



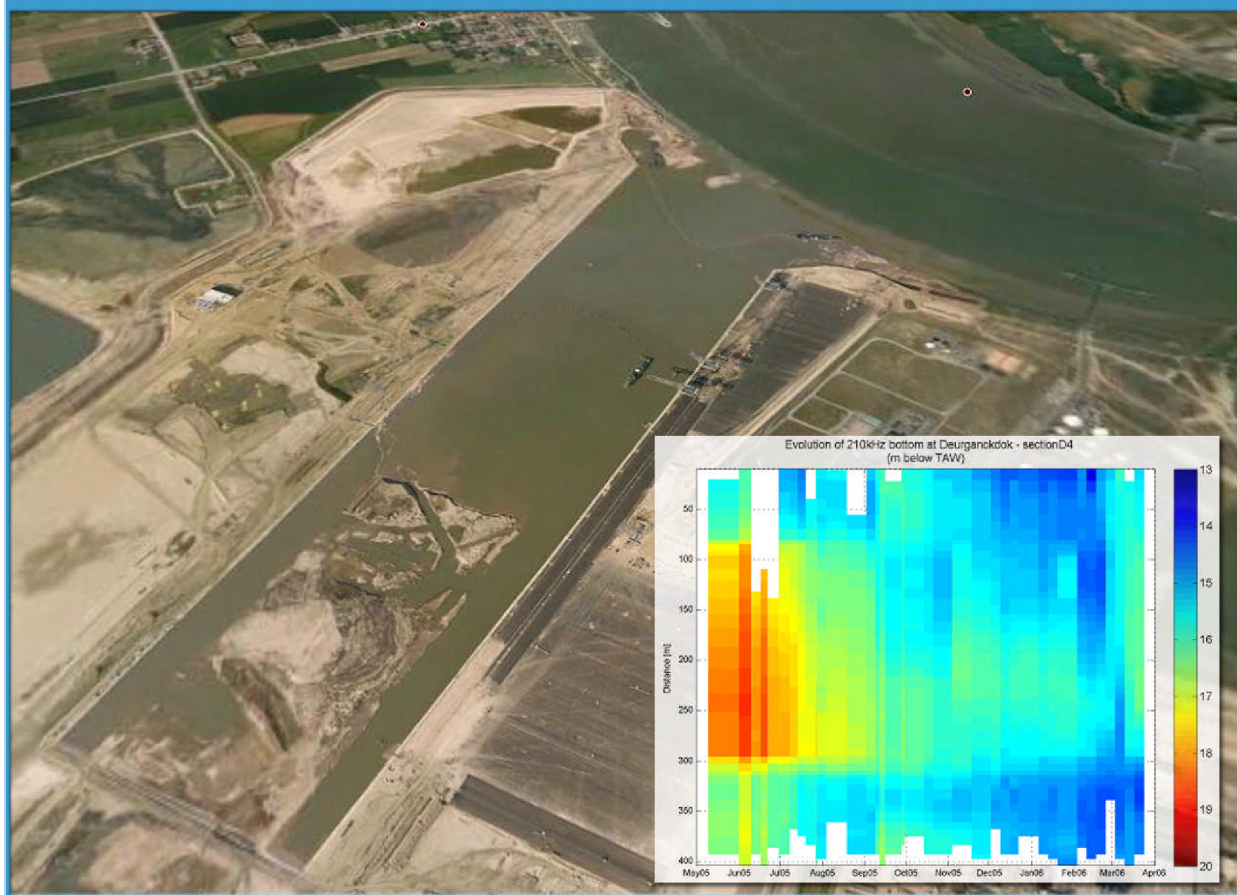
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DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN
WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing

Bestek 16EB/05/04

Deurganckdok – Evolution of water-bed interface in a cross-section of Deurganckdok



Deelrapport 1.4 : Sediment balans 01/01/2007 – 31/03/2007

Report 1.4 : Sediment balance 01/01/2007 – 31/03/2007

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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	3
1.4. STRUCTURE OF THE REPORT	4
2. SEDIMENTATION IN DEURGANCKDOK.....	5
2.1. PROJECT AREA: DEURGANCKDOK.....	5
2.2. OVERVIEW OF THE STUDIED PARAMETERS	6
3. MEASUREMENTS	9
3.1. DEPTH SOUNDINGS	9
3.2. DENSITY MEASUREMENTS	9
3.3. MAINTENANCE DREDGING DATA.....	10
3.4. CAPITAL DREDGING DATA.....	12
4. SEDIMENT BALANCE ANALYSES.....	13
4.1. PROJECT AREA: (SUB)ZONES AND SECTIONS	13
4.2. DEPTH OF THE WATER-BED INTERFACE (210 KC)	15
4.3. EVOLUTION OF WATER-BED INTERFACE (210 KC)	16
4.4. VOLUMETRIC SILTATION RATES [CM/DAY] IN DIFFERENT ZONES AND SECTIONS	17
4.5. CAPITAL DREDGING WORKS	18
5. PRELIMINARY ANALYSIS OF THE DATA	20
6. REFERENCES.....	23

APPENDICES

APPENDIX A.	DEPTH OF THE WATER-BED INTERFACE (210 KC)	A-1
APPENDIX B.	EVOLUTION OF DEPTH OF WATER-BED INTERFACE (210 KC).....	B-1
APPENDIX C.	VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS.....	C-1
APPENDIX D.	MEASURED MASS	D-1
APPENDIX E.	SWEEP BEAM TRACKS	E-1
APPENDIX F.	CAPITAL DREDGING PROGRESS	F-1
APPENDIX G.	HCBS2 REPORTS WINTER CAMPAIGN	G-1

LIST OF TABLES

TABLE 1-1: OVERVIEW OF DEURGANCKDOK REPORTS	2
TABLE 3-1: OVERVIEW OF THE AVAILABLE DEPTH SOUNDINGS SUITABLE FOR ANALYSIS 01/01/2007 – 31/03/2007	9
TABLE 3-2: REFERENCE SITUATION DENSITY MEASUREMENTS (T_{0D}).....	10
TABLE 3-3: SWEEP BEAM MAINTENANCE DREDGING ACTIVITIES IN DEURGANCKDOK AND ON THE SILL OF DEURGANCKDOK BETWEEN JANUARY 2007 AND MARCH 2007 (SOURCE: AFDELING MARITIEME TOEGANG)	11
TABLE 4-1: COORDINATES OF SECTIONS [UTM ED50]	15
TABLE 5-1: CALCULATED TIDAL PRISM DURING CAPITAL DREDGING OPERATIONS AT DEURGANCKDOK	22

LIST OF FIGURES

FIGURE 2-1: OVERVIEW OF DEURGANCKDOK	5
FIGURE 2-2: ELEMENTS OF THE SEDIMENT BALANCE	6
FIGURE 2-3: DETERMINING A SEDIMENT BALANCE.....	7
FIGURE 2-4: TRANSPORT MECHANISMS	8
FIGURE 3-1: NAVITRACKER.....	10
FIGURE 4-1: DEURGANCKDOK: ZONES AND SUBZONES	13
FIGURE 4-2: DEURGANCKDOK: D AND L SECTIONS	14
FIGURE 4-3: EXAMPLE OF A MAP SHOWING DEPTH OF WATER-BED INTERFACE (210 KC) FOR 9/02/07 AND 9/03/07	15
FIGURE 4-4: DIFFERENCE CHARTS OF THE DEPTH SOUNDING ON 9/03/07: IN REFERENCE TO T_{0E} (LEFT), AND TO THE PREVIOUS MEASUREMENT (RIGHT) ON 9/02/07	16
FIGURE 4-5: GRAPH OF EVOLUTION OF THE WATER-BED INTERFACE (210 KC) FOR SECTION L2	17
FIGURE 4-6: VOLUMETRIC SILTATION RATE FOR ZONE 3A.....	18
FIGURE 4-7: OPERATIONAL PART OF DEURGANCKDOK AT THE START OF THE 3 RD PHASE OF CAPITAL DREDGING WORKS	19
FIGURE 4-8: DEPTH OF CAPITAL DREDGING (AND DESIGN DEPTH) ON 14/03/2007	19
FIGURE 5-1: MONTHLY AVERAGED SILTATION RATE FOR THE PREVIOUS MEASUREMENT PERIOD (OCTOBER – DECEMBER 2006) (TOP) AND THE PRESENT MEASUREMENT PERIOD (JANUARY - MARCH 2007)(BOTTOM) (T_{0E} : 24/03/2006)	21

GLOSSARY

BIS	Dredging Information System used in the Lower Sea Scheldt
d	Density of dredged sediment [kg/dm ³]
DGD	Deurganckdok
HCBS	High Concentration Benthic Suspensions
M	mass of dry solids [ton]
ρ_s	density of the solid minerals [kg/dm ³]
ρ_w	density of clear water [kg/dm ³]
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 [m ³]

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.

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
- 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' are summarized in Table 1-1.

Reports of the measurement campaign HCBS2 for which the winter campaign has been carried out simultaneously with the trough tide measurements in this project are listed in APPENDIX G.

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)
Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP)	
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	Salt-Silt distribution & Frame Measurements Deurganckdok 13/3/2006 – 31/05/2006 (I/RA/11283/06.121/MSA)
2.7	Salt-Silt distribution & Frame Measurements Deurganckdok 15/07/2006 – 31/10/2006 (I/RA/11283/06.122/MSA)

Report	Description
2.8	Salt-Silt distribution & Frame Measurements Deurganckdok 15/01/2007 – 15/03/2007 (I/RA/11283/06.123/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)
Analysis	
4	Analysis of Siltation Processes and Factors (I/RA/11283/06.129/MSA)
Calibration	
6.1	Winter Calibration (I/RA/11291/06.092/MSA)
6.2	Summer Calibration and Final Report (I/RA/11291/06.093/MSA)

1.3.2. Measurement actions

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

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

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

1.4. Structure of the report

This report is the sediment balance of the Deurganckdok for the period of 01/01/2007 to 31/03/2007. The first chapter comprises an introduction. The second chapter describes the project. Chapter 3 describes the methodology. The measurement results and processed data are presented in Chapter 4, whereas chapter 5 gives a preliminary analysis of the data.

2. SEDIMENTATION IN DEURGANCKDOK

2.1. Project Area: Deurganckdok

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

1. The dock has a total length of 2750 m and is 450 m wide at the Scheldt end and 400 m wide at the inward end of the dock
2. The bottom of Deurganckdok is provided at a depth of -17 m 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 $+9\text{ m TAW}$

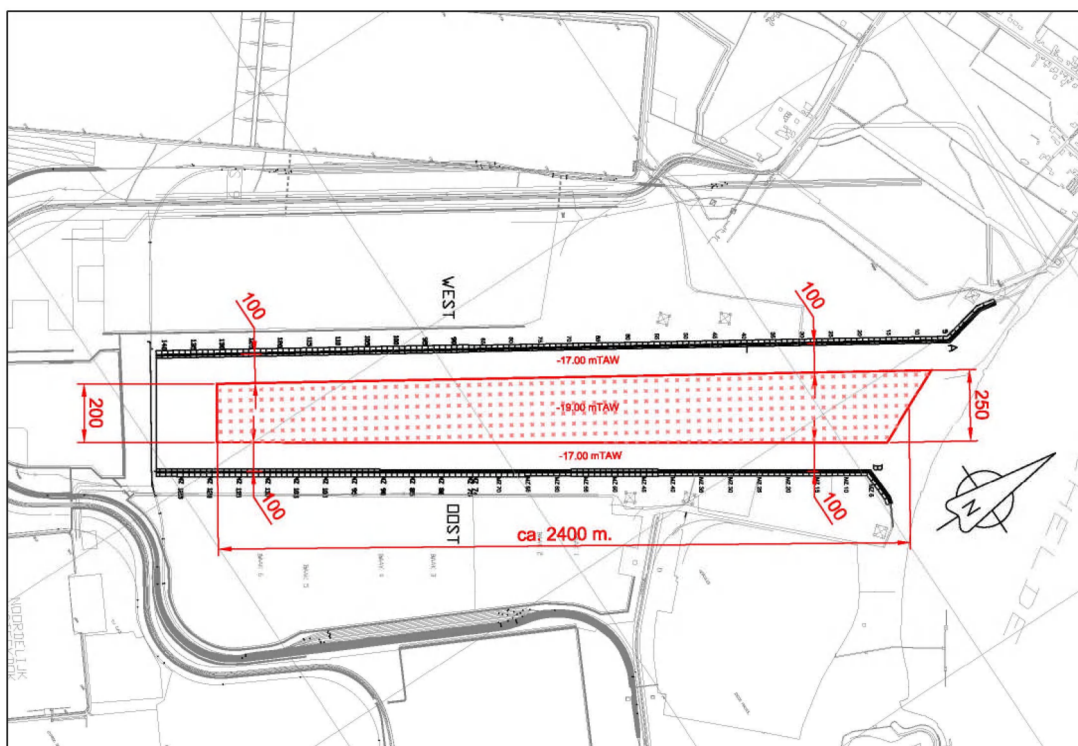


Figure 2-1: Overview of Deurganckdok

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.

2.2. Overview of the studied parameters

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

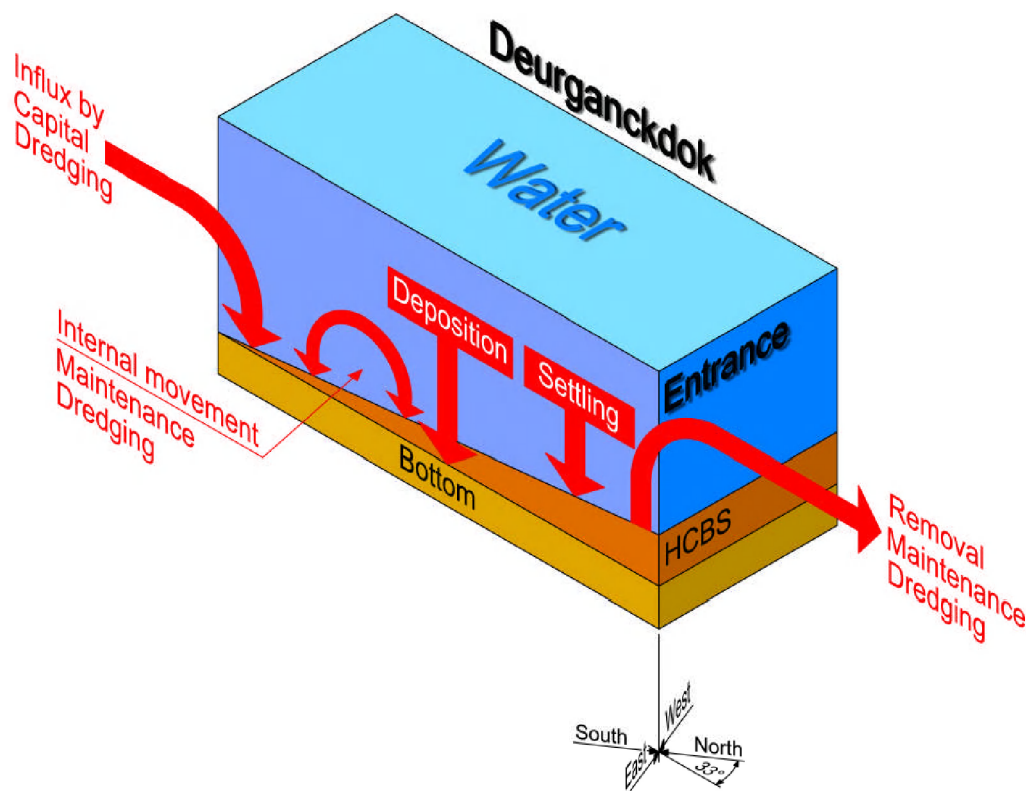


Figure 2-2: Elements of the sediment balance

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

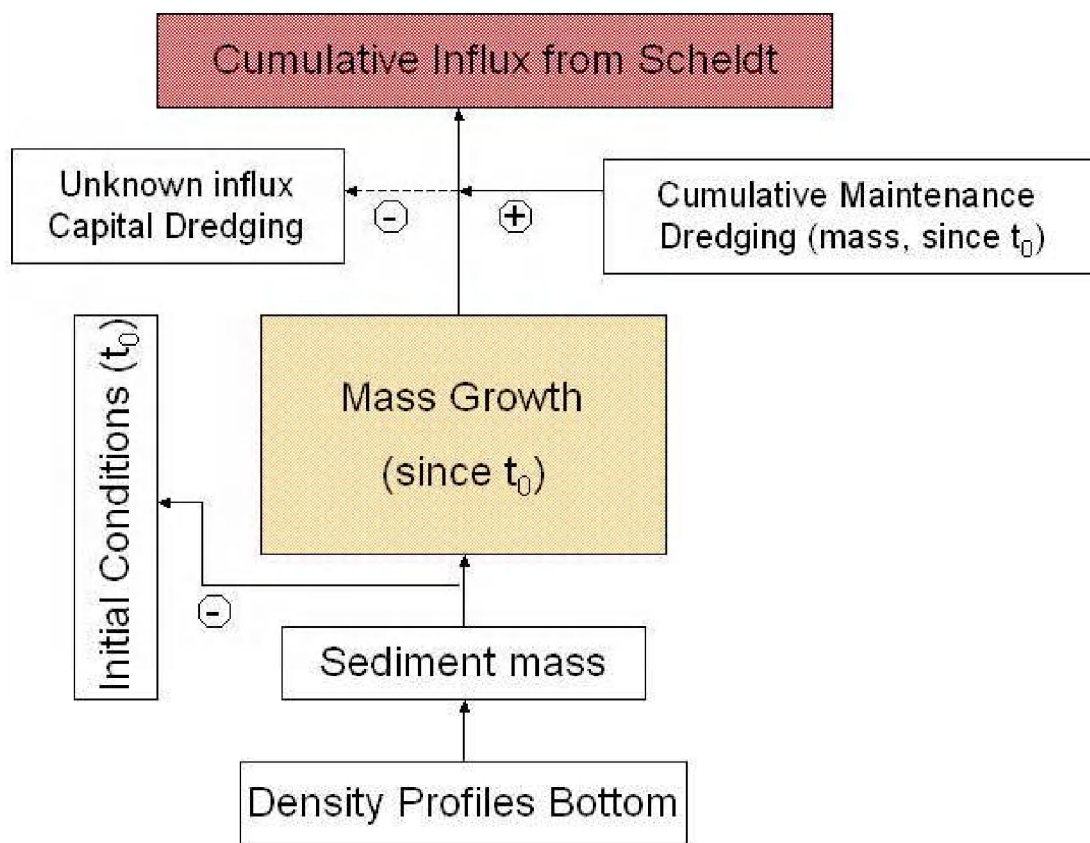


Figure 2-3: Determining a sediment balance

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

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

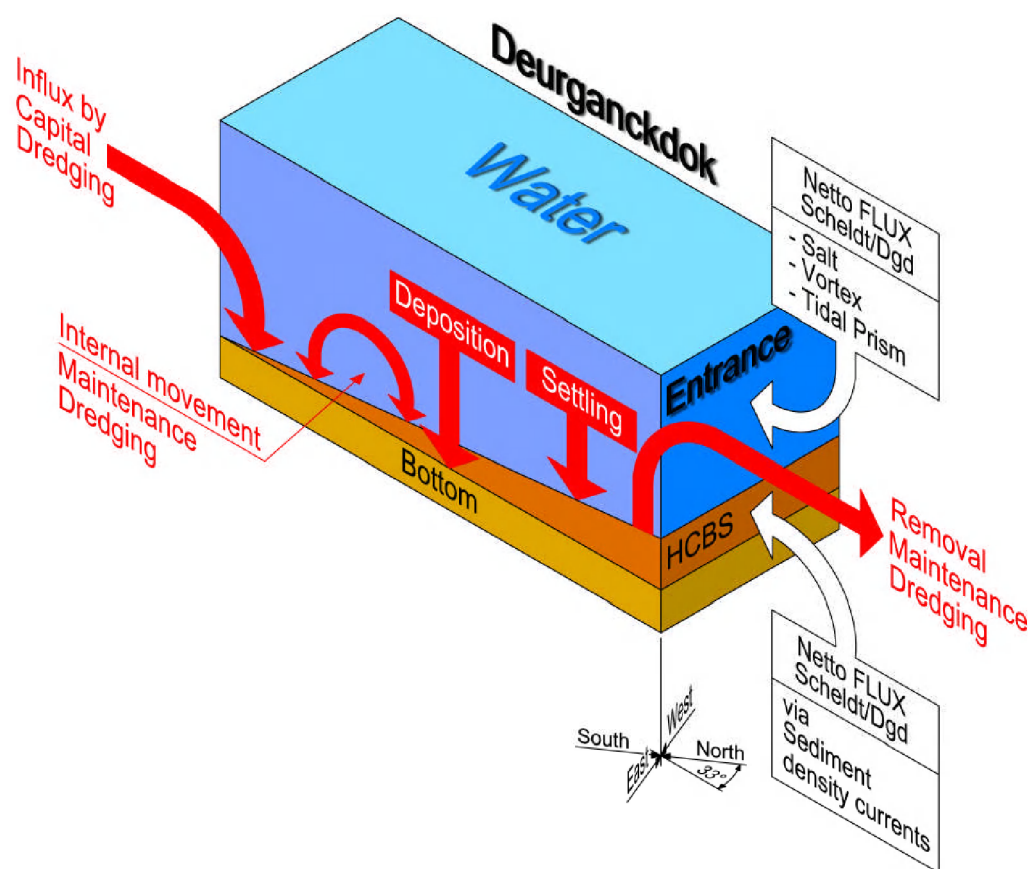


Figure 2-4: Transport mechanisms

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

Following data are being collected to understand these mechanisms:

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

3. MEASUREMENTS

3.1. Depth soundings

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

Table 3-1: Overview of the available depth soundings suitable for analysis 01/01/2007 – 31/03/2007

date	type of measurement	signal	Source
24/03/2006*	dual frequency 210-33 kHz	210	Afdeling Kust
09/02/2007	dual frequency 210-33 kHz	210	Afdeling Kust
09/03/2007	dual frequency 210-33 kHz	210	Afdeling Kust

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

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

A number of analyses were done using the depth soundings in Table 3-1. The raw depth sounding data was processed in ESRI ArcGIS. Only 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.

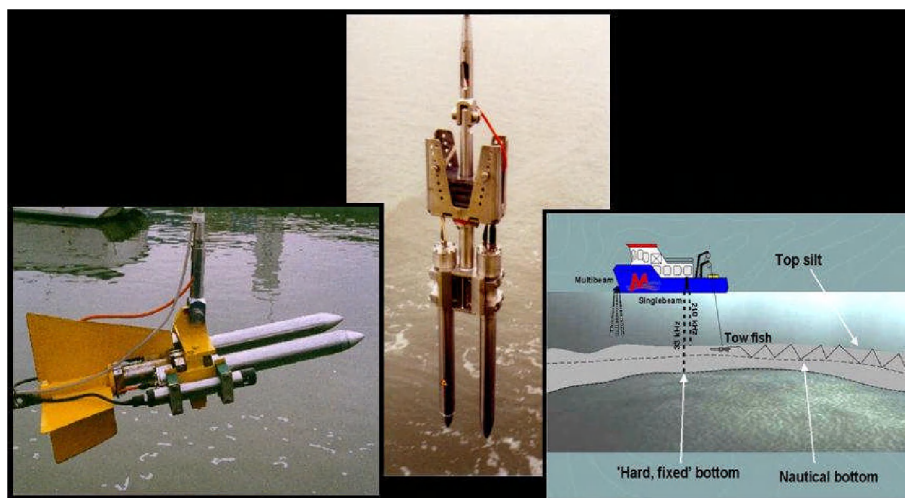


Figure 3-1: Navitracker

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.

There were no density measurements performed during this 3-month period.

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.

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

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

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

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

From	Till	Duration (days)	Location
16/01/2007	16/01/2007	1	Sill DGD
18/01/2007	18/01/2007	1	Sill DGD
22/01/2007	22/01/2007	1	Sill DGD
29/01/2007	29/01/2007	1	Sill DGD
05/02/2007	05/02/2007	1	Sill DGD
12/02/2007	12/02/2007	1	Sill DGD
19/02/2007	19/02/2007	1	Sill DGD
26/02/2007	26/02/2007	1	Sill DGD + DGD
27/02/2007	27/02/2007	1	Sill DGD + DGD
12/03/2007	12/03/2007	1	Sill DGD
19/03/2007	19/03/2007	1	Sill DGD

An overview of the total dredged mass in all zones (BIS data) is provided in APPENDIX D. The sweep beam tracks performed in each week are shown in APPENDIX E. The loggings of the sweep beam tracks show the position and depth of the rake. From the up-down position of the rake and the ship's direction, it is possible to identify whether the ship is sweeping sediment into the Scheldt or not. A thorough analysis of the obtained data revealed some problems though:

- positioning errors result in some sweep beam data positioned on land;
- tracks with slowly decreasing rake depth in time (up to 6 m in difference between start and end of the sweep beam operation) instead of a clear up-down mode;
- deep tracks are followed by less deep tracks in the same week, which seems unrealistic;
- some tracks show rake depths of -22 m TAW, which is unrealistic.

For these reasons, the tracks will not be applied as such in this study. Only the sweep beam locations will be utilised in a qualitative way.

¹ V' = Reduced Volume

3.4. Capital Dredging Data

In February 2007, the 3rd phase of the capital dredging works was initiated. Topographic measurements on a regular grid were supplied by the contractor in order to follow up the capital dredging progress. For the period 01/01/2007 till 31/03/2007 progress data is available for the following dates: 14 March, 19 March and 26 March 2007 and are shown in APPENDIX F. Also the topography prior to the capital dredging works can be found in APPENDIX F. Note that the design depth of the first half of the dock is presented and not the actual bathymetry.

This data allows the computation of the dock's water storage capacity at low and high tide. In order to calculate the tide prism, the decadal tide data at Liefkenshoek was used, which resulted in a yearly averaged high and low tide level of 5.19 and 0.05 m TAW respectively.

4. SEDIMENT BALANCE ANALYSES

4.1. Project Area: (Sub)Zones and Sections

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

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

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

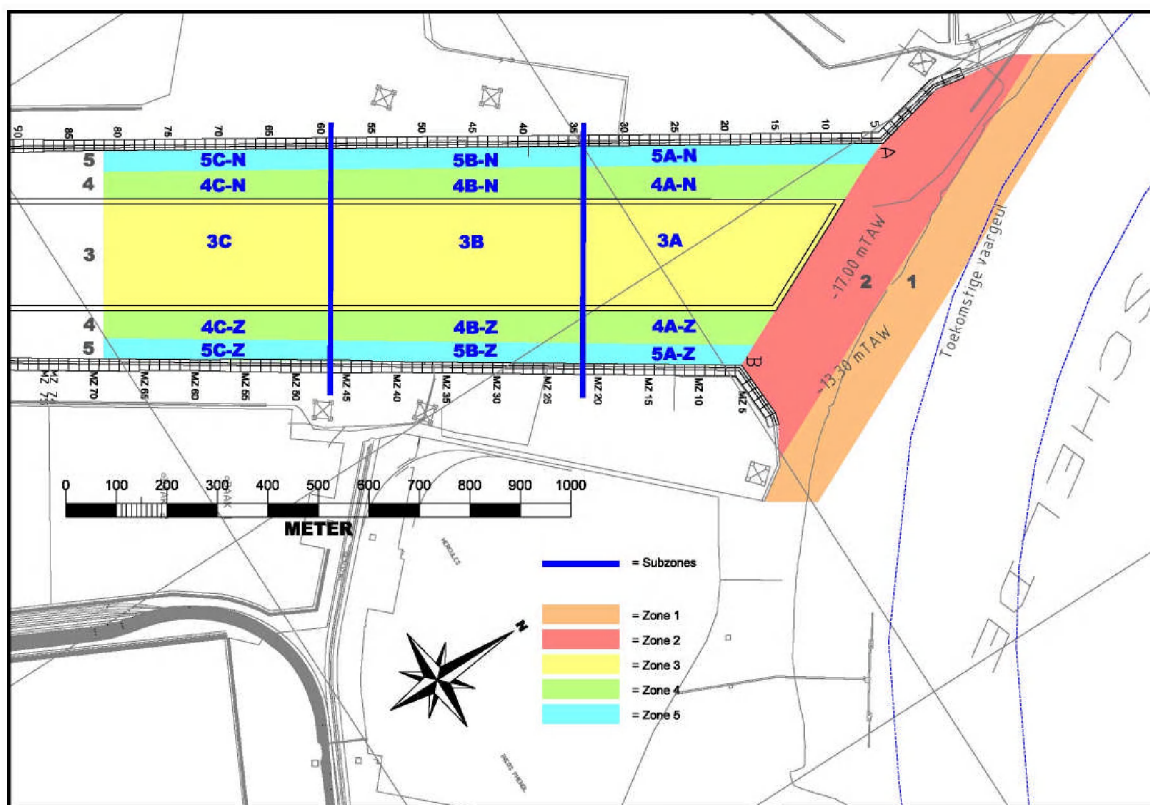


Figure 4-1: Deurganckdok: Zones and Subzones

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.

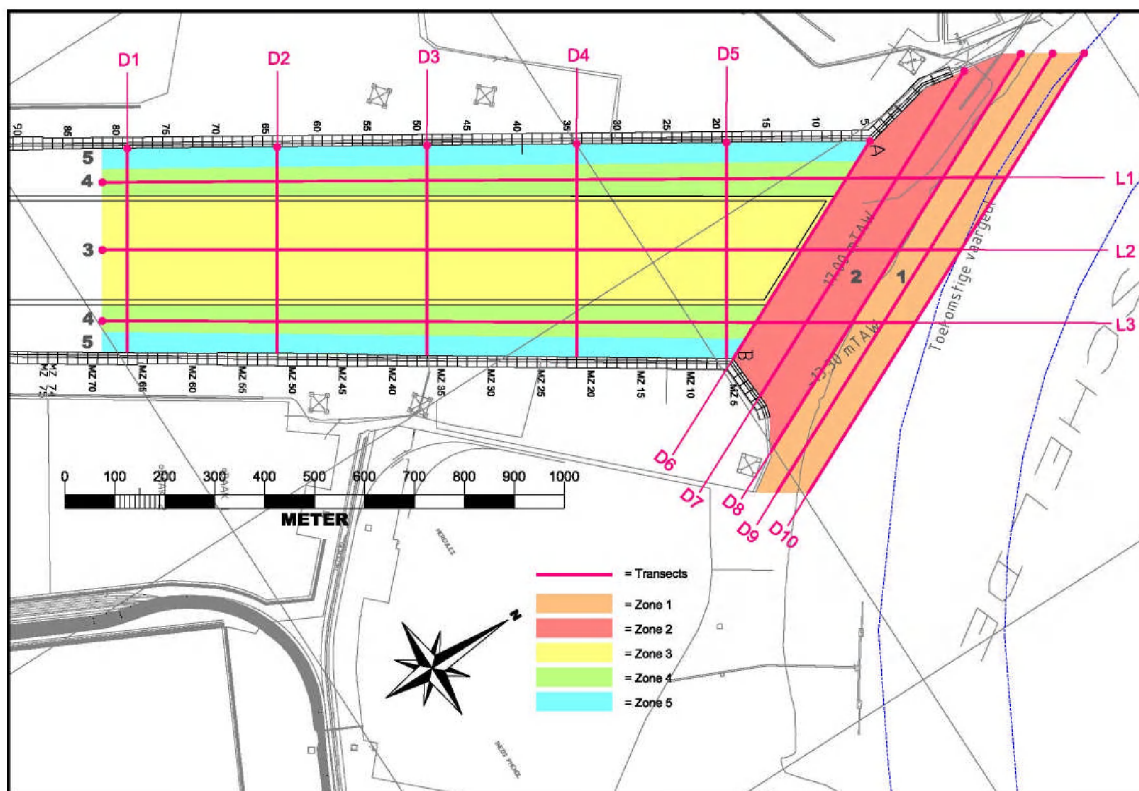


Figure 4-2: Deurganckdok: D and L Sections

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
L Sections				
L1	588748	5684720	587805	5683175
L2	588825	5684565	587921	5683103
L3	588901	5684410	588043	5683028

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

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

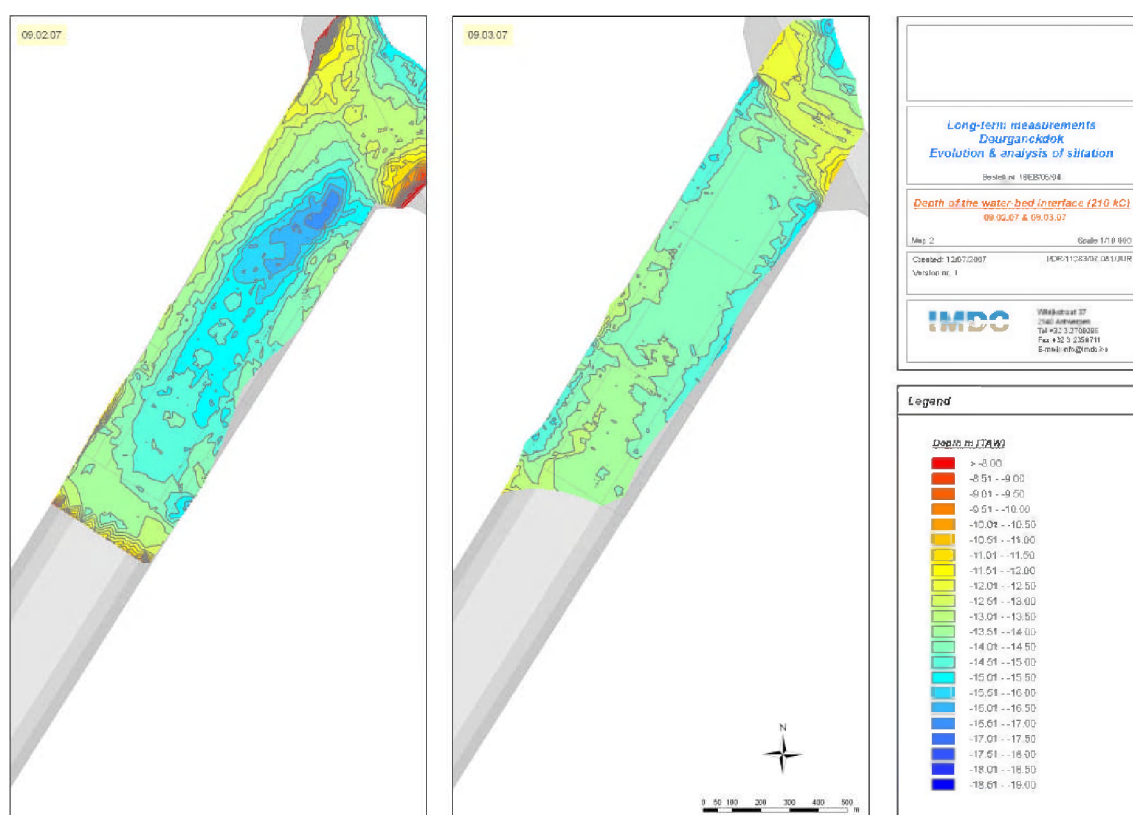


Figure 4-3: Example of a map showing depth of water-bed interface (210 kC) for 9/02/07 and 9/03/07

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

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

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

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

Maps and graphs are shown in APPENDIX B.

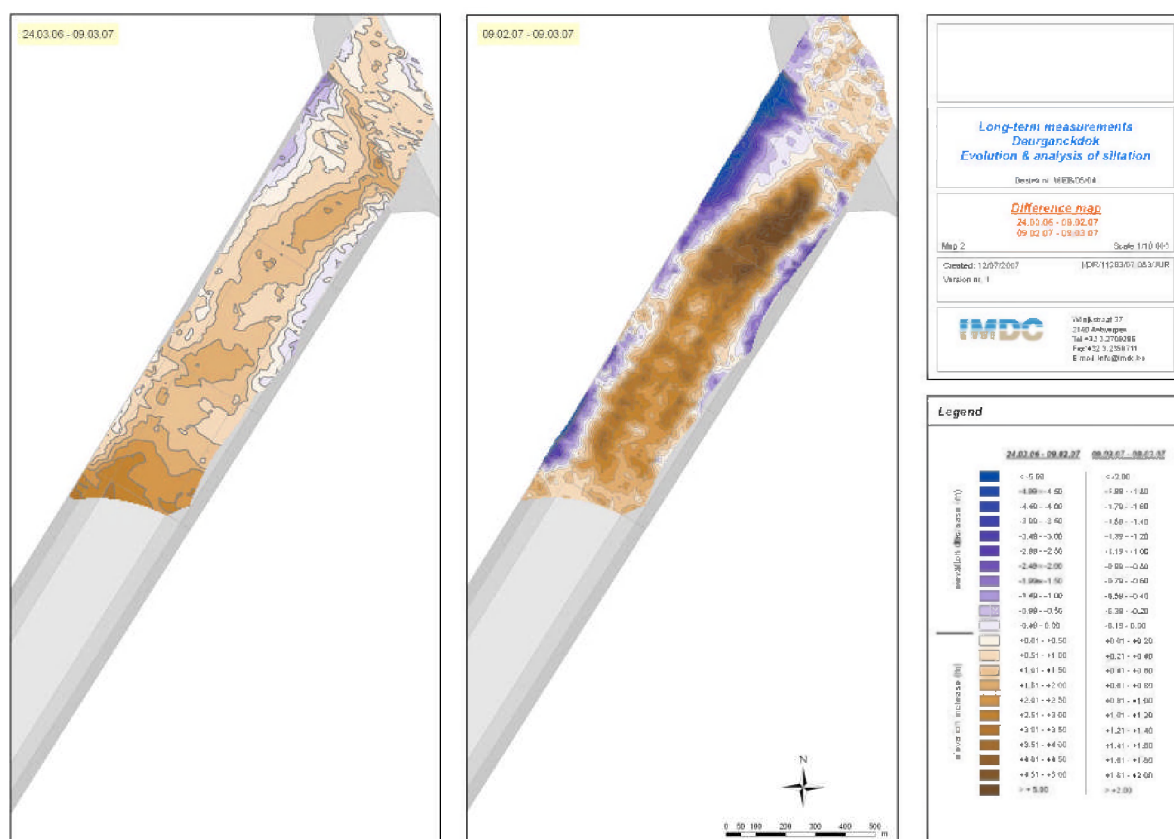


Figure 4-4: Difference charts of the depth sounding on 9/03/07: in reference to t_{0e} (left), and to the previous measurement (right) on 9/02/07

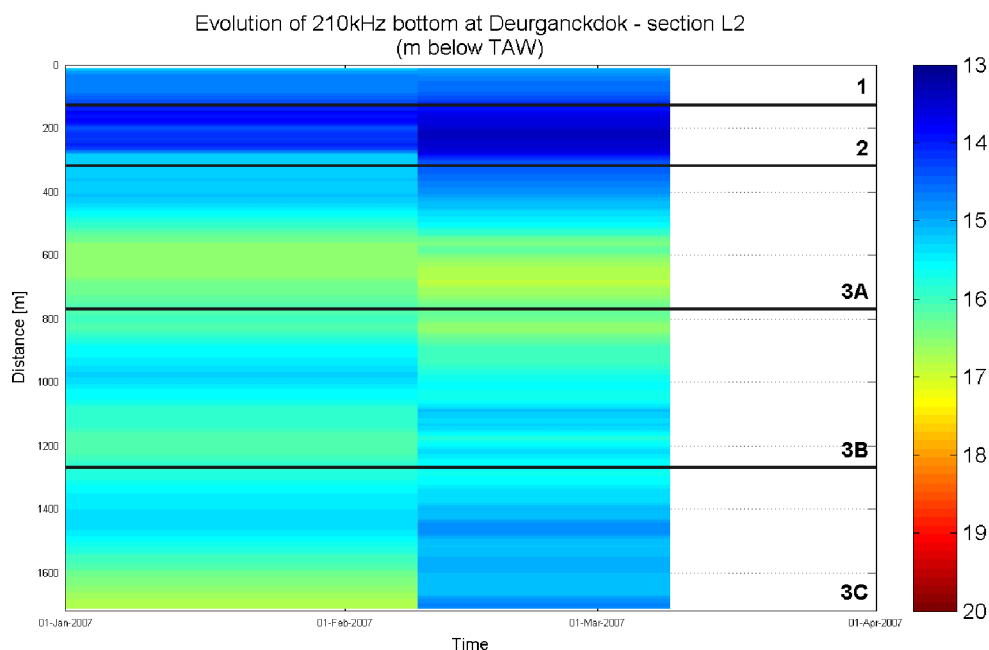


Figure 4-5: Graph of Evolution of the water-bed interface (210 kC) for section L2

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

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

Graphs in APPENDIX C show two parameters:

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

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

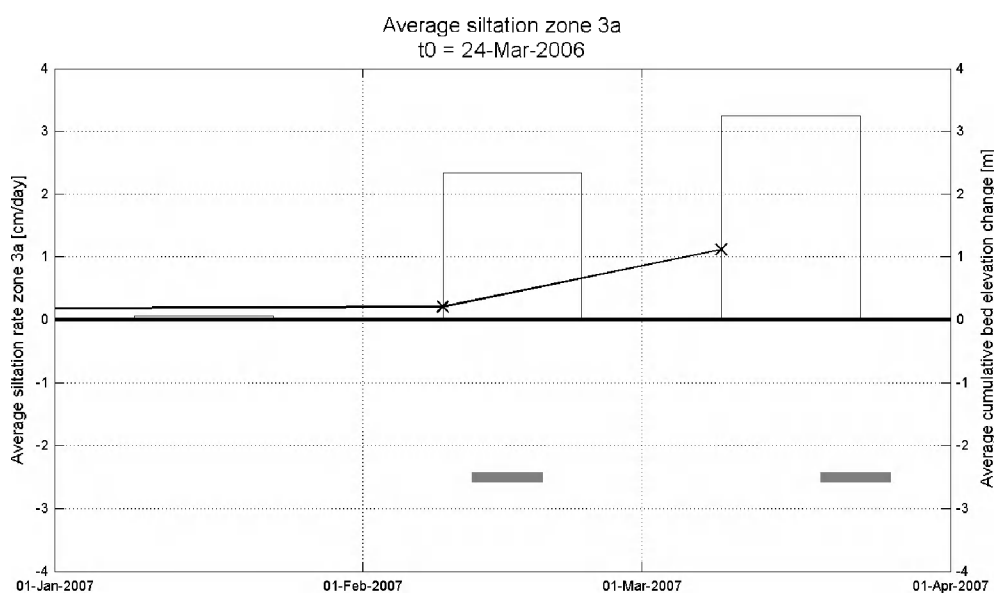


Figure 4-6: Volumetric siltation rate for zone 3a

4.5. Capital dredging works

To compute the tide prism, it is necessary to have an idea about the total dock volume available for water storage during high and low tide. Therefore, the decadal tide data at Liefkenshoek was used and resulted in a yearly averaged high and low tide level of 5.19 and 0.05 m TAW respectively (AMT, 2003). The operational part of the Deurganckdok was determined on basis of the topographic measurements made prior to the capital dredging works (see APPENDIX F). For this operational part of the Deurganckdok (see also Figure 4-7), the design depth was used, whereas for the remainder of the dock the (progress) topographic measurements were applied. An example of such a data set is shown in Figure 4-8.

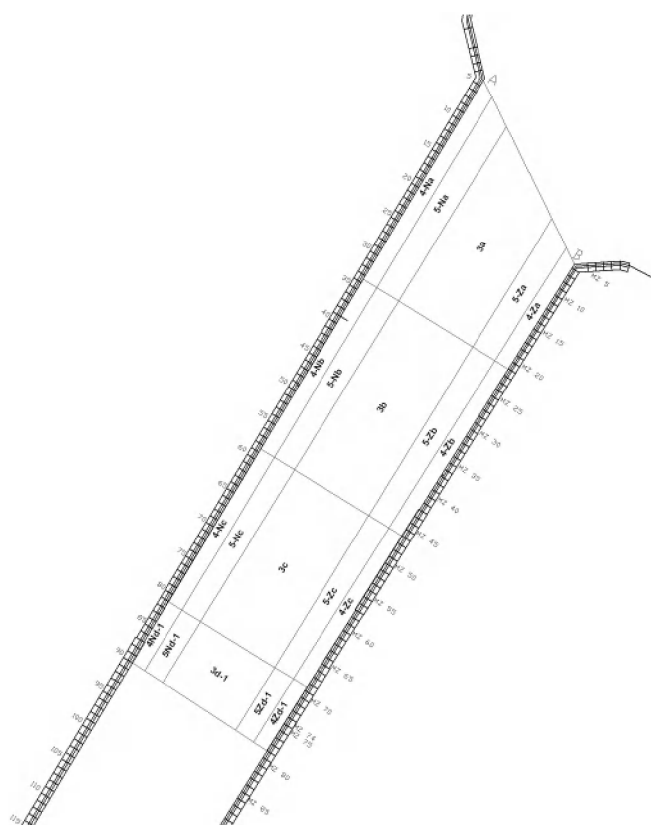


Figure 4-7: Operational part of Deurganckdok at the start of the 3rd phase of capital dredging works

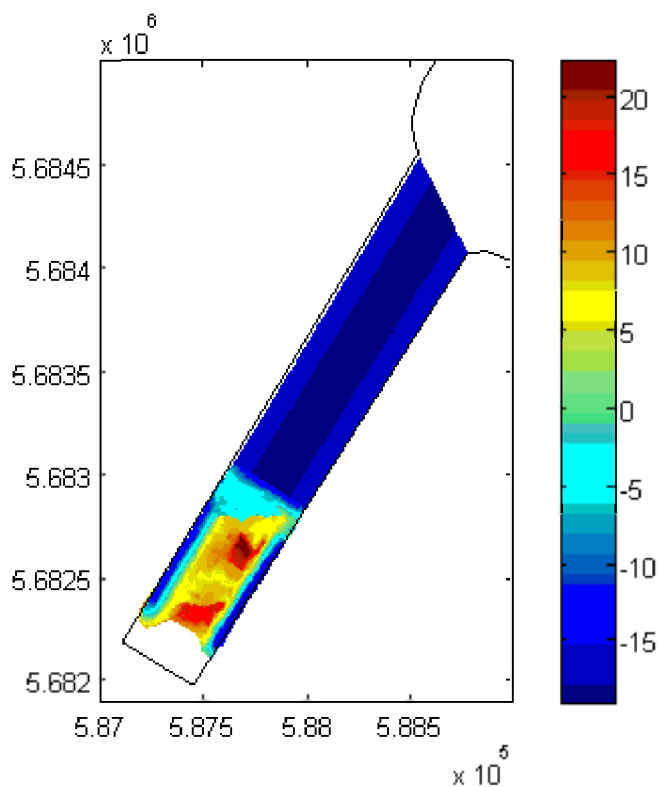


Figure 4-8: Depth of capital dredging (and design depth) on 14/03/2007

5. PRELIMINARY ANALYSIS OF THE DATA

Depth sounding data is processed to show the evolution of the average sludge volume per unit of surface, i.e. the average evolution of bed level as detected by a 210kHz sounder. If more than 50% of the area of a (sub)zone is covered, an average siltation rate is calculated. For the period of January – March 2007, depth soundings were only performed on 9 February and 9 March. During these measurements, an adequate coverage was obtained during depth soundings, except for zone 1 and zones 5A-Z, 5B-Z and 5C-Z.

BIS data revealed that hopper maintenance dredging occurred twice in February and March. The dredging period of 19-26 February contributed for 88% to the total dredged mass in this period, being 389 153 TDS. The primarily dredged zone was zone 3A, being the central trench near the dock entrance, as well as from zone 4A-N. Instead, the entire central trench (zones 3A, 3B and 3C) was dredged in March. The dredged mass per zone was much lower in comparison with February though. Note that the southeastern berthing and adjacent transition zones were not dredged.

Sweep beam maintenance dredging occurred more frequently. Data loggings showed that the dock entrance was dredged weekly. Only on 26-27 February sweep beam dredging was performed inside the dock in zones 5A-N, 4A-N and 3A.

Similar to the bathymetric measurements from October-December 2006, the bed elevation map of 9 February 2007 shows a low bed elevation in zones 3A-3B. However, it is clear that the bathymetry of the first half of the dock experiences large changes in the period 9 February – 9 March 2007. The bed elevation generally increases in the central trench, especially in zones 3A and 3B. The latter even shows increases of up to 5 meters. Instead, the berthing zones 5A-N, 5A-Z, 5B-Z and 5C-N show a lowering in bed elevation for the considered period. These changes in bed elevation can be attributed to a combination of maintenance dredging and sweep beam activities. The latter relocates the solids towards the central trench, thus increasing the bed elevation.

A maximum siltation rate of 4.1 cm/day was observed in zone 3B. Instead, a decrease in bed level was seen in zone 5A-N and measured –6.3 cm/day. This can be attributed to artificial processes such as sweep beam activity from the quay side to the central trench. Averaged over zones A and B (see Figure 5-1), the observed siltation rates are in the same range as previous measurements though. Despite dredging operations at the end of February, the bed level, averaged over zones A and B, increased.

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

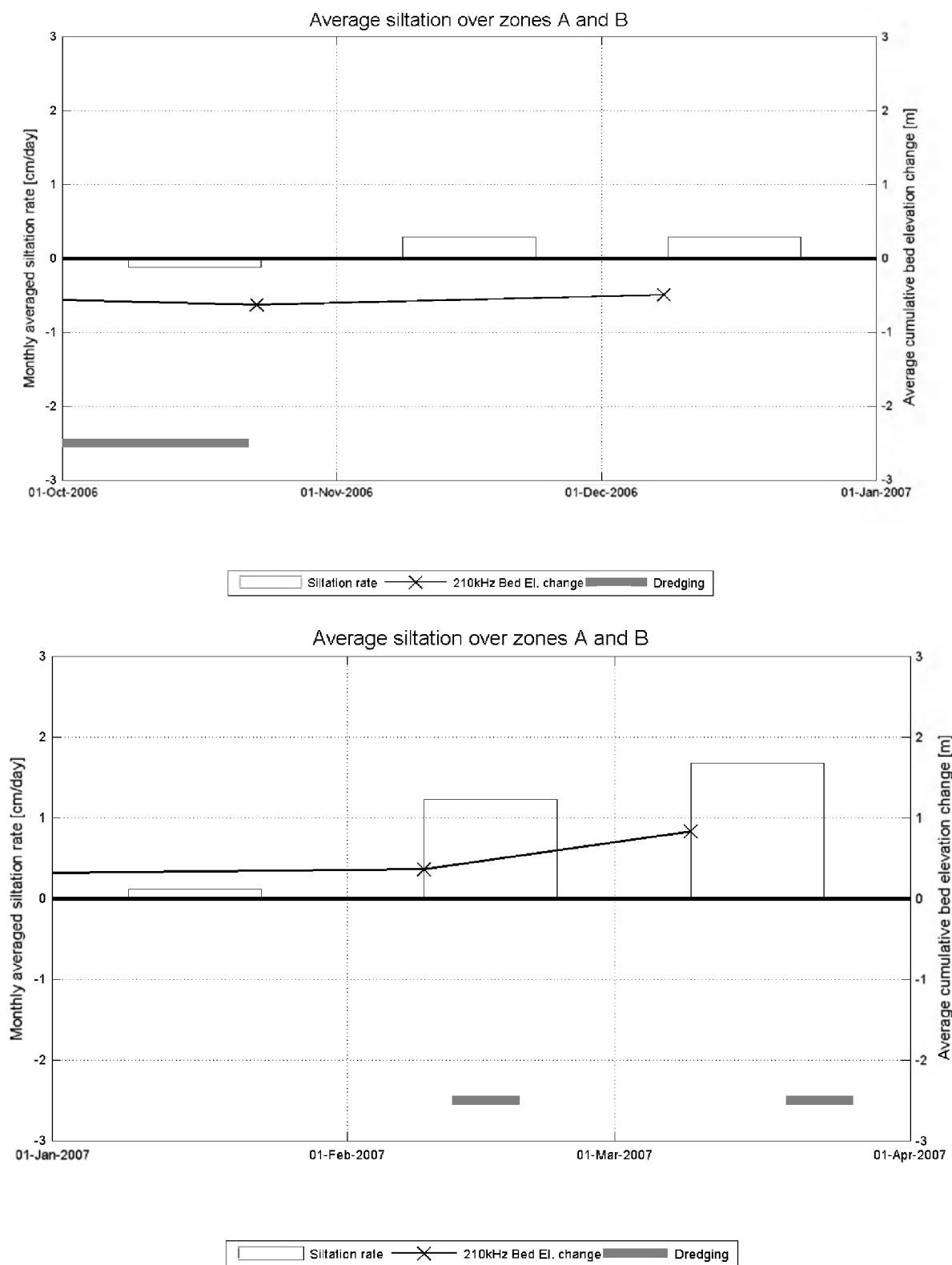


Figure 5-1: Monthly averaged siltation rate for the previous measurement period (October – December 2006) (TOP) and the present measurement period (January - March 2007)(BOTTOM) (t_{0e} : 24/03/2006)

Capital dredging started in February 2007 in order to deepen the remainder of the Deurganckdok to its design depth. Obviously, this leads to an increasing tide prism. Table 5-1 summarises the change of the tide prism during the period February-March. The measurements in March 2007 showed that the tide prism increased with 3% over a period of two weeks.

Table 5-1: Calculated tidal prism during capital dredging operations at Deurganckdok

Date	Dock volume at high tide (10^3 m^3)	Dock volume at low tide (10^3 m^3)	Tide prism (10^3 m^3)
start 3 th phase	15553.1	12111.7	3441.4
14/03/2007	17782.4	13430.1	4352.3
19/03/2007	17983.0	13558.9	4424.2
26/03/2007	17124.9	13642.2	4482.7

6. REFERENCES

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AWZ (2000): Baggerwerken 2000, Westerschelde en Zeeschelde

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

B.1 Difference maps

B.2 Bed elevation evolution per section

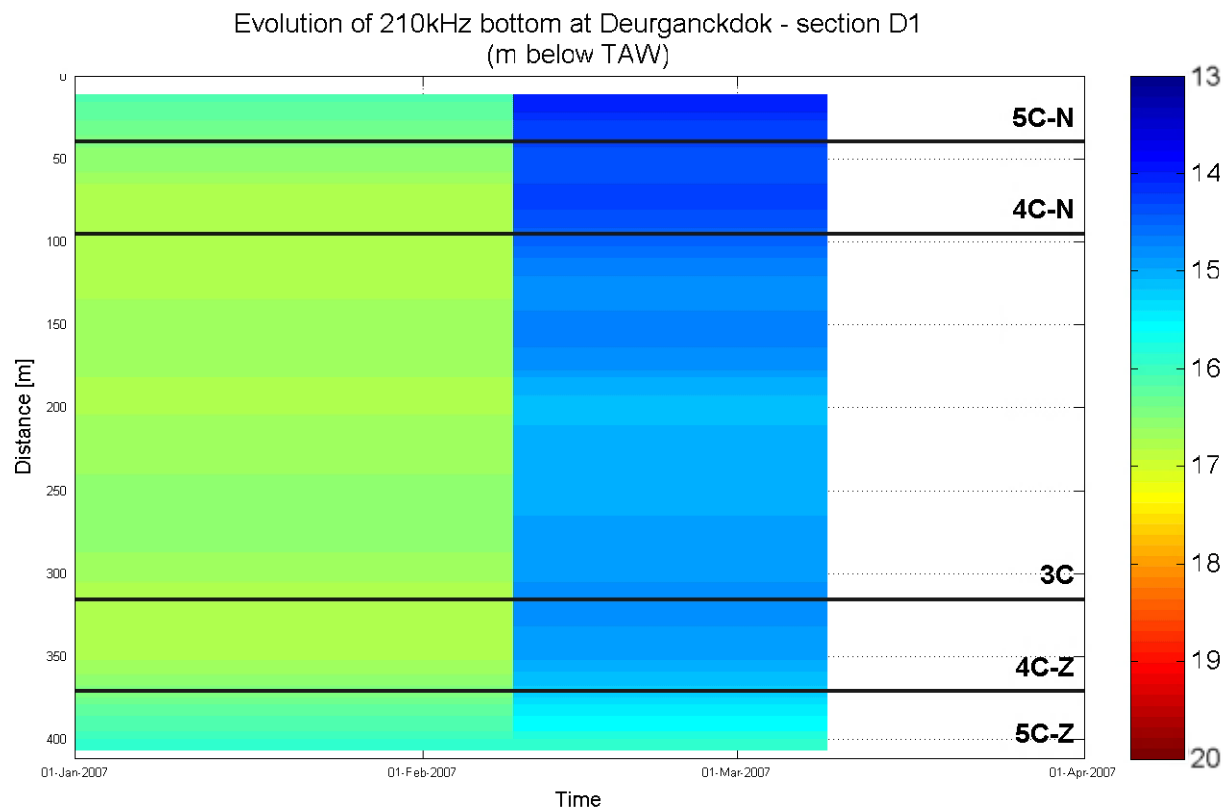
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

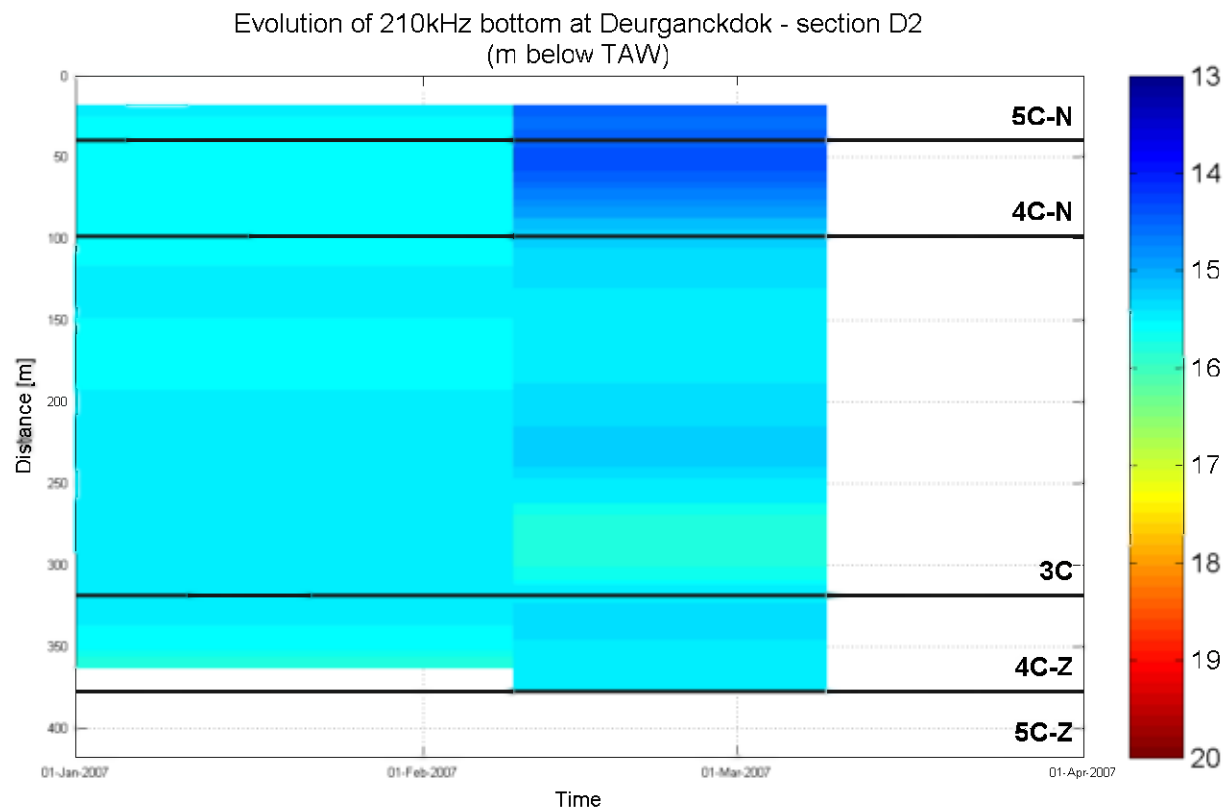
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

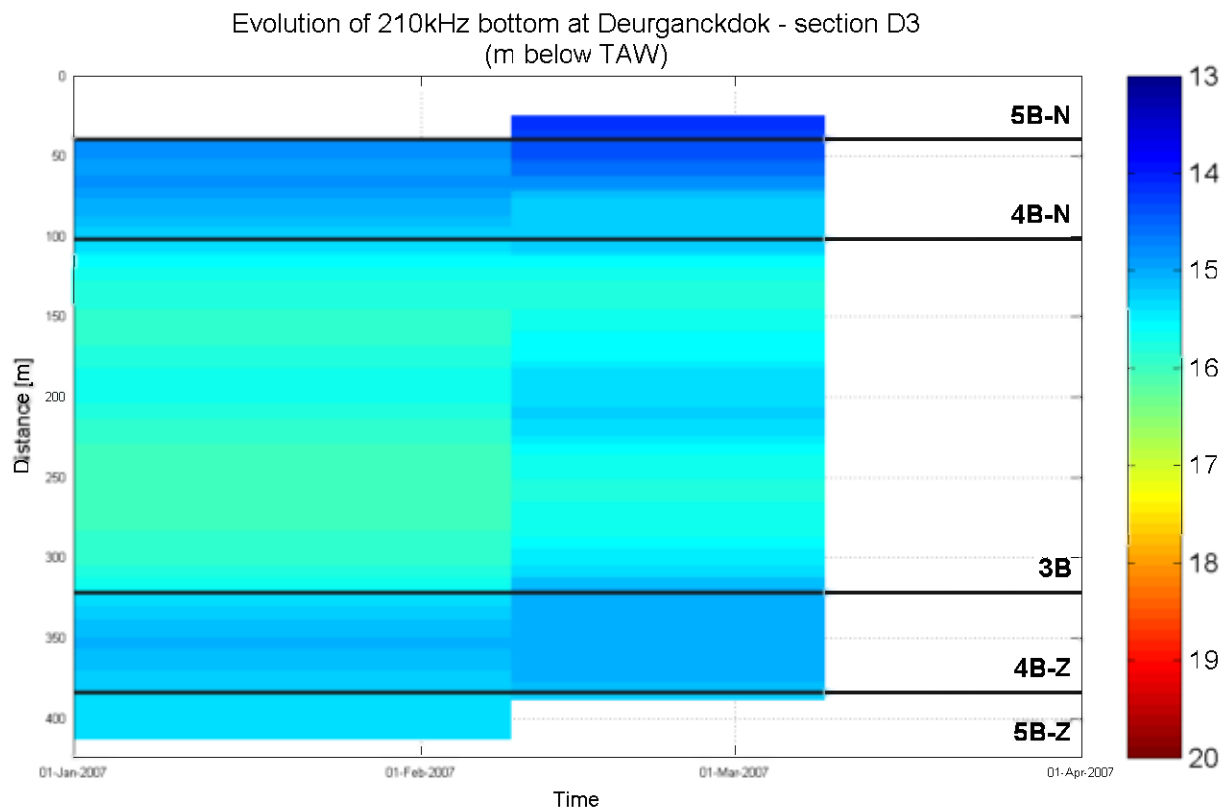
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

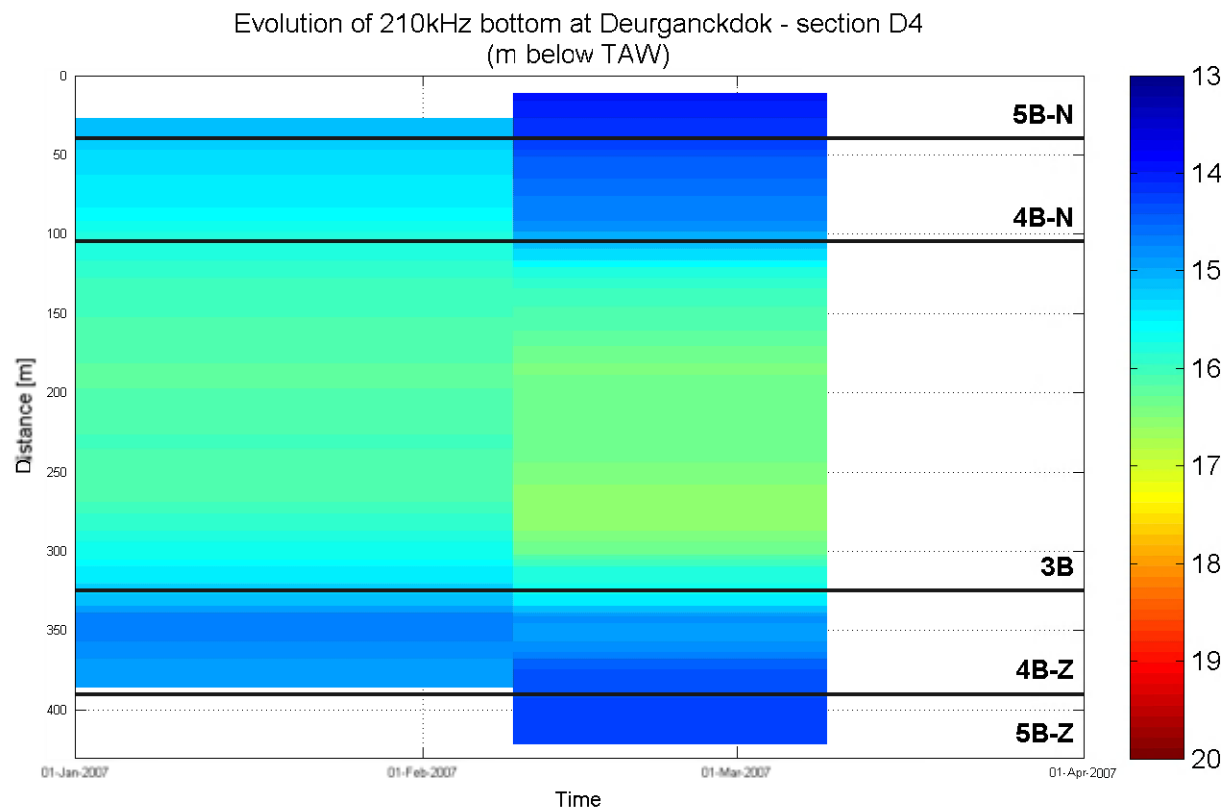
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

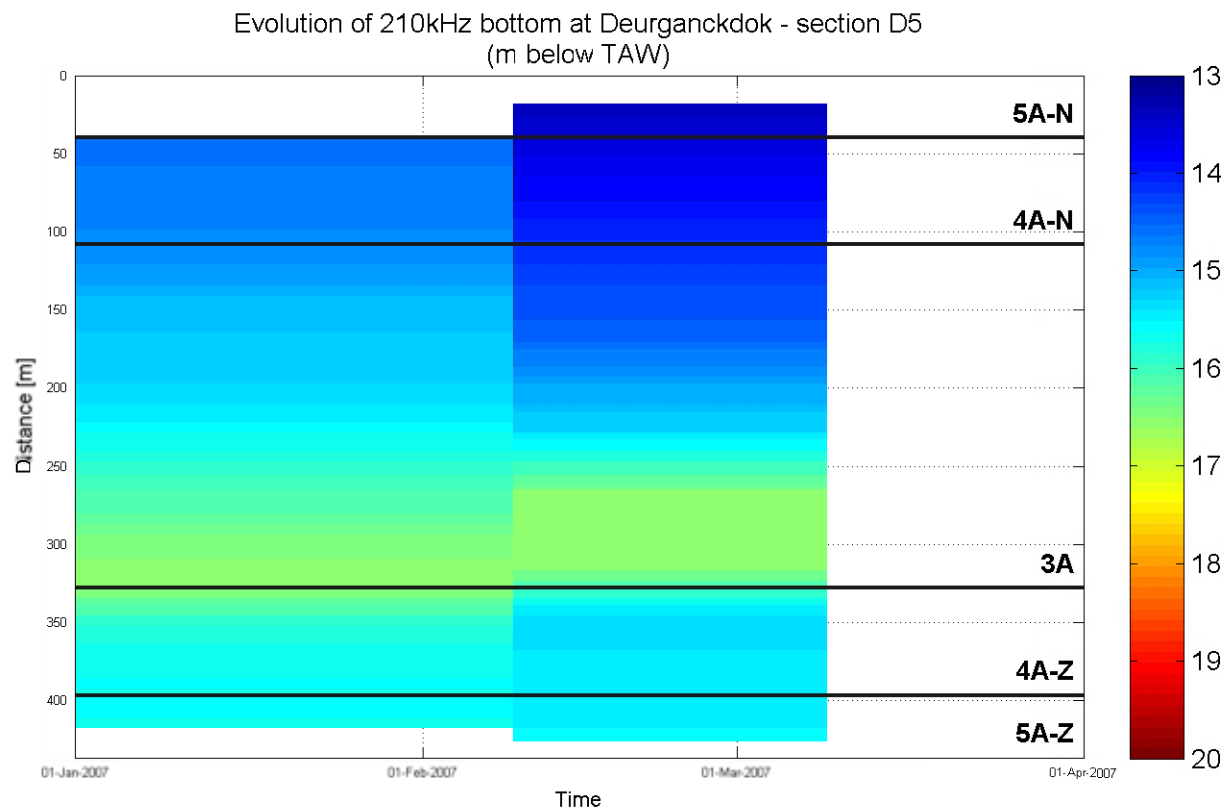
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

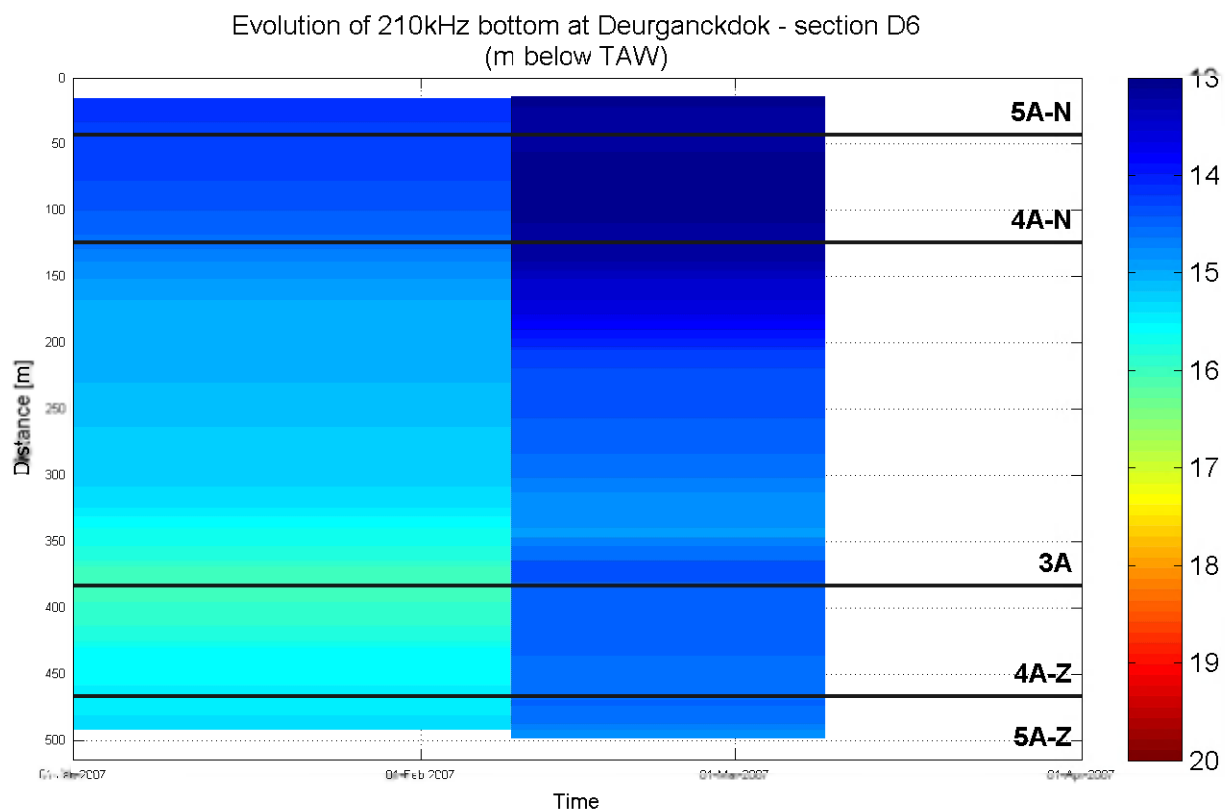
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

Long-term monitoring siltation Deurganckdok

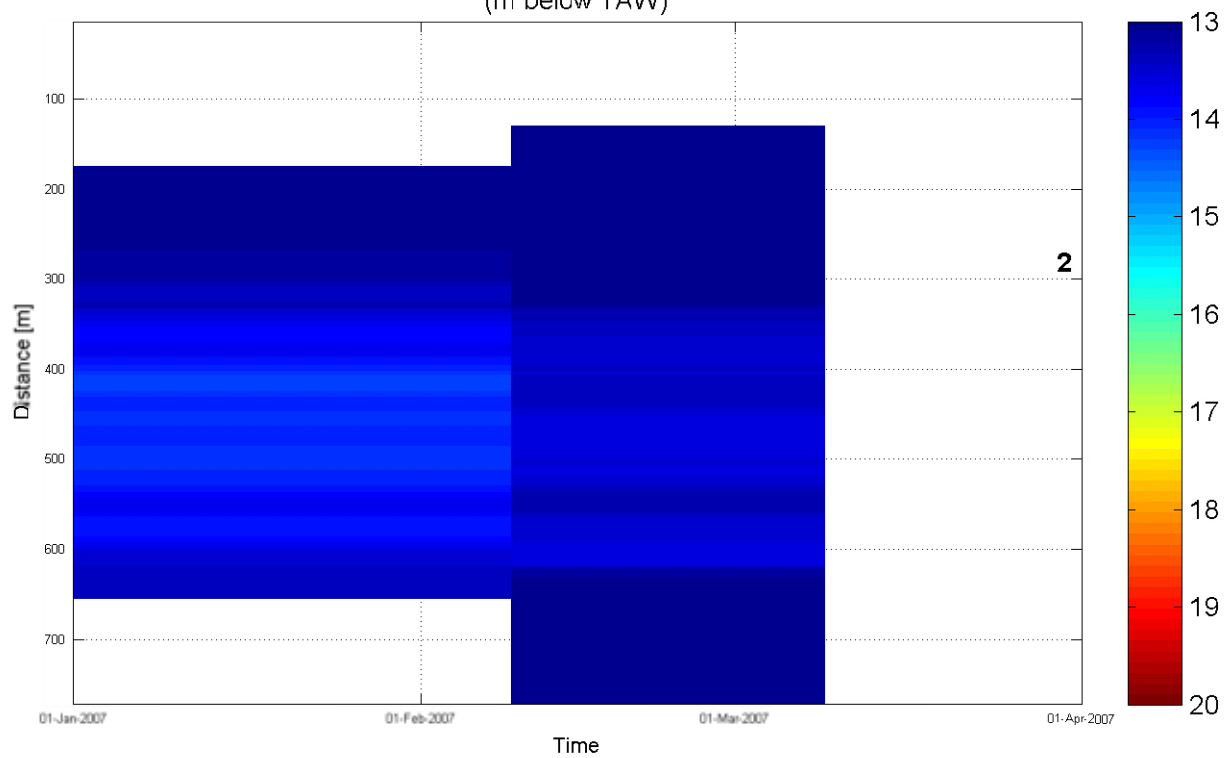
Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD

Evolution of 210kHz bottom at Deurganckdok - section D7
(m below TAW)



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

Long-term monitoring siltation Deurganckdok

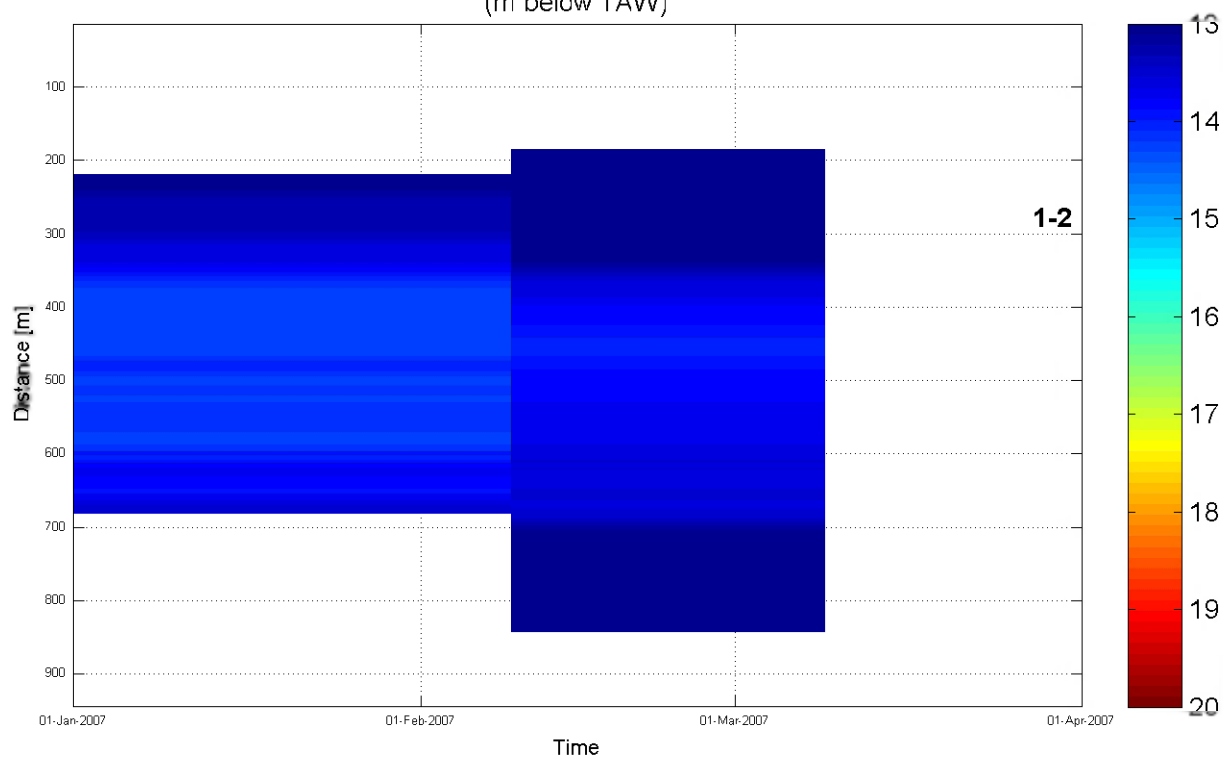
Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD

Evolution of 210kHz bottom at Deurganckdok - section D8
(m below TAW)



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

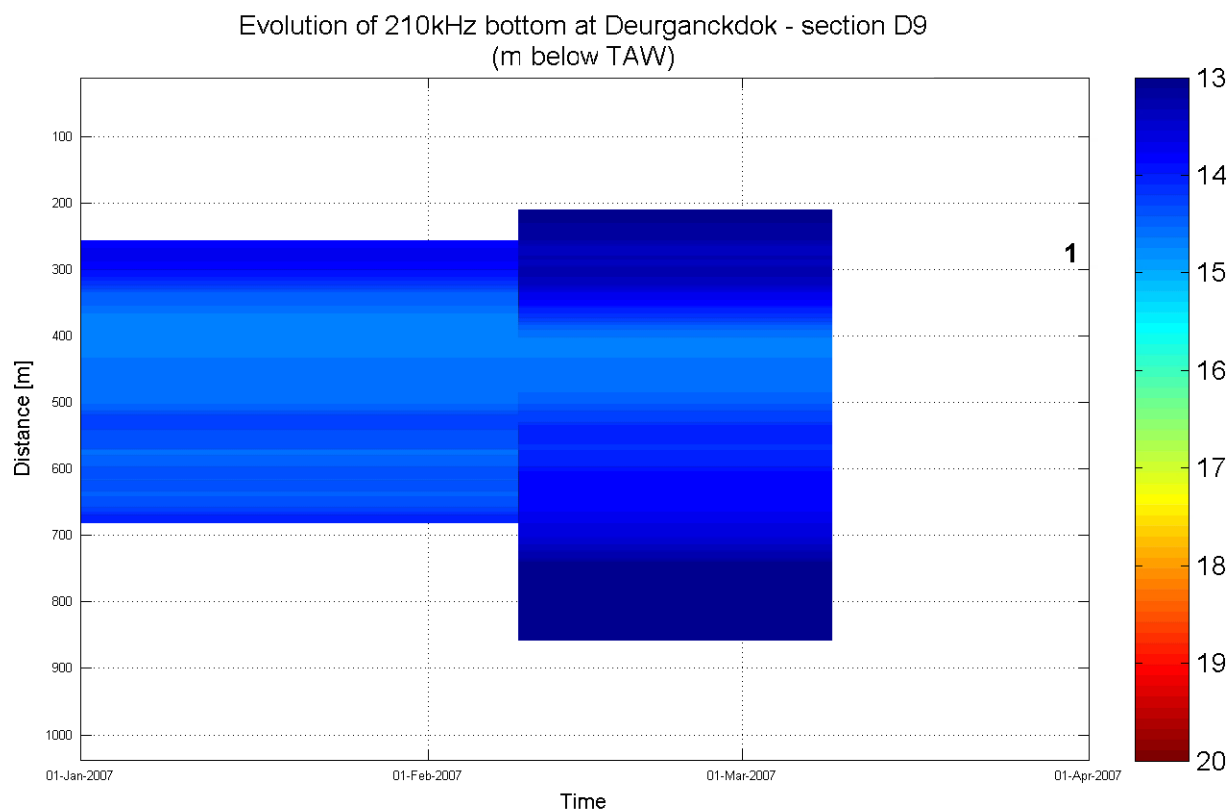
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

Long-term monitoring siltation Deurganckdok

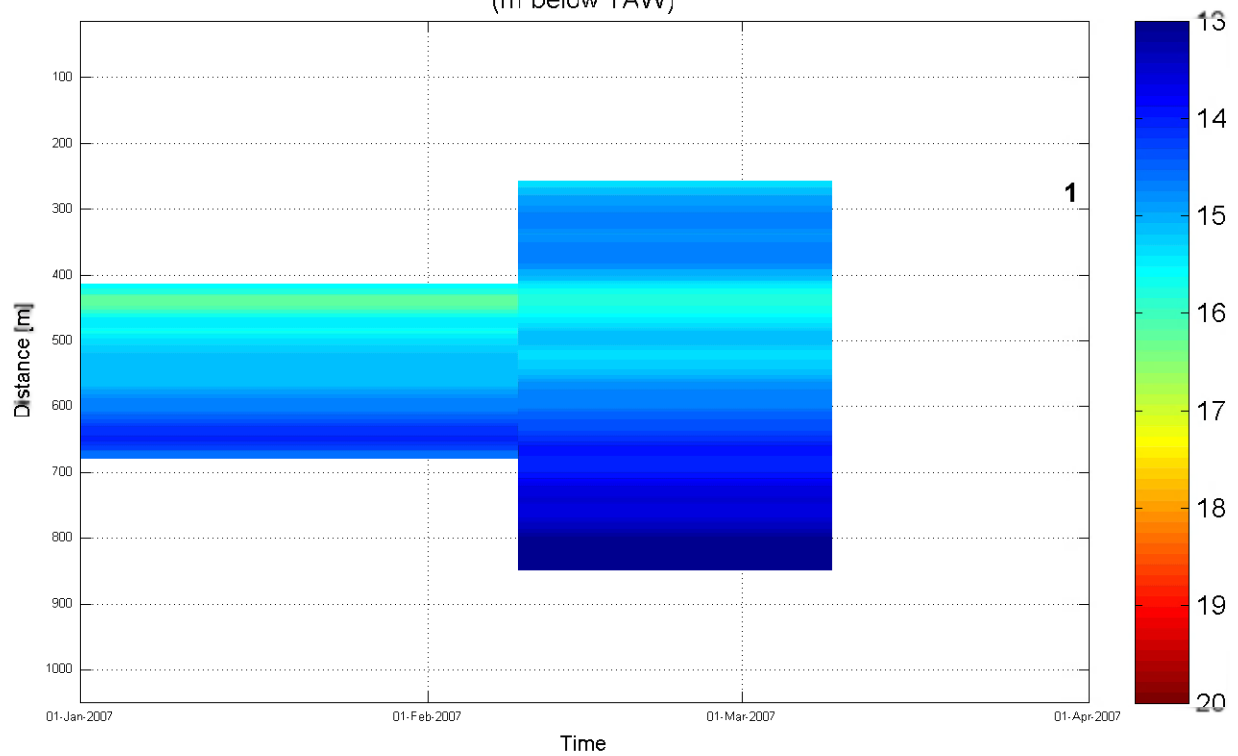
Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD

Evolution of 210kHz bottom at Deurganckdok - section D10
(m below TAW)



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

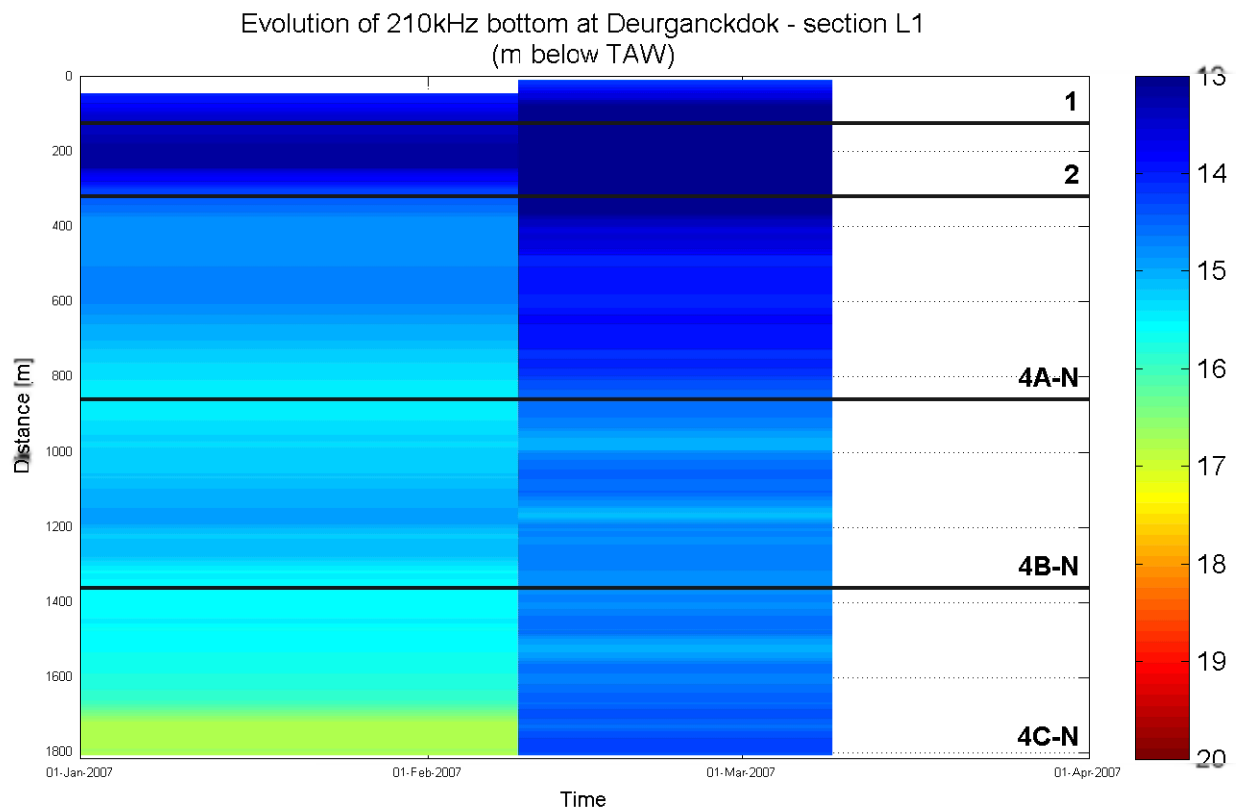
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



I/RA/11283/06.116/MSA

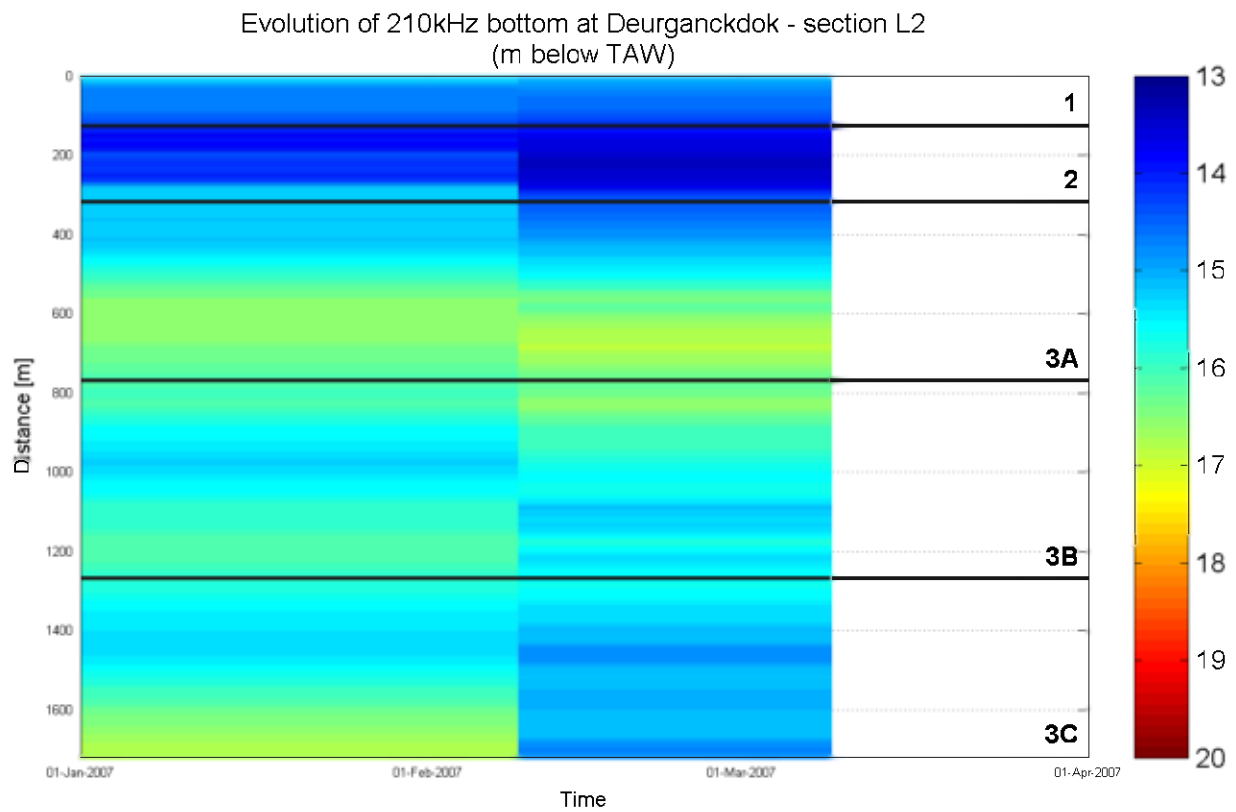
Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:

DGD



Data Processed by:

In association with :



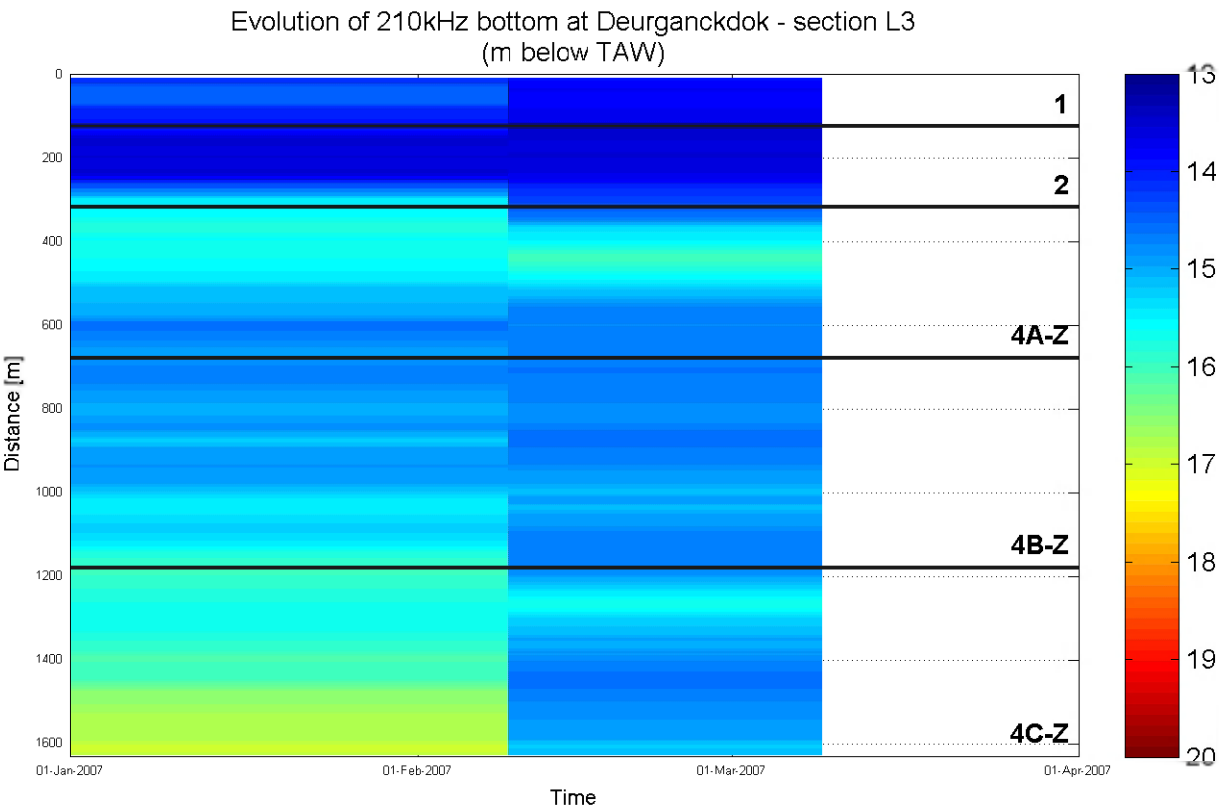
I/RA/11283/06.116/MSA

Long-term monitoring siltation Deurganckdok

Evolution 210kHz bottom

210kHz depth sounder

Location:
DGD



Data Processed by:



In association with :

I/RA/11283/06.116/MSA

APPENDIX C.

VOLUMETRIC SILTATION RATES IN DIFFERENT ZONES AND SECTIONS

C.1 Siltation rates (tabular)

Siltation rates in cm/day

1/ Per zone			
	jan/07	feb/07	Mar07
1	-	-	-
2	0.223	0.185	0.171
3a	0.064	2.337	3.247
3b	0.023	2.926	4.088
3c	0.239	2.4	3.264
4Na	0.33	-2.067	-3.026
4Nb	0.172	0.754	0.987
4Nc	0.411	0.588	0.66
4Za	0.05	0.565	0.771
4Zb	0.081	-0.262	-0.399
4Zc	0.357	1.041	1.315
5Na	0.411	-4.344	-6.247
5Nb	0.303	-0.443	-0.741
5Nc	0.483	-1.8	-2.713
5Za	-	-	-
5Zb	-	-	-
5Zc	-	-	-
Avg	0.242	0.145	0.106

1/ Per section			
	jan/07	feb/07	Mar07
D1	0.549	1.228	1.499
D2	0.081	2.113	2.925
D3	0.069	1.562	2.159
D4	0.018	2.228	3.111
D5	0.117	0.563	0.742
D6	0.337	-1.297	-1.951
D7	0.137	0.298	0.363
D8	0.127	0.636	0.84
D9	0.11	-	-
D10	0.042	-	-
L1	0.286	-0.327	-0.572
L2	0.104	2.194	3.03
L3	0.177	0.149	0.138

C.2 Water-bed interface evolution for ali zones

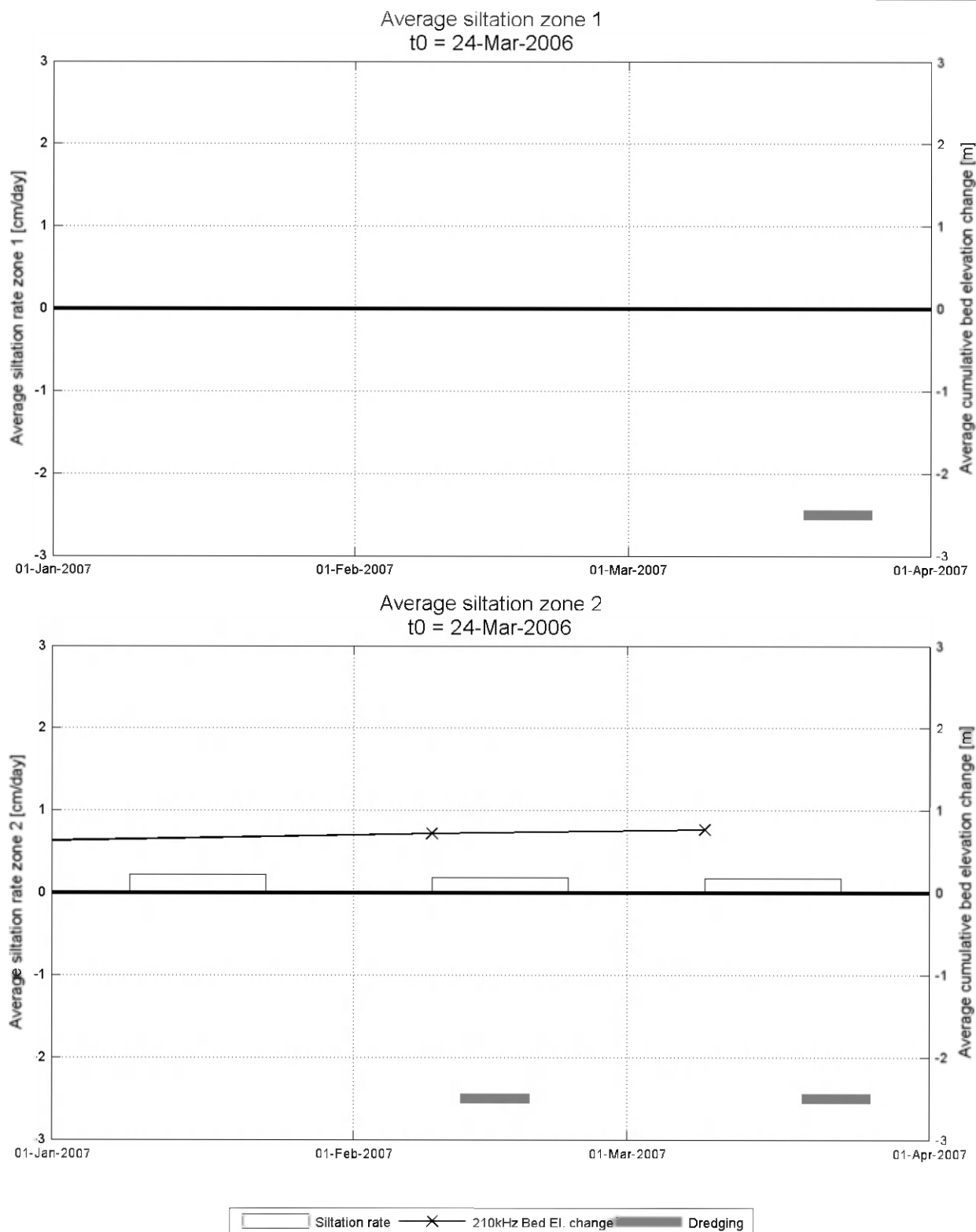
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

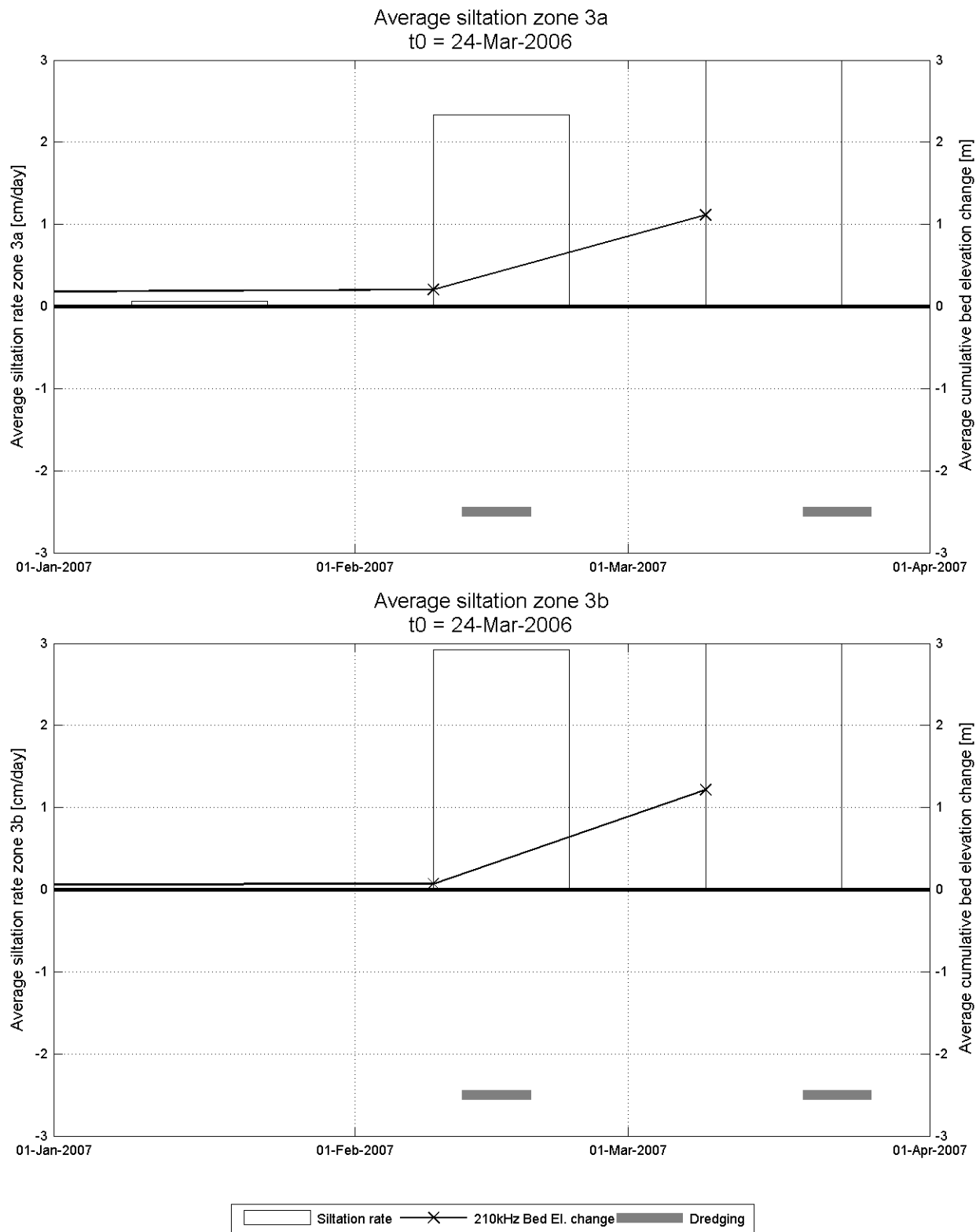
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Reference level: depth sounding 24-Mar-2006

Data Processed by:



In association with :



I/RA/11283/06.116/MSA

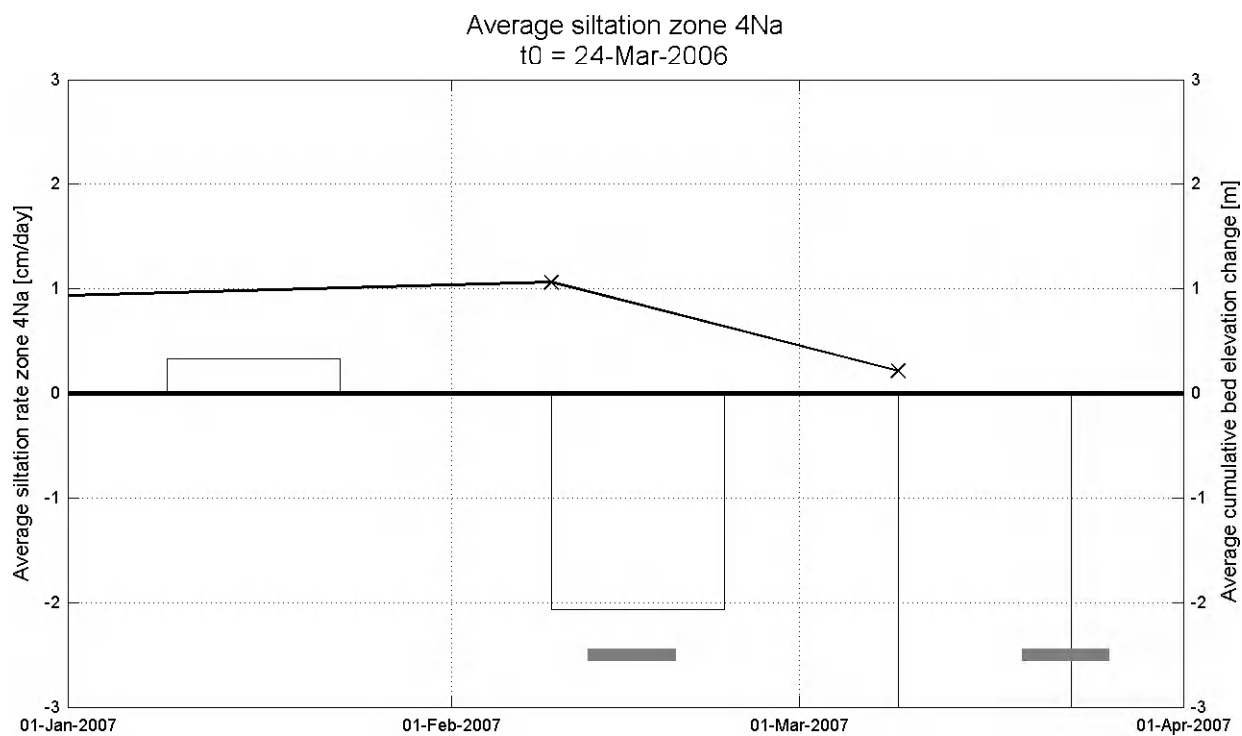
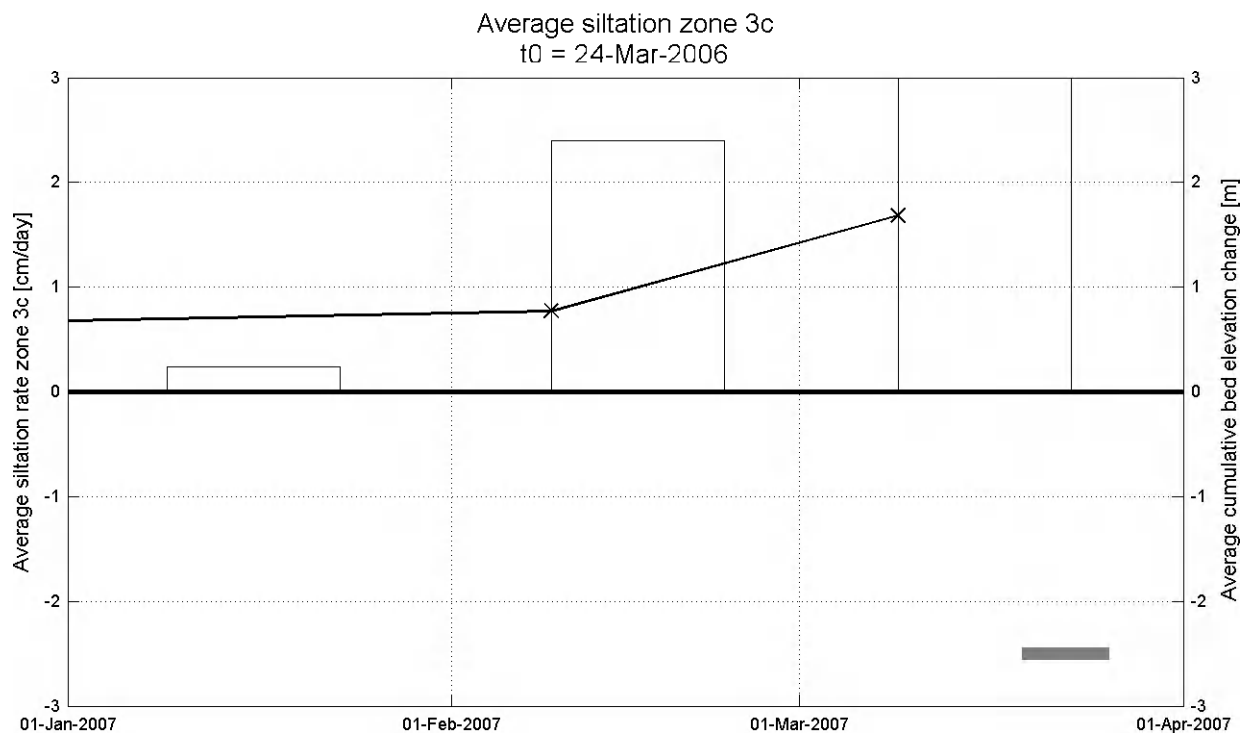
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Siltation rate
 210kHz Bed El. change
 Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:



In association with :

I/RA/11283/06.116/MSA

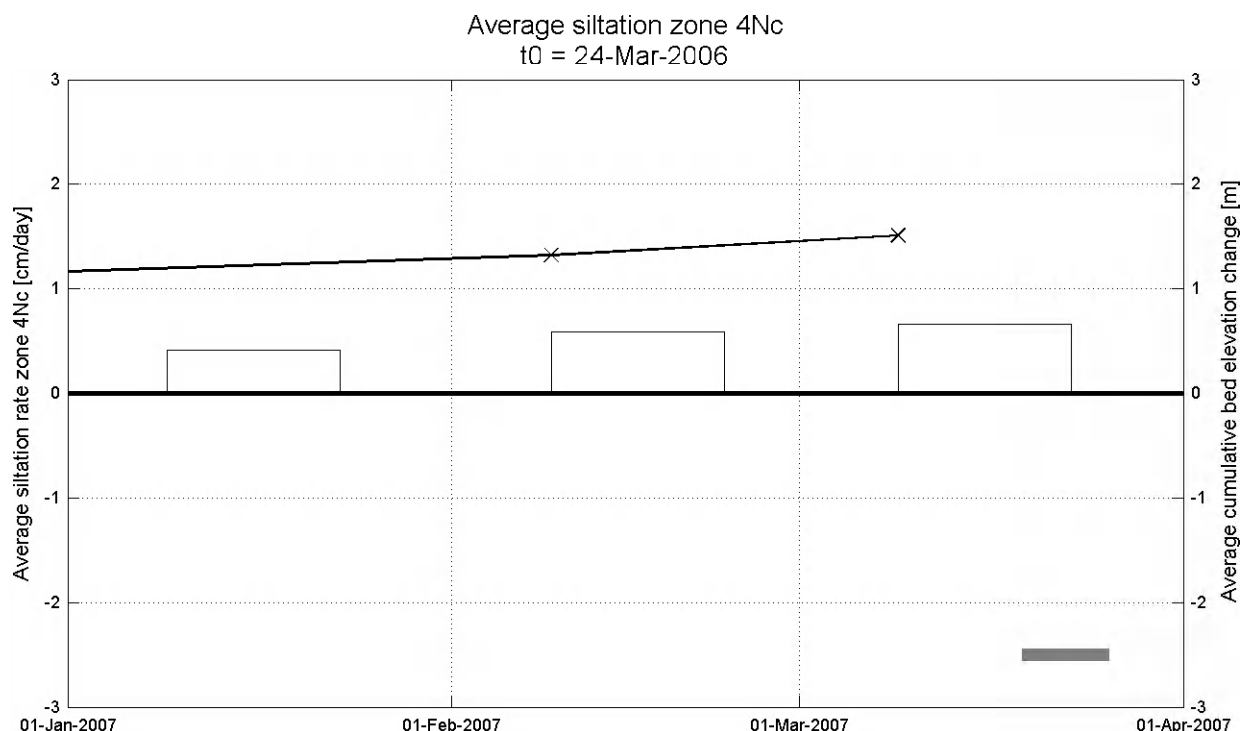
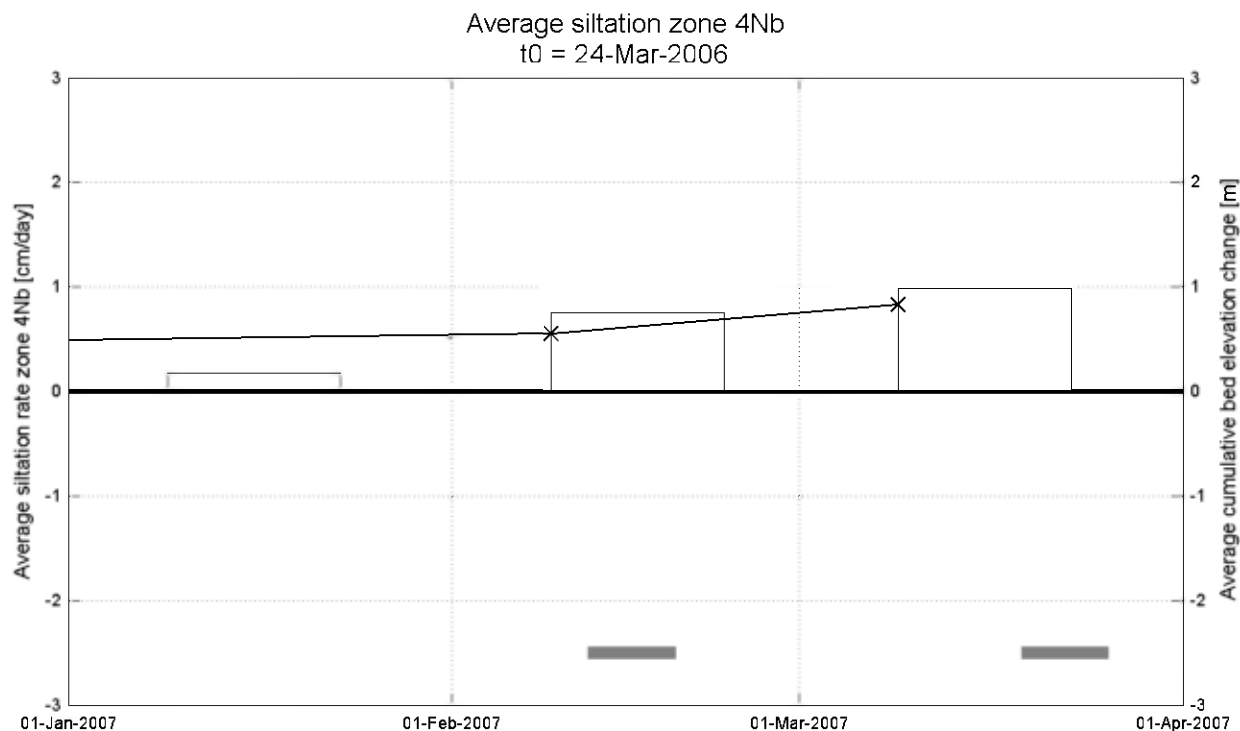
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Siltation rate 210kHz Bed El. change Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

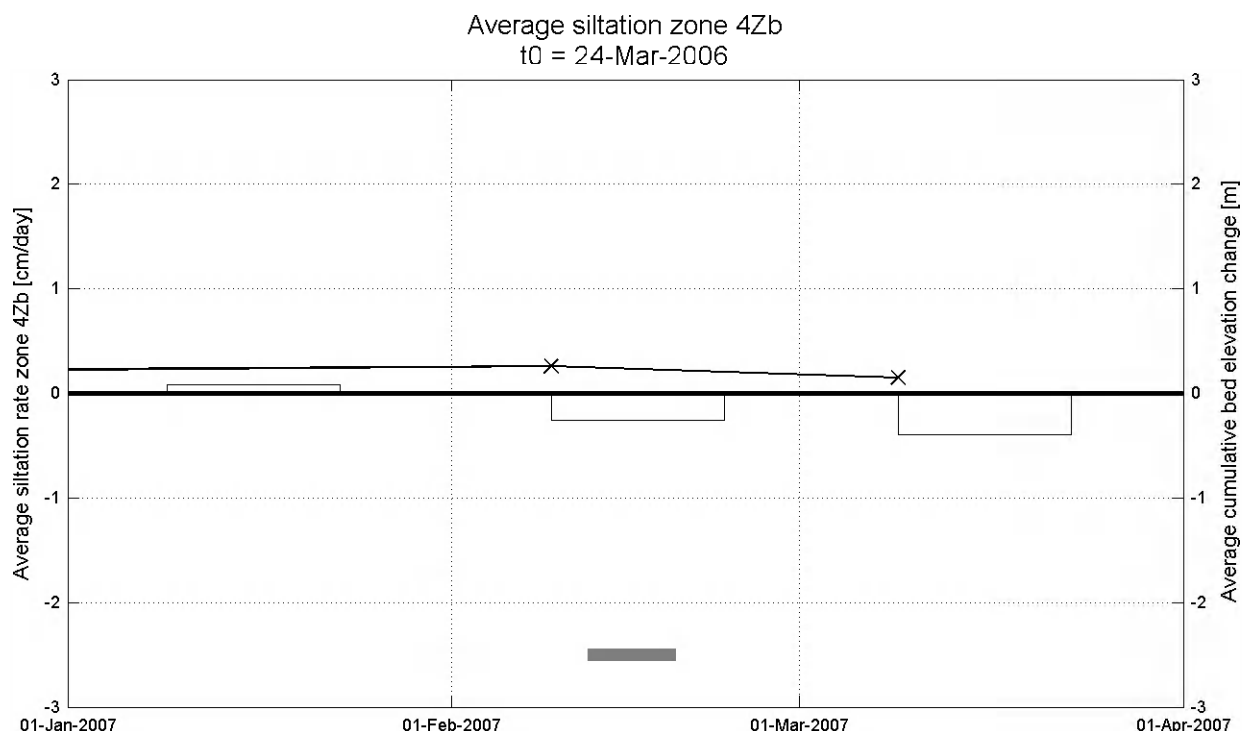
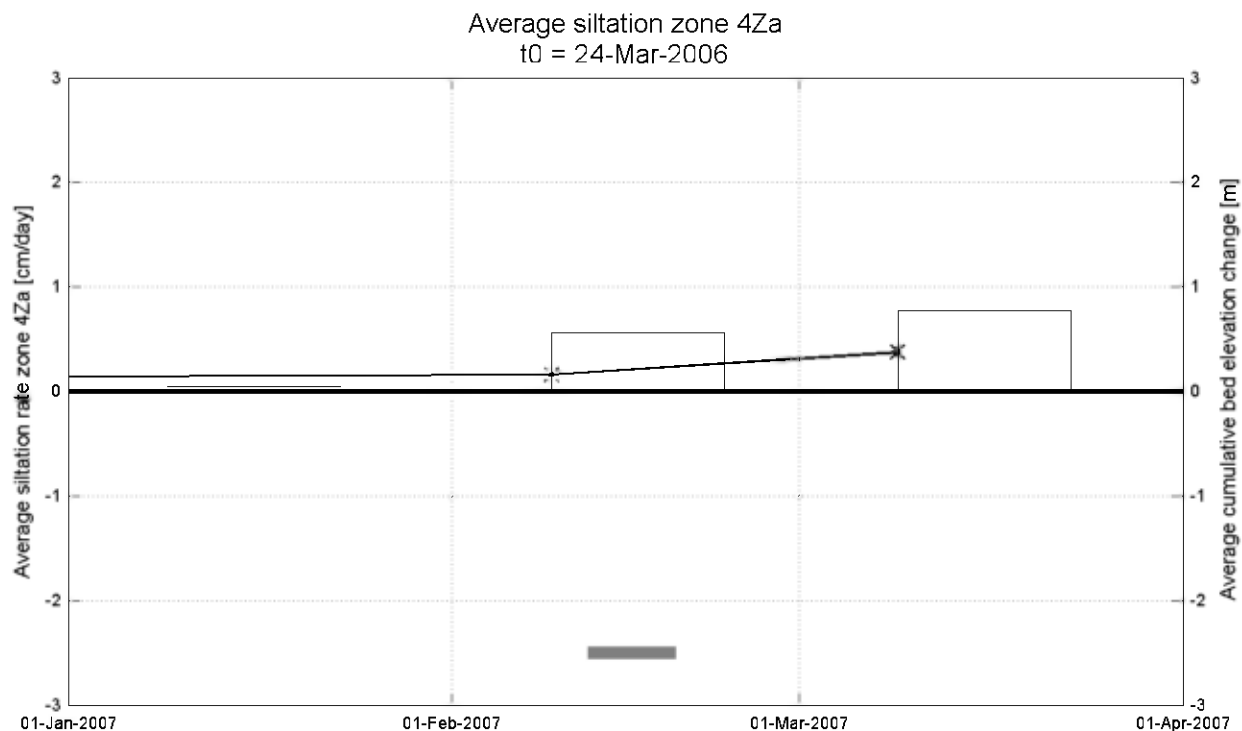
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Siltation rate 210kHz Bed El. change Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

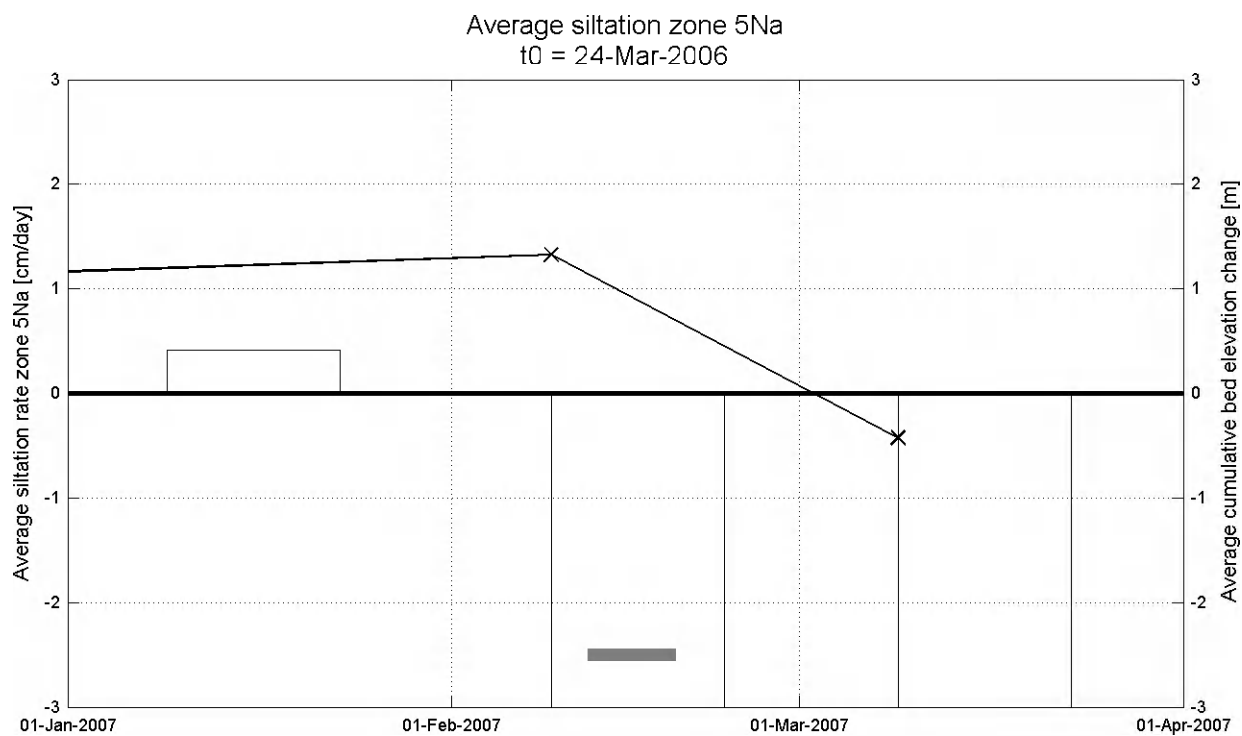
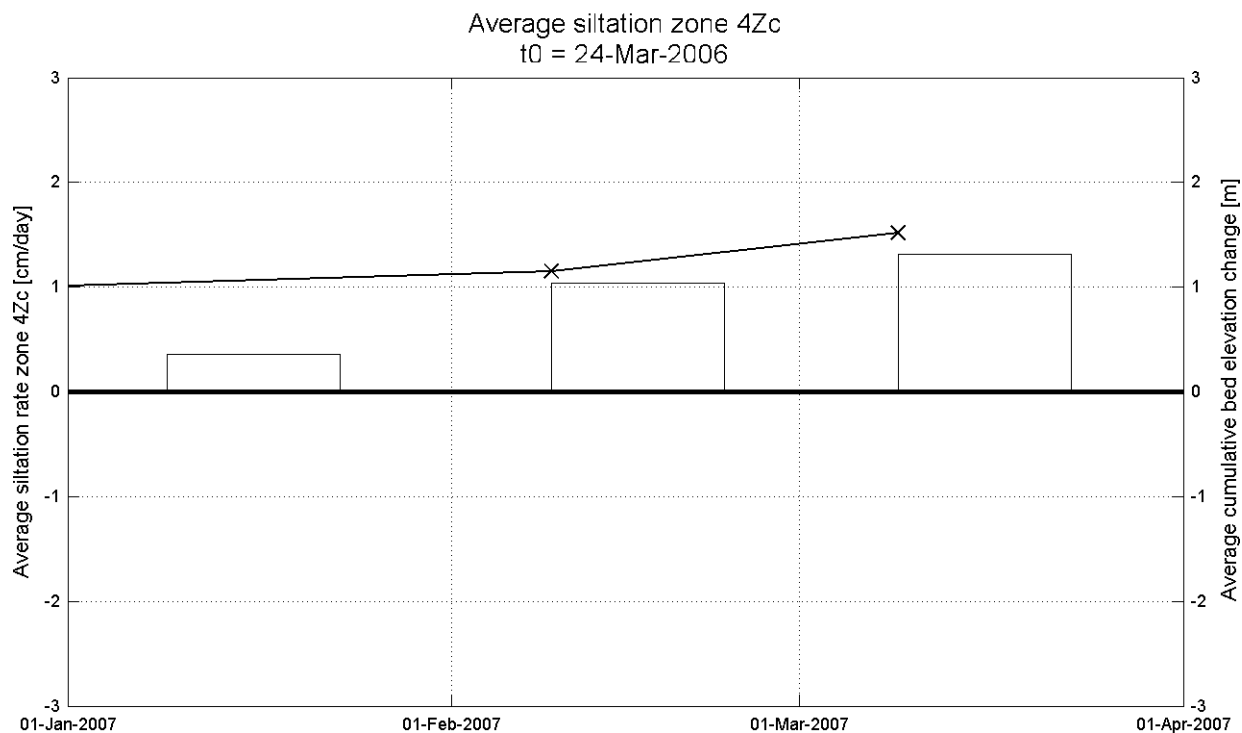
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Siltation rate
 210kHz Bed El. change
 Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

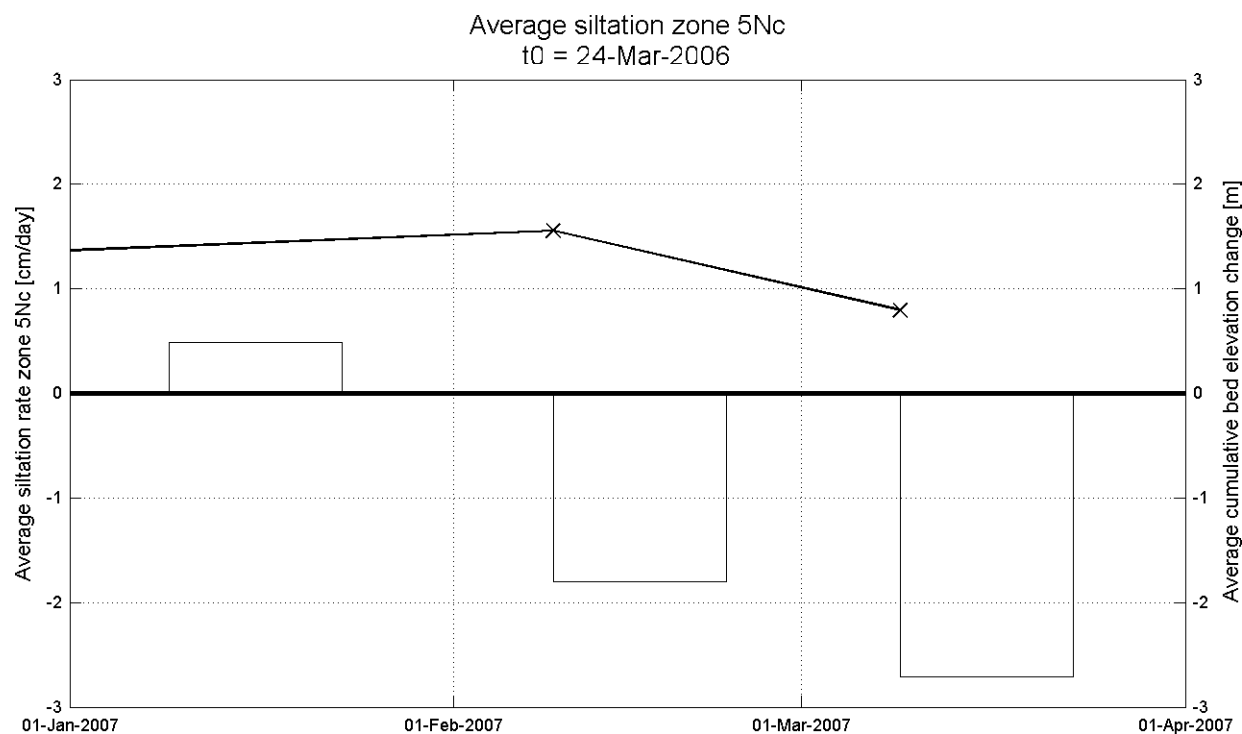
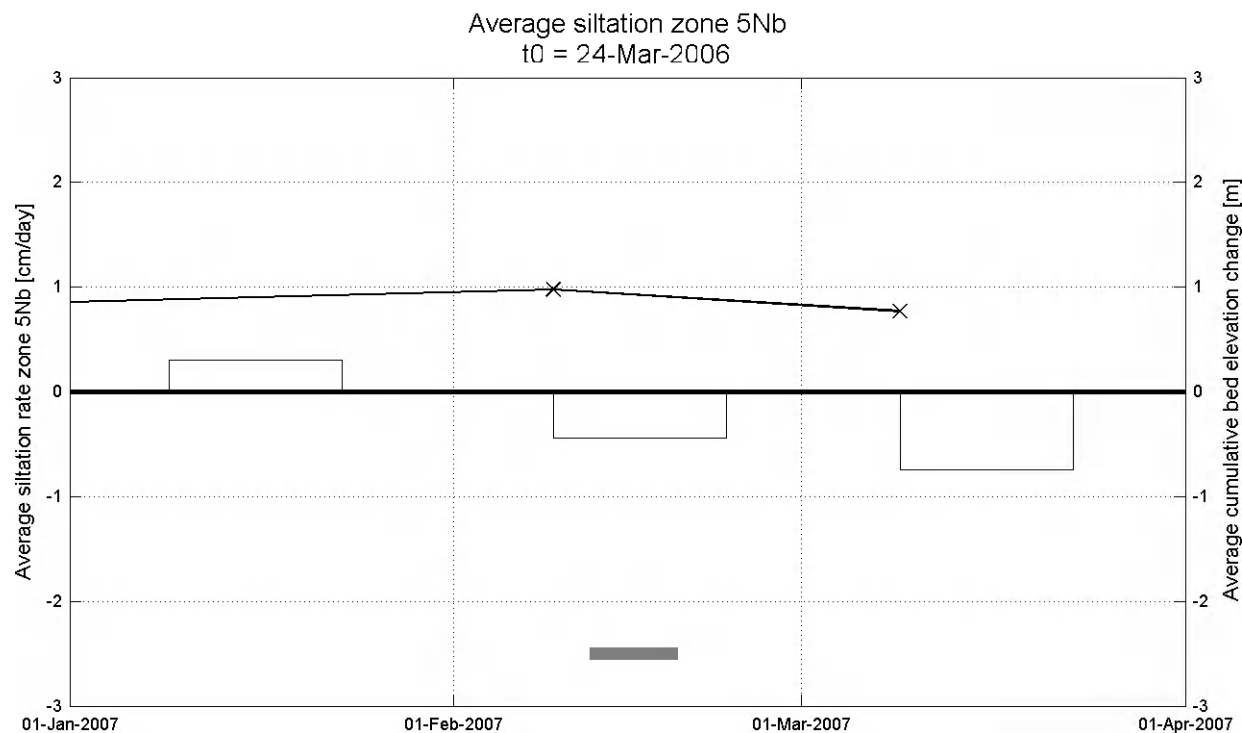
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Siltation rate 210kHz Bed El. change Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

Long-term monitoring siltation Deurganckdok

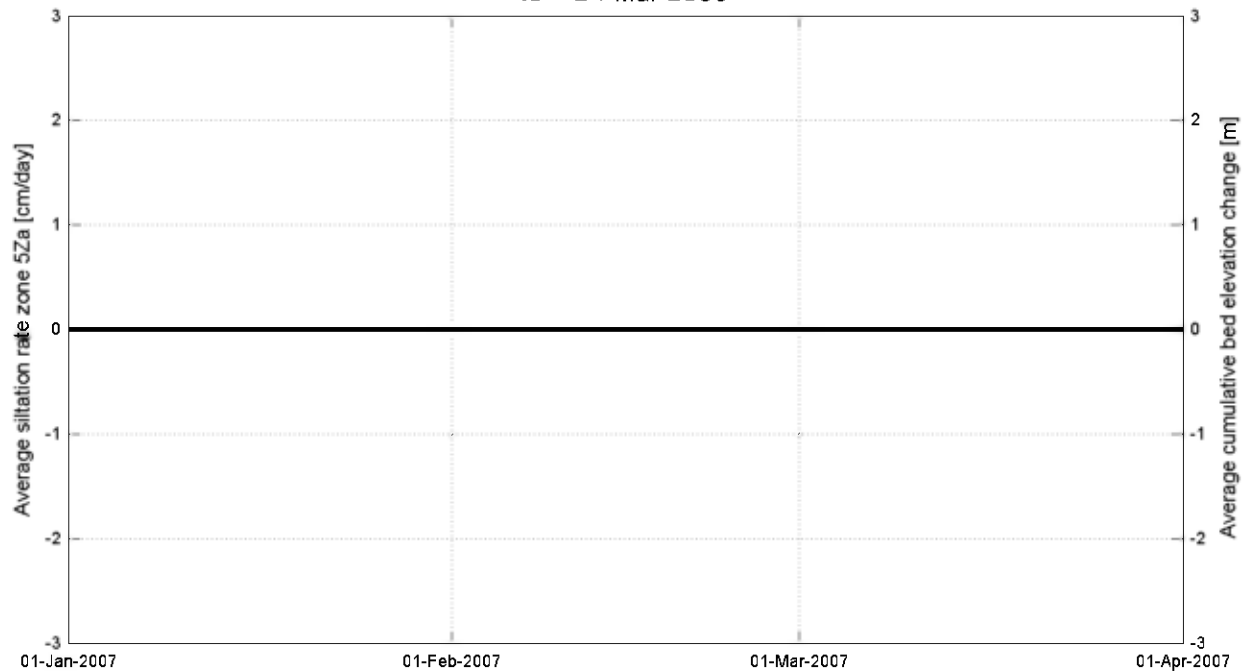
Siltation height / monthly siltation rate

210kHz depth sounder

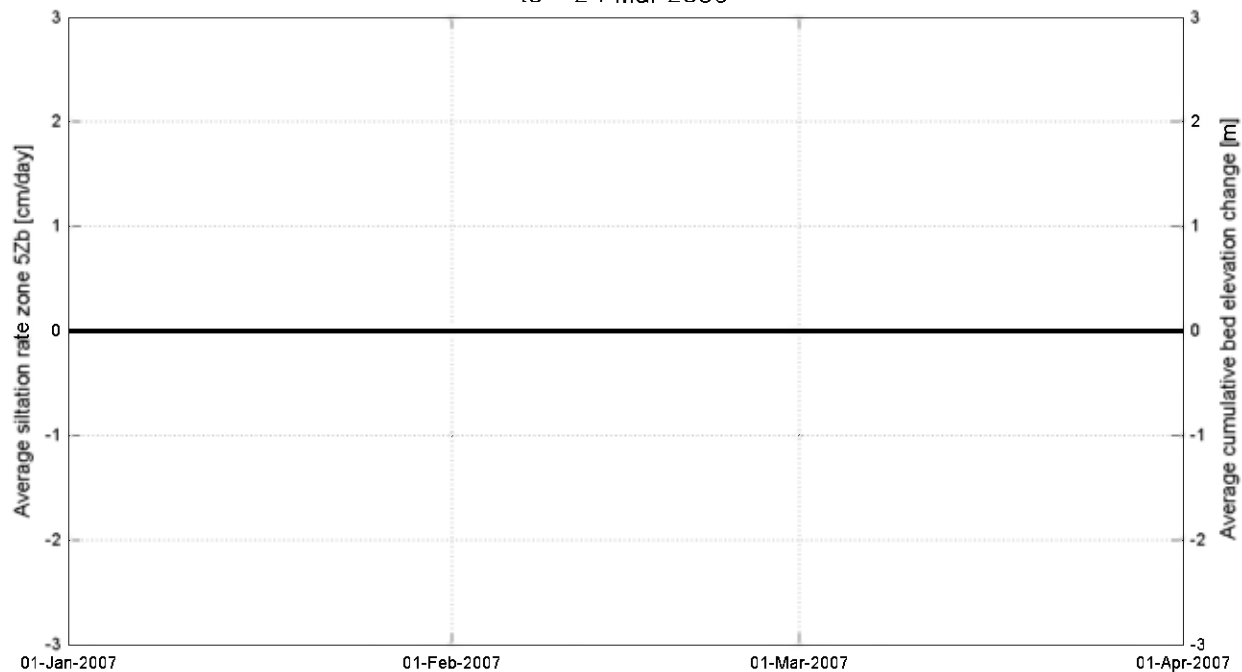
Location:

DGD

Average siltation zone 5Za
t0 = 24-Mar-2006



Average siltation zone 5Zb
t0 = 24-Mar-2006



 Siltation rate
 210kHz Bed El. change
 Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:



In association with :

I/RA/11283/06.116/MSA

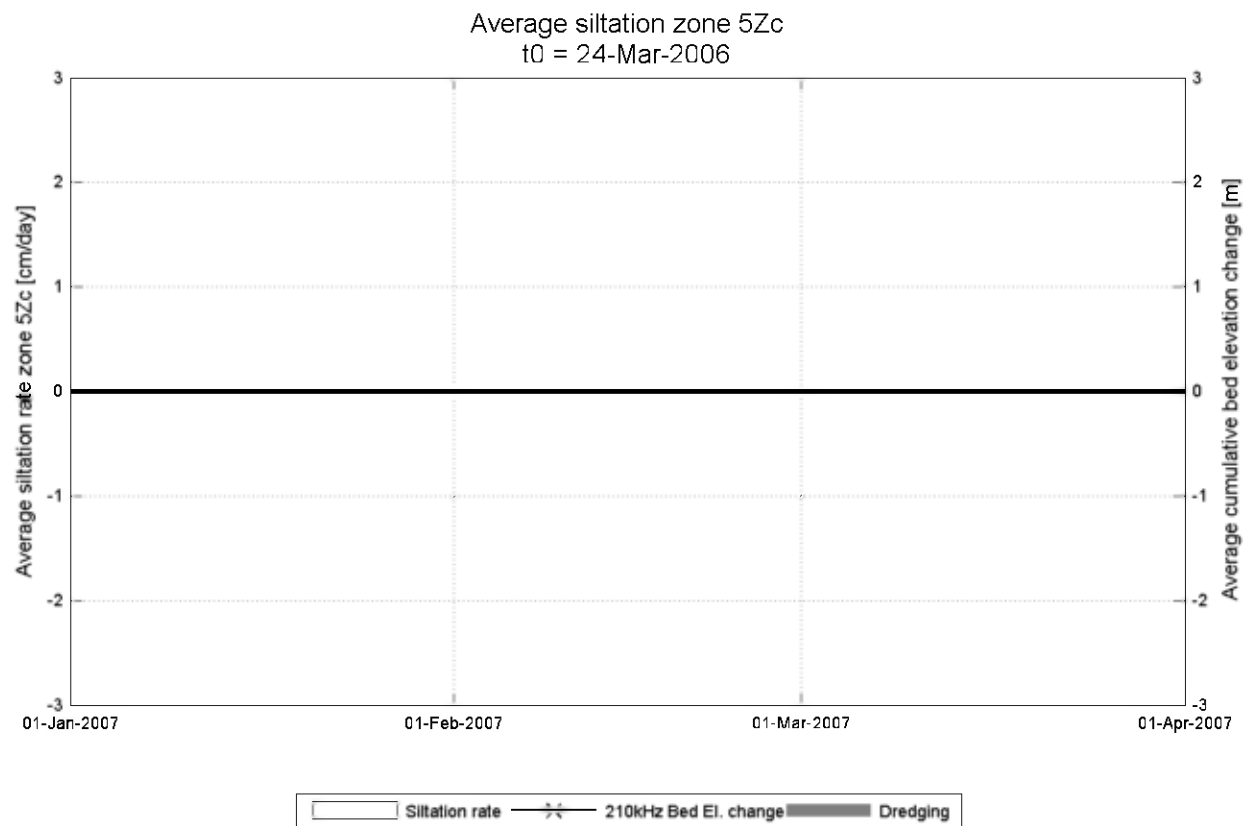
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

C.3 Water-bed interface evolution for all sections

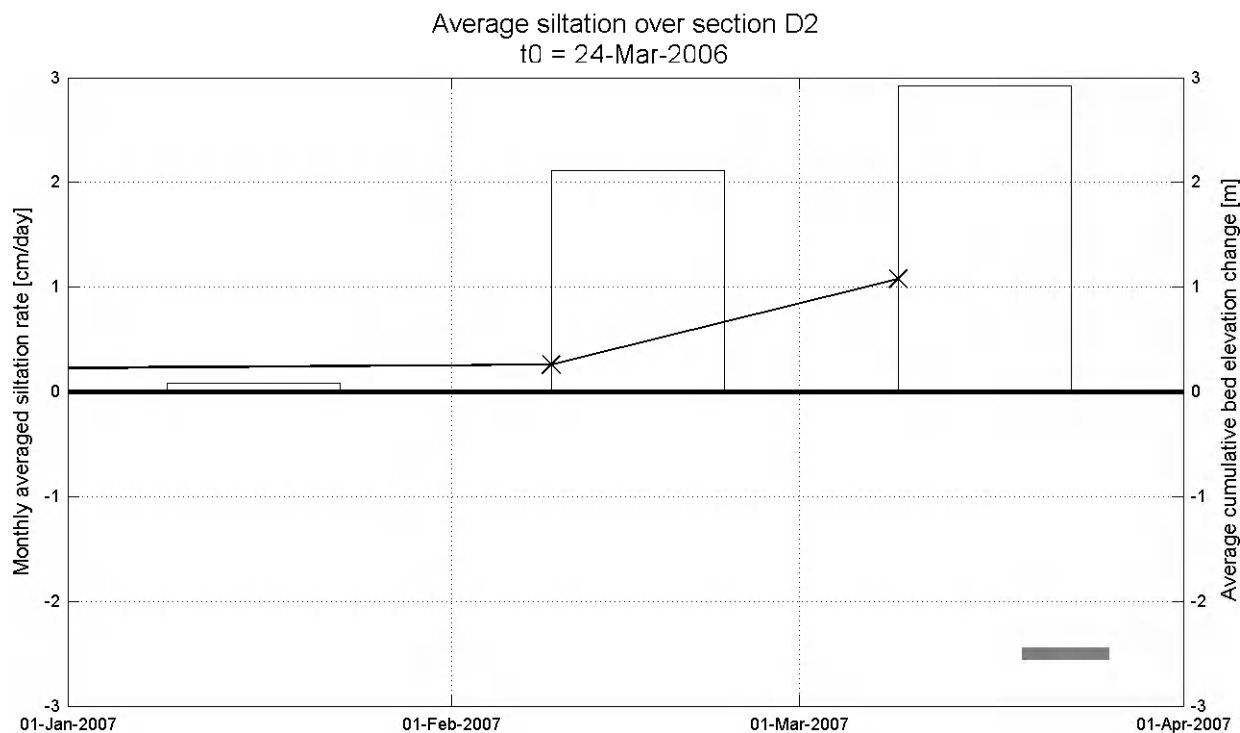
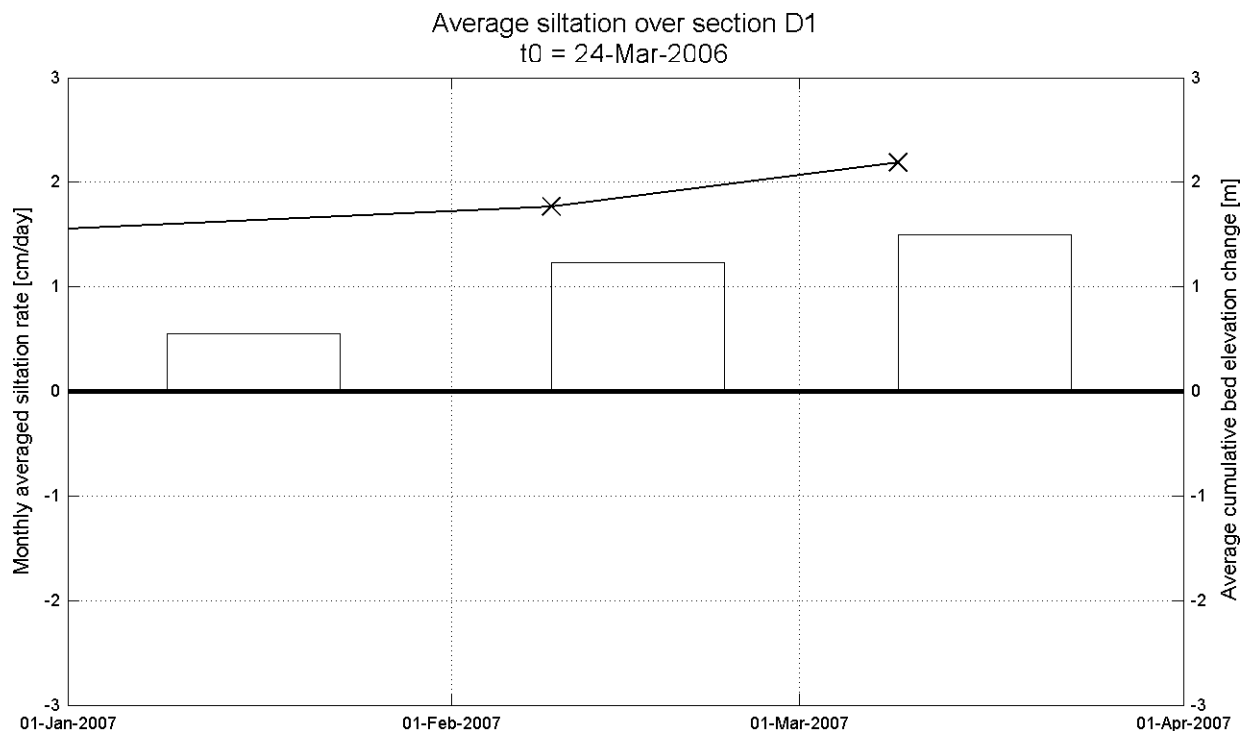
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Siltation rate 210kHz Bed El. change Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:



In association with :

I/RA/11283/06.116/MSA

Long-term monitoring siltation Deurganckdok

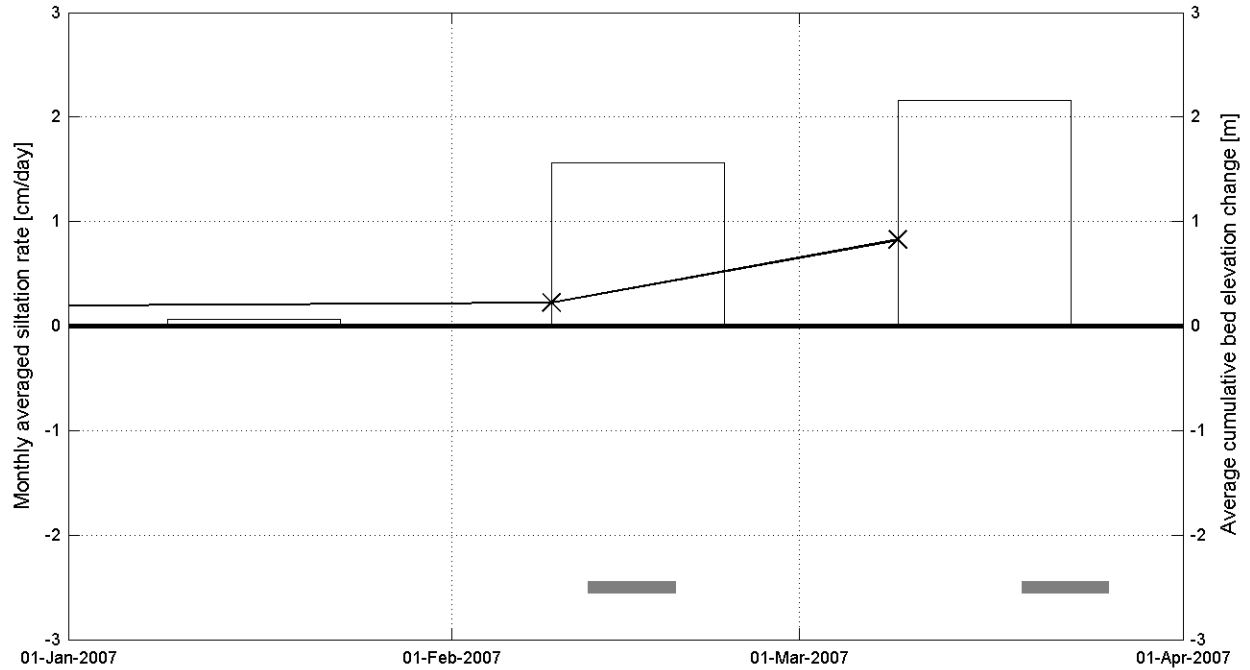
Siltation height / monthly siltation rate

210kHz depth sounder

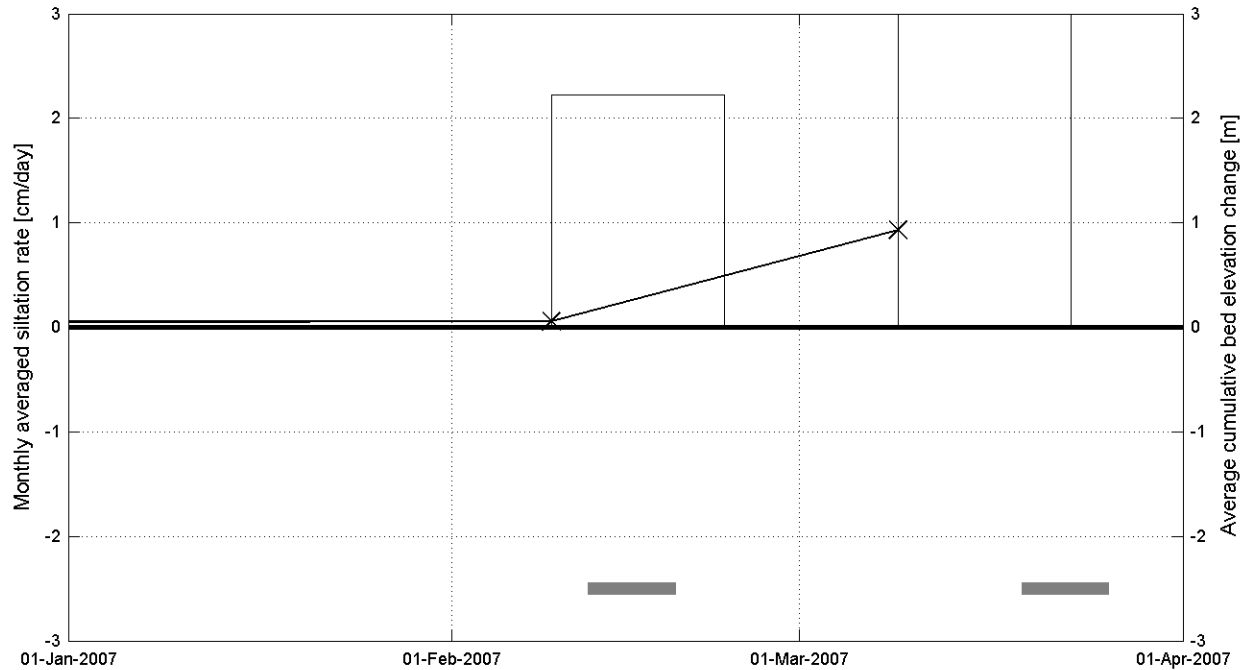
Location:

DGD

Average siltation over section D3
t0 = 24-Mar-2006



Average siltation over section D4
t0 = 24-Mar-2006



Siltation rate — x — 210kHz Bed El. change Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:



In association with :



I/RA/11283/06.116/MSA

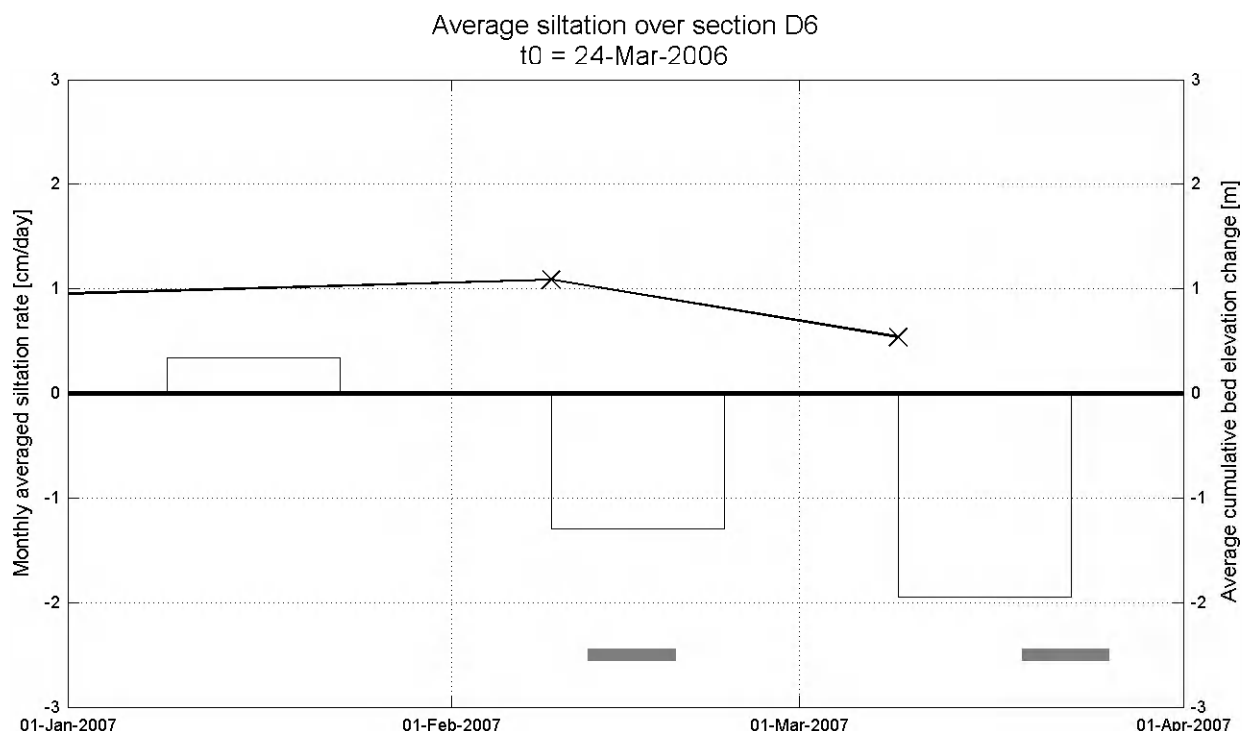
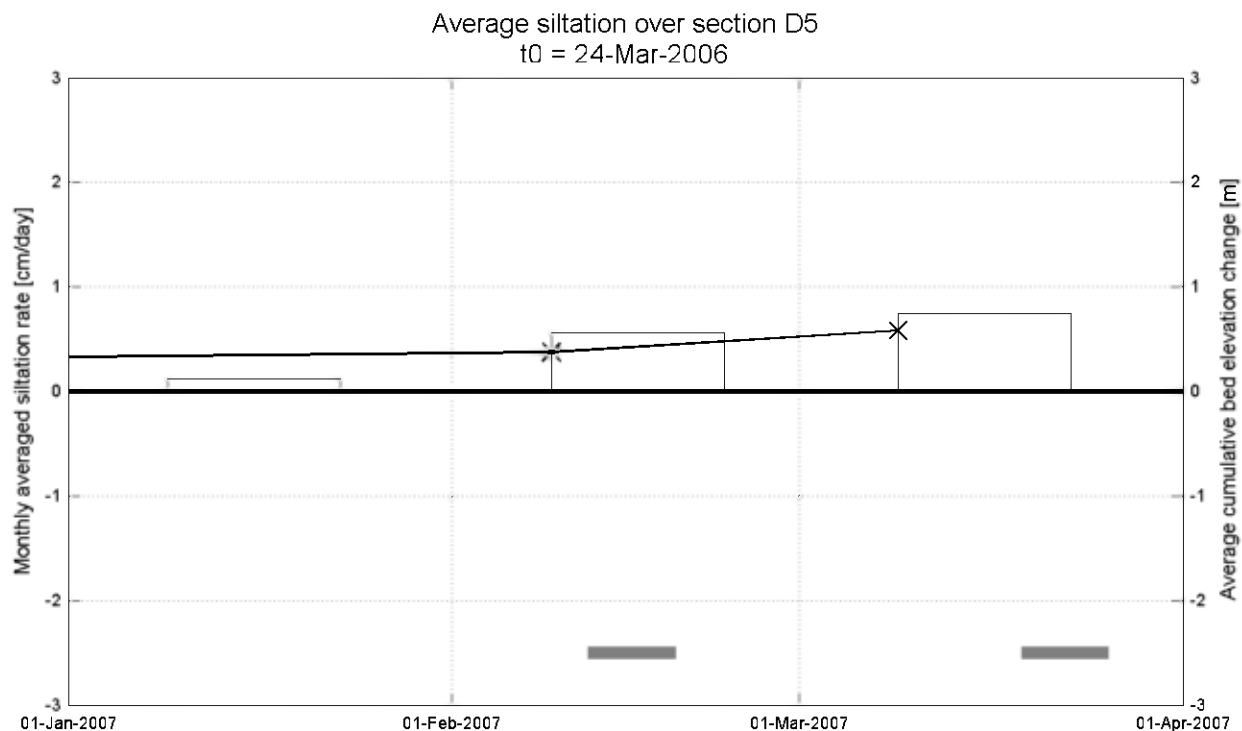
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Siltation rate
 x 210kHz Bed El. change
 Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

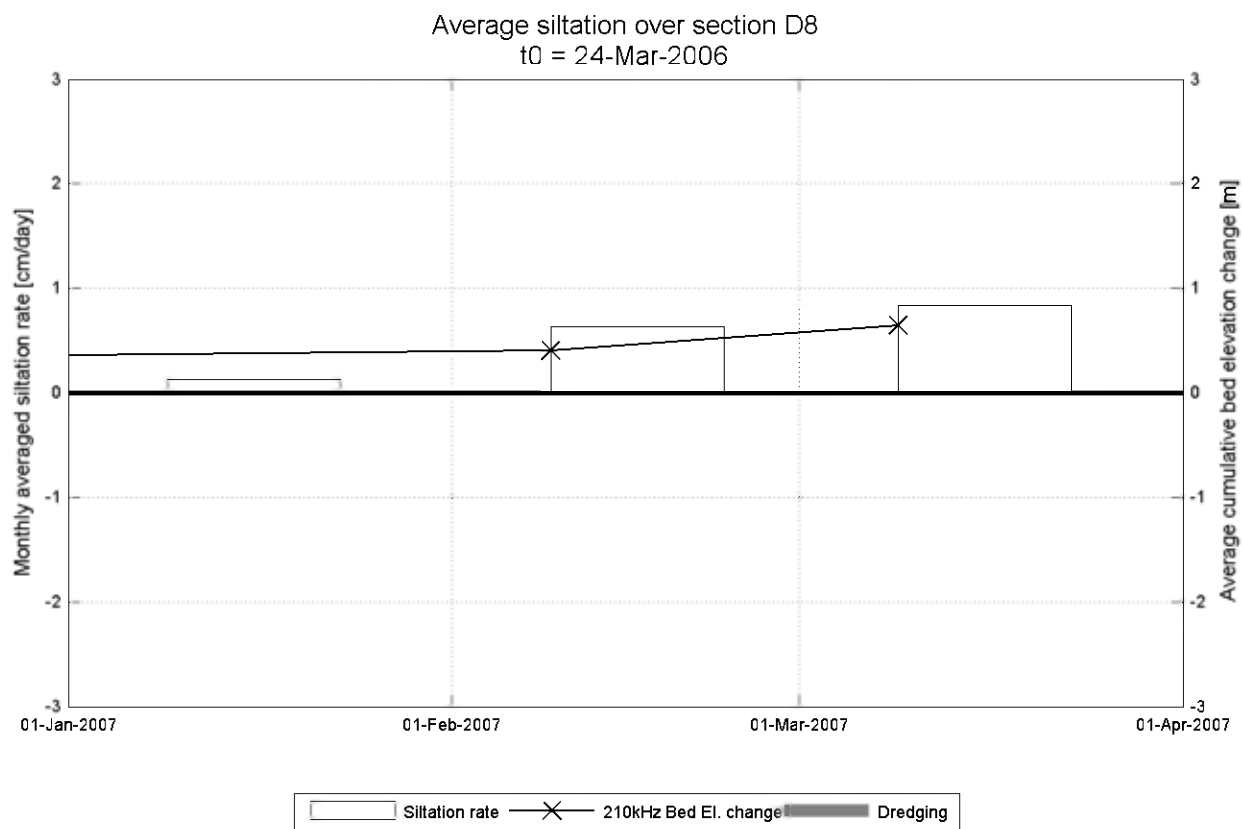
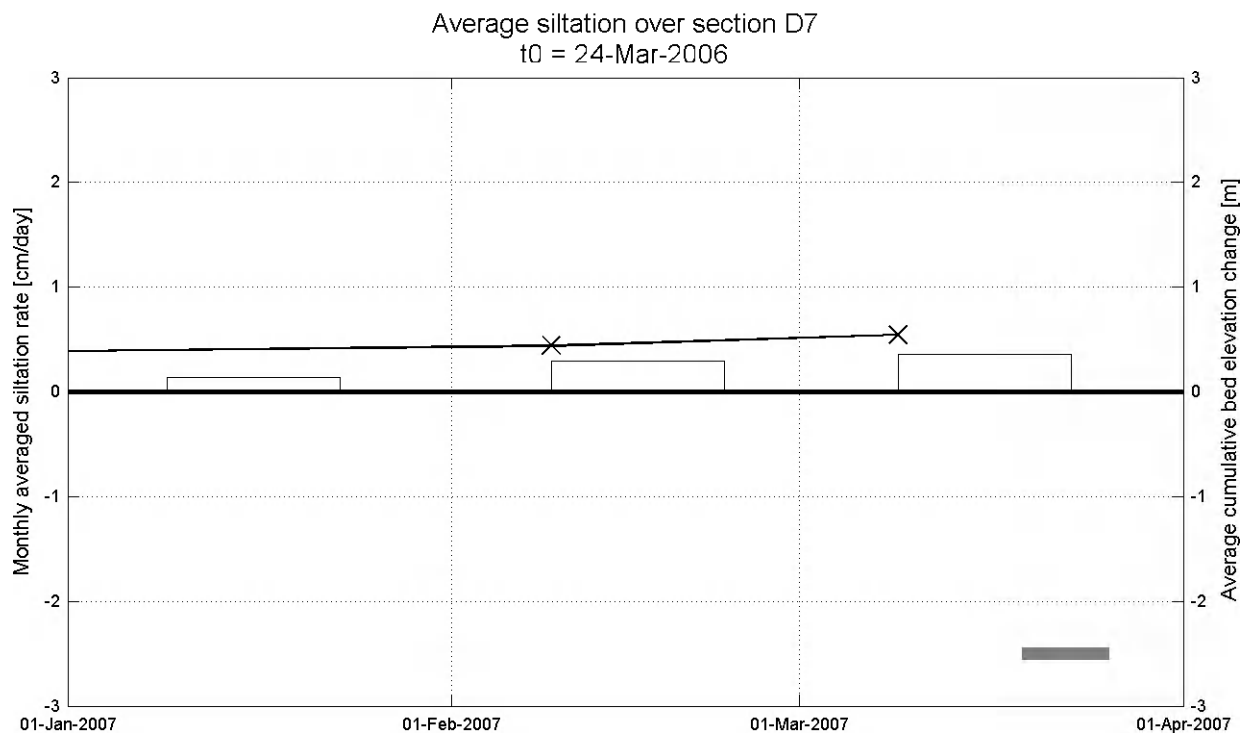
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

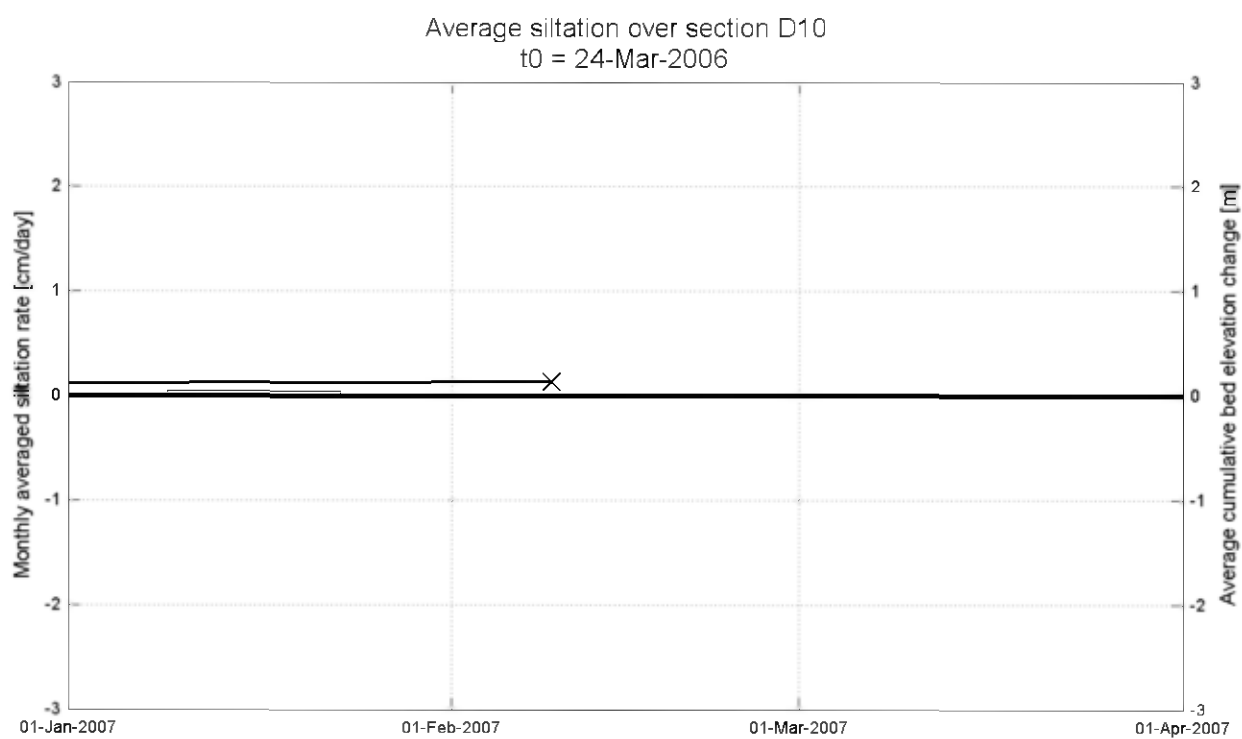
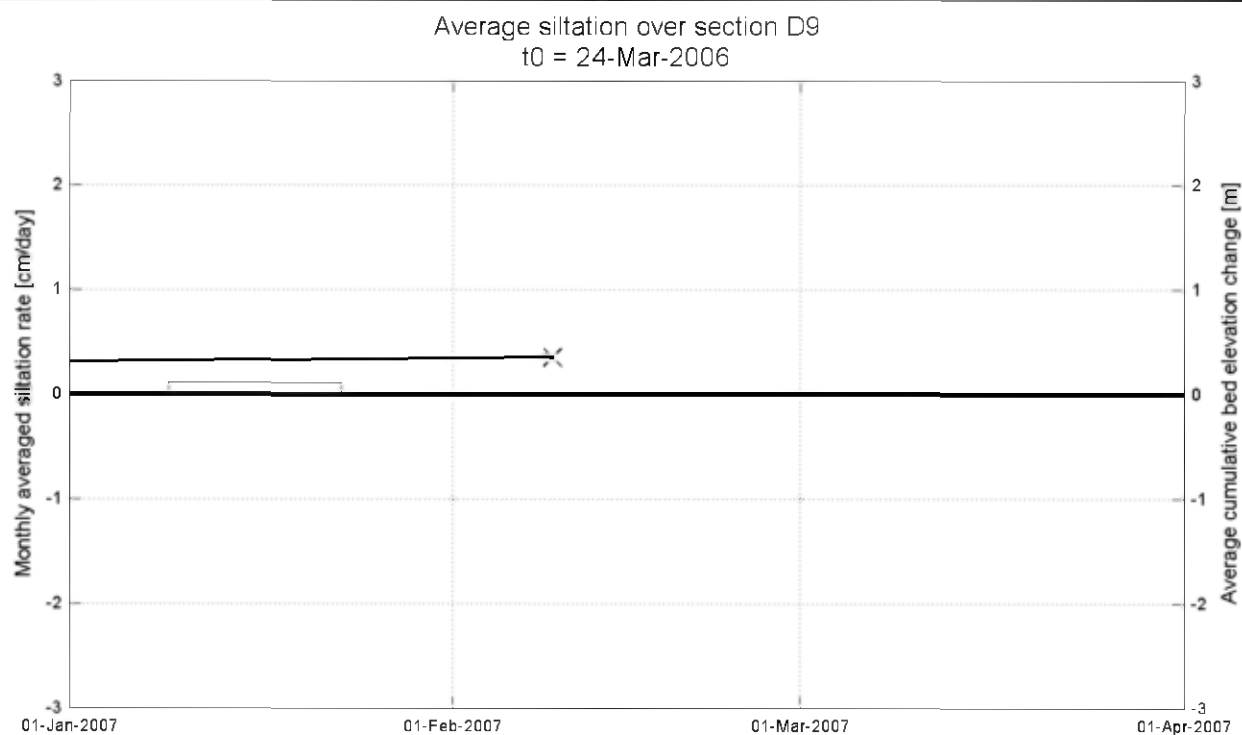
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Siltation rate
 210kHz Bed El. change
 Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

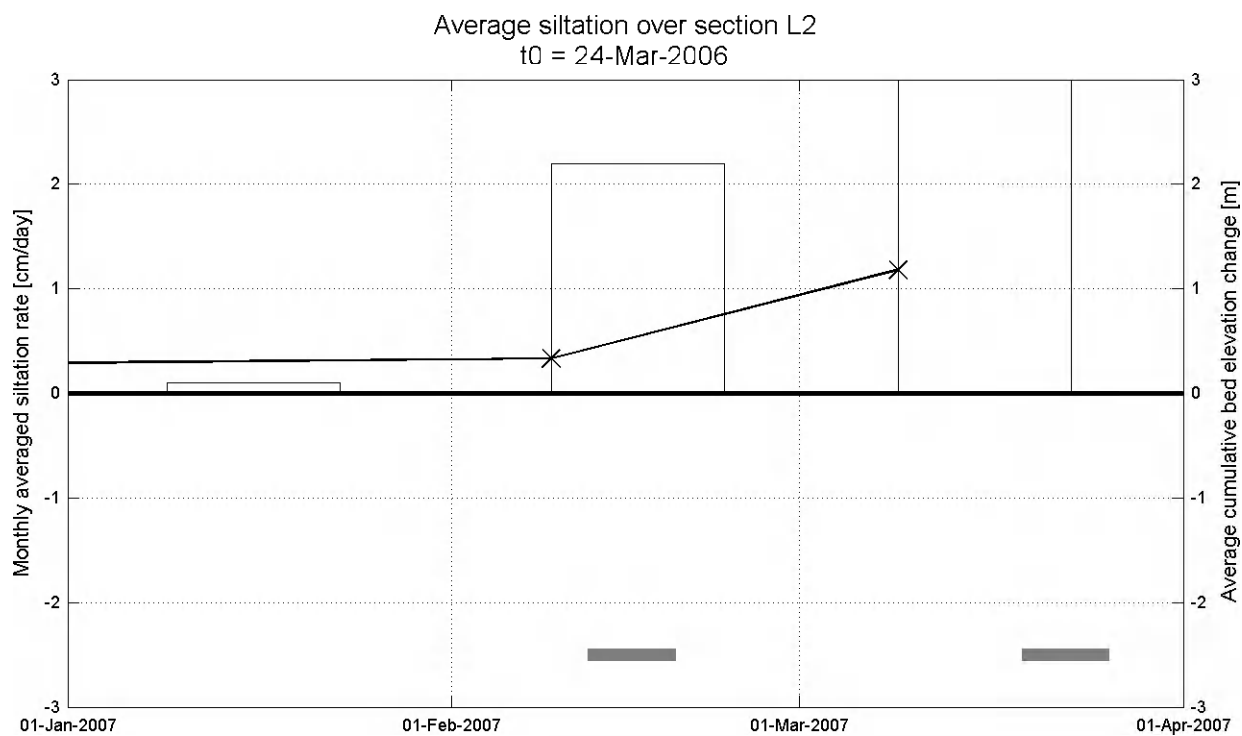
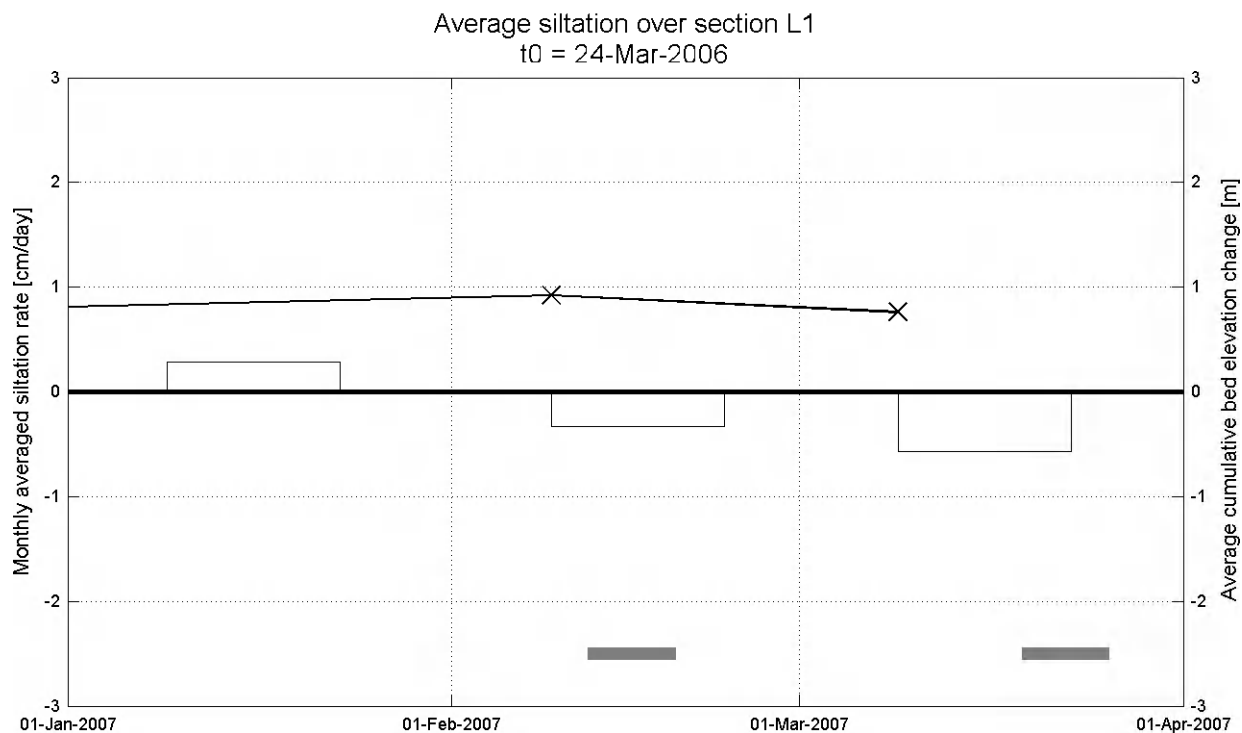
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Siltation rate 210kHz Bed El. change Dredging

Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

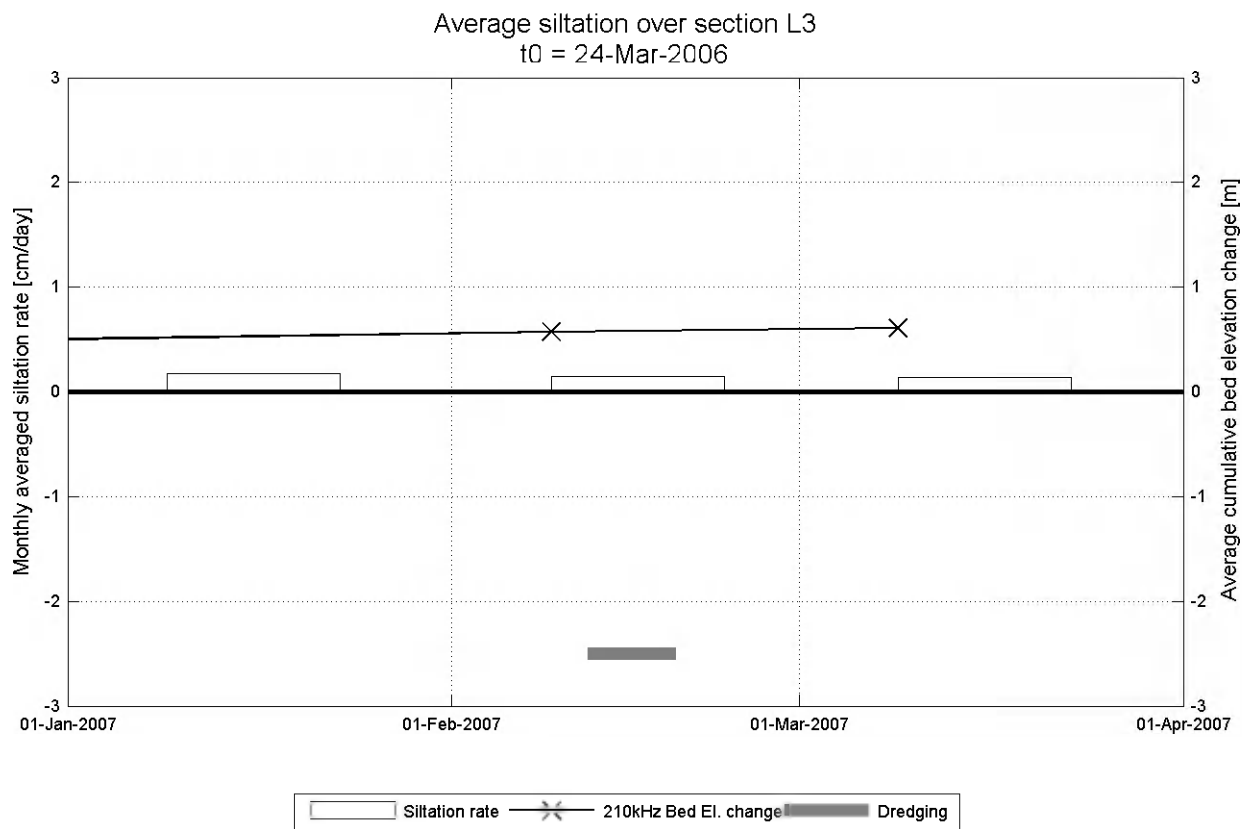
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



Reference level: depth sounding 24-Mar-2006

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

C.4 Siltation rate complete Deurganckdok

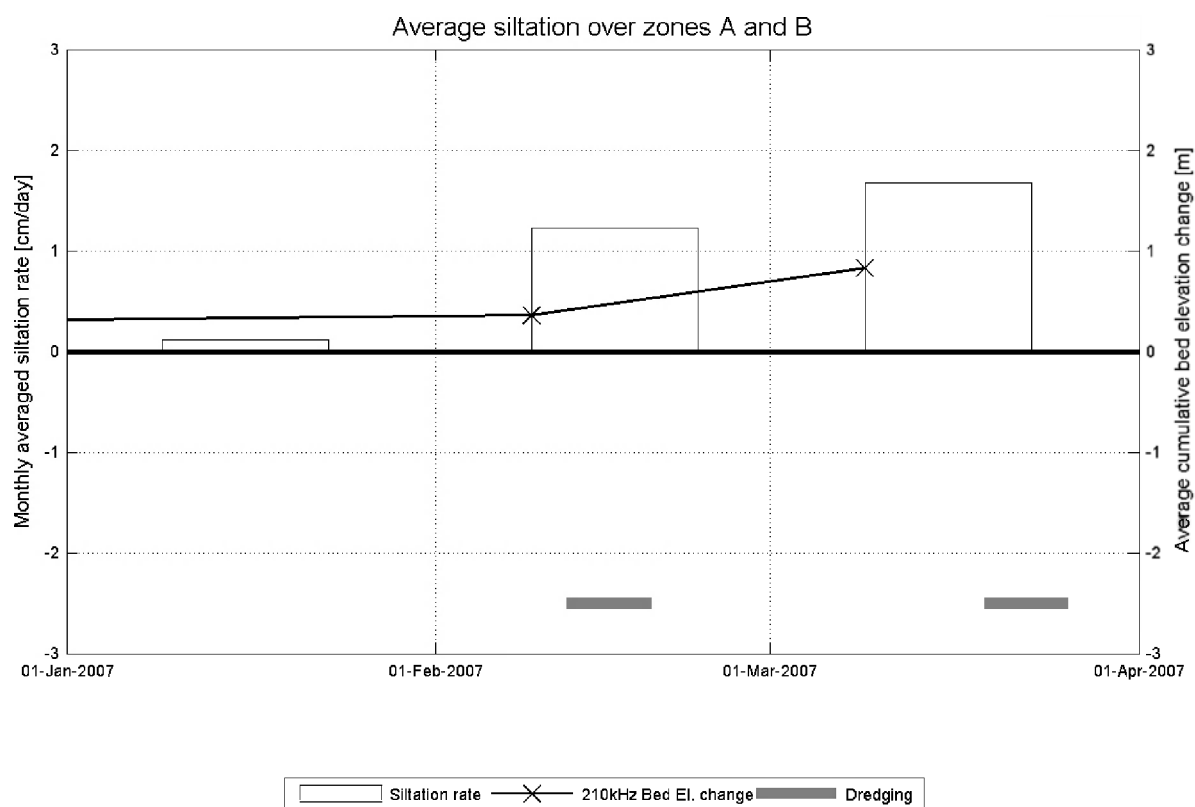
Long-term monitoring siltation Deurganckdok

Siltation height / monthly siltation rate

210kHz depth sounder

Location:

DGD



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

Data Processed by:

In association with :



I/RA/11283/06.116/MSA

APPENDIX D.

MEASURED MASS

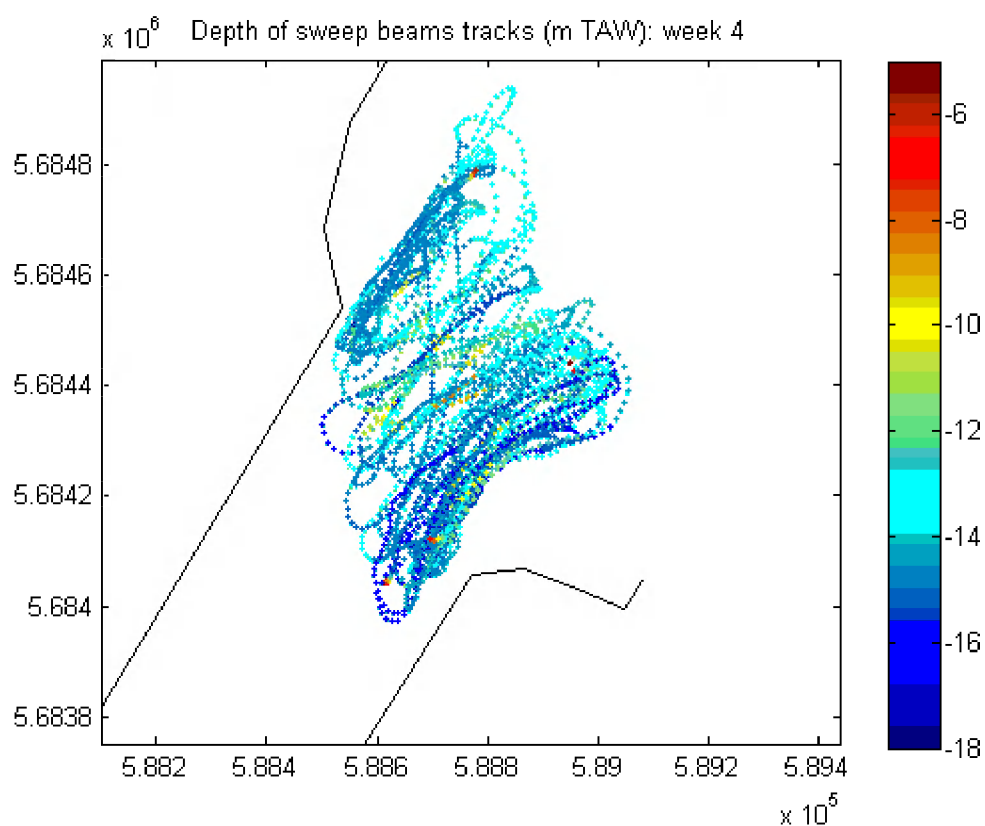
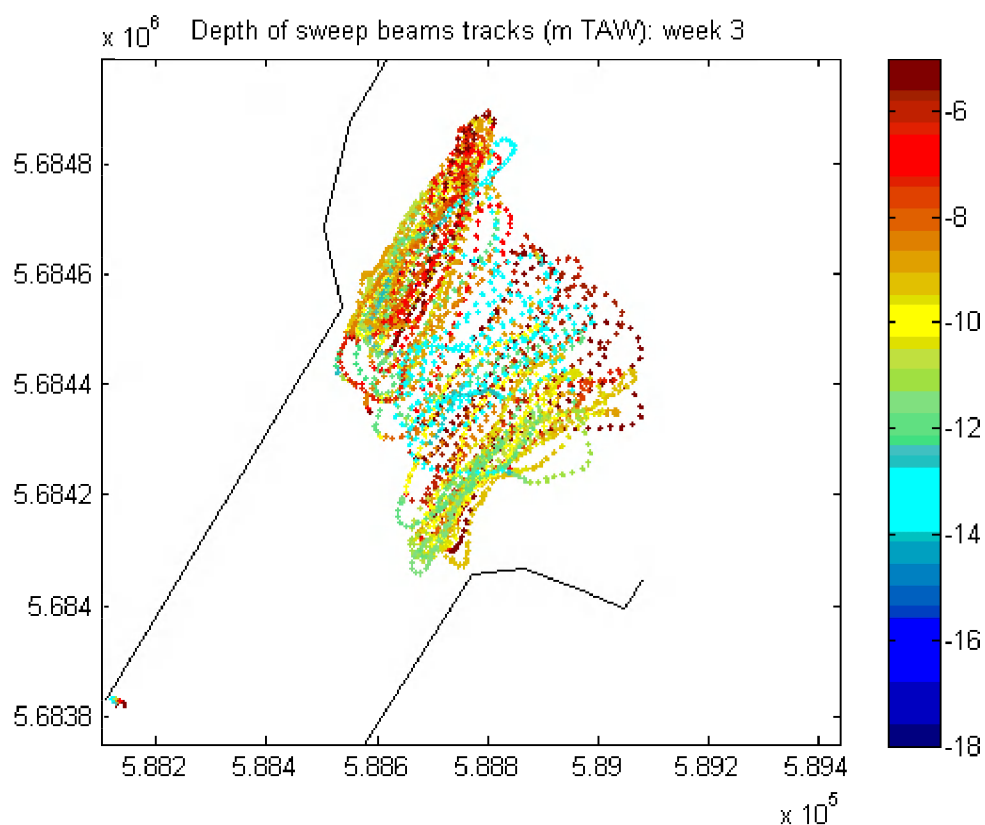
D.1 Tabular results

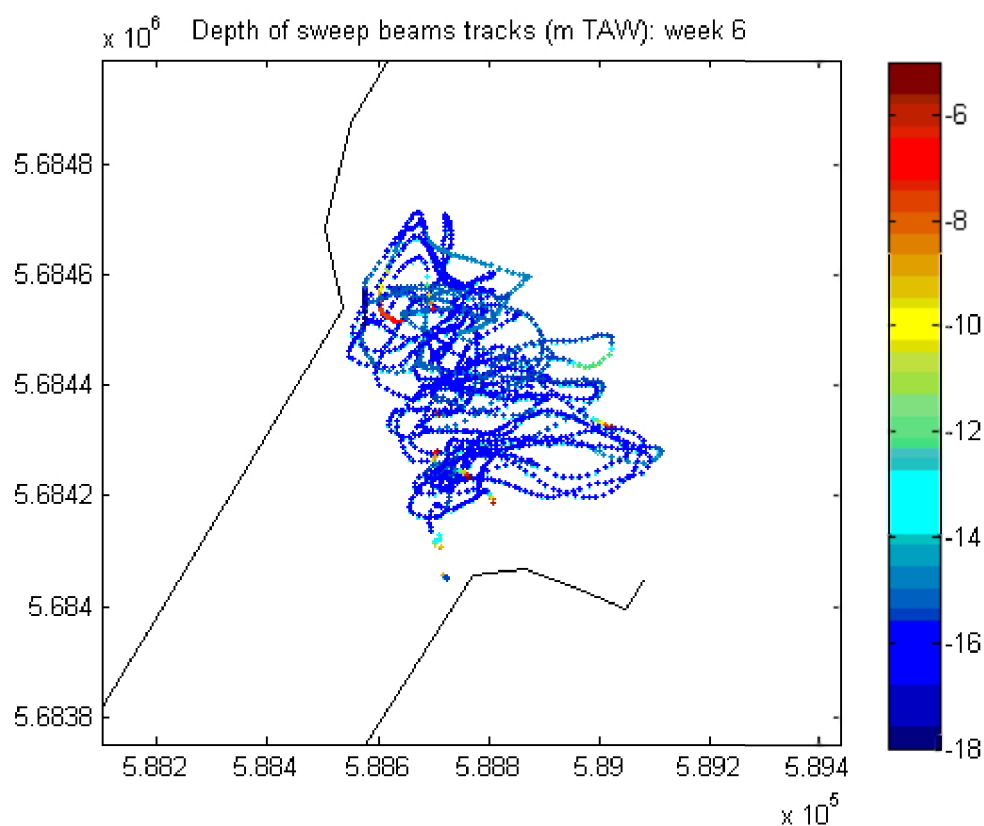
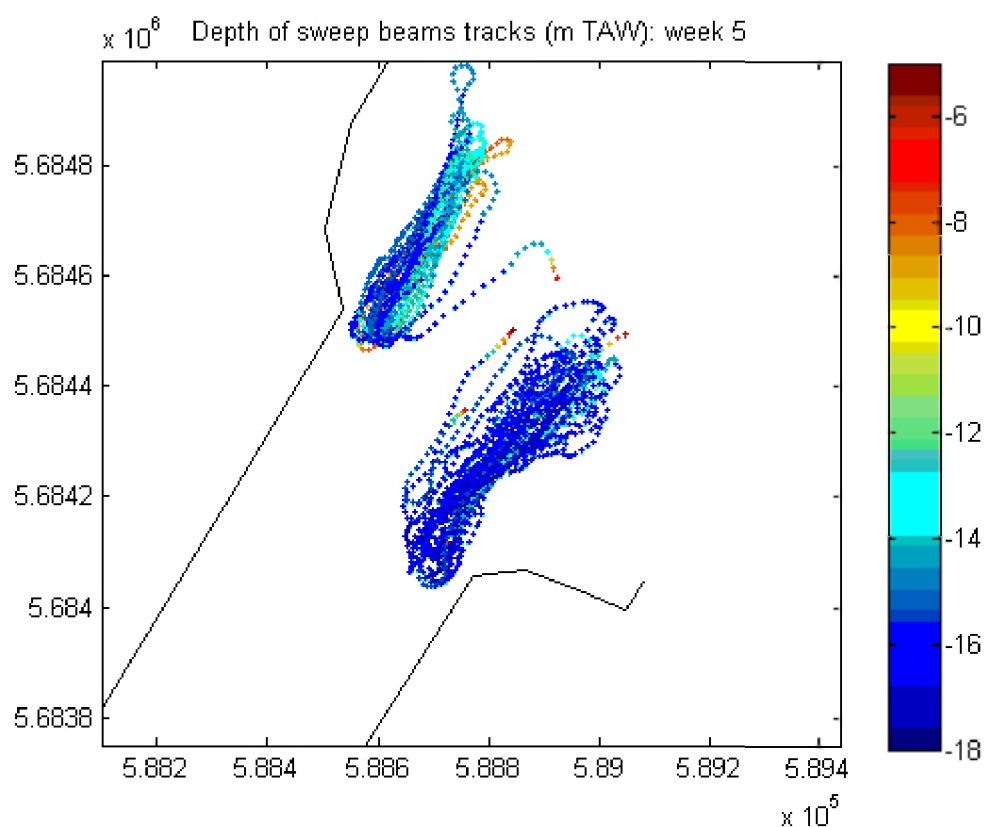
**Total dredged mass in covered area per week (TDS)		
	19-Feb-07	26-Mar-07
ZONE	26-Feb-07	02-April-07
1	0	5
2	3378	303
3a	178798	16023
3b	14465	30011
3c	0	23120
4Na	46529	4714
4Nb	29303	7783
4Nc	0	3852
4Za	15428	0
4Zb	14287	0
4Zc	0	0
5Na	793	0
5Nb	361	0
5Nc	0	0
5Za	0	0
5Zb	0	0
5Zc	0	0
Total	303342	85811

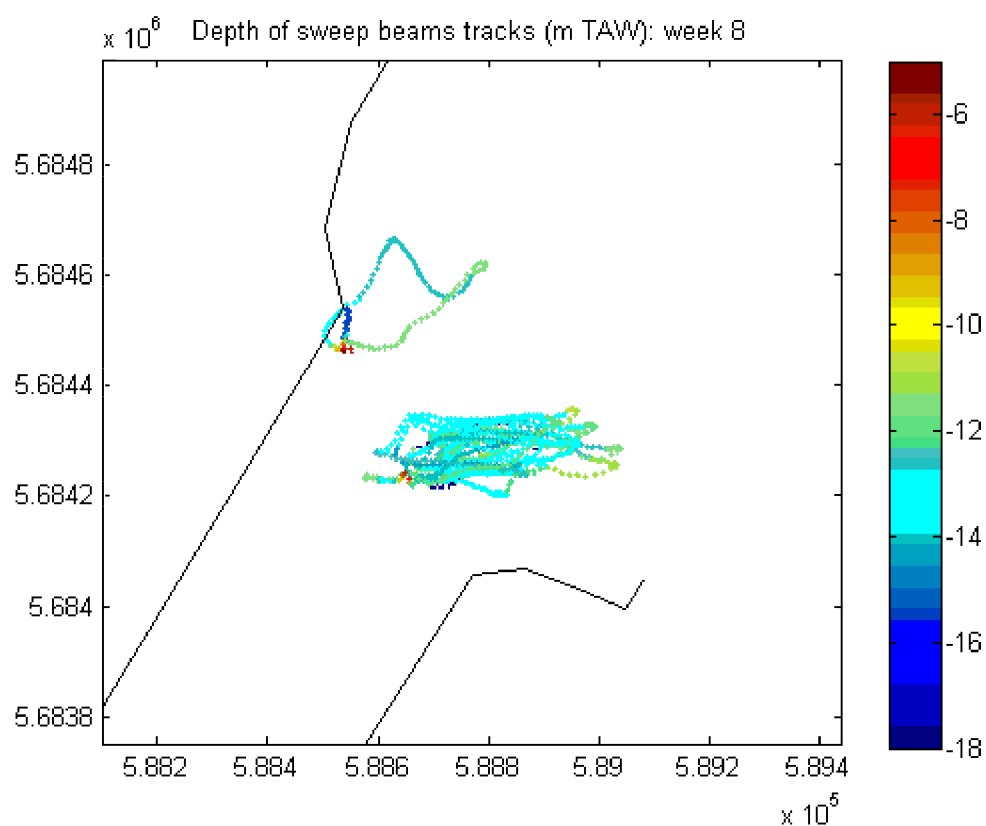
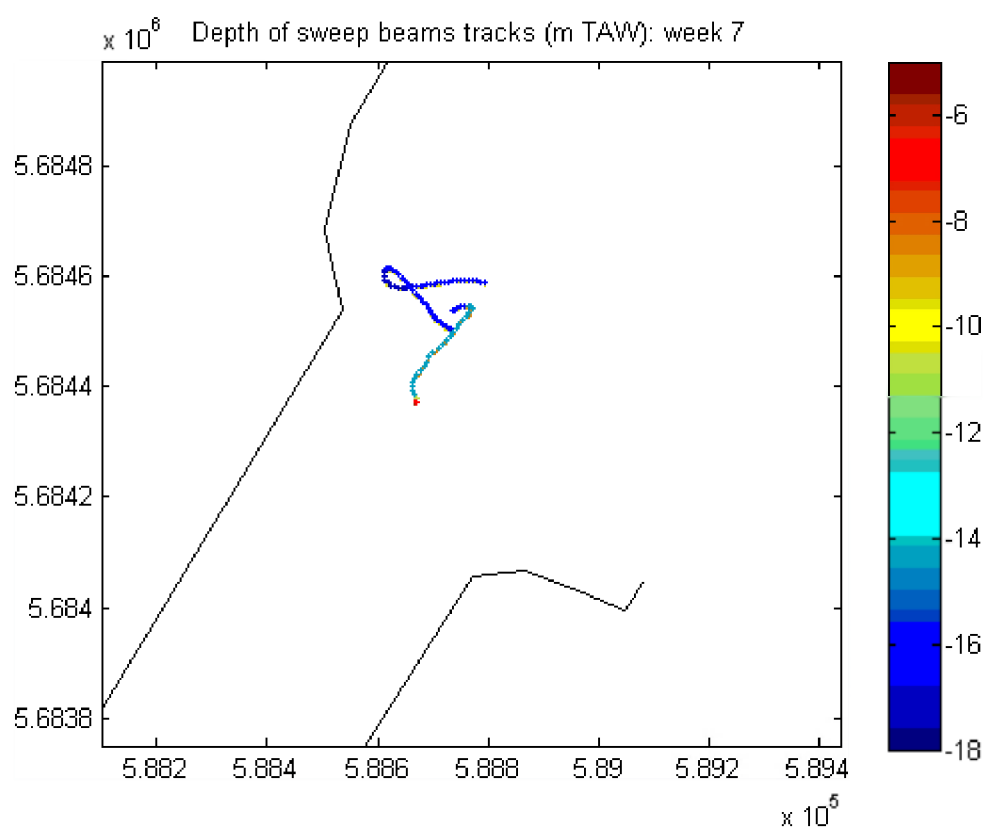
APPENDIX E.

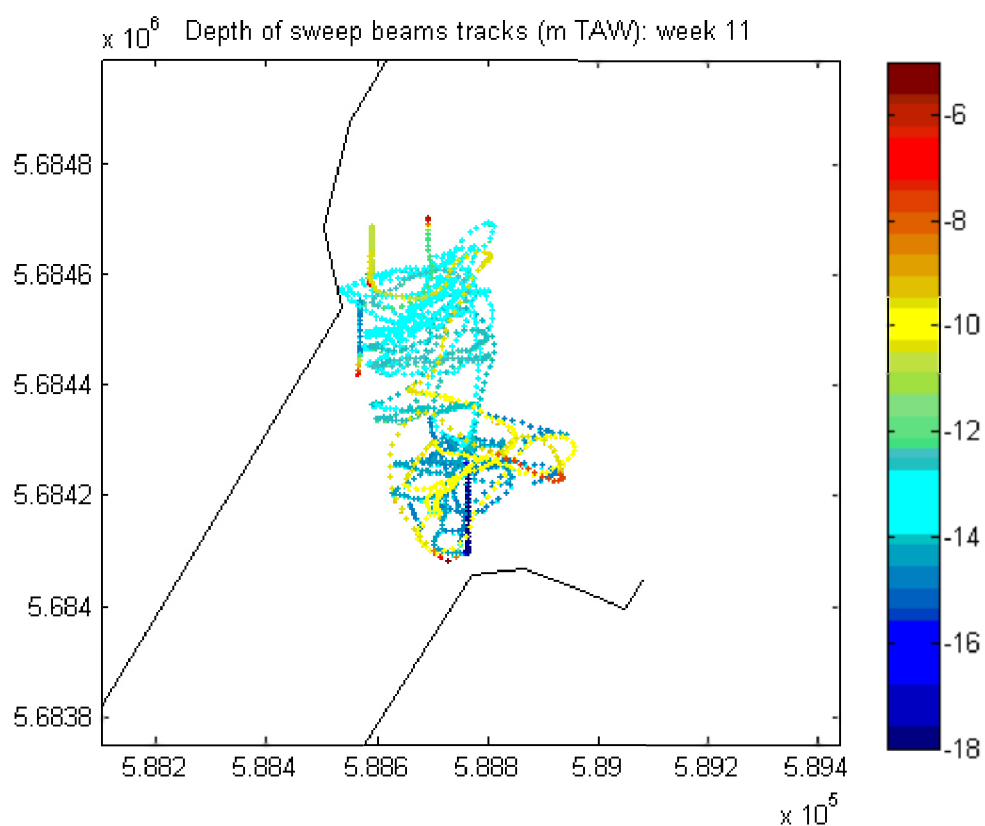
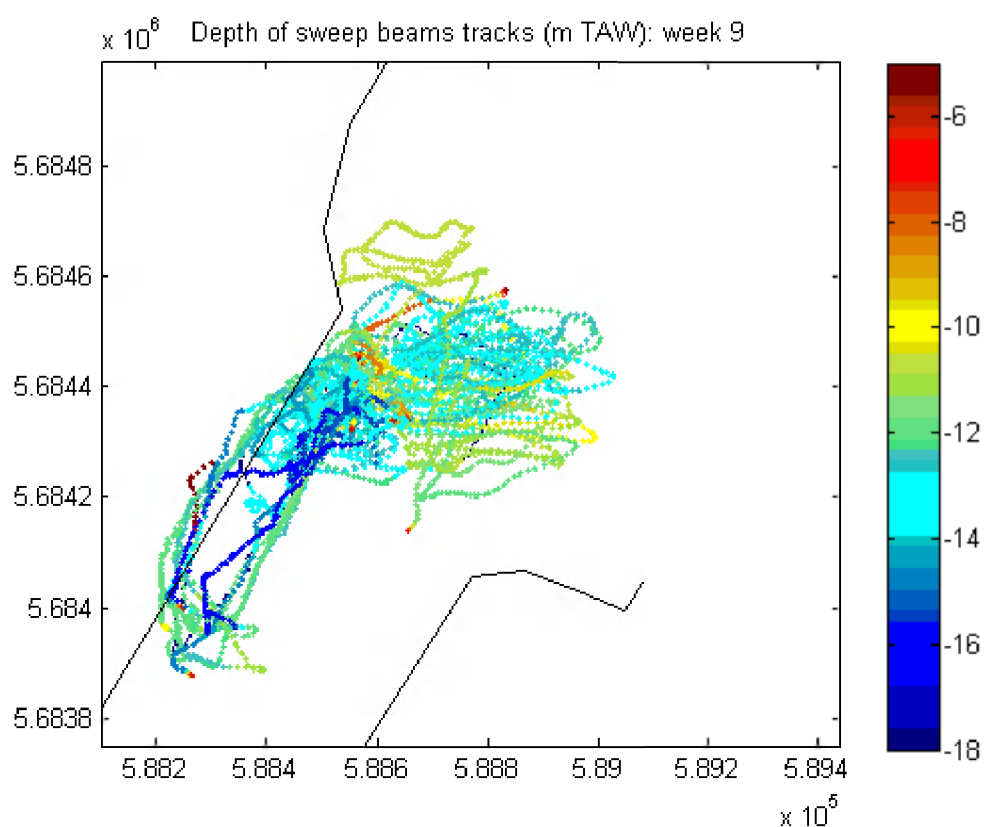
SWEEP BEAM TRACKS

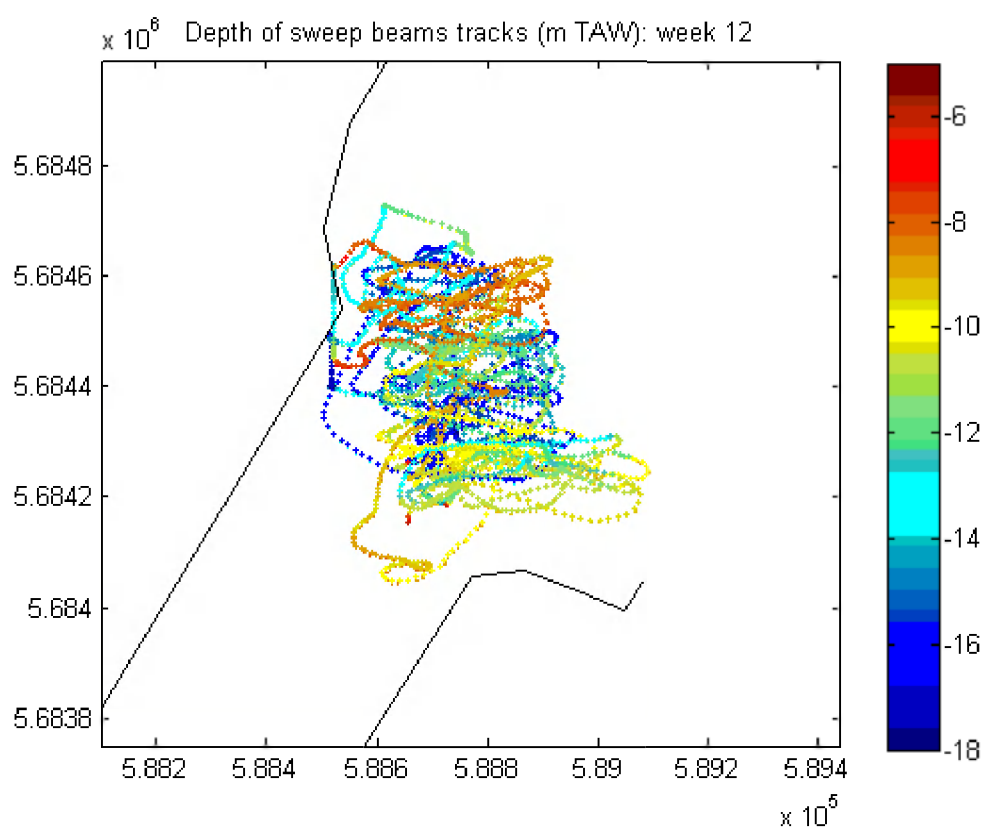
E.1 Depth of sweep beam tracks







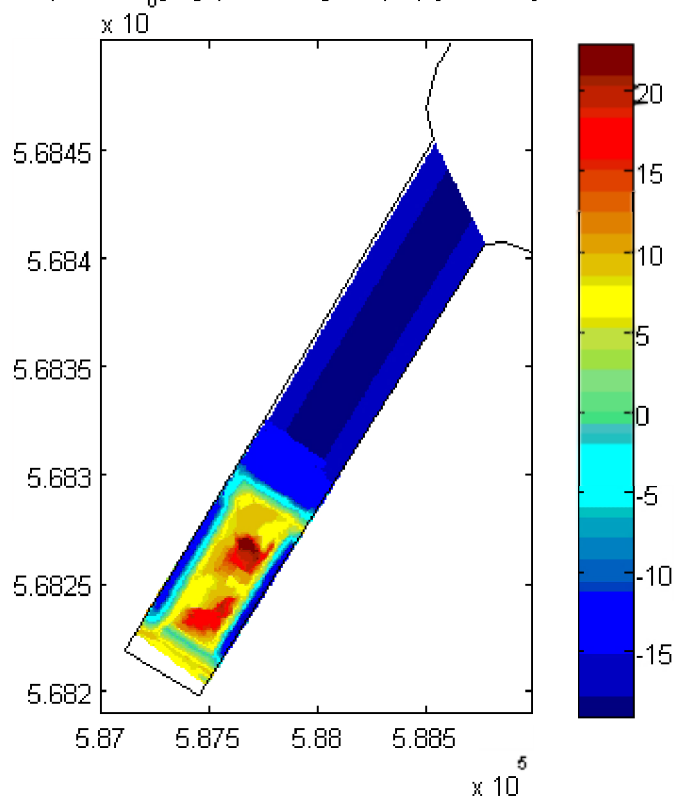




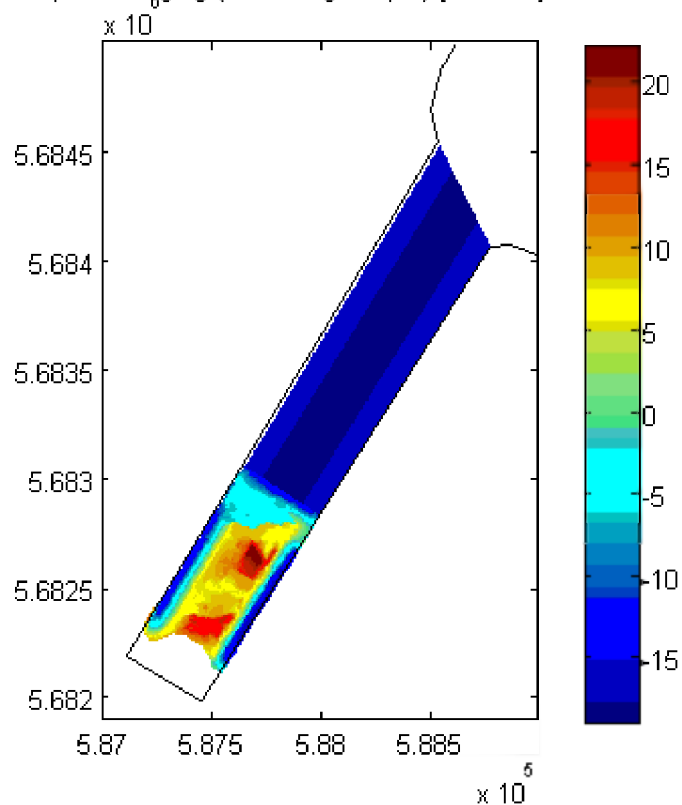
APPENDIX F.

CAPITAL DREDGING PROGRESS

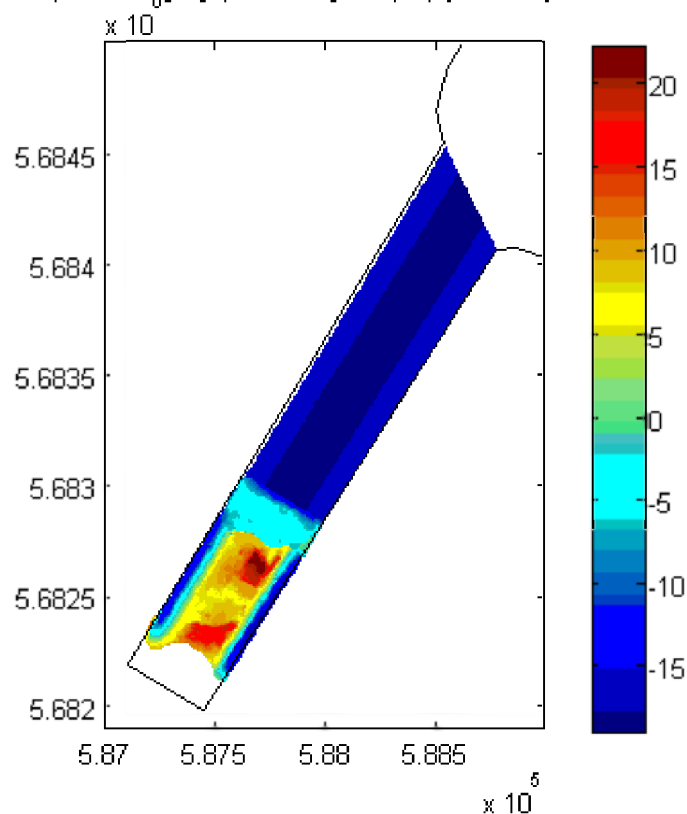
Depth of capital dredging (and design depth) [m TAW]: 14-Feb-2007



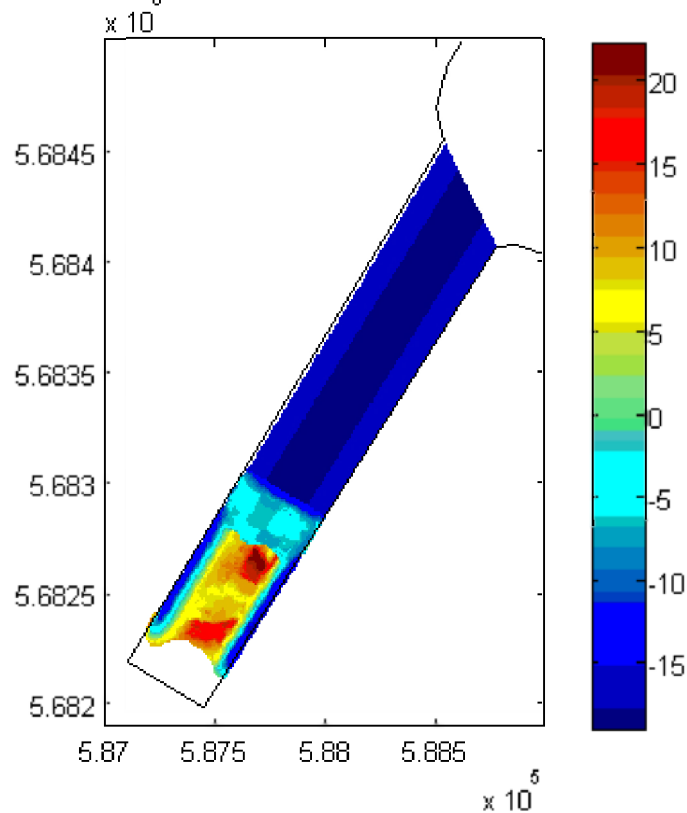
Depth of capital dredging (and design depth) [m TAW]: 14-Mar-2007



Depth of capital dredging (and design depth) [m TAW]: 19-Mar-2007



Depth of capital dredging (and design depth) [m TAW]: 26-Mar-2007



APPENDIX G.

HCBS2 REPORTS WINTER CAMPAIGN

Report	Description
Ambient Conditions Lower Sea Scheldt	
5.3	Overview of ambient conditions in the river Scheldt – January-June 2006 (I/RA/11291/06.088/MSA)
5.4	Overview of ambient conditions in the river Scheldt – July-December 2006 (I/RA/11291/06.089/MSA)
5.6	Analysis of ambient conditions 21/09/05 - 31/3/2007 (I/RA/11291/06.091/MSA)
Calibration	
6.1	Winter Calibration (I/RA/11291/06.092/MSA)
6.2	Summer Calibration and Final Report (I/RA/11291/06.093/MSA)
Through tide Measurements Winter 2006	
7.1	21/3 Scheldewacht – Deurganckdok – Salinity Distribution (I/RA/11291/06.094/MSA)
7.2	22/3 Parel 2 – Deurganckdok (I/RA/11291/06.095/MSA)
7.3	22/3 Laure Marie – Liefkenshoek (I/RA/11291/06.096/MSA)
7.4	23/3 Parel 2 – Schelle (I/RA/11291/06.097/MSA)
7.5	23/3 Laure Marie – Deurganckdok (I/RA/11291/06.098/MSA)
7.6	23/3 Veremans Waarde (I/RA/11291/06.099/MSA)
HCBS Near bed continuous monitoring (Frames)	
8.1	Near bed continuous monitoring winter 2006 (I/RA/11291/06.100/MSA)
INSSEV	
9	Settling Velocity - INSSEV summer 2006 (I/RA/11291/06.102/MSA)
Cohesive Sediment	
10	Cohesive sediment properties summer 2006 (I/RA/11291/06.103/MSA)
Through tide Measurements Summer	
11.1	Through tide measurement Sediview & Siltrofiler 27/9 Stream - Liefkenshoek (I/RA/11291/06.104/MSA)
11.2	Through tide measurement Sediview 27/9 Veremans - Raai K (I/RA/11291/06.105/MSA)
11.3	Through tide measurement Sediview & Siltprofiler 28/9 Stream - Raai K (I/RA/11291/06.106/MSA)
11.4	Through tide measurement Sediview 28/9 Veremans - Waarde(I/RA/11291/06.107/MSA)
11.5	Through tide measurement Sediview 28/9 Parel 2 - Schelle (I/RA/11291/06.108/MSA)
11.6	Through tide measurement Salinity Distribution 26/9 Scheldewacht – Deurganckdok(I/RA/11291/06.161/MSA)
Analysis	
12	Report concerning the presence of HCBS layers in the Scheldt river (I/RA/11291/06.109/MSA)