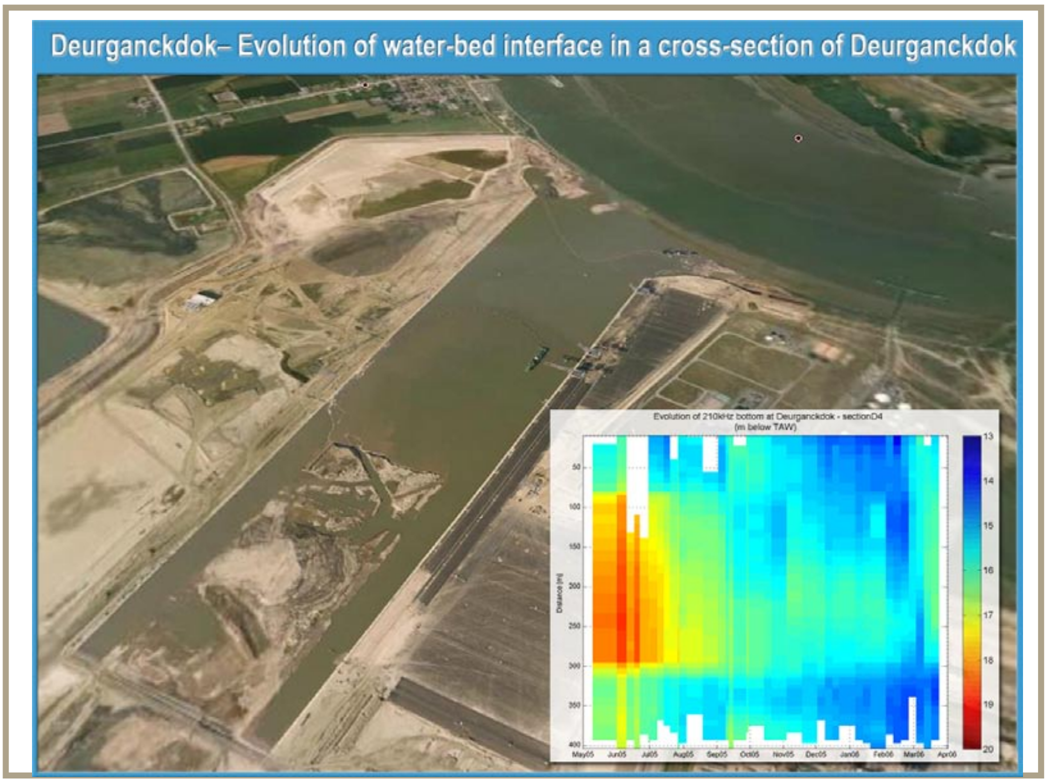
Vlaamse Overheid
Departement Mobiliteit en Openbare Werken

Waterbouwkundig Laboratorium

Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing Bestek 16EB/05/04



Prediction of sediment mass accumulation in DGD: April 2006-2007

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Photo coversheet: Deurganckdok

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1. INTRODUCTION

This memo is part of the study "Long-term measurements in Deurganckdok: monitoring and analysis of siltation". 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).

In a period of three years, i.e. April 2006 – April 2009, siltation of Deurganckdok was monitored. The study aimed at setting up a sediment mass balance. Therefore, bulk density measurements were performed on a regular basis. In parallel, depth sounding data were collected as well. The density measurements were executed from September 2007 on, resulting in one year and a half without any settled sediment mass data. From April 2006 till September 2007, only depth sounding data was collected.

This memo therefore tries to set up a relation between the temporal change of sediment mass and bed height in order to enable an estimation of the settled sediment mass in periods without any bulk density measurements.

The memo consists of the following chapters:

- overview of data availability in order to set up an empirical relationship between measured volumetric and densimetric bed changes (Chapter 2);
- applied methodology (Chapter 3)
- set-up of this empirical model (Chapter 0);
- model validation (Chapter 5);
- application of the empirical model (Chapter 6); and
- conclusions (Chapter 7)

2. AVAILABLE DATA

Data is available with respect to dredging amounts, bulk density and sediment bed height for the period April 2006 until April 2009. Data use was not restricted to only the second measurement year (with respect to density measurements) in order to have a larger data set. A chronological overview is given in Table 1. The table clearly indicates that density measurements were only available from September 2007 on. Remark that density measurements were performed with the Navitracker device till August 2008, after which the DensiTune was used. This has an influence on the density measurements, cf. IMDC (2010).

Table 1: Overview of data availability in the period

depth sounding	***density profiles***	***dredging***	
		start	end
		20/02/2006	25/02/2006
		27/02/2006	28/02/2006
		6/03/2006	11/03/2006
		13/03/2006	18/03/2006
		20/03/2006	25/03/2006
24/03/2006			
14/04/2006			
21/04/2006			
28/04/2006			
		30/04/2006	6/05/2006
12/05/2006			
		14/05/2006	21/05/2006

depth sounding	***density profiles***	***dredging***	
		start	end
26/05/2006		22/05/2006	28/05/2006
		29/05/2006	4/06/2006
9/06/2006		6/06/2006	10/06/2006
30/06/2006			
7/07/2006		3/07/2006	8/07/2006
27/07/2006			
4/08/2006			
7/08/2006			
		21/08/2006	27/08/2006
1/09/2006		28/08/2006	3/09/2006
21/09/2006			
		2/10/2006	8/10/2006
		9/10/2006	15/10/2006
		16/10/2006	22/10/2006
23/10/2006			
8/12/2006			
09/02/2007			
		19/02/2007	25/02/2007
09/03/2007			
		26/03/2007	31/03/2007
		2/04/2007	7/04/2007
		9/04/2007	14/04/2007
27/04/2007			
23/05/2007			
22/06/2007			
27/07/2007			
		20/08/2007	25/08/2007
		27/08/2007	31/08/2007
31/08/2007			
05/09/2007	05/09/2007		
16/10/2007	16/10/2007		
16/11/2007	16/11/2007		
		19/11/2007	24/11/2007
		26/11/2007	30/11/2007
05/12/2007	05/12/2007		
25/01/2008	24/01/2008		
		28/01/2008	03/02/2008
		04/02/2008	10/02/2008

depth sounding	*density profiles*	*dredging*	
		start	end
		11/02/2008	17/02/2008
15/02/2008	22/02/2008		
		18/02/2008	24/02/2008
		03/03/2008	09/03/2008
11/03/2008			
11/04/2008			
	28/4/2008		
9/05/2008			
		12/05/2008	18/05/2008
		19/05/2008	25/05/2008
		26/05/2008	01/06/2008
04/06/2008	05/06/2008		
11/08/2008	11/08/2008		
		11/08/2008	17/08/2008
		18/08/2008	24/08/2008
26/08/2008	26/08/2008		
3/09/2008	11/09/2008		
22/09/2008			
6/10/2008			
20/10/2008	20/10/2008		
		20/10/2008	26/10/2008
7/11/2008	6/11/2008		
28/11/2008			
15/01/2009			
11/02/2009	30/01/2009	9/02/2009	15/02/2009
		16/02/2009	23/02/2009
		24/02/2009	1/03/2009
3/03/2009			
17/03/2009	12/03/2009		
		02/04/2009	02/04/2009

3. METHODOLOGY

In order to calculate the sediment mass growth based on a time series of depth sounding data of Deurganckdok, an empirical relation between these two variables is to be set up. Experience gained during the sediment balance analysis reports is applied. It was indeed observed that increased siltation rates, both volumetric and densimetric, occur after dredging activities. These siltation rates lower till a steady value (as long as the hydrodynamic conditions inside the dock do not change too drastically).

From Table 1, it is clear that no systematic depth soundings have been performed immediately before and after dredging during the first year of measurements. This complicates the calculations because, from time to time, only one depth sounding measurement is performed between two subsequent dredging operations. In order to calculate the sediment mass growth in the different dock zones, a conceptual model for the situation of subsequent depth soundings with intermittent dredging is proposed in Figure 1. An important assumption here is made with respect to the dredging impact on the density profile and is based on the (i) measured density profiles, and (ii) dredging operation method:

- dredging operation method:

  Till August 31st 2007, the hopper head sucked away the sediment mixture at -17 m TAW. In a second run, the remaining sediment was dredged at the same depth. It was however experienced that the non-dredged top bed layer did not settle that quickly so the second run was unable to remove the top layer. See phase 3 in Figure 1.

- bulk density profiles:

  Although the bulk density profiles are influenced by subsequent dredging operations, it is assumed that a “smooth” profile exists as shown in phase 1 of Figure 1. With respect to time periods without dredging, one is referred to §0 and Figure 4. However, after dredging, the top bed layer settles again and is slightly stirred up by dewatering processes like channeling. It is here assumed that this does not affect the local bulk density, i.e. the top layer is simply vertically translated resulting in the bulk density profile of phase 4 in Figure 1. The resulting density at -17 m TAW does not show large vertical gradients so that the profile before dredging is not altered a lot.

With the assumptions mentioned above, the mass growth can be estimated in two possible ways:

- calculate mass growth with an empirical relation, and add the dredged mass to the calculated mass growth;
- calculate the mass growth with an empirical relation, but with volumetric changes corrected for the dredged mass.

In the latter case, a representative bulk density at -17 m TAW should be determined from the density measurements for, e.g., the period September 2007 – August 2008. Based on 356 density profiles, an average density of 1.208 ± 0.083 TDS/m³ could be determined at a depth of -17 m TAW (Figure 2). However, this method of corrected volumetric changes returned a too large sediment accumulation in the dock in comparison to the former method (~24%) and the results of IMDC (2008). Therefore, the former method is selected.

Because predictions of sediment mass growth are made based on statistically determined relations, uncertainty on the predictions should be considered. For this reason, prediction confidence intervals for the mass growth (see Seber and Wild (1989) for the methodology) are determined. Note however that other uncertainties are unquantified and are related to:

- conceptual model assumptions;
- uncertainty on dredged mass amount;
- using the model outside its calibration range;
- …

From the measurements, it is possible to compute the total sediment mass from density profiles and the sediment volume from the depth soundings (i.e. 210 kHz acoustic reflectance signal) for the different defined zones in Deurganckdok. Computed correlations between these two variables are large. Temporal changes of these variables are small in comparison to the total values and, therefore, explains the large correlations (~0.91 for zones 3A-C). It has indeed been observed that correlations between the temporal change of sediment mass and volume are much lower (~0.56 for zones 3A-C). Predictions of temporal increments of bed heights and accumulated sediment mass are nevertheless preferred because it is this variability one is interested in.

In order to determine the relationship with a minimum of external influences, it is crucial to consider mass and volume increases in periods undisturbed by dredging activities. Further, it is very important to validate the calibrated model and investigate whether the model returns good predictions outside its validation range. For that reason, it is decided to split the data set in two for model calibration and validation:

- calibration period: 09/2007 – 08/2008
- validation period: 09/2008 – 04/2009

From Table 1, only four calibration periods are determined being undisturbed by dredging.

The model parameter estimation is performed by minimizing the sum of squared errors between observed and calculated values. For the prediction of sediment accumulation, the 95% prediction confidence interval is determined based on the methodology of Seber and Wild (1989).

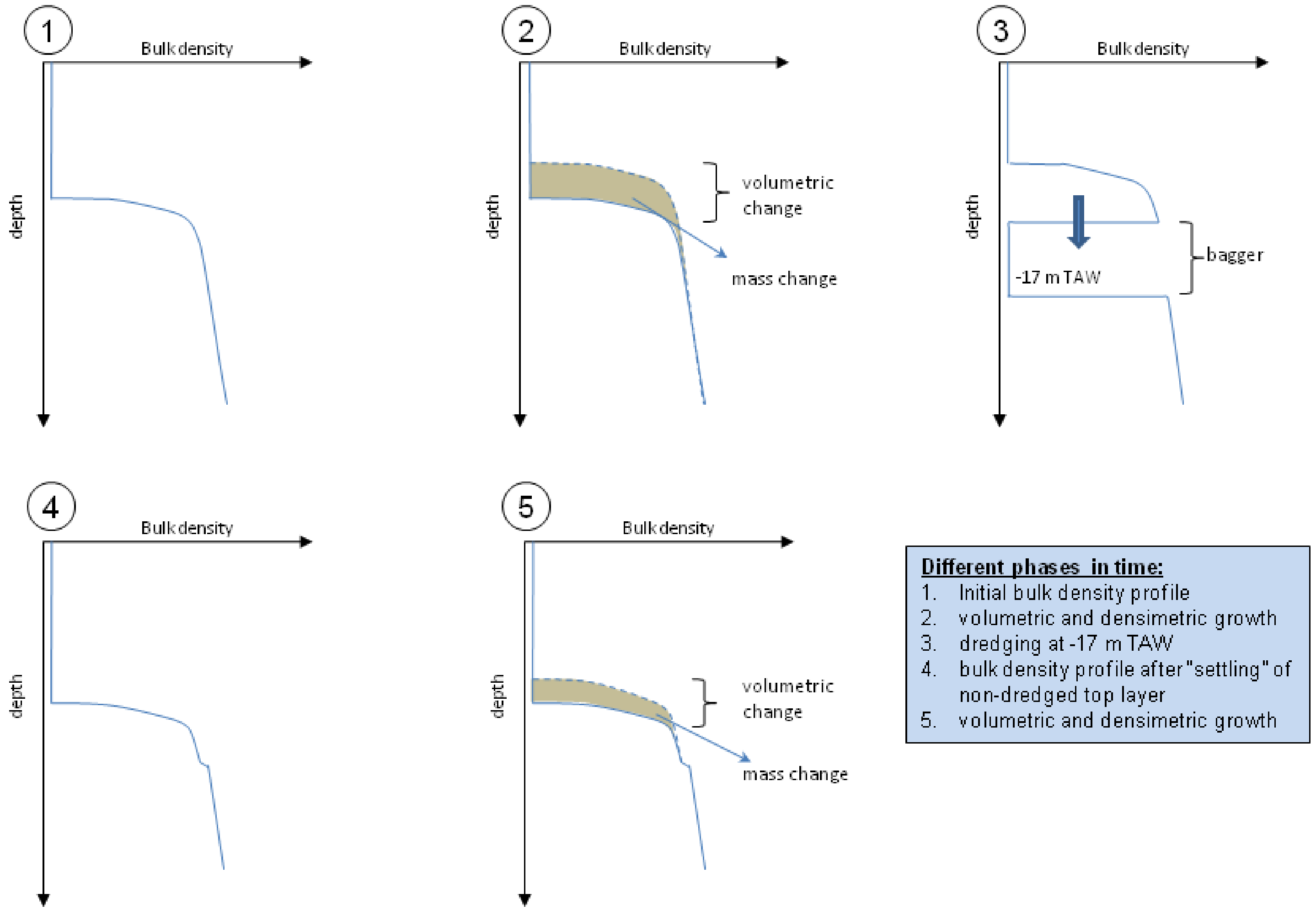

Figure 1: Conceptual siltation model with dredging

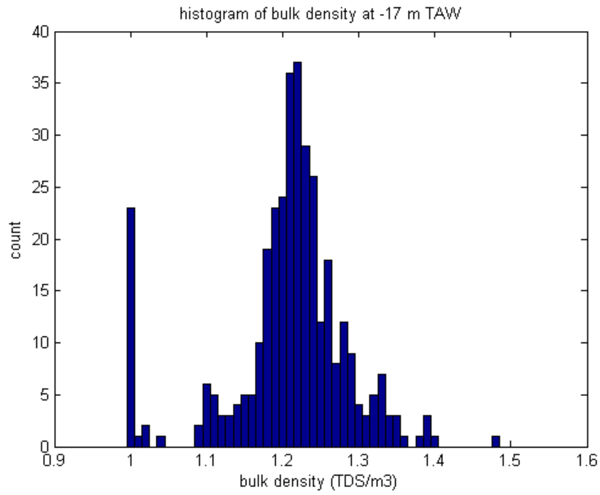

Figure 2: Histogram of measured bulk densities in Deurganckdock at -17 m TAW

4. MODEL IDENTIFICATION AND PARAMETER ESTIMATION

In the different dock zones, sediment settles and consolidates resulting not only in a change of the bed height but also in the bulk density profile. Without any external disturbances like dredging, it is hypothesized that the bed height increases and the density profile is vertically translated to a certain extent. An example is shown in Figure 3. After a dredging operation, a rapid sediment accumulation in the dock occurs because the sediment bed is situated lower than the sill level (appr. -13.5 m TAW); hence, the dock can be considered as a sediment trap.

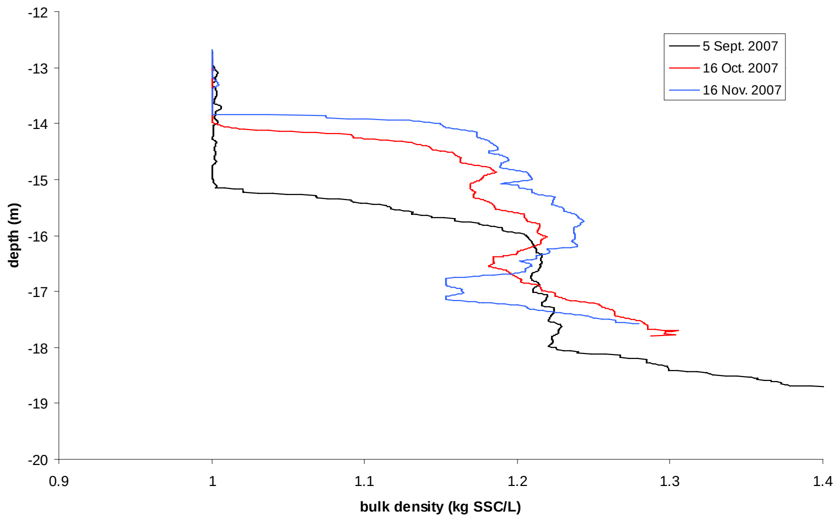

Figure 3: Bulk density profiles in zone 3B of Deurganckdok on 5 September, 16 October and 16 November 2007

When only focusing on the temporal change in sediment mass and volume, one can write the following simple first-approach relation (see Figure 4):

$$\Delta M = \Delta V.\overline{X} \qquad \text{(Eq 1)}$$

with:

$\Delta M: change\ in\ mass\ (TDS)$

$\Delta V: volumetric\ change\ (m^3)$

$\overline{X}: average\ sediment\ concentration\ (\frac{TDS}{m^3})$

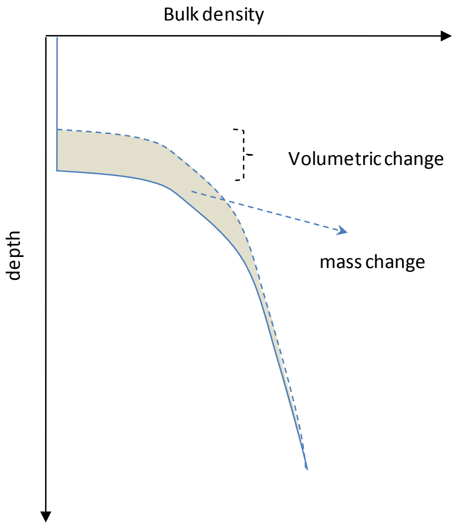

Figure 4: conceptual drawing of volumetric and densimetric change

This simple relation leads to a correlation of 0.74; a lot of variation is still unexplained by the model as shown in Figure 5. The average sediment concentration is here calculated as 0.293 TDS/m³. This corresponds to a bulk density of 1.18 tonnes/m³, which is in the range of concentrations at the top of the sediment bed, cf. Figure 3.

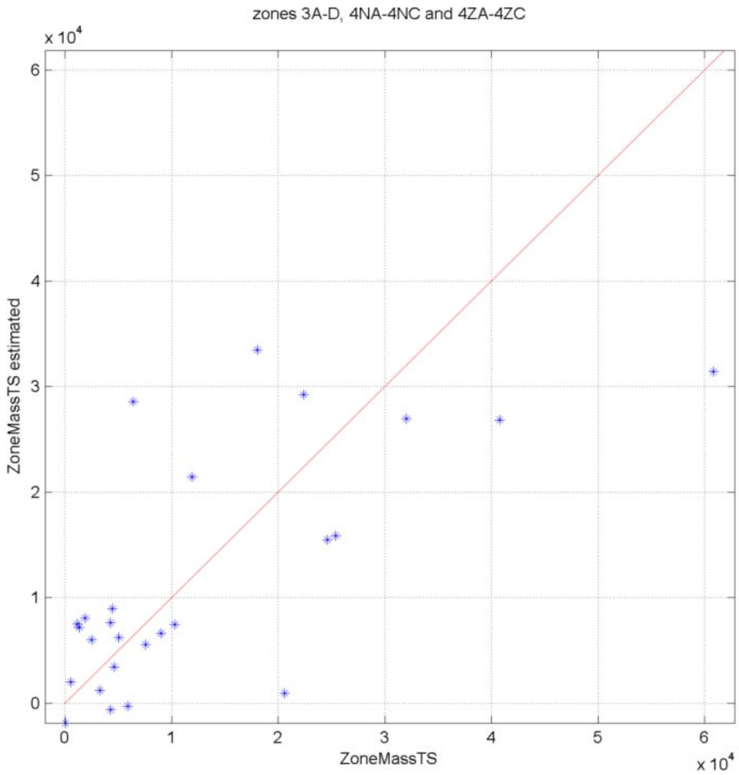

Figure 5: Comparison between measured and computed sediment mass changes (TDS), assuming a linear relationship (Eq. 1) between sediment mass and volume (parameter equals bulk density)

The change in siltation rate along the dock's length is intrinsically considered in the temporal and spatial change of volume and sediment mass. However, several physical phenomena are not considered in this simple relationship, such as increased siltation rates after dredging. More specifically, it was observed that:

- the densimetric mass growth rate increased with the total dredged amount;

- the densimetric mass growth rate decreased with the time period between dredging operation and depth sounding.

In order to investigate the importance of different variables, the correlation matrix is calculated between:

- the mass change between two subsequent density measurements (ΔM)
- the (sediment) volumetric change between two subsequent depth soundings (ΔV);
- the mass dredged between two subsequent density measurements (M_d);
- the time period between two subsequent depth soundings ($\Delta T_{ds\text{-}ds}$); and
- the time between the depth sounding and the last occurring dredging moment ($\Delta T_{d\text{-}ds}$).

Remark however that the correlation matrix assumes a linear relationship between the different variables. This is not necessarily the case, but the correlation allows the identification of important relationships between the mass change and other variables. The results are shown in Table 2, from which can be concluded that:

- a large correlation of 0.87 exists between ΔM and M_d: this confirms the observation of faster siltation in function of the amount of dredged mass;
- a large correlation of 0.74 exists between ΔM and ΔV (as expected);
- ΔM is negatively correlated with $\Delta T_{d\text{-}ds}$, i.e. the longer the depth sounding is separated from the dredging moment, the lower the mass accumulation is.
- $\Delta T_{ds\text{-}ds}$ and $\Delta T_{d\text{-}ds}$ show a large positive correlation so one of them can be considered as redundant.

Table 2: Correlation matrix between different variables

	ΔM	**ΔV**	**M_d**	**$T_{ds\text{-}ds}$**	**$T_{d\text{-}ds}$**
ΔM	1	0.74	0.87	0.28	-0.17
ΔV	0.74	1	0.70	-0.04	0.09
M_d	0.87	0.70	1	0.22	-0.18
$T_{ds\text{-}ds}$	0.28	-0.04	0.22	1	-0.75
$T_{d\text{-}ds}$	-0.17	0.09	-0.18	-0.75	1

From these results, it seems obvious to retain a linear relationship between ΔM and M_d. A comparison between calculated and observed mass changes is shown in Figure 6. Clearly, the results can be improved. After testing several model structures, it appeared that an exponential relation between ΔM and M_d, in combination with ΔV, gave good results with a correlation of 0.95. Note that the exponential relation alone gave a correlation of 0.74; the cause of the improved correlation can be attributed to the large correlation between M_d and ΔV. Their appearance together in Eq. 2 results in an improved model performance, see Figure 7.

$$\Delta M = \Delta V.\overline{X}.e^{\alpha.\Delta M_d} \qquad \text{(Eq. 2)}$$

with:

$\Delta M_d: dredged\ sediment\ mass\ (TDS)$

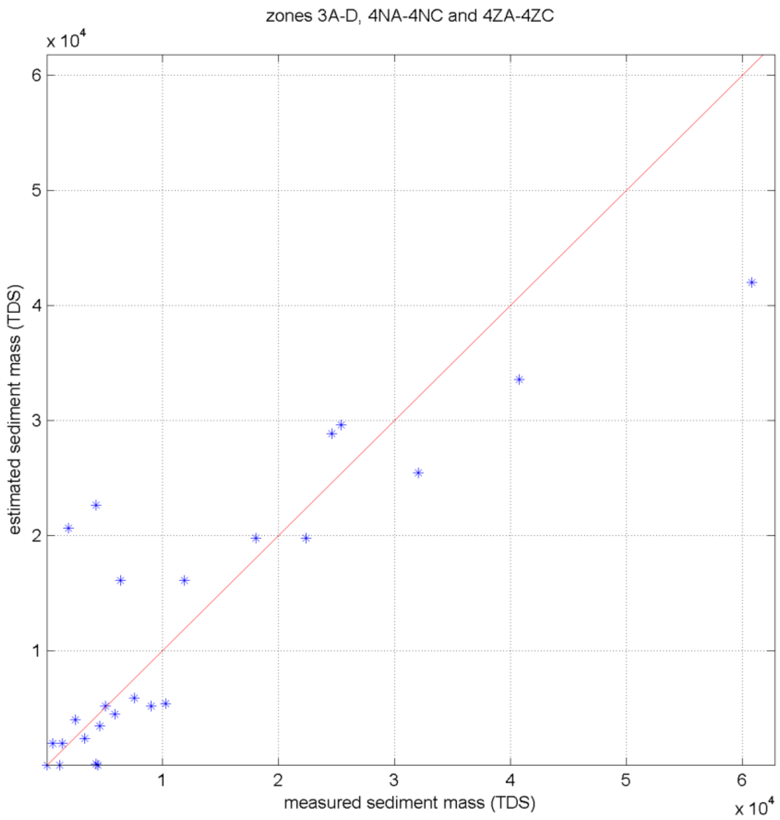

Figure 6: Comparison between measured and computed sediment mass changes (TDS), assuming a linear relationship between sediment mass and amount of dredged mass

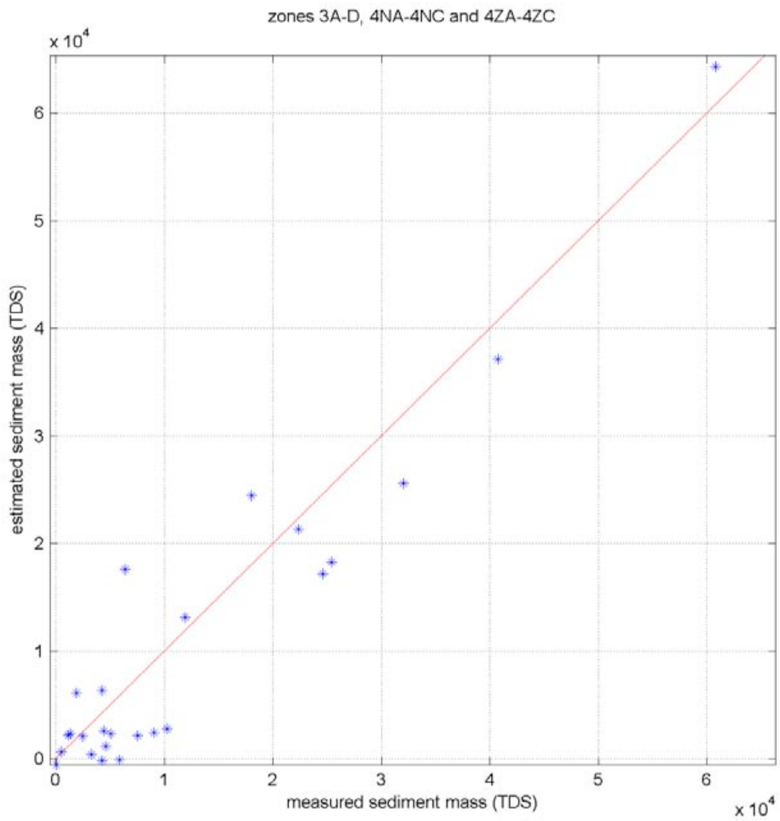

Figure 7: Comparison between measured and computed sediment mass changes (TDS), assuming the non-linear relationship of Eq. 2

Further extending Eq. 2 with a correction term for $\Delta T_{d\text{-}ds}$ results in a correlation coefficient of 0.97:

$$\Delta M = \Delta V.\overline{X}.e^{\alpha.\Delta M_d + \beta.\Delta T_{d-ds}} \qquad \text{(Eq. 3)}$$

with:

ΔT_{d-ds}: *time between dredging and depth sounding (days)*

Results of the model performance are shown in Figure 8.

Physically, the latter correction can be interpreted as follows: when dredging takes place, the upper sediment layers are removed. As long as the sediment bed is situated deeper than the sill level, sediment is trapped in the dock and accumulates quickly. When the sediment bed approaches the sill level, sediment accumulation slows down. As a result, the calculated sediment mass change increases with the amount of dredged sediments and the time between dredging and the depth sounding.

The model parameters for Eq. 2 and 3 are summarized in Table 3.

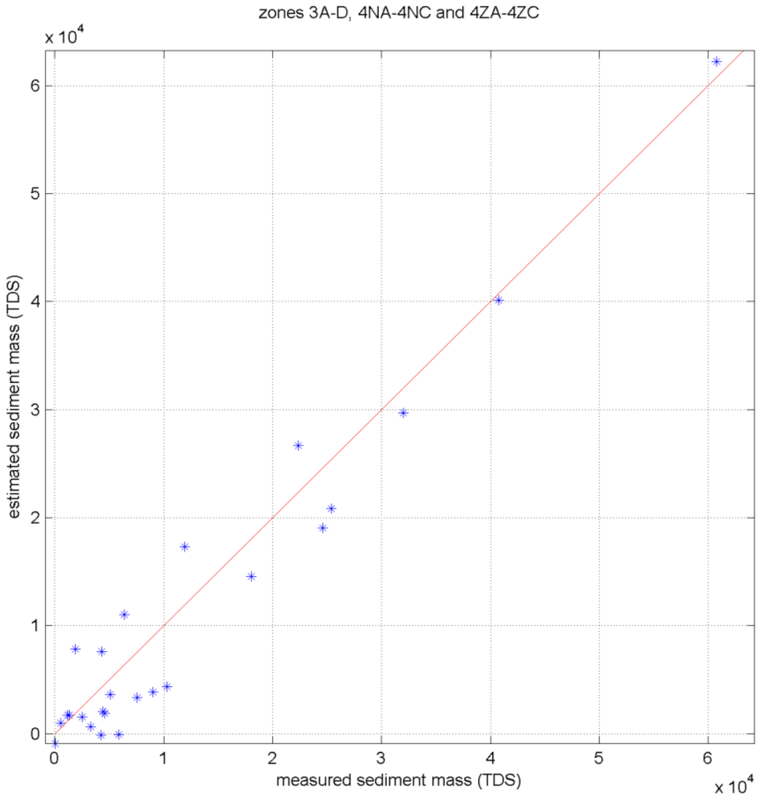

Figure 8: Comparison between measured and computed sediment mass changes (TDS), assuming the non-linear relationship of Eq. 3

Table 3: Summary of parameter values applied in the empirical relationships

Parameters	***Eq. 2***	***Eq. 3***
$\overline{X}\left[\frac{TDS}{m^3}\right]$	0.0858	0.1523
$\alpha\ \left[\frac{days}{TDS}\right]$	1.6018 10^{-5}	1.1467 10^{-5}
$\beta\ [days^{-1}]$	-	-0.018

5. MODEL VALIDATION

The aim of this chapter is to validate the statistical sedimentation model with an independent data set of depth sounding, dredging amounts and densimetric measurements. The validation data consists of densimetric measurements performed in the period September 2008 – March 2009. Comparison plots of observed vs. measured values cannot be prepared because times of predictions and observations do not correspond. For that reason, trend plots of both computed and measured sediment mass accumulation are made. Results are shown in Figure 9 for both investigated models (cf. Eq. 2 and Eq. 3), and clearly indicate that both Eq. 2 and 3 underpredict the sediment mass accumulation.

The cause of this underestimation is related to the use of a different density measurement technique than the one applied during the calibration period, i.e. the DensiTune is applied in the validation period instead of the Navitracker. IMDC (2010) remarks that the DensiTune systematically overestimates local densities which may explain the differences between computations and observations in Figure 9. When accounting for an average overestimation of 0.41 TDS/m² (see IMDC, 2010) for zones 3A-D, 4NA-C and 4ZA-C, a correction on the computed accumulated sediment mass can be made. The results are shown in Figure 10 for both Eq. 2 and Eq.3. Clearly, Eq. 3 performs best and will be retained for the prediction of accumulated sediment mass in the period March 2006 – August 2007 (see §6).

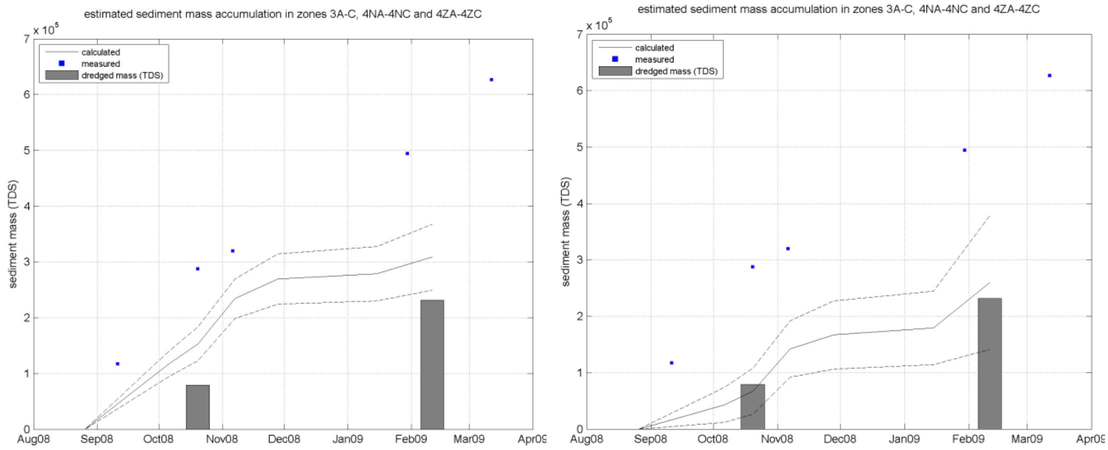

Figure 9: Estimated sediment mass accumulation with its 95% prediction confidence interval for the investigated models: Eq 2. (left) and Eq. 3 (right)

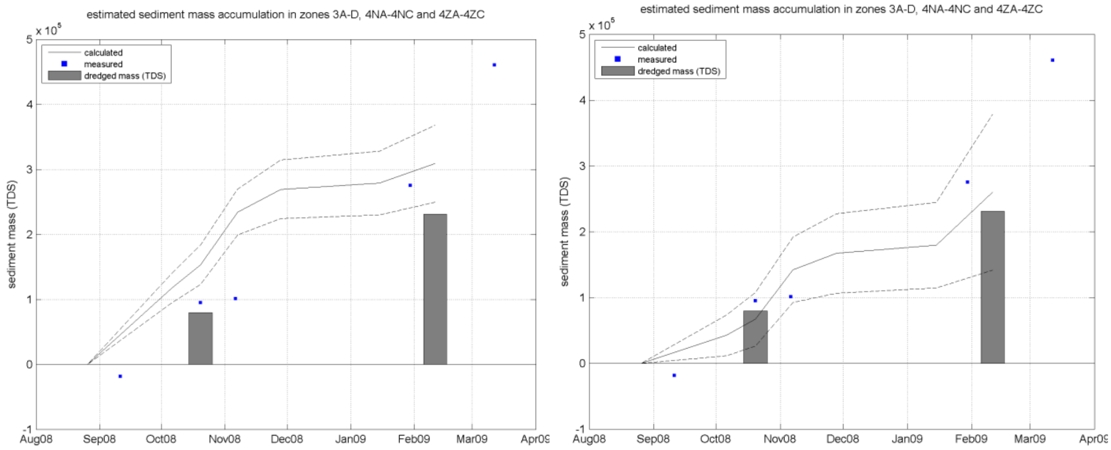

Figure 10: Estimated sediment mass accumulation with its 95% prediction confidence interval for the investigated models, Eq 2. (left) and Eq. 3 (right), with a density correction for the use of the DensiTune

6. PREDICTION OF DENSIMETRIC SILTATION

The goal of the statistical model is to predict the sediment mass growth in Deurganckdok in the period of 24/03/2006 – 31/08/2007. This period includes the measurement campaigns of the measurement campaigns DGD 1 and the first half of DGD 2. The latter in included because also for this period no density measurements were available. An overview of available data with respect to dredging and depth soundings is given in Table 5.

Results of the predicted sediment mass growth rate are shown in:

- Table 6: predicted mean sediment mass growth rates with their 95% prediction confidence intervals;
- Figure 11: predicted total sediment mass accumulation in zones 4A-C, 4NA-NC and 4ZA-4ZC with its 95% prediction confidence interval; also the dredging times are indicated. Clearly, increased siltation of the dock is computed after dredging, in correspondence with previous observations (eg. IMDC (2007))

A model validation has already been performed in §5. Further, an evaluation of the prediction quality can also be made with:

- measured mass growth rates in the periods of August – October 2005 and September 2007 – September 2008 (see Table 7):
  Table 7 clearly indicates that measured sediment mass growth rates generally situate in the 95% confidence interval of the predicted growth rates. Note that the confidence intervals are large, which is proportional to the original data heterogeneity. Sweepbeam dredging is e.g. not included in the model as indicated in Eq. 2 and, thus, its exclusion from the model will lead to possible inaccurate calculations. Obviously, using Eq. 2 outside its calibration range may result in errors too (even though the model validation returns good results).
- the computed evolution of sediment accumulation in the dock based on a physically-based data-driven model (IMDC, 2008), see Figure 12. Because the latter model computes the sediment fluxes at the dock entrance ('in' and 'out'), it returns order of magnitudes of sediment accumulation in the dock, which can be used to validate qualitatively the results of Figure 11. The following observations can be made:
  - First, the residual accumulated sediment mass (after a one-year period with dredging) in the dock can be compared. Whereas IMDC (2008) returns a sediment mass of around 10^5 TDS in April 2007 (see Figure 12), this study gives an accumulation of 1.5 10^5 TDS (see Figure 13). The order of magnitude is similar though when the confidence intervals on the calculated sediment mass accumulation are accounted for (in this study and IMDC(2008)).
  - Second, the natural siltation can be compared as well. Generally speaking, it can be concluded that the order of magnitudes are comparable, taking into account the confidence bands determined in this study and IMDC (2008). Note that the impact of dredging activities is more pronounced in this model in comparison with IMDC (2008). It is indeed implicitly considered in the current model whereas IMDC (2008) does not.

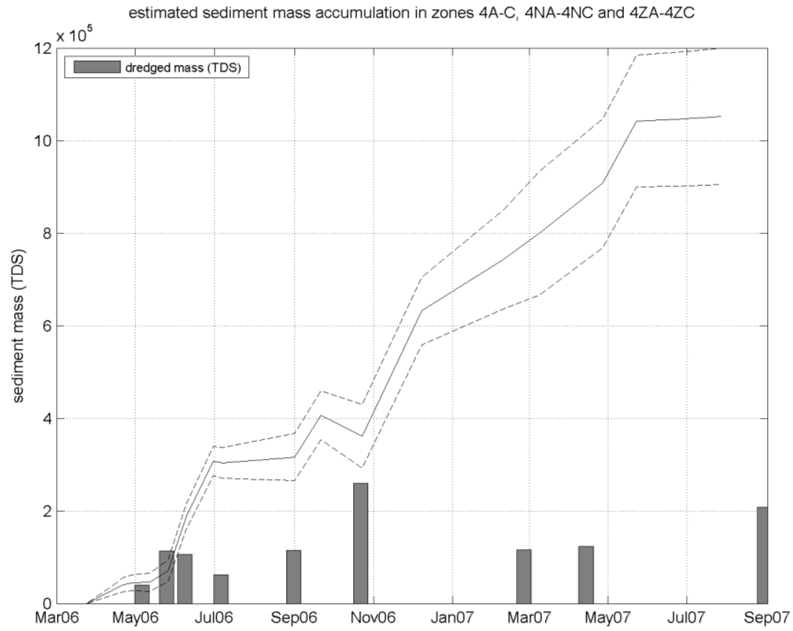

Figure 11: Estimated sediment mass accumulation with its 95% prediction confidence interval

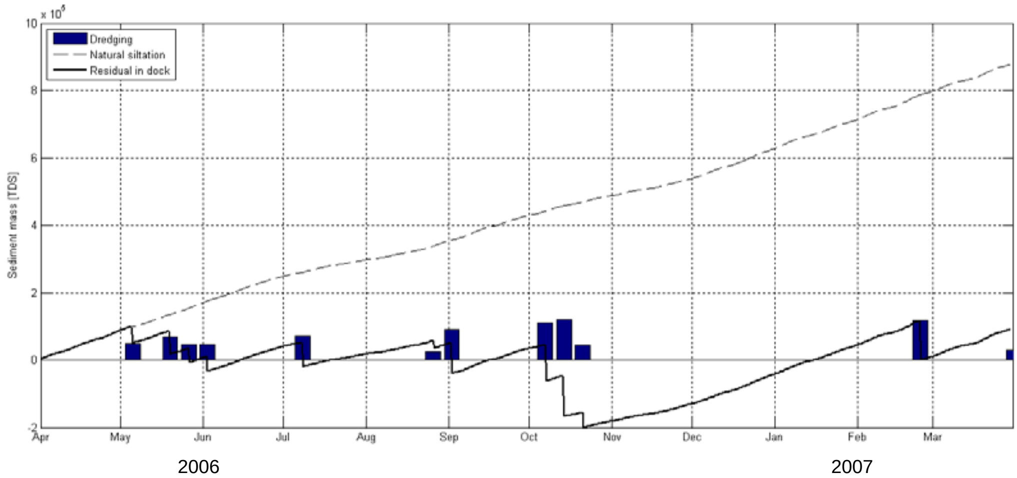

Figure 12: Dredged mass (TDS) per week, cumulative natural inflow of sediments and residual sediments in the dock. Sediment mass present in the dock at April 1st 2006 is set to zero (IMDC, 2008)

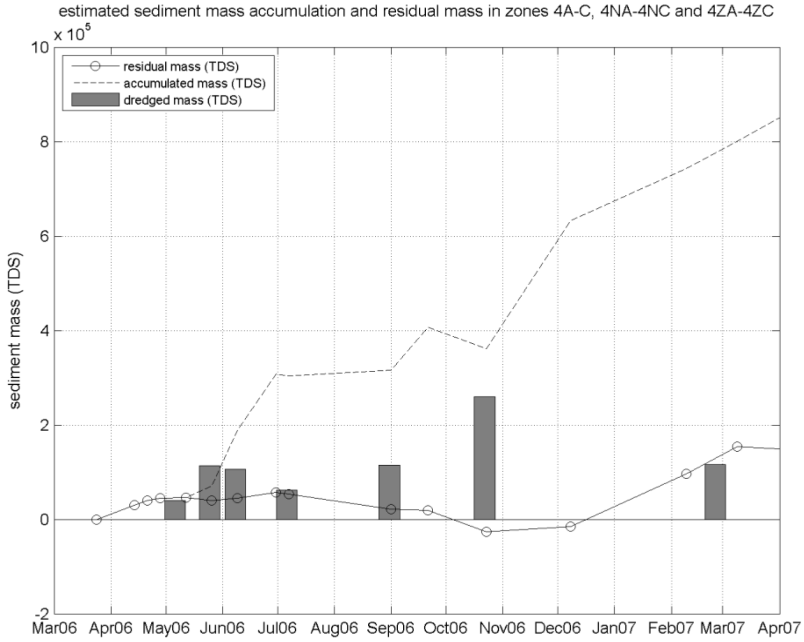

Figure 13: Estimated residual sediment mass in Deurganckdok

7. CONCLUSIONS

This memo tried to set up an empirical model to compute the sediment mass accumulation in the dock based on a time-series of depth soundings. The resulting non-linear model includes effects of dredging and the size of the time interval between depth sounding and preceding dredging activities. Confidence intervals on predicted densimetric changes are determined as well.

A validation study revealed good prediction capabilities with an independent data set. With respect to predicting sediment mass accumulation in the first year of conducted measurements, it could be concluded that the same orders of magnitude are obtained for measured growth rates and results of previous empirical models describing the incoming and outgoing sediment flux at the dock entrance (IMDC, 2008).

8. REFERENCES

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Table 4: Data availability and dredged mass for the period September 2007 – August 2008

peiling	prikken	bagger		dredged mass (TDS)									
				3a	3b	3c	3d	4NA	4NB	4NC	4ZA	4ZB	4ZC
		20/08/2007	25/08/2007										
		27/08/2007	31/08/2007	73694	57249	46513	2	12957	11477	5504	362	75	28
05/09/2007	05/09/2007												
16/10/2007	16/10/2007												
16/11/2007	16/11/2007												
		19/11/2007	24/11/2007										
		26/11/2007	30/11/2007	83520	65578	50508	565	16984	13912	9459	10803	16330	6739
05/12/2007	05/12/2007												
25/01/2008	24/01/2008												
		28/01/2008	03/02/2008										
		04/02/2008	10/02/2008										
		11/02/2008	17/02/2008	89362	79417	65131	488	13315	11781	7863	7609	8634	3917
15/02/2008	22/02/2008												
		18/02/2008	24/02/2008										
		03/03/2008	09/03/2008										
11/03/2008													
11/04/2008													
9/05/2008													
		12/05/2008	18/05/2008										
		26/05/2008	01/06/2008	121616	97124	85715	59720	15551	16986	9976	14872	14975	6783
04/06/2008	05/06/2008												
11/08/2008	11/08/2008												

peiling	prikken	bagger		dredged mass (TDS)									
				3a	3b	3c	3d	4NA	4NB	4NC	4ZA	4ZB	4ZC
		11/08/2008	17/08/2008	59941	33300	11229	3508	11052	5866	1249	8679	5103	487
16/08/2008	16/08/2008												
		18/08/2008	24/08/2008	80335	77573	55195	13759	6768	2514	421	1918	2083	803

Table 5: Data availability and dredged mass for the period March 2006 – August 2007

peiling	bagger		dredged mass (TDS)									
			3a	3b	3c	3d	4NA	4NB	4NC	4ZA	4ZB	4ZC
	06/03/2006 13/03/2006 20/03/2006	11/03/2006 18/03/2006 25/03/2006	44198	47411	501	0	895	757	0	1880	499	0
24/03/2006												
14/04/2006												
21/04/2006												
28/04/2006												
	30/04/2006	06/05/2006	8830	5350	3405	0	4360	3194	581	4781	6960	1817
12/05/2006												
	14/05/2006 22/05/2006	21/05/2006 28/05/2006	50948	50181	12297	0	283	240	0	7	0	0
26/05/2006												
	29/05/2006 06/06/2006	04/06/2006 10/06/2006	28946	29819	5408	0	14047	9449	54	12035	6722	0
09/06/2006												
30/06/2006												

			dredged mass (TDS)									
peiling	**bagger**		**3a**	**3b**	**3c**	**3d**	**4NA**	**4NB**	**4NC**	**4ZA**	**4ZB**	**4ZC**
	03/07/2006	08/07/2006	9874	11337	54	0	13957	8796	4	11628	6722	0
07/07/2006												
27/07/2006												
04/08/2006												
07/08/2006												
	21/08/2006	27/08/2006										
	28/08/2006	03/09/2008	1089	30277	26564	0	572	23168	11127	270	17467	3898
01/09/2006												
21/09/2006												
	02/10/2006	08/10/2006										
	09/10/2006	15/10/2006										
	16/10/2006	22/10/2006	128225	59252	8247	0	33121	13383	2362	7976	6513	224
23/10/2006												
08/12/2006												
09/02/2007												
	19/02/2007	25/02/2007	69815	5574	0	0	17744	11096	0	5957	5442	0
09/03/2007												
	26/03/2007	31/03/2007										
	02/04/2007	07/04/2007										
	09/04/2007	14/04/2007	31813	54107	31200	0	2052	3099	1567	0	0	0
27/04/2007												
23/05/2007												
22/06/2007												
27/07/2007												

			dredged mass (TDS)									
peiling	**bagger**		**3a**	**3b**	**3c**	**3d**	**4NA**	**4NB**	**4NC**	**4ZA**	**4ZB**	**4ZC**
	20/08/2007	25/08/2007										
	27/08/2007	31/08/2007	73694	57249	46513	2	12957	11477	5504	362	75	0
31/08/2007												

Table 6: Estimated mean mass growth rates and its 95% prediction confidence interval

****Estimated mean mass growth (kg/m²/day)**

sounding1	sounding2	3A	3B	3C	4NA	4NB	4NC	4ZA	4ZB	4ZC
24/03/2006	*14/04/2006*	5.38	4.03	1.49	3.07	2.03	1.73	0.60	0.67	1.38
14/04/2006	*21/04/2006*	6.21	4.43	1.15	1.05	1.95	1.77	2.45	2.28	0.44
21/04/2006	*28/04/2006*	2.16	1.83	0.87	1.51	1.31	0.51	1.11	0.09	-0.11
09/06/2006	*30/06/2006*	15.57	14.01	3.15	21.00	16.10	1.03	25.55	11.26	0.11
01/09/2006	*21/09/2006*	0.23	13.01	12.94	1.93	37.28	22.11	NaN	NaN	NaN
23/10/2006	*08/12/2006*	29.83	11.78	1.86	21.50	9.73	1.74	6.82	4.85	0.53
08/12/2006	*09/02/2007*	8.10	3.54	1.29	5.53	2.93	1.71	1.30	1.92	0.95
27/04/2007	*23/05/2007*	13.15	19.79	12.99	3.68	4.46	2.38	1.14	0.59	0.79
23/05/2007	*22/06/2007*	0.31	-0.45	0.31	0.71	0.63	0.04	0.96	1.28	0.66
22/06/2007	*27/07/2007*	0.77	0.39	0.00	1.16	0.22	-0.52	0.37	0.15	-0.43

****Estimated 95 perc prediction confidence interval (kg/m²/day)**

sounding1	sounding2	3A	3B	3C	4NA	4NB	4NC	4ZA	4ZB	4ZC
24/03/2006	*14/04/2006*	1.80	1.37	0.55	1.14	0.76	0.65	0.22	0.25	0.52
14/04/2006	*21/04/2006*	2.96	2.15	0.50	0.46	0.85	0.77	1.07	0.99	0.19
21/04/2006	*28/04/2006*	1.03	0.89	0.38	0.66	0.57	0.22	0.48	0.04	0.05
09/06/2006	*30/06/2006*	0.53	0.36	0.20	0.89	0.58	0.35	0.65	0.36	0.04
01/09/2006	*21/09/2006*	0.12	0.26	0.16	0.43	0.03	0.16	NaN	NaN	NaN
23/10/2006	*08/12/2006*	0.56	0.01	0.02	0.46	0.14	0.11	0.14	0.13	0.15
08/12/2006	*09/02/2007*	1.53	0.90	0.69	2.19	1.48	0.97	0.70	1.04	0.55
27/04/2007	*23/05/2007*	0.22	0.26	0.26	0.55	0.23	0.01	0.42	0.22	0.29
23/05/2007	*22/06/2007*	0.08	0.12	0.09	0.26	0.23	0.02	0.36	0.48	0.25
22/06/2007	*27/07/2007*	0.20	0.09	0.00	0.44	0.08	0.20	0.14	0.06	0.17

Table 7: Comparison between measured and estimated sediment mass growth rates for different time periods (negative growth rates are excluded)

(kg/m².day)	3A	3B	3C	4NA	4NB	4NC	4ZA	4ZB	4ZC
measurement 08/2005 - 10/2005	5.93	0.19		<0			1.78	3.60	
measured range 09/2007 - 09/2008	6.73 - 9.19	4.96 - 6.05	2.07 - 3.83	3.54 - 5.20	2.59 - 3.63	0.50 - 3.58	1.12 - 5.68	1.67 - 4.57	0.043 - 1.88
estimated range 03/2006 - 06/2007	0.22 – 9.64	0.05 – 6.58	0.00 – 2.04	0.45 – 7.72	0.06 - 4.42	0.02 – 2.67	0.23 – 3.52	0.05 – 3.27	0.07 – 1.90