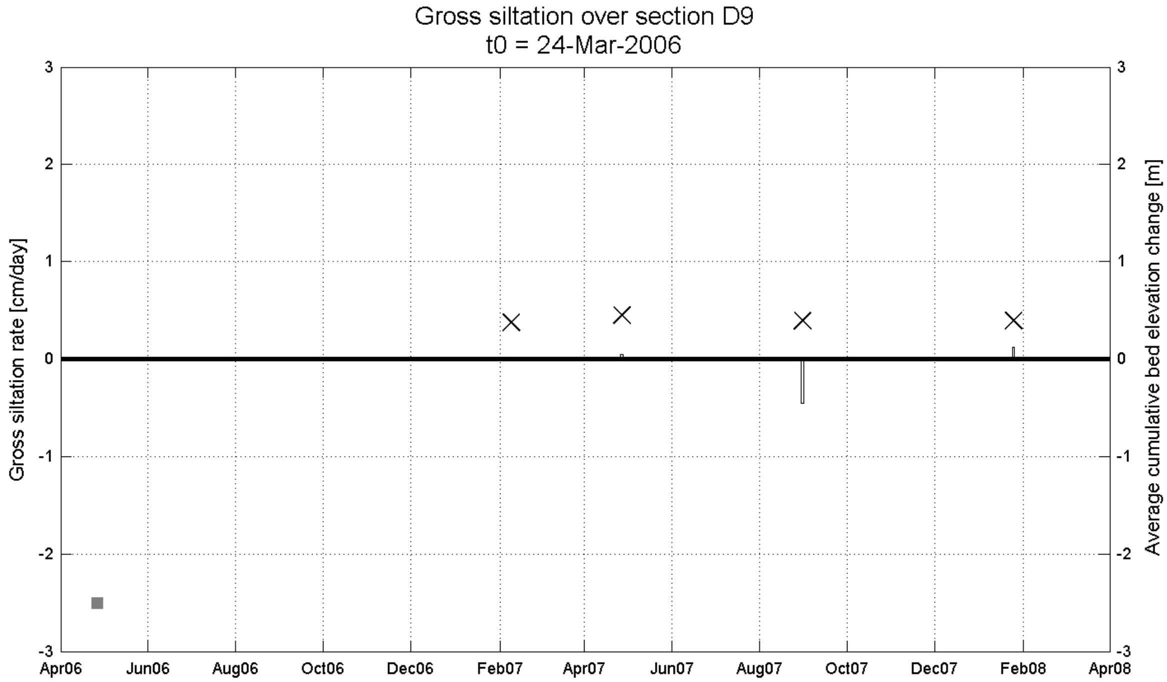
Data Processed by:

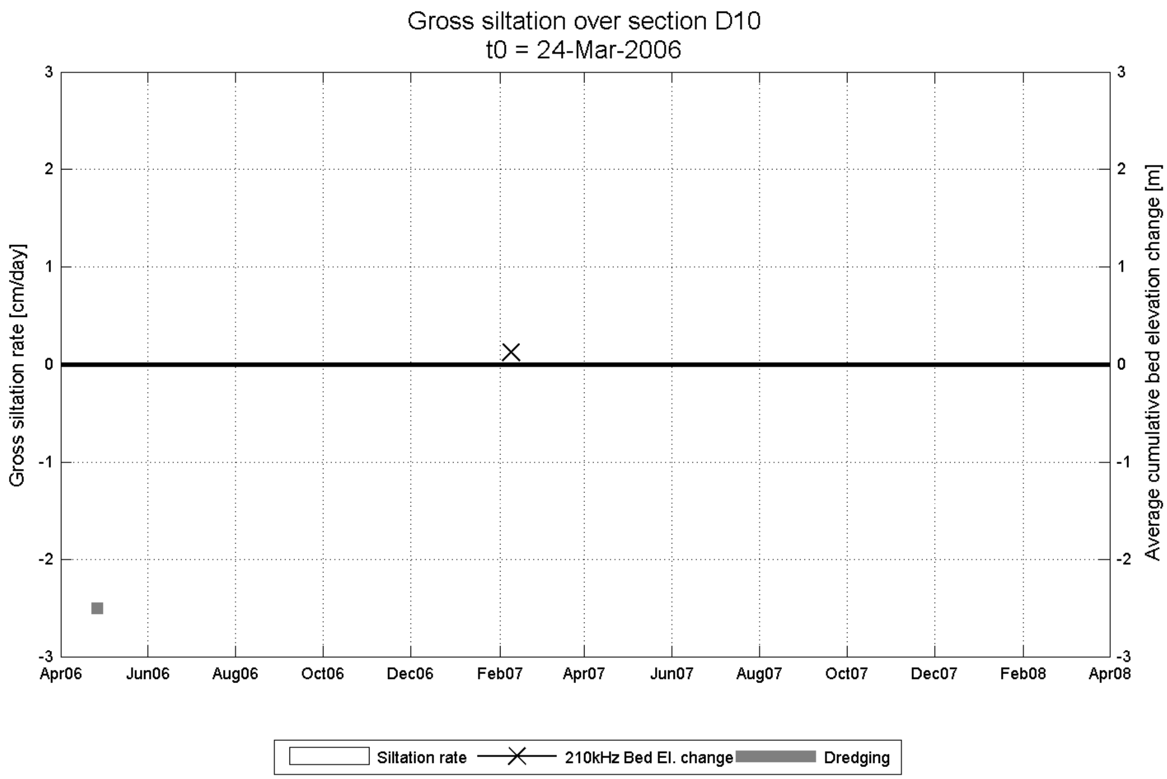
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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

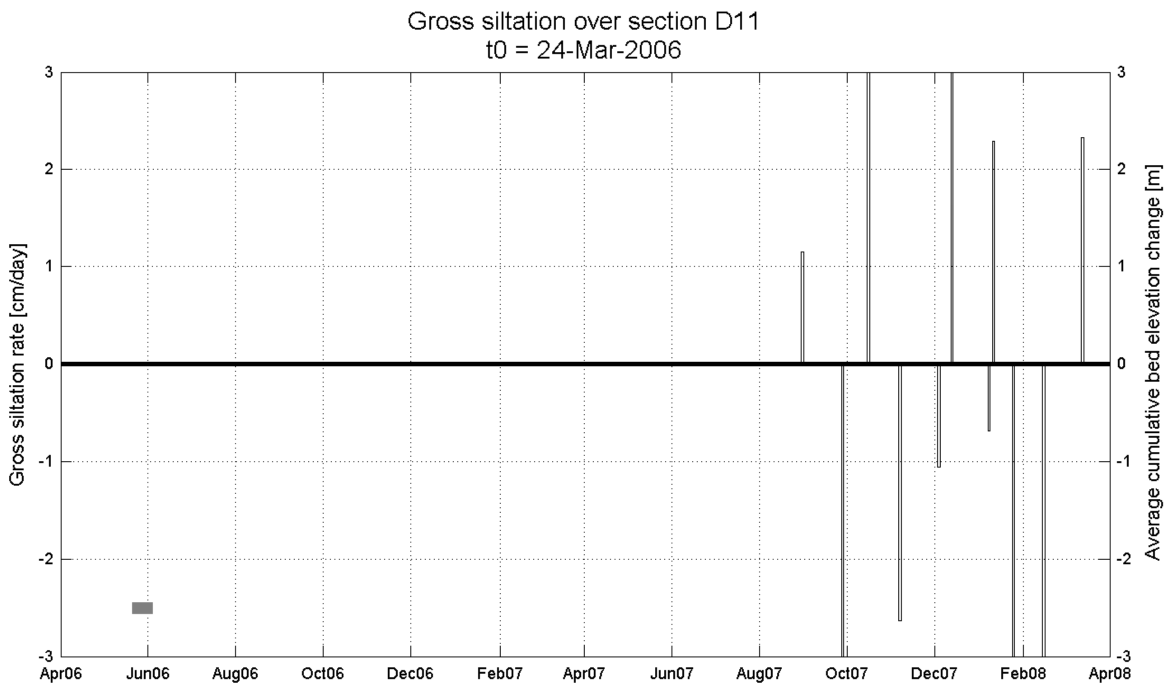


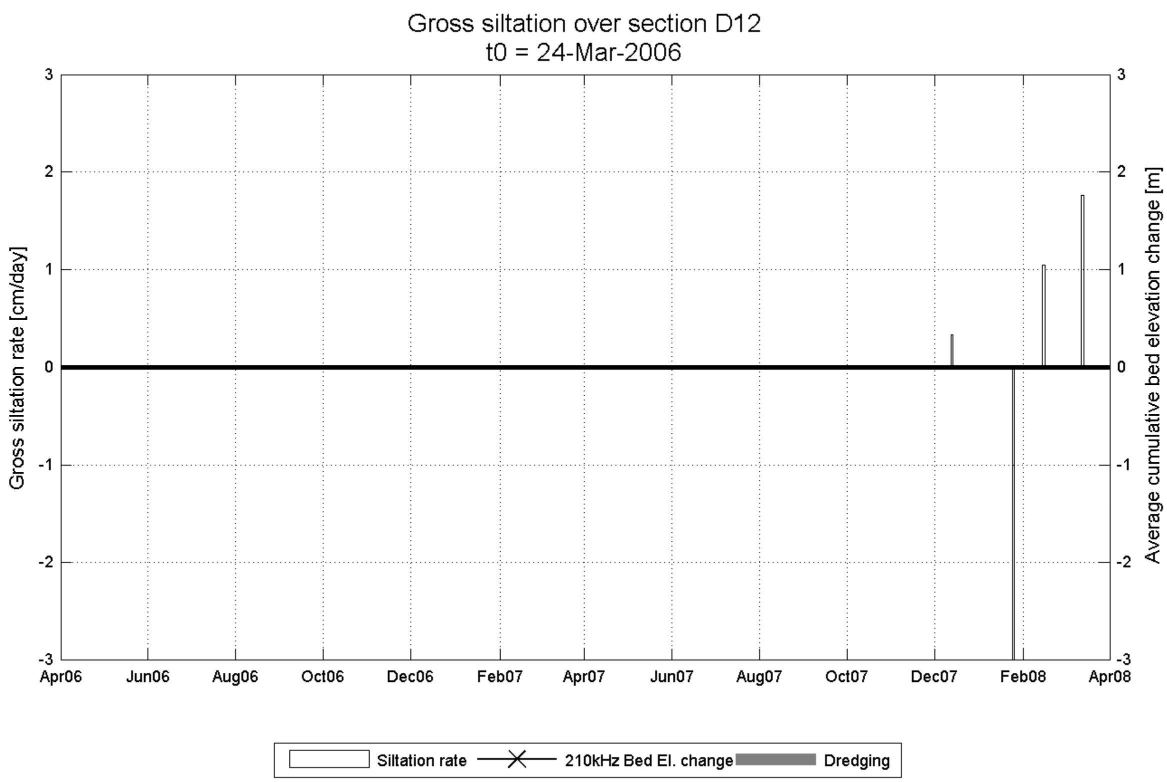


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

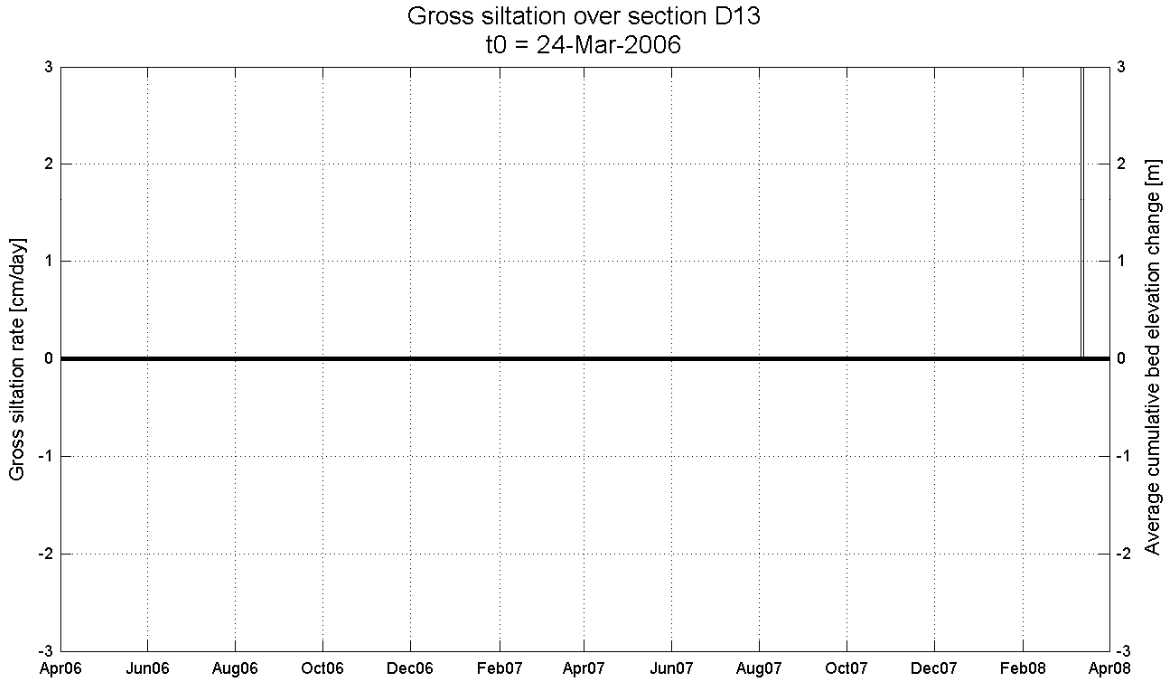
Data Processed by: IMDC

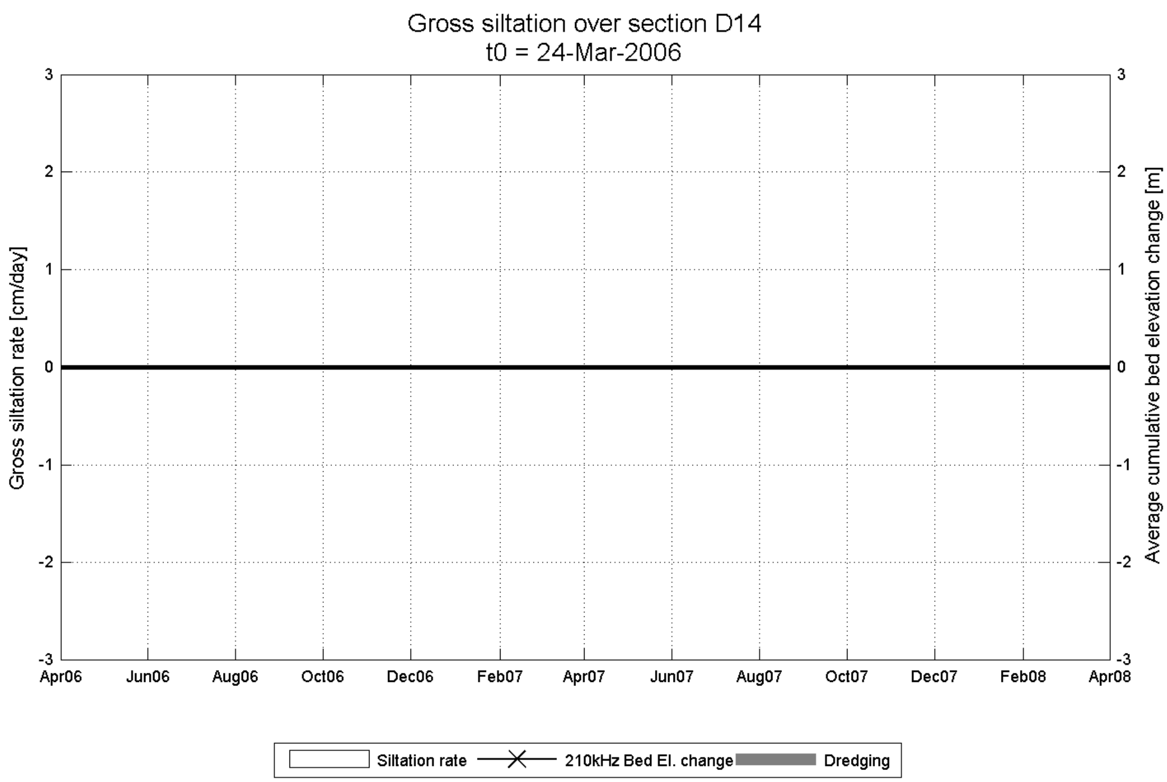
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Reference level: depth sounding 24-Mar-2006

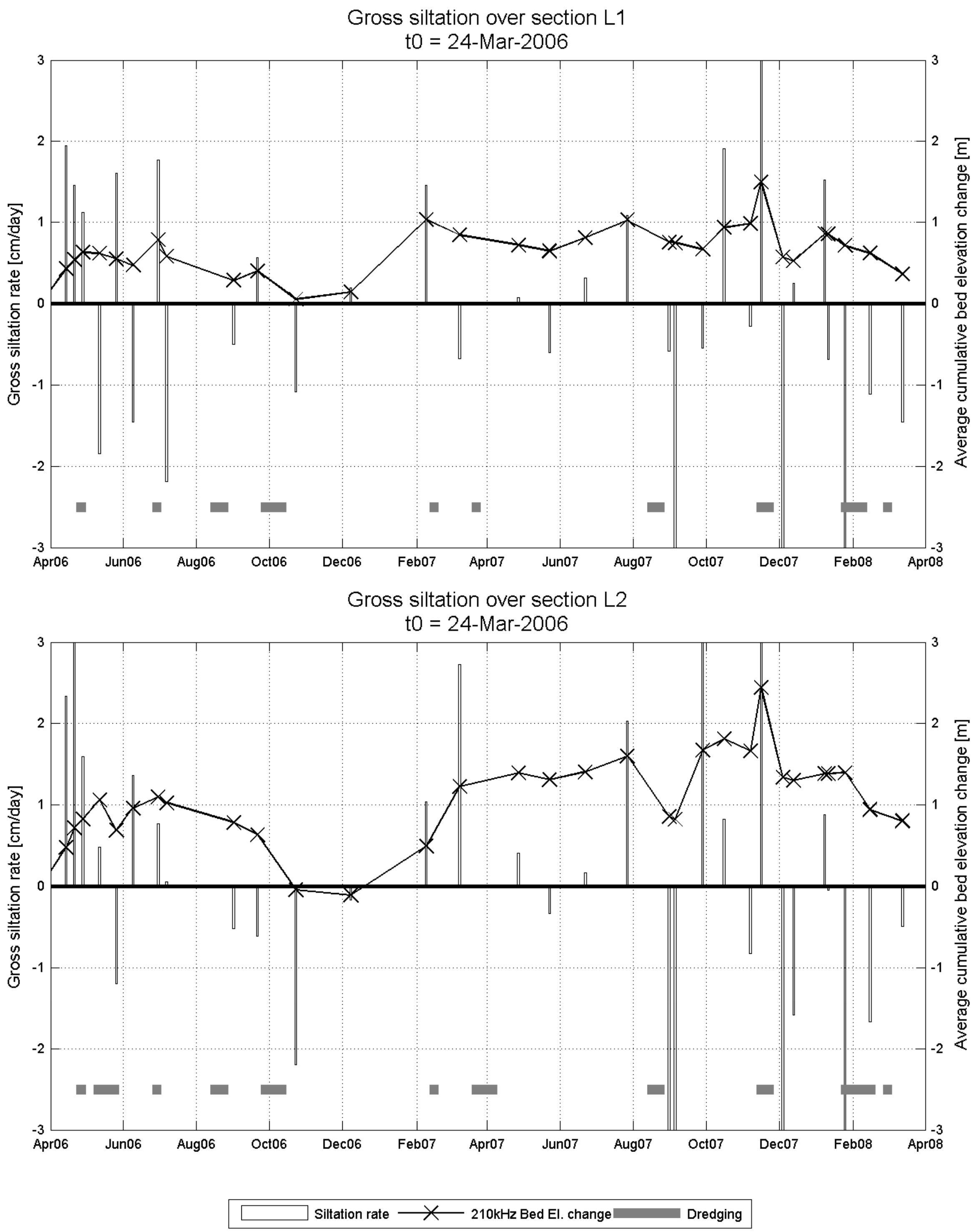
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



Reference level: depth sounding 24-Mar-2006

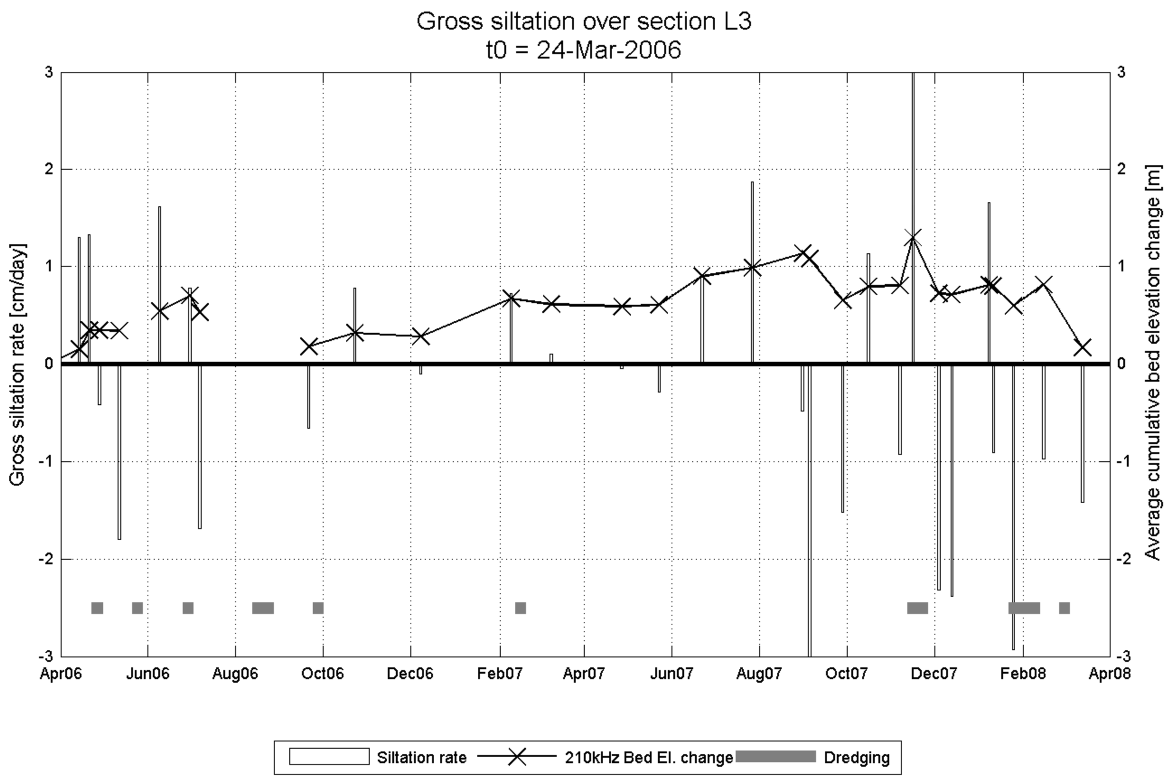
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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

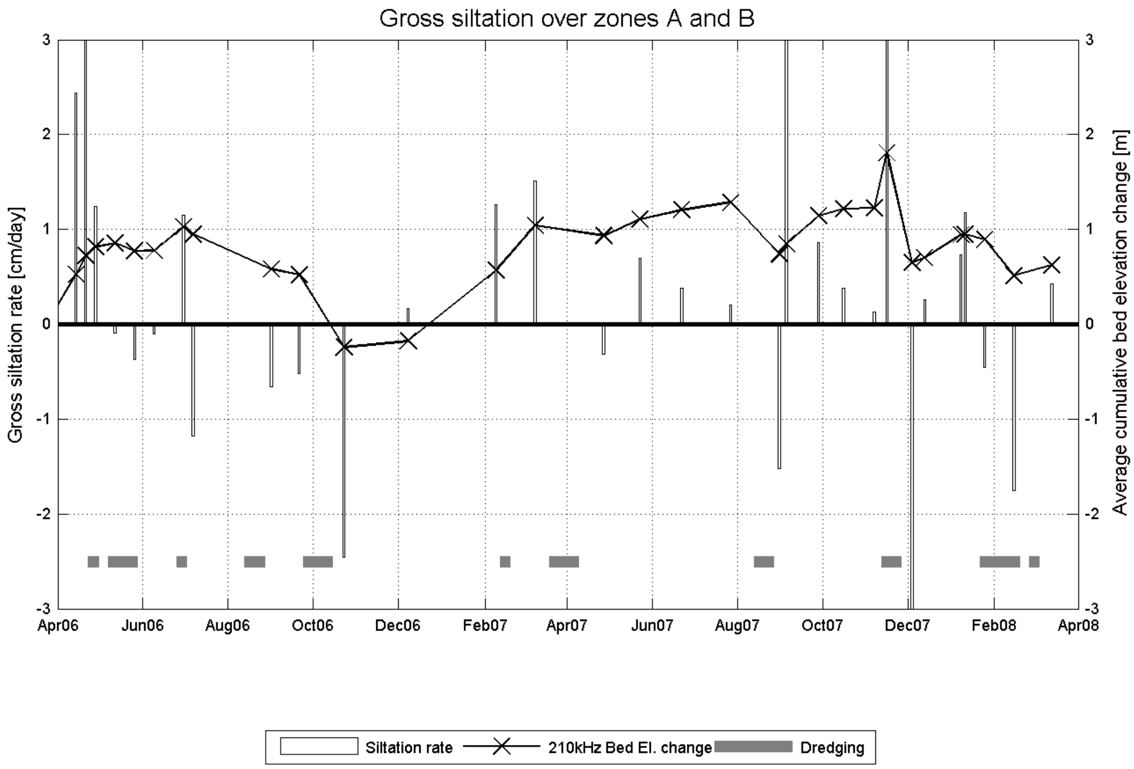


Reference level: depth sounding 24-Mar-2006	Data Processed by: IMDC In association with : I/RA/11283/07.085/MSA

C.4 Siltation rate complete Deurganckdok

Long-term monitoring siltation Deurganckdok

Siltation height / gross 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 :

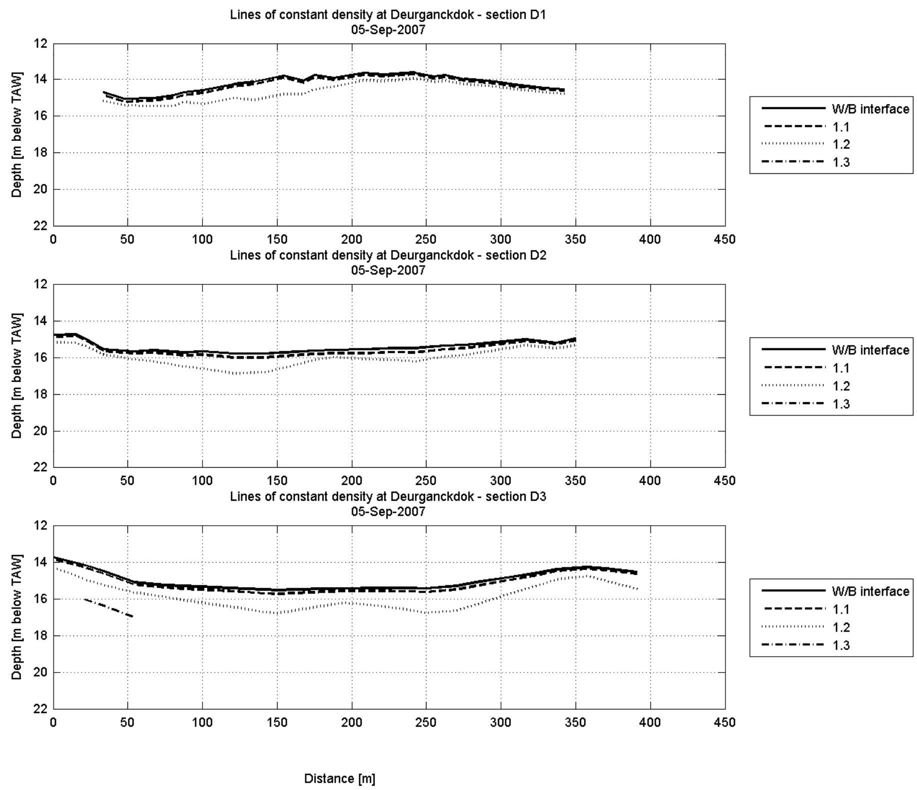
I/RA/11283/07.085/MSA

APPENDIX D.

DEPTH OF PLANES OF CONSTANT DENSITY

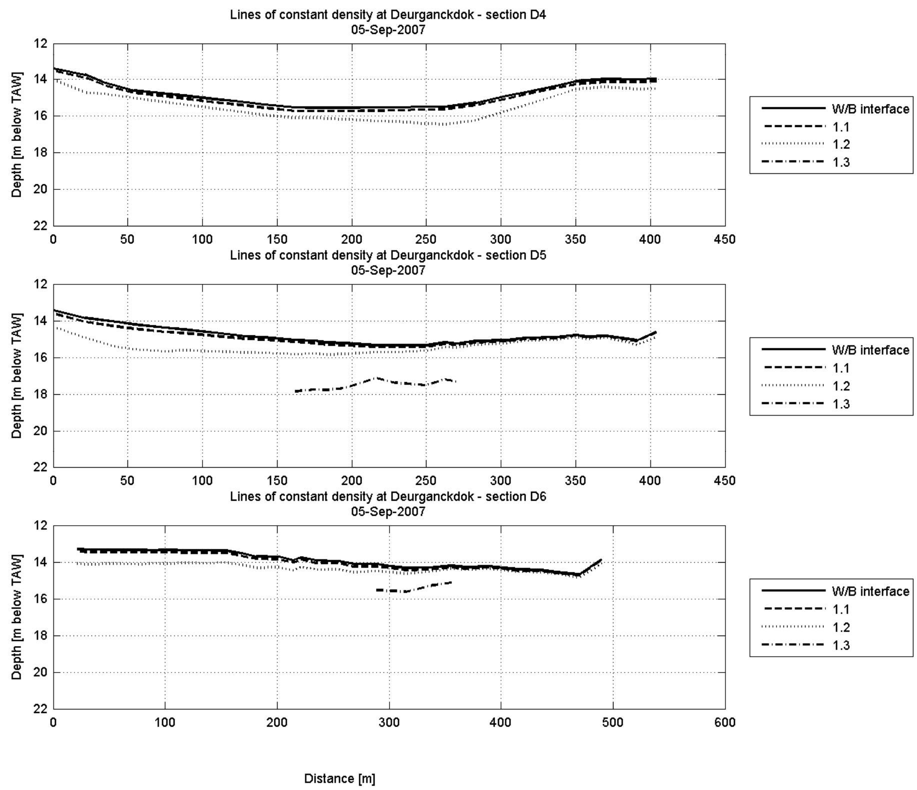
D.1 Measurements September 5th 2007

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



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

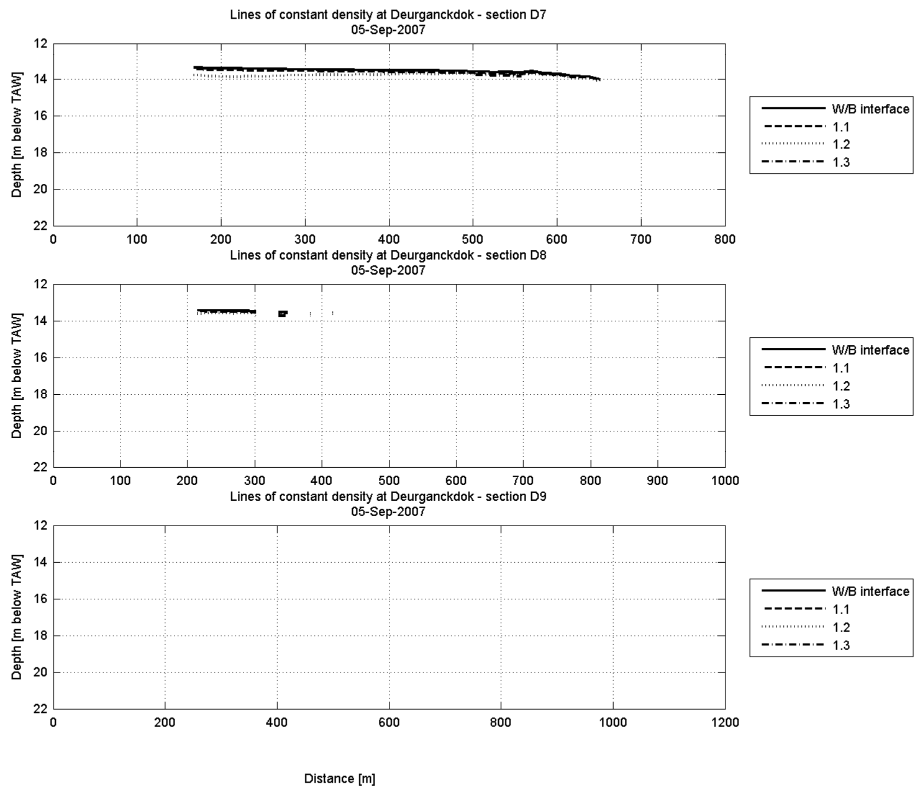
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

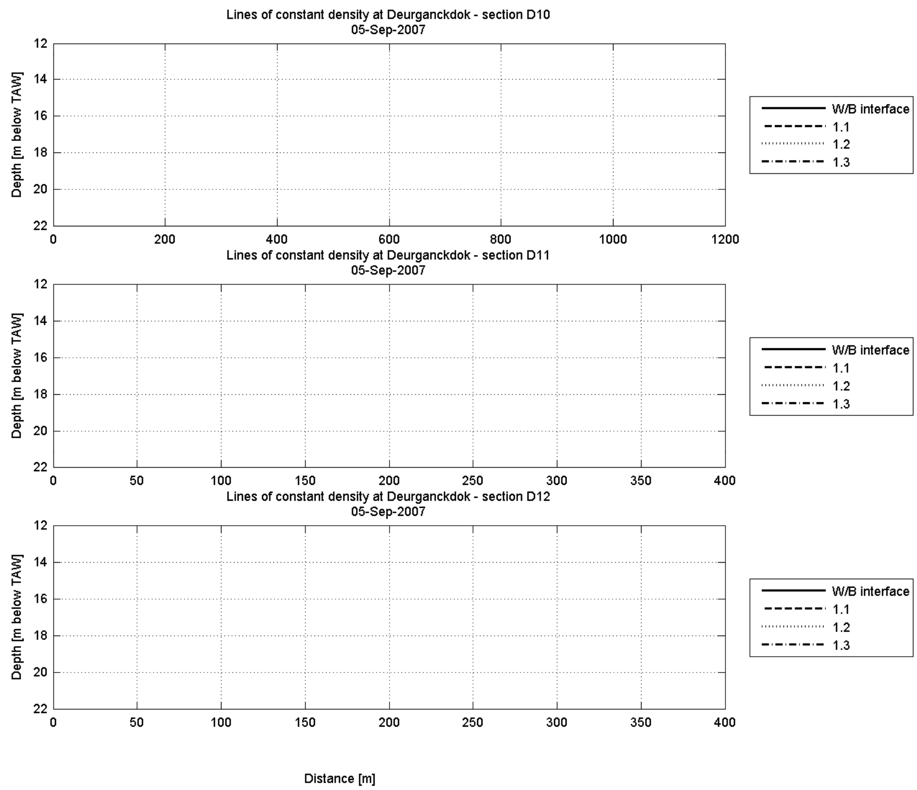
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

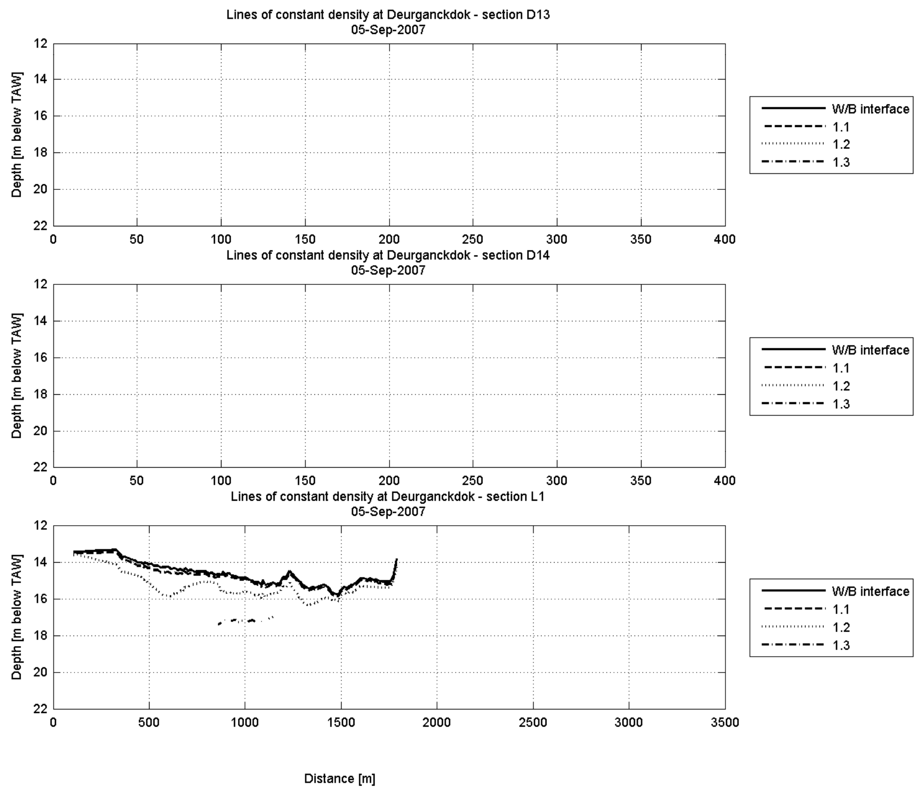
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

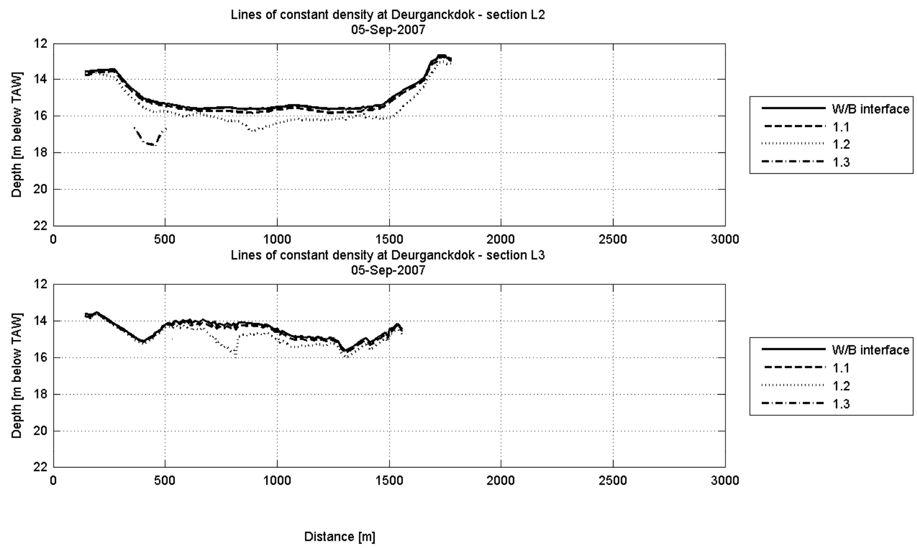
Long-term monitoring siltation Deurganckdok

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



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

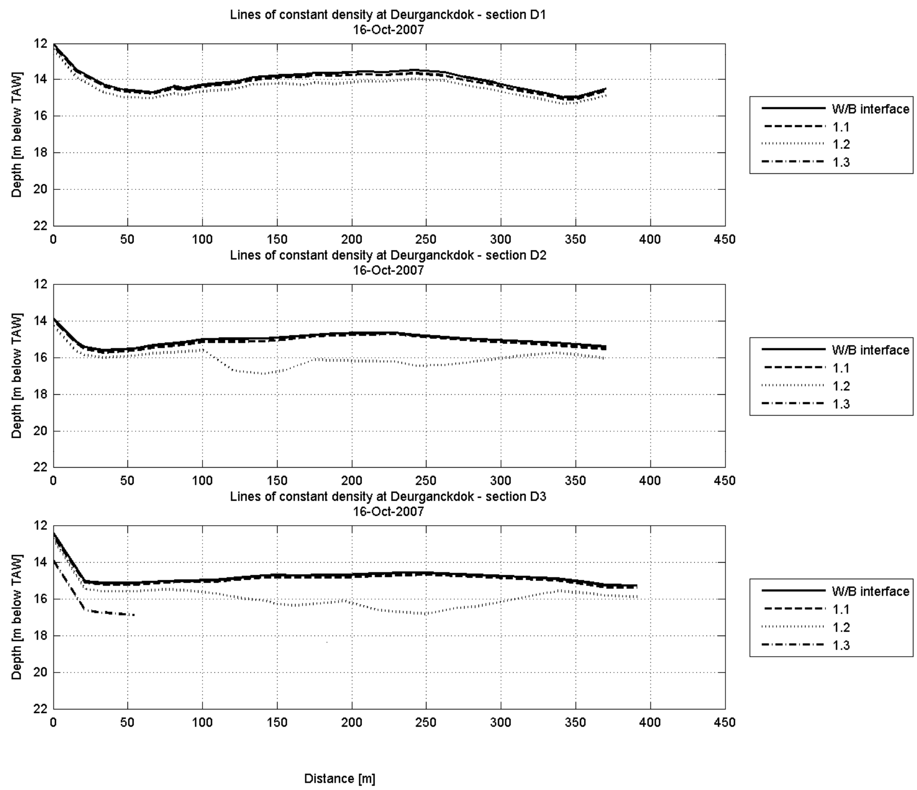
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

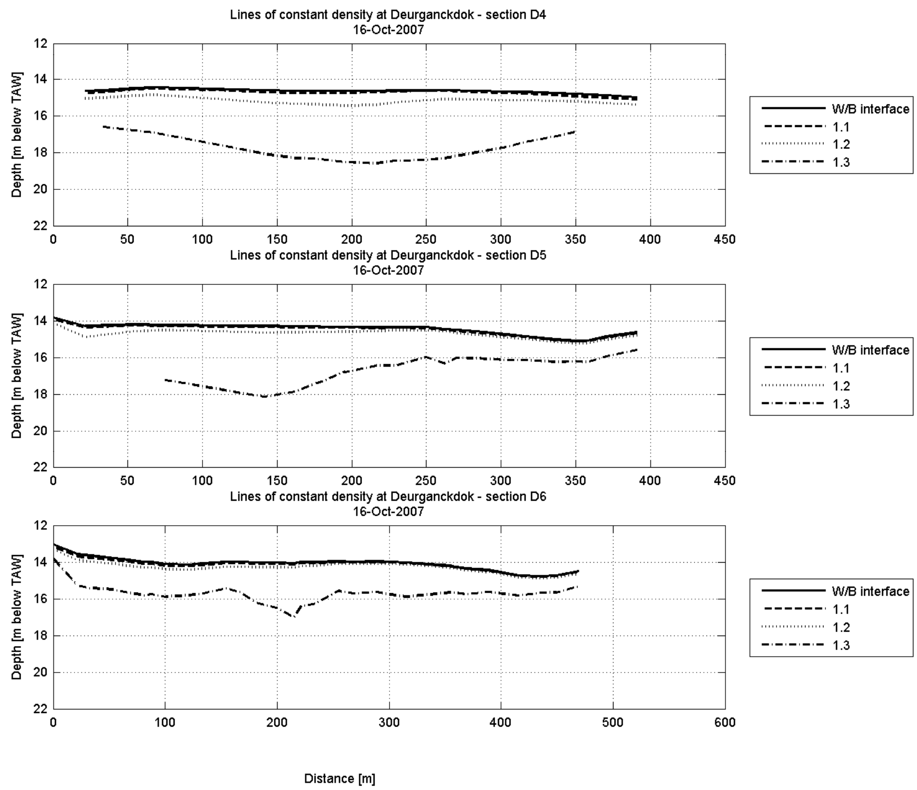
D.2 Measurements October 16th 2007

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



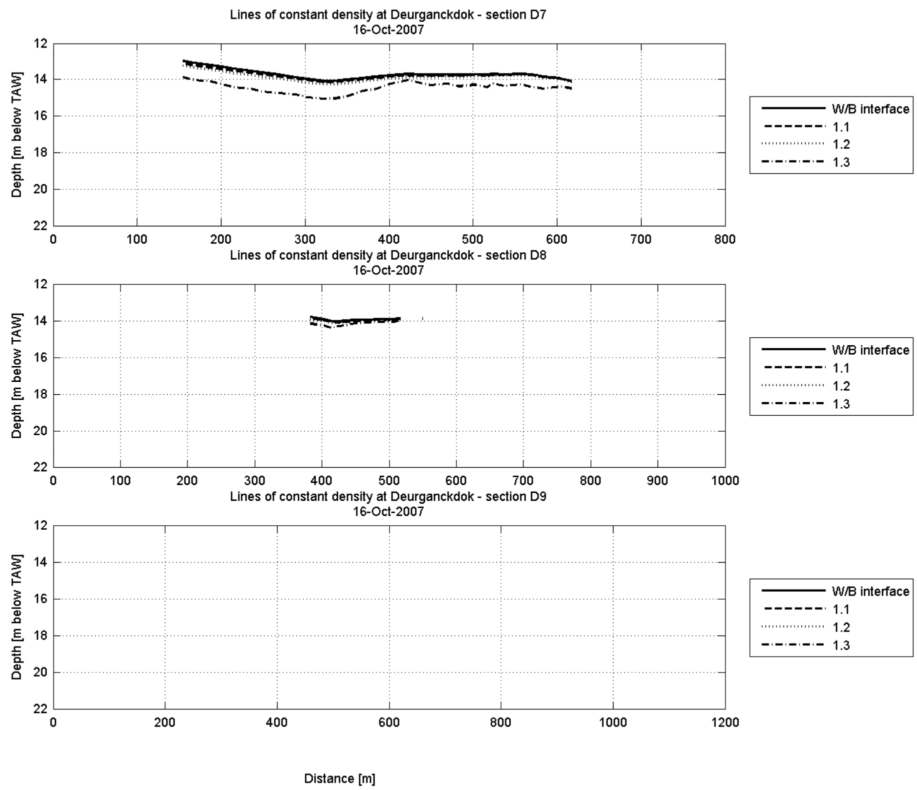
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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



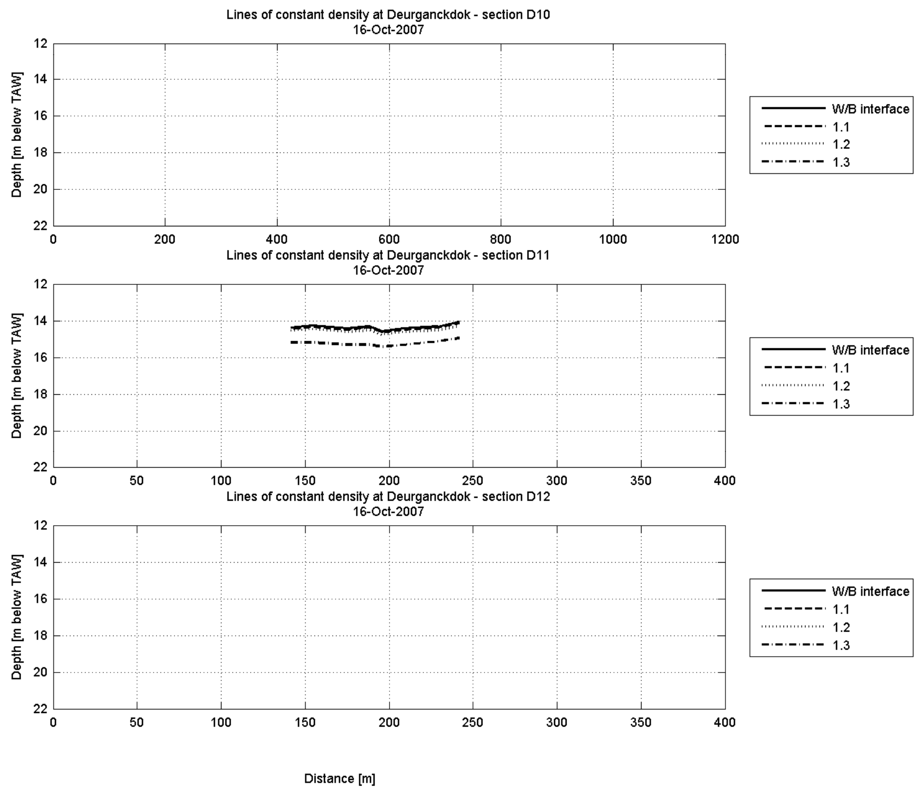
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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



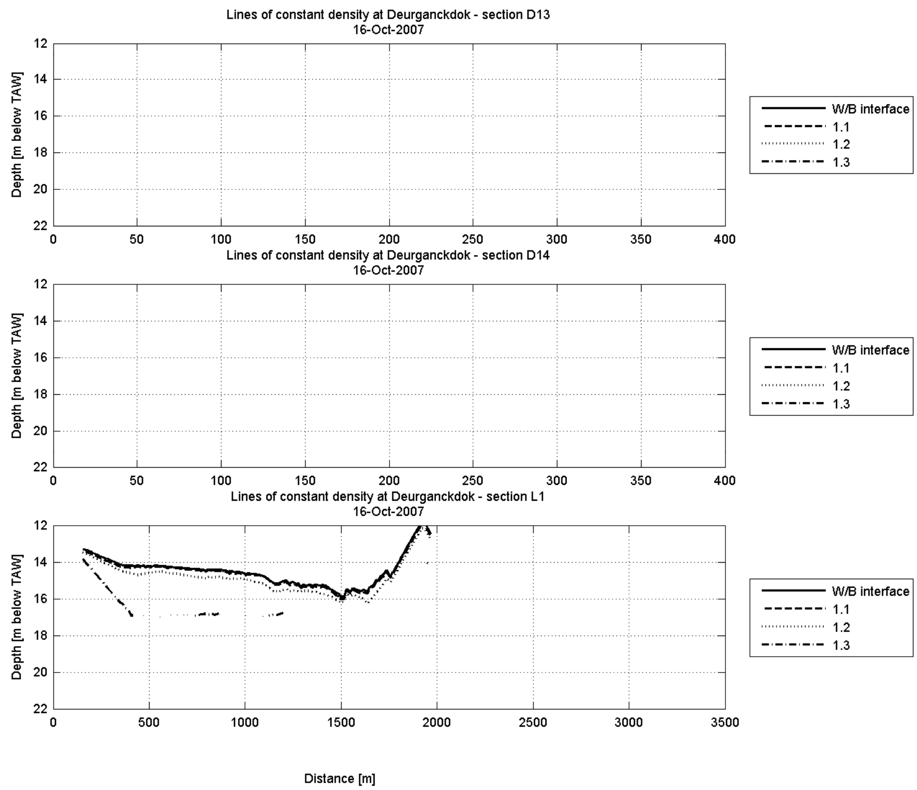
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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



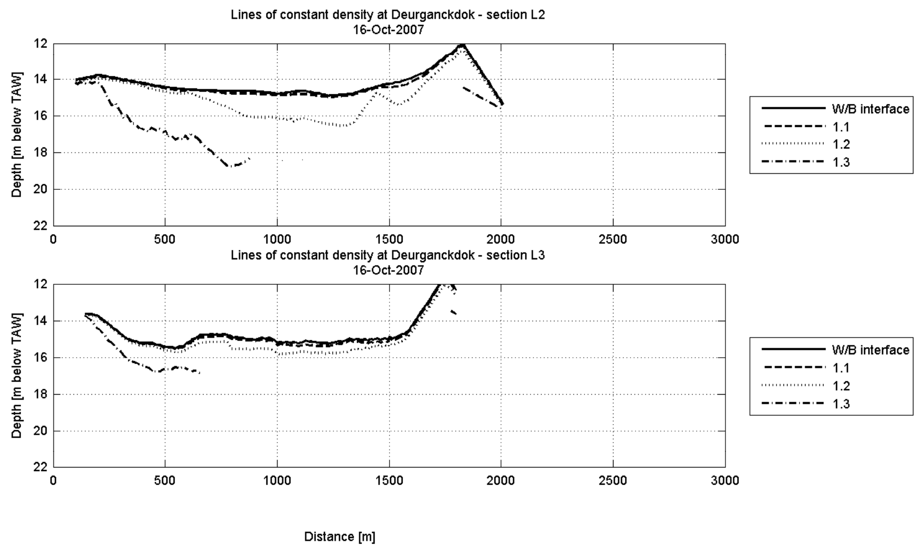
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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

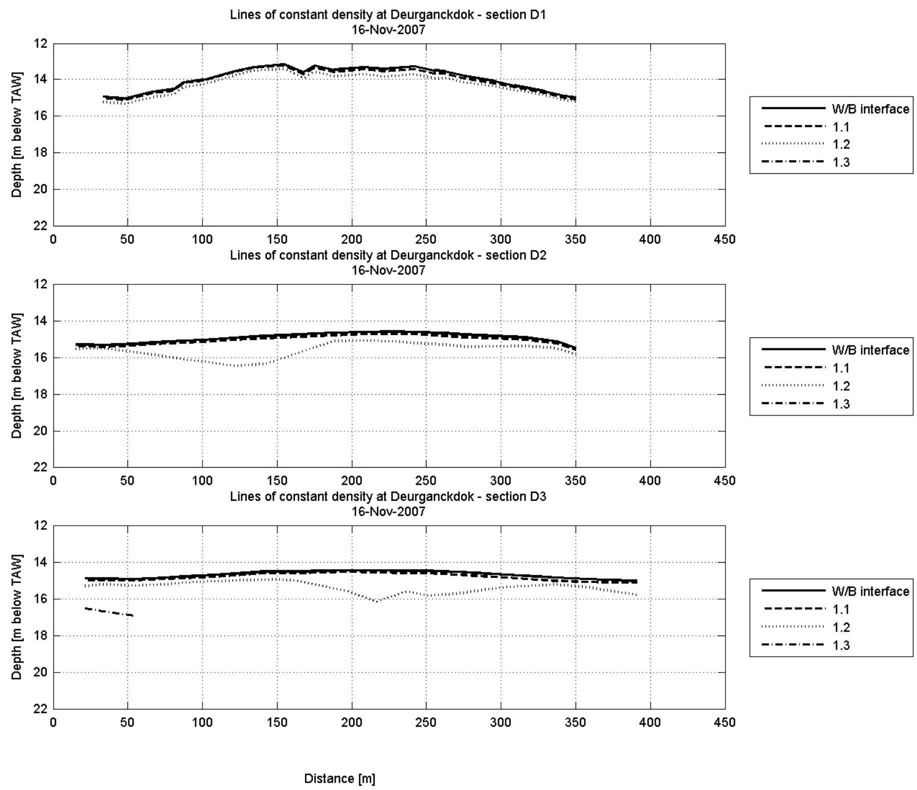


Data Processed by:
In association with :
I/RA/11283/07.085/MSA

D.3 Measurements November 16th 2007

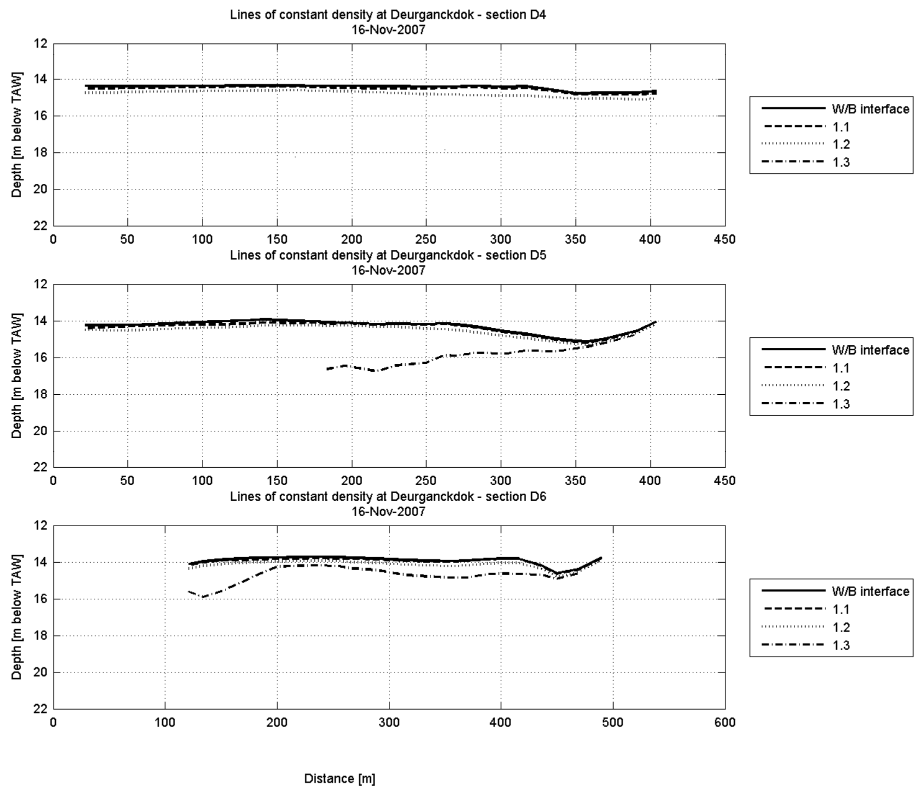
Long-term monitoring siltation Deurganckdok

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



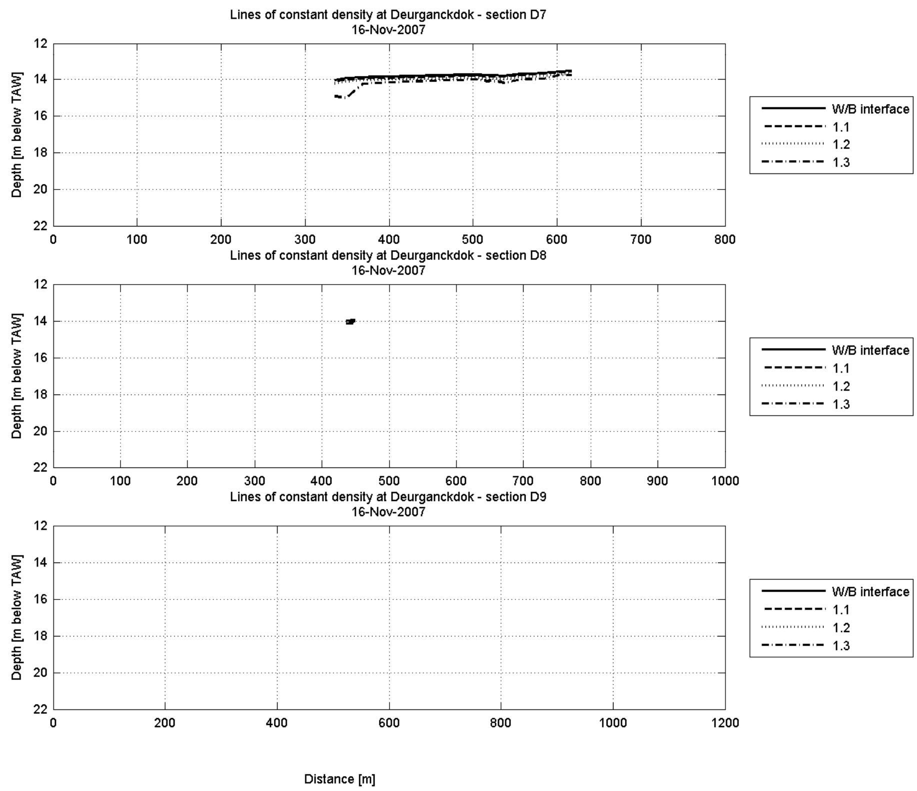
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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



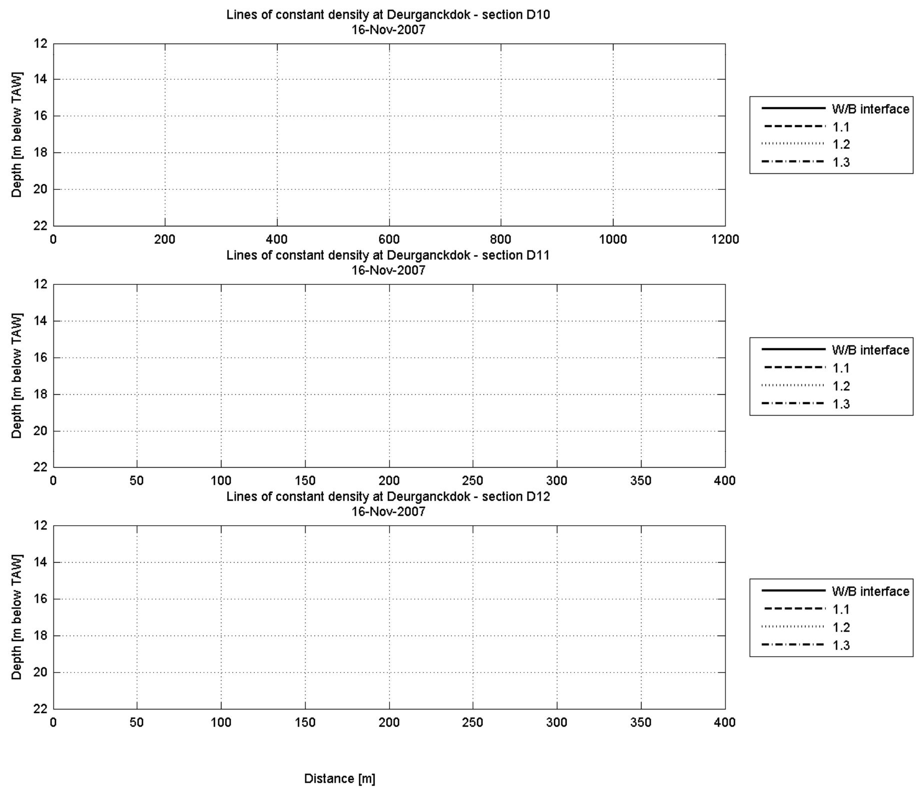
Data Processed by: IMDC
In association with :
I/RA/11283/07.085/MSA

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



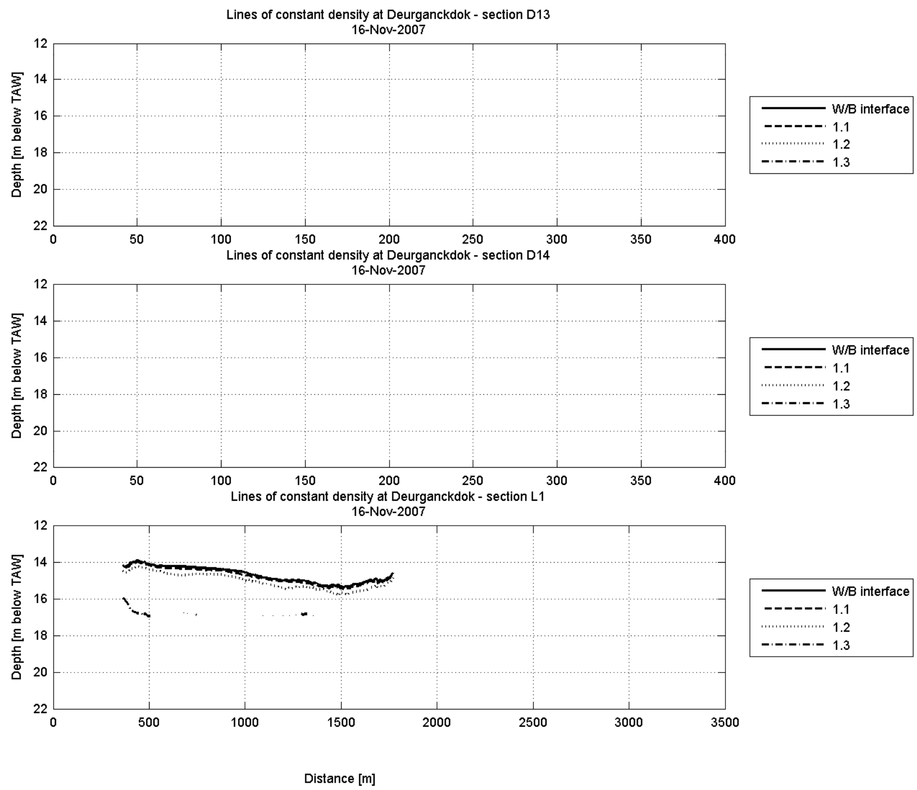
Data Processed by: IMDC
In association with :
I/RA/11283/07.085/MSA

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



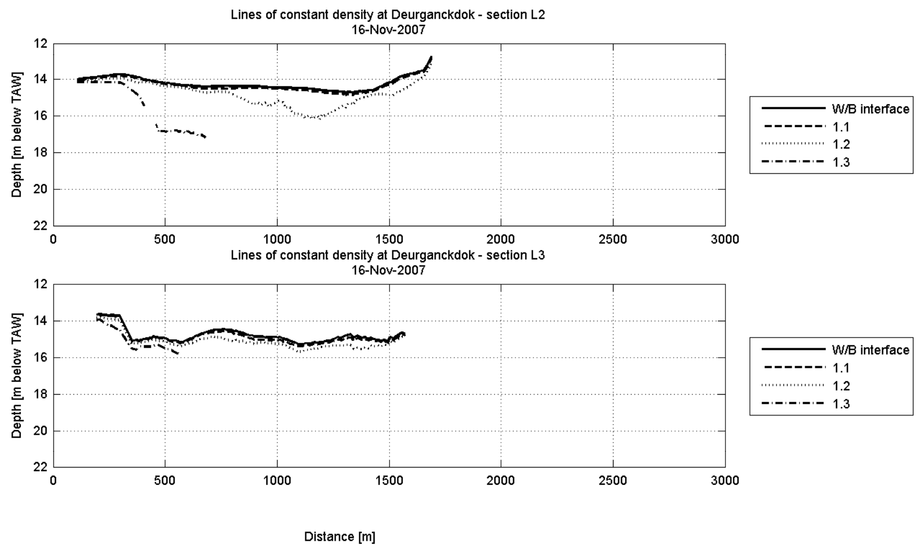
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

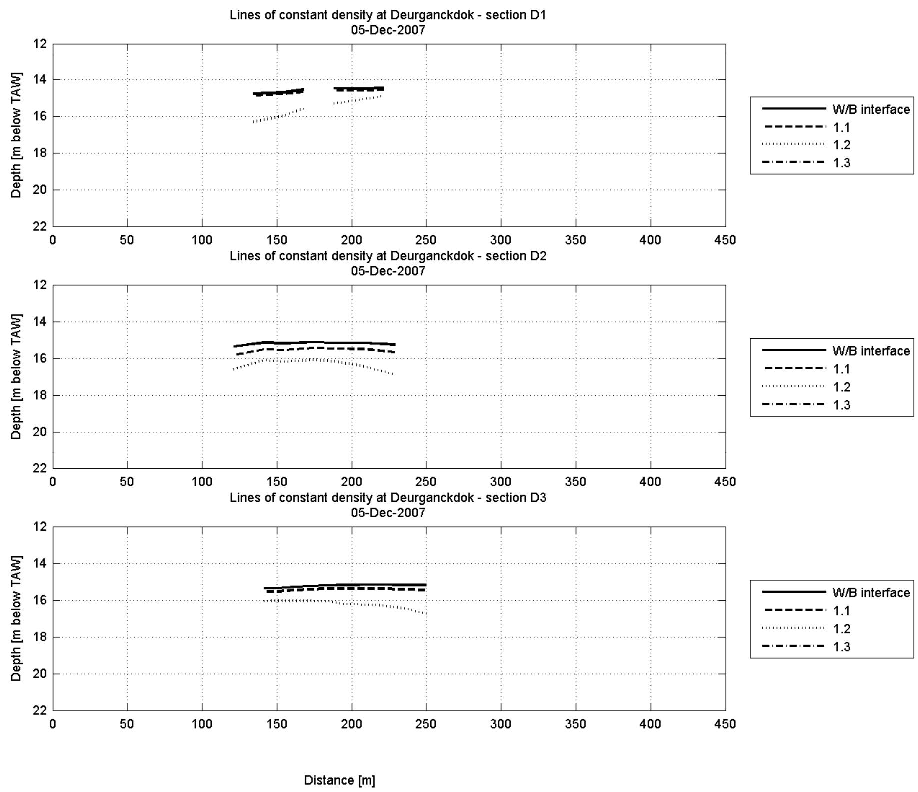
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

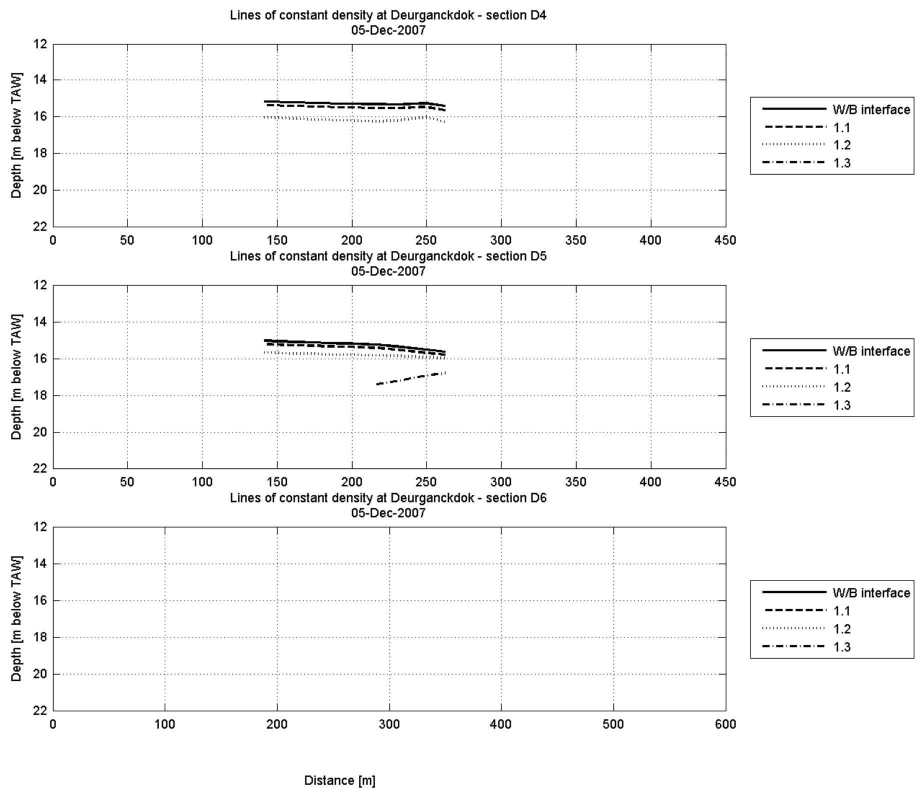
D.4 Measurements December 5th, 2007

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



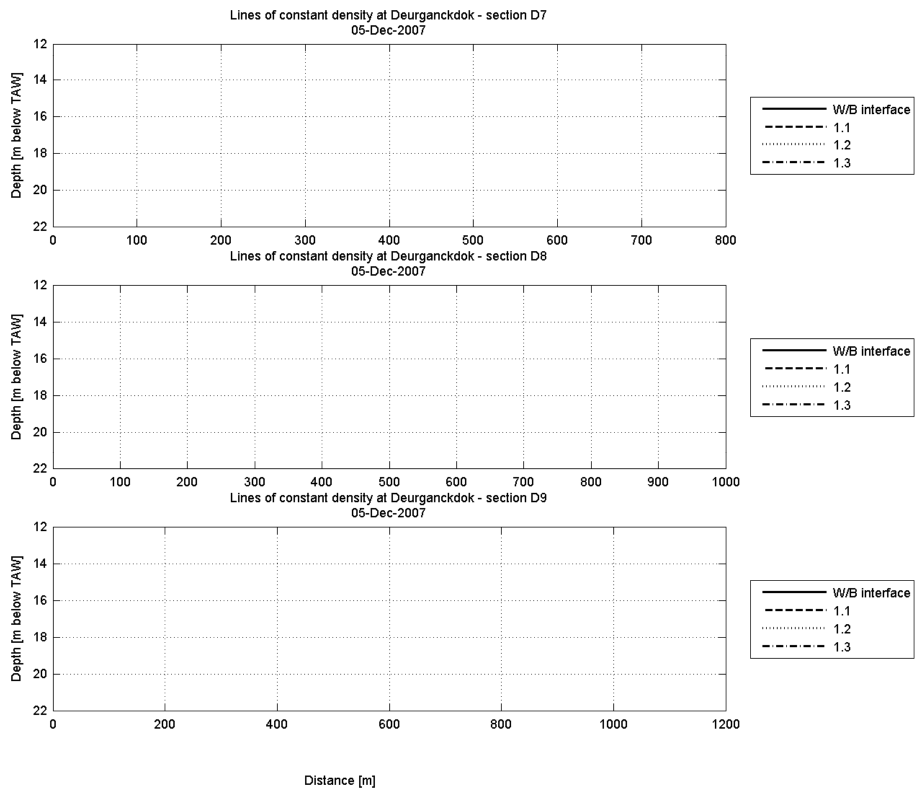
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

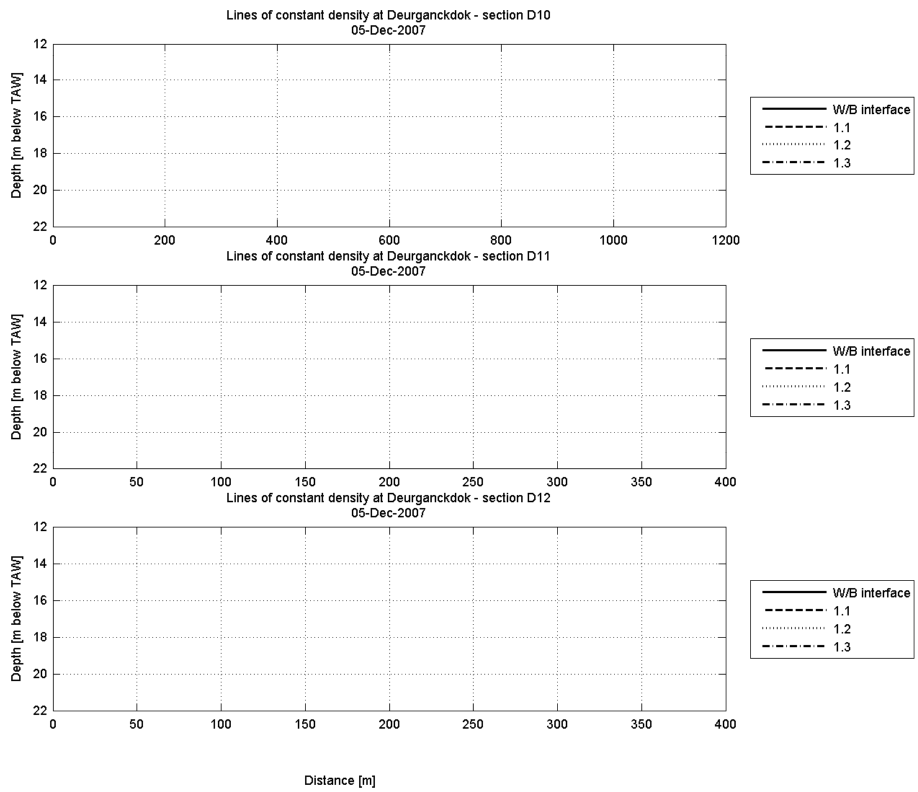
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

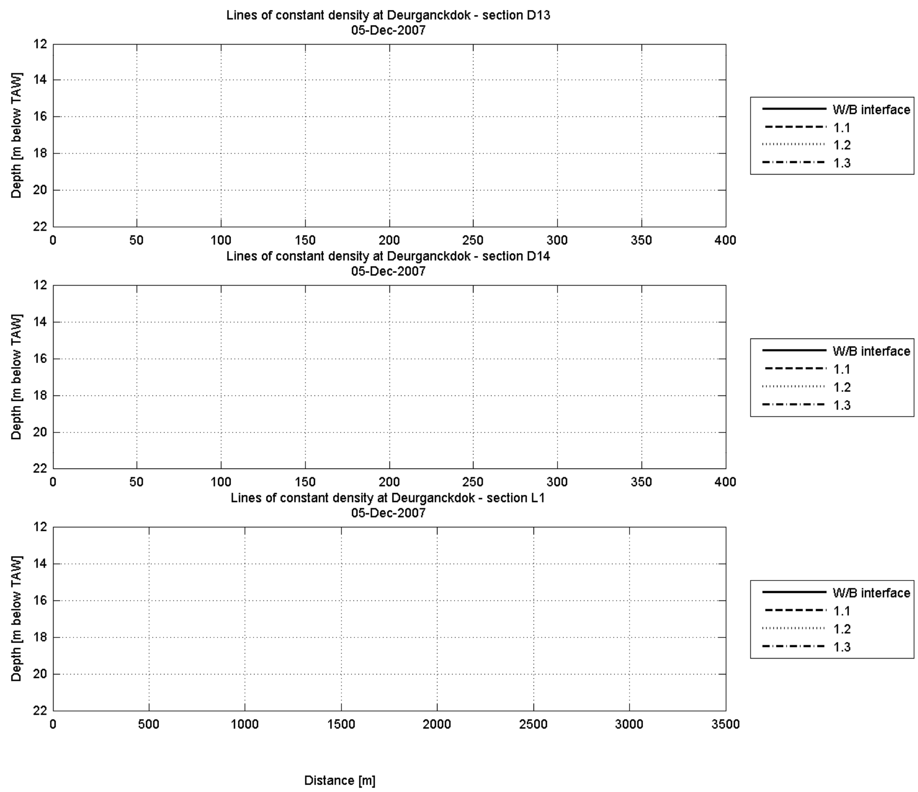
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with :
I/RA/11283/07.085/MSA

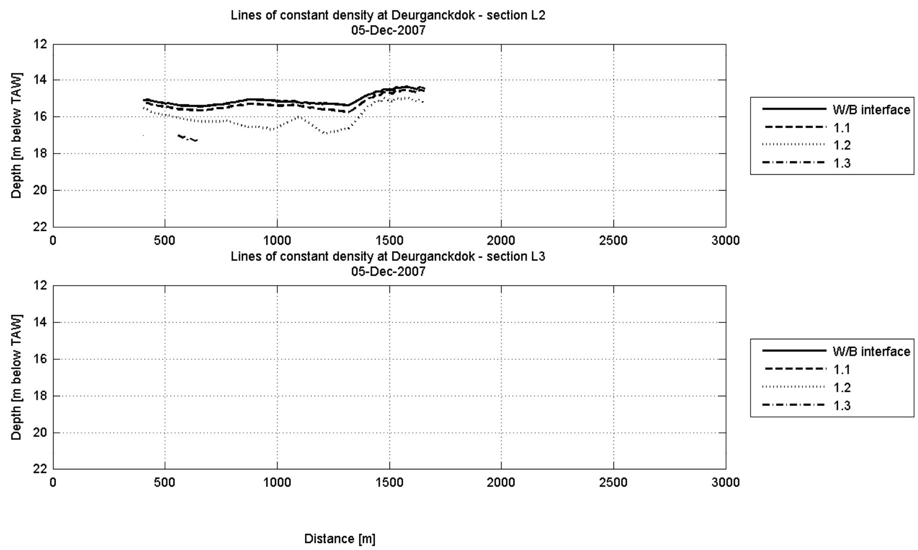
Long-term monitoring siltation Deurganckdok

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



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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

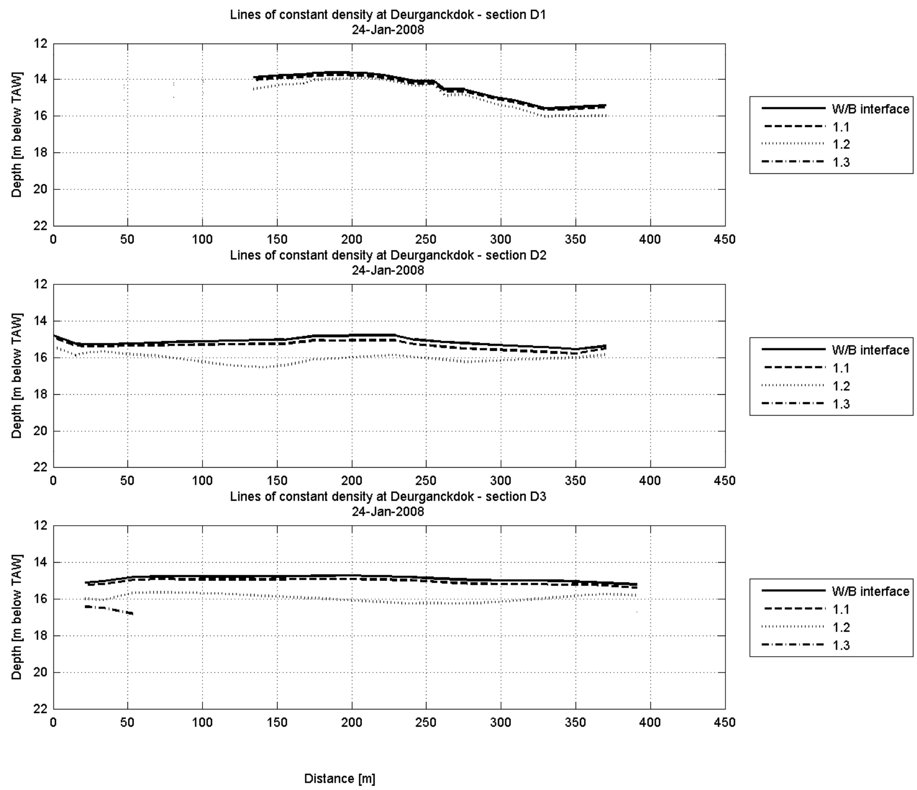


Data Processed by: IMDC
In association with :
I/RA/11283/07.085/MSA

D.5 Measurements January 24th, 2008

Long-term monitoring siltation Deurganckdok

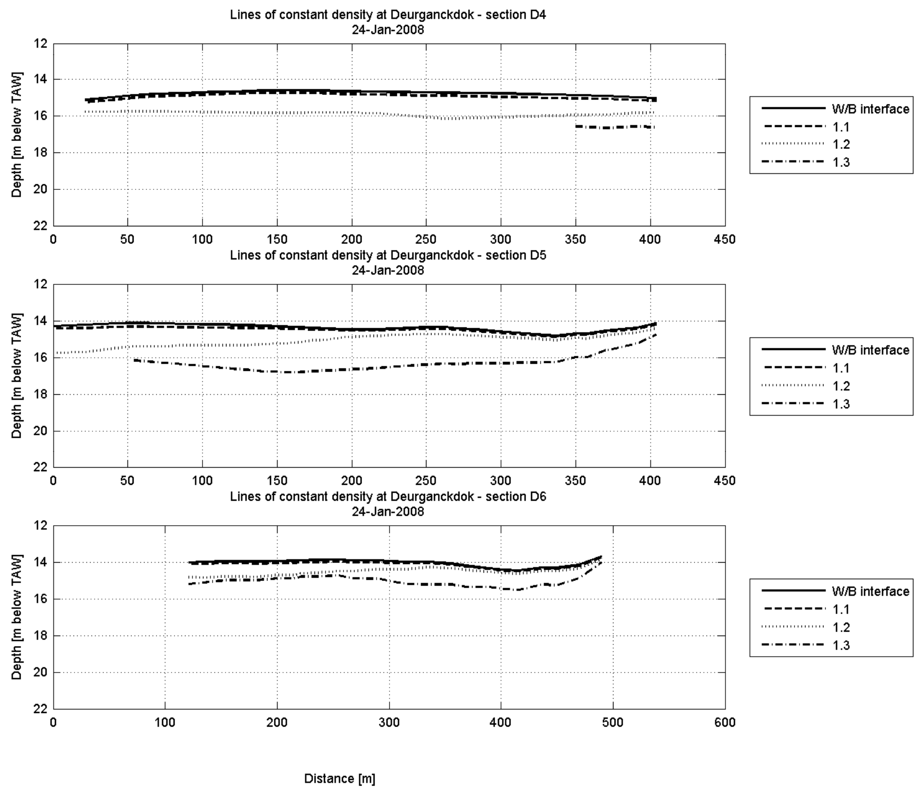
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with :
I/RA/11283/07.085/MSA

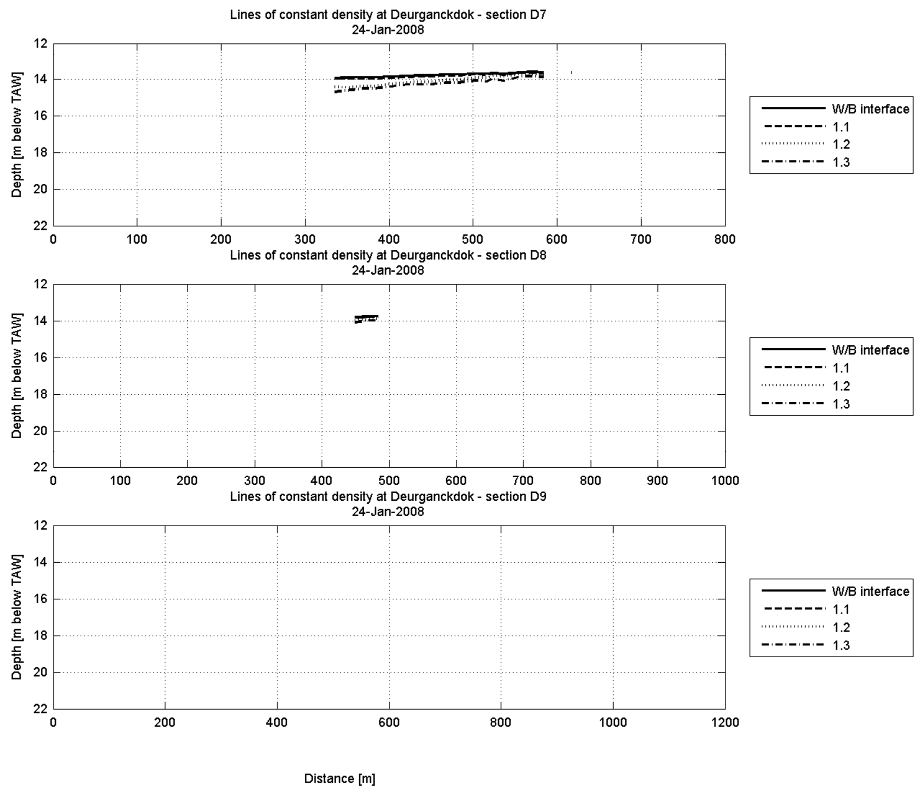
Long-term monitoring siltation Deurganckdok

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



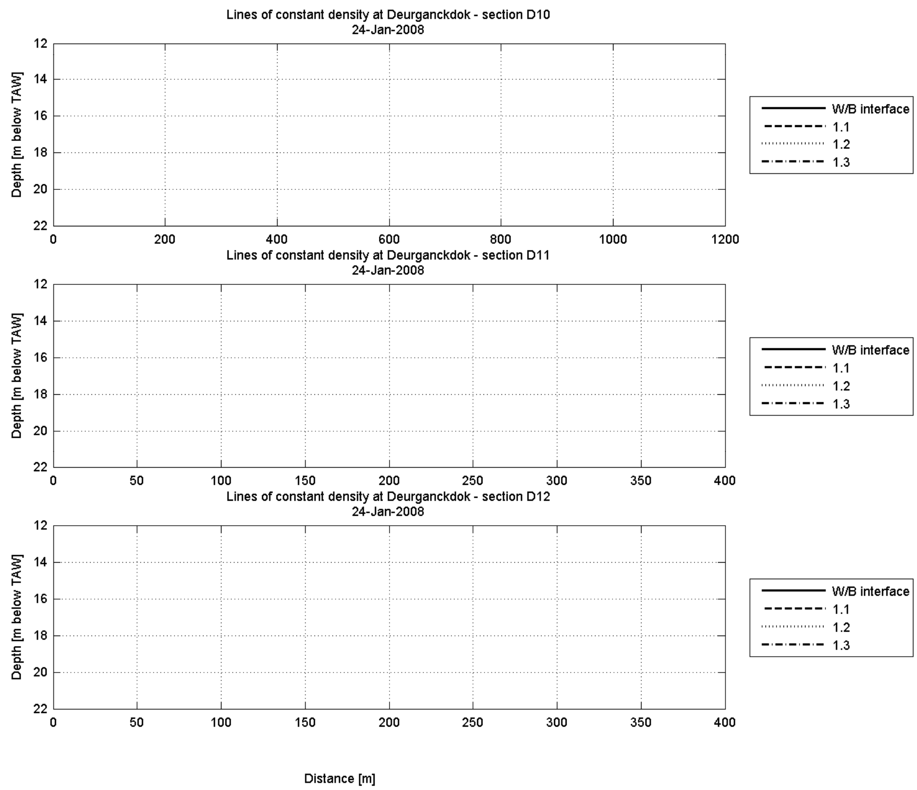
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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



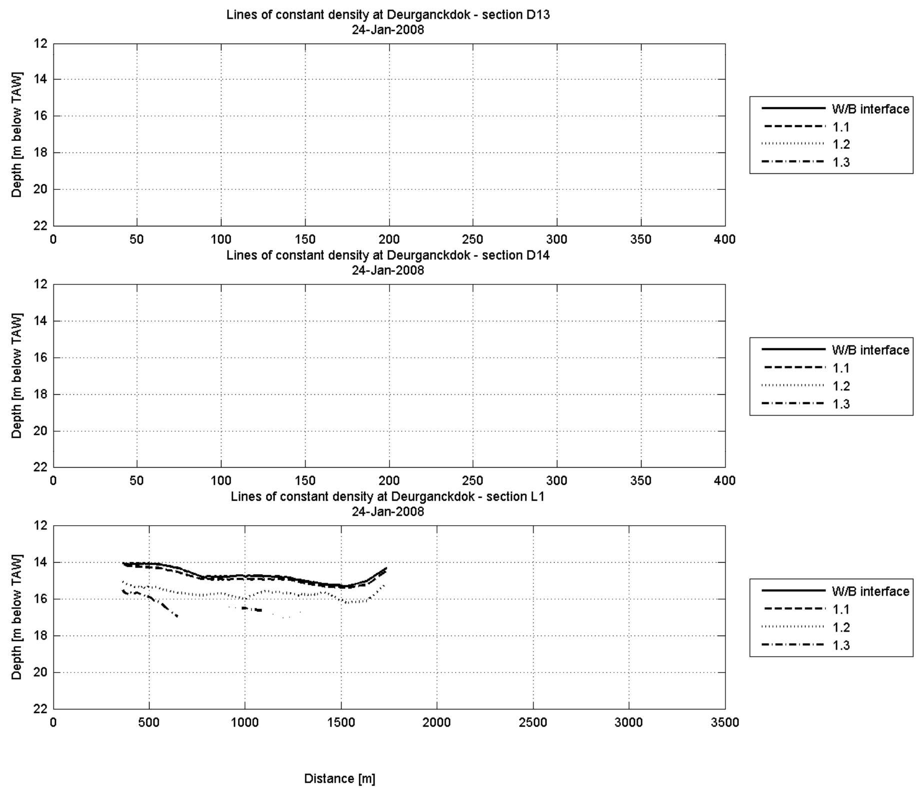
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

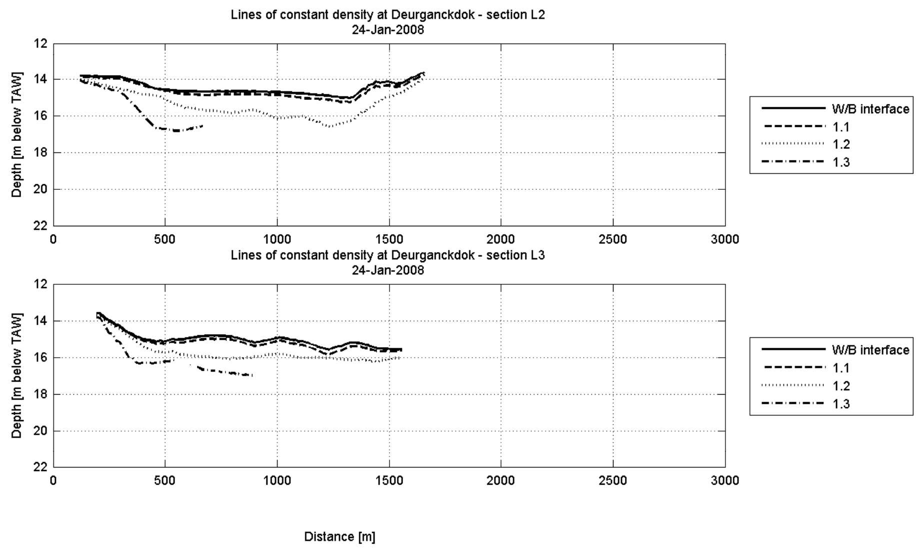
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :

I/RA/11283/07.085/MSA

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

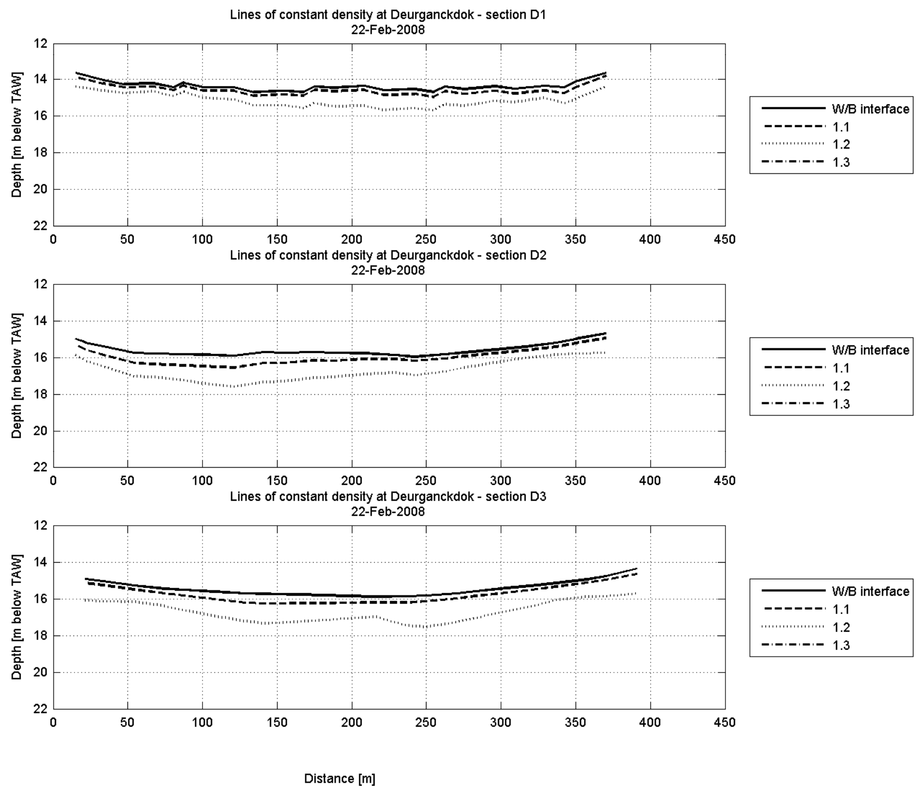


Data Processed by: IMDC
In association with :
I/RA/11283/07.085/MSA

D.6 Measurements February 22nd, 2008

Long-term monitoring siltation Deurganckdok

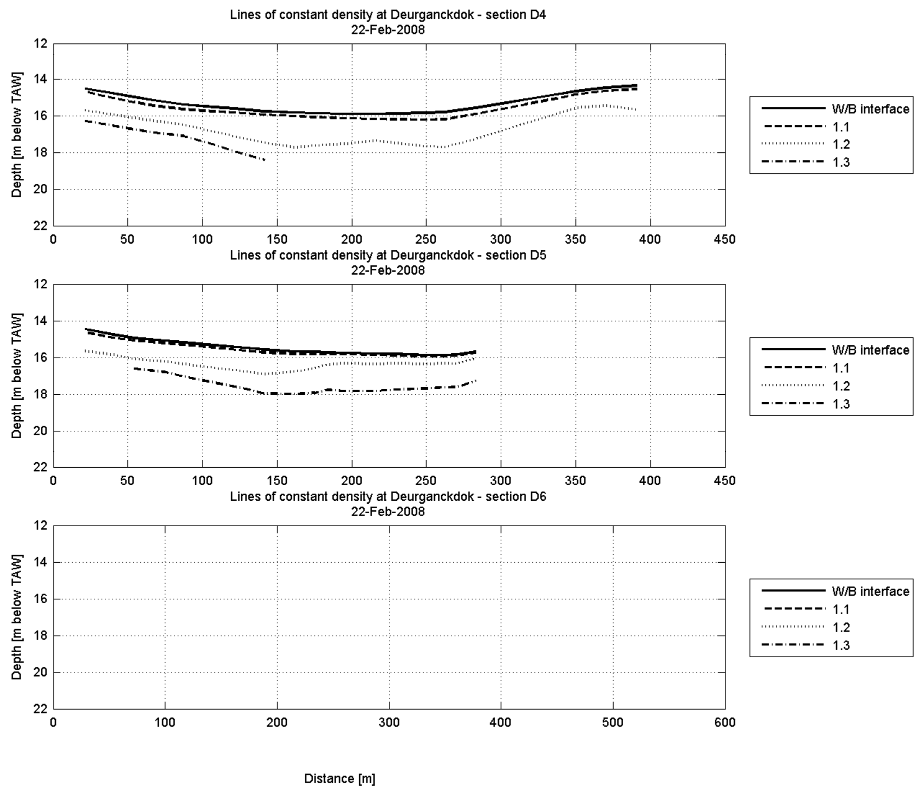
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

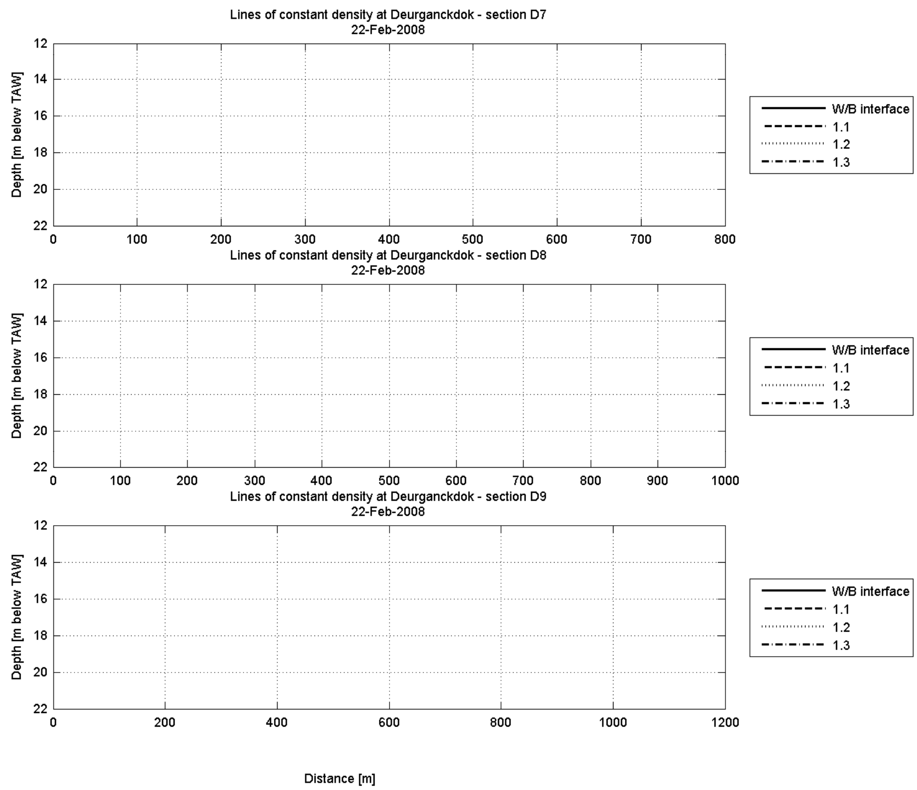
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

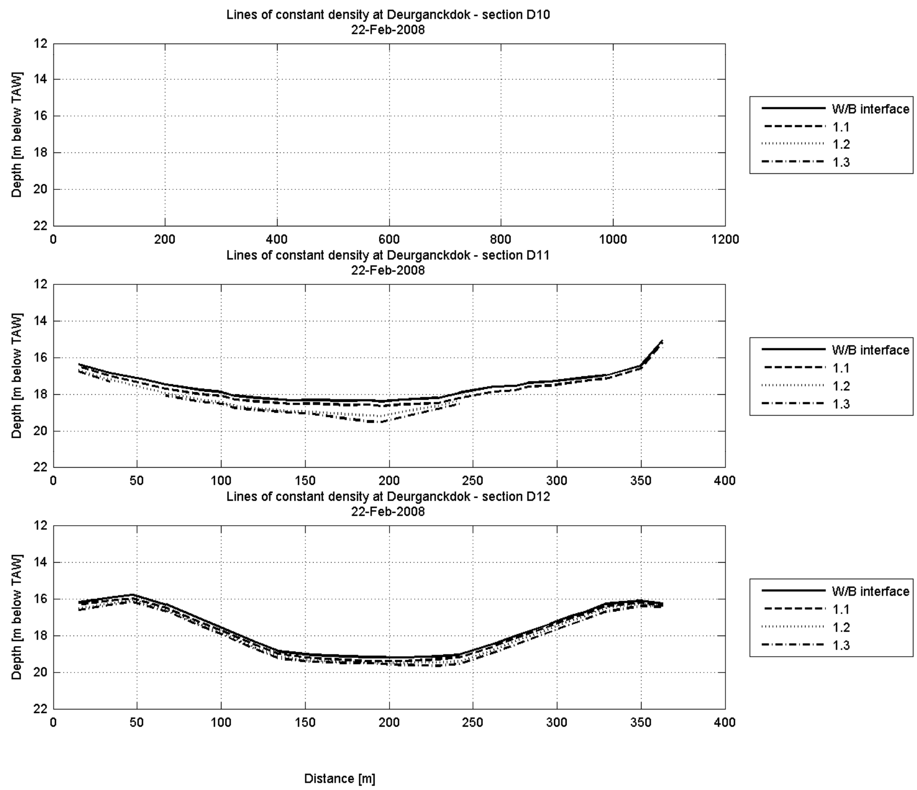
Long-term monitoring siltation Deurganckdok

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



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

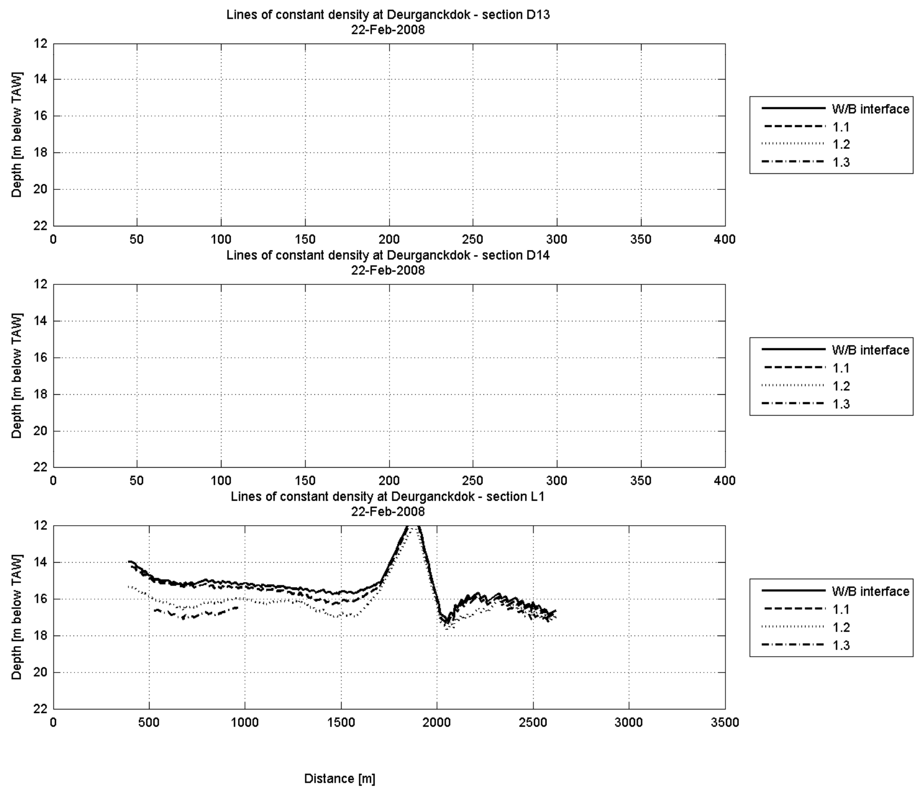
Long-term monitoring siltation Deurganckdok	
Cross sections planes constant density	Equipment(s): NaviTracker
	Location: DGD



Data Processed by: IMDC
In association with :
I/RA/11283/07.085/MSA

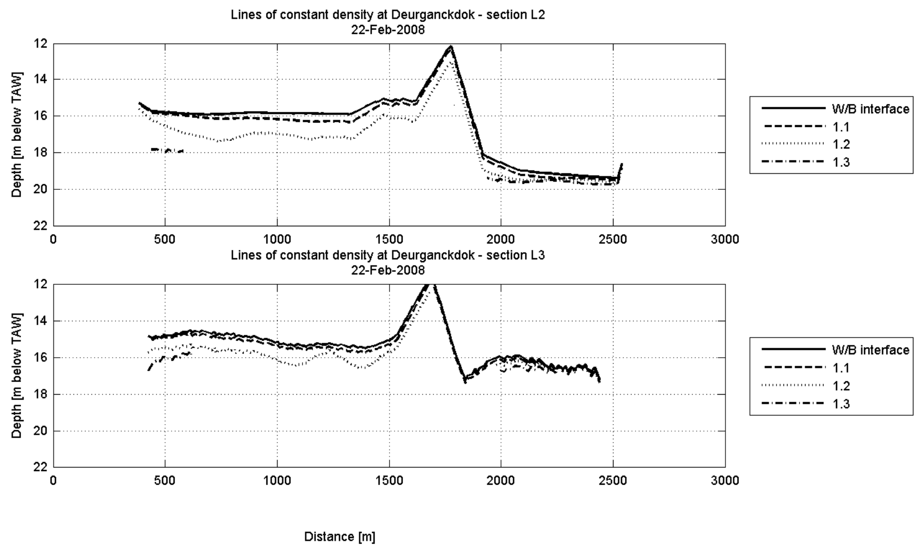
Long-term monitoring siltation Deurganckdok

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



Data Processed by:
In association with :
I/RA/11283/07.085/MSA

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

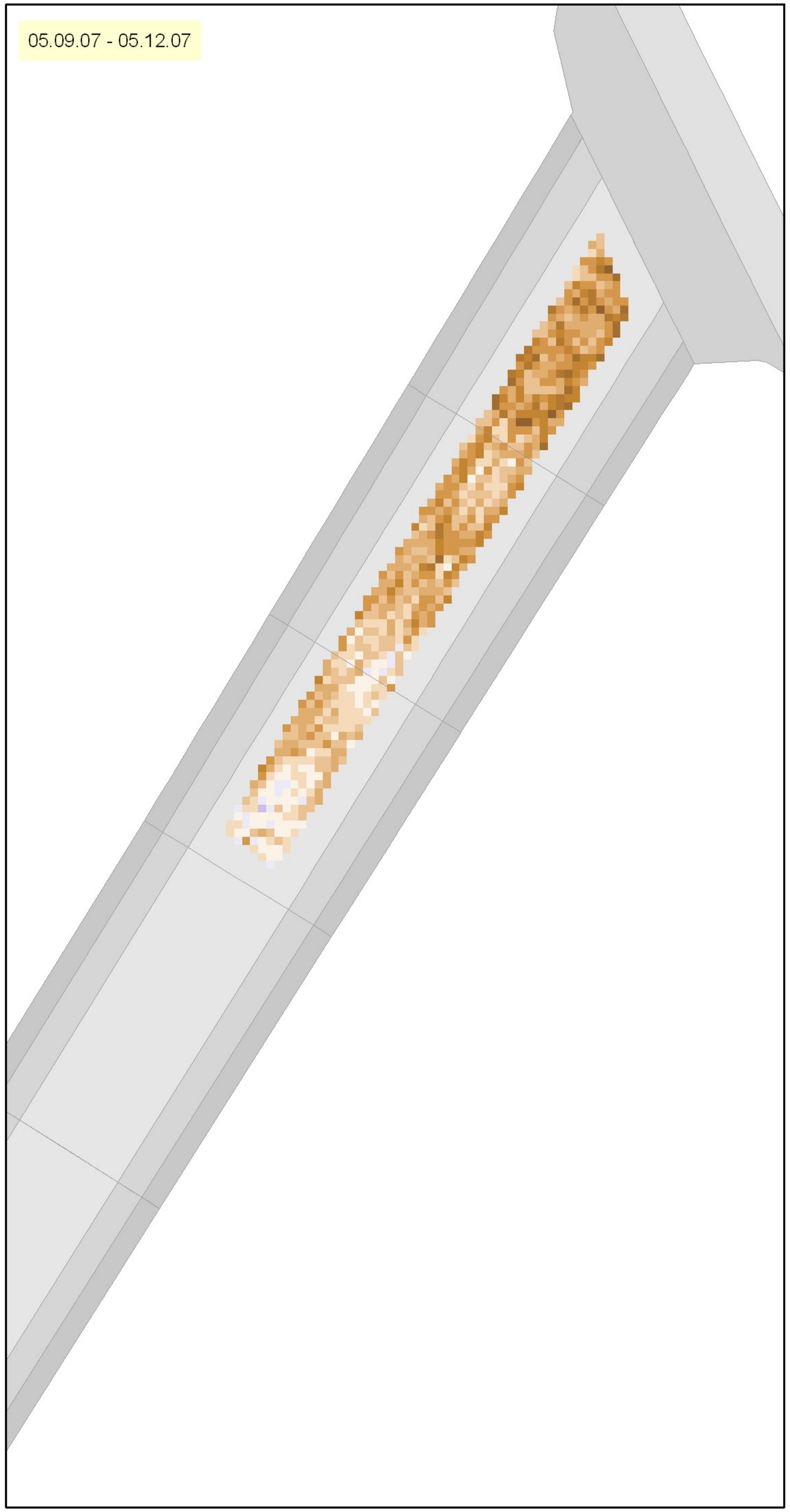


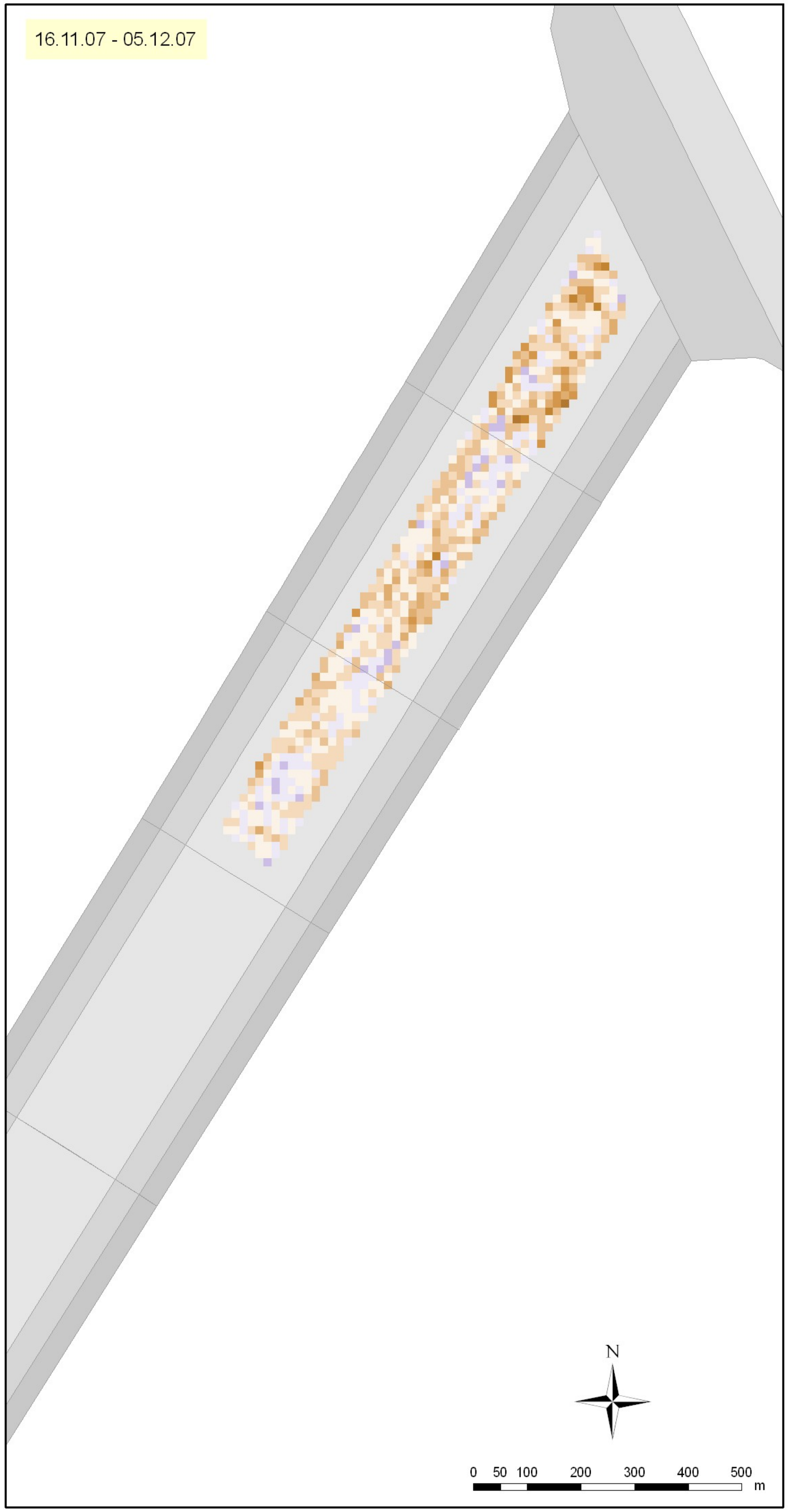
Data Processed by:
In association with :
I/RA/11283/07.085/MSA

APPENDIX E.

AVERAGE MASS GROWTH AND GROWTH RATE

E.1 Difference maps





Long-term measurements Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map total settled mass

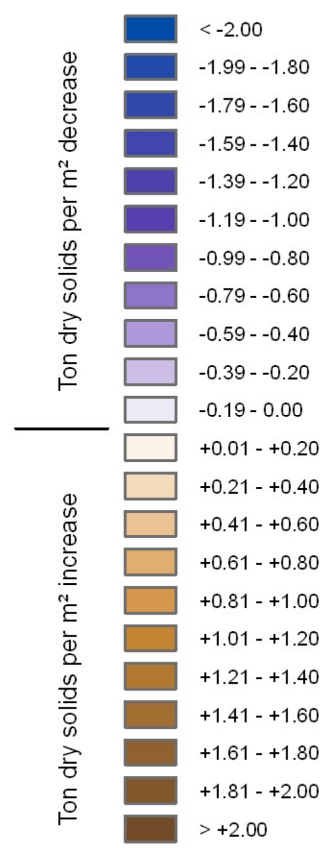
05.09.07 - 05.12.08
16.11.07 - 05.12.08

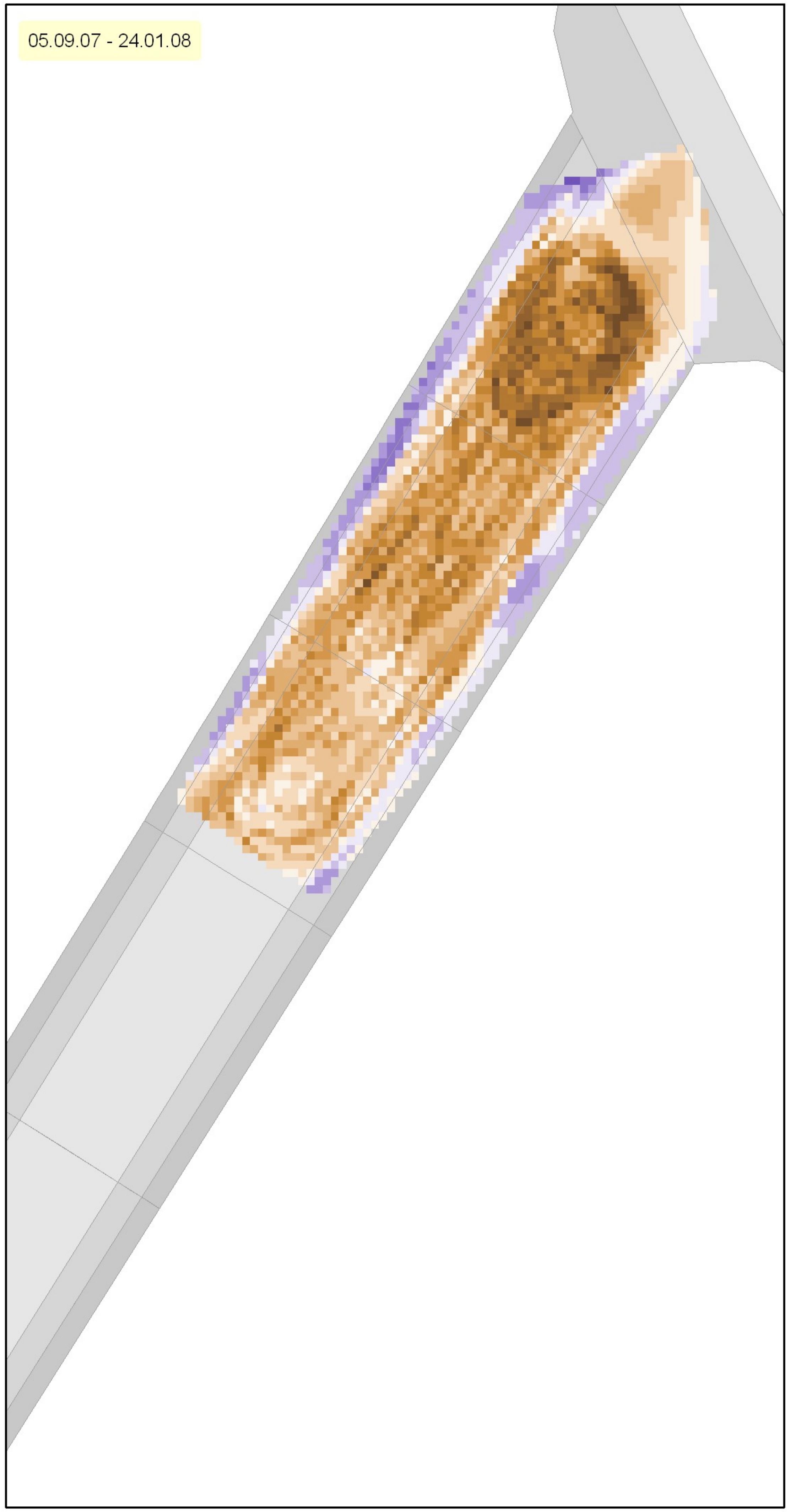
Map 3 Scale 1/10.000

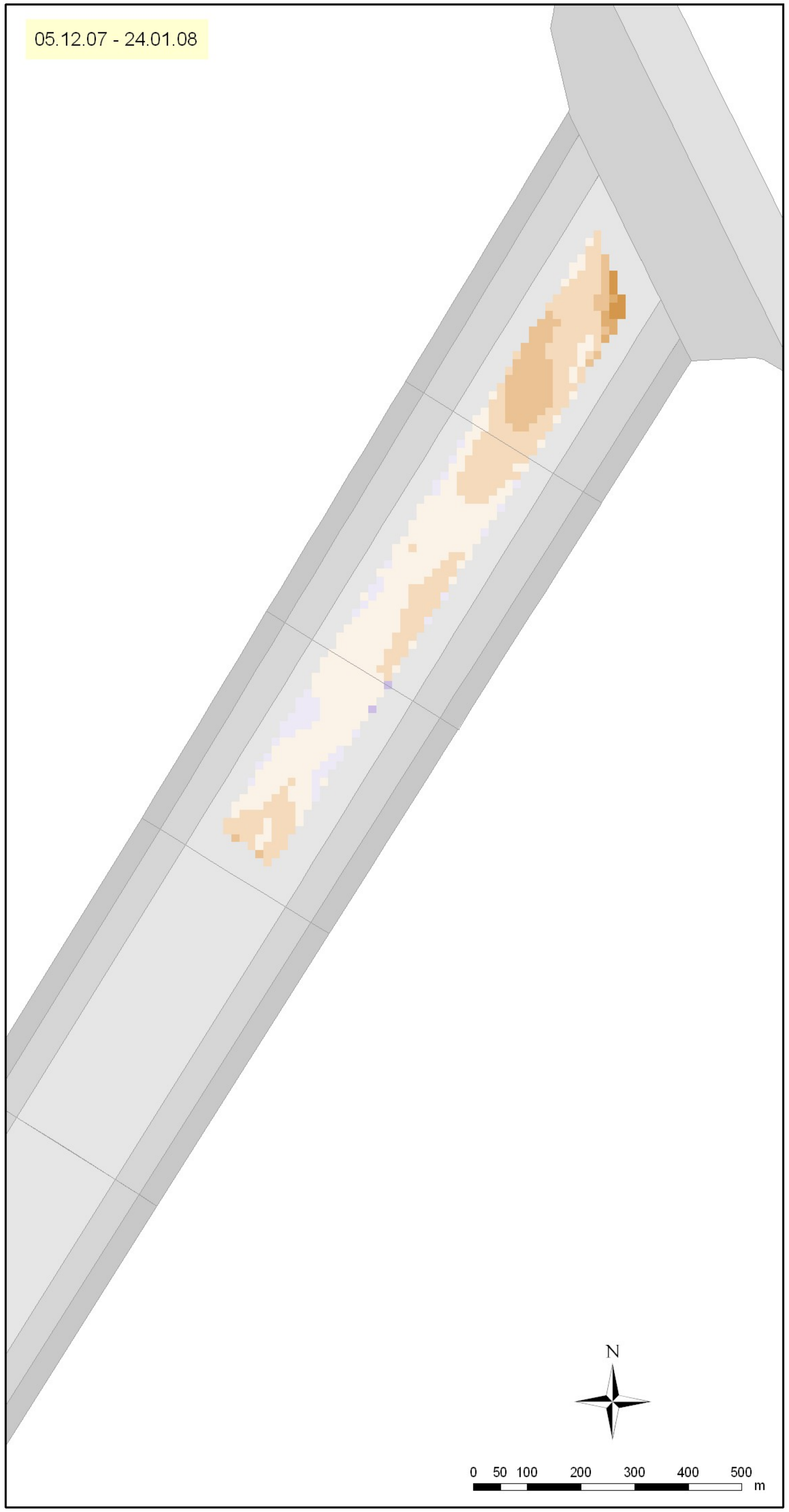
Created: 10/02/2009 I/DR/11283/08.000/JUR
Version nr. 2

IMDC International Marine & Dredging Consultants
Coveliersstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

Legend







Long-term measurements Deurganckdok Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map total settled mass

05.09.07 - 24.01.08
05.12.07 - 24.01.08

Map 4 Scale 1/10.000

Created: 10/02/2009 I/DR/11283/08.000/JUR
Version nr. 2

IMDC International Marine & Dredging Consultants
Covelierstraat 15
2600 Antwerpen
Tel +32 3 270 92 20
Fax +32 3 235 67 11
E-mail: info@imdc.be

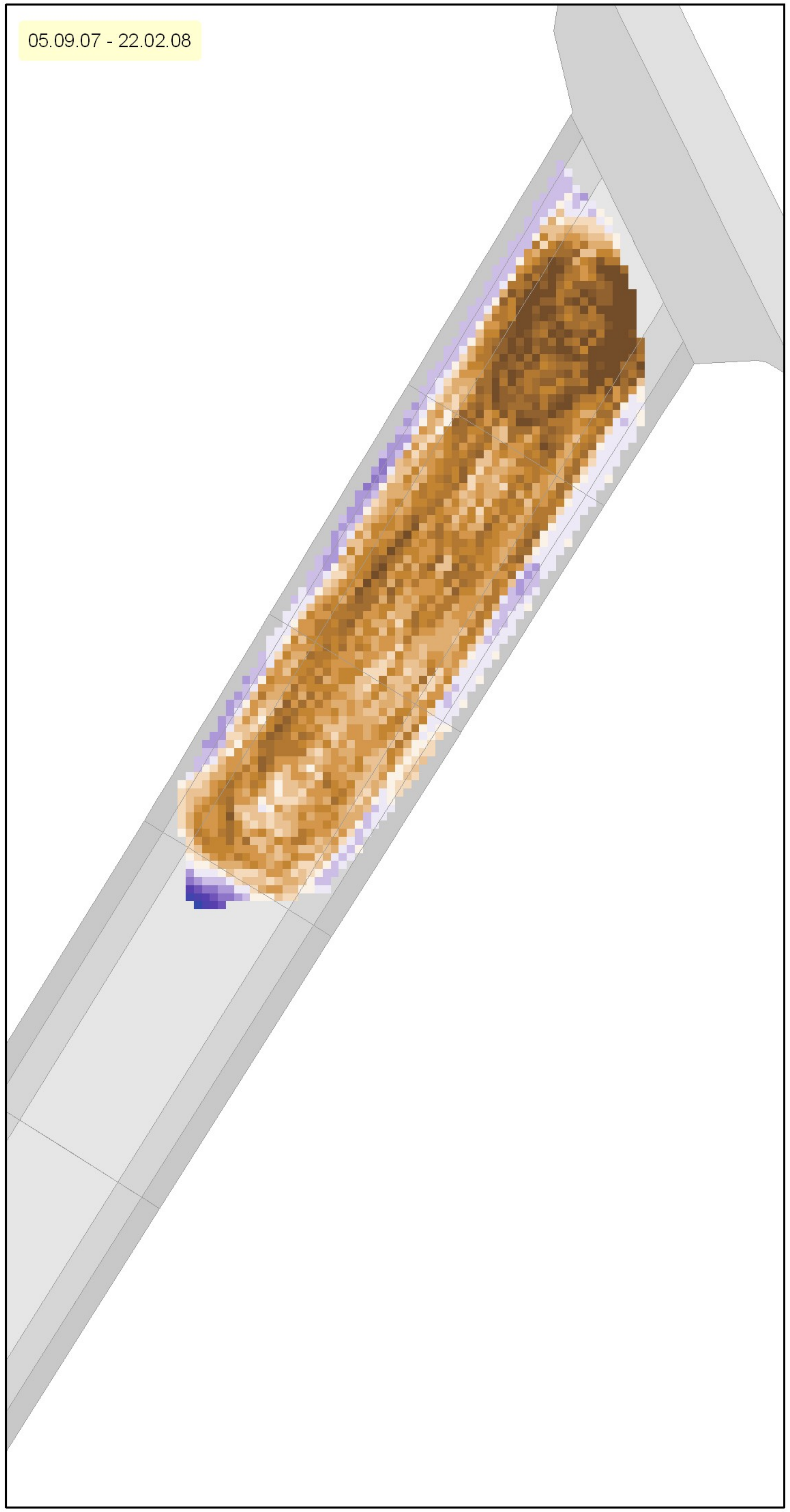
Legend

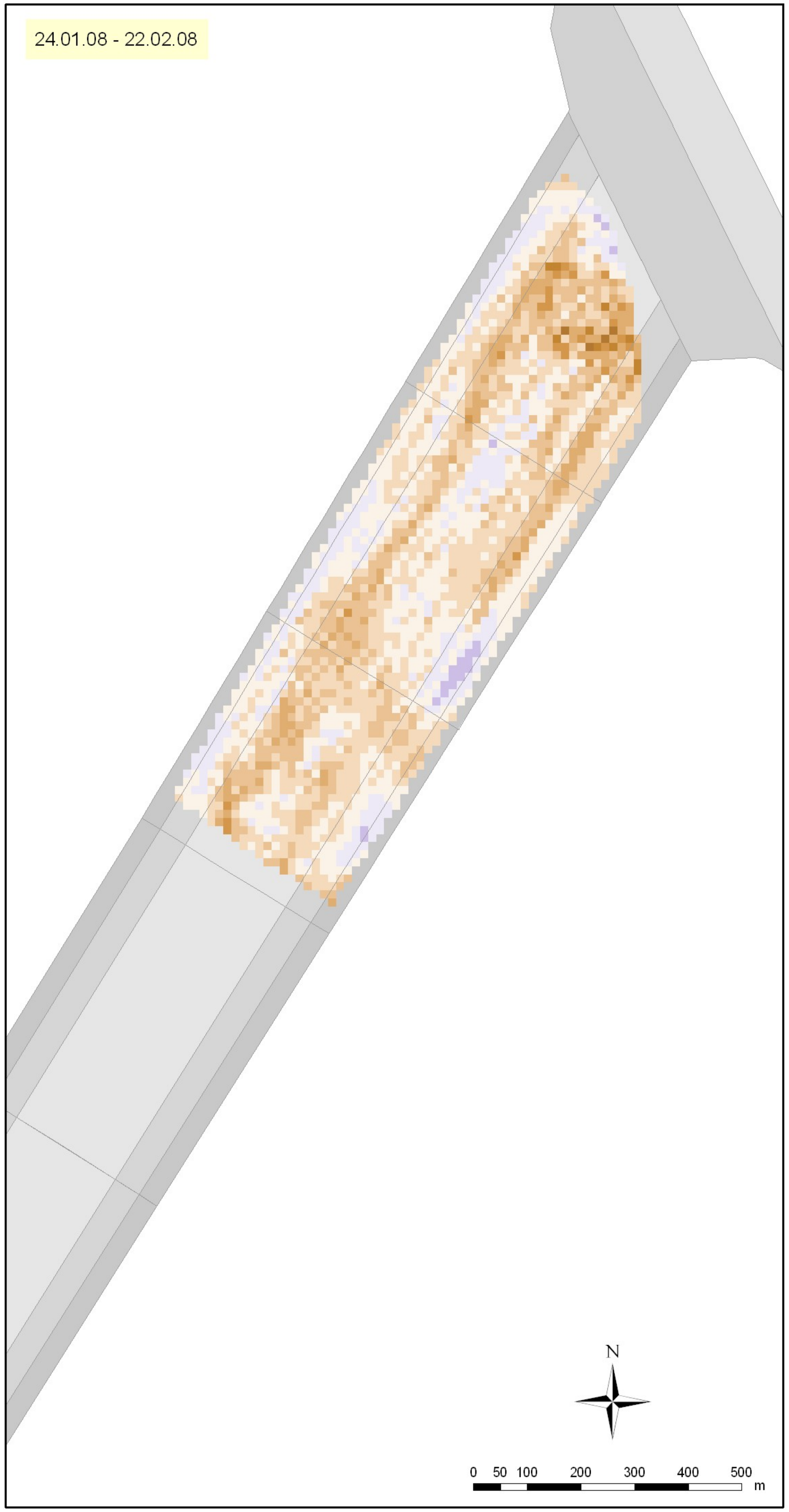
Ton dry solids per m² decrease

	< -2.00
	-1.99 - -1.80
	-1.79 - -1.60
	-1.59 - -1.40
	-1.39 - -1.20
	-1.19 - -1.00
	-0.99 - -0.80
	-0.79 - -0.60
	-0.59 - -0.40
	-0.39 - -0.20
	-0.19 - 0.00
	+0.01 - +0.20
	+0.21 - +0.40
	+0.41 - +0.60
	+0.61 - +0.80
	+0.81 - +1.00
	+1.01 - +1.20
	+1.21 - +1.40
	+1.41 - +1.60
	+1.61 - +1.80
	+1.81 - +2.00
	> +2.00

Ton dry solids per m² increase

W:\11283\GIS\project\rapport 1-14\TDS\K4_vk-TDS_051207-240108.mxd





Long-term measurements
Deurganckdok
Evolution & analysis of siltation

Bestek nr 16EB/05/04

Difference map total settled mass

05.09.07 - 22.02.08
24.01.08 - 22.02.08

Map 5 Scale 1/10.000

Created: 18/09/2008 I/DR/11283/08.000/JUR
Version nr. 1

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International Marine & Dredging Consultants
Covelierstraat 15
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Fax +32 3 235 67 11
E-mail: info@imdc.be

Legend

Ton dry solids per m² decrease
- < -2.00
- -1.99 - -1.80
- -1.79 - -1.60
- -1.59 - -1.40
- -1.39 - -1.20
- -1.19 - -1.00
- -0.99 - -0.80
- -0.79 - -0.60
- -0.59 - -0.40
- -0.39 - -0.20
- -0.19 - 0.00

Ton dry solids per m² increase
- +0.01 - +0.20
- +0.21 - +0.40
- +0.41 - +0.60
- +0.61 - +0.80
- +0.81 - +1.00
- +1.01 - +1.20
- +1.21 - +1.40
- +1.41 - +1.60
- +1.61 - +1.80
- +1.81 - +2.00
- > +2.00

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E.2 Tabular results

**Measured Mass (TDS/m²)

	05-Sep-07	16-Oct-07	16-Nov-07	05-Dec-07	24-Jan-08	22-Feb-08
1	-	-	-	-	-	-
2	0.518	0.576	-	-	-	-
3a	1.403	1.727	1.936	-	1.715	1.185
3b	1.133	1.336	1.501	1.286	1.324	0.911
3c	1.279	1.399	1.463	1.261	1.25	1.027
3d	-	-	-	-	-	0.918
3e	-	-	-	-	-	-
4Na	1.166	1.036	1.197	-	0.941	0.744
4Nb	0.951	0.861	0.942	-	0.82	0.576
4Nc	0.748	0.769	0.82	-	0.748	0.621
4Nd	-	-	-	-	-	0.87
4Ne	-	-	-	-	-	-
4Za	1.018	0.877	1.053	-	0.938	1.003
4Zb	0.929	0.767	0.909	-	0.75	0.682
4Zc	0.74	0.741	0.785	-	0.545	0.624
4Zd	-	-	-	-	-	0.813
4Ze	-	-	-	-	-	-
5Na	1.238	0.878	-	-	0.842	-
5Nb	1.133	0.889	-	-	0.7	-
5Nc	0.896	1.113	-	-	-	-
5Nd	-	-	-	-	-	-
5Ne	-	-	-	-	-	-
5Za	0.809	-	0.842	-	0.681	-
5Zb	0.905	0.609	0.712	-	0.693	-
5Zc	-	0.591	-	-	-	-
5Zd	-	-	-	-	-	-
5Ze	-	-	-	-	-	-
Trench area mean	1.267	1.482	1.629	1.336	1.426	1.037

****Total cumulative mass(TDS/m²)**

	05-Sep-07	16-Oct-07	16-Nov-07	05-Dec-07	24-Jan-08	22-Feb-08
1	-	-	-	-	-	-
2	0.518	0.576	-	-	-	-
3a	1.403	1.727	1.936	-	2.543	2.935
3b	1.133	1.336	1.501	1.882	1.92	2.242
3c	1.279	1.399	1.463	1.773	1.761	2.212
3d	-	-	-	-	-	0.931
3e	-	-	-	-	-	-
4Na	1.166	1.036	1.197	-	1.417	1.606
4Nb	0.951	0.861	0.942	-	1.291	1.444
4Nc	0.748	0.769	0.82	-	1.147	1.35
4Nd	-	-	-	-	-	0.87
4Ne	-	-	-	-	-	-
4Za	1.018	0.877	1.053	-	1.355	1.716
4Zb	0.929	0.767	0.909	-	1.258	1.455
4Zc	0.74	0.741	0.785	-	0.804	1.026
4Zd	-	-	-	-	-	0.813
4Ze	-	-	-	-	-	-
5Na	1.238	0.878	-	-	0.842	-
5Nb	1.133	0.889	-	-	0.7	-
5Nc	0.896	1.113	-	-	-	-
5Nd	-	-	-	-	-	-
5Ne	-	-	-	-	-	-
5Za	0.809	-	0.842	-	0.681	-
5Zb	0.905	0.609	0.712	-	0.693	-
5Zc	-	0.591	-	-	-	-
5Zd	-	-	-	-	-	-
5Ze	-	-	-	-	-	-
Mean	1.267	1.482	1.629	1.98	2.07	2.456

Cumulative dredged mass in covered area (TDS)

	05-Sep-07	16-Oct-07	16-Nov-07	05-Dec-07	24-Jan-08	22-Feb-08
1	0	0	0	17	17	17
2	0	0	0	40	40	256
3a	0	0	0	82226	82226	173636
3b	0	0	0	65581	65581	146444
3c	0	0	0	50526	50526	117129
3d	0	0	0	916	916	1722
3e	0	0	0	0	0	0
4Na	0	0	0	17451	17451	31615
4Nb	0	0	0	14499	14499	26750
4Nc	0	0	0	10326	10326	18867
4Nd	0	0	0	21	21	21
4Ne	0	0	0	0	0	0
4Za	0	0	0	10140	10140	17312
4Zb	0	0	0	15994	15994	24347
4Zc	0	0	0	6723	6723	10390
4Zd	0	0	0	0	0	0
4Ze	0	0	0	0	0	0
5Na	0	0	0	0	0	0
5Nb	0	0	0	0	0	68
5Nc	0	0	0	9	9	15
5Nd	0	0	0	0	0	0
5Ne	0	0	0	0	0	0
5Za	0	0	0	0	0	0
5Zb	0	0	0	0	0	0
5Zc	0	0	0	0	0	0
5Zd	0	0	0	0	0	0
5Ze	0	0	0	0	0	0
Total	0	0	0	274469	274469	568588

Growth rate (kg/m²/day)

	05-Sep-2007 / 16-Oct-2007	16-Oct-2007/ 16-Nov-2007	16-Nov-2007 5-Dec-2007	5-Dec-2007 24-Jan-2008	24-Jan-2008 / 22-Feb-2008
1	-	-	-	-	-
2	1.402	-	-	-	-
3a	7.913	6.731	-	-	13.516
3b	4.963	5.299	20.055	0.777	11.102
3c	2.932	2.073	16.306	-0.228	15.551
3d	-	-	-	-	-
3e	-	-	-	-	-
4Na	-3.183	5.2	-	-	6.503
4Nb	-2.174	2.586	-	-	5.295
4Nc	0.496	1.658	-	-	7.01
4Nd	-	-	-	-	-
4Ne	-	-	-	-	-
4Za	-3.442	5.681	-	-	12.438
4Zb	-3.963	4.573	-	-	6.783
4Zc	0.043	1.419	-	-	7.632
4Zd	-	-	-	-	-
4Ze	-	-	-	-	-
5Na	-8.788	-	-	-	-
5Nb	-5.968	-	-	-	-
5Nc	5.292	-	-	-	-
5Nd	-	-	-	-	-
5Ne	-	-	-	-	-
5Za	-	-	-	-	-
5Zb	-7.199	3.303	-	-	-
5Zc	-	-	-	-	-
5Zd	-	-	-	-	-
5Ze	-	-	-	-	-
Mean	5.262	4.726	18.468	1.809	13.307

****Covered Area (ha)**

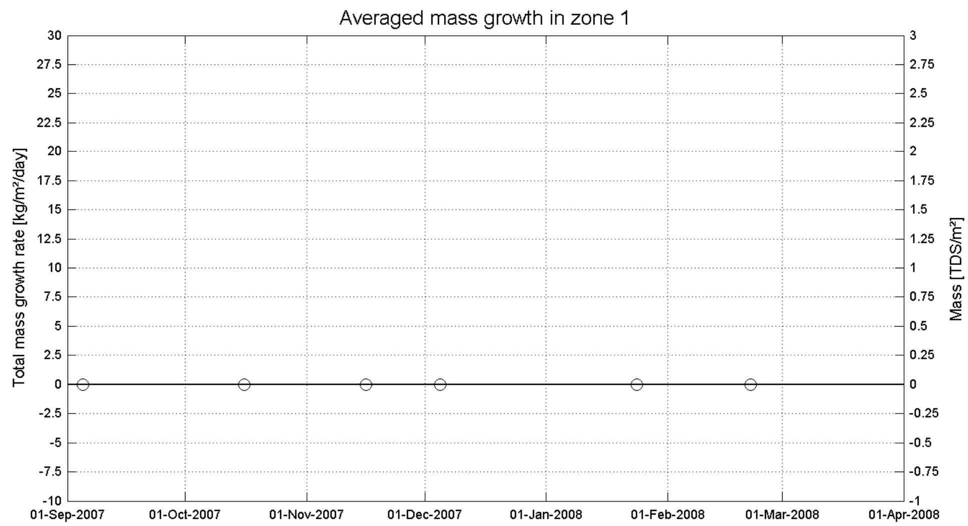
	05-Sep-07	16-Oct-07	16-Nov-07	05-Dec-07	24-Jan-08	22-Feb-08
1	0.18	0.18	0.02	0	0.05	0
2	7.43	7.11	4.16	0	4.1	0
3a	9.92	9.92	9.92	4.82	9.92	8.64
3b	11	11	11	6.41	11	11
3c	9.88	9.88	9.65	5.02	8.93	9.88
3d	1.15	5.67	0	0	0	13.07
3e	0	0	0	0	0	5.02
4Na	3.67	3.67	3.29	0	3.31	3.2
4Nb	3.08	3.08	3.08	0	3.08	3.08
4Nc	2.54	2.59	2.45	0	2.29	2.59
4Nd	0	0.99	0	0	0	3.26
4Ne	0	0	0	0	0	1.31
4Za	2.43	2.43	2.43	0	2.43	1.64
4Zb	3.15	3.15	3.15	0	3.15	3.15
4Zc	2.23	2.59	2.39	0	2.34	2.59
4Zd	0	1.08	0	0	0	3.2
4Ze	0	0	0	0	0	1.22
5Na	1.94	1.87	0.68	0	1.31	0.68
5Nb	1.67	1.55	0.86	0	1.22	0.86
5Nc	1.26	1.33	0.65	0	0.7	0.81
5Nd	0	0.41	0	0	0	1.04
5Ne	0	0	0	0	0	0.27
5Za	1.04	0.63	0.97	0	0.9	0.32
5Zb	1.04	1.06	1.04	0	1.13	0.97
5Zc	0.27	0.97	0.47	0	0.72	0.88
5Zd	0	0.32	0	0	0	1.17
5Ze	0	0	0	0	0	0.38
Total	63.86	71.46	56.21	16.25	56.57	80.19

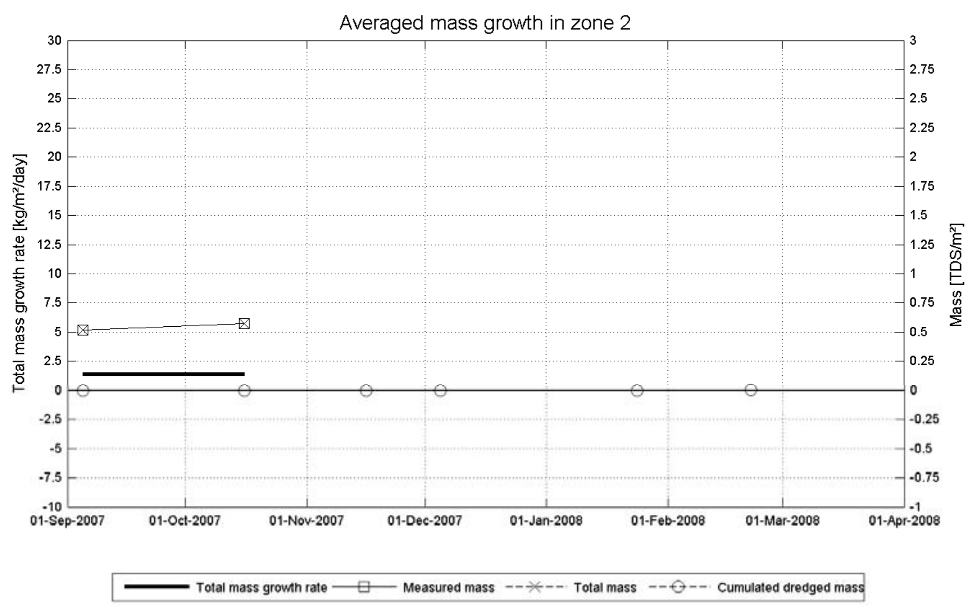
**Percent of zone covered

	05-Sep-07	16-Oct-07	16-Nov-07	05-Dec-07	24-Jan-08	22-Feb-08
1	2	2	0	0	0	0
2	60	58	34	0	33	0
3a	100	100	100	49	100	87
3b	100	100	100	58	100	100
3c	100	100	98	51	90	100
3d	9	43	0	0	0	100
3e	0	0	0	0	0	39
4Na	100	100	90	0	90	87
4Nb	100	100	100	0	100	100
4Nc	98	100	95	0	89	100
4Nd	0	30	0	0	0	100
4Ne	0	0	0	0	0	39
4Za	100	100	100	0	100	68
4Zb	100	100	100	0	100	100
4Zc	86	100	92	0	90	100
4Zd	0	34	0	0	0	100
4Ze	0	0	0	0	0	39
5Na	83	81	29	0	56	29
5Nb	83	78	43	0	61	43
5Nc	70	74	36	0	39	45
5Nd	0	17	0	0	0	43
5Ne	0	0	0	0	0	11
5Za	78	47	73	0	68	24
5Zb	53	54	53	0	57	49
5Zc	15	54	26	0	40	49
5Zd	0	13	0	0	0	49
5Ze	0	0	0	0	0	16
Mean	50	55	43	6	45	60

E.3 For each zone

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





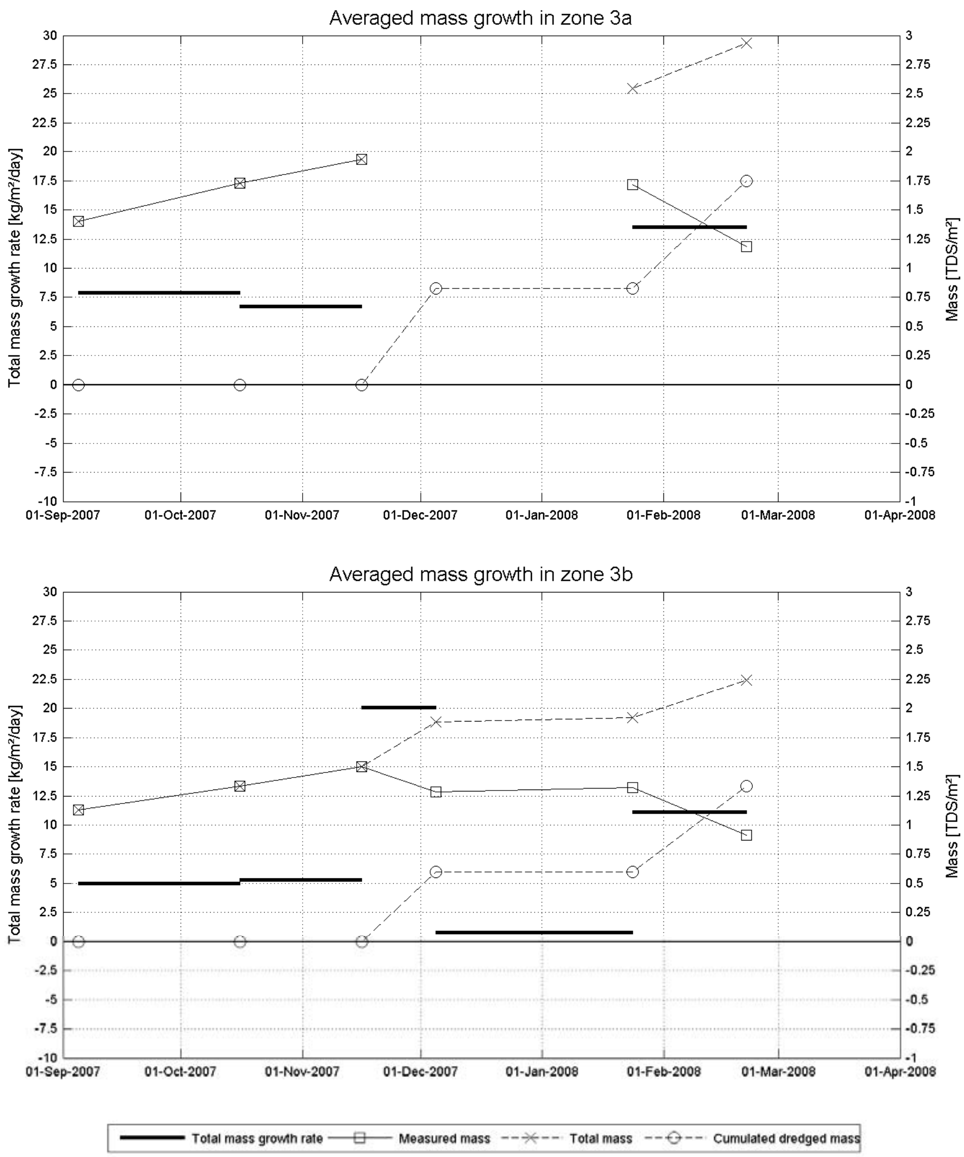
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



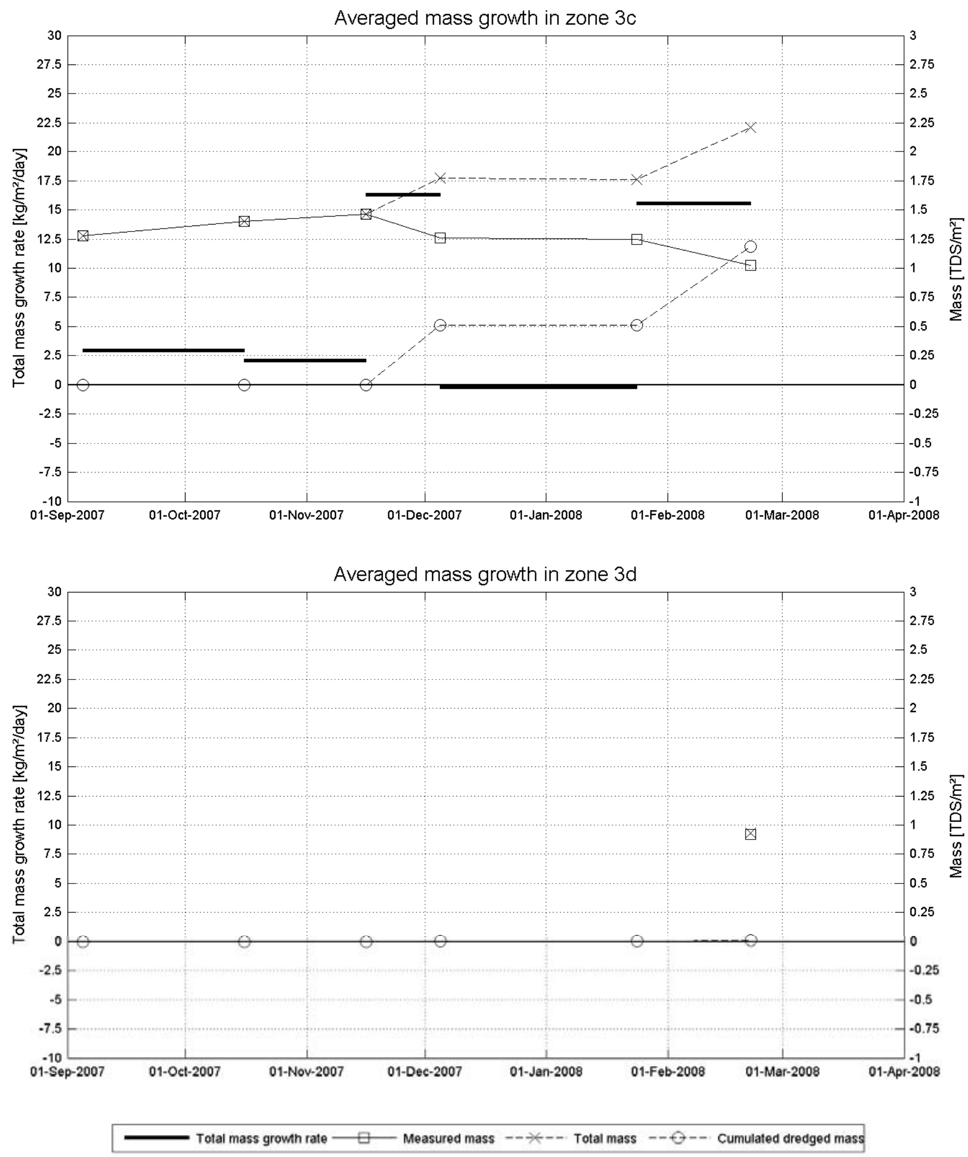
Data Processed by: IMDC

In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



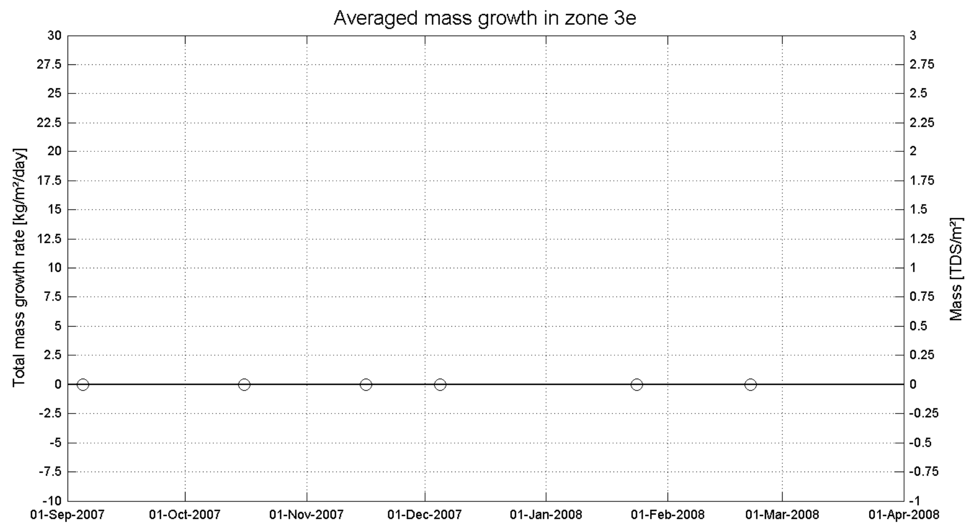
Data Processed by: IMDC

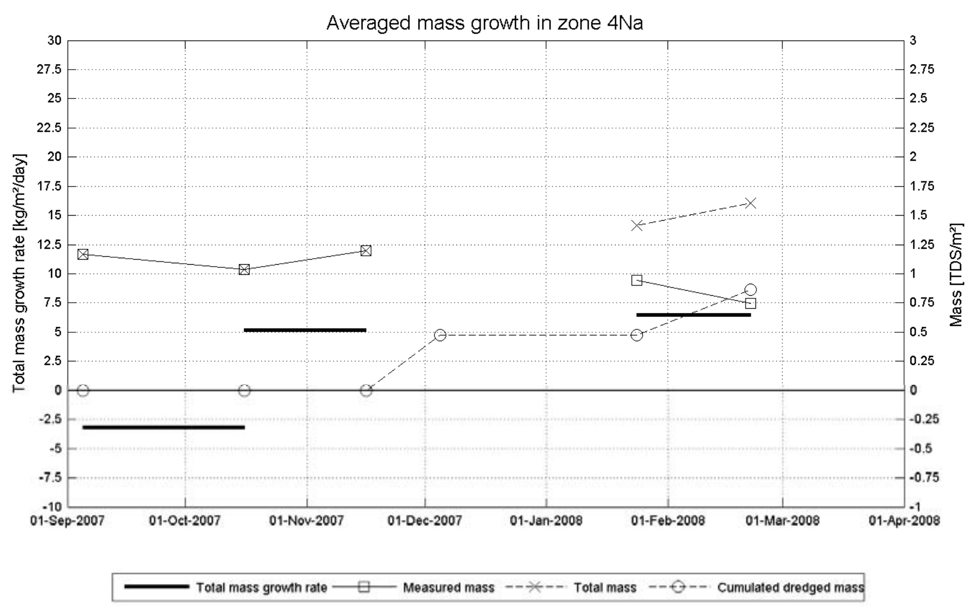
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



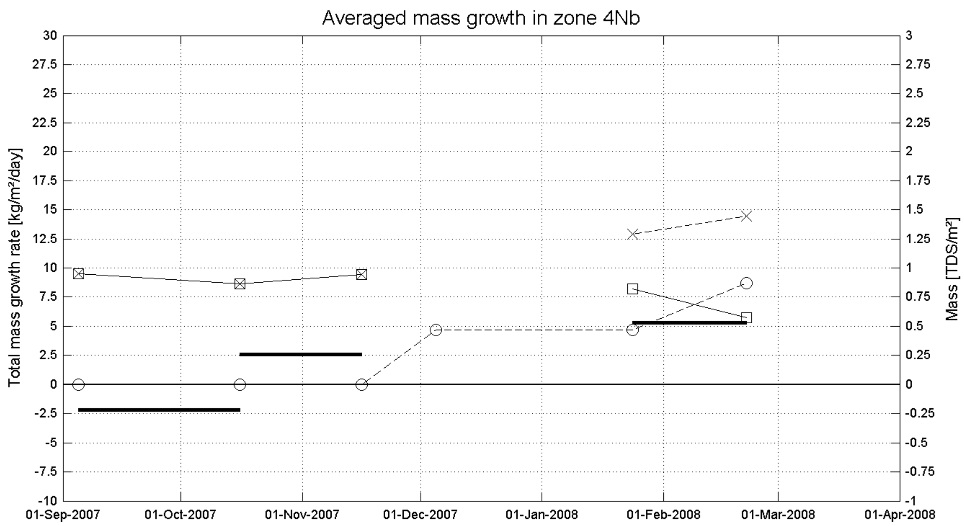


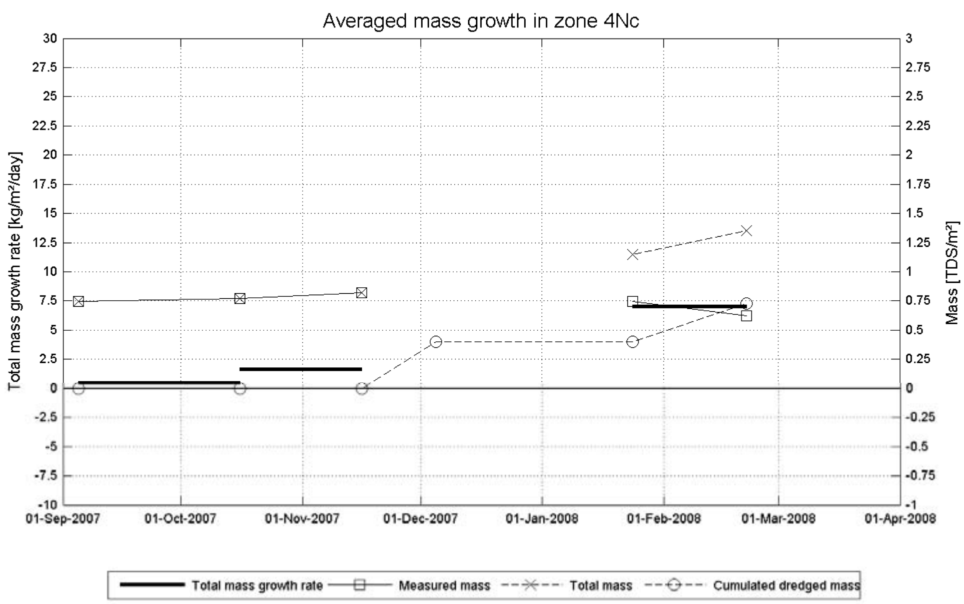
Data Processed by:

In association with :

I/RA/11283/07.085/MSA

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

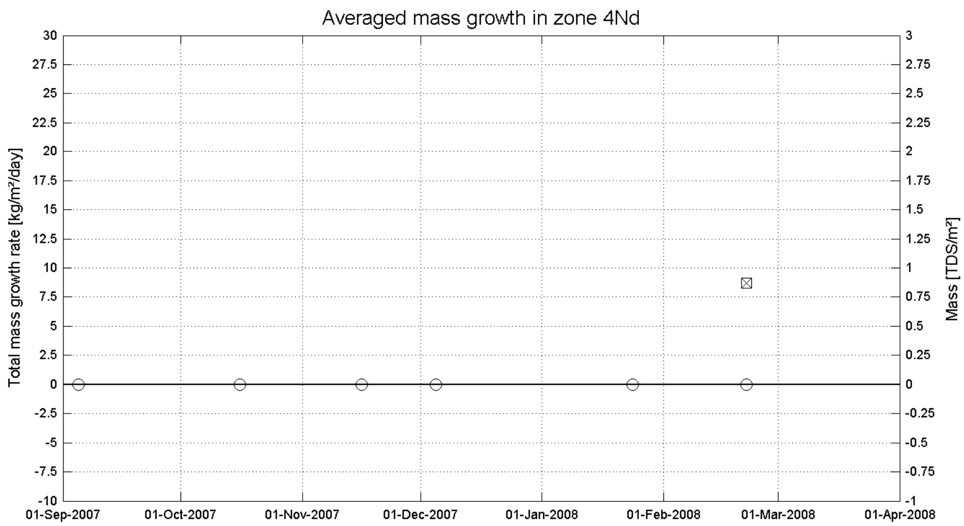


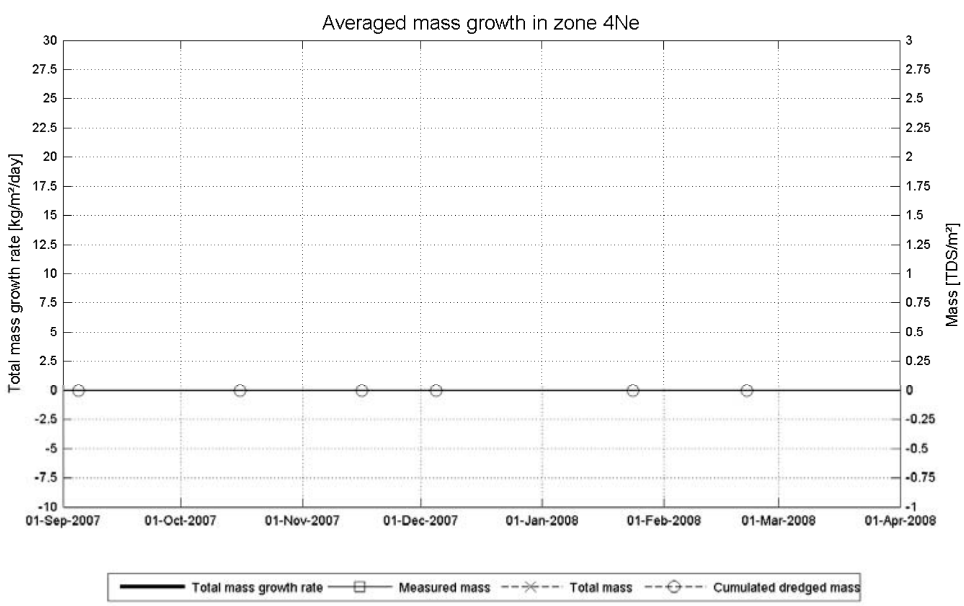


	Data Processed by: IMDC In association with : I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





Data Processed by: IMDC

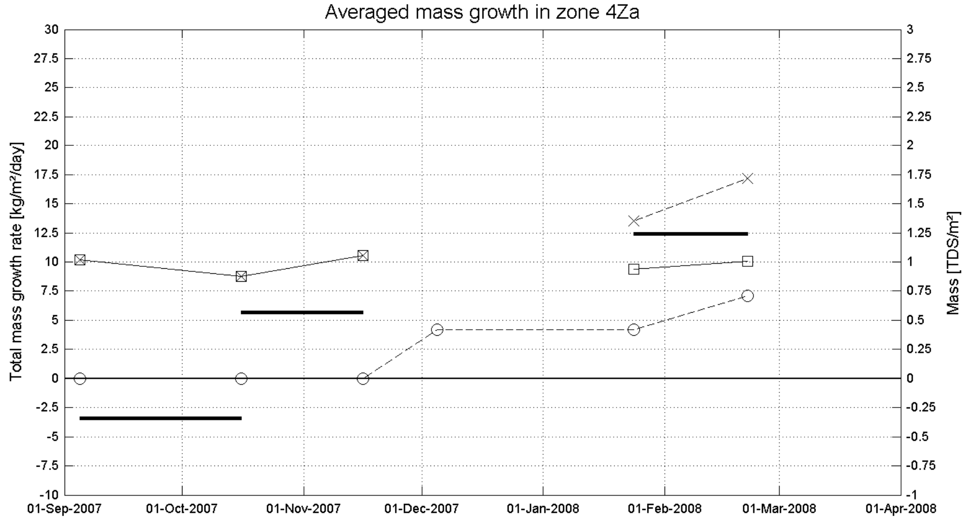
In association with :

I/RA/11283/07.085/MSA

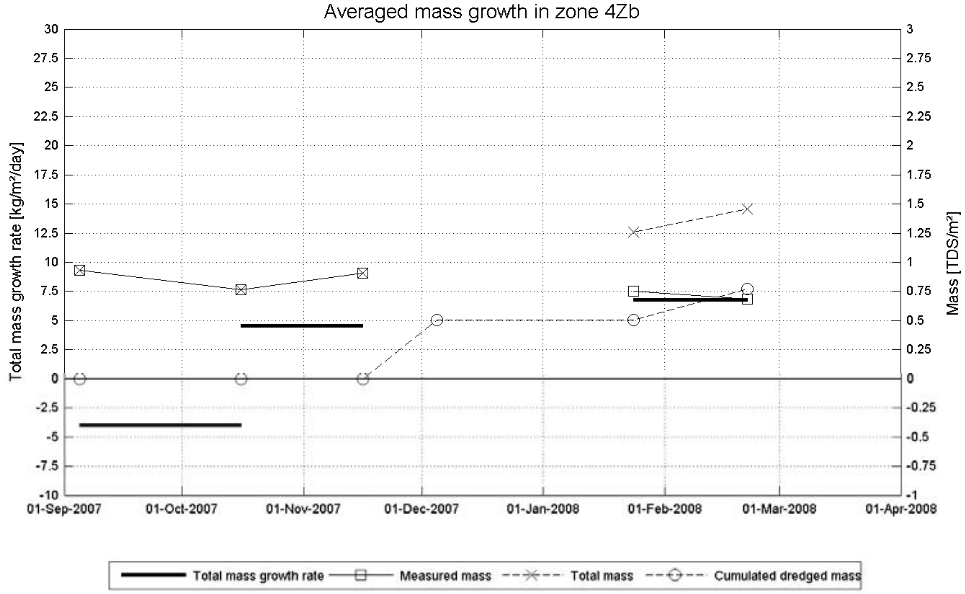
Long-term monitoring siltation Deurganckdok

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

Averaged mass growth in zone 4Za



Averaged mass growth in zone 4Zb

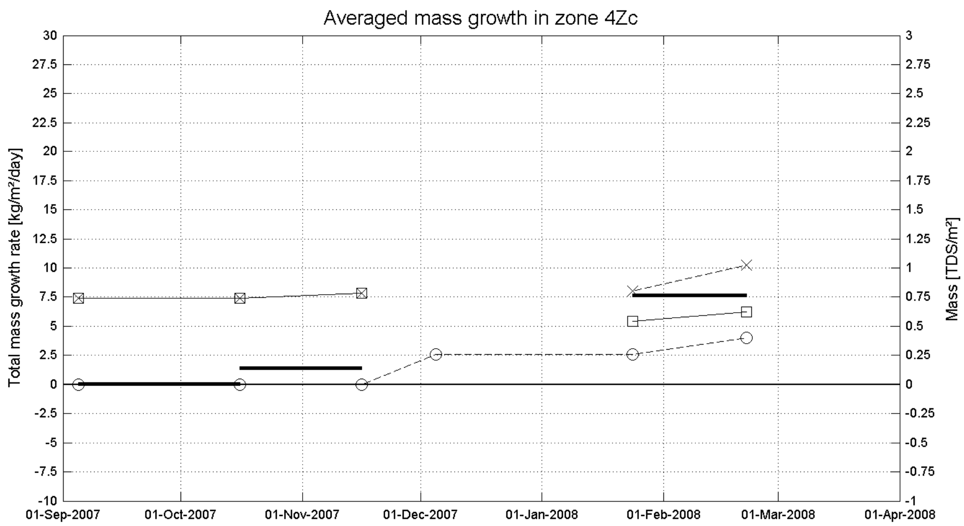


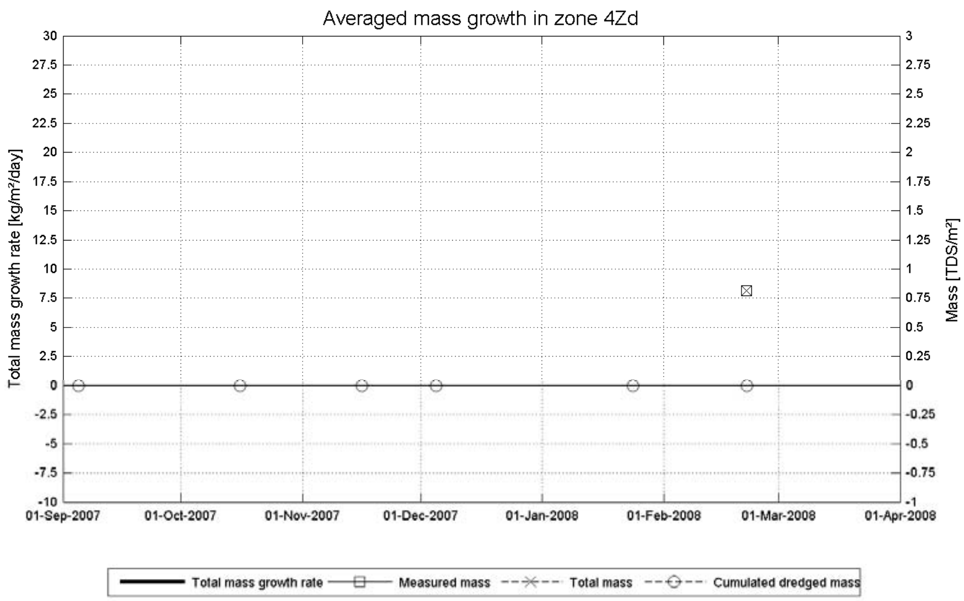
Data Processed by: IMDC

In association with :

I/RA/11283/07.085/MSA

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



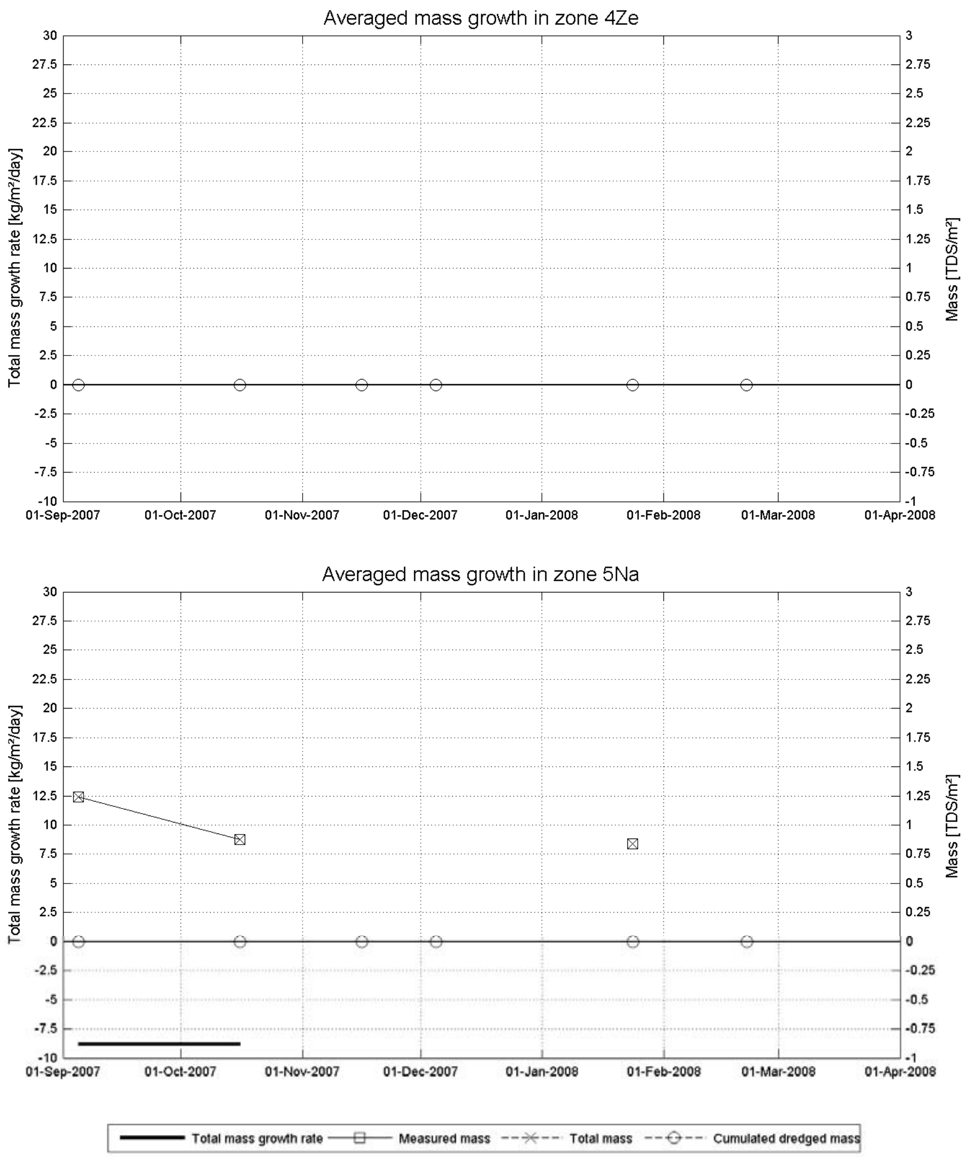


Data Processed by: IMDC

In association with :

I/RA/11283/07.085/MSA

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



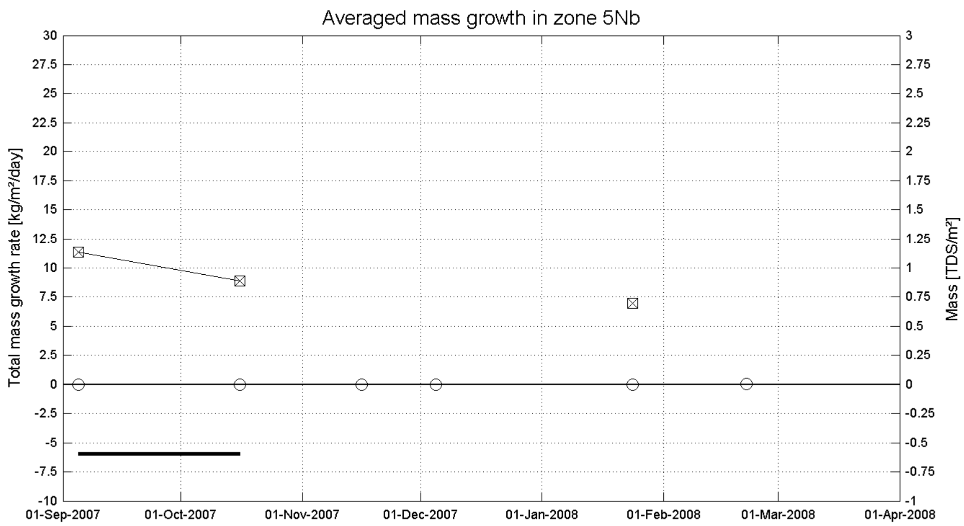
Data Processed by: IMDC

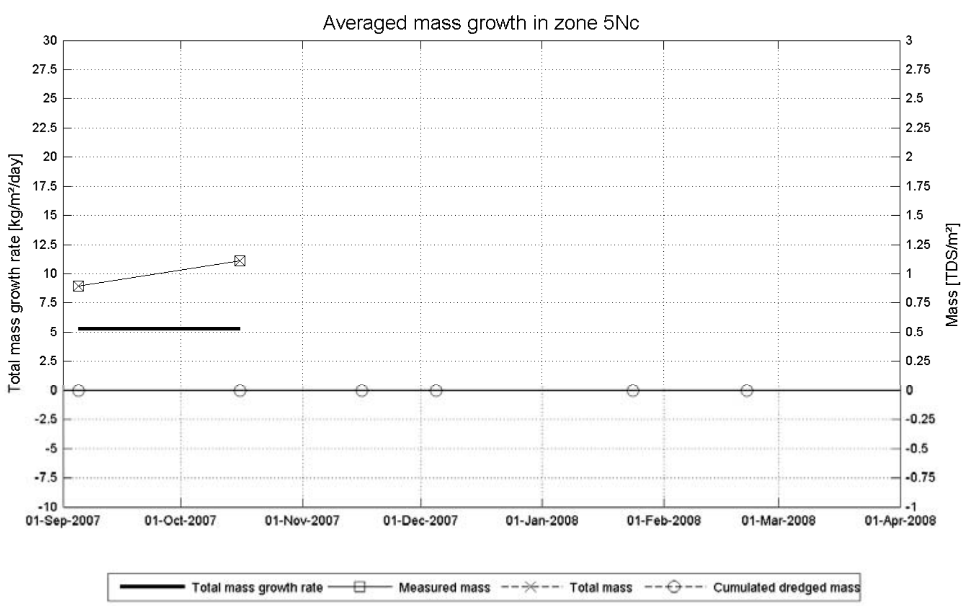
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





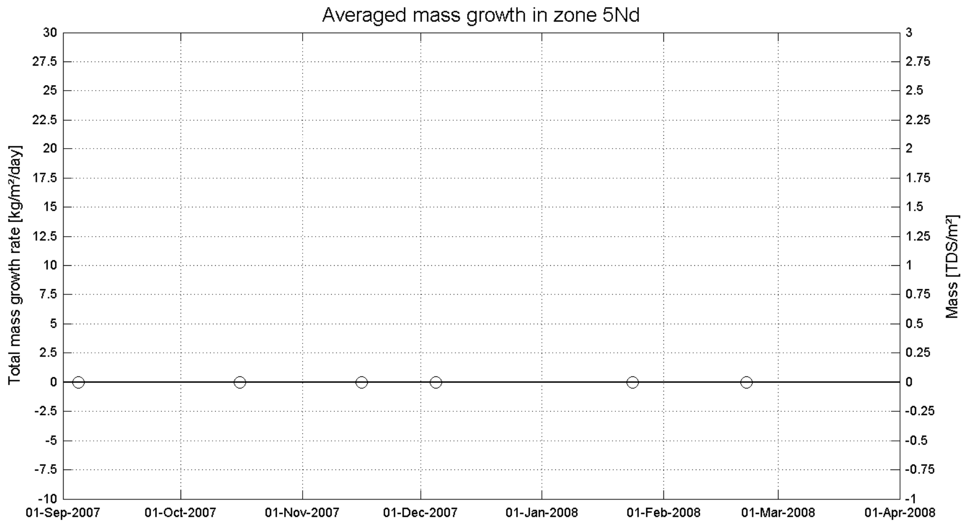
Data Processed by: IMDC

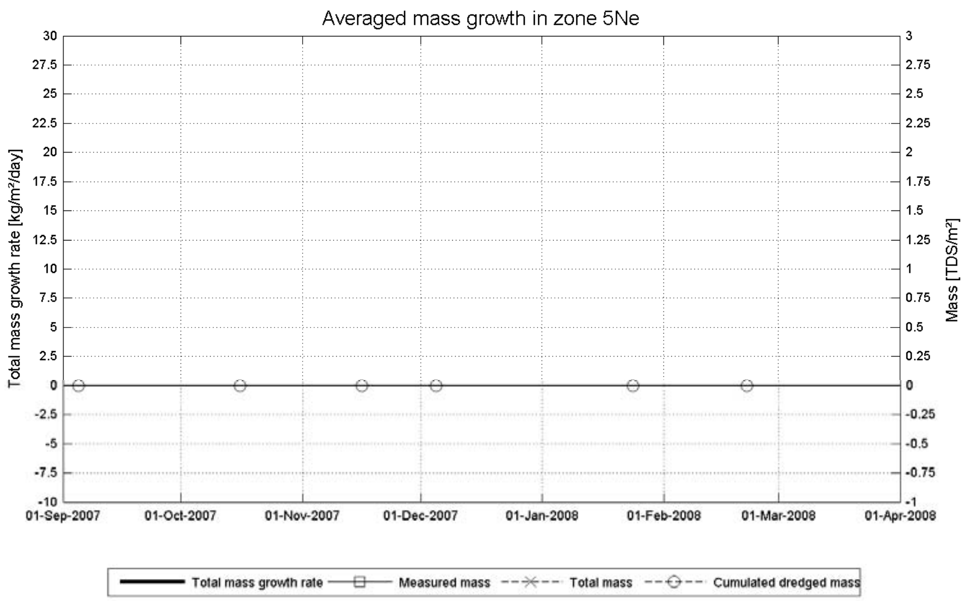
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





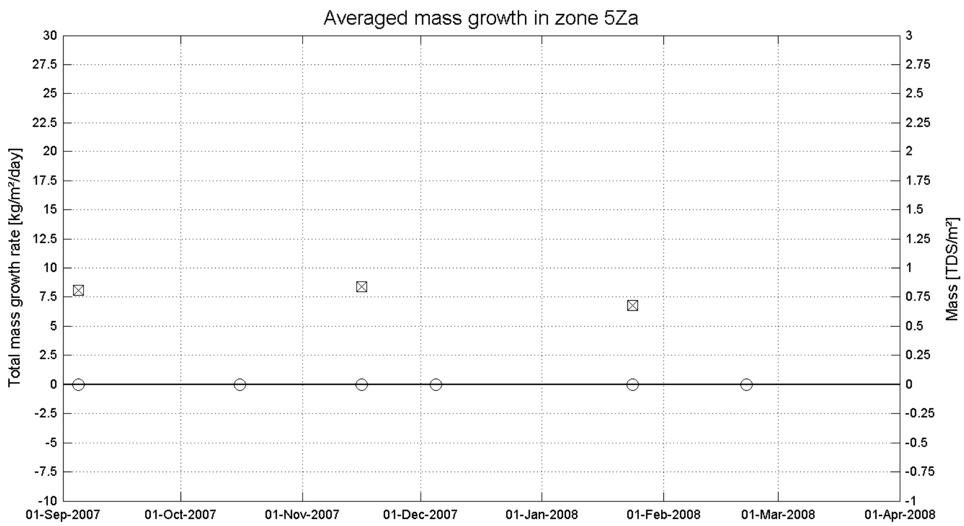
Data Processed by:

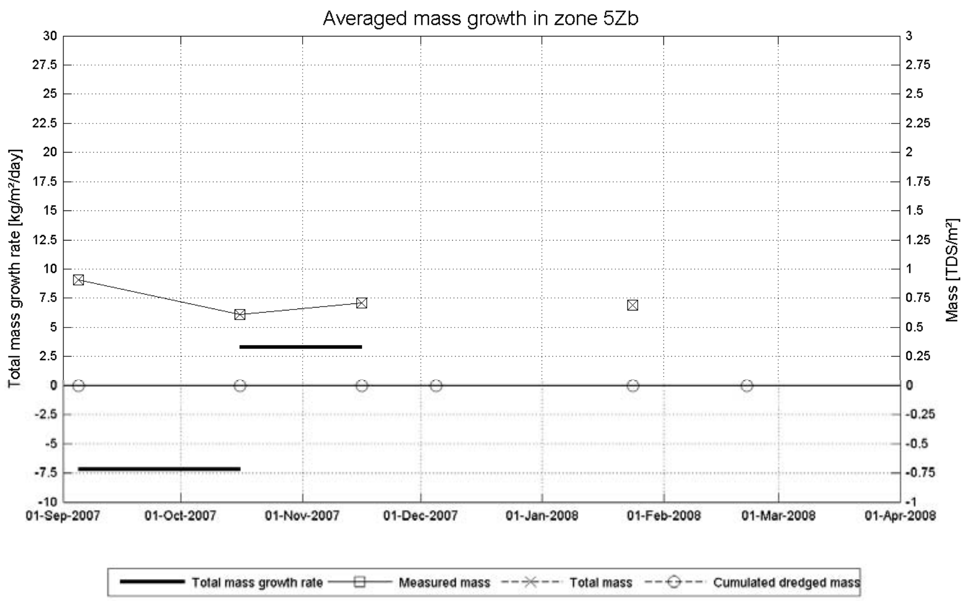
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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





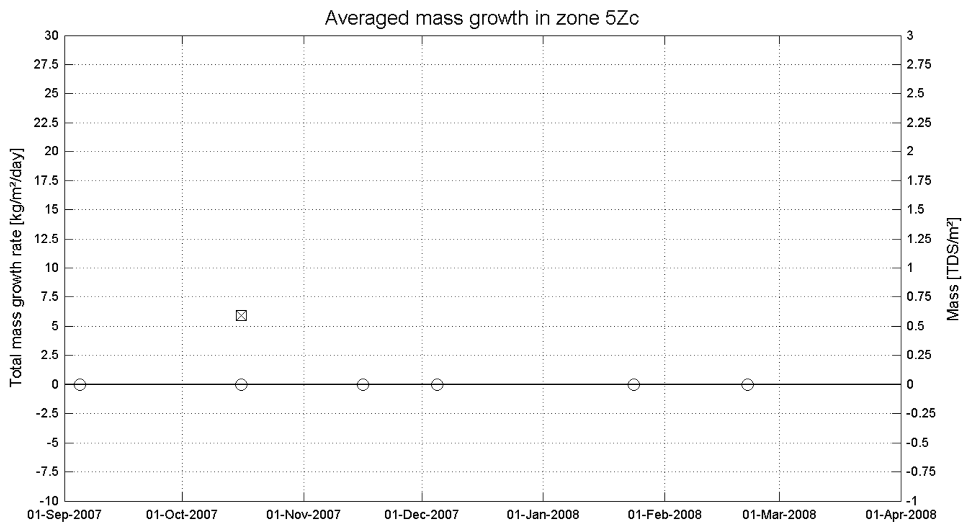
Data Processed by:

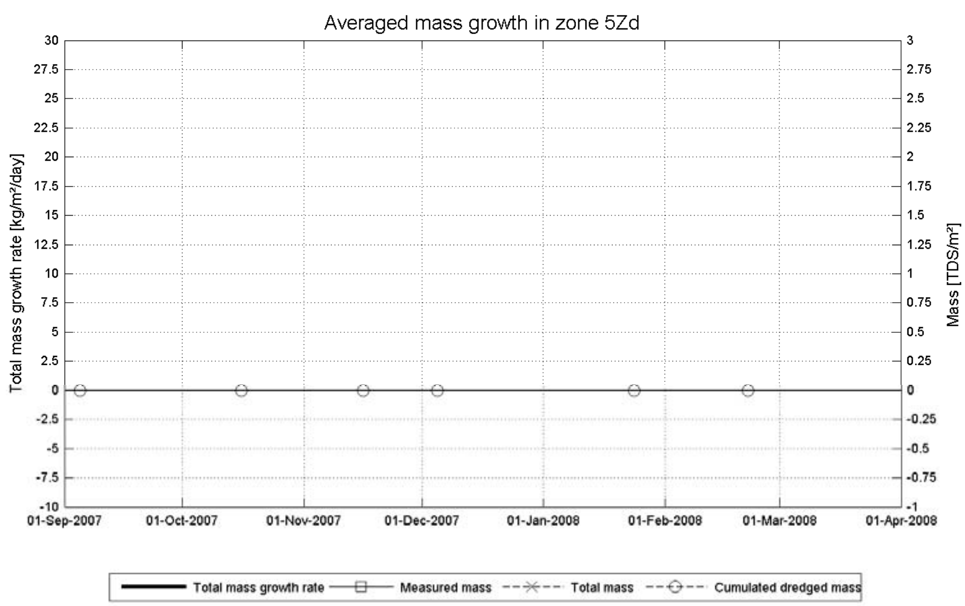
In association with :

I/RA/11283/07.085/MSA

Long-term monitoring siltation Deurganckdok

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



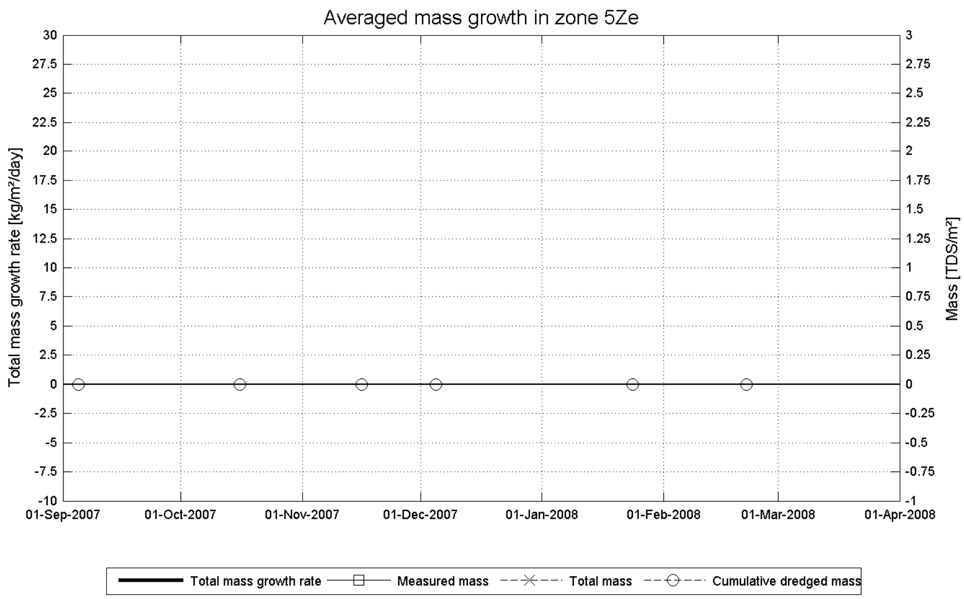


Data Processed by:

In association with :

I/RA/11283/07.085/MSA

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



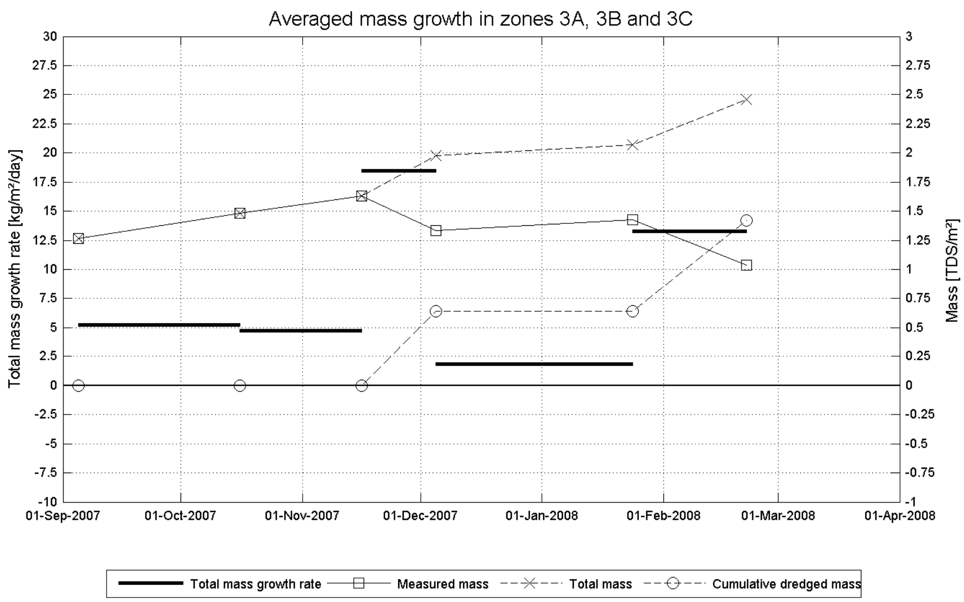
Data Processed by: IMDC

In association with :

I/RA/11283/07.085/MSA

E.4 For complete Deurganckdok

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



	Data Processed by: In association with : I/RA/11283/07.085/MSA

APPENDIX F.

DREDGING DATA

Total dredged mass in covered area per week (TDS)													
	02-Apr-07	**09-Apr-07**	**20-Aug-07**	**27-Aug-07**	**19-Nov-07**	**26-Nov-07**	**28-Jan-08**	**04-Feb-08**	**11-Feb-08**	**18-Feb-08**	**03-Mar-08**		
ZONE	**09-Apr-07**	**14-Apr-07**	**25-Aug-07**	**01-Sep-07**	**24-Nov-07**	**01-Dec-07**	**03-Feb-08**	**10-Feb-08**	**17-Feb-08**	**24-Feb-08**	**09-Mar-08**	**Total (TDS)**	%
1	0	0	141	28	28	0	0	0	0	0	0	196	0.0
2	57	23	1140	177	30	0	72	0	268	0	0	1767	0.2
3a	3111	23207	46059	27635	40406	43114	29277	24258	35827	4033	0	276927	29.0
3b	7854	36043	28619	28630	45720	19857	24791	32056	22571	1099	0	247239	25.9
3c	7213	16162	25493	21020	38674	11835	22477	17659	24994	959	20665	207151	21.7
3d	0	0	2	0	470	95	162	52	274	0	43945	45001	4.7
3e	0	0	0	0	0	0	0	0	0	0	0	0	0.0
4Na	25	435	8759	4198	5662	11322	4564	5226	3524	54	0	43770	4.6
4Nb	60	427	7704	3772	6984	6928	5206	4737	1838	0	0	37656	3.9
4Nc	127	141	3396	2108	5861	3598	2659	3765	1440	27	2176	25297	2.7
4Nd	0	0	0	0	14	0	0	0	0	0	8042	8056	0.8
4Ne	0	0	0	0	0	0	0	0	0	0	0	0	0.0
4Za	0	143	359	3	7480	3323	4483	1118	2009	13	0	18930	2.0
4Zb	0	69	14	61	12214	4116	5141	2847	646	0	0	25109	2.6
4Zc	0	0	0	28	4699	2040	1947	1525	445	0	2305	12990	1.4
4Zd	0	0	0	0	0	0	0	0	0	0	4048	4048	0.4
4Ze	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Na	0	0	3	0	0	0	0	0	0	0	0	3	0.0
5Nb	0	0	29	0	0	0	68	0	0	0	0	98	0.0
5Nc	0	0	19	0	0	0	0	7	0	0	0	26	0.0
5Nd	0	0	0	0	0	0	0	0	0	0	26	26	0.0
5Ne	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Za	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Zb	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Zc	0	0	0	0	0	0	0	0	0	0	0	0	0.0
5Zd	0	0	0	0	0	0	0	0	0	0	2	2	0.0
5Ze	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Total	**18447**	**76649**	**121738**	**87660**	**168243**	**106227**	**100846**	**93251**	**93837**	**6185**	**81209**	**954291**	
%	**1.9**	**8.0**	**12.8**	**9.2**	**17.6**	**11.1**	**10.6**	**9.8**	**9.8**	**0.6**	**8.5**		