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DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN

WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurgangckdok: opvolging en analyse aanslibbing

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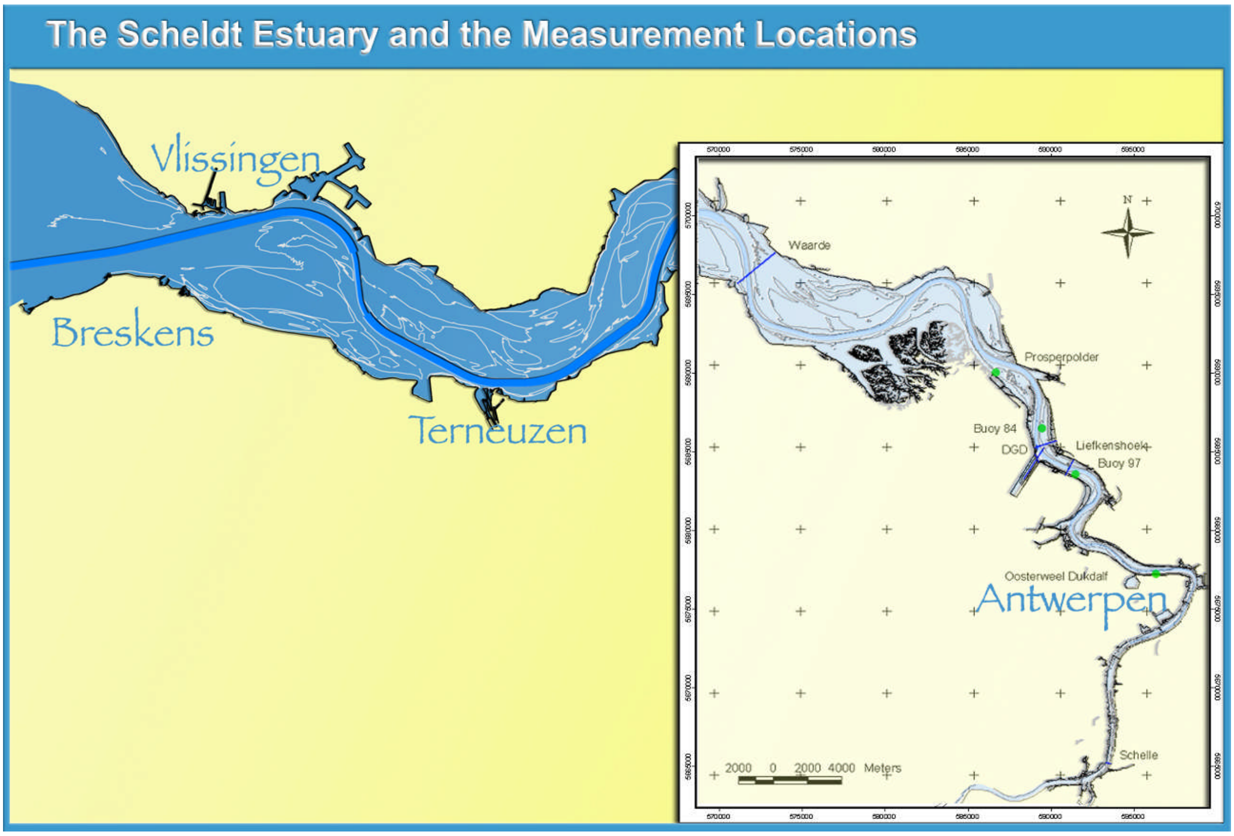

Deelrapport 3.14: Jaarrapport omgevingscondities 2007-2008.

Report 3.14: Boundary conditions: Annual report 2007-2008

1 August 2008

I/RA/11283/07.101/MSA

i.s.m. wl | delft hydraulics en GEMS International

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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 prolonged with an extra year from April 2007 till March 2008.

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 study

1.3.1. Reports

Reports of the project 'Opvolging aanslibbing Deurganckdok' between April 2007 till March 2008 are summarized in Table 1-1.

This report, report 3.14, is one of set of reports for understanding the sediment transport between Deurganckdok and the river Scheldt, which belongs to the second part of this project.

The report is also a continuation of the set of ambient conditions reports of HCBS2 (IMDC, 2005k; IMDC, 2005l; IMDC, 2006l; IMDC, 2006p) and 'Opvolging aanslibbing Deurganckdok' (IMDC, 2007b; IMDC, 2007u; IMDC, 2007w, 2008p). This annual report gives an analysis of the ambient conditions from April 2007 till March 2008 in the river Scheldt. An overview of the HCBS2 and 'Opvolging aanslibbing Deurganckdok' (between April 2006 till March 2007) reports is given in ANNEX A.

Table 1-1: Overview of Deurganckdok II Reports (April 2007 – March 2008)

Report	Description
Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.10	Sediment Balance: Three monthly report 1/4/2007 - 30/06/2007 (I/RA/11283/07.081/MSA)
1.11	Sediment Balance: Three monthly report 1/7/2007 – 30/09/2007 (I/RA/11283/07.082/MSA)
1.12	Sediment Balance: Three monthly report 1/10/2007 – 31/12/2007 (I/RA/11283/07.083/MSA)
1.13	Sediment Balance: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/07.084/MSA)
1.14	Annual Sediment Balance (I/RA/11283/07.085/MSA)
Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP) & Calibrations	
2.09	Calibration stationary equipment autumn (I/RA/11283/07.095/MSA)
2.10	Through tide measurement Siltprofiler 23 October 2007 (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 11 March 2008 Transect I (I/RA/11283/07.088/MSA)
2.13	Through tide measurement Sediview winter 11 March 2008 Transect K (I/RA/11283/07.089/MSA)
2.14	Through tide measurement Sediview winter 11 March 2008 Transect DGD (I/RA/11283/07.090/MSA)

Report	Description
2.15	Through tide measurement Siltprofiler 12 March 2008 (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)
2.19	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	
3.10	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)
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	
4.10	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 fresh water discharge in the river Scheldt.
2. Monitoring Salt and sediment concentration in the Lower Sea Scheldt taken from permanent data acquisition sites at Oosterweel, Prosperpolder 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 using ADCP backscatter intensity over a full cross section (calibrated with the Sediview procedure) and vertical sediment and salt profiles (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, 2006a; IMDC, 2007a; IMDC, 2008f; IMDC, 2008o).

1.4. Specific objectives of the present report

This report will deal with the long term stationary measurements to determine the environmental conditions in the Lower Sea Scheldt between April 2007 and March 2008. The execution of these campaigns, the instruments used, the week plots regarding the results and the preliminary analysis in terms of minimal, maximum, average values and amplitudes per month and per campaign, have been extensively detailed in the appended data reports (report nr. 3.10 to 3.13).

This report will describe the results of the analysis of these long-term measurements. Because their long duration, it will be possible to study the variations of the measured variables on different time scales (ebb/flood, tide, spring tide/average tide/neap tide, seasons). Special attention will be given to the comparison of the results of the present report to those from the period September 2005 to March 2007 (as reported in IMDC 2008t)

The study will stress on the sediment transport, which is of the utmost importance for the development of dredging strategies.

1.5. Structure of this report

Chapter 2 will provide a general summarizing description of the campaign, with a description of the processing method and the boundary conditions (tide, discharge) for the analysis.

In the following chapters, an analysis will be given of the variable variations that influence the sediment transport or that might explain the variations thereof. The variations of the influencing variables will be treated on different time scales (tide, months, neap tide – spring tide cycle, semester, seasons). Chapter 3 will deal with the velocity measurements, chapter 4 will treat the salinity and chapter 5 will treat temperature.

In chapter 6, a similar analysis will be carried out for the variations on the different time scales of the sediment transport. In addition, these variations of the sediment transport will be put into relation with the evolution of the influencing variables as described in the previous chapters.

2. TIDE AND DISCHARGE

This chapter will provide a detailed description of the analysis' general framework. Firstly, the execution of the measurement campaign will be summarized. Then comes a description of the measurement data processing to carry out the analysis and finally, the boundary conditions of the said analysis (tide, discharge and precipitation) will be presented

2.1. Description of the measurement campaign

Various long-term and stationary point measurements were carried out in the Lower Sea Scheldt between April 2007 and March 2008 (Figure 2-1). Besides the two HCBS measurement frames, set up near Buoy 84 and Buoy 97, the permanent instruments of Flanders Hydraulics for continuous monitoring of the Scheldt in Oosterweel and at Prosperpolder were also used. We also refer to the data reports (IMDC 2007v, 2007w, 2008p and 2008q) in which the measured data are presented in detail.

The HCBS measurement locations (Buoy 84 and 97) and the WL station in Oosterweel and Prosperpolder provide the data for the following analysis. In each of these locations except Prosperpolder, measurements have been carried out at two different depths. The location, depth and measurement period for each instrument is given in Table 2-1. Reference is made to the data reports for a description of periods for which no data or incorrect data have been logged.

Table 2-1: UTM Coordinates of the locations and depth of the instruments (downstream top)

Location	***Easting [UTM ED50]***	***Northing [UTM ED50]***	***Period***	***[m] above botttom***	***Elevation [m TAW]***
Buoy 84	588971	5686097	Apr2007 – Mar2008	3.3	-5.8
				0.8	-8.1
Buoy 97	590932	5683350	Apr2007 – Mar2008	3.3	-5.1
				0.8	-7.5
Oosterweel	595574	5677278	Apr2007 – Mar2008	4,5	-2.1
				1.0	-5.7
Prosperpolder	586307	56589501	Apr2007 – Mar2008	1.0	-1.5

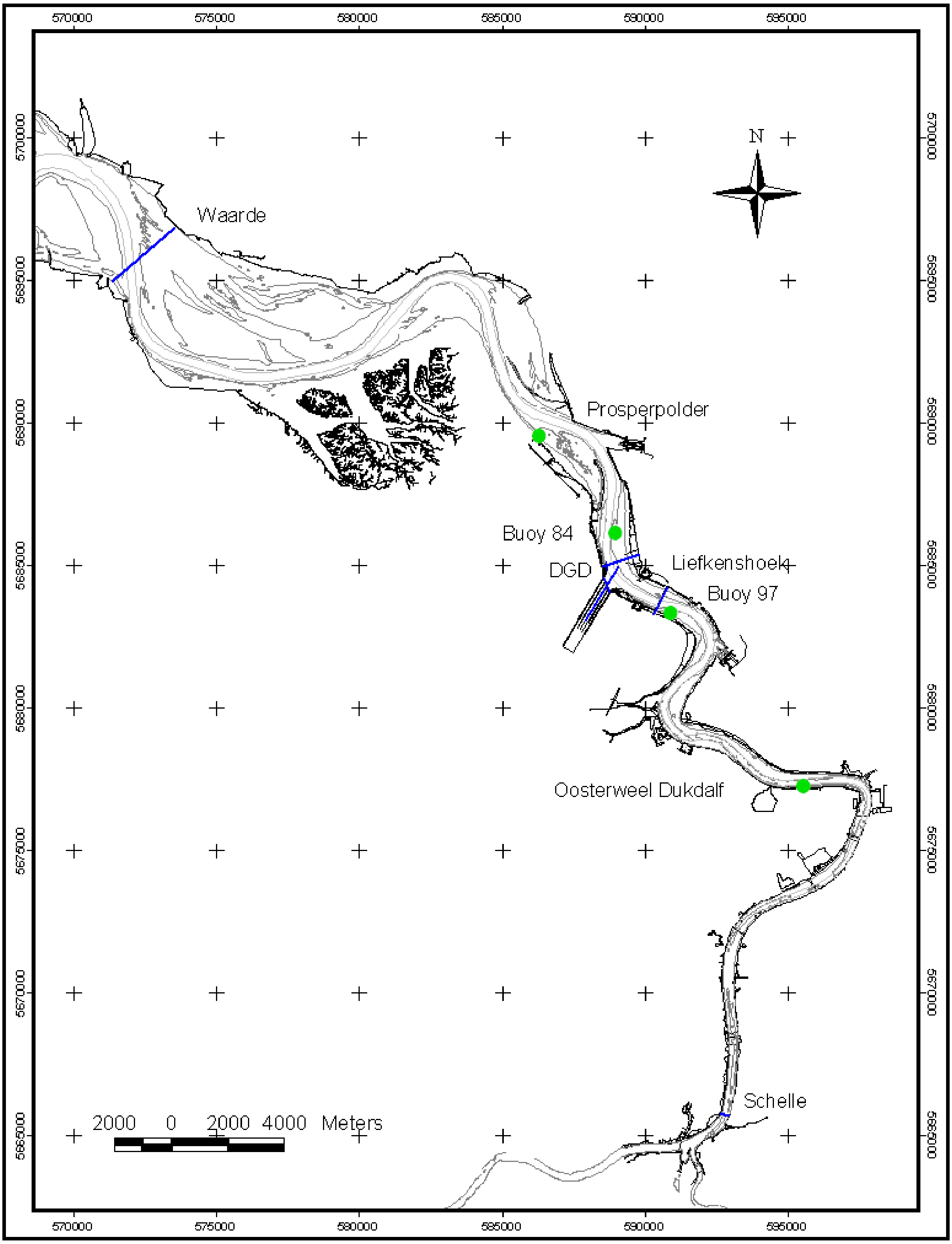

Figure 2-1: Overview of the measurement locations on the Seascheldt for the analysed period

Anderaa RCM9 instruments were use to measure the flow velocity and direction, temperature, pressure, conductivity and turbidity. The measurement frequency was 10 minutes.

The variables analysed in this report (and presented in the data reports) are: flow velocity and direction, salinity, temperature and sediment concentration. Salinity is being derived from the conductivity and the temperature. Sediment concentration is being derived from the calibration of the turbidity meter. At Prosperpolder, the used RCM-9 did not provide any velocity data.

Tidal data were provided by Flanders Hydraulics in the form of water levels every 10 minutes in Zandvliet, Liefkenshoek and Antwerp. Zandvliet was used as a tidal station for the measurement location Buoy 84 and Prosperpolder, Liefkenshoek for Buoy 97, and Antwerp for Oosterweel.

Reference is made to the corresponding data reports (IMDC 2007v, 2007w, 2008p and 2008q) for additional information on measurement locations, instruments and the processing of rough data into analysis variables.

2.2. Data processing

Due to the different measurement times for the various instruments, the data were interpolated on fixed times before being analysed. These interpolated times correspond with the times of the 10 minute tide data of Flanders Hydraulics.

In order to reach a conclusion regarding the variations on the various time scales, the data were sorted out and grouped per tide, ebb or flood. The aim is to be able to calculate minimum, maximum values, amplitude and average values for the variables per episode (tide, ebb, flood). It has to be underlined, that the term amplitude is here understood as the difference between a variable maximum and minimum within an episode. The tides were then classified as neap tide, average tide and spring tide in order to prepare the average tide curves.

2.2.1. Tide, ebb, flood and slack water

In order to be able to calculate the average or extreme values for ebb, flood and tidal periods, the limits of these episodes are first to be determined. The approach was that a tide, an ebb, a flood, is time-delimited by the moments of slack water. These have been defined as the minimal values in flow velocity in pre-determined time intervals. These intervals were determined using a series of average times of high and low tide in a astronomical model of the tidal water level times in Antwerp. The aim is to produce a series of time intervals wide enough (about half a tide) en approximately centred on a moment of low or high tide in order to seek the minimum velocity within this interval, determining the moment of the corresponding low or high slack water. Because of the measurement frequency, the time tags of slack water have been determined with an accuracy of 10 minutes.

Once the slack water time tags known, the measurement data were classified per flood (from time of low water slack – LWS – to high water slack– HWS), per ebb (from HWS to LWS) and tide (flood and ebb, LWS1 – LWS2) and calculations were made for the maximum, minimum, amplitude (max-min), and the average value per episode and per analysed variable. Note that at Prosperpolder, where no velocity data were measured, the classification of the data occurred using the water level data from Zandvliet, where a tide runs from the moment of low water to a subsequent low water.

2.2.2. Neap tide – Spring tide cycle

Spring tide is defined as the first tide immediately following the fifth moon passage at Ukkel, and to be calculated from the time of new or full moon. Neap tide is being determined in the same way, from the time of the first and the last quarter (Claessens & Meyvis, 1994).

In order to avoid having to use an astronomic model, an approach was used in which the difference between the various tidal types is calculated, using the measured tidal. This approach is based on the fact that spring tides are characterized by a larger and neap tide by a smaller amplitude than an average tide. That is why the observed tides with the largest amplitudes are considered as spring tide and those with the smallest amplitudes are considered as neap tide in this analysis. If Δh_{neap} stands for the tidal difference of an average neap tide, Δh_{spring} for the tidal difference of an average spring tide and Δh_{aver} for the tidal difference of an average tide then a neap, spring and average tide will be defined as follows (Δh is the measured tidal difference for a particular tide):

- Neap tide: $\Delta h \leq 0.5\ (\Delta h_{neap} + \Delta h_{aver})$
- Spring tide: $\Delta h \geq 0.5\ (\Delta h_{spring} + \Delta h_{aver})$
- Average tide: $0.5\ (\Delta h_{neap} + \Delta h_{aver}) < \Delta h < 0.5\ (\Delta h_{spring} + \Delta h_{aver})$

The coefficients Δh_{neap}, Δh_{aver} and Δh_{spring} were determined in every tidal location by multiplying the average amplitude of a neap, average and spring tide for the decade 1991-2000 respectively in Zandvliet, Liefkenshoek and Antwerp (see §2.3.1.3 for a description of the average tide for the previous decade) with a correction factor, representing the relation of the average tidal difference in the tidal location during the previous decade and the average tidal difference observed during the period studied in this report.

The limits resulting thereof between a neap tide, an average tide and a spring tide are illustrated in Table 2-2. In Zandvliet for example, a tide with an amplitude smaller than 4.57m is regarded as a neap tide, with an amplitude higher than 5.35m as a spring tide. The tides in between are regarded as average tides.

Table 2-2: Considered amplitude limit [m] between a neap an average and a spring tide in Zandvliet, Liefkenshoek and Antwerpen

	Zandvliet	***Liefkenshoek***	***Antwerpen***
Neap – Average Limit	4.57	4.75	4.91
Average –Spring Limit	5.35	5.54	5.68

Table 2-3 gives the number of neap, average and spring tides recorded during the measurement period according to the above classification for the available tidal locations. The difference in number of tides observed between the various locations is caused by the fact that sometimes data are missing in the tide data received. It can be observed that classification follows a relation of 25 % neap tide, 40 % average tide, 35 % spring tide.

Once the various tides have been classified per category, the tidal average curves are calculated for all variables. These were obtained by classification for each tide from a certain type of all available values per time tag (that is every 10 minutes) compared with HW. Then an average value is calculated for each time tag related to HW.

In addition, the measurements are classified per trimester and per summer, winter of year. Winter is here defined as the period between October and March, and summer the period between April and September by analogy with analyses of similar long term measurements campaigns.

Table 2-3: Amount of neap, average and spring tides measured during considered period (Winter: Oct 2007-Mar 2008, Summer: Apr 2007-Sep 2007, Year: Apr 2007-Mar 2008)

		Apr-Jun	***Jul-Sep***	***Oct-Dec***	***Jan-Mar***	***Summer***	***Winter***	***Year***
Zandvliet	Neap	40	34	45	49	74	94	168
	Avg	75	55	84	54	130	138	268
	Spring	54	68	49	65	122	114	236
	Total	169	157	178	168	326	346	672
Liefkenshoek	Neap	38	34	46	49	72	95	167
	Avg	77	54	85	55	131	140	271
	Spring	54	66	47	66	120	113	233
	Total	169	154	178	170	323	348	671
Antwerpen	Neap	37	34	46	47	71	93	164
	Avg	78	55	85	57	133	142	275
	Spring	54	68	47	66	122	113	235
	Total	169	157	178	170	326	348	674

2.3. Boundary conditions of the analysis

2.3.1. Tidal variations

2.3.1.1. Tide measurements during the measurement campaign

The digitalized tidal series with a measurement frequency of 10 minutes in Zandvliet, Liefkenshoek and Antwerp were provided by the 'Waterbouwkundig Laboratorium en Hydrologisch Onderzoek, Cel Hydrometrie Schelde'. The accuracy thereof is indicated with 2 cm for height and 2 minutes for time (Claessens & Meyvis, 1994).

In Annex-Figure B-1 to Annex-Figure B-3 the course of HW, LW and the tidal amplitude per tide over the measurement period is presented for the various tidal locations. The periodic cycles between tides with a large amplitude (regarded as spring tide) and with a low amplitude (regarded as neap tide) are very clear.

2.3.1.2. Average tidal curves during the measurement campaign

From the tidal data provided, the average tidal curves were calculated for the tide gauges, see Annex-Figure B-4 to Annex-Figure B-6

From these curves, the average HW & LW levels, the average tidal amplitude and the average duration of rising and falling could be determined, see Table 2-4 and Table 2-5. Because Flanders Hydraulics provided the data per 10 minutes, there the precision in the determination of the duration calculated for rising, falling and tide is 20 minutes.

Table 2-4: Averaged HW,LW [mTAW] and tidal amplitude [m] for a neap, an average and a spring tide at Zandvliet, Liefkenshoek and Antwerp, April 2007-March 2008

	Neap tide			***Average tide***			***Spring tide***		
	HW	***LW***	***Amp***	***HW***	***LW***	***Amp***	***HW***	***LW***	***Amp***
Zandvliet	4.52	0.43	4.09	5.09	0.04	5.05	5.54	-0.30	5.84
Liefkenshoek	4.62	0.38	4.24	5.22	-0.03	5.25	5.68	-0.18	5.86
Antwerpen	4.72	0.34	4.38	5.29	-0.13	5.42	5.72	-0.41	6.13

Table 2-5: Average duration [h:mm] of rising and falling for an averaged neap, average and spring tide at Zandvliet, Liefkenshoek and Antwerpen, April 2007-March 2008

	Neap tide			***Average tide***			***Spring tide***		
	Flood	***Ebb***	***Tide***	***Flood***	***Ebb***	***Tide***	***Flood***	***Ebb***	***Tide***
Zandvliet	5:50	6:40	12:30	5:40	6:50	12:30	5:20	7:10	12:30
Liefkenshoek	5:50	6:50	12:40	5:30	7:10	12:40	5:10	7:00	12:10
Antwerpen	5:50	6:50	12:40	5:20	7:10	12:30	5:00	7:10	12:10

2.3.1.3. Comparison with the decade values and previous investigation

A comparison of the present results with the results from the previous investigation (Table 2-6 and Table 2-8) shows that the tidal parameters obtained from both investigations are comparable.

The average neap tide, average tide and average spring tide (water levels and duration) over the period 1991-2000 in the tidal locations of Zandvliet, Liefkenshoek and Antwerp were provided by Flanders Hydraulics and given in Table 2-7 and Table 2-9. When comparing these tables with Table 2-4 and Table 2-5, we find that the classification of tides in various categories on the basis of the amplitude brings results that are sufficiently close to the astronomical reality in terms of level of high and low water, amplitude and duration of the episodes.

Table 2-6: Averaged HW,LW [mTAW] and tidal amplitude [m] for a neap, an average and a spring tide at Zandvliet, Liefkenshoek and Antwerp for September 2005 to March 2007 (IMDC 2008t)

	Neap tide			***Average tide***			***Spring tide***		
	HW	***LW***	***Amp***	***HW***	***LW***	***Amp***	***HW***	***LW***	***Amp***
Zandvliet	4.52	0.43	4.09	5.05	0.03	5.01	5.50	-0.19	5.68
Liefkenshoek	4.61	0.38	4.24	5.17	-0.04	5.20	5.63	-0.27	5.90
Antwerpen	4.72	0.31	4.41	5.25	-0.09	5.34	5.70	-0.31	6.01

Table 2-7: Averaged HW,LW [mTAW] and tidal amplitude [m] for a neap, an average and a spring tide at Zandvliet, Liefkenshoek and Antwerp for the decennium 1991-2000 (data Flanders Hydraulics)

	Neap tide			***Average tide***			***Spring tide***		
	HW	***LW***	***Amp***	***HW***	***LW***	***Amp***	***HW***	***LW***	***Amp***
Zandvliet	4.59	0.43	4.16	5.14	0.09	5.05	5.58	-0.14	5.72
Liefkenshoek	4.63	0.39	4.24	5.19	0.05	5.13	5.63	-0.18	5.81
Antwerpen	4.77	0.34	4.43	5.29	0.00	5.29	5.72	-0.23	5.95

Table 2-8: Average duration [h:mm] of rising and falling for an averaged neap, average and spring tide at Zandvliet, Liefkenshoek and Antwerpen for September 2005 to March 2007 (IMDC 2008t)

	Neap tide			***Average tide***			***Spring tide***		
	Flood	***Ebb***	***Tide***	***Flood***	***Ebb***	***Tide***	***Flood***	***Ebb***	***Tide***
Zandvliet	5:50	6:40	12:30	5:30	7:00	12:30	5:20	7:00	12:20
Liefkenshoek	5:50	6:40	12:30	5:30	7:10	12:40	5:20	7:10	12:30
Antwerpen	5:50	6:40	12:30	5:30	7:20	12:50	5:10	7:20	12:30

Table 2-9: Average duration [h:mm] of rising and falling for an averaged neap, average and spring tide at Zandvliet, Liefkenshoek and Antwerpen for the decennium 1991-2000 (data Flanders Hydraulics)

	Neap tide			***Average tide***			***Spring tide***		
	Flood	***Ebb***	***Tide***	***Flood***	***Ebb***	***Tide***	***Flood***	***Ebb***	***Tide***
Zandvliet	6:02	6:36	12:38	5:40	6:44	12:24	5:26	6:52	12:18
Liefkenshoek	5:59	6:40	12:39	5:34	6:50	12:24	5:16	7:02	12:18
Antwerpen	5:55	6:44	12:39	5:25	7:00	12:25	5:01	7:18	12:19

2.3.1.4. Tidal effects

The Scheldt is ‘macrotidal’, it is an estuary with a tidal amplitude larger than 4 m. The tidal amplitude largely determines the possibility of the flow to mix fresh water with salt water and to transport sediments. Therefore, it is important to know the general effects of the tide in the Scheldt.

In estuaries, the tidal wave is strongly changed on the one hand as a result of the side effects of bottom friction of the flow and on the other hand the narrowing of the estuaries in the upstream direction (convergence). In Dyer (1995), we read that convergence causes a partial reflection of the tidal wave on the one hand and the compression thereof in an increasingly smaller cross section on the other hand, resulting in an increase of the tidal amplitude. Bottom friction has the opposite effect; it will increase with the decreasing water depth and increasing flow velocity due to which energy will be extracted from the tidal wave and the amplitude thereof will decrease. In the Lower Sea Scheldt and the Western Scheldt the convergence effects are larger than the friction effects, which is proven by the fact that the tidal amplitude increases starting from the estuary (Vlissingen) to Schelle and then decreases upstream of Schelle. This phenomenon is indicated as 'hyper synchronous' (see Dyer, 1995). Table 2-10 provides information about some tidal gauges from the Scheldt basin regarding the average tidal amplitudes. The values of the tidal amplitudes also allow to split up the Scheldt into two parts; that is the downstream part from the estuary to somewhere next to Schelle and an upstream part from Schelle to Gentbrugge. This report will extensively treat the downstream part of the river.

In the Lower Sea Scheldt, the tidal amplitude is relatively large compared with the water depth; the relation between both variables is about 0.3. For estuaries with a relatively large relation between tidal amplitude and water depth (> 0.3) there is an important asymmetry in the tide - (see Annex-Figure B-4 - Annex-Figure B-6) and in the flow velocity curves (see chapter 3). The largest flow velocities appear during flood. This asymmetry in the tidal curve is due to the fact that during the beginning of the flood, the friction effects are larger than at the end of the flood when the water depth is larger. In the Lower Sea Scheldt the convergence effect on the tidal amplitude is larger than the effect of the friction, and that is why the propagation velocity of the tidal wave is increasing (Savenije & Veling E,2005), see Table 2-10, giving an indication of the average delay of the moment of HW compared to Vlissingen and the average propagation velocity of the HW. The increasing propagation velocity of the tidal wave (as far as Antwerp) causes the high water to propagate increasingly faster from the estuary while the low waters stay behind. The result thereof is a decreased flood duration, an increased ebb duration and an increasingly more asymmetric velocity course with a typical flood dominating character of the tidal flow. The flood dominating character of the flow is most distinct for spring tides. For a neap tide, the low waters are higher and the high waters are lower, hence the friction effects are somewhat less important at the beginning of the flood and somewhat more important at the end thereof compared to spring tide.

Table 2-10: Tidal amplitude (m) for an averaged spring, average and neap tide, duration (hh.mm) rising and falling, delay of HW comparated to Vlissingen, distance to mouth (km) and propagation velocity of HW (km/h) at several tidal gauges of the Scheldt for the decennium 1981-1990 (Claessens & Meyvis, 1994).

	Aver. Tidal amplitude.			***Gemiddelde Duration***		***Decelaration HW***	***Distance to***	***Propagation***
	neap tide (m)	***aver tide (m)***	***spring tide (m)***	***rising (hh.min)***	***falling (hh.min)***	***tov Vlissingen (hh.min)***	***mouth (km)***	***velocity HW (km/h)***
Vlissingen	2.97	3.80	4.46	5h57	6h28	0h00	2.00	
Hansweert	3.61	4.41	5.03	6h01	6h24	0h56	35.80	31.55
Prosperpolder	4.02	4.94	5.64	5h41	6h45	1h22	55.98	50.20
Antwerpen	4.31	5.19	5.87	5h22	7h03	1h44	77.60	58.96
Schelle	4.49	5.33	5.93	5h28	6h57	2h22	91.23	21.52
St. Amands	4.32	4.99	5.46	4h57	7h29	2h53	107.85	32.17
Dendermonde	3.55	3.96	4.24	4h48	7h37	3h31	120.72	20.32
Melle	1.97	2.14	2.29	4h14	8h11	5h14	149.74	14.16

2.3.2. Fresh water discharge and precipitation

Flanders Hydraulics has collected discharge data in a number of gauging stations situated outside the tidal influence. These discharges are then converted into discharge at the mouth of the various tributaries and into a total upstream discharge on the Scheldt at Schelle, see AZ (1974).

The stations are located at Melle (Scheldt), Dendermonde (Dender), Eppegem (Zenne), Haacht (Dijle), Itegem (Grote Nete) and Grobbendonk (Kleine Nete). At Melle and Dendermonde, the discharge is measured with an acoustic discharge meter, while in the other stations the water height is measured and the discharge is then calculated from the calibrated relation with the water height. The discharge at the mouth of the rivers are determined from the discharge monitored at the stations by comparing the surface of the hydrographic basin at the mouth and the one at the station, assuming that the flow is proportional to the surface. This gives the following results in terms of multiplication factor of the discharge monitored at the station: for the Zenne 1.13, for the Dijle 1.08, for the Kleine Nete 1.46 and for the Grote Nete 1.35. The surplus flow produced by the Durme, the Beneden Nete, the Rupel and the side discharge of the Scheldt between Melle and Schelle are being calculated by comparing their basin with the surface of the hydrographic basin of the rivers measured, showing that the sum of the flows may be obtained by dividing the total discharge of the monitored rivers by 5.05. The total discharge at Schelle can now be found by adding up all flows. By computing the total discharge by this way, it is assumed that the concentration time is equal in all rivers, that there is no phase shift between the flow at the mouth of a tributary and the discharge at Schelle and that the precipitation is equally distributed over the complete hydrographic basin of the Scheldt.

During the measurement period (April 2007 – March 2008), the average fresh water discharge at Schelle was 118 m^3/s, with extreme decade average values between 37 m^3/s and 539 m^3/s. These data compare well with the data obtained from September 2005 to March 2007 (IMDC 2008t), where the average upper discharge at Schelle was 108 m^3/s, with extreme decade average values between 28 m^3/s and 466 m^3/s. The monthly statistics of the fresh water discharge are shown in Table 2-11. Annex-Figure B-7 displays the daily and decade average discharge values during the measurement period and daily. A comparison of the decade averaged discharge with the long term decade averaged discharge shows that the fresh water discharge in the Scheldt indeed showed average characteristics in the current measurement period.

Table 2-11 Statistics of the monthly fresh water discharge [m^3/s] at Schelle.

	2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Min.	37.67	51.39	67.74	89.61	56.77	39.84	42.20	56.24	79.38	92.91	75.59	104.99	37.67
Max.	82.04	155.96	166.03	217.00	172.45	123.26	186.32	206.16	448.75	253.89	220.02	539.22	539.22
Avg.	55.08	97.91	107.12	140.64	88.85	60.47	74.80	106.91	190.92	151.67	113.92	251.20	118.10
Std.	11.13	22.92	20.95	38.91	30.44	20.45	39.73	42.29	129.55	35.20	40.07	108.09	78.28

3. FLOW VELOCITY AND DIRECTION

The flow velocity is one of the determining factors for the suspended sediment transport and a high degree of correlation is expected between these two variables. In this chapter, the flow measurements will be first analysed in terms of maximum and average flow velocity and average flow direction. Then, the average flow velocity curves will be presented and analysed in terms of moments of maximum flow velocity and of slack water.

3.1. Maximum and average values per ebb/flood

Table 3-1 and Table 3-2 display the monthly averages of the maximum ebb and flood flow velocities for neap tide, average tide and spring tide conditions in the various measurement locations. Table 3-3 and Table 3-4 display the monthly averages of the average flow velocities and directions per ebb and Table 3-5 and Table 3-6 display the monthly averages of the average flow velocities and directions per flood and for an average neap tide, an average tide and an average spring tide.

The maximum and average flow velocities for ebb and flood and the flow direction for the maximum ebb and flood velocities for the complete measurement period are given in Annex-Figure C-1 to Annex-Figure C-18.

A comparison of the present data, with those from September 2005 to March 2007 (IMDC 2008t) shows that the velocity data during both periods show very similar characteristics. As can be expected, assuming a logarithmic velocity profile, for both datasets the velocity measured by the top instrument is larger than the one measured by the bottom instrument.

Both datasets also indicate a strong connection between the tidal amplitude and the velocity course. The tables indicate that in both datasets the maximum and average velocities increase from neap tide to spring tide. Now and then, both courses shift in relation to each other (for example the average flood velocities at Oosterweel in July 2007, which do not differ between an average tide and spring tide), meaning that regardless of how strong the relation between both variables is, other factors (discharge, for instance) than the tidal strength will have an influence on the velocity course (and most probably also on the sediment transport).

Table 3-1: Maximal ebb phase velocity [m/s] for each month and measurement station

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	0.52	0.62	0.54	0.57	0.55	-	0.50	0.53	0.57	0.54	-	0.53	0.55
	Avg tide	0.65	0.63	0.64	0.59	0.58	0.55	0.59	0.59	0.62	0.60	-	0.65	0.61
	Spring tide	0.73	0.66	0.63	0.62	0.62	0.62	0.60	0.66	0.65	-	-	0.68	0.64
Buoy 84 (-5.6 m TAW)	Neap tide	0.62	0.68	0.61	0.64	0.61	0.54	0.60	0.63	0.69	0.63	0.61	0.59	0.62
	Avg tide	0.77	0.72	0.71	0.67	0.66	0.66	0.70	0.72	0.75	0.68	0.65	0.72	0.71
	Spring tide	0.84	0.77	0.72	0.72	0.74	0.73	0.72	0.78	0.79	0.74	-	0.79	0.76
Buoy 97 (-7.8 m TAW)	Neap tide	0.56	0.55	0.51	0.54	0.52	0.47	0.52	0.50	0.60	0.51	0.54	0.53	0.53
	Avg tide	0.57	0.55	0.55	0.58	0.56	0.55	0.56	0.56	0.55	0.58	0.58	0.58	0.56
	Spring tide	0.61	0.55	0.56	0.57	0.59	0.60	0.60	0.64	0.57	0.64	0.61	0.62	0.60
Buoy 97 (-5.3 m TAW)	Neap tide	0.67	0.68	0.65	0.66	0.65	0.58	0.62	0.70	0.69	0.62	0.66	0.64	0.65
	Avg tide	0.74	0.71	0.71	0.70	0.72	0.71	0.69	0.81	0.67	0.71	0.73	0.74	0.71
	Spring tide	0.78	0.75	0.75	0.73	0.78	0.78	0.76	0.92	0.69	0.82	0.78	0.81	0.77
Oosterweel (- 5.8 m TAW)	Neap tide	0.63	-	-	0.69	0.66	0.65	-	-	0.62	0.65	0.66	0.59	0.64
	Avg tide	0.70	-	-	0.70	0.70	0.70	-	-	0.65	0.66	0.69	0.65	0.68
	Spring tide	0.74	-	-	0.73	0.71	0.75	-	-	0.60	0.68	0.70	0.72	0.72
Oosterweel (- 2.3 m TAW)	Neap tide	0.85	0.90	0.90	-	0.89	0.86	0.91	0.91	0.87	0.90	0.88	0.79	0.87
	Avg tide	0.92	0.94	0.96	0.92	0.95	0.94	0.99	0.94	0.90	0.93	0.92	0.90	0.93
	Spring tide	0.95	0.99	-	0.96	0.95	1.00	1.01	0.99	0.93	0.95	0.95	0.98	0.97

Table 3-2: Maximal flood phase velocity [m/s] for each month and measurement station

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	0.72	0.72	0.75	0.78	0.66	-	0.65	0.76	0.75	0.79	-	0.80	0.73
	Avg tide	0.91	0.84	0.88	0.92	0.85	0.82	0.94	0.87	0.90	0.94	-	0.95	0.89
	Spring tide	0.97	1.03	0.97	0.96	1.01	0.97	1.09	1.03	1.03	-	-	1.02	1.01
Buoy 84 (-5.6 m TAW)	Neap tide	0.84	0.82	0.84	0.81	0.72	0.70	0.75	0.85	0.83	0.94	0.90	0.76	0.80
	Avg tide	1.10	0.99	1.01	0.96	0.92	0.90	1.01	0.98	1.08	0.99	0.95	0.95	0.99
	Spring tide	1.22	1.14	1.16	1.00	1.10	1.08	1.19	1.19	1.32	1.07	-	1.16	1.14
Buoy 97 (-7.8 m TAW)	Neap tide	0.74	0.77	0.75	0.81	0.70	0.70	0.73	0.81	0.78	0.85	0.75	0.73	0.76
	Avg tide	0.99	0.96	0.95	0.93	0.90	0.93	0.95	0.95	0.94	0.97	0.97	0.92	0.95
	Spring tide	1.16	1.13	1.09	1.00	1.06	1.09	1.07	1.16	1.04	1.10	1.09	1.11	1.09
Buoy 97 (-5.3 m TAW)	Neap tide	0.84	0.91	0.95	0.97	0.85	0.83	0.86	0.99	0.93	0.99	0.87	0.84	0.90
	Avg tide	1.11	1.10	1.11	1.12	1.09	1.10	1.15	1.19	1.09	1.11	1.16	1.02	1.11
	Spring tide	1.32	1.25	1.24	1.16	1.27	1.37	1.30	1.26	1.21	1.29	1.34	1.26	1.28
Oosterweel (- 5.8 m TAW)	Neap tide	0.60	-	-	0.69	0.63	0.64	-	-	0.73	0.78	0.69	0.65	0.65
	Avg tide	0.85	-	-	0.85	0.84	0.84	-	-	0.85	0.87	0.92	0.86	0.86
	Spring tide	0.97	-	-	0.84	0.98	1.02	-	-	0.74	1.00	1.04	1.10	1.02
Oosterweel (- 2.3 m TAW)	Neap tide	0.66	0.78	0.84	-	0.70	0.73	0.72	0.84	0.85	0.85	0.81	0.76	0.77
	Avg tide	0.92	0.93	0.88	0.97	0.94	0.97	0.96	0.99	0.98	1.01	0.99	0.97	0.97
	Spring tide	0.90	1.02	-	0.97	1.10	1.17	1.02	1.17	1.07	1.17	1.22	1.23	1.11

Table 3-3: Averaged ebb phase velocity [m/s] for each month and measurement station

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	0.30	0.36	0.30	0.28	0.29	-	0.28	0.28	0.29	0.28	-	0.28	0.30
	Avg tide	0.33	0.36	0.33	0.32	0.30	0.30	0.32	0.32	0.32	0.31	-	0.33	0.32
	Spring tide	0.36	0.37	0.34	0.33	0.33	0.32	0.34	0.35	0.33	-	-	0.38	0.34
Buoy 84 (-5.6 m TAW)	Neap tide	0.38	0.40	0.37	0.35	0.35	0.30	0.35	0.37	0.39	0.36	0.34	0.33	0.36
	Avg tide	0.43	0.43	0.41	0.40	0.38	0.37	0.39	0.41	0.41	0.39	0.36	0.40	0.40
	Spring tide	0.47	0.45	0.42	0.41	0.41	0.42	0.43	0.45	0.43	0.42	-	0.45	0.43
Buoy 97 (-7.8 m TAW)	Neap tide	0.33	0.32	0.30	0.32	0.29	0.26	0.31	0.30	0.32	0.29	0.30	0.31	0.30
	Avg tide	0.35	0.34	0.35	0.35	0.33	0.31	0.34	0.35	0.31	0.35	0.33	0.34	0.34
	Spring tide	0.37	0.37	0.38	0.36	0.36	0.36	0.38	0.38	0.31	0.40	0.36	0.36	0.37
Buoy 97 (-5.3 m TAW)	Neap tide	0.42	0.42	0.41	0.42	0.39	0.34	0.39	0.45	0.39	0.37	0.39	0.39	0.40
	Avg tide	0.48	0.47	0.46	0.46	0.45	0.42	0.45	0.54	0.40	0.46	0.45	0.46	0.45
	Spring tide	0.49	0.52	0.51	0.49	0.49	0.49	0.50	0.63	0.42	0.52	0.48	0.49	0.49
Oosterweel (- 5.8 m TAW)	Neap tide	0.42	-	-	0.47	0.44	0.44	-	-	0.43	0.42	0.44	0.39	0.43
	Avg tide	0.50	-	-	0.54	0.50	0.50	-	-	0.43	0.47	0.50	0.46	0.48
	Spring tide	0.56	-	-	0.55	0.53	0.55	-	-	0.41	0.50	0.52	0.51	0.53
Oosterweel (- 2.3 m TAW)	Neap tide	0.57	0.63	0.62	-	0.61	0.59	0.62	0.61	0.58	0.60	0.61	0.52	0.59
	Avg tide	0.65	0.68	0.68	0.69	0.69	0.67	0.72	0.66	0.62	0.65	0.68	0.61	0.66
	Spring tide	0.70	0.73	-	0.71	0.71	0.73	0.76	0.72	0.68	0.69	0.71	0.68	0.71

Table 3-4:Averaged ebb phase direction [deg] for each month and measurement station

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	359	354	0	2	350	-	357	356	354	0	-	358	357
	Avg tide	1	355	358	7	357	346	1	360	1	4	-	356	360
	Spring tide	358	359	356	8	359	355	0	1	1	-	-	357	360
Buoy 84 (-5.6 m TAW)	Neap tide	357	358	1	358	356	2	359	359	355	0	352	348	357
	Avg tide	357	358	359	353	356	358	0	358	358	358	356	355	358
	Spring tide	359	359	1	354	358	359	0	355	359	359	-	355	358
Buoy 97 (-7.8 m TAW)	Neap tide	295	297	300	300	298	302	301	302	302	298	301	297	300
	Avg tide	293	298	297	296	296	298	297	300	296	297	298	294	297
	Spring tide	290	297	295	296	294	295	297	300	297	294	297	295	295
Buoy 97 (-5.3 m TAW)	Neap tide	291	288	289	289	288	287	290	289	288	286	289	289	289
	Avg tide	290	288	289	287	287	288	287	288	287	286	287	288	287
	Spring tide	289	289	288	287	287	288	287	308	287	287	287	288	288
Oosterweel (- 5.8 m TAW)	Neap tide	266	-	-	274	273	272	-	-	272	274	271	272	271
	Avg tide	266	-	-	272	272	272	-	-	270	273	271	271	271
	Spring tide	266	-	-	272	272	272	-	-	268	273	271	270	271
Oosterweel (- 2.3 m TAW)	Neap tide	261	265	264	-	264	264	263	262	263	263	263	262	263
	Avg tide	260	263	263	261	261	263	261	263	261	261	262	260	262
	Spring tide	260	264	-	261	261	263	261	261	262	260	262	262	262

Table 3-5: Average flood phase velocity [m/s] for each month and measurement station

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	0.46	0.48	0.48	0.50	0.42	-	0.44	0.48	0.47	0.49	-	0.47	0.47
	Avg tide	0.56	0.54	0.55	0.58	0.54	0.49	0.55	0.51	0.54	0.55	-	0.57	0.54
	Spring tide	0.58	0.59	0.58	0.58	0.57	0.54	0.59	0.57	0.57	-	-	0.55	0.57
Buoy 84 (-5.6 m TAW)	Neap tide	0.54	0.53	0.52	0.56	0.46	0.45	0.49	0.55	0.53	0.55	0.56	0.47	0.51
	Avg tide	0.66	0.60	0.61	0.61	0.59	0.57	0.60	0.58	0.63	0.59	0.59	0.58	0.60
	Spring tide	0.70	0.66	0.66	0.62	0.64	0.62	0.65	0.65	0.69	0.61	-	0.64	0.65
Buoy 97 (-7.8 m TAW)	Neap tide	0.51	0.50	0.49	0.51	0.47	0.46	0.49	0.53	0.53	0.53	0.49	0.47	0.50
	Avg tide	0.61	0.59	0.58	0.59	0.58	0.58	0.58	0.57	0.58	0.60	0.60	0.56	0.58
	Spring tide	0.68	0.66	0.63	0.60	0.62	0.64	0.63	0.67	0.62	0.64	0.64	0.62	0.64
Buoy 97 (-5.3 m TAW)	Neap tide	0.59	0.62	0.63	0.63	0.58	0.55	0.59	0.68	0.63	0.62	0.57	0.55	0.60
	Avg tide	0.71	0.71	0.70	0.72	0.71	0.70	0.71	0.79	0.68	0.71	0.72	0.66	0.71
	Spring tide	0.79	0.76	0.77	0.72	0.76	0.77	0.76	0.81	0.73	0.76	0.78	0.74	0.76
Oosterweel (- 5.8 m TAW)	Neap tide	0.40	-	-	0.48	0.43	0.44	-	-	0.49	0.50	0.47	0.43	0.44
	Avg tide	0.52	-	-	0.54	0.53	0.53	-	-	0.52	0.54	0.54	0.54	0.53
	Spring tide	0.57	-	-	0.53	0.57	0.57	-	-	0.48	0.56	0.58	0.60	0.58
Oosterweel (- 2.3 m TAW)	Neap tide	0.44	0.54	0.57	-	0.51	0.51	0.52	0.58	0.59	0.56	0.56	0.52	0.53
	Avg tide	0.52	0.57	0.60	0.64	0.62	0.61	0.63	0.64	0.63	0.64	0.62	0.63	0.62
	Spring tide	0.56	0.58	-	0.64	0.65	0.66	0.64	0.68	0.66	0.67	0.69	0.69	0.65

Table 3-6: Average flood phase direction [deg] for each month and measurement station

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	188	185	183	190	187	-	188	188	188	187	-	186	187
	Avg tide	181	180	179	188	182	161	178	181	182	181	-	181	181
	Spring tide	180	177	174	187	179	175	174	180	178	-	-	179	178
Buoy 84 (-5.6 m TAW)	Neap tide	185	184	184	178	186	186	186	183	185	180	182	186	184
	Avg tide	179	181	180	175	182	183	181	181	179	178	180	183	180
	Spring tide	177	177	180	175	179	181	179	180	178	176	-	181	179
Buoy 97 (-7.8 m TAW)	Neap tide	109	110	106	108	109	105	108	109	105	107	111	107	108
	Avg tide	109	109	109	110	109	107	108	108	107	109	112	106	109
	Spring tide	104	111	106	111	108	109	107	112	107	109	112	103	108
Buoy 97 (-5.3 m TAW)	Neap tide	113	113	111	109	114	111	110	114	115	117	113	114	113
	Avg tide	113	113	112	113	114	114	113	111	117	117	116	113	114
	Spring tide	115	112	113	113	114	113	113	121	116	117	115	113	114
Oosterweel (- 5.8 m TAW)	Neap tide	91	-	-	95	95	96	-	-	93	94	96	98	95
	Avg tide	90	-	-	93	94	97	-	-	97	94	95	98	95
	Spring tide	88	-	-	94	95	95	-	-	98	95	94	97	94
Oosterweel (- 2.3 m TAW)	Neap tide	84	90	93	-	93	94	96	98	97	96	95	95	94
	Avg tide	85	90	94	94	96	94	97	95	97	96	94	96	95
	Spring tide	86	91	-	94	95	93	98	97	96	96	93	95	93

3.2. Tidal average velocity curves

For each measurement location the tidal average velocity curve has been calculated. The tidal average velocity course is in those curves presented in function of the time related to HW, and for an average neap tide, an average average tide and an average spring tide, see Annex-Figure C-19 to Annex-Figure C-24. These figures clearly show the asymmetric character of the velocities (see §2.3.1.4). Beside the asymmetry, which is the result of the convergence and friction effects in the estuary, the velocity curves in the measurement locations are influenced by local effects. All locations are situated at the edge or outside the navigation channel (ebb channel), and hence the local geometry and bathymetry dominate the velocity curve especially during the flood (whirlpool formation, embankments, vertical constructions).

During flood, there is a clear maximum and sometimes a double peak, while during ebb the velocity course is more regular. The maximum during flood is more distinct during a spring tide than during a neap tide.

These tidal average curves allow to determine the average values and the time of maximum flow velocity during ebb and flood for an average neap tide, an average tide and an average spring tide, see Table 3-7. The maximum flow velocity during ebb and flood is larger during a spring tide than during a neap tide. However, the increase in maximum flow velocity is larger during flood than during ebb. The maximum flood velocity during a spring tide in the measurement locations is 42%-57% larger than during a neap tide, while the maximum ebb velocity is only 10-22% larger during a spring tide than during a neap tide (see § 2.3.4.).

The average of the maximum flood velocity compares generally well with the data from September 2005 – March 2007 (IMDC 2008t), with the difference between the two datasets of approximately 5 %. Larger differences are observed for spring tide conditions at the lower measurement station at buoy 84 and Oosterweel (respectively 8 % and 16 % lower from April 2007 to March 2008). This might be to a statistical error, as the datasets at the lower instrument at buoy 84 and Oosterweel are the smallest ones in the present investigation.

The maximum ebb velocity at Buoy 84 and 97 compares well with the data from September 2005 – March 2007 (IMDC 2008t), with typical differences of 3 % between the datasets. At Oosterweel, the differences in the maximum ebb velocity is larger, ranging from 7-13% lower velocities from April 2007 to March 2008.

At all measurement locations, the maximum velocity is always observed at flood. This maximum in the flood flow is always observed about 1 hour before HW. During a neap tide, the maximum flood flow is generally observed earlier (about 1 h20 before HW) than during spring tide (about 0h40 before HW). At ebb, the course is more regular (less distinct peaks). In the most downstream (Buoys 84&97) locations, the maximum at ebb is generally observed at 2h40 after HW, independently of the tidal strength. More upstream in Oosterweel, the minimum values are spread from 3h40 to 4h00 after HW.

This compares well with the data from September 2005 – March 2007 (IMDC 2008t). The maximum difference in the time of the flood peak between both datasets is 10 minutes, which is the sampling frequency. The time of the ebb peak is equal in both datasets for Buoy 84 and 97. There are some differences in the time of the ebb velocity maximum between the two datasets at Oosterweel, with a maximum difference of 30 minutes during spring tide.

Table 3-7: Average tide curve for the flow velocity. Value [m/s] and time to HW [h:min] of the maximum velocity for the flood and the ebb phase for an averaged neap, average and spring tide, April 2007-March 2008

			Velocity		***Time to HW***	
			Flood	***Ebb***	***Flood***	***Ebb***
Buoy 84		Neap	**0.69**	0.50	-1:20	2:40
	-8.1 m TAW	Average	**0.86**	0.56	-0:50	2:40
		Spring	**0.98**	0.59	-0:40	2:40
Buoy 84		Neap	**0.73**	0.58	-1:30	2:40
	-5.8 m TAW	Average	**0.96**	0.66	-0:50	2:40
		Spring	**1.11**	0.71	-0:50	2:40
Buoy 97		Neap	**0.70**	0.50	-1:20	2:40
	-7.5 m TAW	Average	**0.91**	0.54	-1:00	2:40
		Spring	**1.06**	0.57	-0:40	2:40
Buoy 97		Neap	**0.84**	0.62	-1:20	2:40
	-5.1 m TAW	Average	**1.08**	0.69	-1:00	2:40
		Spring	**1.25**	0.75	-0:40	2:40
Oosterweel		Neap	**0.61**	0.59	-1:10	4:00
	-5.7 m TAW	Average	**0.82**	0.63	-0:50	3:50

			Velocity		*Time to HW*	
			Flood	***Ebb***	***Flood***	***Ebb***
		Spring	**0.96**	0.67	-0:40	3:40
Oosterweel		Neap	0.73	**0.82**	-1:10	3:50
	-2.1 m TAW	Average	**0.93**	0.87	-0:50	3:50
		Spring	**1.07**	0.90	-0:40	3:50

Slack water is the moment when the ebb flow changes into flood flow. In theory, this is the moment when the velocity equals zero. Due to the appearance of among others whirlpools, secondary flows, horizontal and vertical salinity gradients, the flow velocity never equals zero, and hence the moment of slack water in the measurement data is taken as the moment of minimum velocity. The velocity data indicate that both low and high water slack in general appear earlier during neap tide than during spring tide, see Table 3-8.

The tidal averaged flow directions are shown in Annex-Figure C-25 to Annex-Figure C-30. Note that no standard deviations are plotted in this figure, as they are not well defined for directional data. These figures indicate that the flow is very gradually changing its direction at Buoy 84 and (see also Annex-Figure C-19 to Annex-Figure C-24.) that slack lasts for a certain time (±1h00). At buoy 97 and Oosterweel on the contrary, the transition at high slack water is rather fast, whereas the low water slack tide shows a more gradual transition. Through tide measurements (e.g. partial reports 7.1-7.6 of HCBS 2 ANNEX A) indicate that the low water slack commences at a different moment depending on the location of the measurement point in the cross section. The flow direction in the measurement points in shallower regions changes earlier than in the measurement points located in the navigation channel. This phase shifting in low water slack over a cross section can take about 1 hour. High water slack is more synchronic along the width of the river. These differences in slack time period result from the fact that the ebb flow principally follows the main channel while the flood flow spreads more over the whole sections and is at its maximum in the regions close to the banks. Other effects influencing the moment of slack are the vertical and horizontal salinity gradients. The Scheldt is known to be a well-mixed estuary, but even small vertical salinity gradients can have an important influence on the flow pattern (Winterwerp et al., 2006). Note that the moments of high water slack in the present measurement period coincide well with those reported in the period September 2005 – March 2007 (IMDC, 2008t) (a maximum difference of 10 minutes in the moment of high water slack was found between the datasets). Larger discrepancies were found in the moment of low water slack, which is due to the ambiguity in the determination of the low water slack (especially for the second one) due to influence of the data cut-off at the edges. A possible workaround would be to group all tides with a time vector of hours to low water level, instead of high water level. This would effectively give a better resolution around low water slack. This analysis is not done however in the present report.

Table 3-8: Average tide curve for the flow velocity. Time to HW of the low (LSW) and high (HSW) slack water and duration of the rising, falling and of the tide for an averaged neap, average and spring tide, April 2007-March 2008

			LSW 1	***HSW***	***LSW 2***	***LSW 1 to HSW***	***HSW to LSW 2***	***Total***
Buoy 84		Neap	-6:40	1:00	7:10	7:40	6:10	13:50
	-8.1 m TAW	Average	-5:50	1:00	7:30	6:50	6:30	13:20

			LSW 1	***HSW***	***LSW 2***	***LSW 1 to HSW***	***HSW to LSW 2***	***Total***
		Spring	-5:30	1:00	7:20	6:30	6:20	12:50
Buoy 84		Neap	-6:30	1:00	7:00	7:30	6:00	13:30
	-5.8 m TAW	Average	-5:40	1:00	7:30	6:40	6:30	13:10
		Spring	-5:30	1:00	7:20	6:30	6:20	12:50
Buoy 97		Neap	-6:00	1:00	7:00	7:00	6:00	13:00
	-7.5 m TAW	Average	-5:50	1:00	7:30	6:50	6:30	13:20
		Spring	-5:20	1:10	7:40	6:30	6:30	13:00
Buoy 97		Neap	-5:40	1:00	7:40	6:40	6:30	13:10
	-5.1 m TAW	Average	-5:30	1:10	7:50	6:40	6:40	13:10
		Spring	-5:10	1:10	7:50	6:20	6:40	13:00
Oosterweel		Neap	-6:00	0:50	7:10	6:50	6:20	13:10
	-5.7 m TAW	Average	-5:30	1:00	7:30	6:30	6:30	13:00
		Spring	-5:20	1:10	7:40	6:30	6:30	13:00
Oosterweel		Neap	-5:50	0:50	7:30	6:40	6:40	13:20
	-2.1 m TAW	Average	-5:30	1:00	7:50	6:30	6:50	13:20
		Spring	-5:00	1:10	8:00	6:10	6:50	13:00

3.3. Conclusion

In general, the velocity data recorded from April 2007 to March 2008 correspond to those measured from September 2005 to March 2007 (IMDC 2008t). This was to be expected, because the major influence on the flow velocity, the tide has very similar characteristics in this period. Furthermore, the fresh water discharge also had similar characteristics in both measurement periods.

4. SALINITY

Salt concentration or salinity is used as an indicator for seawater and also analysed in this sense. It is assumed that the interaction and exchange processes between salt and fresh water is one of the determining factors for the sediment transport. In this chapter, the maximum, minimum and average values are first presented, paying attention to the identification of salt and fresh water and mixtures thereof. After that, the salinity amplitude will be analysed, stressing the various regimes of interaction between tidal related and discharge related flow processes, and the location of the salt penetration front. Then follow the tidal average salinity curves and the analysis thereof in terms of time and duration of slack. Finally, high salinity gradients, which might cause flows of highly concentrated sediment, will be tracked.

4.1. Minimum, maximum and average values

Table 4-1 and Table 4-2 indicate the maximum, minimum and average monthly salinity for the various measurement locations and the period April 2007 – March 2008. Also see Annex-Figure D-1 to Annex-Figure D-8.

It has to be first indicated that RCM-9s with old conductivity sensors were used at Buoy 84 and that an intercomparison of the various instruments showed that these instruments recorded higher conductivities than the other instruments.

The average salinity during the measurement period is the highest at Prosperpolder (situated furthest downstream) and the lowest at Oosterweel (situated furthest upstream) and is decreasing gradually in upstream direction. In all locations, we find a higher salinity during the months of July until November compared to the rest of the year. The highest value (16.5) was measured in Prosperpolder in November 2007 and in Buoy 84 in October 2007. The lowest value was measured at Oosterweel (0.4) in December 2007. These values compare well with the maximum and minimum values found from September 2005 – March 2007. The maximum salinities at Buoy 97 and Oosterweel are somewhat (about 2 to 2.5 ppt) lower than those from September 2005 – March 2007.

The monthly averaged salinities for most of these instruments show that the salinities at the upper and lower instrument are very similar (they are slightly lower at the upper instrument), which means that stratification is not important and that the Scheldt estuary can be classified as well mixed (Dyer, 1995). No attempt was made to compare the minimum and maximum monthly salinities of the upper and lower instruments, as these are very sensitive to missing data. The monthly averaged salinities show comparable values to those measured from September 2005 – March 2007 (IMDC 2008t), although the maxima of these averages tend to be somewhat lower and the minima of these averages somewhat higher than were found from September 2005 – March 2007.

At Oosterweel, there is very little variation in minimum value, which ranges from 0.4 to 2 ppt. When successive high discharge peaks (for example January 2008) occur the maximum value (and also the value at further downstream locations) comes close to this minimum threshold (5 ppt). This minimum value, varying between 0 and 1 ppt, gives the background value of pure fresh water.

During an earlier campaign (IMDC, 1999), a similar phenomenon was observed in further downstream locations (Prosperpolder and Noord Ballast), where maximum salinity values reached a threshold around 32 ppt with slightly higher values during summer. Hence, this is the characteristic of pure seawater.

Salt concentration values between these two thresholds indicate more or less concentrated mixtures of sea and fresh water. For example, Dahl (1956) makes the difference between fresh brackish and salt water on the basis of the salt content (Table 4-4). Based on this division, the measurement locations in Buoy 84 & 97 and Prosperpolder may be regarded as moderately brackish, while Oosterweel is on the limit between slightly and moderately brackish.

These thresholds phenomenon and the exchanges between fresh water and seawater are the tangible sign of the interaction between two types of flow regimes: the penetrating salty tidal wave propagating upstream and the fresh discharge flowing downstream. The interaction between these two mechanisms characterizes the estuaries such as the Lower Sea Scheldt and determines their flow pattern, their sediment transport regime and their ecosystem. The study hereinafter is further getting into the details of this interaction processes.

Table 4-1: Monthly maximal salinity [ppt] for each measurement station

	2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	7.99	14.36	15.43	15.18	14.62	15.33	16.53	12.56	6.82	7.53	9.42	9.82	16.53
Buoy 84 (-5.6 m TAW)	7.75	12.81	13.79	12.99	13.1	15.39	15.65	16.16	12.09	9.18	10.25	10.62	16.16
Buoy 97 (-7.8 m TAW)	10.21	11.38	12.49	11.47	10.68	12.59	12.85	12.75	9.98	7.13	8.08	8.24	12.85
Buoy 97 (-5.3 m TAW)	10.14	11.34	12.39	11.47	10.64	12.54	12.77	12.67	9.9	7.07	8.07	8.23	12.77
Oosterweel (- 5.8 m TAW)	7.69	-	-	8.58	8.51	10.3	-	-	4.11	4.63	5.98	6.04	10.3
Oosterweel (- 2.3 m TAW)	7.84	9.44	9.06	9.23	8.56	10.28	9.08	8.12	7.36	4.63	5.93	6.03	10.28
Prosperpolder (- 1.5 m TAW)	12.5	14.66	15.69	14.23	13.92	15.26	16.21	16.53	12.53	9.97	11.14	11.43	16.53

Table 4-2: Monthly minimal salinity [ppt] for each measurement station

	2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	3.64	8.99	7.97	6.74	6.29	8.55	10.23	6.02	0.54	2.26	4.72	1.43	0.54
Buoy 84 (-5.6 m TAW)	3.46	8.51	8.29	6.36	5.71	9.05	9.2	7.28	1.98	3.82	3.68	1.41	1.41
Buoy 97 (-7.8 m TAW)	2.52	6.81	6.37	4.04	2.87	7.04	5.85	3.92	0.98	2.23	1.89	0.65	0.65
Buoy 97 (-5.3 m TAW)	2.42	6.48	5.15	3.85	3.66	6.68	5.93	3.57	0.82	2.02	1.72	0.5	0.5
Oosterweel (- 5.8 m TAW)	1.97	-	-	0.57	0.53	1.78	-	-	0.4	0.42	0.45	0.42	0.4
Oosterweel (- 2.3 m TAW)	0.77	1.71	1.16	0.89	0.9	1.65	0.99	0.52	0.4	0.42	0.45	0.46	0.4
Prosperpolder (- 1.5 m TAW)	4.38	8.14	9.84	7.25	6.78	8.77	9.74	7.98	2.83	4.56	4.22	2.16	2.16

Table 4-3: Monthly averaged salinity [ppt] for each measurement station

	2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	5.87	11.01	11.39	10.41	9.69	11.95	12.86	9.79	4.37	5.33	7.57	5.09	9.03
Buoy 84 (-5.6 m TAW)	5.77	10.46	10.88	9.65	10.05	11.94	12.05	11.13	5.96	6.35	6.86	5.53	8.96
Buoy 97 (-7.8 m TAW)	6.94	9.42	9.94	8.50	7.97	10.04	9.90	8.97	4.48	4.81	5.05	4.09	7.44
Buoy 97 (-5.3 m TAW)	6.81	9.29	9.70	8.32	7.88	9.90	9.74	8.78	4.33	4.71	4.93	3.96	7.31
Oosterweel (- 5.8 m TAW)	4.77	-	-	3.92	4.12	5.91	-	-	1.30	1.94	2.41	2.22	3.54
Oosterweel (- 2.3 m TAW)	3.45	5.74	4.91	4.58	4.44	5.85	4.66	3.44	1.96	1.93	2.37	2.29	3.65
Prosperpolder (- 1.5 m TAW)	8.45	9.99	12.24	10.66	9.53	11.91	12.24	11.60	6.50	6.84	7.10	6.34	9.60

Table 4-4: Classification of the homoiohaline waters (Dahl, 1956)

			Salt content in ppt
Fresh water			0.0-0.5
Brackish water	Oligohalien	Slightly brackish water	0.5-5.0
	Mesohalien	Moderately brackish water	5.0-18.0
	Polyhalien	Very brackish water	18.0-30.0
Salt water	Euhalien		30.0-35
	Metahalien		36-40

4.2. Salinity amplitude

Annex-Table D-1 displays the average difference between maximum and minimum salinity per tide (salinity amplitude) and per measurement location for an average neap tide, an average average tide and an average spring tide over various periods, see also Annex-Figure D-1b - Annex-Figure D-7b and Annex-Figure D-9. It is important to know the salinity amplitude and its variations because these are the main reason for the arising of density flows. Density flows cause an increased water exchange between the access channels or the Deurganckdok and the river. Hence, they can be responsible for an important part of the important sediment transports.

The various figures and tables (especially Annex-Table D-1, Annex-Figure D-8 en Annex-Figure D-9) show that the salinity amplitude is being determined by the relative strength of the two flow mechanisms mentioned above: on the one hand **tide related flow mechanism** of which the strength is influenced by the neap tide-spring tide cycle and by storms, and for which the tidal amplitude can constitute a good indicator of the strength, and on the other hand **discharge related flow mechanisms** of which the strength is influenced by precipitation and for which the absolute salinity constitutes a good indicator of the strength. It goes without saying that the distance to the estuary mouth also plays an important role in the interaction between both mechanisms.

In a normal situation (that is without extreme precipitation), the tidal amplitude seems to have a dominant effect on the salinity amplitude in the measurement locations downstream, while the absolute salinity value (discharge) has an important effect on the salinity amplitude in the measurement locations upstream.

When discharge increases, the fresh water characteristics push the salty water characteristics downstream. In one point, the salinity minimum at low tide will easier reach the fresh water threshold in periods with high precipitation. When there is a certain “critical” discharge (also depending on the amplitude of the tide) the tidal influence in the location is no longer felt in terms of salinity and even at high tide the maximum salinity values are not much higher than the fresh water threshold. At the other end, at the mouth (and the smaller the discharge, the easier upstream), the fresh water is so well mixed in salt water that both the maximum and minimum salt concentrations during a tide are close to the seawater threshold.

Hence, the variations in discharge cause the longitudinal salt profile to constantly change. The variations due to the discharge are not symmetric. For a high discharge, the salinity will very suddenly decrease, while a decreasing discharge will cause the salinity to slowly increase. The salty front will slowly but continuously propagate due to diffusion and advection processes, as a result of which high salinity values may also be measured in the upstream locations, until the discharge is sufficiently high to chase away the salinity front. Annex-Figure D-10 tot Annex-Figure D-12 provide an illustration of the hysteresis for the three measurement locations.

The effect of the absolute salinity value (as an indicator for the relative strength of the upper discharge mechanisms) on the salinity amplitude may also be observed in the measurement locations downstream (i.e. Oosterweel) where the salinity strongly decreases just after the local flow peaks.

The tidal effects work on a shorter time scale (one or several tides) compared to the effect of the mechanisms of salt diffusion – backflow caused by a high discharge (dry and wet periods, seasons) but can be felt with decreasing force from downstream to upstream in all locations.

Due to the interaction between these two kinds of mechanisms, and on the basis of the salinity amplitude several regimes were distinguished, each one with a different grades of correlation between tidal and salinity amplitude. The correlation can be illustrated by studying the magnitude of the cross-correlation between tidal and salinity amplitude for each of the periods observed hereinafter (Annex-Figure D-13 - Annex-Figure D-16).

- Saline regime: This is the regime that is dominating in the most downstream location in normal situations where the effect of diffusion – backflow is hardly felt. There is not sufficient fresh water to form a contrast with the salt water. Both the maximum and minimum values in salinity are high, as a result of which the salinity amplitude remains moderate and fairly constant. The amplitude course is fairly independent from the tidal amplitude with correlation factors of about 0.54 (Buoy 84, May to July 2007)
- Greatly brackish regime: For this regime, the two types of mechanisms are in balance. The contrast between maximum and minimum values of the salinity depends both on the tidal amplitude and on the discharge, which also determines the average value. Here, the salinity amplitude is the biggest compared with the other regimes, as well as the correlation strength with factors of 0.8 (Oosterweel, September - October 2007).
- Slightly brackish regime: This regime occurs when discharge is strong enough and the location is upstream enough to keep the salt penetration front downstream of the measurement location during the lower part of the tide. In this sense, the effects of diffusion – backflow become more important than the tidal effects. The maximum salinity values will decrease compared with the above described regime, while the minimum values equal the fresh water threshold, as a result of which the values of the salinity amplitude and the connection with the tidal force will decrease, with coefficients of 0.28. (Oosterweel, January to February 2008)
- Fresh water regime: This regime occurs when the discharge is so large compared with the tidal amplitude that the saline front will remain downstream the location during the whole tide. The tidal effect will only be felt by the propagation of the water wave. The salinity will strive to reach a constant value with an amplitude nearing zero. Because of the insufficient amount of data for Oosterweel, the correlation is not significant enough to be interpreted (Oosterweel, December 2007)

Although the denomination was inspired by the Dahl classification (1956), it has to be noted that the salinity values dominating per regime do not correspond with the values in Table 4-4.

In Buoy 84 and Prosperpolder, the saline regime dominates in normal circumstances. In Buoy 97 the greatly brackish regime dominates, although in periods of high discharge coupled with low amplitudes, a slightly brackish or even a fresh water regime can occur. In Oosterweel, both the greatly and the slightly brackish regime occur.

For a greatly brackish regime, the salinity amplitudes reach their highest values.

In more upstream locations and/or for higher flows compared to the tidal amplitude, the slightly brackish regime dominates. The salinity amplitude for this regime is smaller but due to the fact that the saline front is shifting to and from along the location during the tide, high longitudinal gradients in salinity and therefore high sediment concentrations may be expected.

A comparison of Annex-Table D-1 with Annex-Table C-1 from IMDC (2008t) shows that the salinity amplitude tends to be smaller (up to 2.5 ppt for Oosterweel) between April 2007 and March 2008 than between September 2005 and March 2007. However, both datasets show a similar trend with respect to the dependence on the spring and neap tidal data.

4.3. Tidal average salinity curves

A tidal salinity curve was drawn up for each measurement location. The course of this salinity is expressed as function of the time compared with high tide for neap tide, average tide and spring tide, see Annex-Figure D-17 to Annex-Figure D-22. With these curves, the average time tags of maximum and minimum salinity may be determined in function of the tidal amplitude, see Table 4-5. Because the data have been measured with a frequency of 10 minutes, there is an inaccuracy in the time tags calculated of 10 minutes at the most.

Extreme values in salinity may also be used to calculate the times of slack water. The moment of low water - and high water slack will then be defined as respectively the moment of minimum and maximum salinity.

Table 4-5: Average tidal curve for the relative salinity. Time to HW of the moments of minimum (Min1 & Min2) and maximum (Max) salinity and duration of the rising, falling and of the tide for an averaged neap, average and spring tide, April 2007-March 2008

			Min 1	***Max***	***Min 2***	***Min 1 to Max***	***Max to Min 2***	***Total Duration***
Buoy 84		Neap	-6:00	0:30	6:20	6:30	5:50	12:20
	-8.1 m TAW	Average	-5:50	0:50	6:10	6:40	5:20	12:00
		Spring	-5:40	0:50	6:30	6:30	5:40	12:10
Buoy 84		Neap	-6:10	0:30	6:30	6:40	6:00	12:40
	-5.8 m TAW	Average	-5:50	0:40	6:30	6:30	5:50	12:20
		Spring	-5:40	0:40	6:40	6:20	6:00	12:20
Buoy 97		Neap	-6:10	0:50	7:40	7:00	6:50	13:50
	-7.5 m TAW	Average	-5:30	1:00	7:10	6:30	6:10	12:40
		Spring	-5:40	1:00	7:10	6:40	6:10	12:50
Buoy 97		Neap	-5:50	0:50	7:00	6:40	6:10	12:50
	-5.1 m TAW	Average	-5:50	0:50	6:50	6:40	6:00	12:40
		Spring	-5:50	0:50	7:20	6:40	6:30	13:10
Oosterweel		Neap	-4:50	0:40	7:00	6:30	6:20	12:50
	-5.7 m TAW	Average	-4:40	0:50	7:20	6:30	6:30	13:00
		Spring	-4:40	1:00	7:40	6:40	6:40	13:20
Oosterweel		Neap	-5:10	0:50	7:10	6:00	6:20	12:20
	-2.1 m TAW	Average	-4:50	0:40	7:30	5:30	6:50	12:20
		Spring	-4:30	1:00	7:40	5:30	6:40	12:10
Prosperpolder		Neap	-4:50	0:20	6:40	5:10	6:20	11:30
	-1.5 m TAW	Average	-4:50	0:30	6:50	5:20	6:20	11:40
		Spring	-4:20	0:40	6:40	5:00	6:00	11:00

In general, we note that both the moments of minimum and maximum salinity appear earlier during neap tide than during spring tide. That is why a “flood” takes longer and an “ebb” less long at neap tide than at spring tide.

The time tags of minimum and maximum salinity, used to determine moments of slack water and mentioned in Table 4-5, can only be applied locally. The measurement locations are only situated at one point, vertically and close to the river bank. The effects of vertical stratification (the vertical salinity gradient is the largest around slack water), of horizontal stratification (over the cross section), of two-layered flows (especially around LW-slack) and of local flow phenomena (whirlpool formation, access channels, secondary flows etc.) can have a strong influence on the moment of slack water. This is the reason that some large differences in the moments of maximum and minimum salinity can be found between April 2007-March 2008 and September 2005 to March 2007.

4.4. Longitudinal gradients

High longitudinal gradients of salinity may cause density flows and hence sediment transport. Longitudinal gradients will here be assessed by using an estimate formula:

$$\partial S / \partial x = \left(dS / dt \right) 1 / V = \frac{S_{i+1} - S_i}{t_{i+1} - t_i} \frac{1}{\overline{V_{i,i+1}}}$$

with S_i the salinity in at time i, t_i the time i, $1\overline{V_{i,i+1}}$ the average flow velocity between time tags i and i+1.

This formula is being calculated for each measurement time (that is every 10 minutes). Per episode (tide, ebb, flood), the monthly average value has been calculated. Table 4-7 en Table 4-8 give the monthly average gradients for ebb and flood, as well as the dominating regimes. Table 4-6 displays the average values per trimester for the tidal averages.

In contrast to the data from September 2005 to March 2007, the present data show that in Buoy 84 and Buoy 97, the gradients are larger during flood than during ebb. In Oosterweel, the gradients are slightly larger during ebb. Strikingly, no clear relation can be derived between the gradients and the tidal amplitude. Most of the time, the gradients even decrease with the amplitude. The largest gradients are in general found for greatly brackish regime, the smallest for fresh water regime. For a slightly brackish regime, intermediate values are obtained, as a result of which we might think at first that there are no important salinity gradients near the salt penetration front.

Since the greatly brackish regime is also characterized by a high salinity, the regime goes hand in hand with the highest spatial variations in salinity of all, and hence represents the critical condition in terms of sediment transport caused by salt and fresh water exchanges and mixing processes.

Table 4-6: Quarterly average value of the tide averaged horizontal salinity gradient [ppt/km] and flow regime for each measurement station

		Apr-Jun 2007	Jul-Sep 2007	Oct-Dec 2007	Jan-Mar 2008
Buoy 84 (-8.1 m TAW)	Neap tide	0.40	0.51	0.33	1.14
	Avg tide	0.50	0.56	0.51	0.35
	Spring tide	0.52	0.69	0.76	0.49
Buoy 84 (-5.6 m TAW)	Neap tide	0.40	0.49	0.51	0.44
	Avg tide	0.41	0.40	0.44	0.44
	Spring tide	0.43	0.50	0.49	0.46
Buoy 97 (-7.8 m TAW)	Neap tide	0.55	0.62	0.64	0.47
	Avg tide	0.52	0.54	0.55	0.47
	Spring tide	0.44	0.53	0.50	0.47
Buoy 97 (-5.3 m TAW)	Neap tide	0.41	0.46	0.46	0.38
	Avg tide	0.39	0.39	0.39	0.33
	Spring tide	0.33	0.38	0.37	0.32
Oosterweel (- 5.8 m TAW)	Neap tide	0.53	0.57	0.25	0.36
	Avg tide	0.48	0.52	0.27	0.31
	Spring tide	-	0.53	0.34	0.31
Oosterweel (- 2.3 m TAW)	Neap tide	0.44	0.49	0.38	0.28
	Avg tide	0.43	0.45	0.32	0.24
	Spring tide	0.37	0.45	0.34	0.25

Table 4-7: Monthly average value of the ebb phase averaged horizontal salinity gradient [ppt/km] and flow regime for each measurement station

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	0.26	0.27	0.35	0.44	0.46	-	-	-	0.24	1.01	-	0.24	0.40
	Avg tide	0.32	0.33	0.46	0.45	0.40	0.64	0.43	0.61	0.32	-	-	0.27	0.42
	Spring tide	0.34	0.47	0.44	0.50	0.48	0.84	0.59	0.83	-	-	-	0.39	0.51
Buoy 84 (-5.6 m TAW)	Neap tide	0.23	0.31	0.39	0.47	0.45	0.38	0.43	0.41	0.46	0.36	0.36	0.41	0.40
	Avg tide	0.27	0.36	0.35	0.28	0.38	0.37	0.39	0.49	0.31	0.37	0.34	0.40	0.36
	Spring tide	0.31	0.41	0.38	0.33	0.48	0.43	0.42	0.51	0.31	0.34	-	0.46	0.41
Buoy 97 (-7.8 m TAW)	Neap tide	0.35	0.52	0.60	0.59	0.58	0.44	0.57	0.60	0.52	0.36	0.37	0.49	0.50
	Avg tide	0.35	0.46	0.49	0.44	0.62	0.37	0.53	0.51	0.36	0.36	0.35	0.44	0.44
	Spring tide	0.31	0.39	0.44	0.41	0.44	0.37	0.47	0.38	0.31	0.27	0.35	0.38	0.38
Buoy 97 (-5.3 m TAW)	Neap tide	0.26	0.34	0.41	0.46	0.37	0.31	0.40	0.38	0.33	0.32	0.31	0.32	0.35
	Avg tide	0.27	0.29	0.37	0.32	0.32	0.28	0.35	0.40	0.26	0.27	0.24	0.31	0.31
	Spring tide	0.25	0.28	0.33	0.28	0.32	0.28	0.31	0.33	0.25	0.22	0.25	0.28	0.28
Oosterweel (- 5.8 m TAW)	Neap tide	0.57	-	-	0.50	0.57	0.66	-	-	0.22	0.27	0.33	0.42	0.50
	Avg tide	0.51	-	-	0.53	0.51	0.58	-	-	0.29	0.30	0.34	0.31	0.41
	Spring tide	-	-	-	0.52	0.53	0.58	-	-	0.35	0.29	0.32	0.35	0.43
Oosterweel (- 2.3 m TAW)	Neap tide	0.44	0.50	0.54	-	0.48	0.55	0.53	0.40	0.31	0.28	0.28	0.34	0.43
	Avg tide	0.41	0.51	0.52	0.50	0.43	0.53	0.52	0.41	0.24	0.26	0.26	0.26	0.39
	Spring tide	0.40	0.53	-	0.50	0.46	0.52	0.51	0.43	0.26	0.25	0.26	0.29	0.38

*Blue frame: Saline regime
*Red frame: Greatly brackish regime
*Green frame: Slightly brackish regime
*Purple fame: Fresh water regime

Table 4-8: Monthly average value of the flood phase averaged horizontal salinity gradient [ppt/km] and flow regime for each measurement station

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	0.49	0.44	0.64	0.70	0.59	-	-	-	0.44	2.53	-	0.43	0.73
	Avg tide	0.44	0.52	0.66	0.71	0.63	0.86	0.47	0.98	0.63	-	-	0.43	0.64
	Spring tide	0.45	0.73	0.63	0.91	0.73	1.04	0.79	0.93	-	-	-	0.61	0.74
Buoy 84 (-5.6 m TAW)	Neap tide	0.33	0.48	0.57	0.59	0.59	0.52	0.58	0.62	0.59	0.48	0.62	0.48	0.54
	Avg tide	0.32	0.47	0.50	0.43	0.54	0.51	0.53	0.58	0.42	0.48	0.53	0.56	0.49
	Spring tide	0.34	0.51	0.60	0.48	0.67	0.53	0.56	0.67	0.44	0.44	-	0.56	0.54
Buoy 97 (-7.8 m TAW)	Neap tide	0.50	0.61	0.69	0.66	0.91	0.59	0.74	0.70	0.69	0.54	0.54	0.57	0.65
	Avg tide	0.45	0.62	0.62	0.55	0.66	0.64	0.66	0.74	0.61	0.50	0.59	0.65	0.61
	Spring tide	0.49	0.49	0.58	0.57	0.72	0.59	0.63	0.62	0.60	0.46	0.64	0.67	0.60
Buoy 97 (-5.3 m TAW)	Neap tide	0.43	0.53	0.47	0.57	0.62	0.46	0.53	0.52	0.56	0.46	0.42	0.46	0.50
	Avg tide	0.39	0.45	0.47	0.45	0.48	0.47	0.52	0.49	0.42	0.37	0.37	0.43	0.44
	Spring tide	0.39	0.36	0.42	0.42	0.48	0.44	0.46	0.44	0.44	0.32	0.39	0.44	0.42
Oosterweel (- 5.8 m TAW)	Neap tide	0.49	-	-	0.47	0.55	0.60	-	-	0.28	0.30	0.35	0.40	0.48
	Avg tide	0.46	-	-	0.47	0.48	0.55	-	-	0.26	0.30	0.32	0.32	0.39
	Spring tide	-	-	-	0.44	0.48	0.54	-	-	0.33	0.29	0.29	0.37	0.41
Oosterweel (- 2.3 m TAW)	Neap tide	0.35	0.41	0.46	-	0.41	0.46	0.43	0.34	0.30	0.28	0.24	0.29	0.36
	Avg tide	0.31	0.39	0.43	0.40	0.36	0.44	0.41	0.36	0.22	0.24	0.21	0.23	0.33
	Spring tide	0.29	0.39	-	0.39	0.38	0.43	0.40	0.37	0.23	0.21	0.23	0.28	0.31

*Blue frame: Saline regime
*Red frame: Greatly brackish regime
*Green frame: Slightly brackish regime
*Purple fame: Fresh water regime

5. TEMPERATURE

The aim of this chapter is to determine whether the seasonal cycle has an influence on the sediment transport. Indeed, the quantities of available sediments might be influenced by temperature and light-related processes (biological activity, increase of flocculation,...). The temperature course has been taken in this sense. First we will present the monthly minimum, maximum and average values. Then, we will study the evolution of the temperature amplitude. Finally, we will present the tidal averaged temperature curves.

5.1. Minimum, maximum and average values

Table 5-1 and Table 5-2 display for the various measurement locations the monthly maximum and minimum temperatures, also see Annex-Figure E-1a -Annex-Figure E-7a and Annex-Figure E-8. Table 5-3 displays the monthly average temperature.

The warmest months during the measurement period were July and August 2007 (up to 22.3 °C in Oosterweel). The coldest temperatures were measured in December 2007 and January 2008 (3.6 °C in Oosterweel). The maximum water temperatures are significantly lower than recorded from September 2005 to March 2007 (IMDC, 2008t), when water temperatures up to 25.9 °C were measured. The lowest temperature measured from September 2005 to March 2007 (2.7 °C), is quite comparable to the lowest temperature measured between April 2007 to March 2008.

Table 5-1: Monthly maximal temperature [°C] for each measurement station

	2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	12.66	18.48	21.68	21.02	21.29	20.38	16.99	13.65	9.71	6.9	8.72	9.48	21.68
Buoy 84 (-5.6 m TAW)	12.68	18.49	21.63	21.02	21.18	20.2	17.21	13.63	9.24	8.57	8.58	9.51	21.63
Buoy 97 (-7.8 m TAW)	17.66	18.66	21.9	21.11	21.5	20.49	17.59	13.88	9.36	9.08	8.89	9.97	21.9
Buoy 97 (-5.3 m TAW)	17.7	18.68	21.89	21.21	21.5	20.6	17.59	13.99	9.4	9.17	8.85	9.95	21.89
Oosterweel (- 5.8 m TAW)	16.06	-	-	20.85	21.08	20.12	-	-	8.73	8.41	7.96	9.16	21.08
Oosterweel (- 2.3 m TAW)	16.08	17.56	21.52	20.67	20.87	20.13	16.68	10.95	8.77	8.44	7.94	9.15	21.52
Prosperpolder (- 1.5 m TAW)	18.53	18.39	22.21	22.26	22.14	20.44	18.49	14.19	9.43	8.84	9.09	10.67	22.26

Table 5-2: Monthly minimal temperature [°C] for each measurement station

	2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	10.03	16	17.55	18.56	19.52	18.44	12.92	8.54	5.41	5.24	7.3	7.81	5.24
Buoy 84 (-5.6 m TAW)	10.06	15.99	17.54	18.54	19.52	16.56	12.88	8.48	5.37	5.21	6.31	7.72	5.21
Buoy 97 (-7.8 m TAW)	9.99	16.25	17.7	18.7	19.64	16.82	12.8	8.52	5.4	5.02	6.38	7.43	5.02
Buoy 97 (-5.3 m TAW)	9.95	16.25	17.7	18.71	19.64	16.85	12.79	8.5	5.28	4.99	6.38	7.28	4.99
Oosterweel (- 5.8 m TAW)	9.65	-	-	18.65	19.2	15.96	-	-	5.24	5.04	5.4	6.72	5.04
Oosterweel (- 2.3 m TAW)	9.63	16.06	19.46	18.56	19.2	15.98	13.87	7.33	3.62	4.15	5.39	6.72	3.62
Prosperpolder (- 1.5 m TAW)	9.87	15.65	17.39	18.37	19.36	16.35	12.61	8.38	6.3	5.4	6.08	7.58	5.4

Table 5-3: Monthly averaged temperature [°C] for each measurement station

	2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	11.11	17.21	20.08	19.86	20.43	19.40	15.14	11.09	7.47	5.77	7.89	8.57	14.37
Buoy 84 (-5.6 m TAW)	11.13	17.19	20.08	19.81	20.41	18.45	15.63	11.05	7.43	6.77	7.24	8.54	13.48
Buoy 97 (-7.8 m TAW)	14.27	17.25	20.20	19.84	20.51	18.55	15.69	11.11	7.47	6.87	7.34	8.56	13.76
Buoy 97 (-5.3 m TAW)	14.29	17.26	20.20	19.96	20.49	18.56	15.70	11.12	7.46	6.85	7.36	8.54	13.88
Oosterweel (- 5.8 m TAW)	12.75	-	-	20.07	20.16	18.28	-	-	7.81	7.01	6.64	8.08	13.08
Oosterweel (- 2.3 m TAW)	12.71	16.84	20.58	19.45	20.17	18.27	15.54	8.83	6.74	6.37	6.63	8.08	12.18
Prosperpolder (- 1.5 m TAW)	13.38	16.72	19.99	19.76	20.39	18.56	15.58	10.98	8.36	7.25	7.26	8.56	14.17

5.2. Temperature amplitude

Annex-Figure E-1b to Annex-Figure E-7b and Annex-Figure E-9 display the average difference between maximum and minimum temperature per tide (temperature amplitude) and per measurement location for an average neap tide, an average tide and an average spring tide and for various periods, see also Annex-Figure E-1b - Annex-Figure E-7b. The table shows that the temperature amplitude is somewhat influenced both by seasons (absolute water temperature) and by the tidal amplitude. Furthermore, the location of the measurement point is of importance.

The most important factor determining the size of the temperature amplitude is the seasonal variation at Buoy 97 and the lower instrument at Oosterweel. Here, the larger temperature differences per tide occur during winter, during summer these differences are smaller. At the other locations, no seasonal variation in the temperature amplitude is present. The influence of the tidal amplitude is of minor importance. In general, the temperature amplitude is larger in the upstream measurement locations and is about 0.8 °C there and about 0.4 °C downstream. In the downstream location (Buoy 84) there is very little mixture of fresh and salt water resulting in a small and almost constant temperature amplitude. However, at Prosperpolder, large temperature amplitudes exist, probably as a result of local effects. An analogous phenomena probably occurs at the upstream end, where there is too little salt water to create a temperature difference. The brackish regions, such as in Buoy 97 and Oosterweel, where there is an important interaction between the upstream and downstream processes, present larger differences than at Buoy 84.

5.3. Tidal average temperature curves

Hence, the tidal temperature difference is limited and will almost never be greater than 2°C. Interesting to note however is the temperature course during a tide for the different measurement locations. This tidal course of the temperature is represented in the tidal averaged temperature curves, which were drawn up for each of the measurement locations.

The course of these tidal averaged temperatures is measured as function of time in relation to high water and this for neap tide, average tide and spring tide, see Annex-Figure E-10 - Annex-Figure E-16.

Analysis of the heat exchange between seawater and fresh water in the estuary is not as simple as de analysis of the salt exchange, for which seawater (high salinity) and fresh water (low salinity) are easily tracked. To be able to analyse the effects of the interaction on both water masses with their own temperature and to explain the shape of the tidal temperature curves in each measurement locations, one should first be able to determine the boundary conditions (temperature in the deep sea and far enough upstream) in order to separate the periods for which the sea is warmer than de Upper Scheldt from the periods for which the sea is colder.

6. SEDIMENT CONCENTRATION

The fine fraction of suspended material (that is the sediment) is of the utmost importance in an estuary. Due to the estuary processes (tidal movement, salinity, residual flow etc.) the concentration thereof strongly varies in time and place and affects the deposition, erosion and transport processes of the sediment. In this sense, the present study aims at providing a better insight in the processes and their influencing factors (flow velocity, salinity, temperature). This knowledge forms the basis to determine the strategies for dredging and dumping, both in the framework of a productive and cost-effective working methods, and to draw up environmental permits.

The measurements presented here aim at quantifying the variation of sediment in suspension in different time scales and in space. Due to the high variability of the sediment concentration in the water column and especially near the bottom, it is often very difficult to distinguish the effects of local erosion and sedimentation from the general sediment transport, hence it is also very difficult to see the correlations between the measured concentrations in the different measurement locations.

In the first part of this chapter, the different behaviour of the sediment transport between ebb and flood phases will be studied with regard to the maximum and average values for both phases. Attention will then be paid to the different time scales governing the variations in sediment concentration. Afterwards, the focus will be put on the general course of the concentration along the tide. In a third part, the variations along the neap tide – spring tide cycle will be analysed, as well as the correlation between flow velocity and sediment concentration. Finally, a fourth part gives an introduction to the analysis of the long-term variations of the suspended sediment concentration.

6.1. Ebb and flood variations

Long-term ADCP flow measurements, 13-hour measurements, and the tidal velocity curves show that the flow patterns radically differ between ebb and flood. This leads to think that the sediment transport too is totally different between these two types of episodes.

The maximum, minimum and average sediment concentrations at ebb and flood have been displayed in Annex-Figure F-1 - Annex-Figure F-12. Table 6-1 and Table 6-2 provide the monthly maximum recorded values of the sediment concentration at ebb and flood for the measurement locations and for an average average neap tide, average tide and average spring tide.

Table 6-3 and Table 6-4 give the monthly average ebb and flood sediment concentrations for an average neap tide, average average tide and average spring tide, also mentioning each time the flow regimes as defined in §4. Annex-Table F-1- Annex-Table F-3 provide the average sediment concentration per ebb, per flood and per tide and this per trimester, per summer, per winter and per year and for an average neap tide, average average tide and average spring tide.

Table 6-1: Maximal ebb phase suspended sediment concentration (mg/l) for an averaged neap, average and spring tide

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	599	395	337	462	503	-	242	382	635	418	-	535	438
	Avg tide	1159	452	394	423	543	724	354	512	610	668	-	598	515
	Spring tide	1180	588	456	491	590	750	445	797	618	-	-	621	638
Buoy 84 (-5.6 m TAW)	Neap tide	274	228	232	224	409	239	203	289	469	246	499	342	304
	Avg tide	688	297	256	262	470	435	286	417	449	431	653	689	393
	Spring tide	893	412	263	315	598	517	374	649	473	517	-	950	566
Buoy 97 (-7.8 m TAW)	Neap tide	882	1033	371	258	938	352	259	491	924	427	751	947	634
	Avg tide	1128	1028	521	359	877	797	344	756	892	589	789	1200	740
	Spring tide	1123	1302	495	498	1087	947	506	1458	1014	811	858	1692	1035
Buoy 97 (-5.3 m TAW)	Neap tide	536	504	260	273	542	291	280	375	670	314	788	718	476
	Avg tide	615	468	320	332	529	478	345	433	522	475	868	1017	488
	Spring tide	722	528	350	351	585	549	417	399	550	565	828	1491	690
Oosterweel (- 5.8 m TAW)	Neap tide	430	-	-	78	819	393	-	-	551	294	1322	563	578
	Avg tide	465	-	-	253	652	639	-	-	584	662	1230	822	679
	Spring tide	481	-	-	186	728	590	-	-	675	729	1212	1151	813
Oosterweel (- 2.3 m TAW)	Neap tide	313	292	-	-	285	231	130	311	430	131	765	208	289
	Avg tide	366	338	-	179	360	376	144	805	389	430	814	451	403
	Spring tide	371	343	-	139	431	407	162	1304	332	487	812	689	559

*Blue frame: Saline regime
*Red frame: Greatly brackish regime
*Green frame: Slightly brackish regime
*Purple fame: Fresh water regime

Table 6-2: Maximal flood phase suspended sediment concentration (mg/l) for an averaged neap, average and spring tide

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	561	334	265	306	369	-	256	367	688	320	-	477	390
	Avg tide	1247	447	361	397	486	745	321	603	538	699	-	622	501
	Spring tide	1259	595	375	378	554	691	392	865	517	-	-	624	610
Buoy 84 (-5.6 m TAW)	Neap tide	156	139	122	116	152	119	142	181	294	169	300	192	177
	Avg tide	362	180	149	190	245	215	193	293	303	277	337	398	244
	Spring tide	486	251	169	213	330	290	249	488	330	355	-	567	351
Buoy 97 (-7.8 m TAW)	Neap tide	459	556	439	336	583	354	335	475	771	451	833	835	545
	Avg tide	845	683	563	473	881	764	614	926	838	744	881	984	748
	Spring tide	1041	776	870	502	1075	877	754	1309	913	798	865	1362	959
Buoy 97 (-5.3 m TAW)	Neap tide	277	262	208	221	291	194	191	270	299	248	294	349	263
	Avg tide	364	320	245	237	335	332	251	304	327	344	459	443	314
	Spring tide	489	380	278	260	397	375	360	332	368	378	592	1102	496
Oosterweel (- 5.8 m TAW)	Neap tide	357	-	-	138	638	391	-	-	455	413	876	324	447
	Avg tide	408	-	-	191	579	666	-	-	415	577	872	505	548
	Spring tide	424	-	-	353	751	802	-	-	333	498	966	791	711
Oosterweel (- 2.3 m TAW)	Neap tide	328	614	-	-	398	342	233	600	539	264	741	250	393
	Avg tide	387	706	-	157	518	604	230	1148	384	459	772	382	488
	Spring tide	380	770	-	172	744	696	255	1593	292	444	769	626	638

*Blue frame: Saline regime
*Red frame: Greatly brackish regime
*Green frame: Slightly brackish regime
*Purple fame: Fresh water regime

Table 6-3: Average ebb phase suspended sediment concentration (mg/l) for an averaged neap, average and spring tide.

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	256	176	139	180	239	-	134	216	331	162	-	265	210
	Avg tide	549	201	187	211	281	398	214	333	351	367	-	338	279
	Spring tide	612	289	218	226	342	449	276	524	346	-	-	437	365
Buoy 84 (-5.6 m TAW)	Neap tide	119	100	111	104	176	112	105	164	248	128	258	146	148
	Avg tide	287	122	117	132	216	189	156	256	256	231	324	312	200
	Spring tide	377	182	121	147	287	258	214	416	266	292	-	439	285
Buoy 97 (-7.8 m TAW)	Neap tide	428	365	150	120	325	135	126	234	407	221	436	366	277
	Avg tide	581	413	226	181	371	321	176	442	367	373	510	547	357
	Spring tide	613	620	286	211	560	476	271	883	361	447	544	816	536
Buoy 97 (-5.3 m TAW)	Neap tide	313	242	169	162	285	162	171	229	313	169	379	239	237
	Avg tide	342	256	195	207	319	276	224	286	265	292	456	435	275
	Spring tide	391	312	245	219	360	333	293	278	272	346	484	722	390
Oosterweel (- 5.8 m TAW)	Neap tide	219	-	-	34	271	154	-	-	255	107	473	156	208
	Avg tide	248	-	-	71	225	244	-	-	319	278	460	319	279
	Spring tide	267	-	-	56	286	274	-	-	427	276	579	476	358
Oosterweel (- 2.3 m TAW)	Neap tide	162	160	-	-	136	100	59	137	201	52	318	88	131
	Avg tide	188	159	-	51	162	175	68	471	190	191	343	183	191
	Spring tide	218	167	-	44	211	201	75	730	165	206	402	321	284

*Blue frame: Saline regime
*Red frame: Greatly brackish regime
*Green frame: Slightly brackish regime
*Purple fame: Fresh water regime

Table 6-4: Average flood phase suspended sediment concentration (mg/l) for an averaged neap, average and spring tide.

		2007 Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2007 Jan	Feb	Mar	Year
Buoy 84 (-8.1 m TAW)	Neap tide	175	125	97	133	143	-	112	157	270	120	-	227	155
	Avg tide	479	186	164	191	228	331	196	277	294	267	-	329	237
	Spring tide	520	248	193	204	291	373	250	434	312	-	-	363	313
Buoy 84 (-5.6 m TAW)	Neap tide	78	71	-	81	74	68	71	102	170	98	181	93	95
	Avg tide	194	95	89	110	136	128	123	175	196	180	224	190	146
	Spring tide	256	142	94	120	189	183	171	295	214	224	-	273	202
Buoy 97 (-7.8 m TAW)	Neap tide	189	181	148	113	158	106	109	157	267	200	307	240	185
	Avg tide	313	248	181	153	241	242	157	315	282	307	419	350	258
	Spring tide	409	311	268	165	368	331	232	574	319	371	485	569	384
Buoy 97 (-5.3 m TAW)	Neap tide	153	130	113	114	133	104	107	141	125	100	129	74	117
	Avg tide	201	150	122	137	185	179	138	186	135	160	202	144	153
	Spring tide	240	187	158	141	220	201	199	183	152	195	270	347	223
Oosterweel (- 5.8 m TAW)	Neap tide	221	-	-	60	309	206	-	-	190	172	397	129	213
	Avg tide	254	-	-	90	284	317	-	-	190	268	414	206	262
	Spring tide	274	-	-	100	349	362	-	-	136	239	490	357	344
Oosterweel (- 2.3 m TAW)	Neap tide	196	311	-	-	215	170	105	222	228	73	328	103	175
	Avg tide	232	302	-	77	241	268	103	588	159	209	377	156	226
	Spring tide	244	339	-	79	343	301	122	844	143	219	391	298	320

*Blue frame: Saline regime
*Red frame: Greatly brackish regime
*Green frame: Slightly brackish regime
*Purple fame: Fresh water regime

Similar as what was found for the period from September 2005 to March 2007, the average sediment concentrations in Buoy 84 and 97 are higher during ebb than during flood, with the largest peak recorded by the lowest instruments and during flood. At Oosterweel, the average sediment concentration is slightly larger at flood, and it is during this period the largest peaks occur, again for the lowest station. In contrast to what was found in IMDC 2008t, there is no clear correlation between the flow regime and the sediment concentrations. Both the average and maximum sediment concentrations appear to be somewhat lower from April 2007 to March 2008 than from September 2005 to March 2007.

The tables and figures mainly indicate that the variations in sediment concentration are governed by phenomena working on different time scales:

- When a consolidated layer is suddenly brought back to suspension, peaks occur in the course of the maximum values. Although this increase is almost instantaneous, it is also the result of lengthy sedimentation and consolidation processes.
- Within one tide, and due to the nature of the velocity course itself, the variations in suspended sediment concentration are very high.
- Flow velocity is a determining factor for the bringing and keeping of sediment in suspension. In §3 a clear relation has been indicated between average flow velocity and tidal amplitude, due to which variations in sediment concentration are expected along the neap tide – spring tide cycle.
- Variations on a more prolonged time scale may occur. The availability of the sediments may change through the seasonal cycles. In §4 we also noted that the interaction between tidal flow and discharge (and hence between precipitation, wet and dry seasons), and the relation between the force of these two mechanisms lead to the shifting of zones with high spatial salinity gradients (greatly brackish) and zones with important mixing processes (saline front, slightly brackish), which are able to strongly influence the suspension.

These factors cannot be separated from each other, thus making it difficult to analyse them and to draw general conclusions. The high variability of the sediment concentration in the water column and especially near the bottom, and the turbulent variations in the flow, combined with the point character of the measurements as well as interventions in the sediment balance by dredging and dumping, form as many obstacles for a general understanding. A typical problem is to distinguish the effects of local erosion and sedimentation from the general sediment transport (advection) on the Scheldt.

Nevertheless, this analysis will try to isolate the various phenomena and clarify them hereinafter.

6.2. Variations along one tide

6.2.1. Tidal variations

The data reports of the measurement campaign (IMDC 2007v, 2007w, 2008p and 2008q) show the 10 minute evolution on week plots for all variables, among which sediment concentration. Several peaks can be found per tide. The variations between the tides as function of the tidal difference are clearly visible too.

The course of the flow velocity along one tide (as developed in §3.2), putted in parallel with erosion and sedimentation processes may explain the occurrence of some of the peaks in the concentration course. The flow pattern and the erosion – sedimentation processes could explain three different peaks during an episode (ebb or flood):

- The sediment layer formed during slack will have a lower density and will easily erode when the flow velocity increases just after the slack, resulting in a first possible concentration peak.
- In §3.1, we saw that the average velocity values were following the neap tide – spring tide cycle, with high amplitude tides showing higher velocities. Along this cycle, during the periods with the smallest amplitudes (neap tides) sedimentation would prevail, allowing the consolidation of layers of settled sediments. During the phases of the cycle with higher velocity (spring tides and, to a lesser degree, average tides), (part of) those consolidated

layers can be eroded and brought back into suspension. Consolidation – erosion cycles of this type can also be imagined on longer time scales (seasonal, dry-humid years and periods for instance). The resistance against erosion of those layers, consolidated on various time scales, is higher than the settled layers during slack. Erosion of those layers only occurs when the flow velocity (and thus the bed shear stress) is higher than a certain threshold. During the phase of increasing flow velocity, and during the erosion phase of the consolidation-erosion cycle (i.e. during spring tide, an to a lesser degree average tide for the tidal amplitude cycle), this threshold can be exceeded, causing the erosion of all or a part of a consolidated layer which can be brought in suspension, leading to the apparition of a second peak.

- A third peak in the concentration during increasing velocity phase will coincide with the maximum flood velocity, which is in general more distinct during a spring tide than during a neap tide. During ebb, the velocity course shows a more uniformed pattern than during flood, for which more peaks are recorded. Hence, the apparition of a maximum velocity concentration peak should be less frequent during ebb than during flood.

6.2.2. Tidal averaged sediment concentration curves

For each of the measurement locations, a tidally averaged sediment concentration curve has been drawn. The course of this sediment concentration curve is measured as a function of the time in relation with high water and this for neap tide, average tide and spring tide, see Annex-Figure F-15 - Annex-Figure F-20. These curves allow us to determine the average time tags of the peaks in sediment concentration as function of the tidal amplitude (see also Table 6-5). Because the data have been measured with a frequency of 10 minutes, there is an inaccuracy in the time tags calculated of 10 minutes at the most. In general, the time tags in this table show a reasonable agreement with the time tags found in the data from September 2005 to March 2007 (IMDC 2008t), which indicates that the tidally averaged sediment concentration curves are qualitatively similar to those from September 2005 to March 2007. This is confirmed by a visual comparison of the graphs.

- **Buoy 84**: During flood (considered here as going from low water slack to high water slack), a first small concentration peak can be observed at the bottom station about 4h30 to HW. This peak is the reflection of a small velocity peak that is also only observed at the bottom location. The maximum concentration for the flood occurs about 3h00 to HW in both stations but more pronounced for the bottom one. The flood flow is in full development at this moment (maximum flood velocity occurs about 1h00 to HW), which leads to think that the concentration peak is generated by the erosion of the layer that settled during the low water slack. Another concentration peak occurs together with the velocity peak about 1h00 to HW. Finally, a last peak during flood is observed in both stations, only for average and spring tide, about 0h30 after HW. At that moment the flood velocity is fully decreasing towards slack, which means that the concentration peak cannot be explained by the velocity course or local erosion processes. During ebb (from HWS to LWS), a first concentration peak occurs about 2h00 after HW, half an hour before the first ebb velocity peak, which is very weak during neap tide conditions. This first ebb peak can thus only be explained by the erosion of the layer that settled during high water slack. The velocity peak at about 2h30 after HW, which is also the maximal ebb velocity, does not find any reflected image in the concentration course. The second velocity peak about 4h00 is well reflected in the concentration. The peak in the concentrations at the upper measurement instrument here is the most pronounced of all. As can be observed by comparing both curves, the velocity course is far from being perfectly reflected in the concentration course. Some of the velocity peaks (even the biggest ones) does not create any concentration peak. The relation between the velocity peaks amplitude is also not the same as the one between corresponding concentration peaks (when corresponding). Furthermore, in a more global way, it can be observed that while the velocity pattern is clearly flood-oriented, the biggest concentrations values are recorded during ebb (especially at the upper measurement instrument). This shows that the concentration in one point of the estuary is not that much the consequence of local erosion-sedimentation processes than from the global sediment transport in the river, which is it self the consequence of multiple local processes. In this way, the higher concentrations during ebb can be explained by the fact that in this location, the ebb flow is loaded with more sediment that the flood flow “coming” from the sandy environment at the Plaat van Doel).

- **Buoy 97**: The first concentration peak during ebb (between 4h30 and 4h00 to HW, principally in the bottom station and for average and spring tides) and flood (2h30 after HW) occurs during the increasing velocity phase after the slacks and is due to the erosion of the during slack settled layers. Note that the peak at 7h00 h to HW during spring tide conditions in the lower measurement instrument does not correspond to a physical phenomenon, but is an artefact due to an extreme event that occurred in a period of large flood duration. The first velocity peak for both phases (-3h40 for flood and +2h40 for ebb) does not generate any peak in the concentration course. After the erosion peak, the two other peaks during flood (-2h00 and -0h30) can be correlated with velocity peaks (about -2h00 and -0h50). In the top station, there is some delay between the velocity and the concentration peaks, which can be explained by the time needed for the sediment to spread vertically. During ebb, a second peak (+3h30), which is the maximum concentration for the whole tidal course, occurs half an hour before the maximum ebb velocity value (+4h00) and has to be explained by the global transport on the river. A third and last peak during ebb occurs at +6h00 together with a velocity peak. Here also, the global concentration pattern is ebb-oriented while the biggest velocities are recorded during flood.
- **Oosterweel**: The velocity curve shows a double peak pattern (-3h30 and –1h00, the second one being the biggest) during flood and a quite continuous pattern during ebb with a peak around +4h00. Note that this peak is more pronounced than the one found in the data from September 2005 to March 2007 (IMDC 2008t). During flood, the first velocity peak generates a small peak in the concentration, most visible for the bottom station and by average or spring tide. The biggest flood concentration peaks occurs between the two velocity peaks and is probably due to the erosion of the settled layers. The third flood peak is correlated with the second velocity peak. During ebb, a first concentration peak occurs during the increase of the velocity after slack by erosion of the settled layers, a second, peak is synchronous with the velocity maximum. In this location, there is a better correspondence between the ebb-flood proportions of the velocity and the concentration course.

Table 6-5: Average tidal curves of the sediment concentration, time to HW of the minimal (around slack waters) and maximal (during flood and ebb phase, max value of both in bold characters) concentration for an average neap, average and spring tide

			Min around LSW 1	***Max during flood***	***Min around HSW***	***Max during ebb***	***Min around LSW 2***
Buoy 84		Neap	-5:20	-3:40	1:10	4:20	6:20
	-8.1 m	Average	-5:20	-3:40	1:20	4:10	7:10
	TAW	Spring	-5:20	-3:40	1:30	4:10	7:00
Buoy 84		Neap	-4:40	-1:00	1:20	4:10	7:00
	-5.8 m	Average	-4:20	-1:00	1:30	4:00	7:10
	TAW	Spring	-4:20	-0:50	1:30	4:00	7:10

			Min around LSW 1	*Max during flood*	*Min around HSW*	*Max during ebb*	*Min around LSW 2*
Buoy 97		Neap	-5:30	-4:20	1:10	3:50	7:10
	-7.5 m	Average	-5:20	-4:10	1:20	3:40	7:10
	TAW	Spring	-5:00	-4:00	1:20	2:20	7:30
Buoy 97		Neap	-4:50	-2:10	1:30	3:50	7:40
	-5.1 m	Average	-4:40	-2:10	1:30	3:30	7:40
	TAW	Spring	-4:30	-2:10	1:40	3:30	7:30
Oosterweel		Neap	-4:50	-2:00	0:50	2:20	7:20
	-5.7 m	Average	-4:30	-2:00	1:00	2:10	7:20
	TAW	Spring	-5:10	-2:10	1:10	2:20	7:40
Oosterweel		Neap	-4:50	-2:00	1:20	2:20	7:20
	-2.1 m	Average	-4:40	-2:10	1:20	2:10	7:40
	TAW	Spring	-4:30	-2:10	1:40	2:20	7:50

6.3. Neap tide – spring tide variations and influence of flow velocity

The velocity course during a neap tide is different from the one during a spring tide. The flow during flood is also qualitatively different for a spring tide and a neap tide. During a spring tide the flood velocities are more asymmetric and they display a distinct double peak. During a neap tide the flood course of the velocity occurs more gradually. This means that along neap tide-spring tide cycle the peak flood velocities relatively increases in a more pronounced way than the peak ebb velocities, hence resulting in a relatively higher erosion of sediment during a spring tide flood than during a neap tide flood.

In Buoy 84, for instance, the average sediment concentration at respectively lower and upper measurement instrument the during a spring tide (Annex-Table F-1 - Annex-Table F-3) is 87 and 101% higher than during a neap tide and the increase can mainly be felt during flood (102% and 112%) than during ebb (93% and 92% respectively). Similar percentages (but slightly higher) were found for the period from September 2005 to March 2007.

In Buoy 97, the increase between neap and spring tide is also larger at flood than at ebb but in a less distinct way (100% and 74% for the lower and upper instrument, 107% and 94% during flood and 93% and 64% for ebb). In Oosterweel, (68% and 99% increase between neap and spring tide for the lower and upper instrument) the flood flow does not really overrule the ebb-oriented character and the increase (62% and 82% for flood; 72% and 116% for ebb) occurs mainly during ebb, in contrast to what was found from September 2005 to March 2007, where it was found that the increase between neap and spring tide was lower (40%) and was spread evenly between ebb and flood.

Also to be observed, is that the increase in sediment transport between neap tide and spring is felt in amore pronounced way at the bottom stations during the winter. In summer, the increase along the cycle is identical for the lower and higher stations.

In the upstream direction, the influence of the tidal amplitude on the flow velocity is less obvious and the flow is mainly ebb oriented. Although difficult to draw any conclusions or to observe any trends for the sediment transport because the configuration in each of the measurement locations is different (depth, distance to water channel, quay-walls, banks and other constructions which might influence the sediment transport).

Transport is among others determined by the flow velocity. The relation between tidal amplitude and flow velocity found in §3.1, might form an explanation for the concentrations variations in the neap tide – spring tide cycle. In Annex-Figure F-21 to Annex-Figure F-26, the ebb, respectively flood average sediment concentration has been measured in function of the ebb, respectively flood average flow velocity. The figures clearly indicate that the average sediment concentration is in significant correlation with the average flow velocity. For buoy 84 and 97, the correlation factor is fairly high (0.28-0.58) both for ebb and flood. In Oosterweel, it seems that the sediment concentration can only be correlated with the velocity at flood (0.31-0.33). At ebb, the correlation factors are fairly low (especially at the lower instrument) and the significance is fairly high, indicating that there is no relation between both variables here. This might among others be explained by the fact that in Oosterweel the flow is more ebb oriented and hence more concentrated in the navigation channel. Because the instrument is located outside the channel, it is normal that no relation can be found between both variables.

A correlation of velocity and sediment concentration was found here, but the flow velocity is far from being the sole factor influencing the sediment concentration, and the relation with the tidal amplitude of §3.1 only forms a partial explanation for the development in the neap tide – spring tide cycle.

Another process that might form the basis of the development of sediment concentrations is the occurrence of high salinity amplitudes and hence of gradients causing density flows. We have seen that these also depend on the tidal amplitude and hence the neap tide – spring tide cycle, but also on the flow regime and hence on the interaction between tidal amplitude and discharge. The sediment availability also forms an important factor. We will discuss this below.

6.4. Prolonged variations

The variations on a long time scale of the sediment concentrations may be caused by different, although not always independent influence factors. For example:

- Fresh water discharge (shifting of zones with high salinity gradients and intense mixing processes of salt and fresh water, larger sediment input from the non-tidal related part of the basin)
- Temperature (biological activity, climate factors, organic material in suspension and aggregation/ flocculation of sediment particles),
- Storm surges,
- Land erosion (terrestrial input of fine sediments).

We will hereinafter first study the evolutions along the seasonal cycle, then the influence of the interaction between discharge and tidal effects.

6.4.1. Seasonal cycle

Temperature is a variable, which is clearly season related. That is why temperature may be used to show the season related variation of the sediment concentration. Annex-Figure F-27 - Annex-Figure F-32 display the tidal average sediment concentration in function of the tidal average water temperature for the measurement stations. The coefficients are all negative and between –0.17 and –0.45 included, meaning that periods with a low water temperature (winter) correspond with periods with a higher sediment concentration than in periods with higher temperatures (summer) en that both variables are correlated in a comparable way as the correlation with the velocity. This corroborates with the seasonal influences that are clearly visible in Annex-Table F-1 to Annex-Table F-3, which shows on average 25 % higher concentrations in winter than in summer, with maximum differences of 60 %. However care must be taken in interpreting these results, because (as can be seen in par 5.1) the temperatures that occur mostly are around 8 and 20°C and hence the temperature data used in the correlation analysis is not homogeneously distributed. This explains the peaks in the sediment concentrations around these temperatures, because any extreme event leading to a high sediment concentration is more likely to occur at one of these temperatures, because they occur most frequent.

6.4.2. Interaction tide – discharge

Table 6-1 to Table 6-4 indicate the ebb and flood maximum and average sediment concentration of the different flow regimes discussed in chapter 4.

According to the literature (see for example Dyer, 1995) in mesotidal and macrotidal estuaries (i.e. estuaries with average top big tidal amplitudes), there is one zone with higher sediment concentrations than elsewhere. The turbidity maximum is usually found at the upstream end of the salt penetration front, that is a zone with a salinity of 1-5. The inter-tidal saline regime contains this saline front for each tide thus explaining the higher concentration values. In the present dataset the maximum sediment concentrations occur at Buoy 97 suggesting that the turbidity maximum is indeed occurring in the studied area.

7. CONCLUSION

The analysis of the measurements has clearly proven that the variables measured vary in a very complex way with the tide, along neap tide-spring tide cycles and with the seasons. The tide related and the neap tide-spring tide variations may be explained by the hydrodynamics of the estuary. The seasonal related variations are caused by climate, physical, chemical and biological processes.

Flow velocity, salinity, sediment concentration and temperature clearly vary with the tide. Furthermore, sediment concentration, salinity and temperature display prolonged variations (seasons). The influence of seasons is in direct relation with the climatological cycle. However, the influence on the sediment concentration and salinity is indirectly related due to variations in discharge and biological activity.

Nevertheless, the data in the current measurement period, which ranges from April 2007 to March 2008, compares well with those measured between September 2005 and March 2007 (IMDC 2008t). For the flow velocity data this could be expected, as these are mainly determined by the astronomical tide, which does not show much variation across the years, and because the fresh water flow discharge in the river Scheldt showed very similar statistics for both periods. However, the data also compared well both qualitatively and quantitatively for the salinity and the sediment concentration.

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IMDC (2006c) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.2 22 March 2006 Parel 2 – Deurganckdok (downstream), I/RA/11291/06.095/MSA.

IMDC (2006d) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.3 22 March 2006 Laure Marie – Liefkenshoek, I/RA/11291/06.096/MSA.

IMDC (2006e) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.4 23 March 2006 Parel 2 – Schelle, I/RA/11291/06.097/MSA.

IMDC (2006f) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.5 23 March 2006 Laure Marie – Deurganckdok (downstream), I/RA/11291/06.098/MSA.

IMDC (2006g) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.6 23 March 2006 Veremans – Waarde, I/RA/11291/06.099/MSA.

IMDC(2006h) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.1 Opmeting stroming en zout- en sedimentbeweging aan de ingang van het Deurganckdok (SiltProfiler), I/RA/11283/06.087/WGO.

IMDC(2006i) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.3. Opmeting stroming en zout-en sedimentbeweging aan de ingang van het Deurganckdok (ADCP), I/RA/11283/06.110/BDC

IMDC (2006j). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 8.1: Vaste meetopstelling in zake bodemgedrag, I/RA/11291/06.100/MSA.

IMDC (2006k) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.6 Zout en slibverdeling Deurganckdok 17/03/2006 – 23/05/2006, I/RA/11283/06.121/MSA.

IMDC (2006l) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 5.3 Overview of ambient conditions in the river Scheldt – Januari-June 2006 (I/RA/11291/06.089/MSA), in opdracht van AWZ.

IMDC(2006m): Studie van de stromingsvelden en sedimentuitwisseling aan de ingang van Deurganckdok. Current and Sediment flux measurements November 17th 2005 (I/RA/15030/06.021/BDC).

IMDC (2006n). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 9: Valsnelheid slib – INSSEV, I/RA/11291/06.102/MSA, in opdracht van AWZ.

IMDC (2006o). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 2.7: Silt distribution and frame measurements 15/07/2006 – 31/10/2006. (I/RA/11291/06.122/MSA).

IMDC (2007a) 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 (2007b). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 5.4 Overview of ambient conditions in the river Scheldt – July-December 2006 (I/RA/11291/06.089/MSA), in opdracht van AWZ.

IMDC (2007c). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.1 Through tide Measurement Sediview & Siltprofiler 27/9 Stream - Liefkenshoek (I/RA/11291/06.104/MSA), in opdracht van AWZ.

IMDC (2007d). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.2 Through tide Measurement Sediview 27/9 Veremans - Raai K (I/RA/11291/06.105/MSA), in opdracht van AWZ.

IMDC (2007e). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.3 Through tide Measurement Sediview & Siltprofiler 28/9 Stream - Raai K (I/RA/11291/06.106/MSA), in opdracht van AWZ.

IMDC (2007f). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.4 Through tide Measurement Sediview 28/9 Veremans - Waarde(I/RA/11291/06.107/MSA), in opdracht van AWZ.

IMDC (2007g). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.5 Through tide Measurement Sediview 28/9 Parel 2 - Schelle (I/RA/11291/06.108/MSA), in opdracht van AWZ.

IMDC (2007h). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 11.6 Through tide Measurement Salinity Distribution 26/9 Scheldewacht – Deurganckdok in opdracht van AWZ.

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

IMDC (2007n) 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 (2007o) 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 (2007p) 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 (2007q) 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 (2007r) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing 2. Deelrapport 1.10: Sediment Balance: Three monthly report 1/4/2007 – 30/06/2007 (I/RA/11283/07.081/MSA)

IMDC (2007s) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing 2. Deelrapport 1.11: Sediment Balance: Three monthly report 1/7/2007 – 30/09/2007 (I/RA/11283/07.082/MSA)

IMDC (2007t) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing 2. Deelrapport 2.16: Salt-Silt distribution Deurganckdok summer (21/6/2007 – 30/07/2007) (I/RA/11283/07.092/MSA)

IMDC (2007v) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing 2. Deelrapport 3.10: Boundary conditions: Three monthly report 1/04/2007 – 30/06/2007 (I/RA/11283/07.097/MSA)

IMDC (2007w) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing 2. Deelrapport 3.11: Boundary conditions: Three monthly report 1/07/2007 – 30/09/2007 (I/RA/11283/07.098/MSA)

IMDC (2008a) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.5: Through tide measurement Sediview average tide 24/10/2007 (I/RA/11283/06.120/MSA)

IMDC (2008b) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 4.1: Analysis of siltation Processes and Factors (I/RA/11283/06.129/MSA)

IMDC (2008c) 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 (2008d) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.13: Sediment Balance: Four monthly report 1/01/2007 – 31/03/2007 (I/RA/11283/07.084/MSA)

IMDC (2008e) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 1.14: Annual Sediment Balance. (I/RA/11283/07.085/MSA)

IMDC (2008f) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.09: Calibration stationary equipment autumn (I/RA/11283/07.095/MSA)

IMDC (2008g) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.10: Through tide measurement SiltProfiler 23 October 2007 (I/RA/11283/07.086/MSA)

IMDC (2008h) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.11: Through tide measurement Salinity Profiling winter 12 March 2008 (I/RA/11283/07.087/MSA)

IMDC (2008i) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.12: Through tide measurement Sediview winter 11 March 2008 – Transect I (I/RA/11283/07.088/MSA)

IMDC (2008j) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.13: Through tide measurement Sediview winter 11 March 2008 – Transect K (I/RA/11283/07.089/MSA)

IMDC (2008k) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.14: Through tide measurement Sediview winter 11 March 2008 – Transect DGD (I/RA/11283/07.090/MSA)

IMDC (2008l) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.15: Through tide measurement SiltProfiler winter 12 March 2008 (I/RA/11283/07.091/MSA)

IMDC (2008m) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.17: Salt-Silt distribution & Frame Measurements Deurganckdok autumn (17/9/2007-10/12/2007) (I/RA/11283/07.093/MSA)

IMDC (2008n) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.18: Salt-Silt distribution & Frame Measurements Deurganckdok winter (18/02/2007-31/03/2008) (I/RA/11283/07.094/MSA)

IMDC (2008o) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.19: Calibration stationary & mobile equipment winter (I/RA/11283/07.096/MSA)

IMDC (2008p) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 3.12: Boundary conditions: Three monthly report 1/9/2007 – 31/12/2007 (I/RA/11283/07.099/MSA)

IMDC (2008q) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 3.13: Boundary conditions: Three monthly report 1/1/2008 – 31/3/2007 (I/RA/11283/07.100/MSA)

IMDC (2008r) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 3.14: Boundary conditions: Annual report (I/RA/11283/07.101/MSA)

IMDC (2008s) Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 4.10: Analysis of siltation Processes and Factors (I/RA/11283/07.102/MSA)

IMDC (2008t) Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 5.6 Analysis of the ambient conditions in the river Scheldt – September 2005 - March 2007 (I/RA/11291/06.091/MSA), in opdracht van AWZ.

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ANNEX A. : OVERVIEW OF HCBS2 AND OPVOLGING AANSLIBBING DEURGANCKDOK REPORTS

Report	Description of HCBS2
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)
~~5.5~~	~~Overview of ambient conditions in the river Scheldt : RCM-9 buoy 84 & 97 (1/1/2007 -31/3/2007) (I/RA/11291/06.090/MSA)~~[1]
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 2006	
11.1	Through Tide Measurement Sediview and Siltprofiler 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 and 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 Measurements Sediview 28/9 Parel 2 - Schelle (I/RA/11291/06.108/MSA)
11.6	Through Tide measurement Longitudinal Salinity Distribution 26/9 Scheldewacht

[1] The data, foreseen for Report 5.5 is reported in report 3.1. Boundary conditions: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.127/MSA) including HCBS 2 report 5.5 (Deurganckdok).

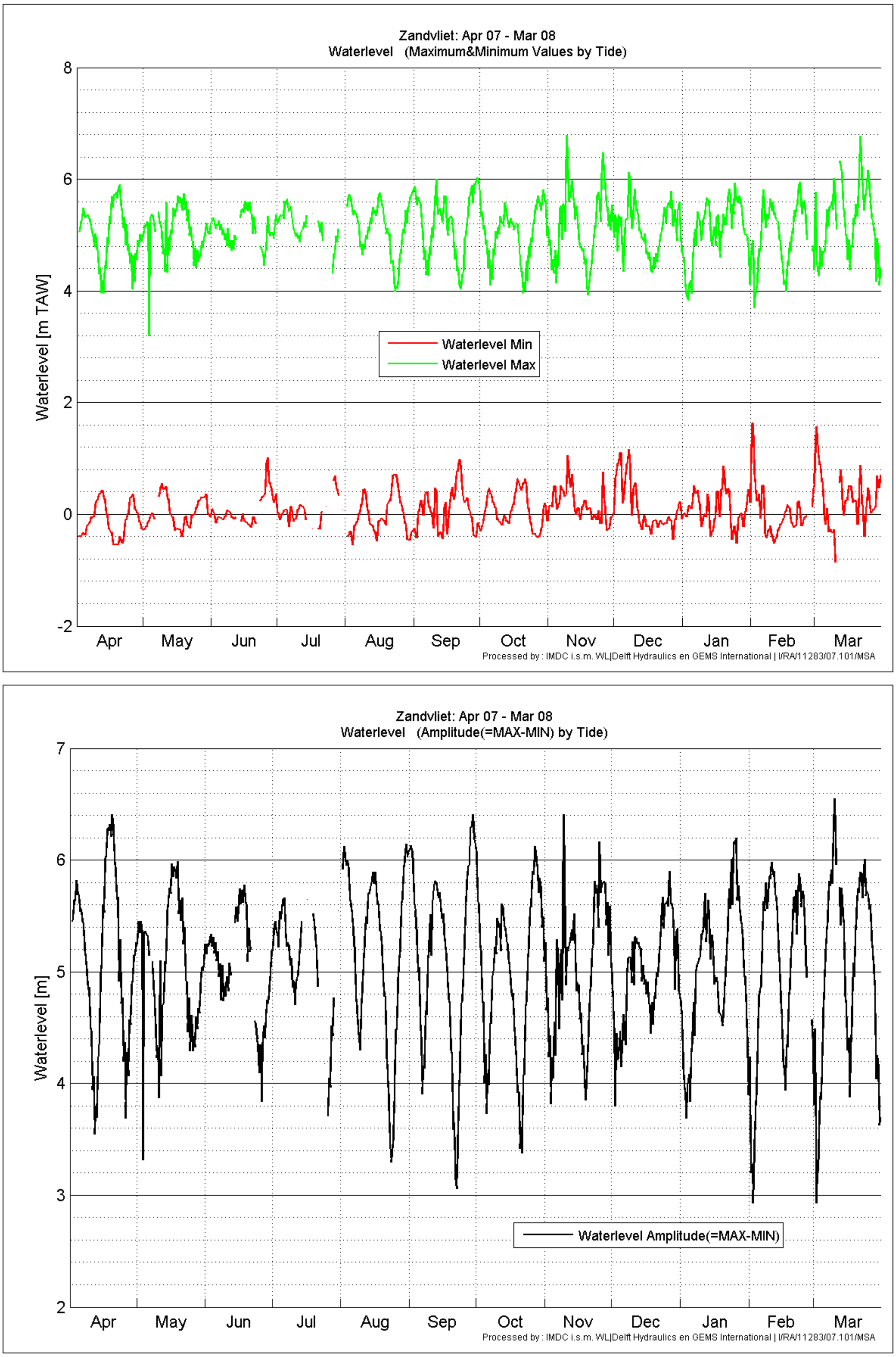
Report	Description of HCBS2
Ambient Conditions Lower Sea Scheldt	
	– Deurganckdok (I/RA/11291/06.161/MSA)
Analysis	
12	Report concerning the presence of HCBS layers in the Scheldt river (I/RA/11291/06.109/MSA)

Report	Description of Opvolging aanslibbing Deurganckdok between April 2006 till March 2007
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 average tide 27/09/2006 Parel 2 (I/RA/11283/06.119/MSA)
2.5	Through tide measurement Sediview average tide (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)
2.8	Salt-Silt distribution & Frame Measurements Deurganckdok 12/02/2007 – 18/04/2007 (I/RA/11283/06.123/MSA)
2.9	Calibration stationary equipment autumn (I/RA/11283/07.095/MSA)

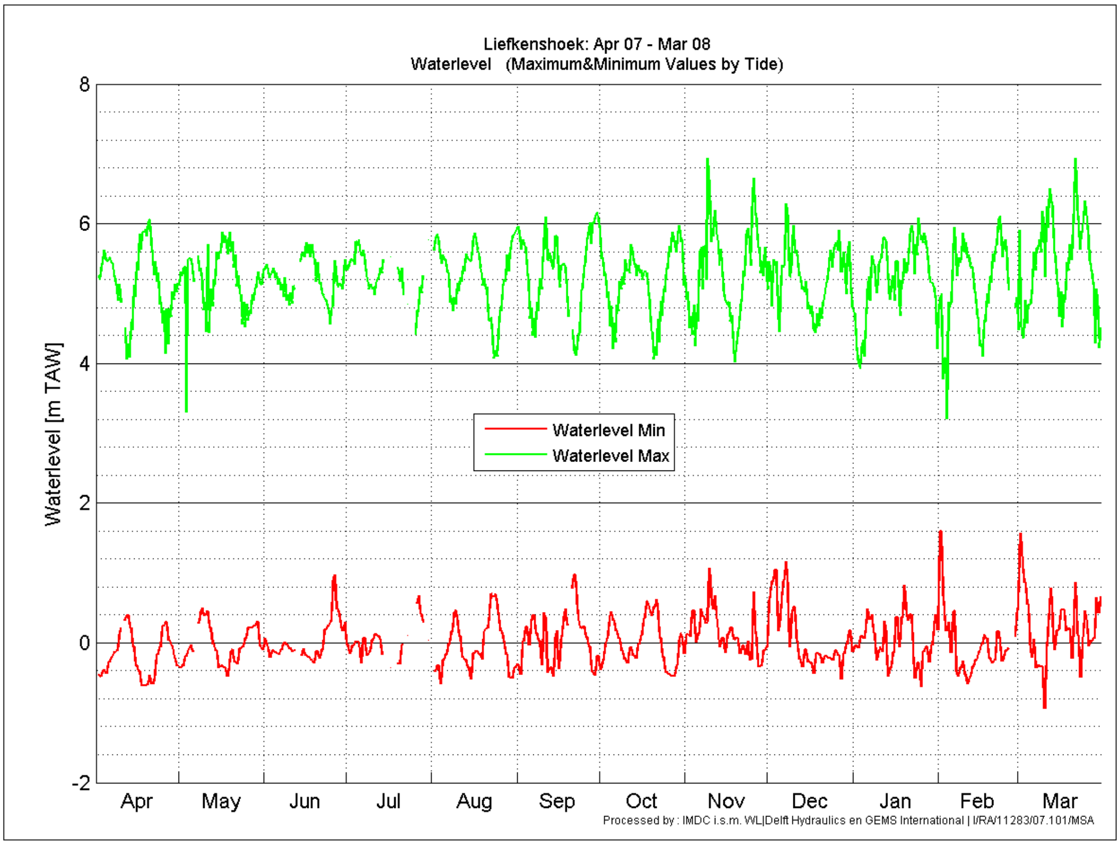
Report	Description of Opvolging aanslibbing Deurganckdok between April 2006 till March 2007
Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels	
3.1	Boundary conditions: Three monthly report 1/1/2007 – 31/03/2007 (I/RA/11283/06.127/MSA) including HCBS 2 report 5.5
~~3.2~~	~~Boundary condtions: Annual report (I/RA/11283/06.128/MSA)~~[2]
Analysis	
4.1	Analysis of Siltation Processes and Factors (I/RA/11283/06.129/MSA)

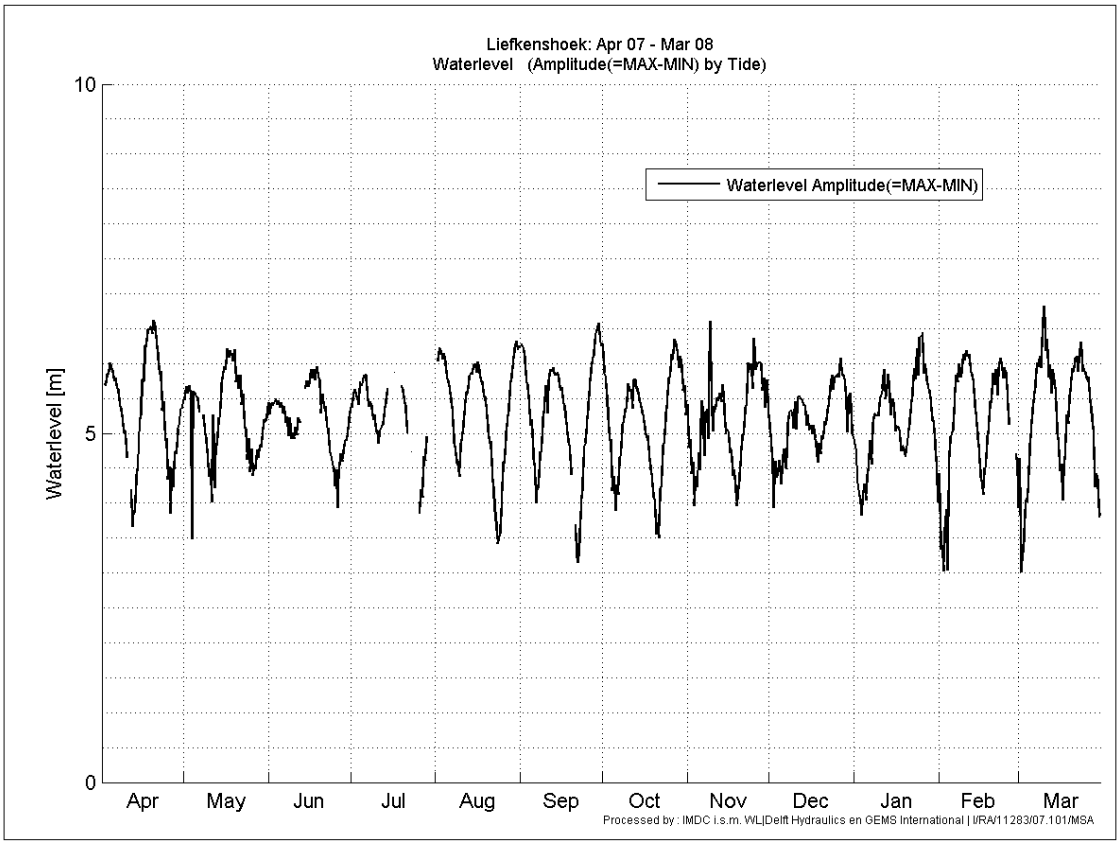
[2] considered in report 5.6 ‘Analysis of ambient conditions during 2006’ (I/RA/11291/06.091/MSA) in the framework of the study ‘Extension of the study about density currents in the Beneden Zeeschelde’

ANNEX B. : FIGURES FOR TIDE AND DISCHARGE

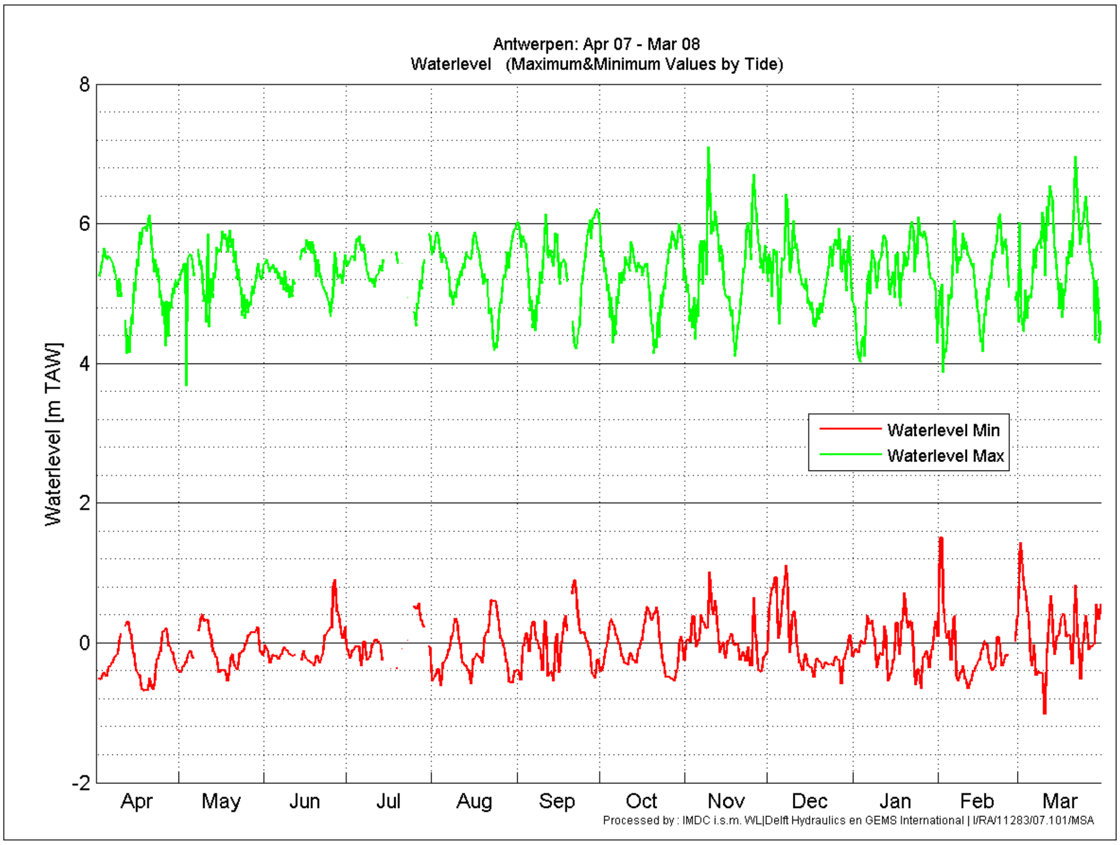


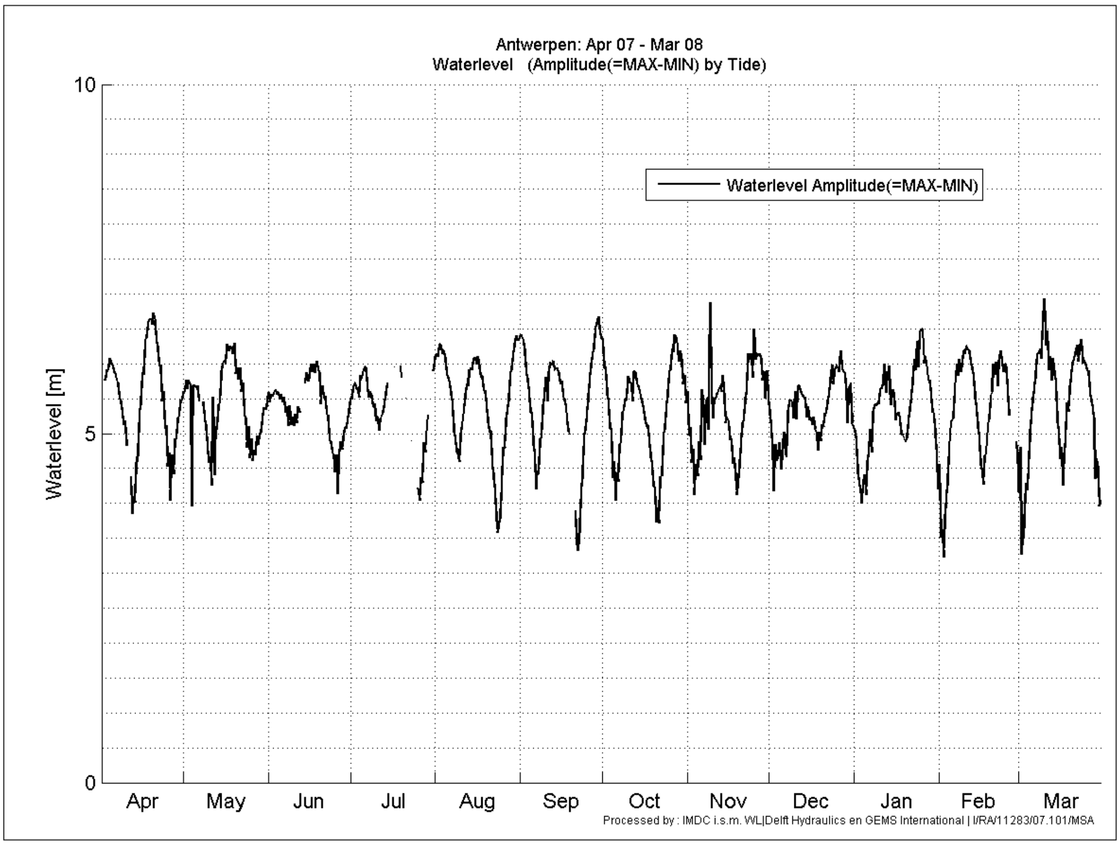
Annex-Figure B-1: Zandvliet April 2007 – March2008. (a) HW and LW (b) Tidal Amplitude



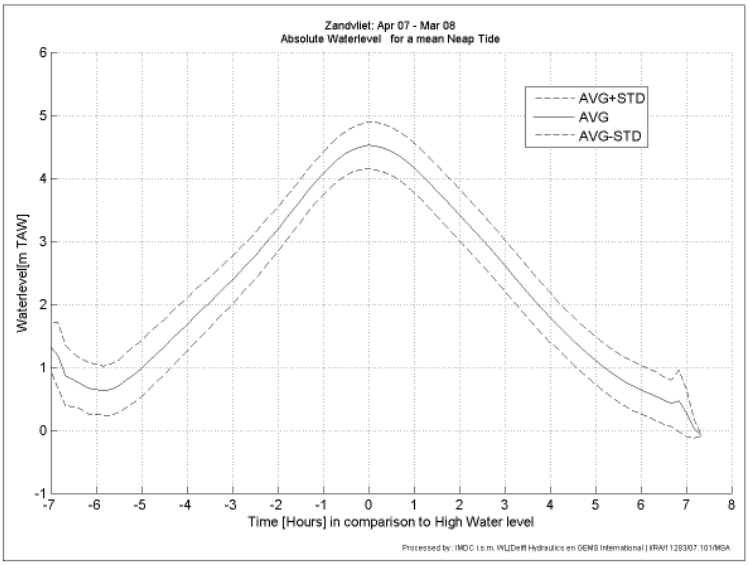


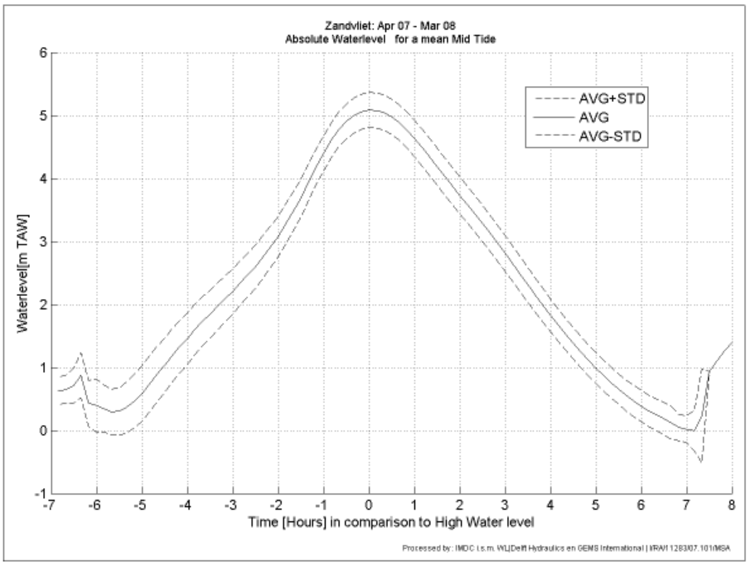
Annex-Figure B-2: Liefkenshoek April 2007 – March2008. (a) HW and LW (b) Tidal Amplitude

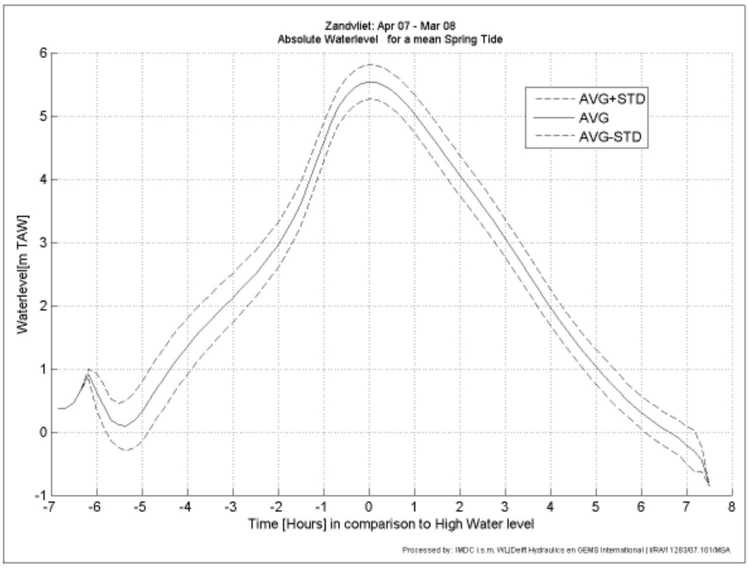




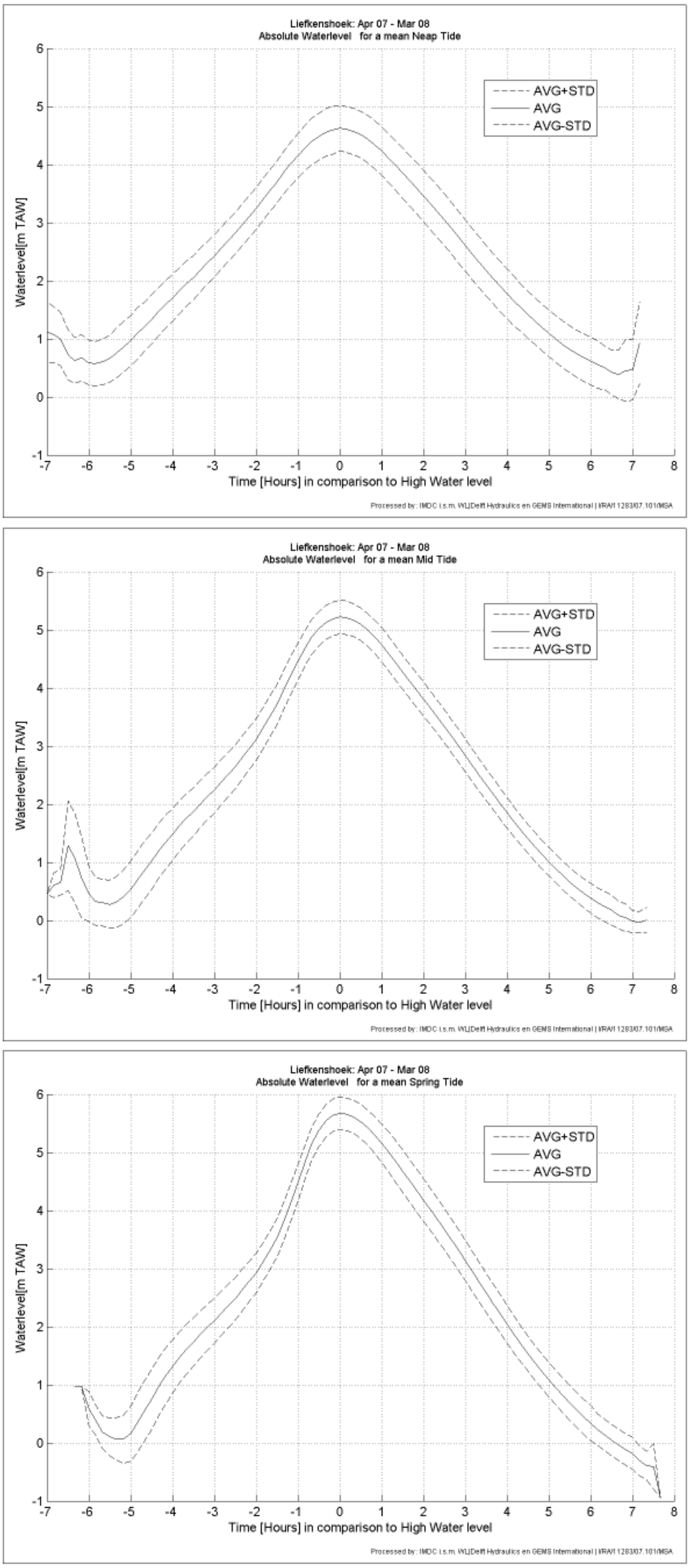
Annex-Figure B-3: Antwerpen April 2007 – March2008. (a) HW and LW (b) Tidal Amplitude



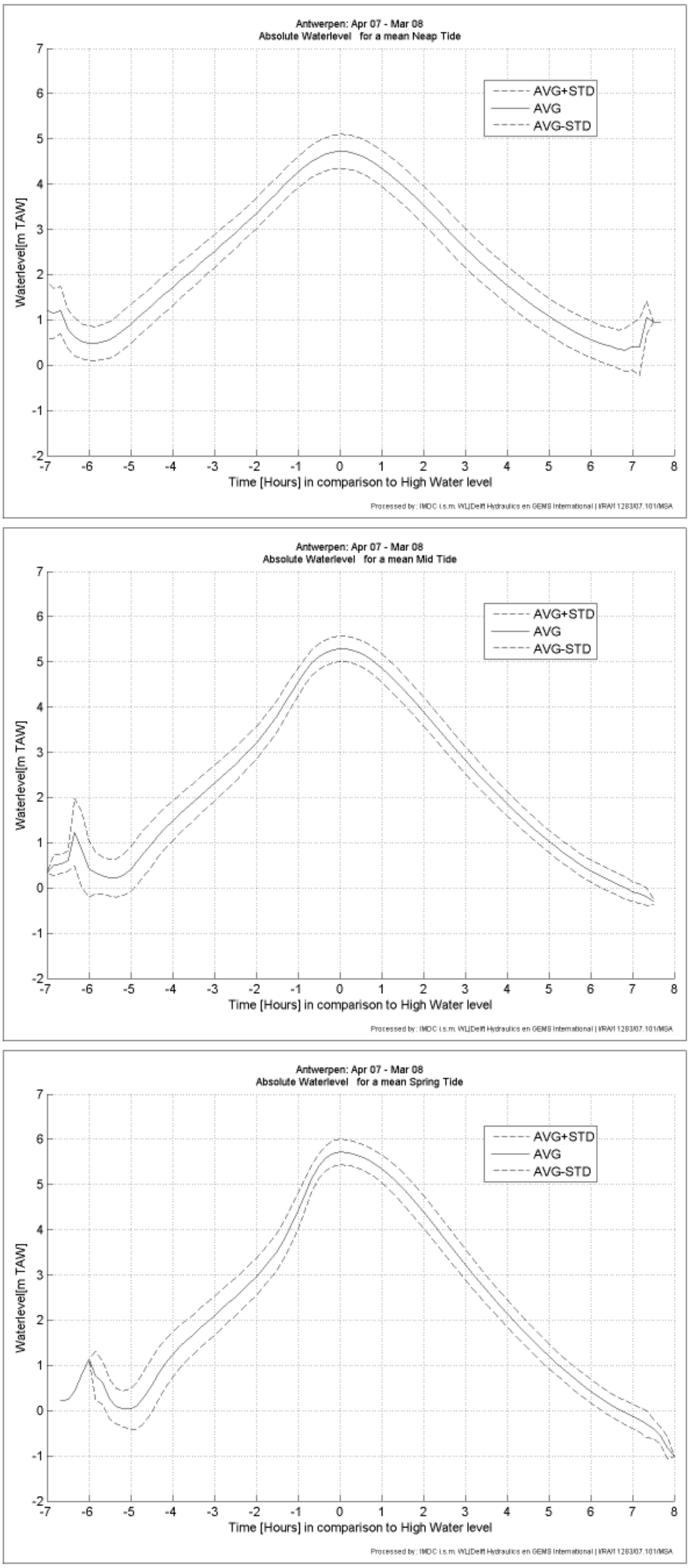




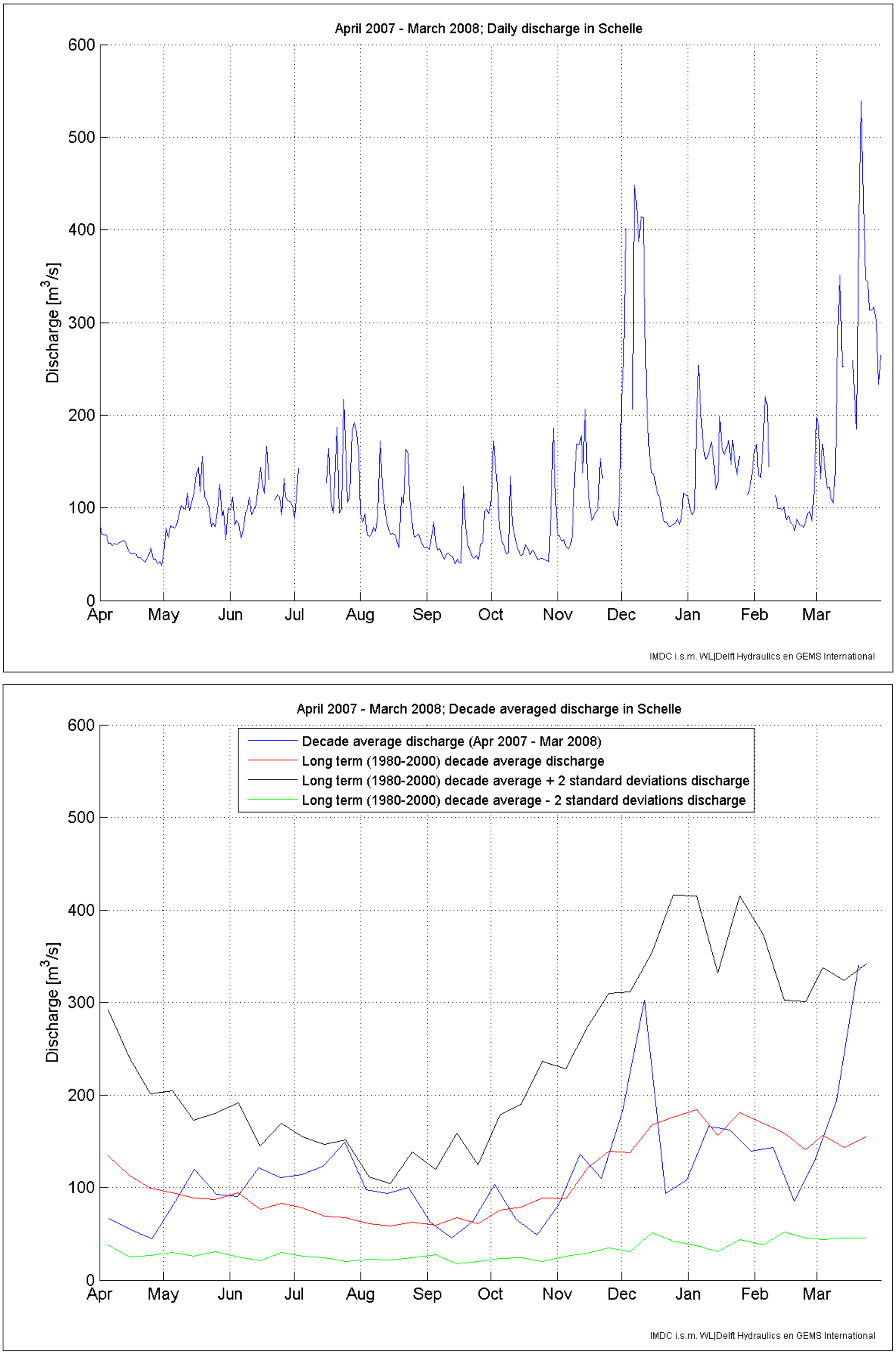
Annex-Figure B-4: Zandvliet, Averaged (a) neap tide, (b) average tide and (c) spring tide curve, April 2007 – March2008



Annex-Figure B-5: Liefkenshoek, Averaged (a) neap tide, (b) average tide and (c) spring tide curve, April 2007 – March 2008

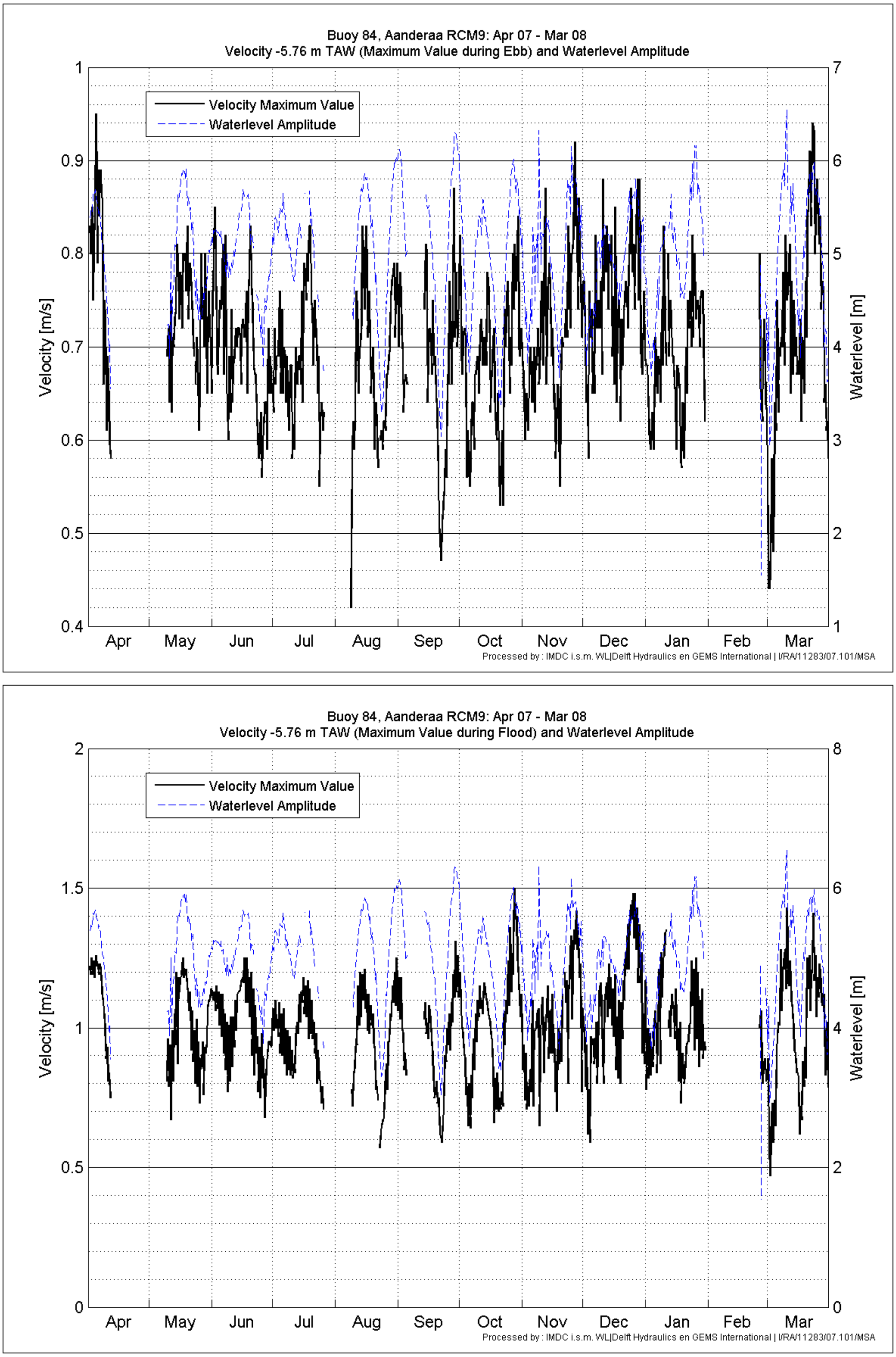


Annex-Figure B-6: Antwerpen, Averaged (a) neap tide, (b) average tide and (c) spring tide curve, April 2007 – March 2008

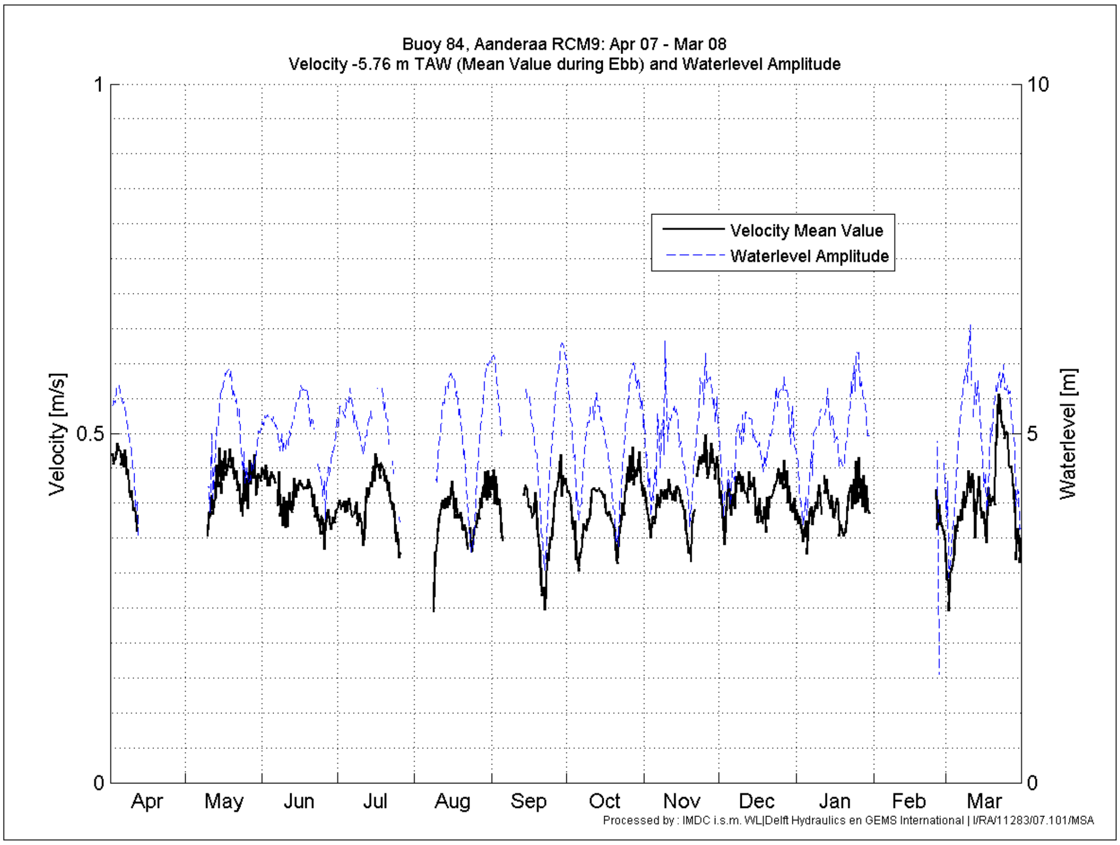


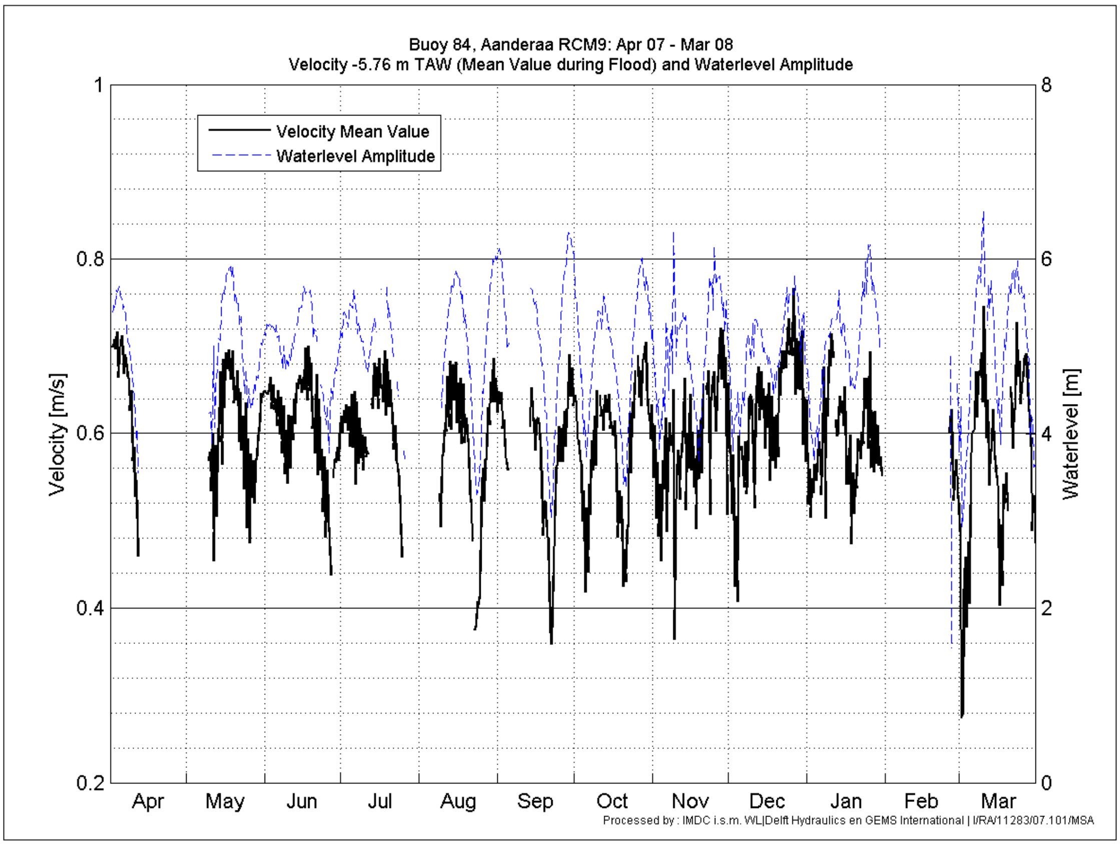
Annex-Figure B-7: (a) Day averaged and (b) decade averaged Scheldt discharge at Schelle

ANNEX C. : FIGURES FOR FLOW VELOCITY AND DIRECTION

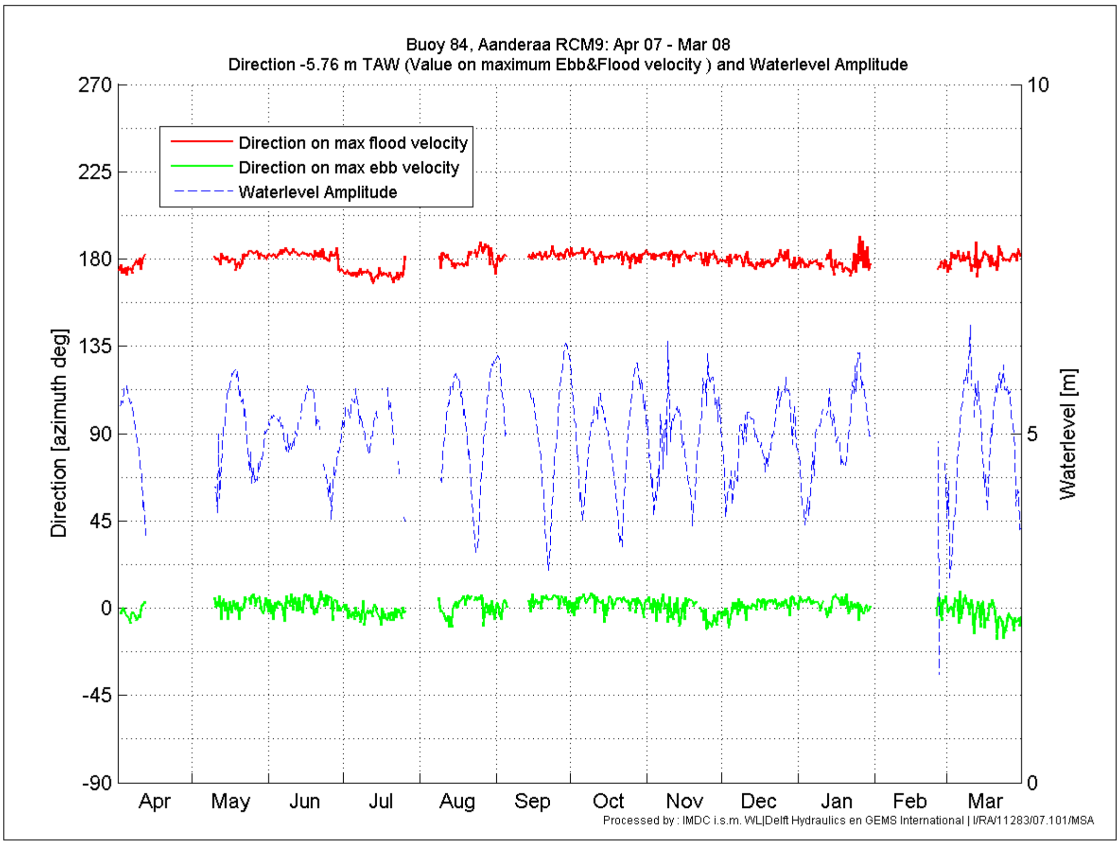


Annex-Figure C-1: Buoy 84 (-5.8m TAW), maximal (a) ebb & (b) flood phase velocity and tidal amplitude at Zandvliet, April 2007 – March 2008

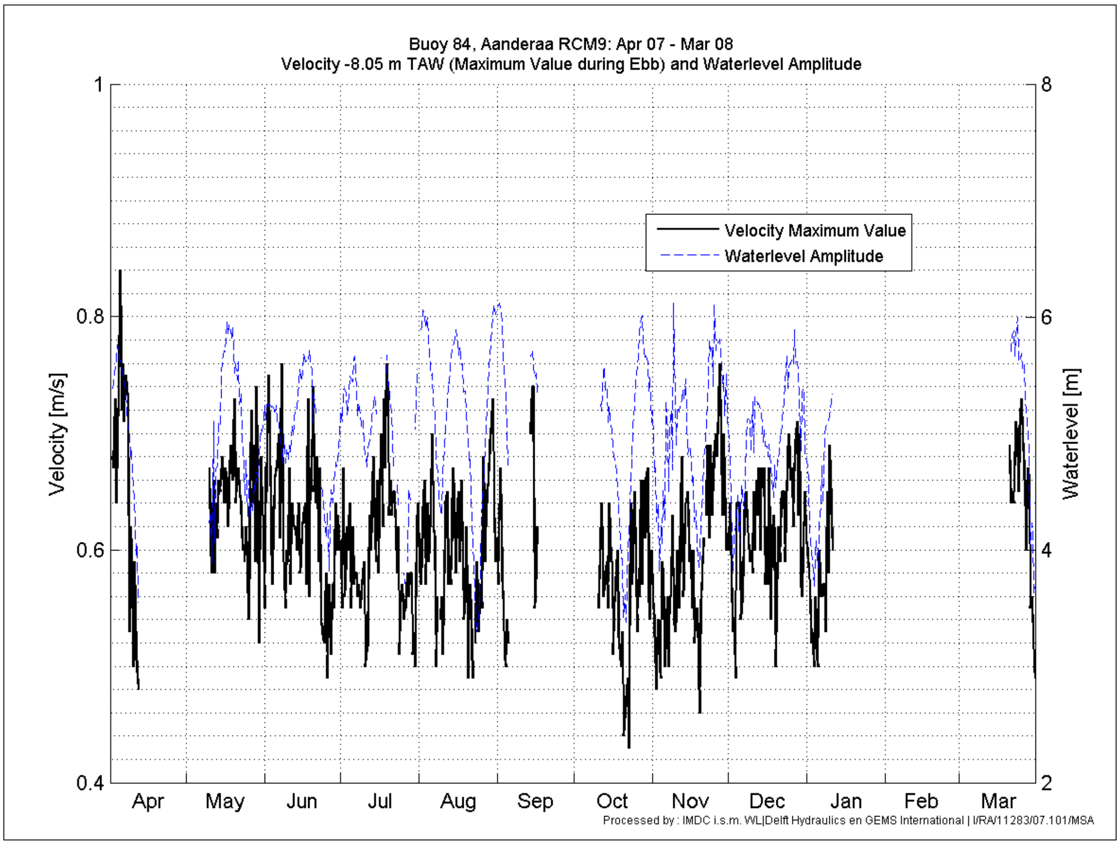


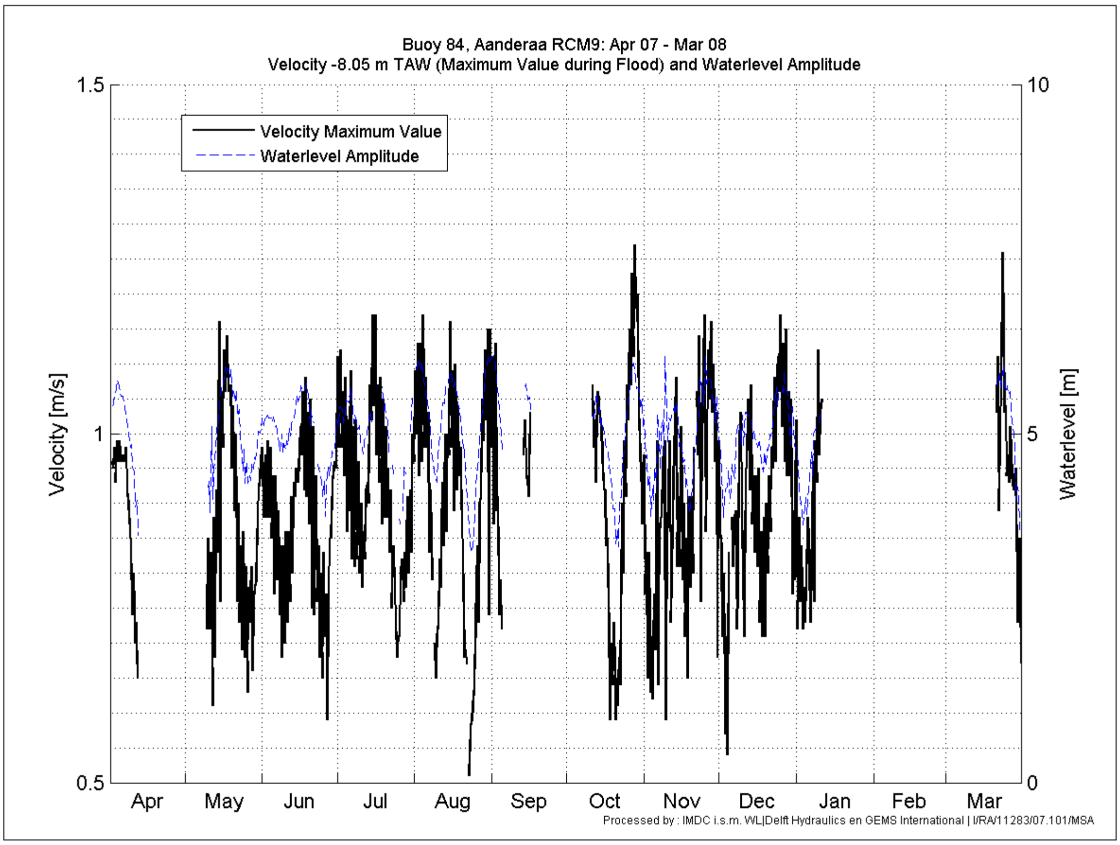


Annex-Figure C-2: Buoy 84 (-5.8m TAW), averaged (a) ebb & (b) flood phase velocity and tidal amplitude at Zandvliet, April 2007 – March 2008

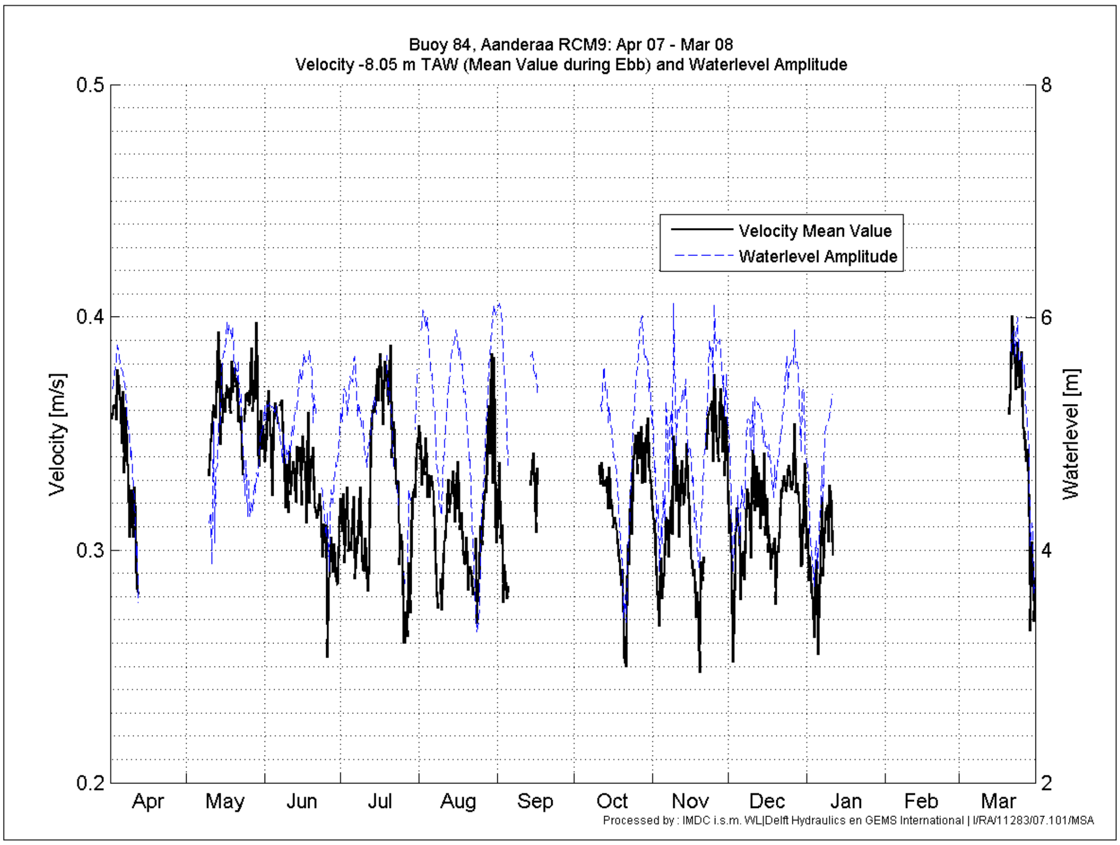


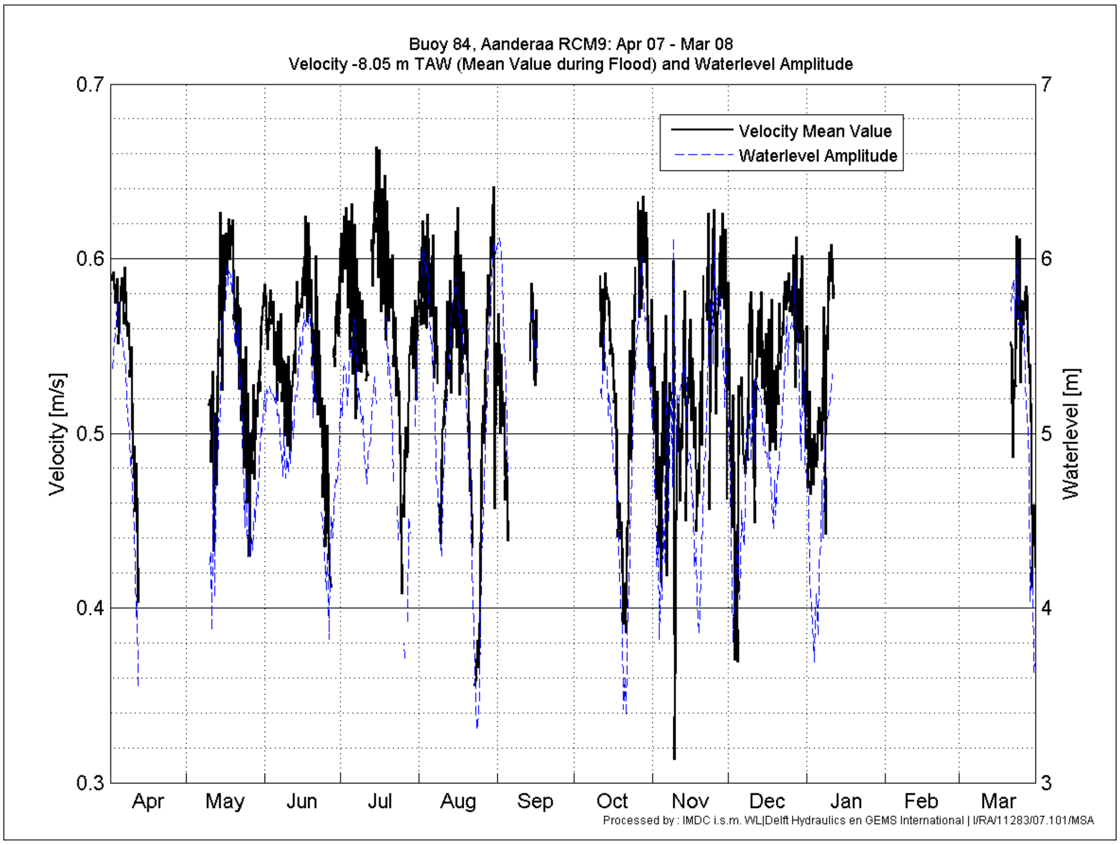
Annex-Figure C-3: Buoy 84 (-5.8m TAW), flow direction on maximal ebb phase and flood phase velocity, April 2007 – March 2008



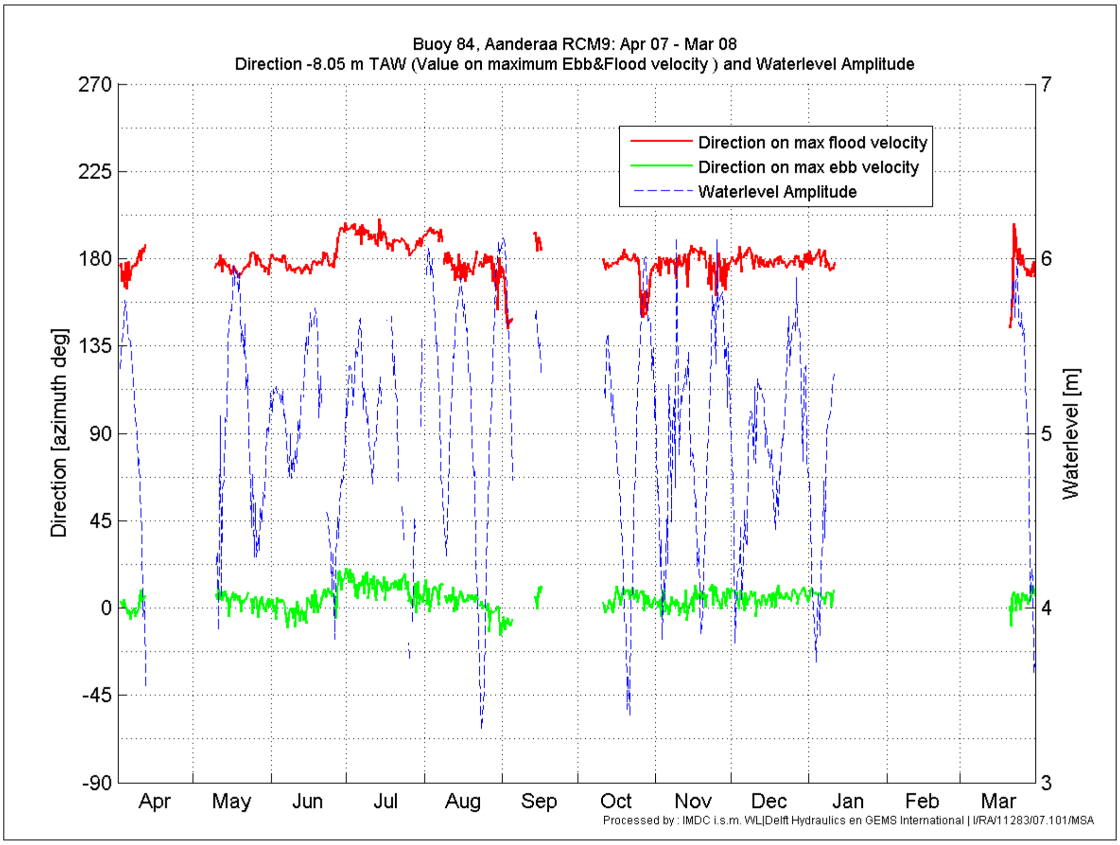


Annex-Figure C-4: Buoy 84 (-8.1m TAW), maximal (a) ebb & (b) flood phase velocity and tidal amplitude at Zandvliet, April 2007 – March 2008

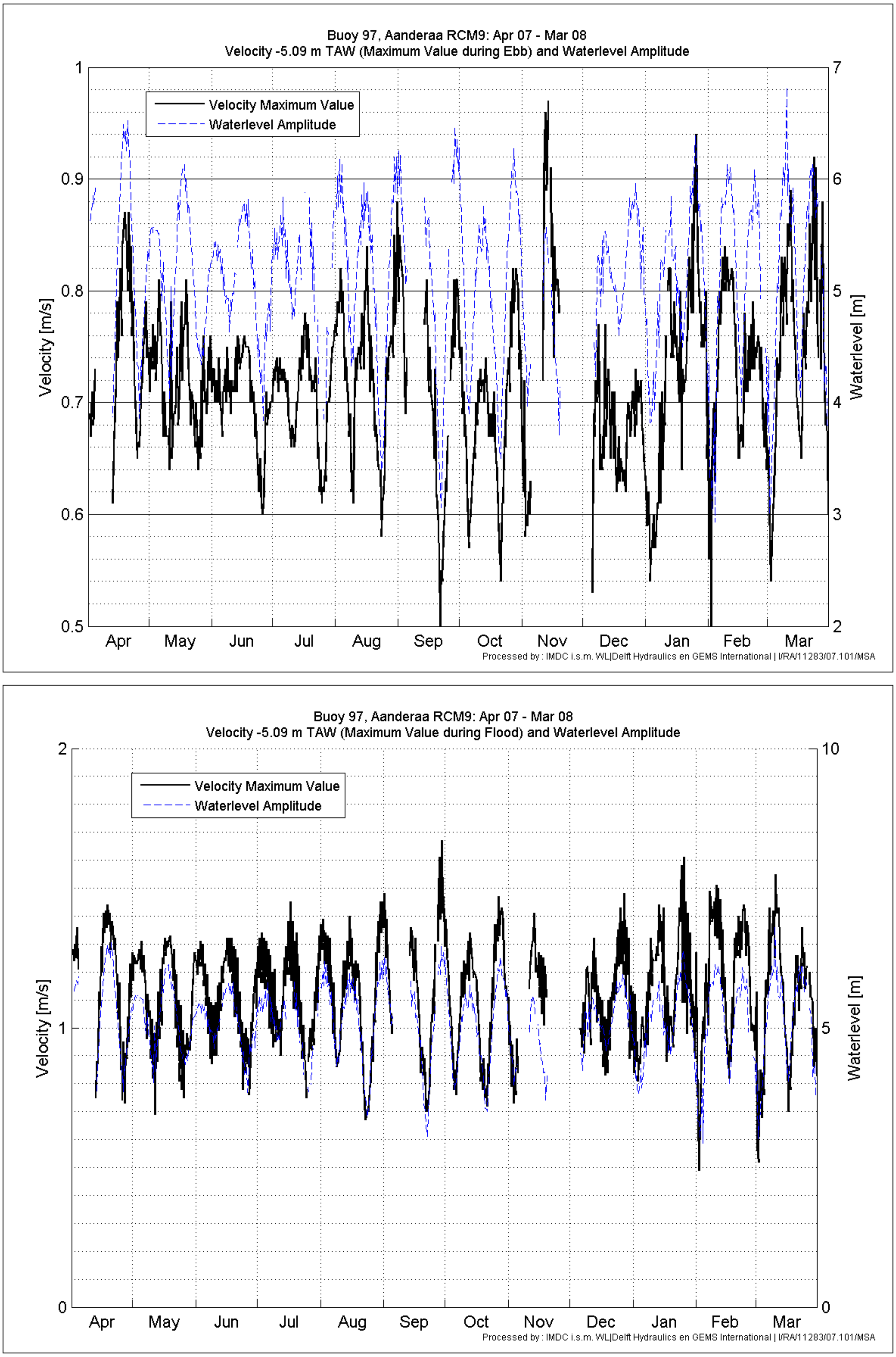




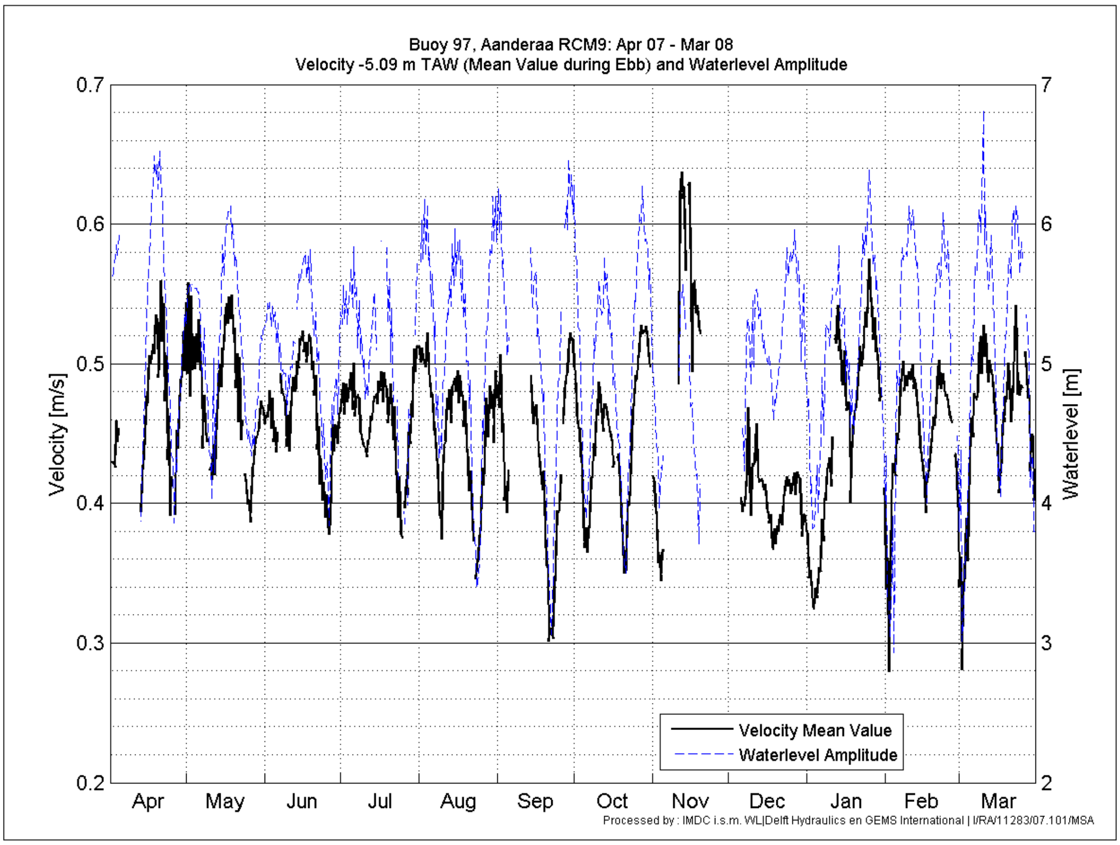
Annex-Figure C-5: Buoy 84 (-8.1m TAW), averaged (a) ebb & (b) flood phase velocity and tidal amplitude at Zandvliet, April 2007 – March 2008

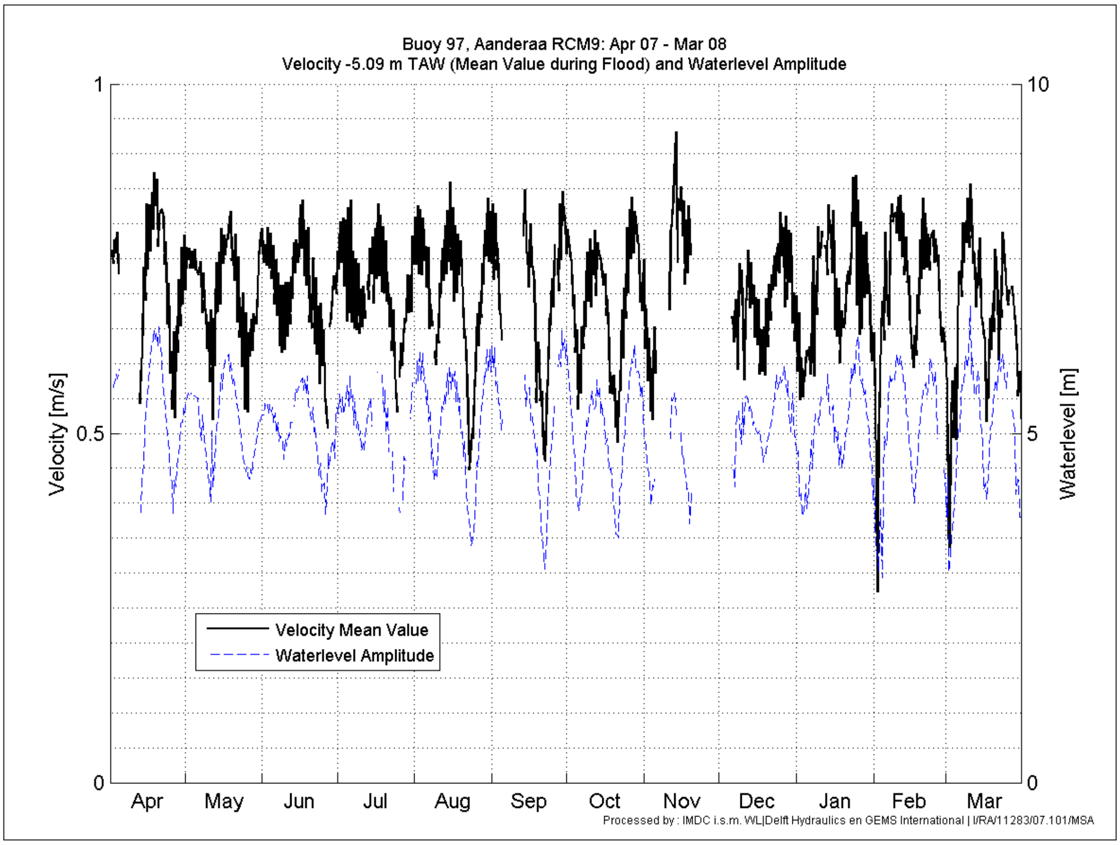


Annex-Figure C-6: Buoy 84 (-8.1m TAW), flow direction on maximal ebb phase and flood phase velocity, April 2007 – March 2008

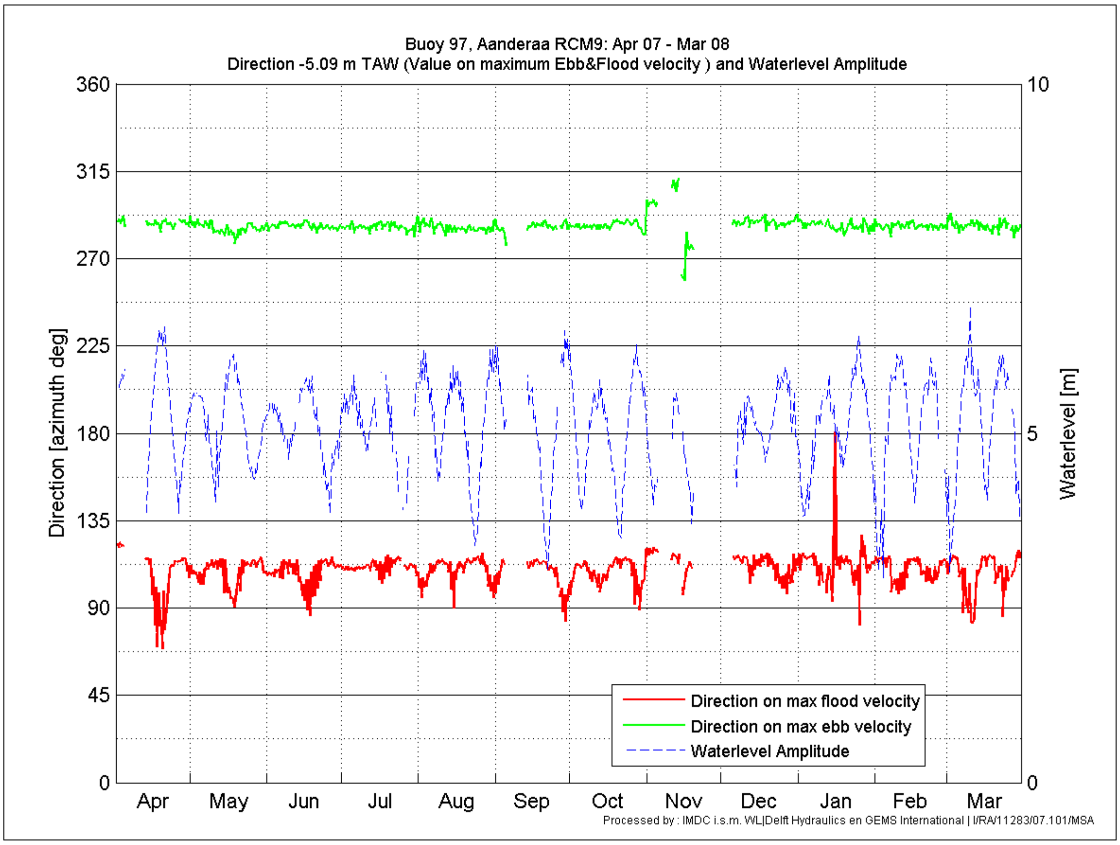


Annex-Figure C-7: Buoy 97 (-5.1m TAW), maximal (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2007 – March 2008

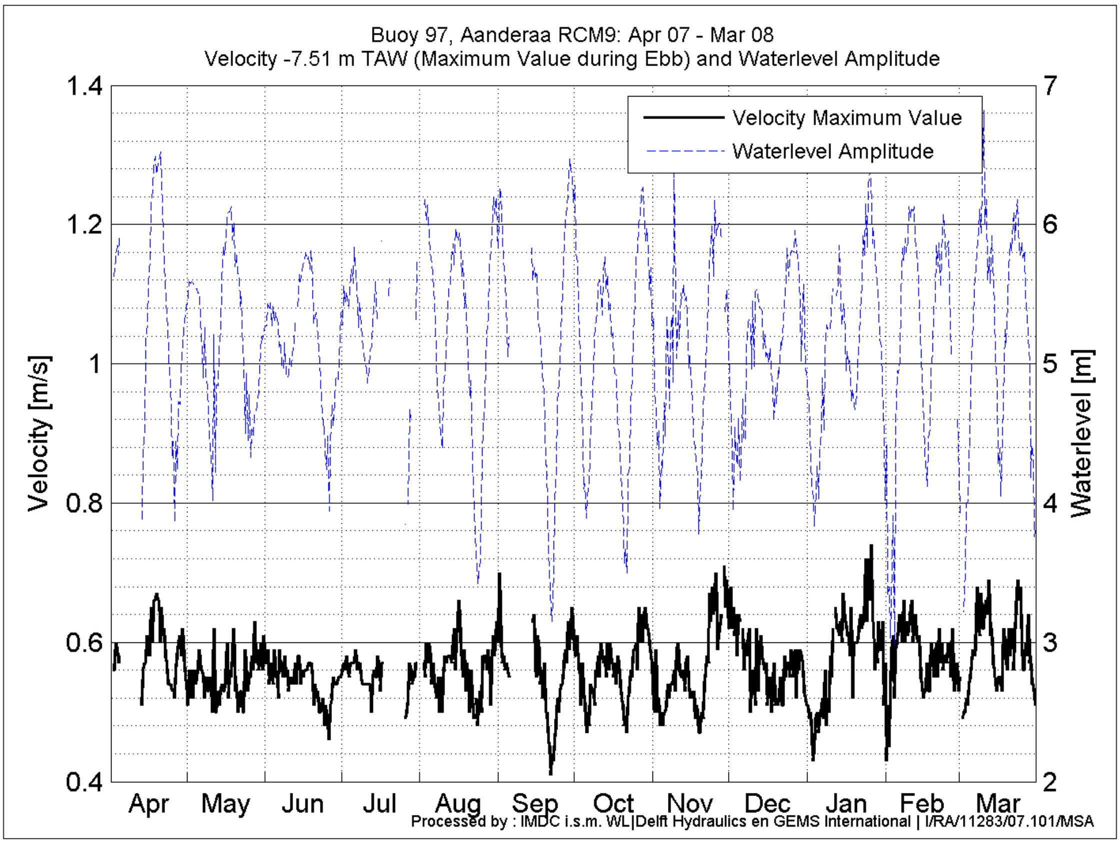


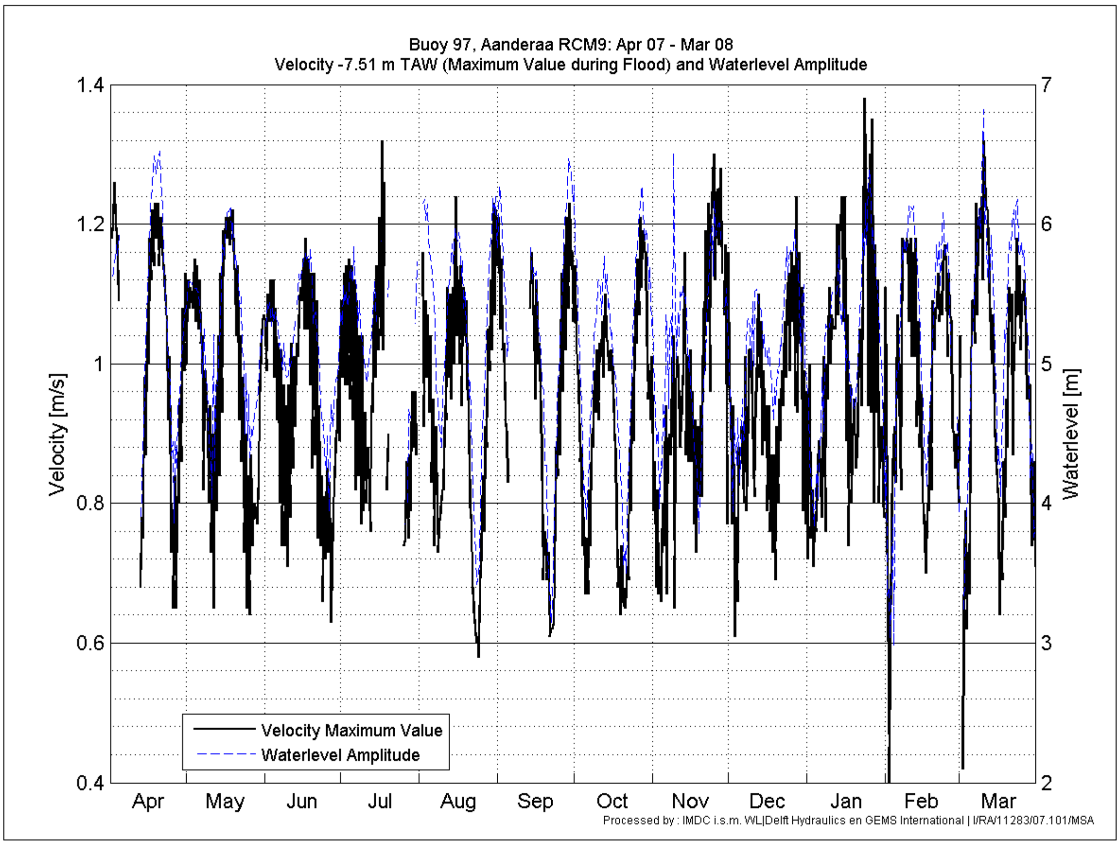


Annex-Figure C-8: Buoy 97 (-5.1m TAW), averaged (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2007 – March 2008

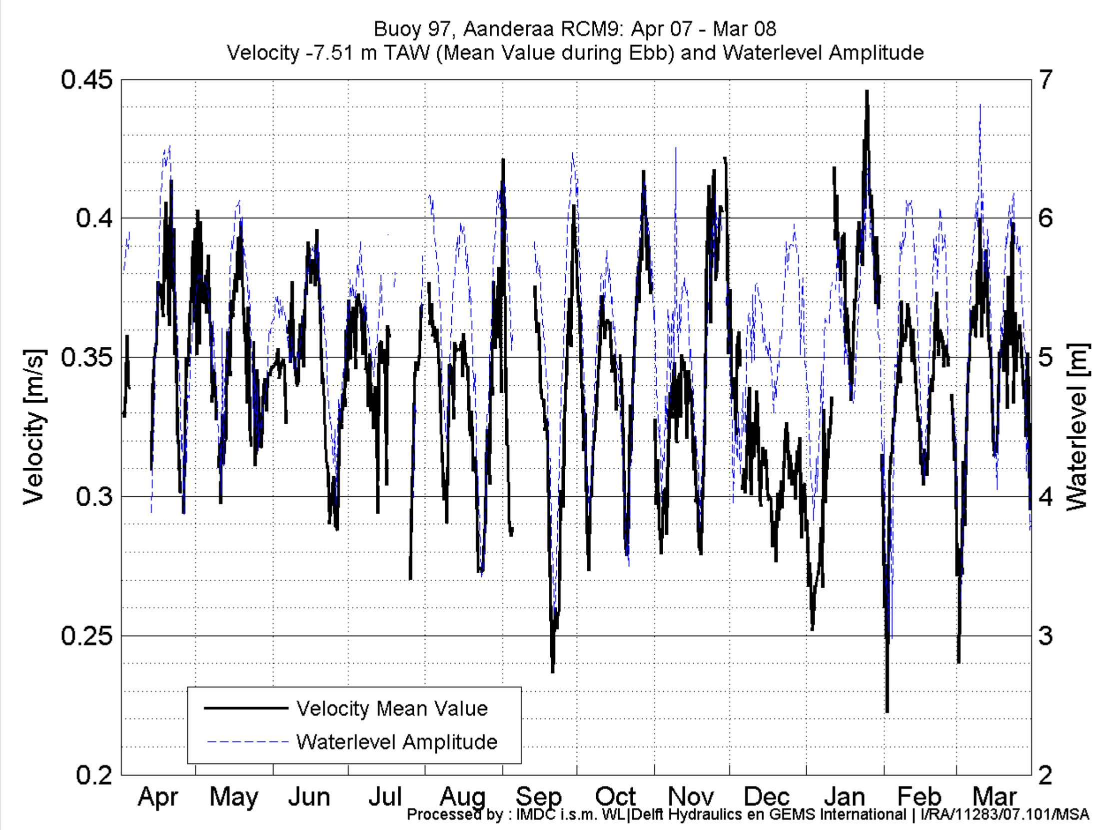


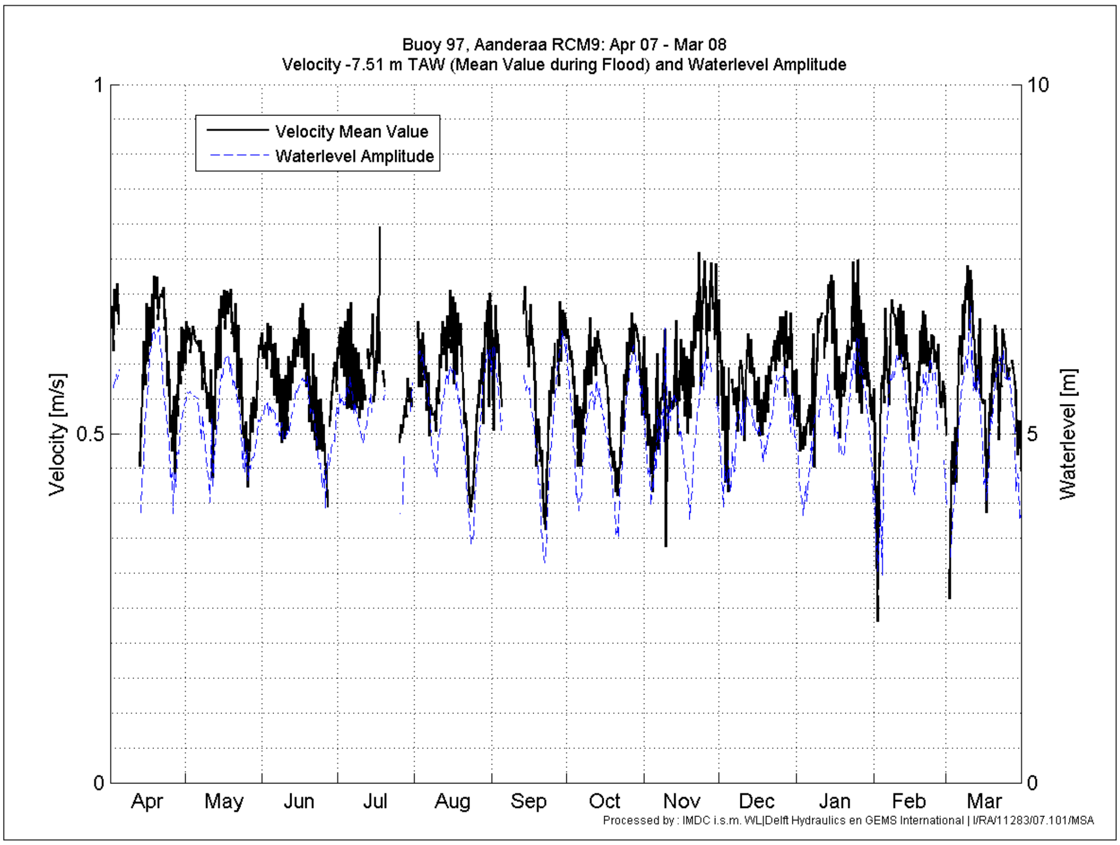
Annex-Figure C-9: Buoy 97 (-5.1m TAW), flow direction on maximal ebb phase and flood phase velocity and water level amplitude, April 2007 – March 2008



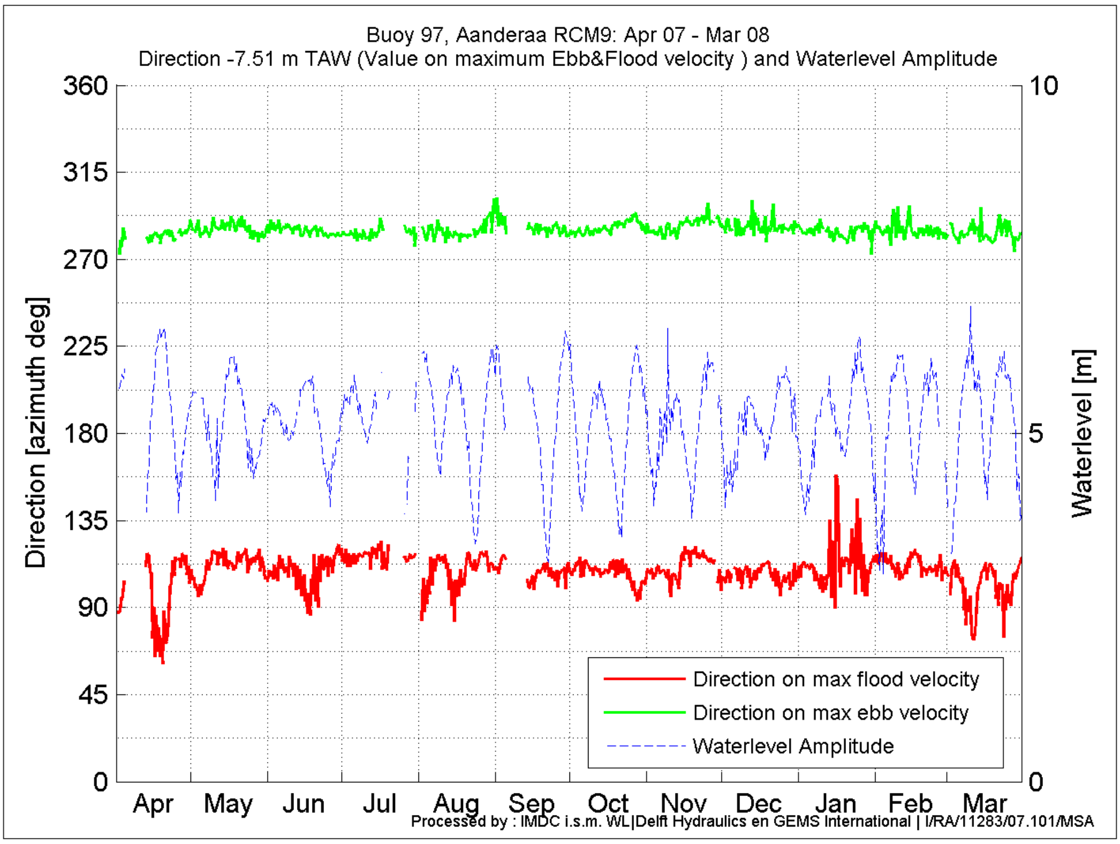


Annex-Figure C-10: Buoy 97 (-7.5m TAW), maximal (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2007 – March 2008

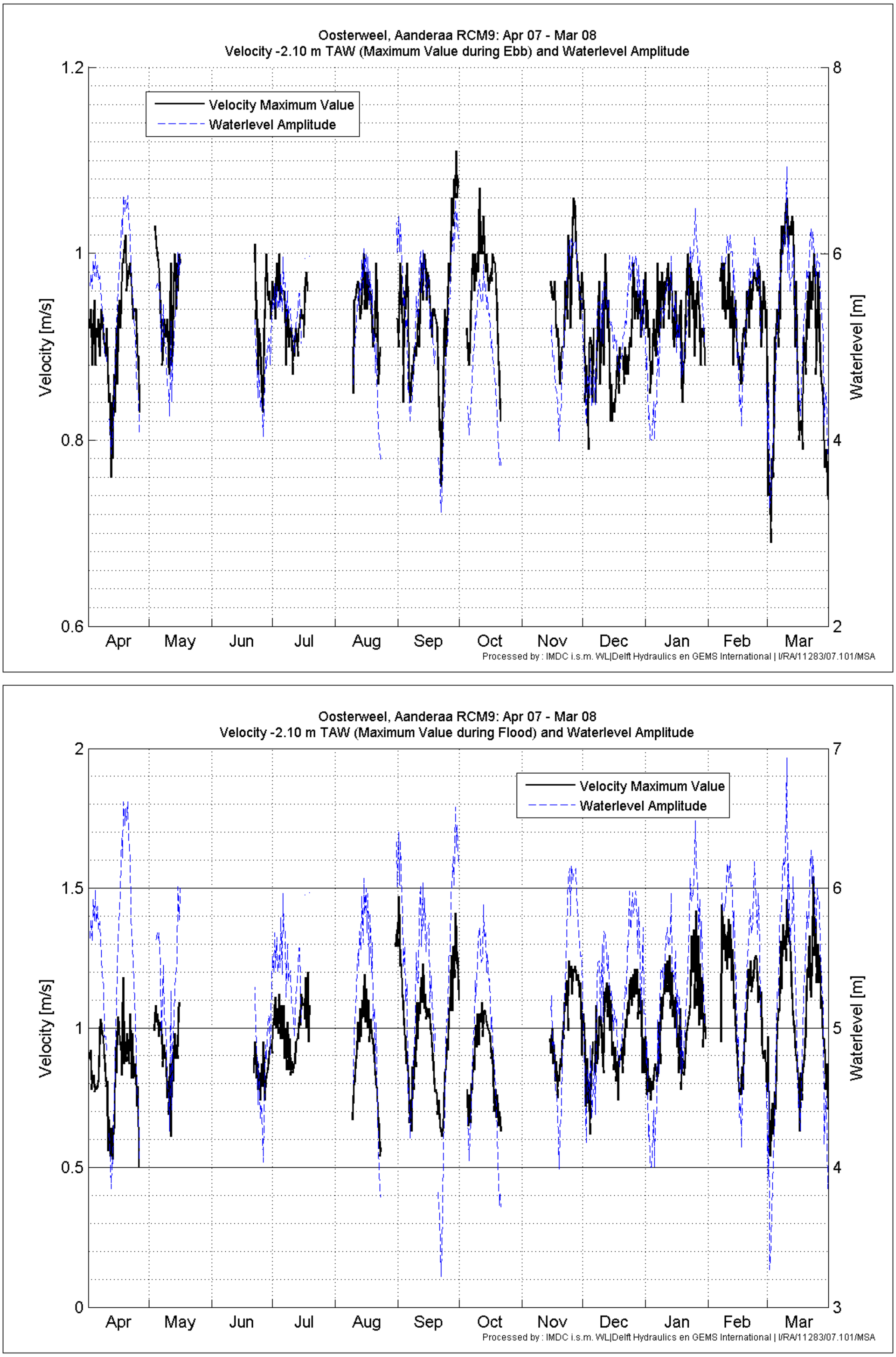




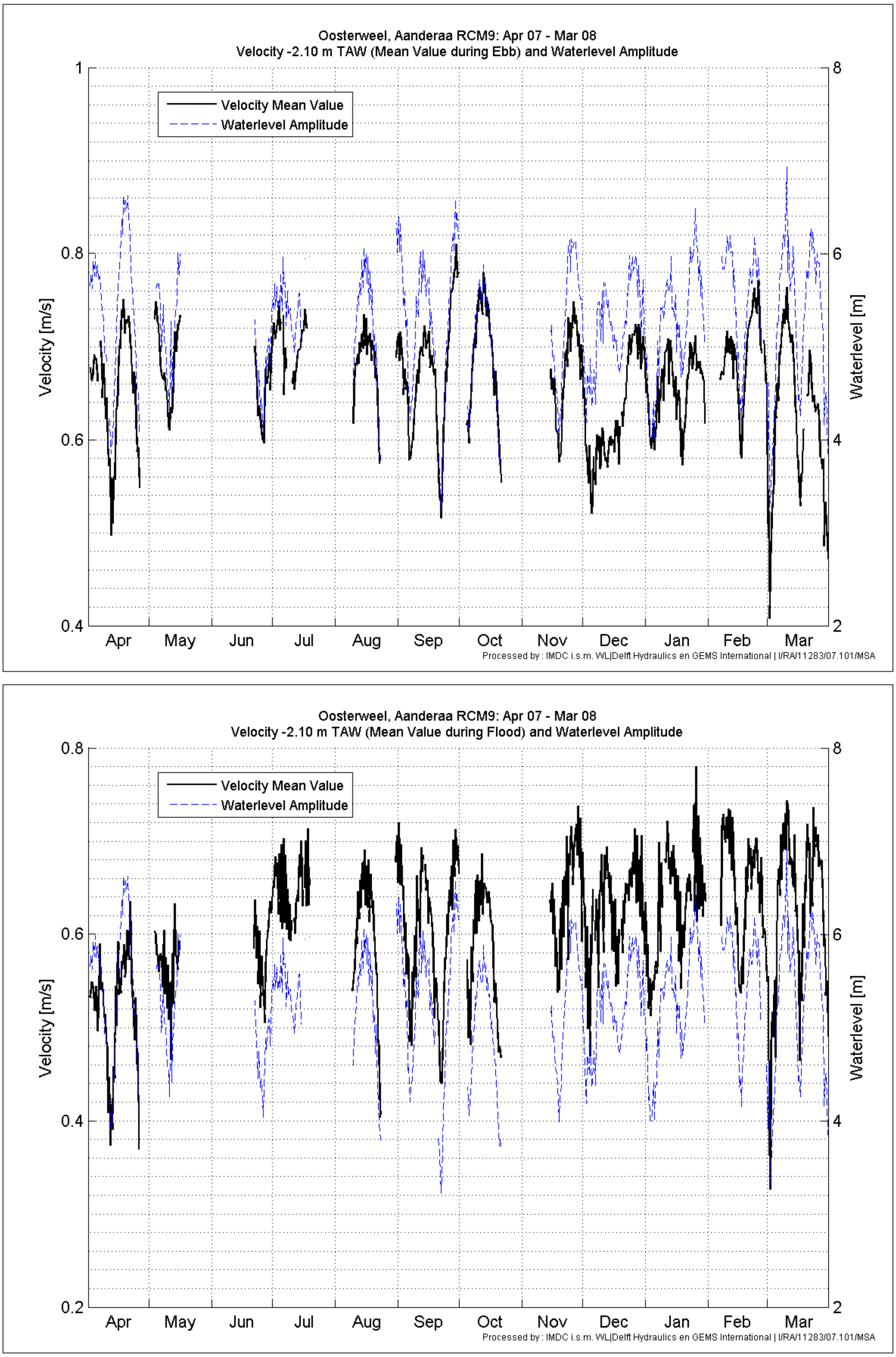
Annex-Figure C-11: Buoy 97 (-7.5m TAW), averaged (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2007 – March 2008



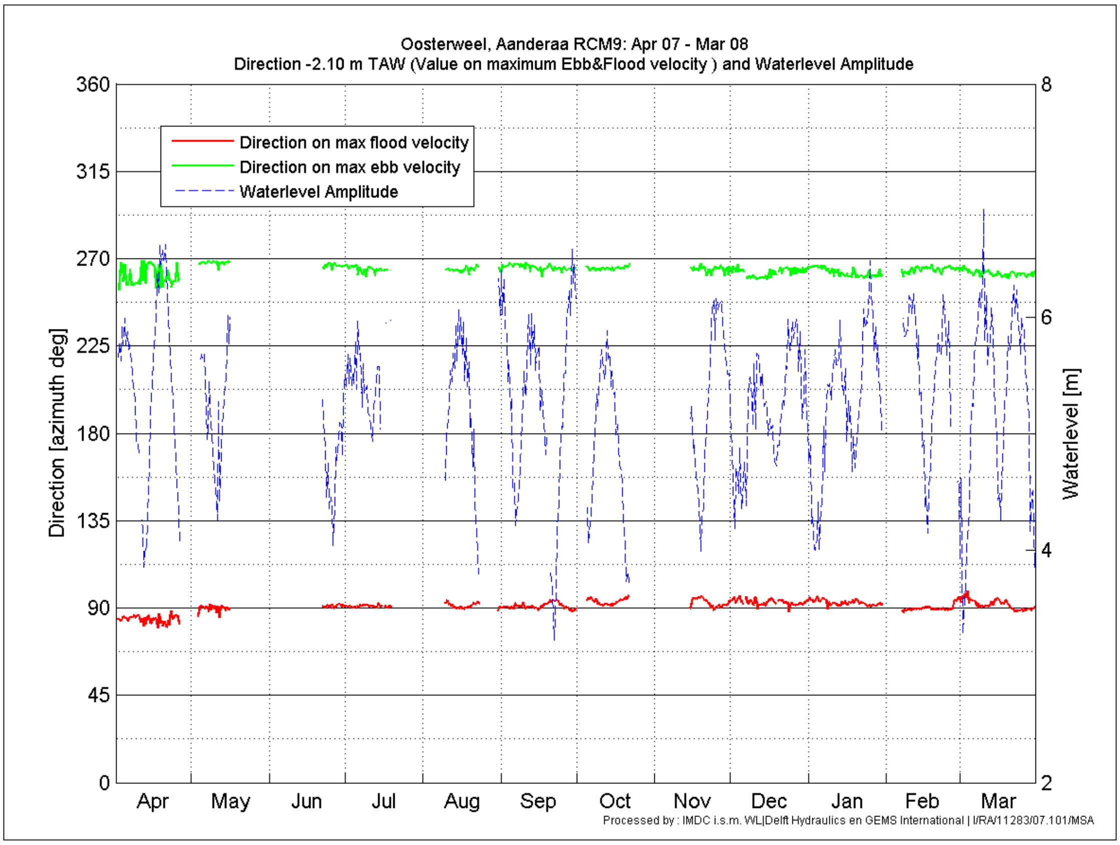
Annex-Figure C-12: Buoy 97 (-7.5m TAW), flow direction on maximal ebb phase and flood phase velocity and water level amplitude, April 2007 – March 2008



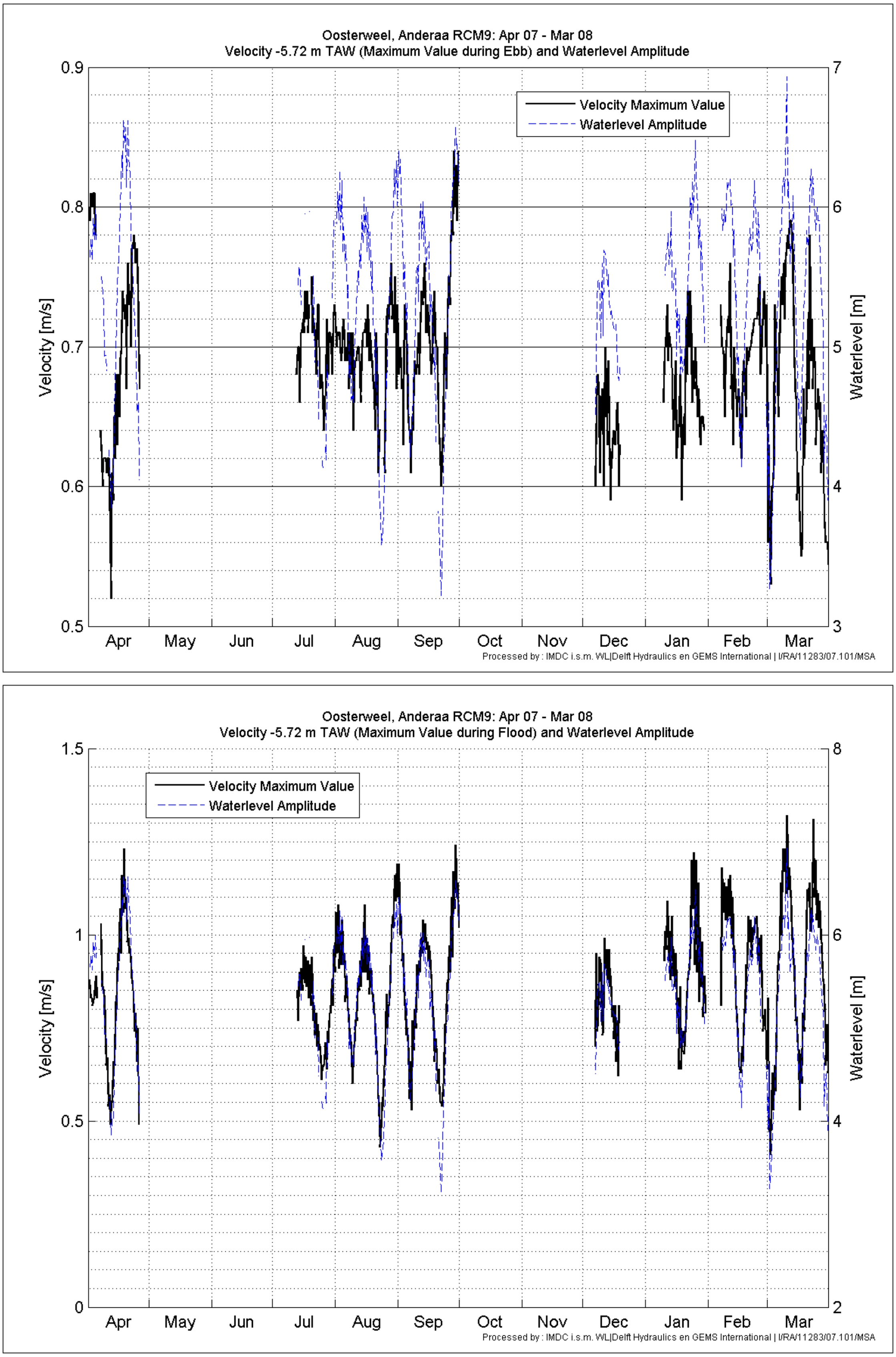
Annex-Figure C-13: Oosterweel (-2.1m TAW), maximal (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2007 – March 2008



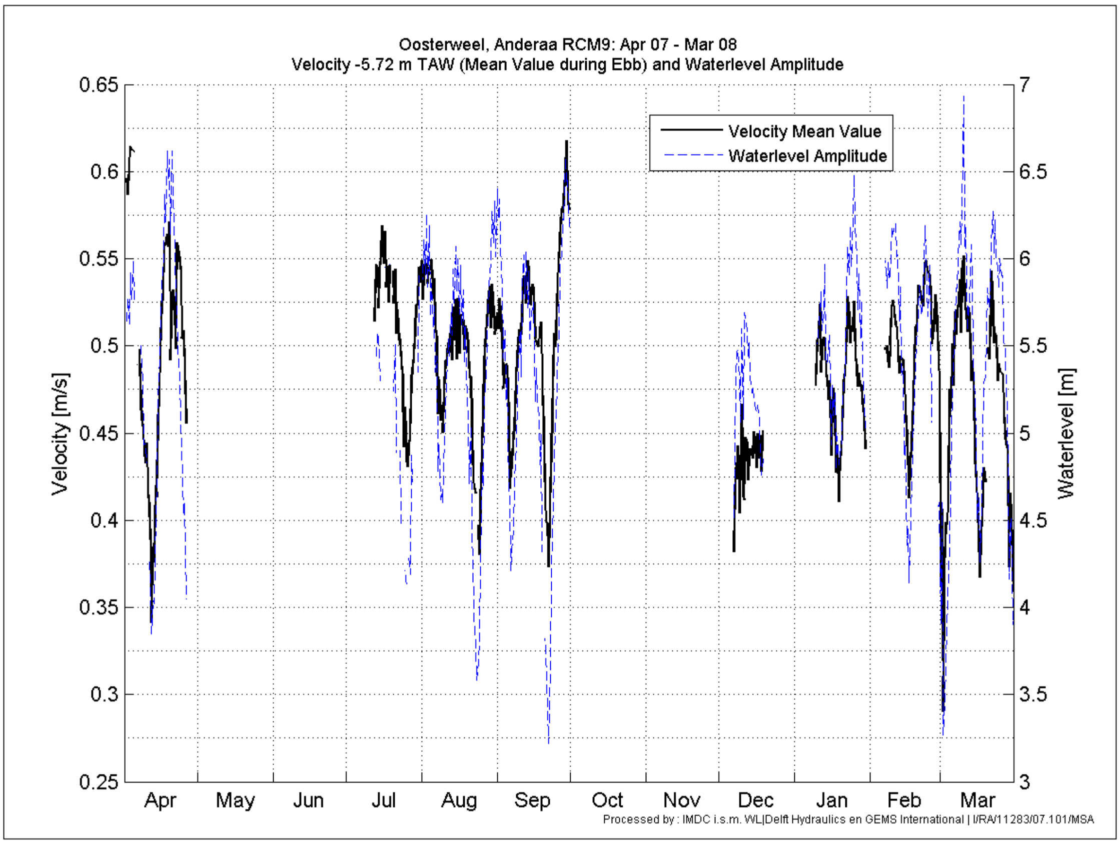
Annex-Figure C-14: Oosterweel (-2.1m TAW), averaged (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2007 – March 2008

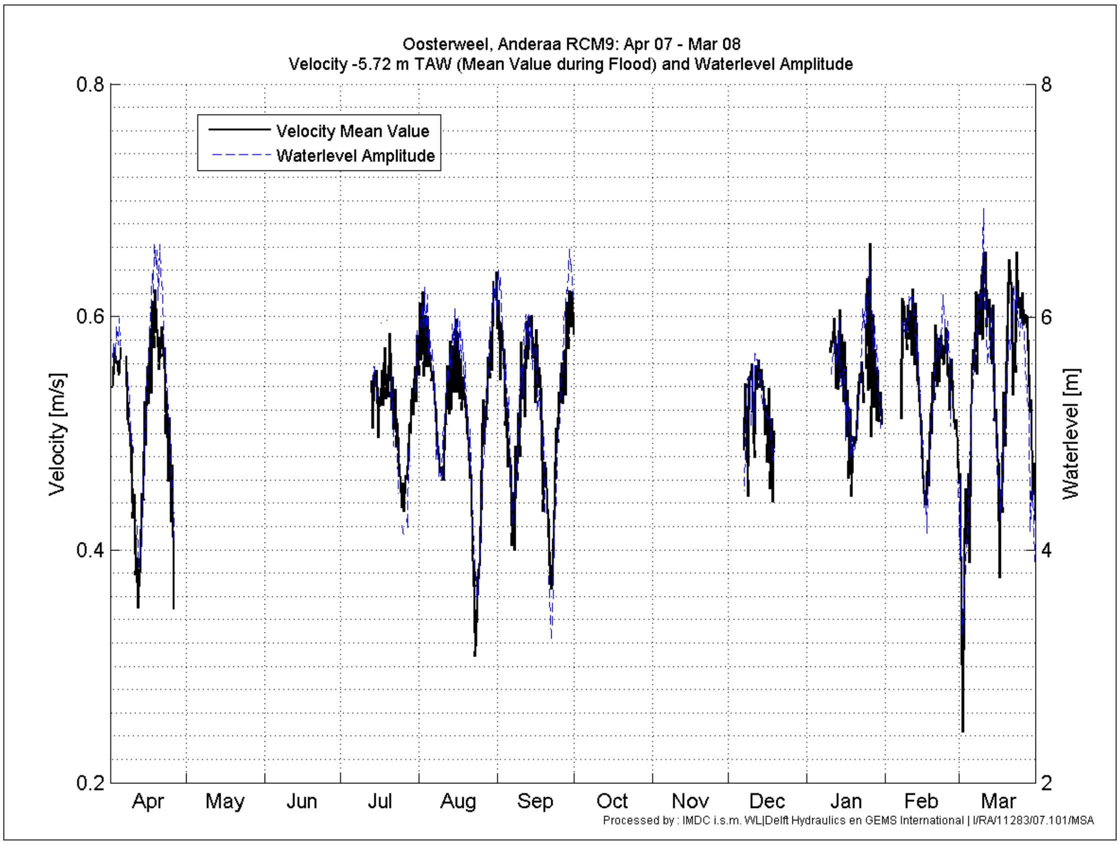


Annex-Figure C-15: Oosterweel (-2.1m TAW), flow direction on maximal ebb phase and flood phase velocity and water level amplitude, April 2007 – March 2008

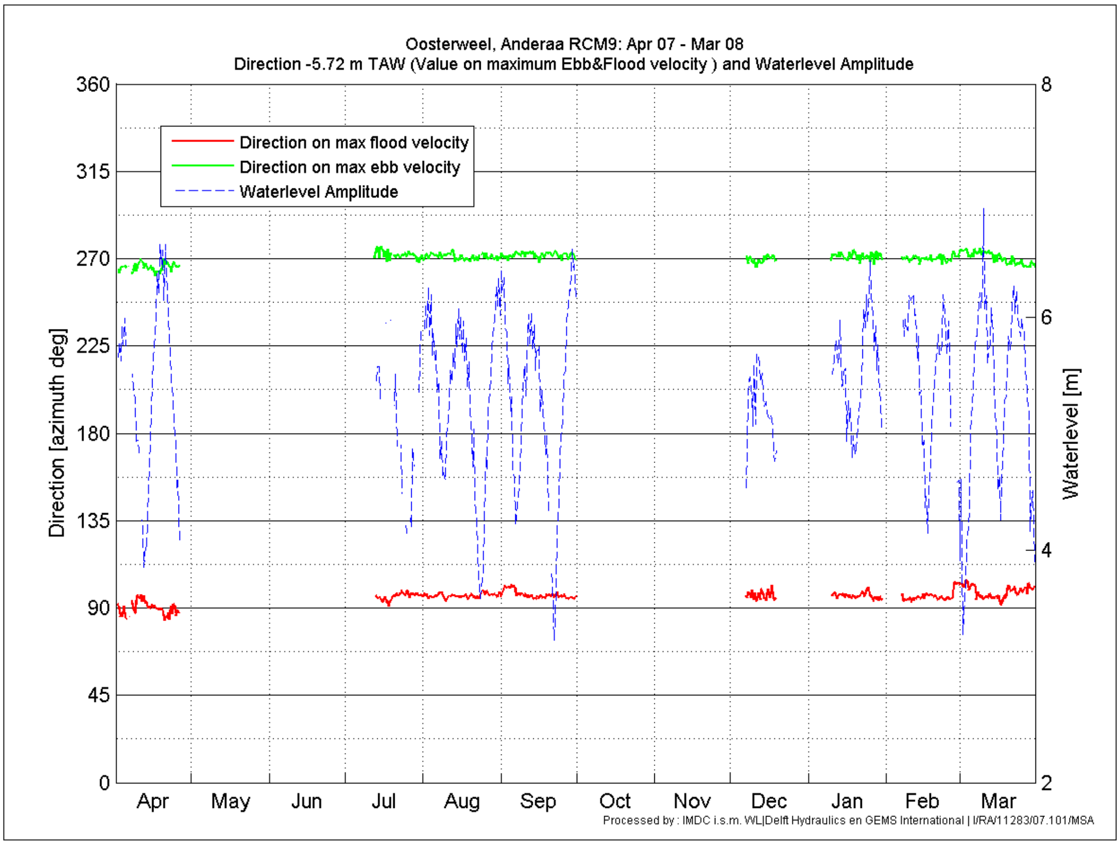


Annex-Figure C-16: Oosterweel (-5.7m TAW), maximal (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2007 – March 2008

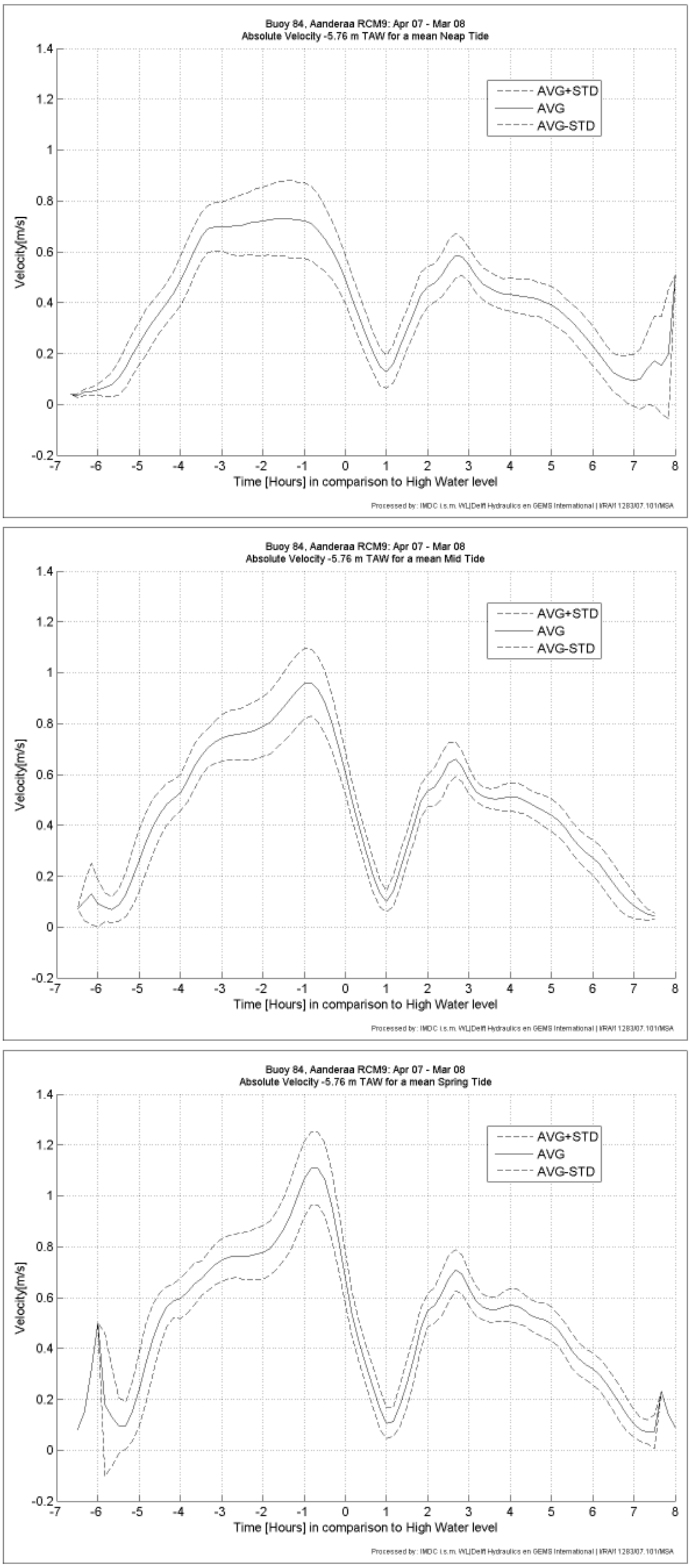




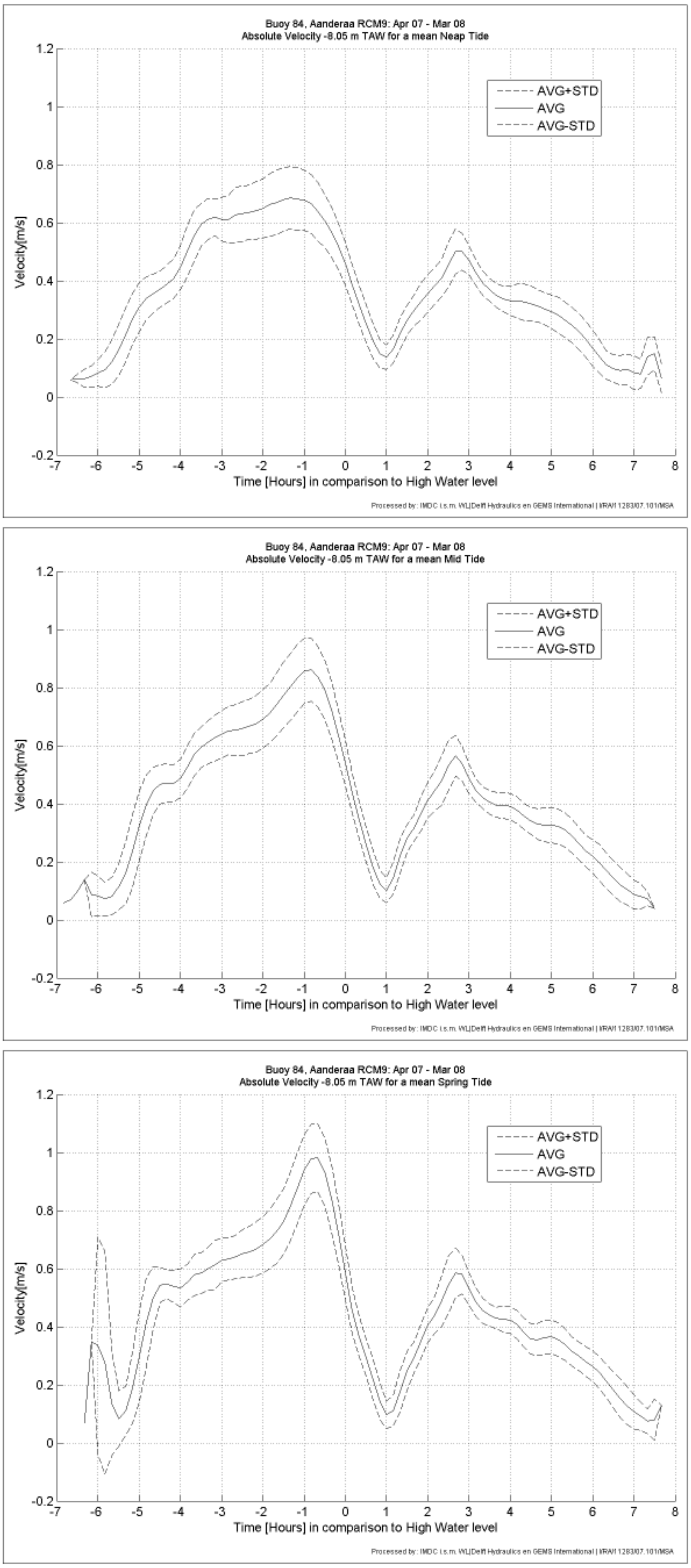
Annex-Figure C-17: Oosterweel (-5.7m TAW), averaged (a) ebb & (b) flood phase velocity and tidal amplitude at Liefkenshoek, April 2007 – March 2008



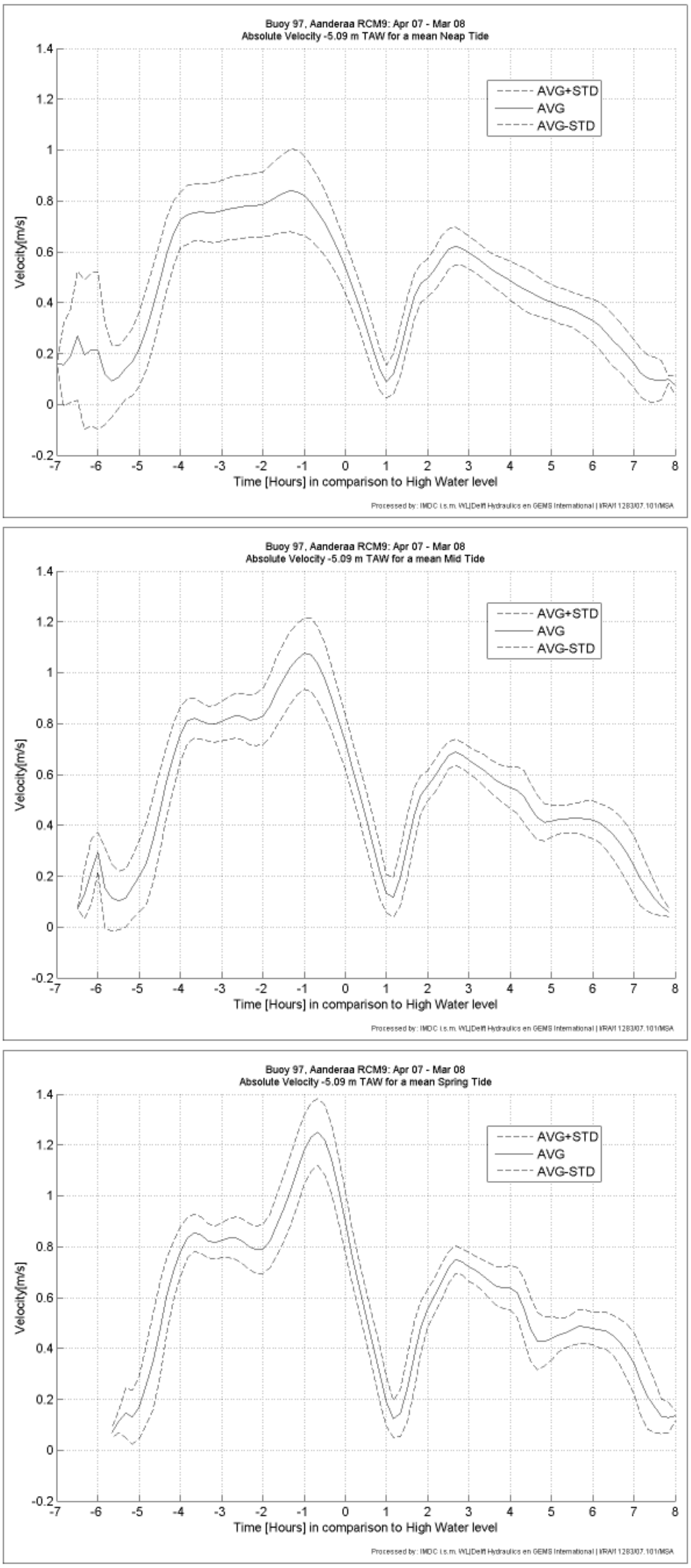
Annex-Figure C-18: Oosterweel (-5.7m TAW), flow direction on maximal ebb phase and flood phase velocity, April 2007 – March 2008



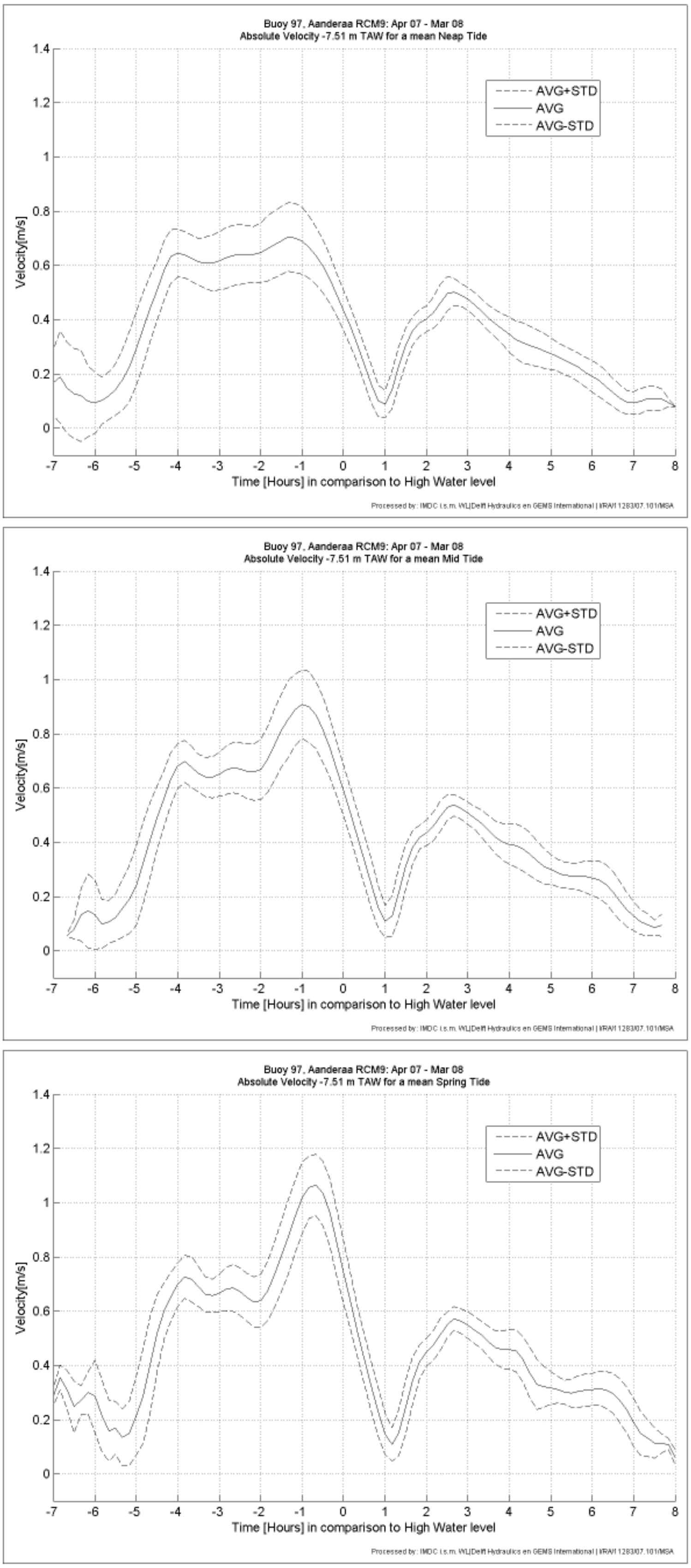
Annex-Figure C-19: Buoy 84 (-5.76m TAW), averaged tidal curve of the flow velocity for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008



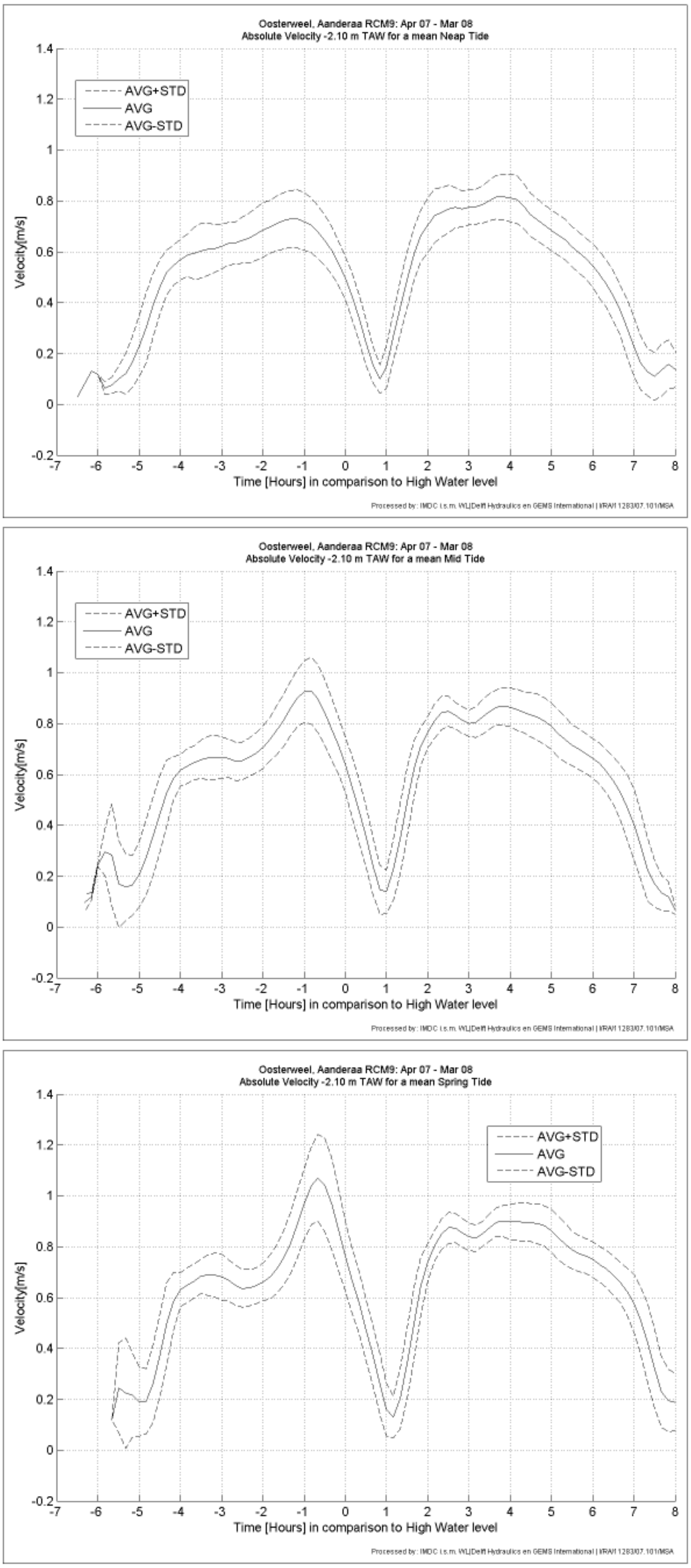
Annex-Figure C-20: Buoy 84 (-8.1m TAW), averaged tidal curve of the flow velocity for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008



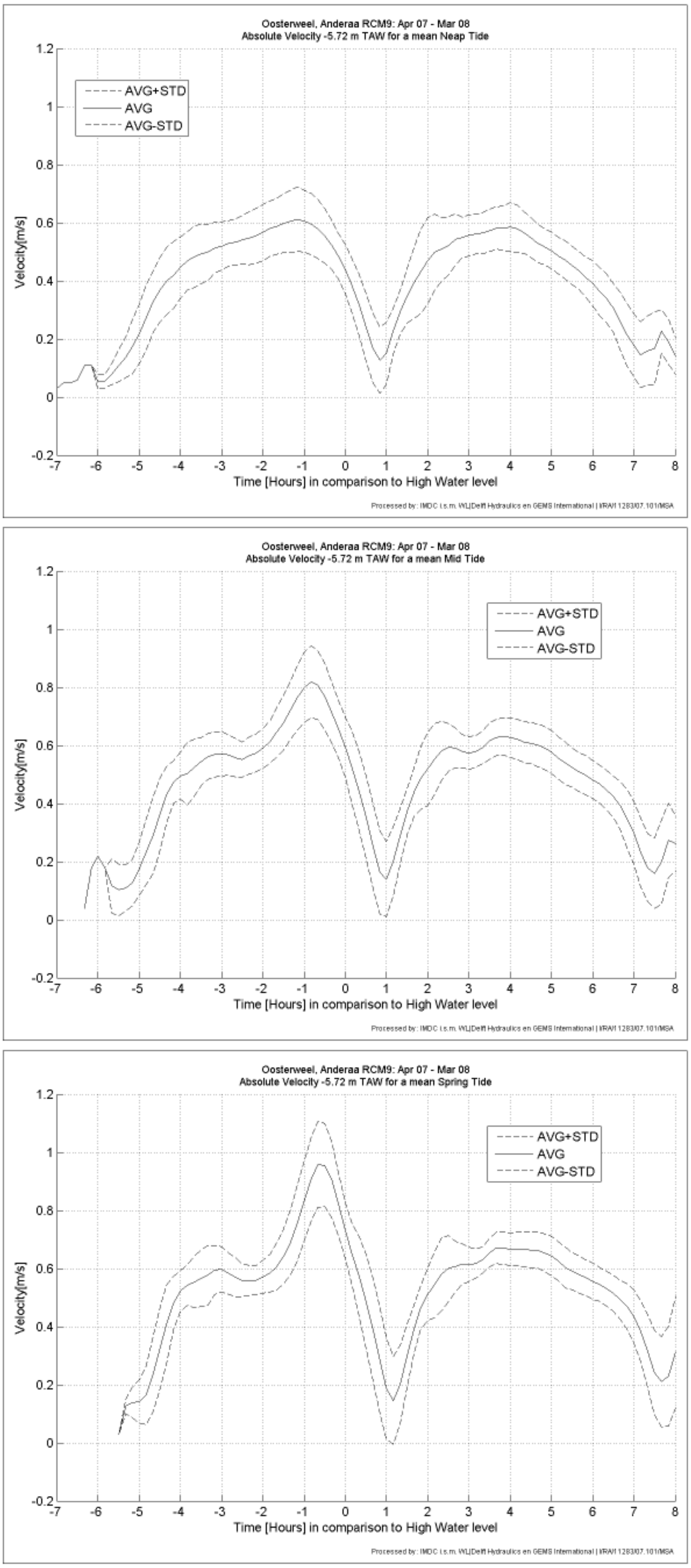
Annex-Figure C-21: Buoy 97 (-5.1m TAW), averaged tidal curve of the flow velocity for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008



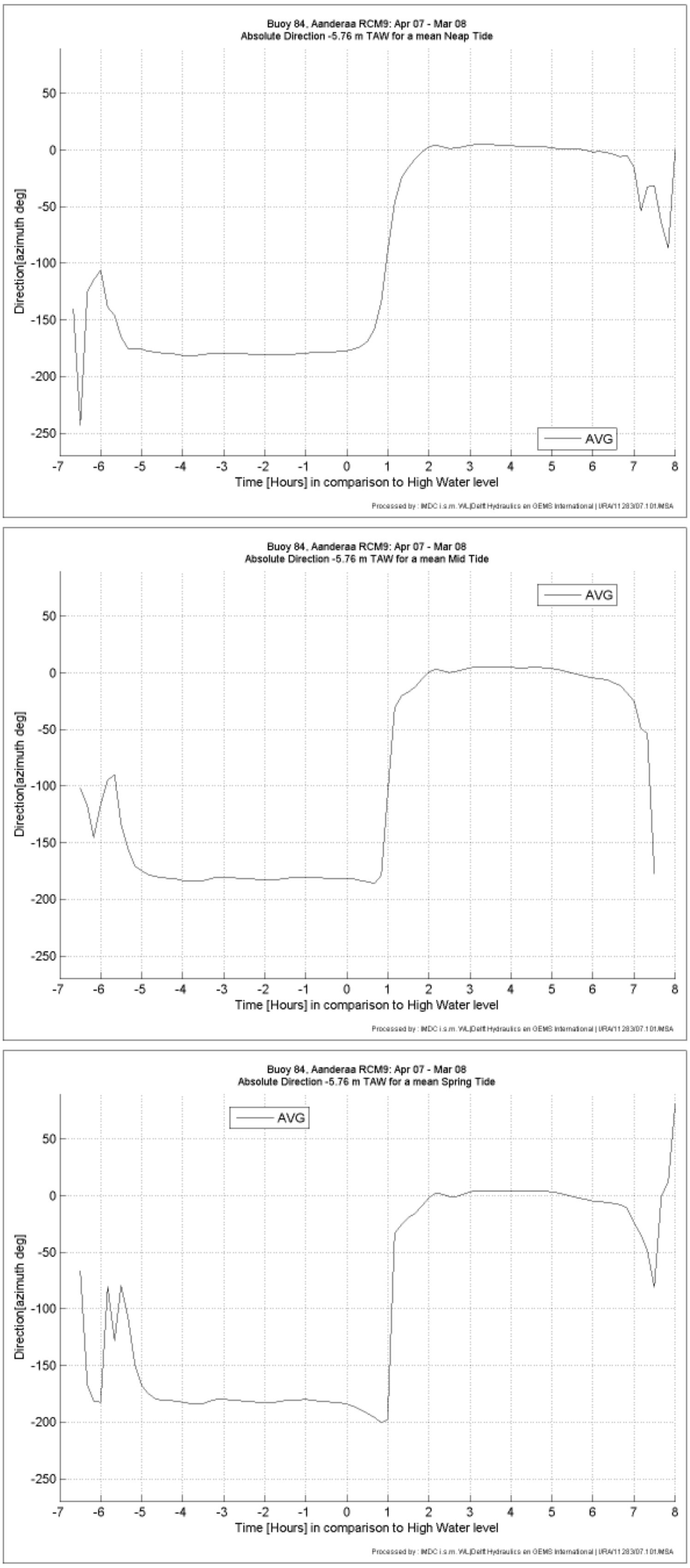
Annex-Figure C-22: Buoy 97 (-7.5m TAW), averaged tidal curve of the flow velocity for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008



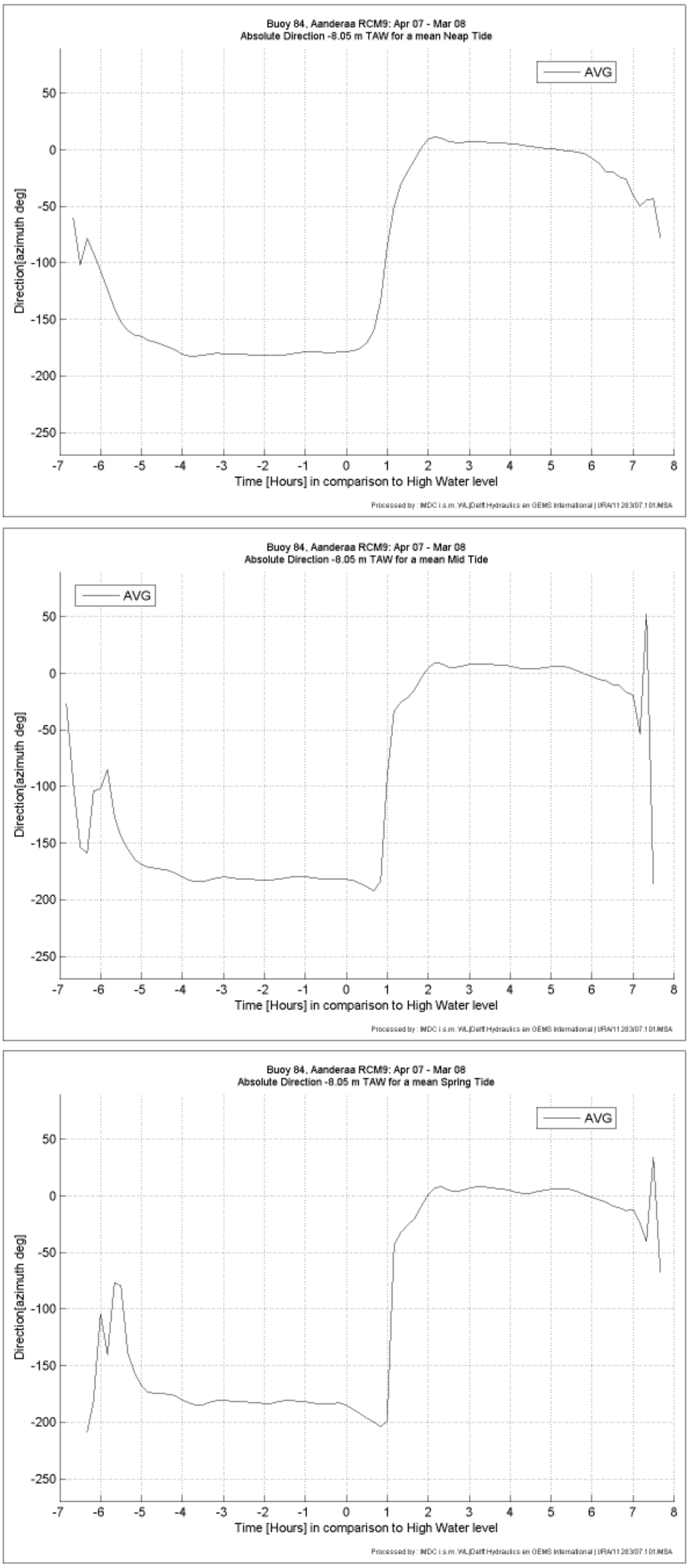
Annex-Figure C-23: Oosterweel (-2.1m TAW), averaged tidal curve of the flow velocity for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008



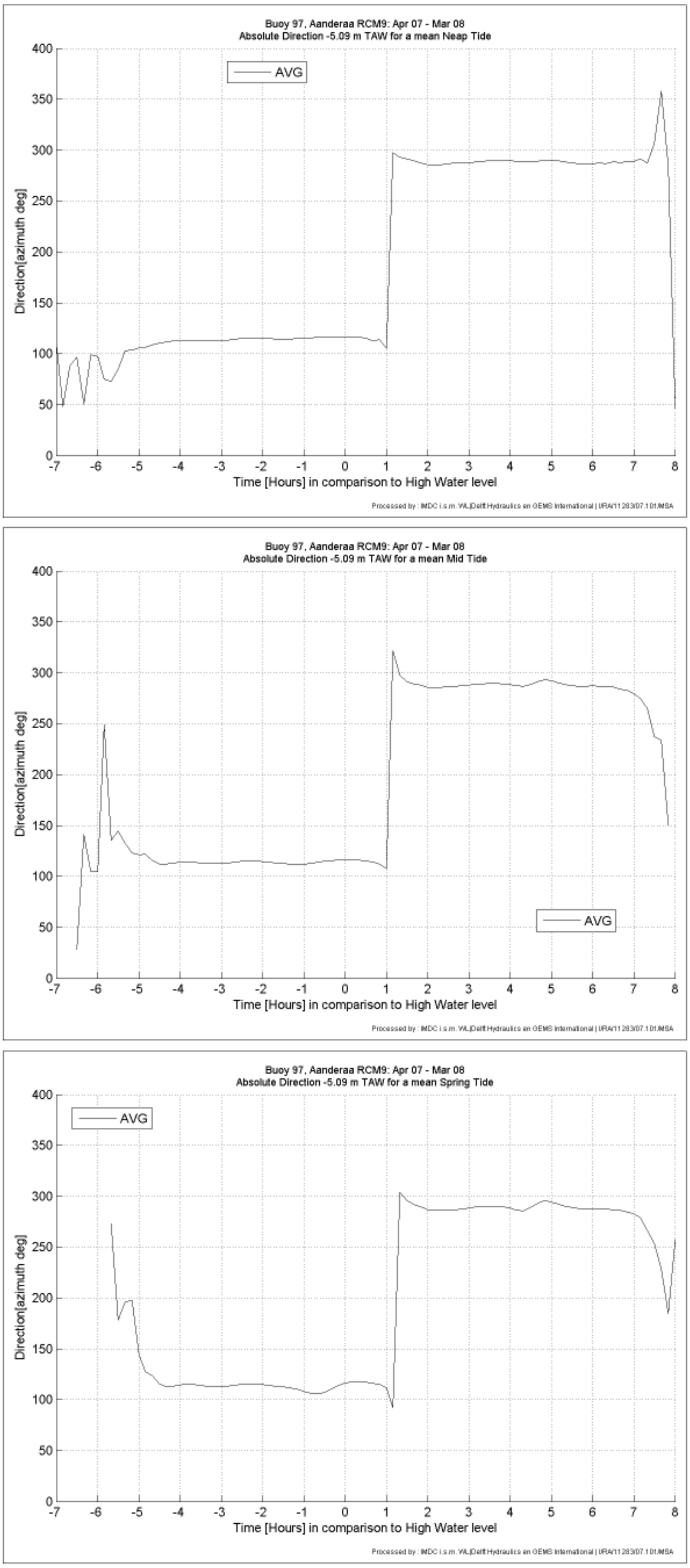
Annex-Figure C-24: Oosterweel (-5.7m TAW), averaged tidal curve of the flow velocity for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008



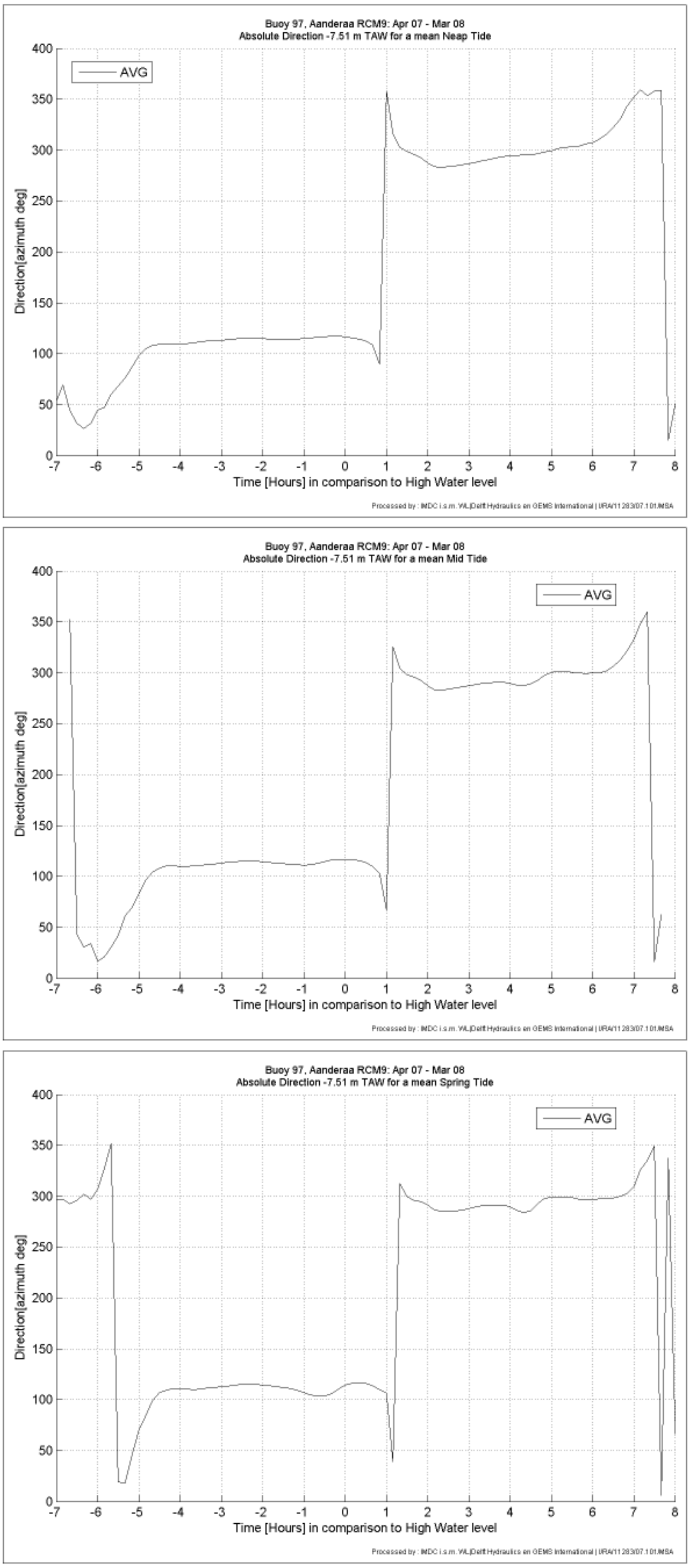
Annex-Figure C-25: Buoy 84 (-5.76m TAW), averaged tidal curve of the flow direction for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008



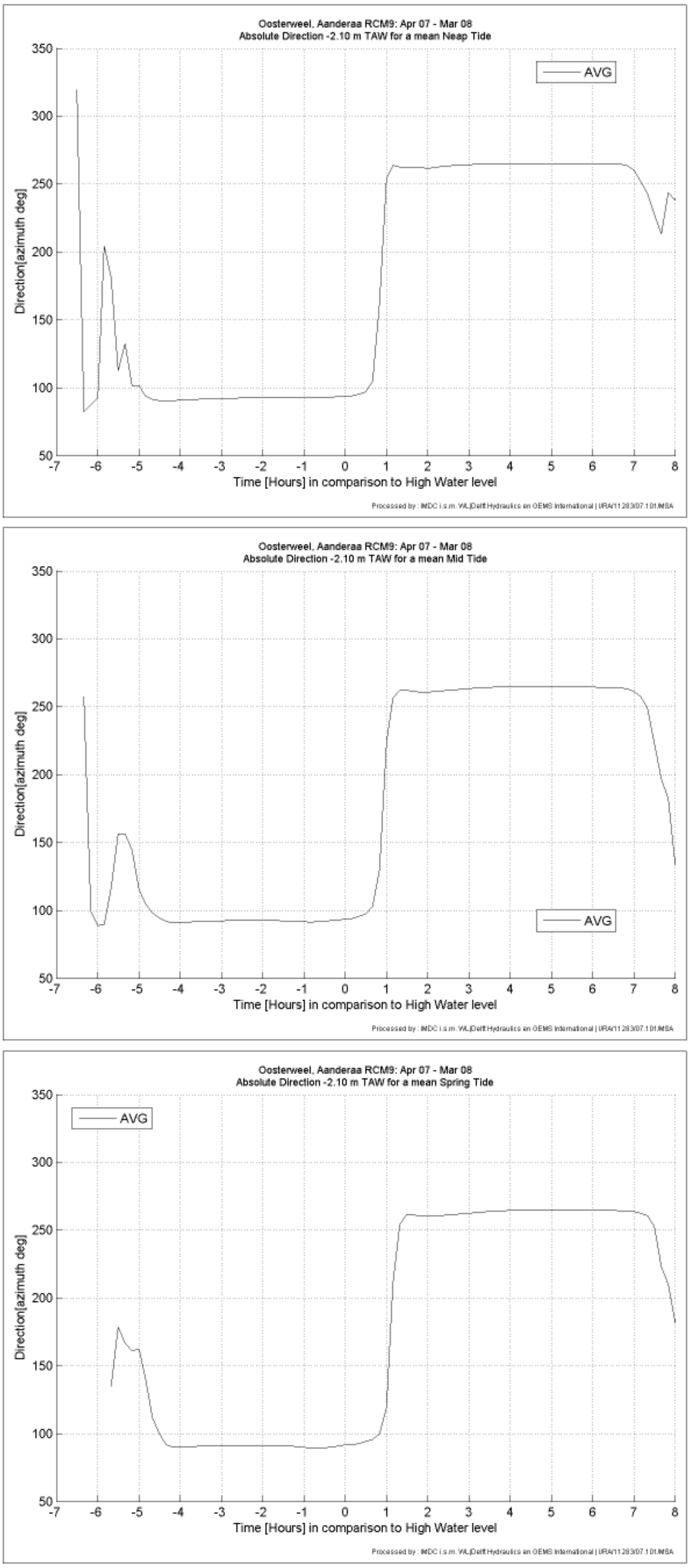
Annex-Figure C-26: Buoy 84 (-8.1m TAW), averaged tidal curve of the flow direction for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008



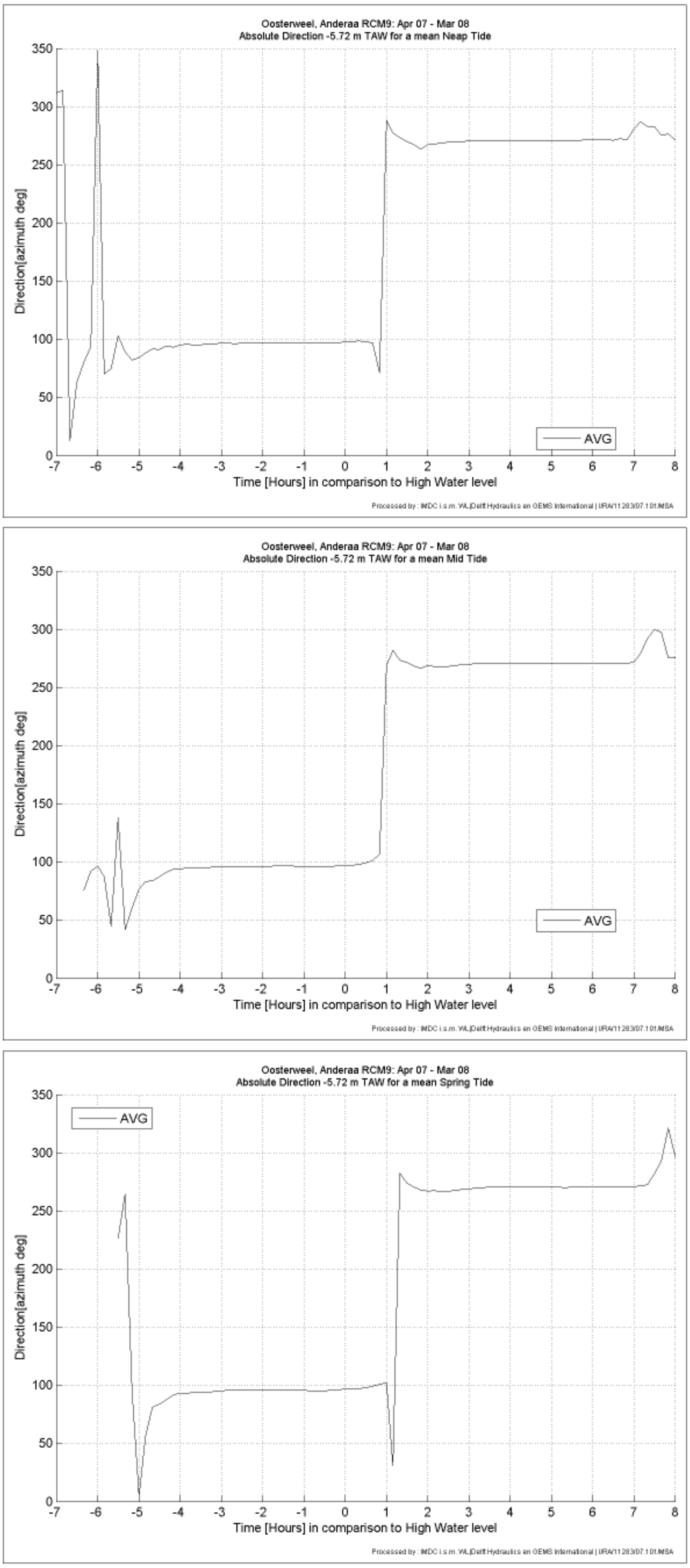
Annex-Figure C-27: Buoy 97 (-5.1m TAW), averaged tidal curve of the flow direction for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008



Annex-Figure C-28: Buoy 97 (-7.5m TAW), averaged tidal curve of the flow direction for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008

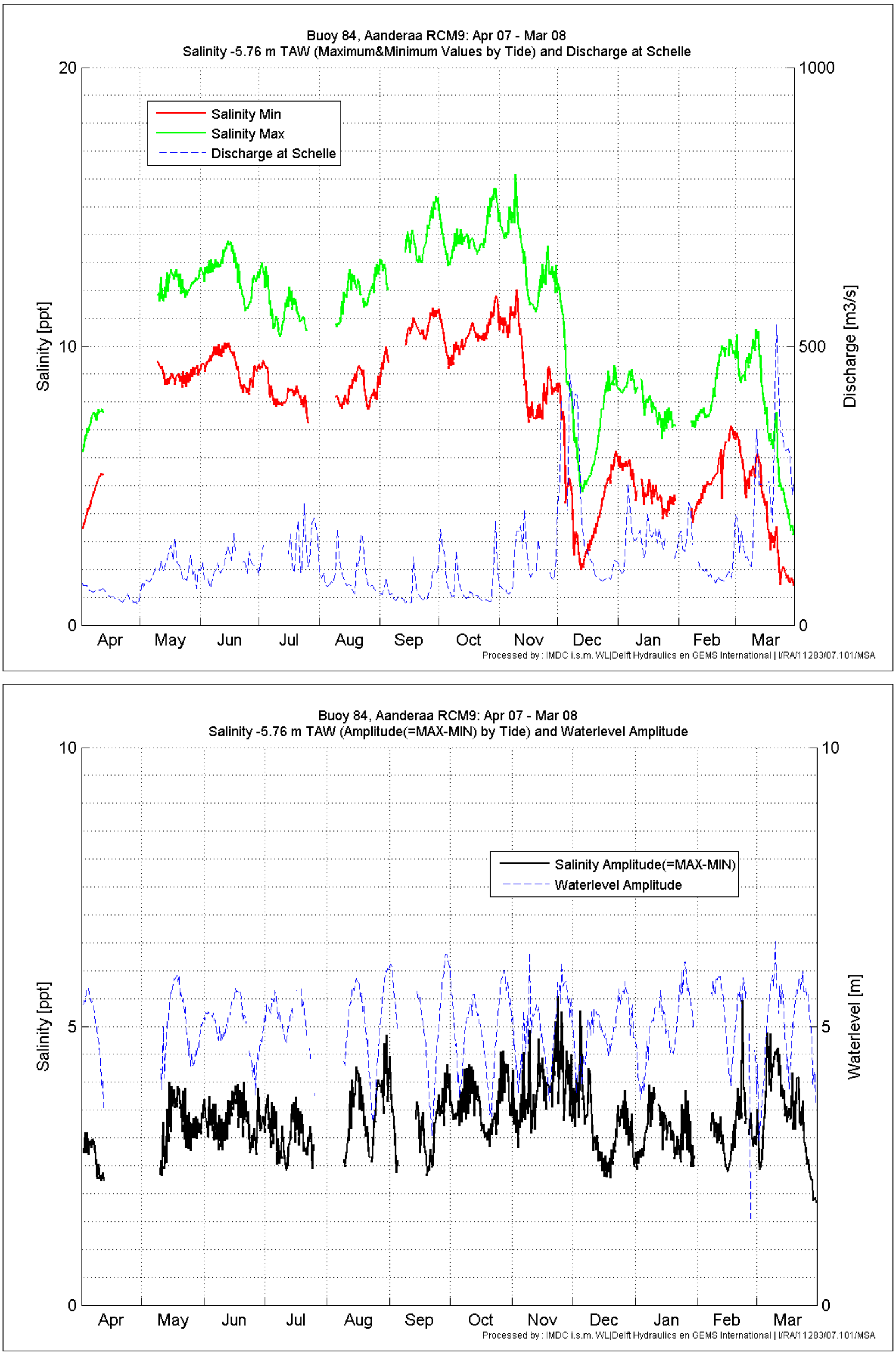


Annex-Figure C-29: Oosterweel (-2.1m TAW), averaged tidal curve of the flow direction for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008

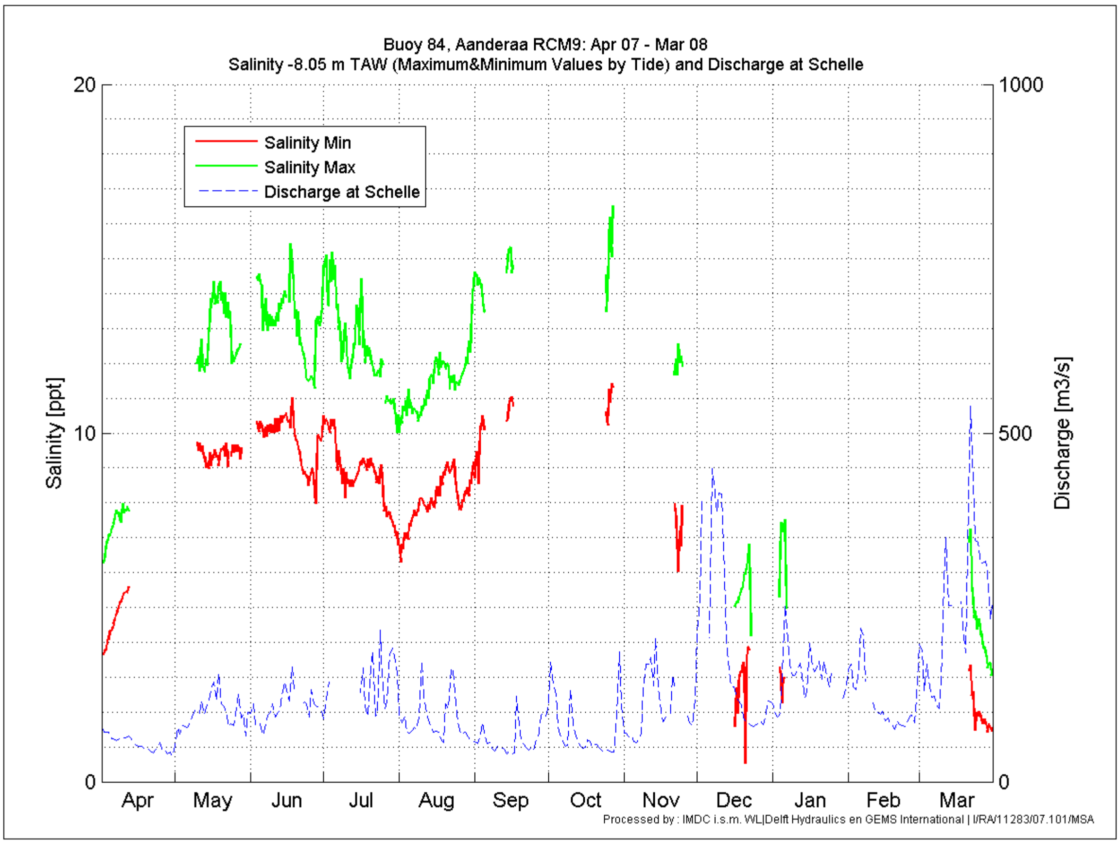


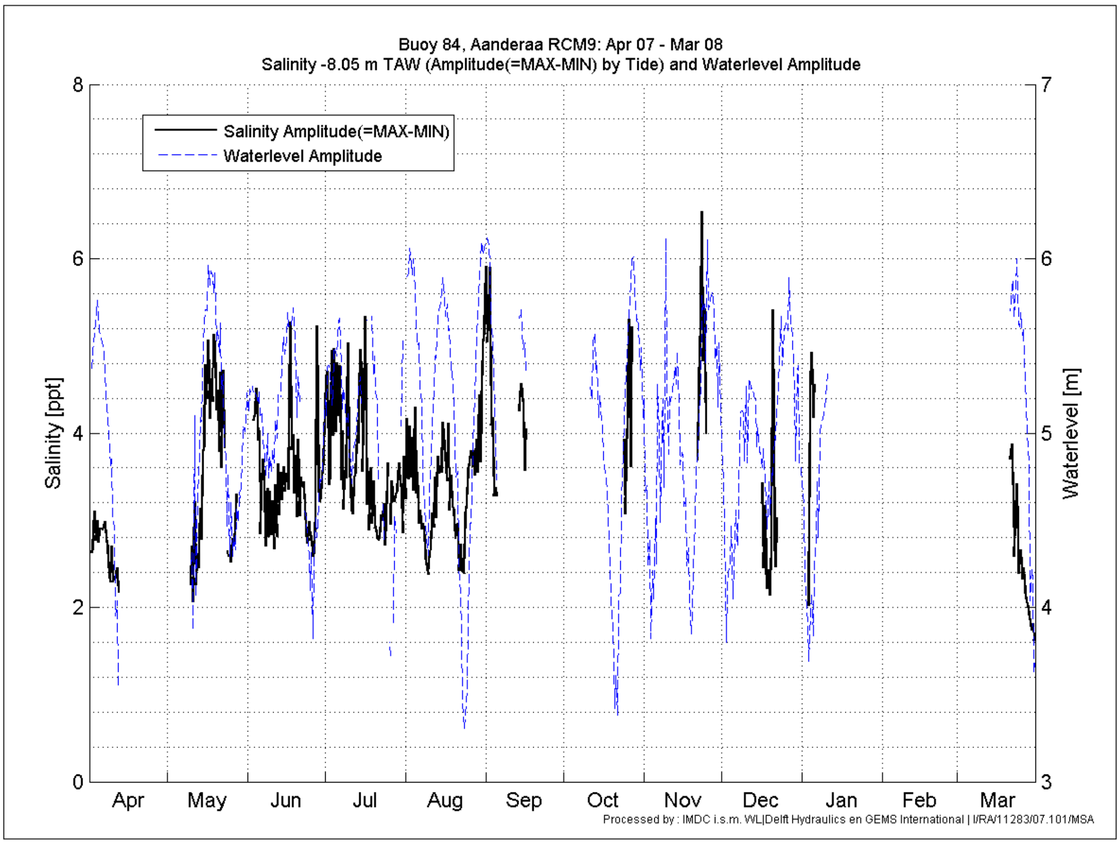
Annex-Figure C-30: Oosterweel (-5.7m TAW), averaged tidal curve of the flow direction for (a) a neap, (b) an average and (c) a spring tide, April 2007 – March 2008

ANNEX D. : FIGURES FOR SALINITY

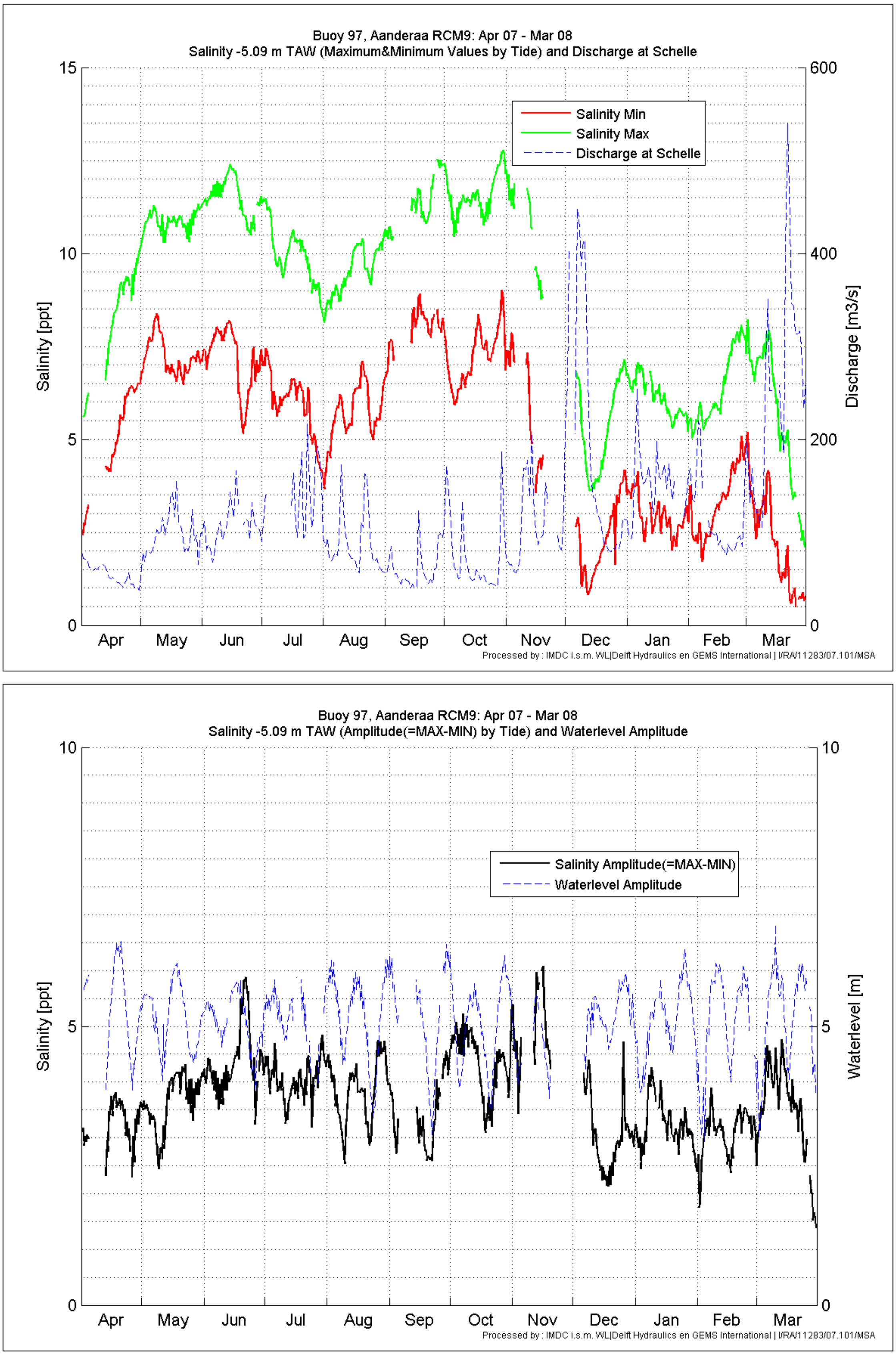


Annex-Figure D-1: Buoy 84 (-5.8m TAW), April 2007 – March 2008, (a) tidal max and min salinity and discharge at Schelle, (b) tidal salinity and water level amplitude

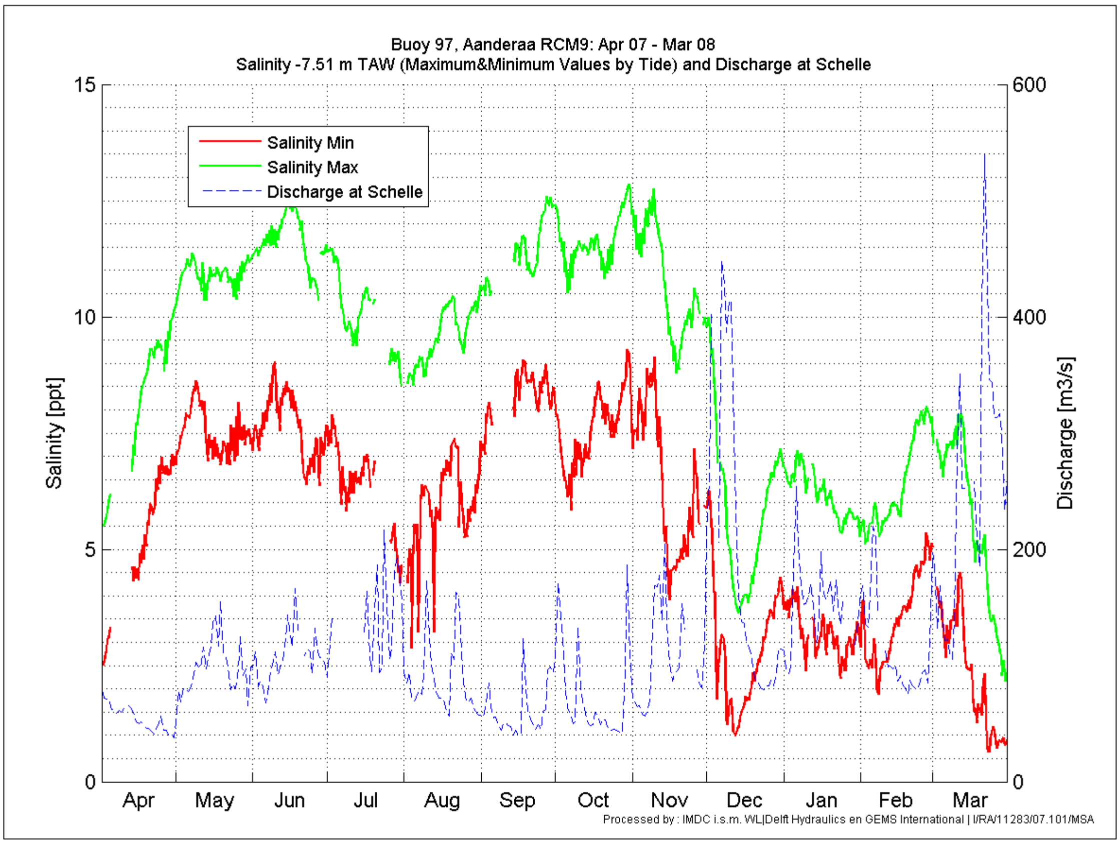


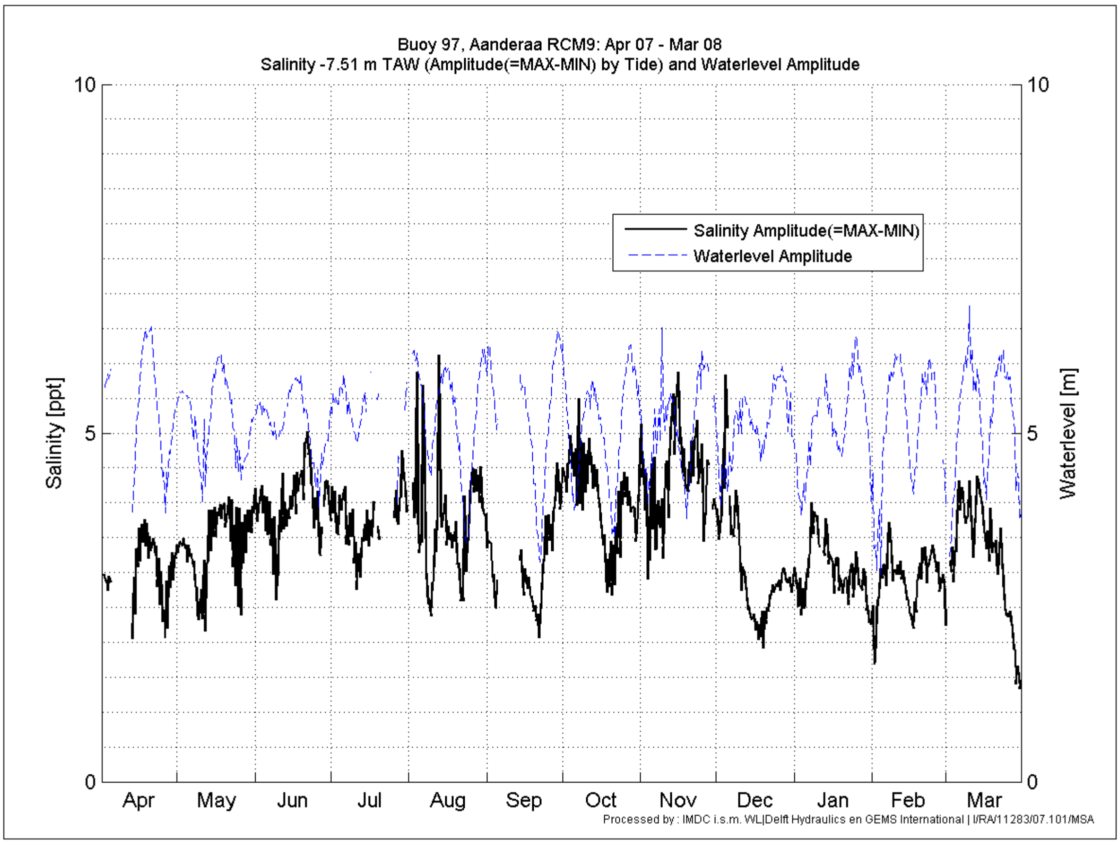


Annex-Figure D-2: Buoy 84 (-8.1m TAW), April 2007 – March 2008, (a) tidal max and min salinity and discharge at Schelle, (b) tidal salinity and water level amplitude

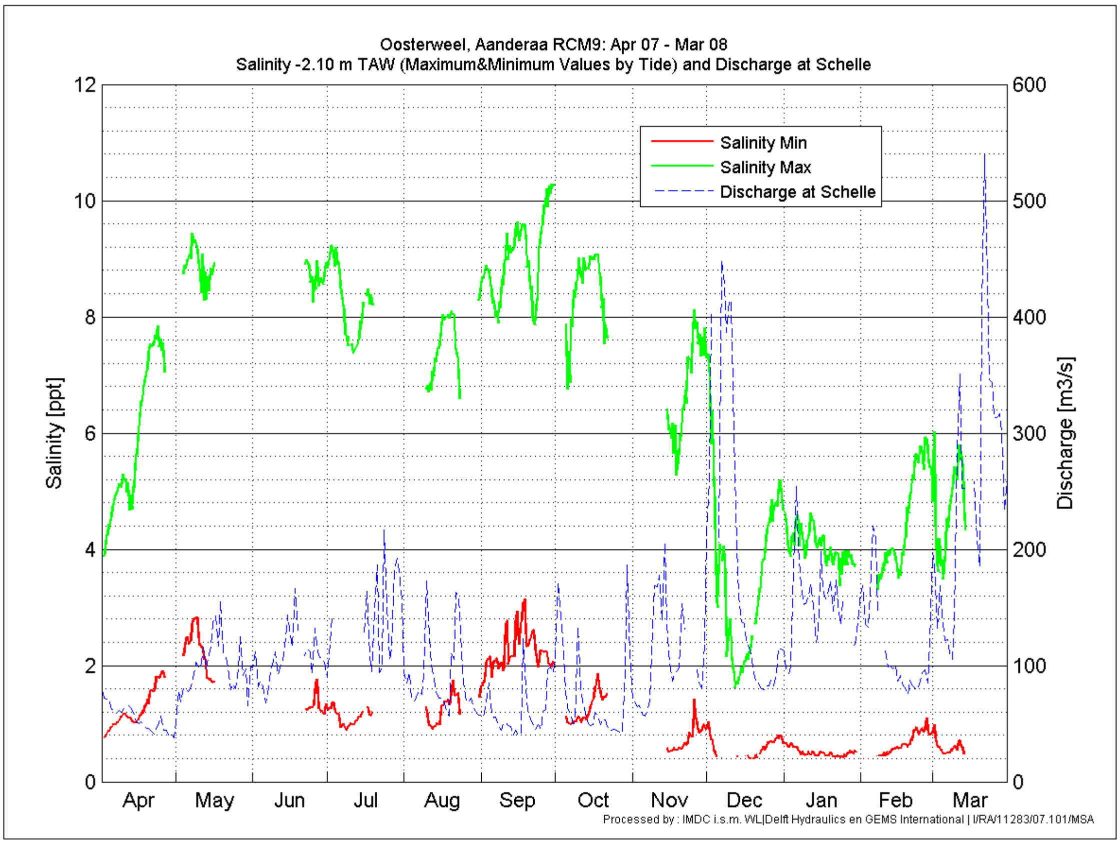


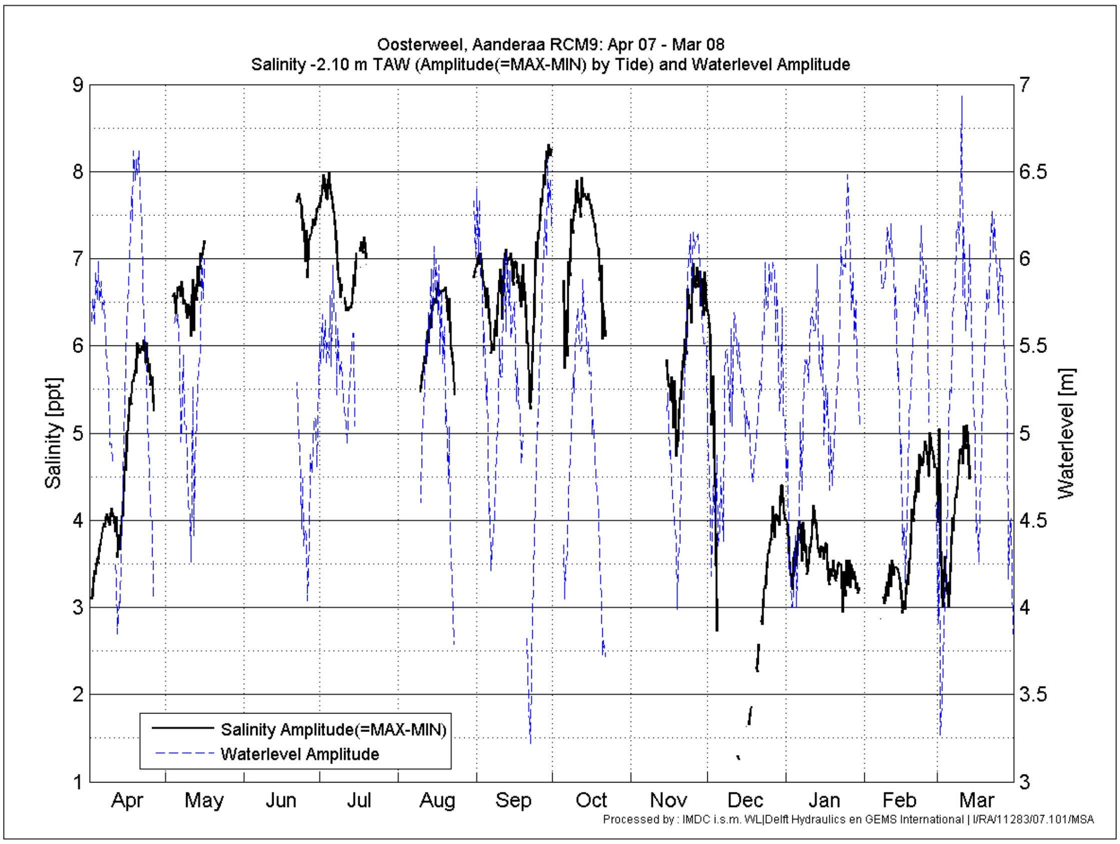
Annex-Figure D-3: Buoy 97 (-5.1m TAW), April 2007 – March 2008, (a) tidal max and min salinity and discharge at Schelle, (b) tidal salinity and water level amplitude



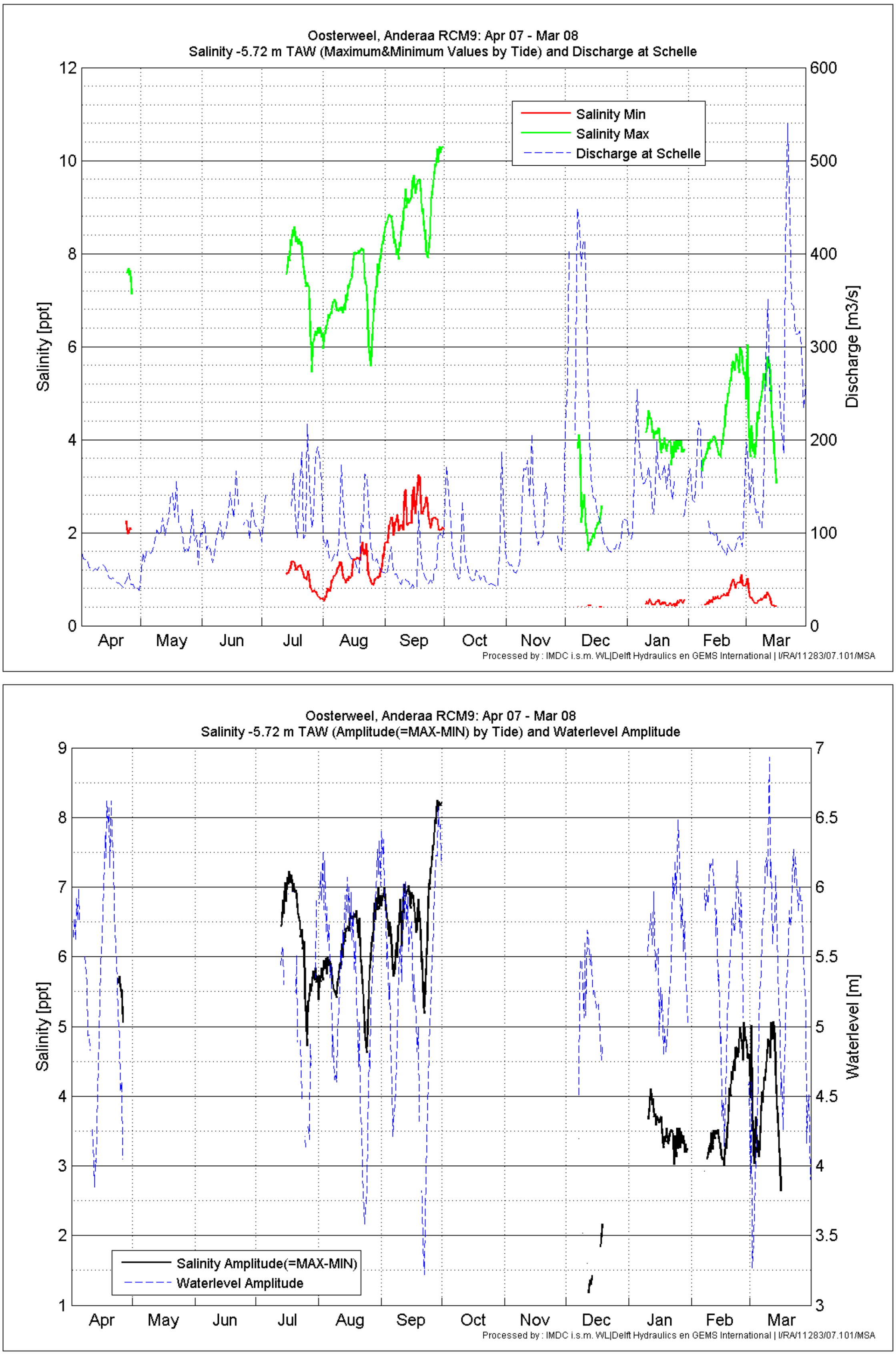


Annex-Figure D-4: Buoy 97 (-7.5m TAW), April 2007 – March 2008, (a) tidal max and min salinity and discharge at Schelle, (b) tidal salinity and water level amplitude

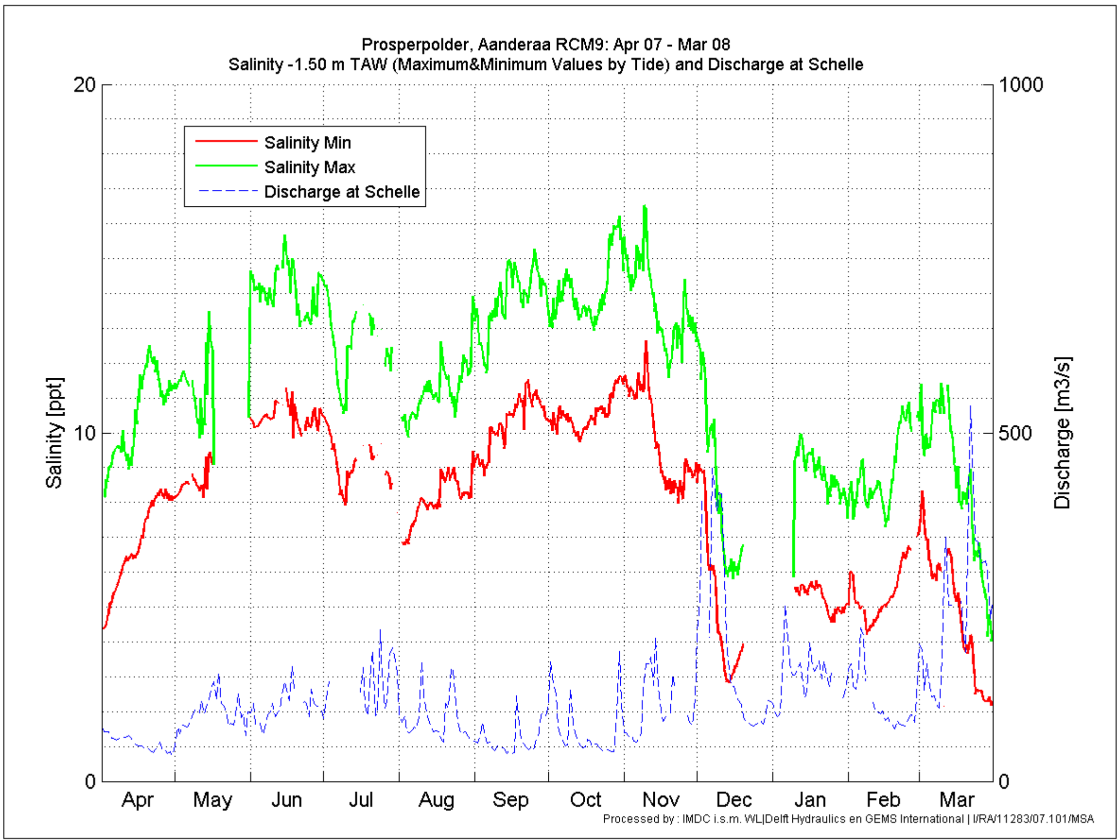


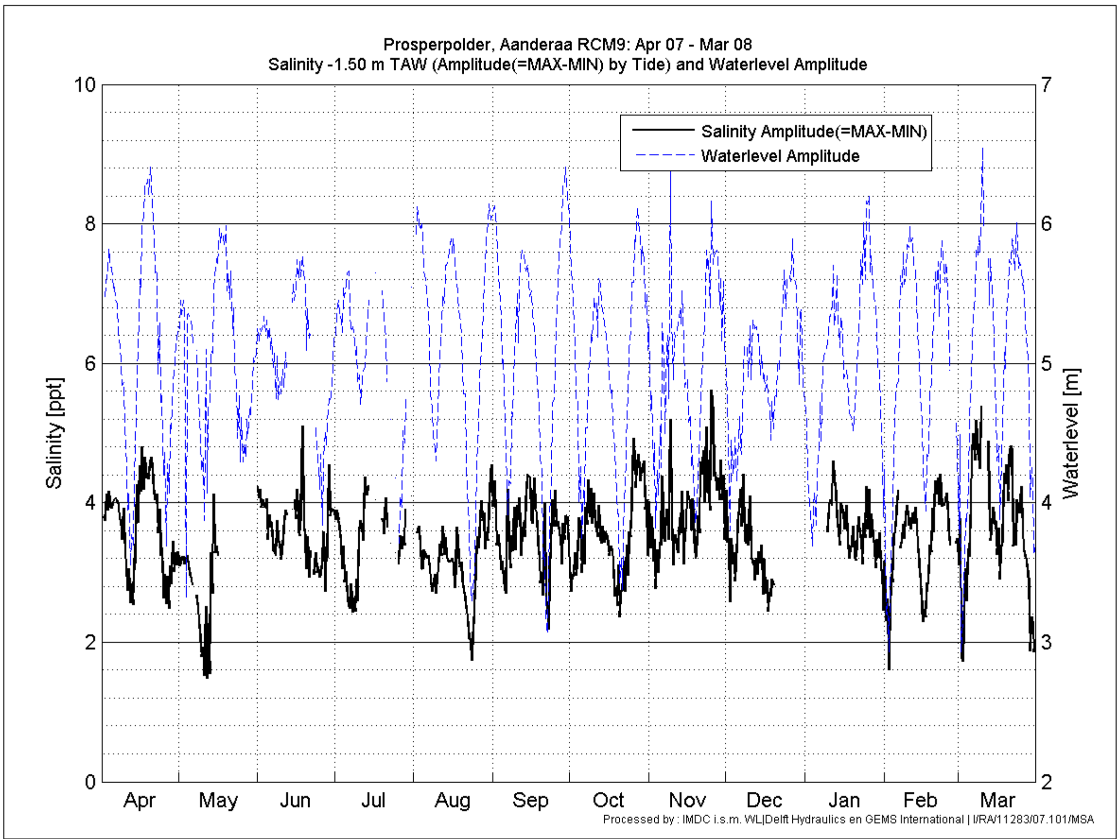


Annex-Figure D-5: Oosterweel (-2.1m TAW), April 2007 – March 2008, (a) tidal max and min salinity and discharge at Schelle, (b) tidal salinity and water level amplitude

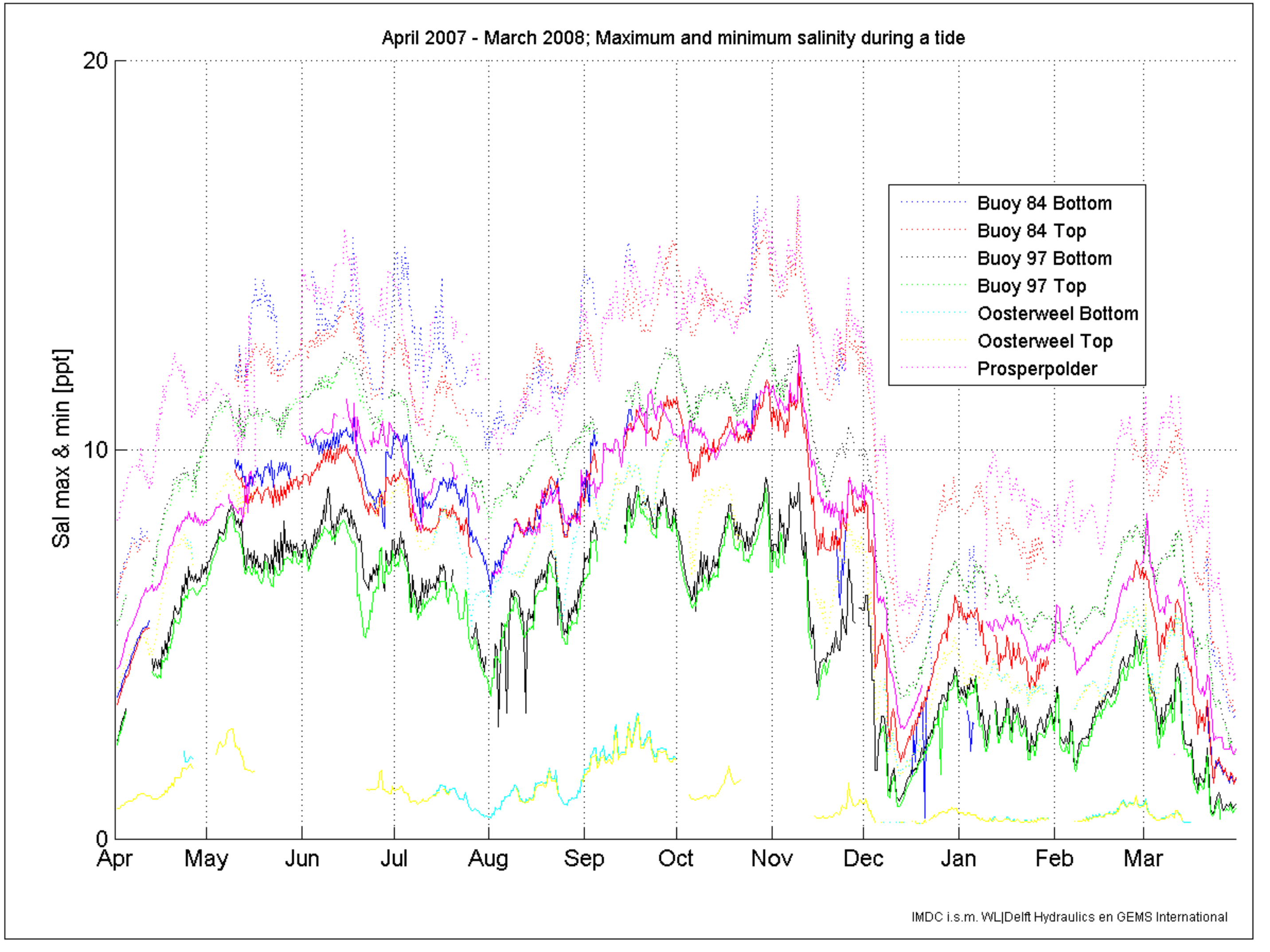


Annex-Figure D-6: Oosterweel (-5.7m TAW), April 2007 – March 2008, (a) tidal max and min salinity and discharge at Schelle, (b) tidal salinity and water level amplitude

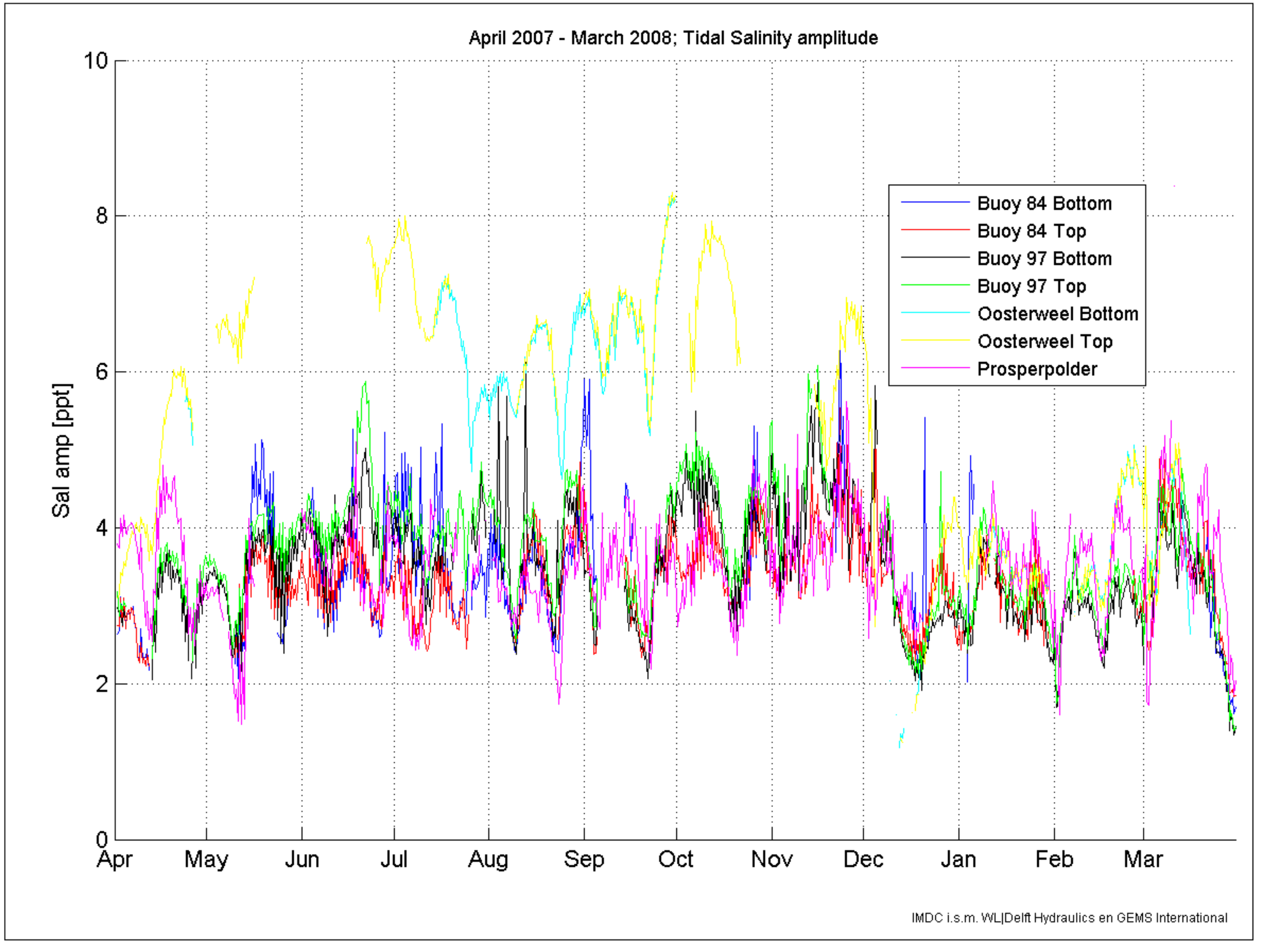




Annex-Figure D-7 Prosperpolder (-1.5m TAW), April 2007 – March 2008, (a) tidal max and min salinity and discharge at Schelle, (b) tidal salinity and water level amplitude



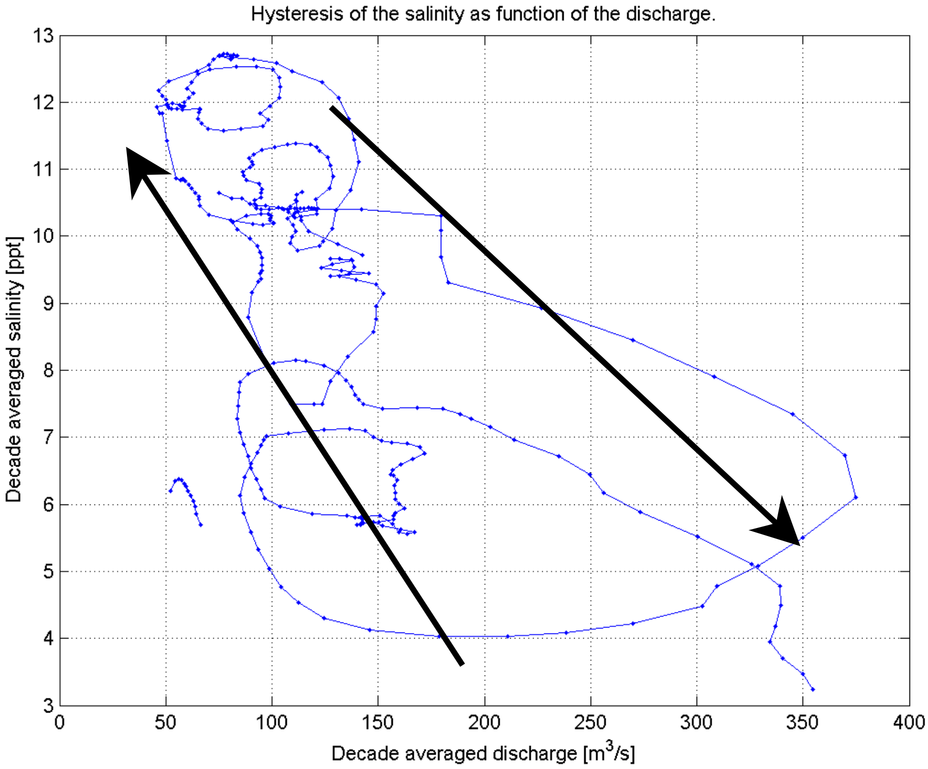
Annex-Figure D-8: Maximal (__) en minimal (…) tidal salinity for all measurement stations



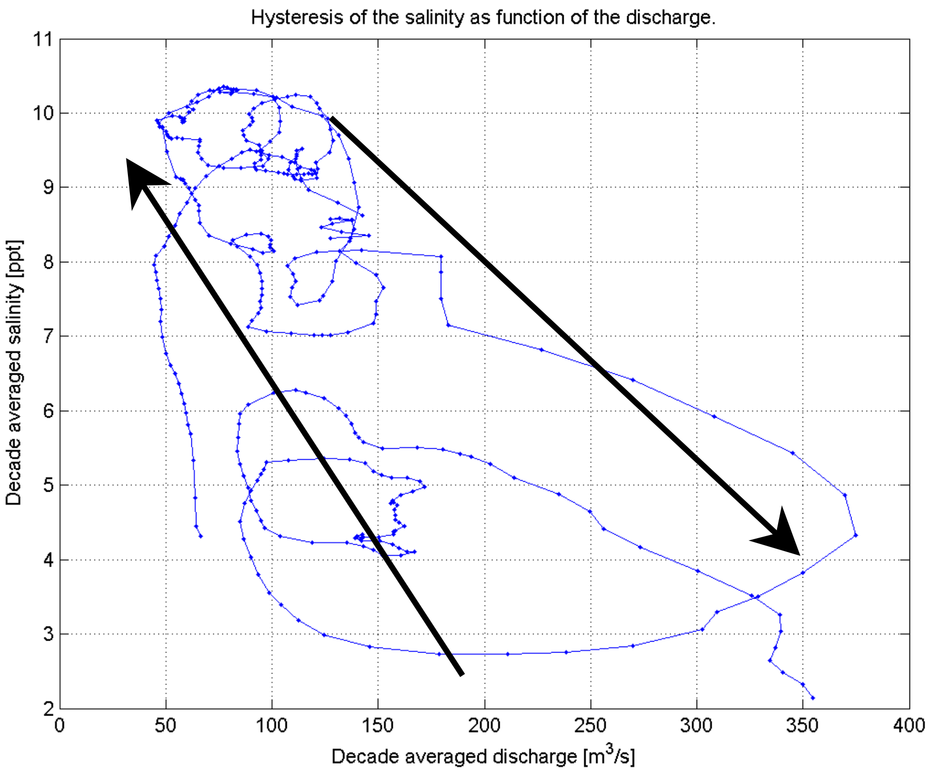
Annex-Figure D-9: Tidal amplitude of the salinity for all measurement stations

Annex-Table D-1: Averaged Tidal salinity amplitude [ppt] (ΔS), standard deviation (σ), and amount of tide in the sample (N) for every measurement station during considered period (Summer: Apr 2007-Sep 2007, Winter: Oct 2007-Mar 2008, Year: Apr 2007-Mar 2008)

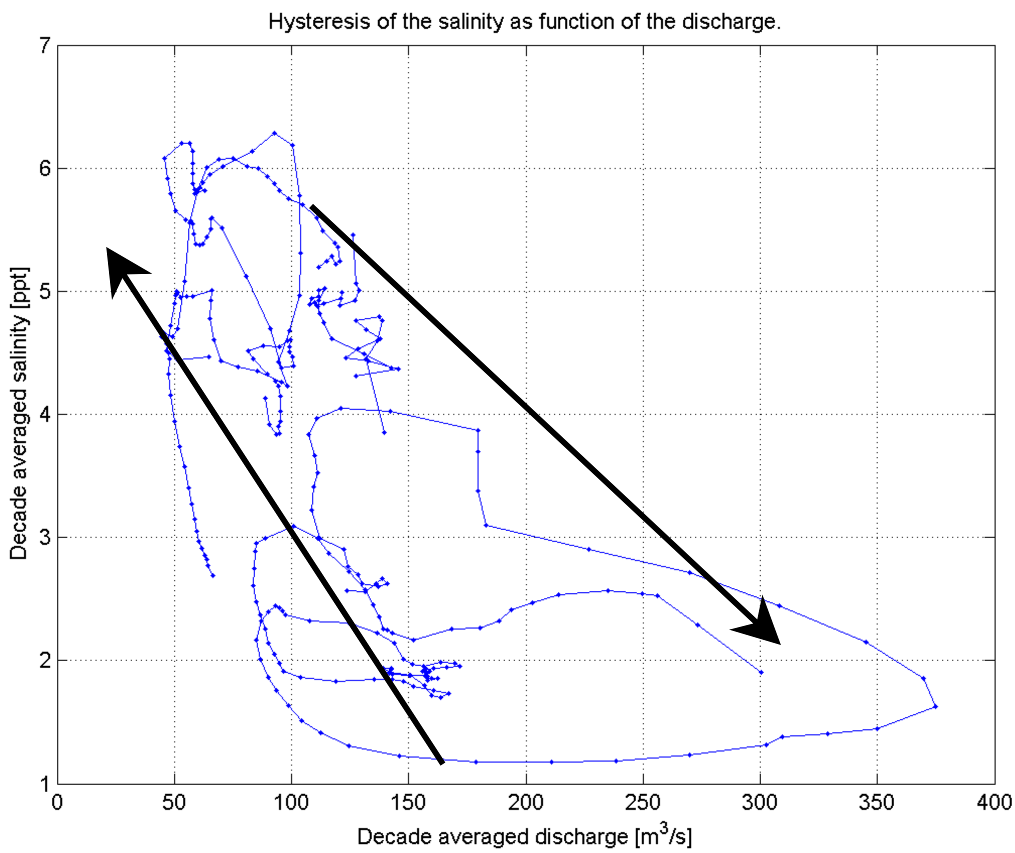
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year		
			ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N	ΔS	σ	N
Buoy 84		Neap	2.78	0.61	26	2.94	0.48	18	2.18	0.06	2	2.89	1.44	10	2.84	0.56	44	2.77	1.33	12	2.83	0.78	56
	-8.1 m	Avg	3.29	0.63	46	3.43	0.60	45	3.39	1.01	15	2.06	0.10	4	3.36	0.62	91	3.11	1.05	19	3.32	0.71	110
	TAW	Spring	3.78	0.79	34	4.00	0.73	52	4.78	0.94	9	2.94	0.55	11	3.91	0.76	86	3.77	1.19	20	3.88	0.85	106
		All	3.32	0.77	106	3.61	0.75	115	3.78	1.23	26	2.78	1.00	25	3.47	0.77	221	3.29	1.22	51	3.44	0.88	272
		Neap	2.78	0.41	25	2.93	0.53	21	3.46	0.51	46	2.81	0.52	31	2.85	0.47	46	3.20	0.60	77	3.07	0.58	123
	-5.6 m	Avg	3.19	0.36	58	3.04	0.43	46	3.36	0.59	83	3.24	0.58	43	3.12	0.40	104	3.32	0.58	126	3.23	0.52	230
	TAW	Spring	3.43	0.43	37	3.62	0.49	54	3.91	0.59	49	3.53	0.67	42	3.54	0.48	91	3.73	0.65	91	3.64	0.58	182
		All	3.18	0.45	120	3.28	0.57	121	3.54	0.61	178	3.23	0.66	116	3.23	0.51	241	3.41	0.65	294	3.33	0.60	535
Buoy 97		Neap	3.08	0.71	32	3.13	0.74	27	3.93	0.85	48	2.62	0.60	45	3.10	0.72	59	3.30	0.99	93	3.22	0.90	152
	-7.8 m	Avg	3.63	0.58	73	3.41	0.62	50	3.68	0.97	80	3.11	0.56	54	3.54	0.60	123	3.45	0.87	134	3.49	0.76	257
	TAW	Spring	3.63	0.43	51	3.81	0.59	58	3.87	0.72	47	3.25	0.48	67	3.73	0.53	109	3.50	0.67	114	3.61	0.61	223
		All	3.52	0.61	156	3.52	0.68	135	3.80	0.88	175	3.03	0.60	166	3.52	0.64	291	3.43	0.85	341	3.47	0.76	632
		Neap	3.42	0.69	32	3.38	0.70	30	4.13	0.72	35	2.82	0.65	47	3.40	0.69	62	3.38	0.94	82	3.39	0.84	144
	-5.3 m	Avg	4.00	0.70	73	3.66	0.47	56	3.82	1.13	64	3.35	0.60	50	3.85	0.63	129	3.61	0.96	114	3.74	0.81	243
	TAW	Spring	3.79	0.51	51	4.04	0.39	55	3.95	0.81	35	3.47	0.49	69	3.92	0.47	106	3.63	0.65	104	3.78	0.58	210
		All	3.81	0.67	156	3.75	0.56	141	3.94	0.96	134	3.25	0.63	166	3.78	0.62	297	3.56	0.86	300	3.67	0.76	597
Oosterweel		Neap	5.37	0.27	3	5.74	0.53	40	2.33	0.72	4	3.52	0.60	20	5.71	0.52	43	3.32	0.76	24	4.86	1.31	67
	- 5.8 m	Avg	5.67	0.07	2	6.44	0.45	47	1.46	0.33	5	3.70	0.47	42	6.41	0.47	49	3.47	0.83	47	4.97	1.62	96
	TAW	Spring	-	-	0	6.75	0.73	48	1.60	0.00	1	3.90	0.65	45	6.75	0.73	48	3.85	0.73	46	5.33	1.63	94
		All	5.49	0.25	5	6.34	0.71	135	1.82	0.64	10	3.75	0.59	107	6.31	0.72	140	3.59	0.80	117	5.07	1.56	257
		Neap	5.82	1.42	27	6.00	0.44	21	5.55	1.37	28	3.56	0.52	27	5.90	1.10	48	4.57	1.44	55	5.19	1.45	103
	- 2.3 m	Avg	6.31	1.29	31	6.73	0.54	49	5.33	2.13	45	3.60	0.37	40	6.57	0.92	80	4.51	1.79	85	5.51	1.76	165
	TAW	Spring	5.19	1.30	32	7.13	0.60	42	5.79	1.61	28	3.93	0.66	53	6.29	1.37	74	4.57	1.40	81	5.39	1.63	155
		All	5.76	1.40	90	6.74	0.68	112	5.52	1.80	101	3.74	0.57	120	6.31	1.17	202	4.55	1.56	221	5.39	1.64	423
Prosperpolder		Neap	2.79	0.51	33	2.92	0.57	34	3.26	0.45	45	2.76	0.61	38	2.86	0.54	67	3.03	0.58	83	2.95	0.57	150
	- 1.5 m	Avg	3.44	0.55	64	3.40	0.50	55	3.51	0.48	72	3.66	0.48	48	3.42	0.53	119	3.57	0.48	120	3.49	0.51	239
	TAW	Spring	4.00	0.44	42	3.54	0.46	68	4.22	0.60	37	4.02	0.74	64	3.72	0.50	110	4.10	0.70	101	3.90	0.63	211
		All	3.45	0.67	139	3.36	0.55	157	3.61	0.62	154	3.58	0.81	150	3.40	0.61	296	3.60	0.72	304	3.50	0.67	600



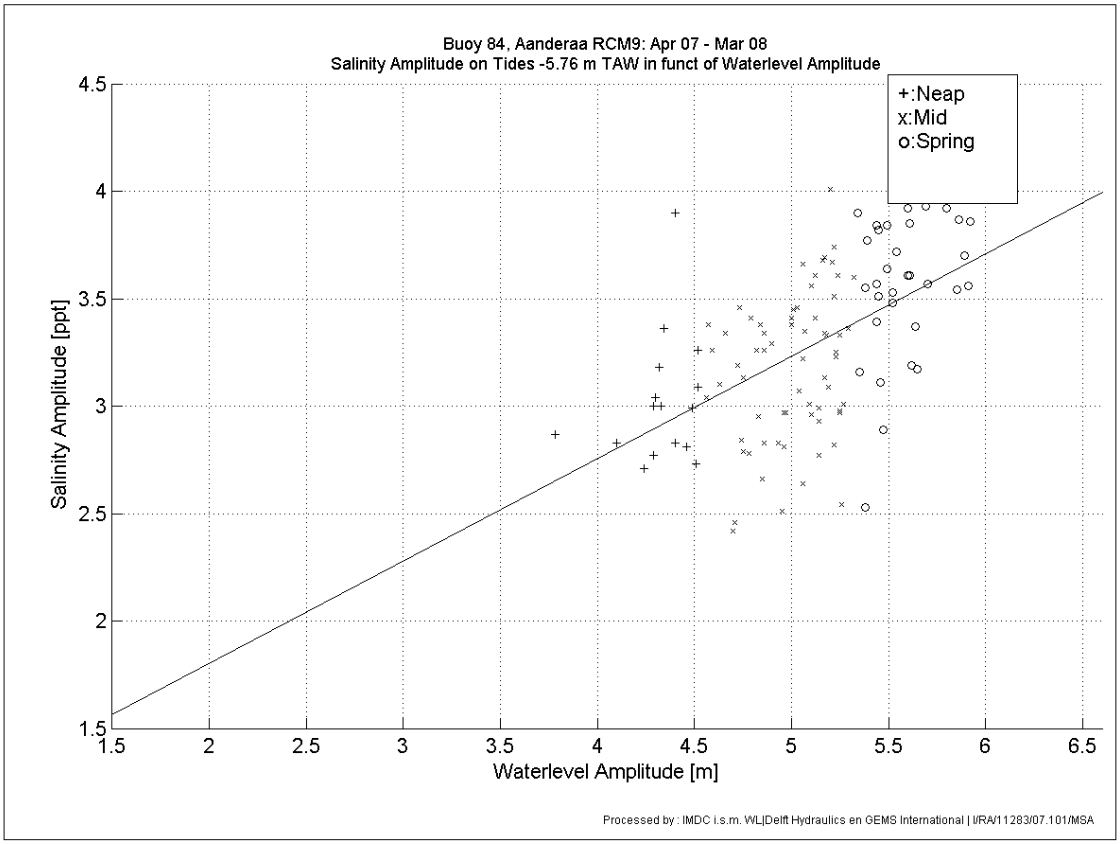
Annex-Figure D-10: Buoy 84 (-5.8m TAW), Sept'05 – March'07, Decade averaged salinity vs decade averaged discharge



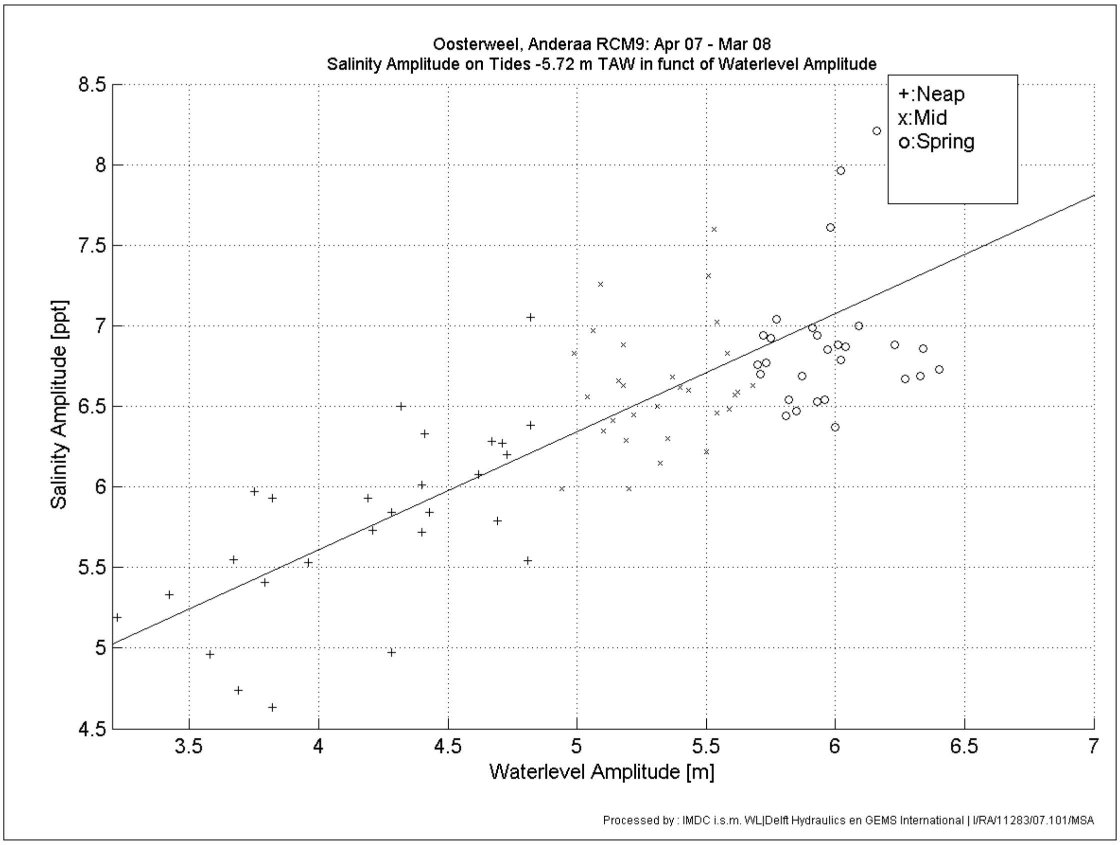
Annex-Figure D-11: Buoy 97 (-5.1m TAW), April 2007– March 2008, Decade averaged salinity vs decade averaged discharge



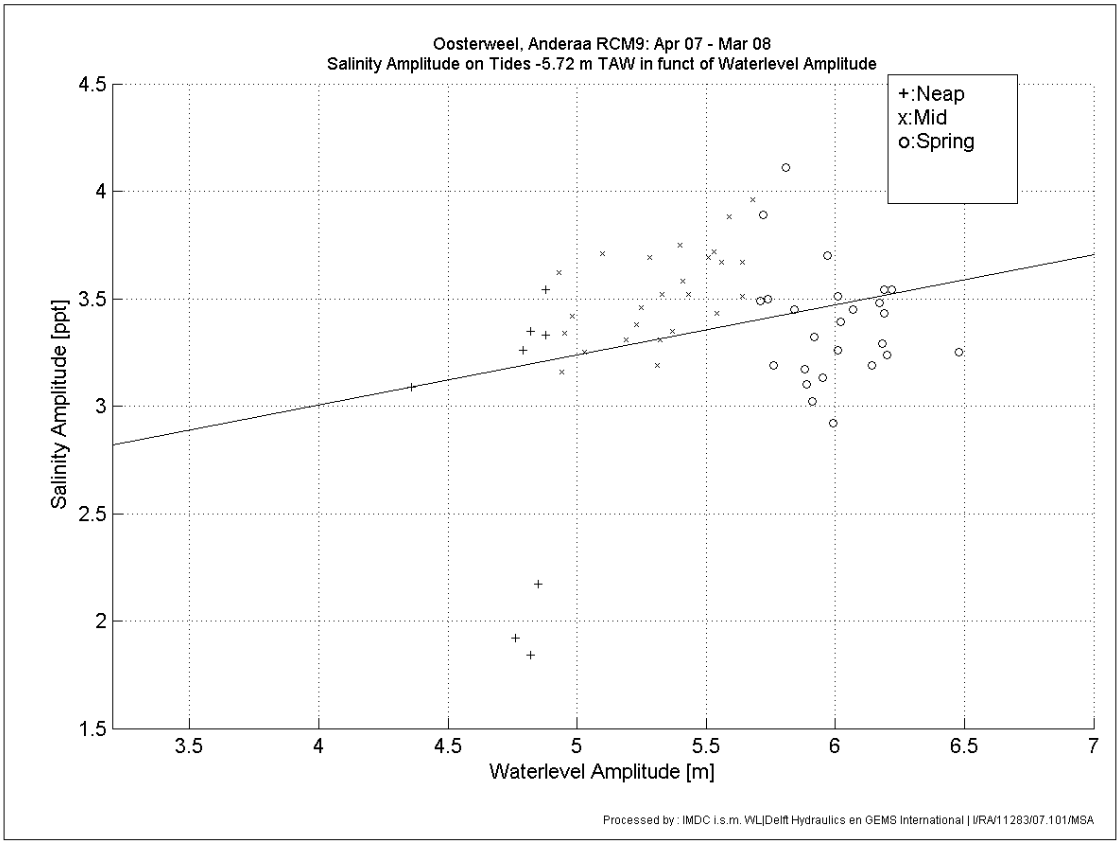
Annex-Figure D-12: Oosterweel (-5.8m TAW), April 2007– March 2008, Decade averaged salinity vs decade averaged discharge



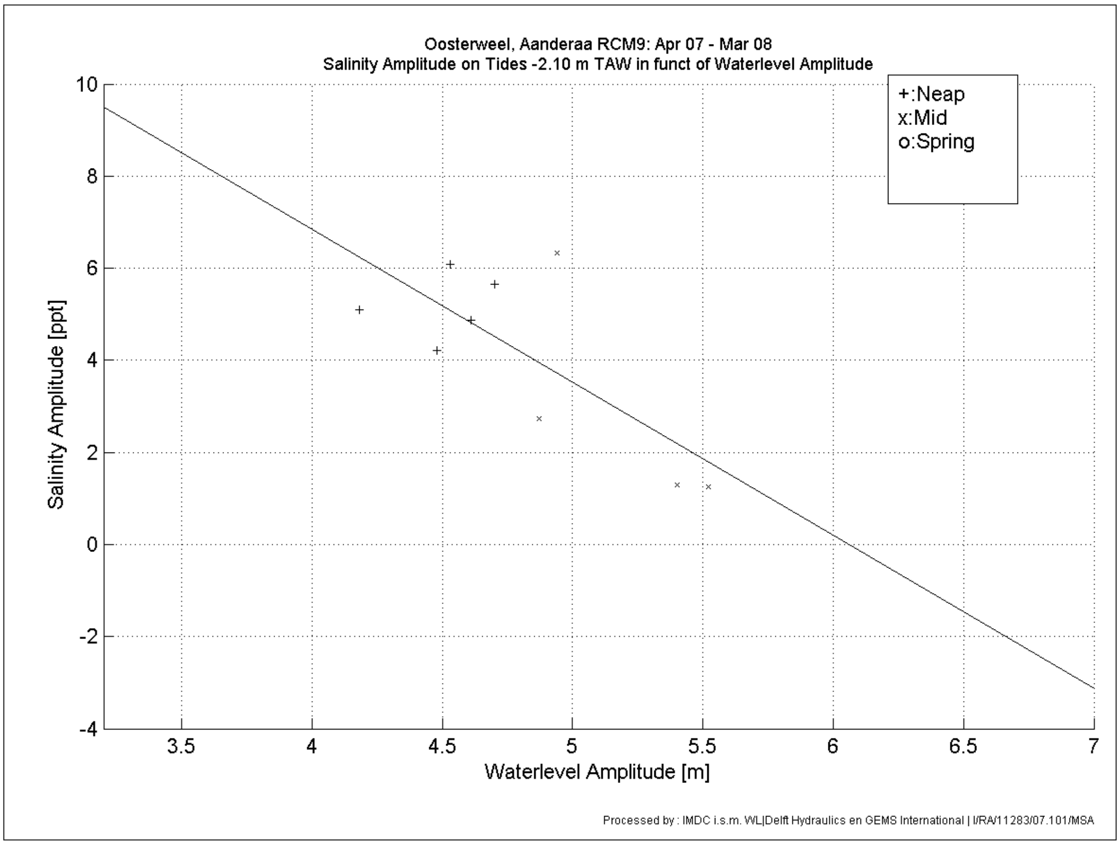
Annex-Figure D-13: Buoy 84 (-5.6m TAW), Amplitude of the salinity vs tidal amplitude. Saline regime. May 15th 2007 – July 15th 2007. (R = 0.54; sig = 0.00; n = 114;)



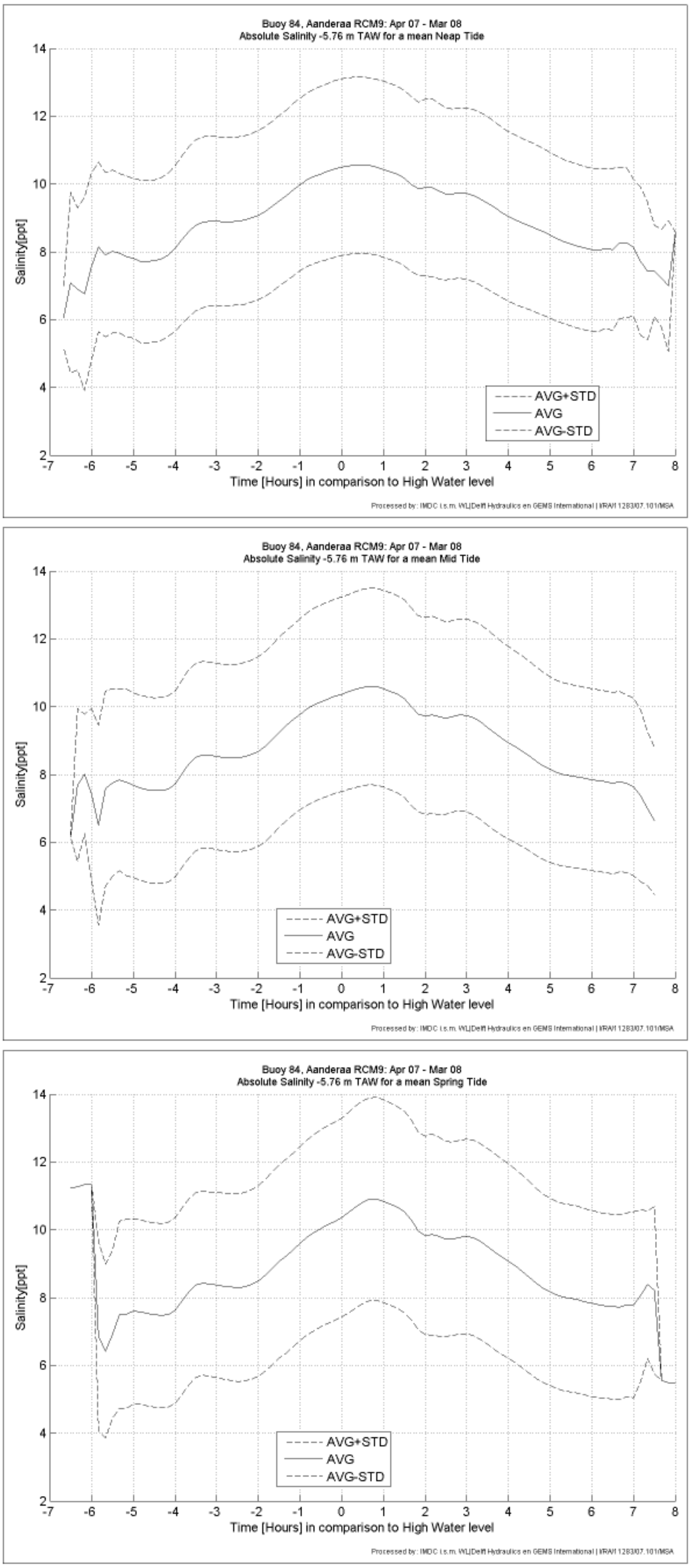
Annex-Figure D-14: Oosterweel (-5.7m TAW), Amplitude of the salinity vs tidal amplitude. Aug 15th 2007 – Oct 15th 2007. Greatly brackish regime. (R = 0.80; sig = 0.00; n = 89;)



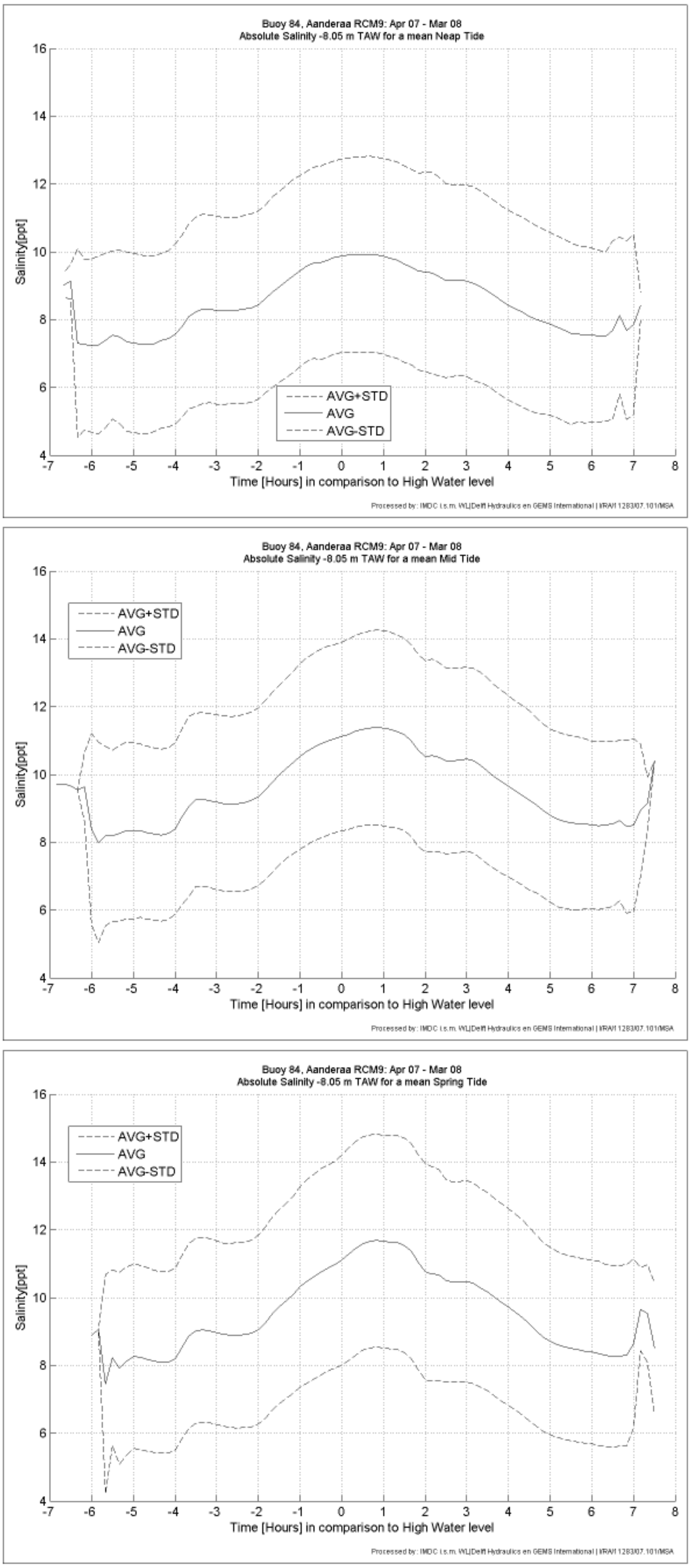
Annex-Figure D-15: : Oosterweel (-5.7m TAW), Amplitude of the salinity vs tidal amplitude. Dec 15th 2007 – Feb 15th 2008. Slightly brackish regime. (R = 0.28; sig = 0.03; n = 58;)



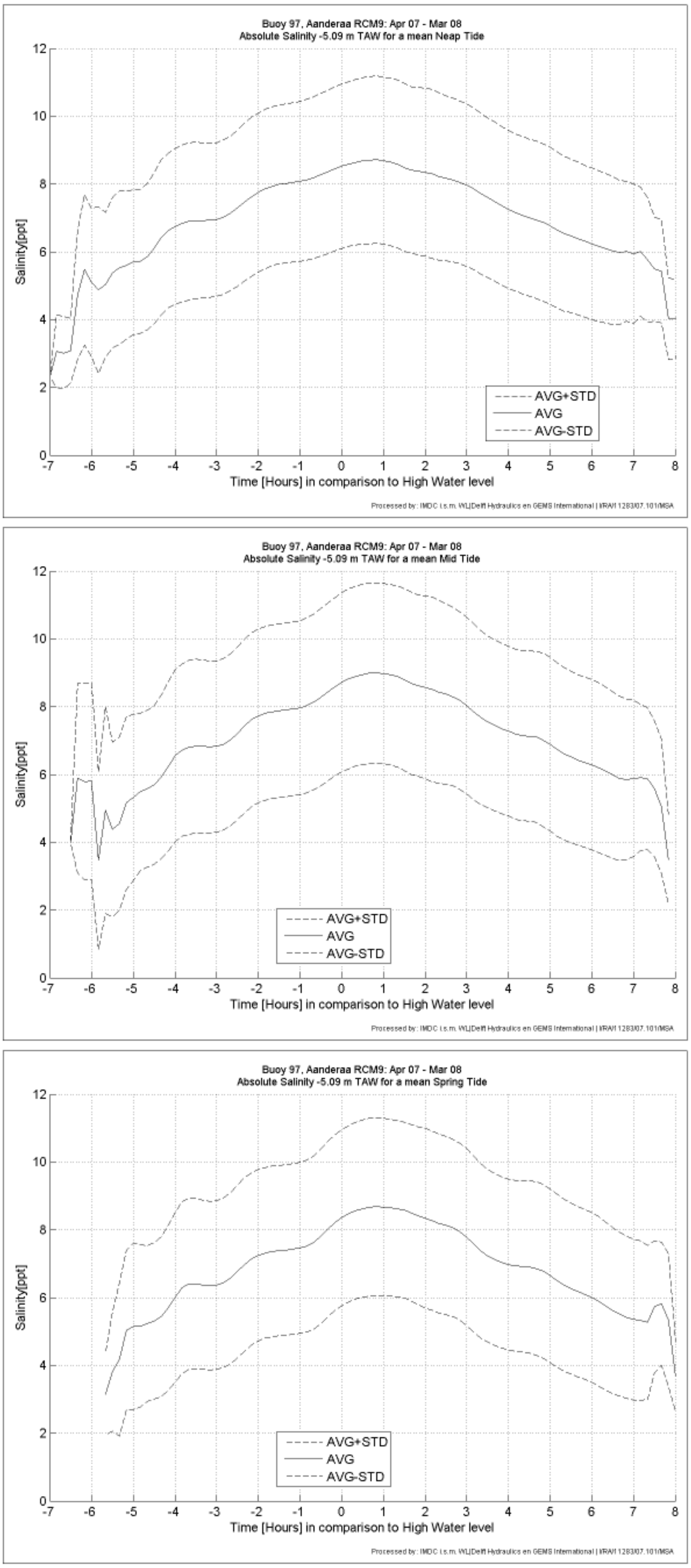
Annex-Figure D-16: Oosterweel (-2.1m TAW), Amplitude of the salinity vs tidal amplitude. Dec 1st 2007 – Dec 15th 2007. (R = -0.74; sig = 0.02; n = 9;). Fresh water regime.



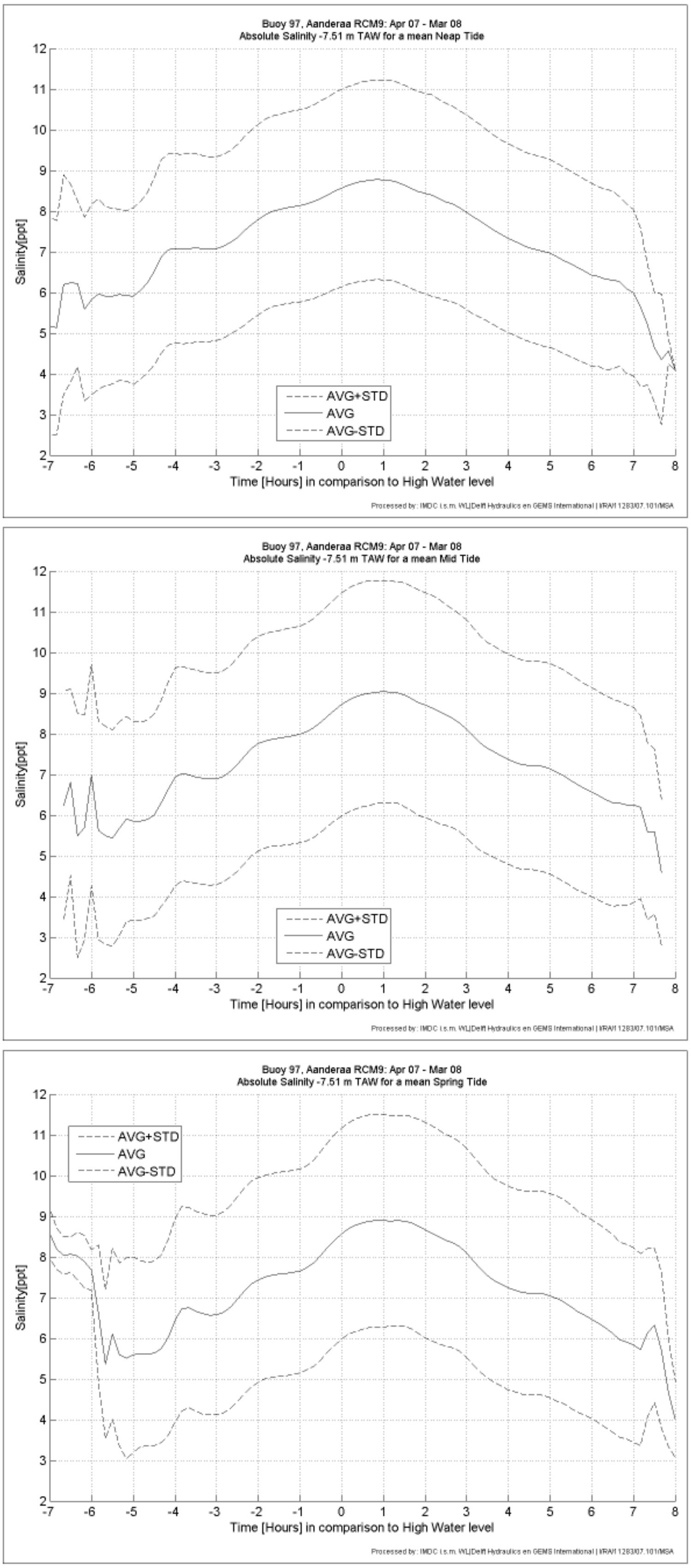
Annex-Figure D-17: Buoy 84 (-5.8m TAW), April 2007 – March 2008, Average tidal curve of the salinity for an average (a) neap tide, (b) average tide, (c) spring tide



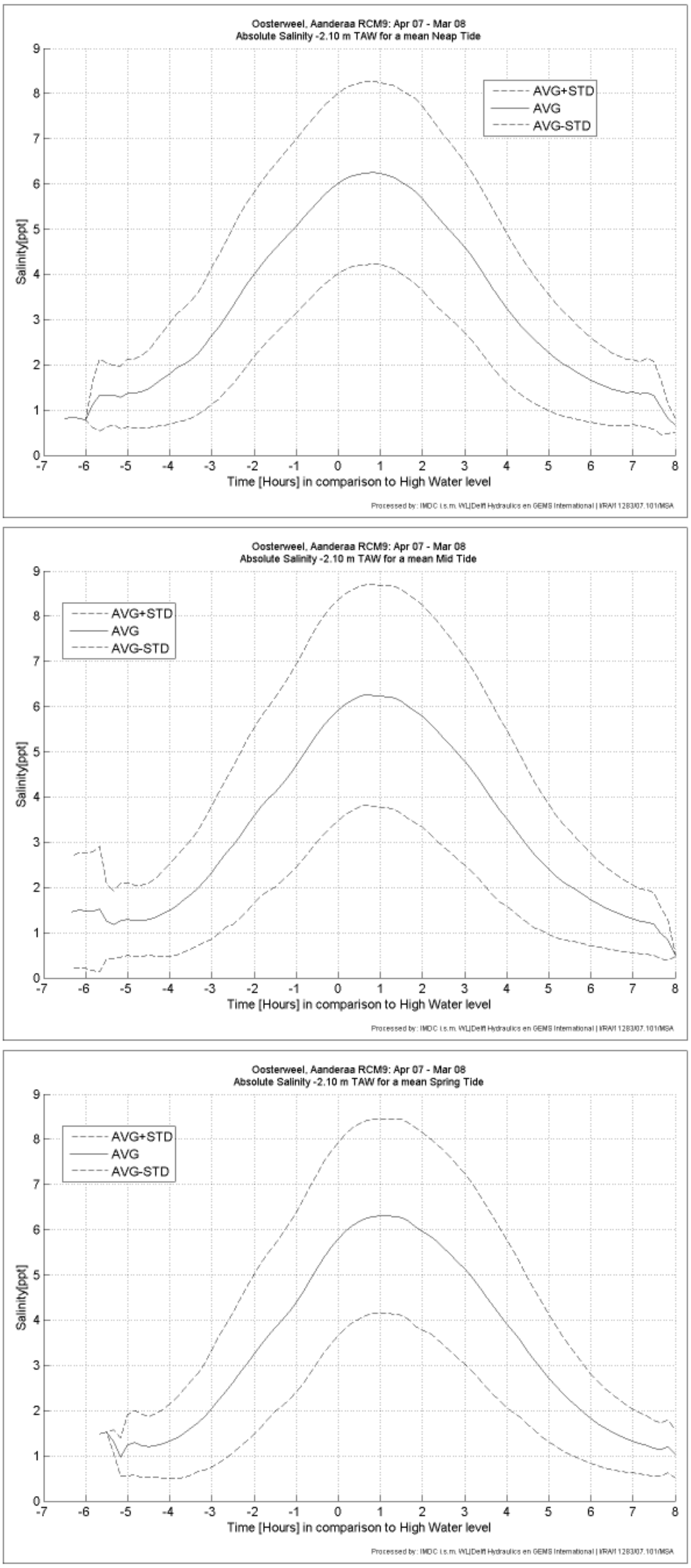
Annex-Figure D-18: Buoy 84 (-8.1m TAW), April 2007 – March 2008, Average tidal curve of the salinity for an average (a) neap tide, (b) average tide, (c) spring tide



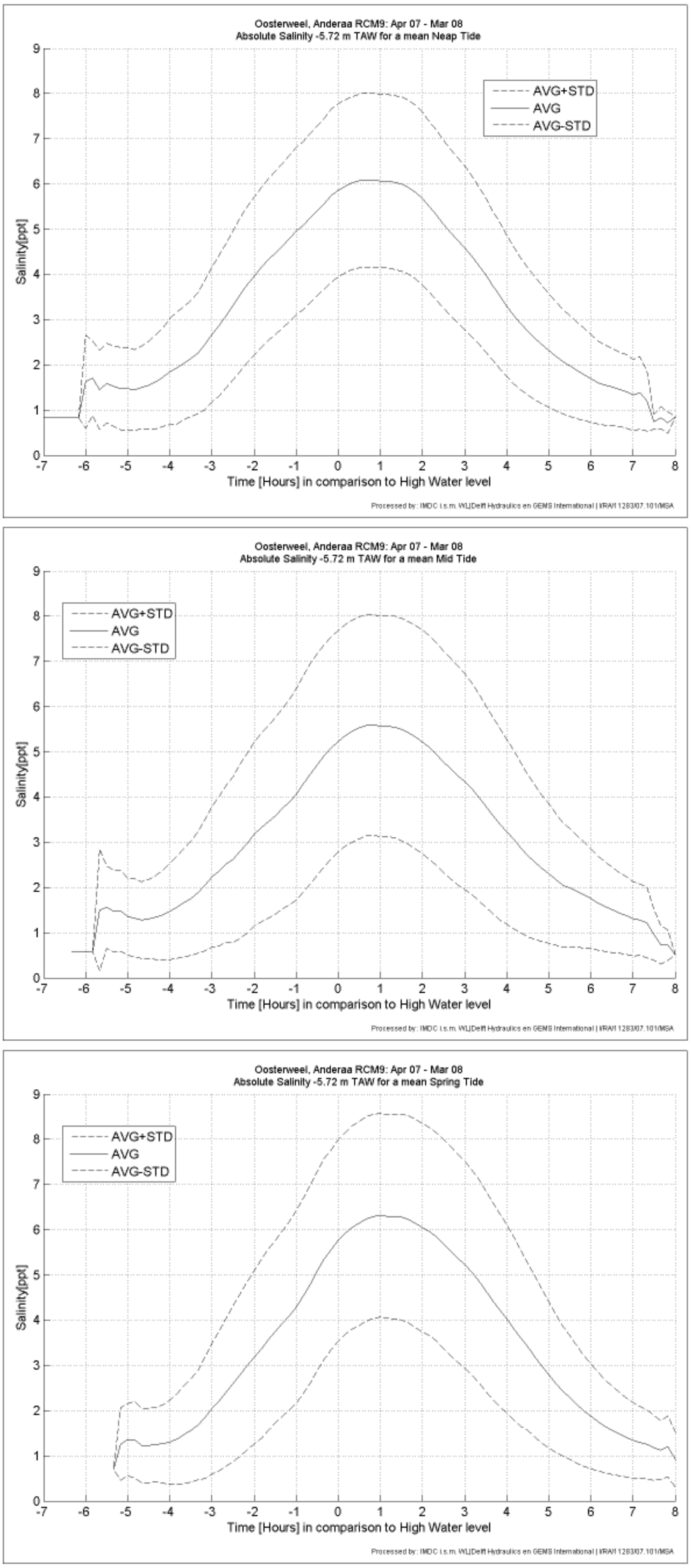
Annex-Figure D-19: Buoy 97 (-5.1m TAW), April 2007 – March 2008, Average tidal curve of the salinity for an average (a) neap tide, (b) average tide, (c) spring tide



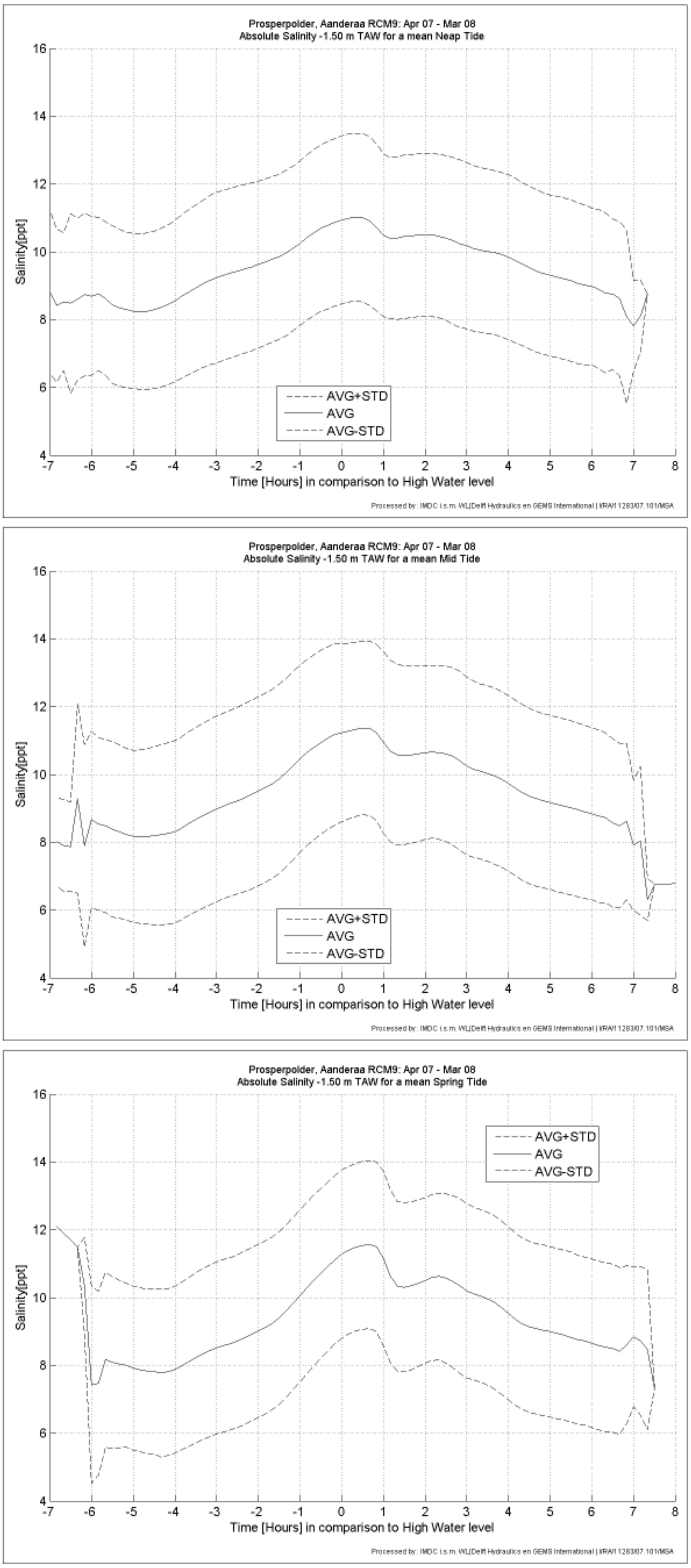
Annex-Figure D-20: Buoy 97 (-7.5m TAW), April 2007 – March 2008, Average tidal curve of the salinity for an average (a) neap tide, (b) average tide, (c) spring tide



Annex-Figure D-21: Oosterweel (-2.1m TAW), April 2007 – March 2008, Average tidal curve of the salinity for an average (a) neap tide, (b) average tide, (c) spring tide

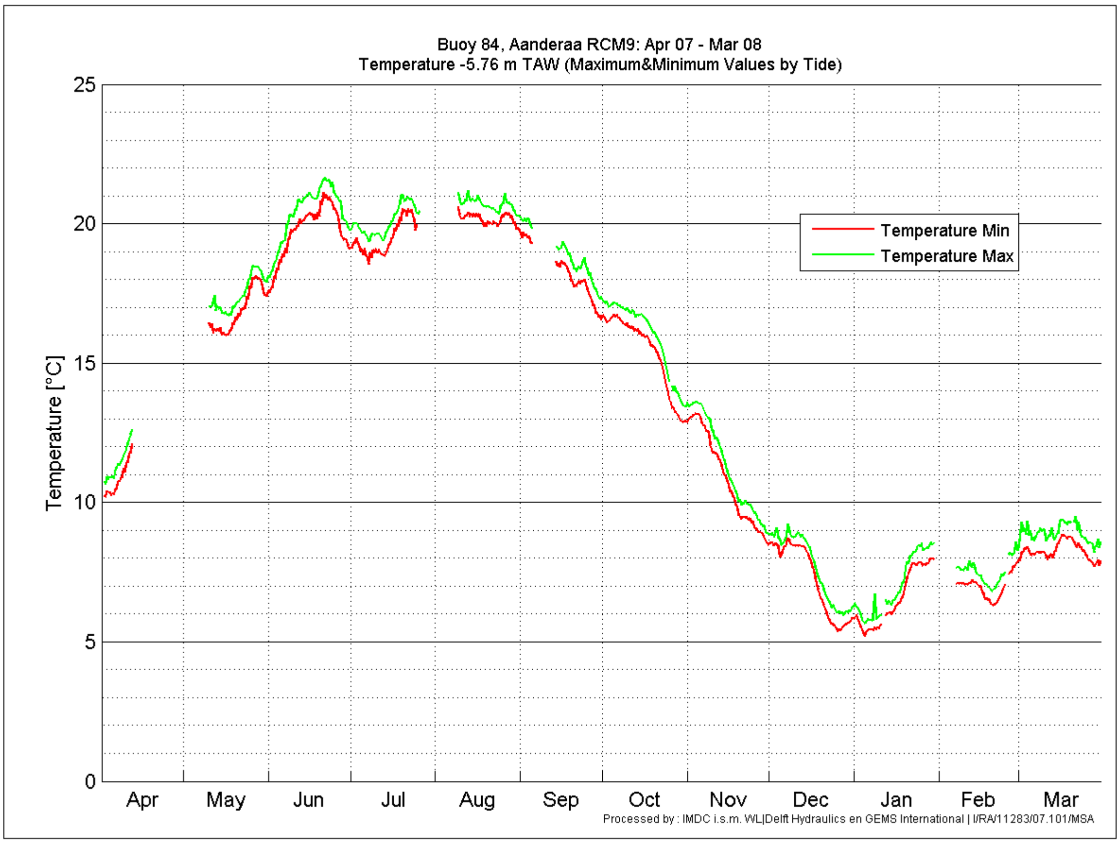


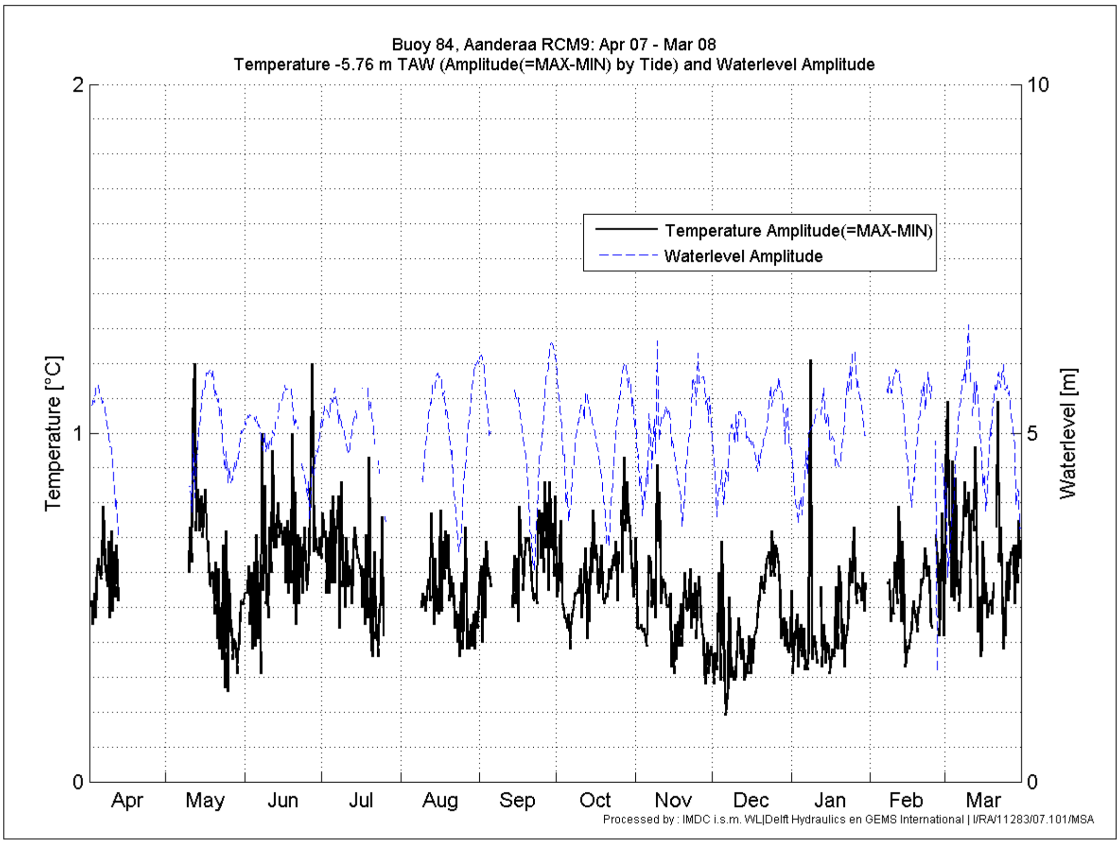
Annex-Figure D-22: Oosterweel (-5.7m TAW), April 2007 – March 2008, Average tidal curve of the salinity for an average (a) neap tide, (b) average tide, (c) spring tide



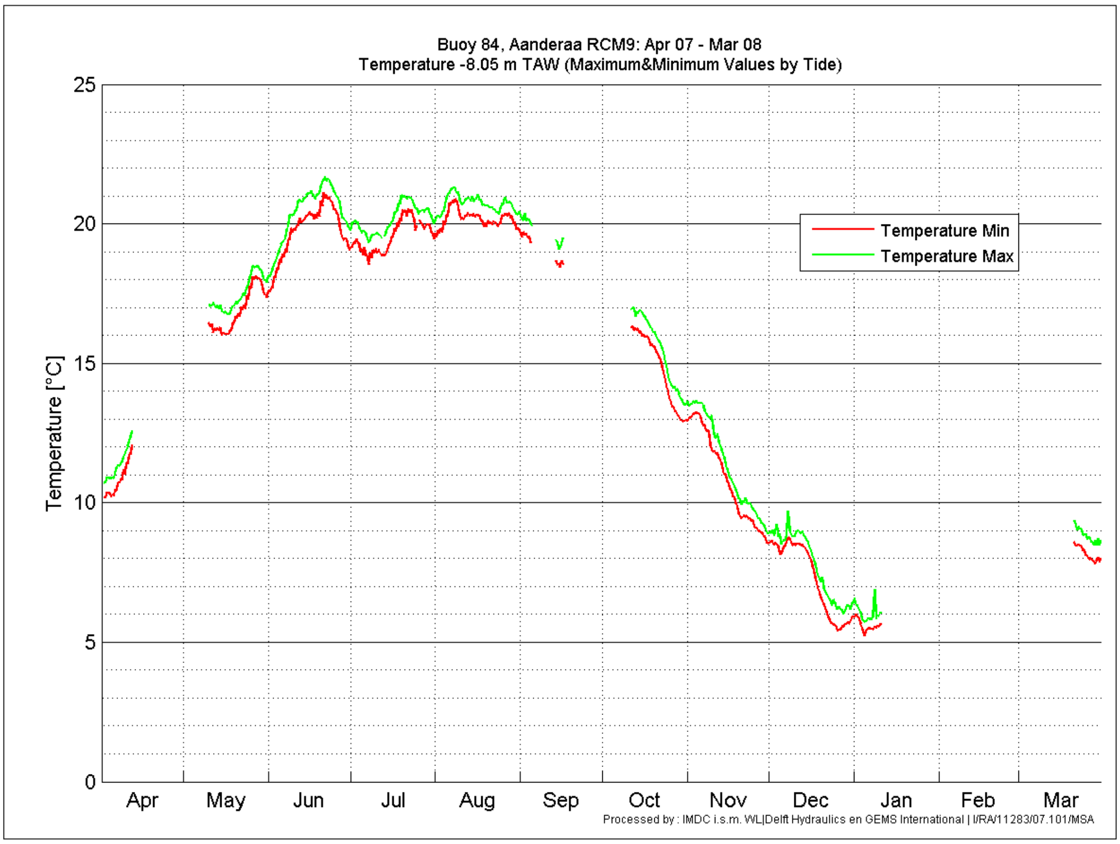
Annex-Figure D-23 Prosperpolder (-1.5m TAW), April 2007 – March 2008, Average tidal curve of the salinity for an average (a) neap tide, (b) average tide, (c) spring tide

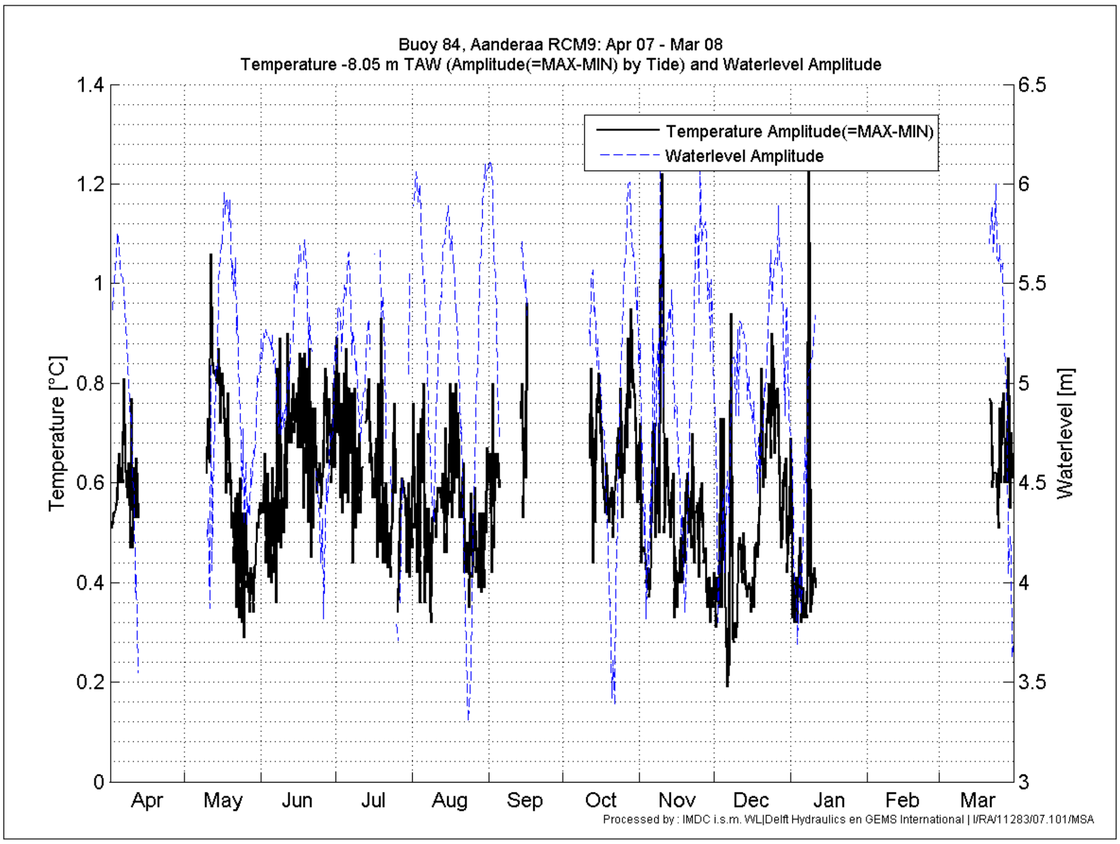
ANNEX E.: FIGURES TEMPERATUUR



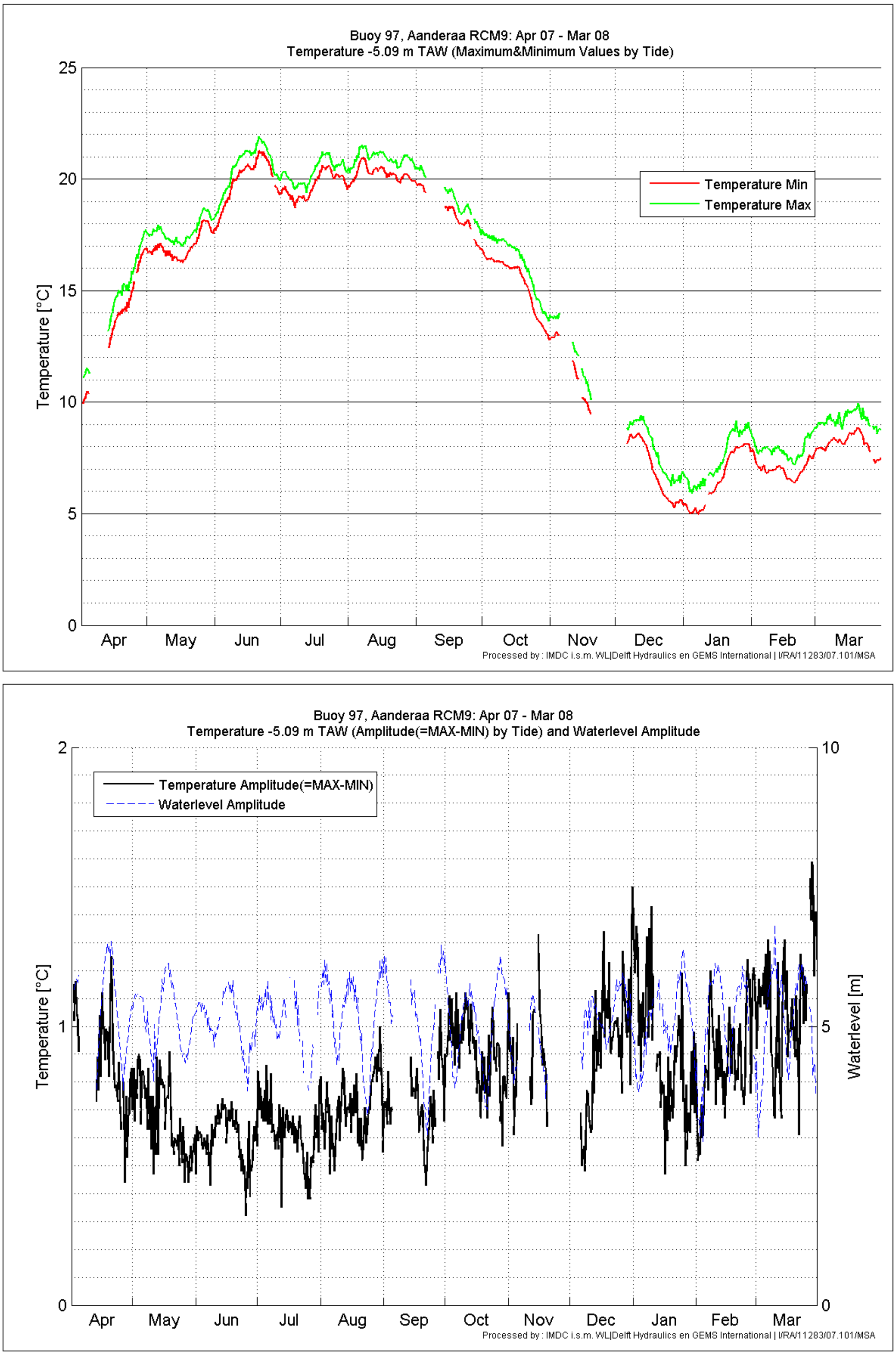


Annex-Figure E-1: Buoy 84 (-5.8m TAW), April 2007 – March 2008, (a) tidal maximum and minimum temperature, (b) tidal temperature and water level amplitude

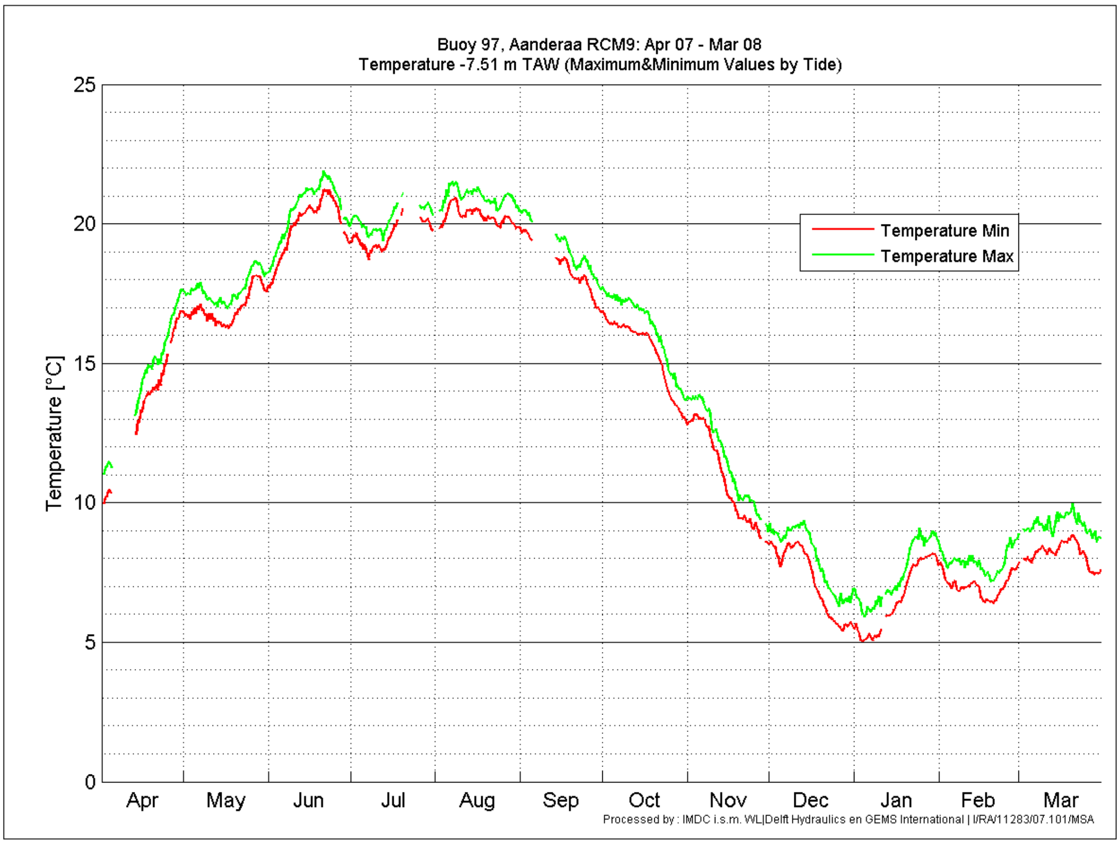


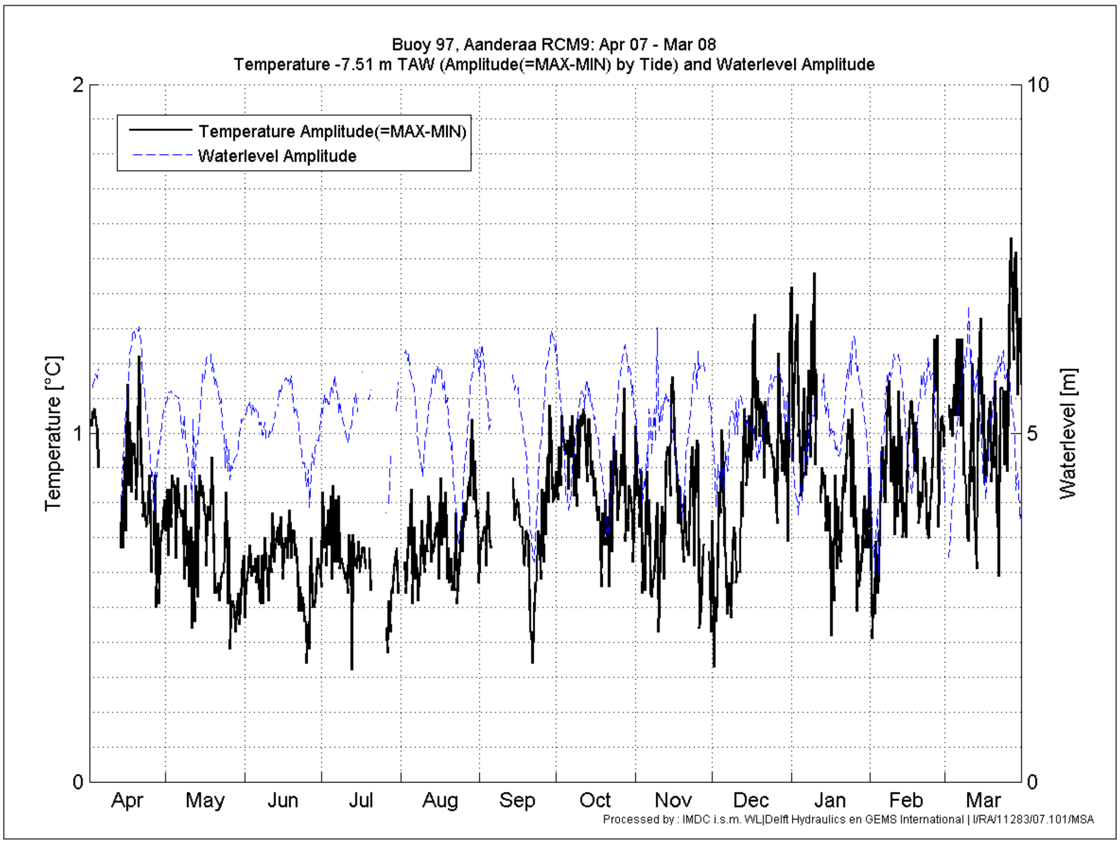


Annex-Figure E-2: Buoy 84 (-8.1m TAW), April 2007 – March 2008, (a) tidal maximum and minimum temperature, (b) tidal temperature and water level amplitude

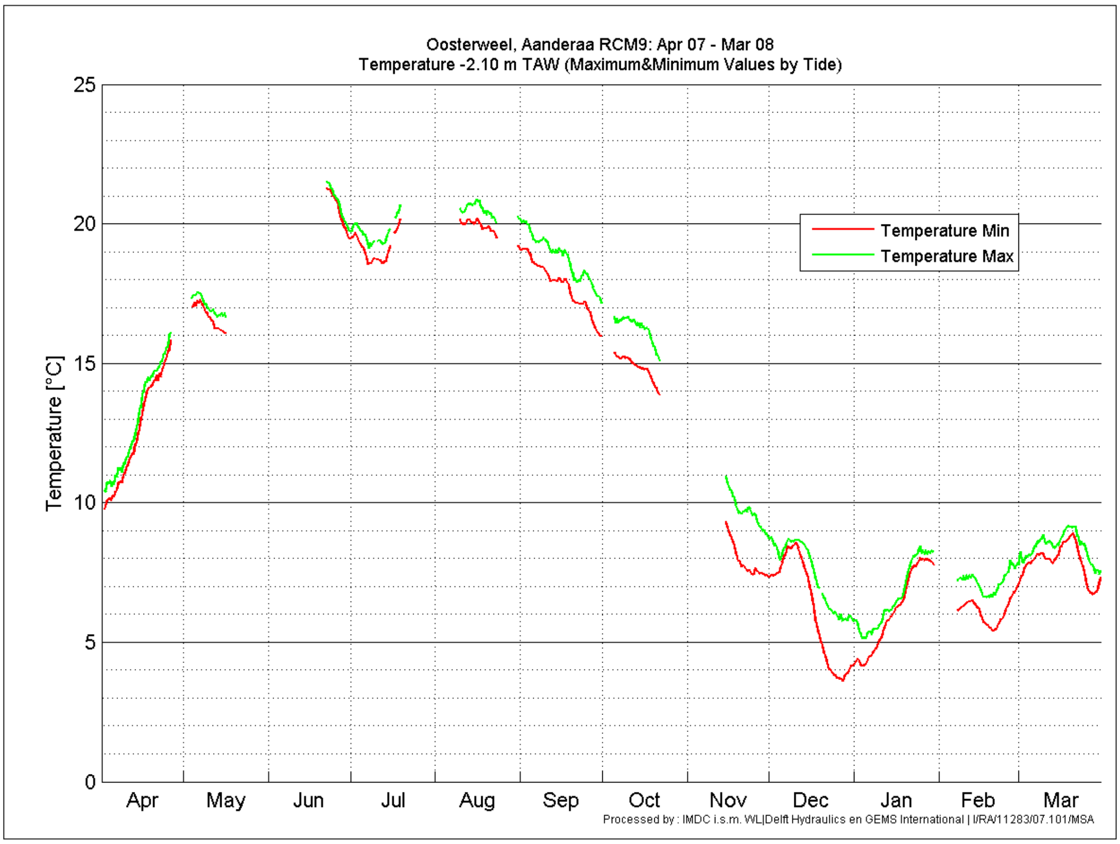


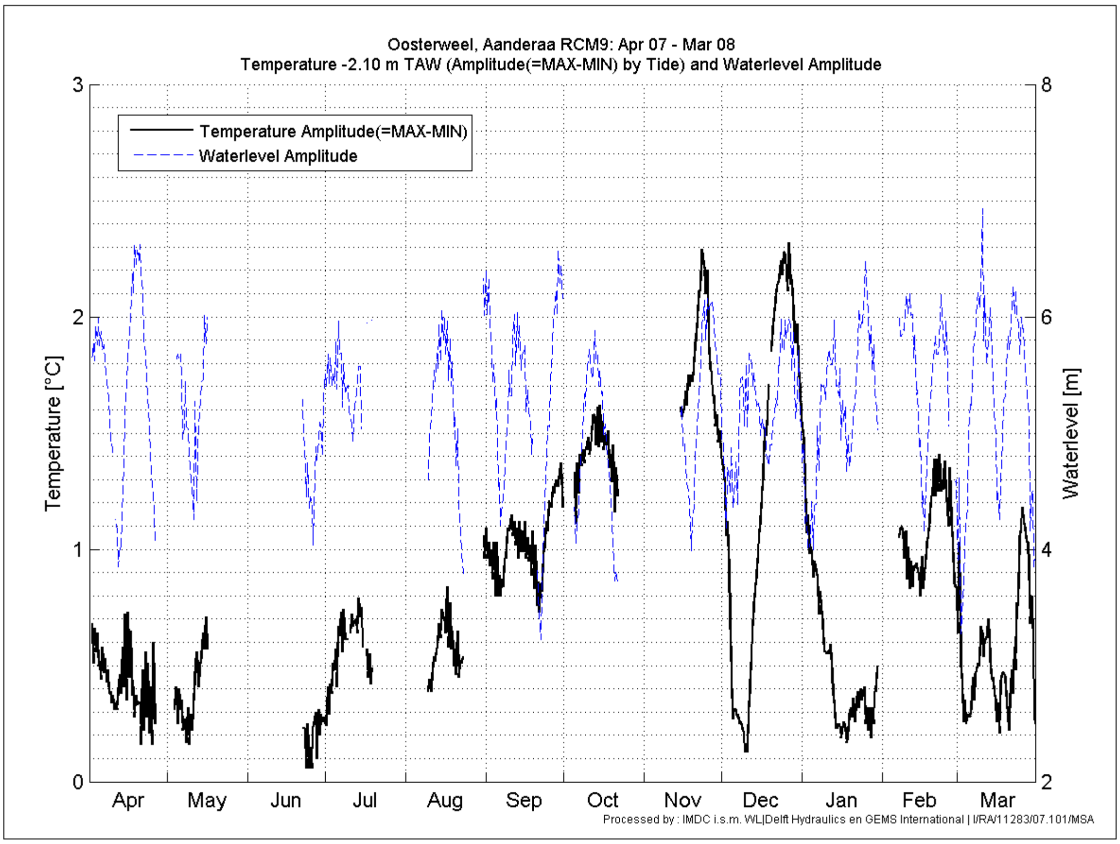
Annex-Figure E-3: Buoy 97 (-5.1m TAW), April 2007 – March 2008, (a) tidal maximum and minimum temperature, (b) tidal temperature and water level amplitude



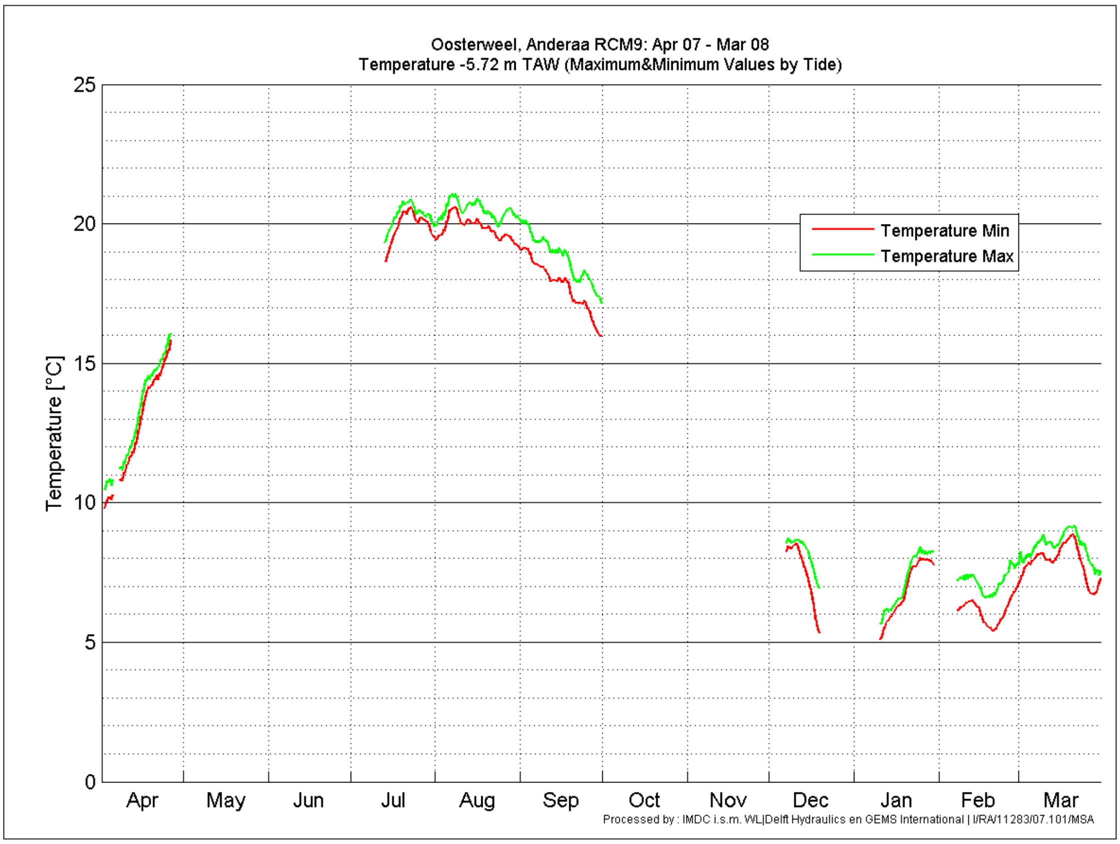


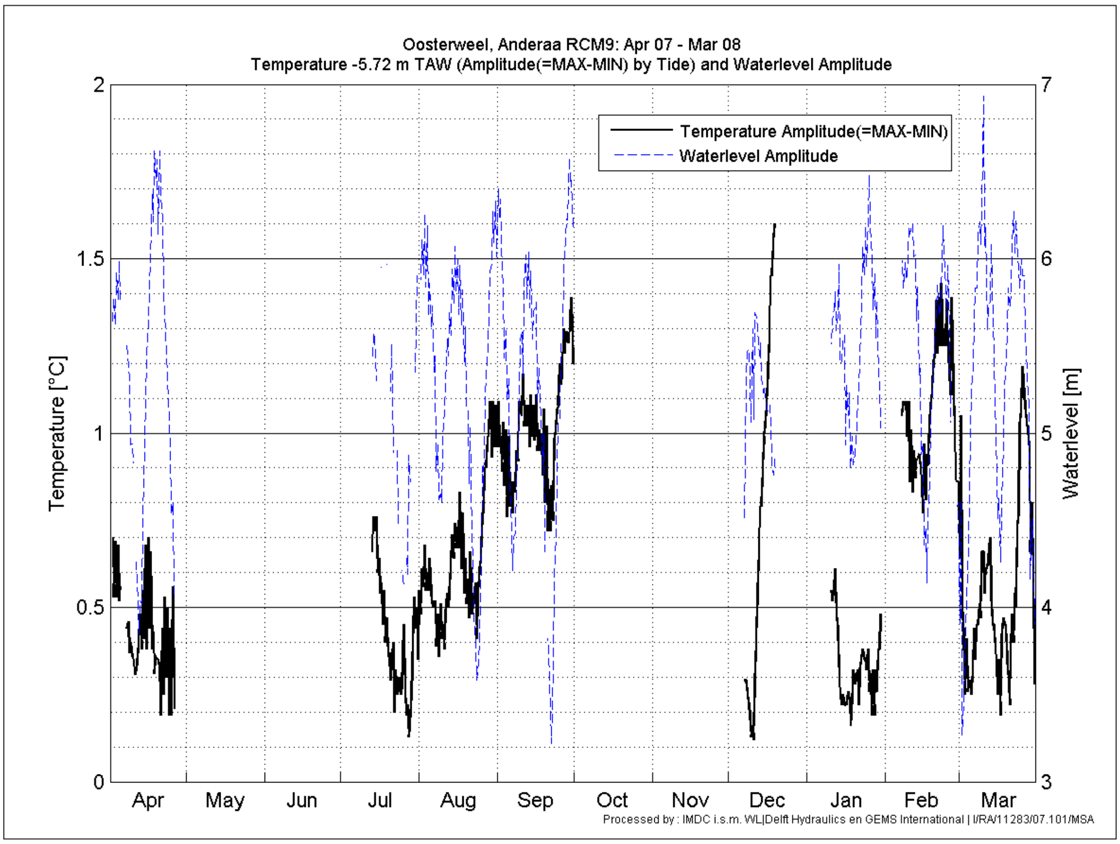
Annex-Figure E-4: Buoy 97 (-7.5m TAW), April 2007 – March 2008, (a) tidal maximum and minimum temperature, (b) tidal temperature and water level amplitude



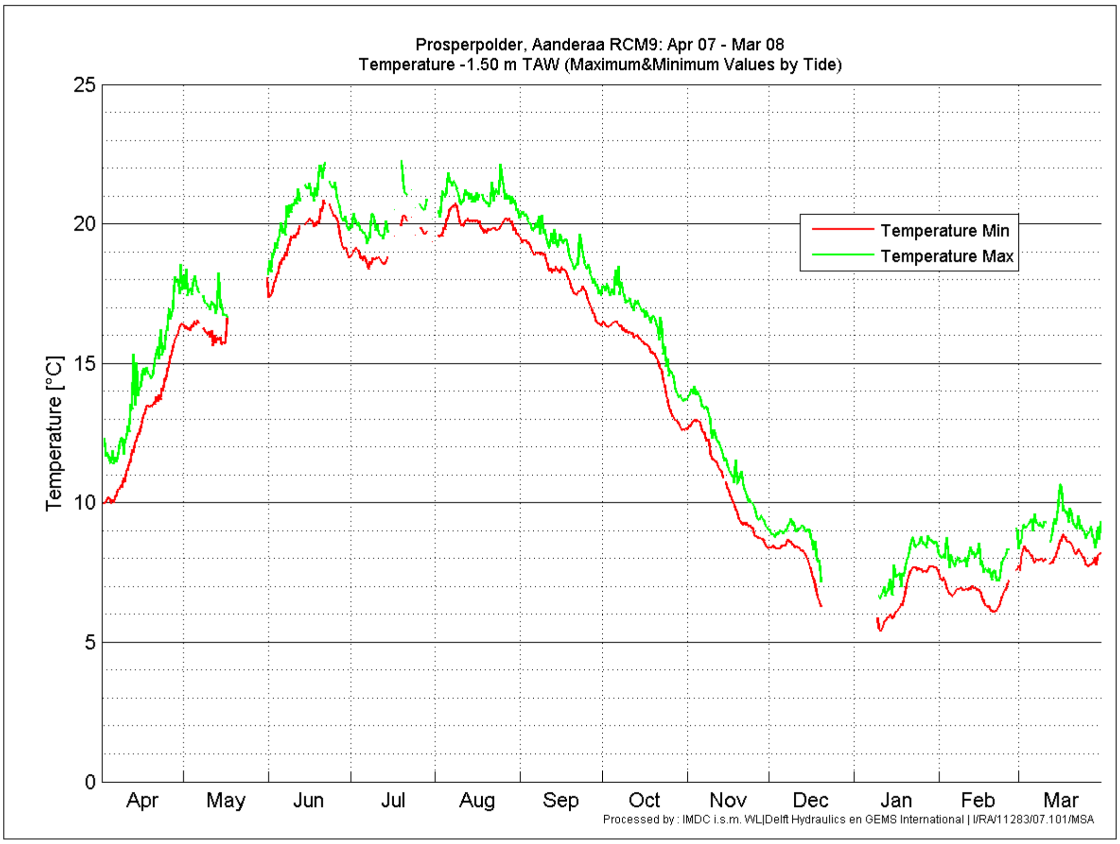


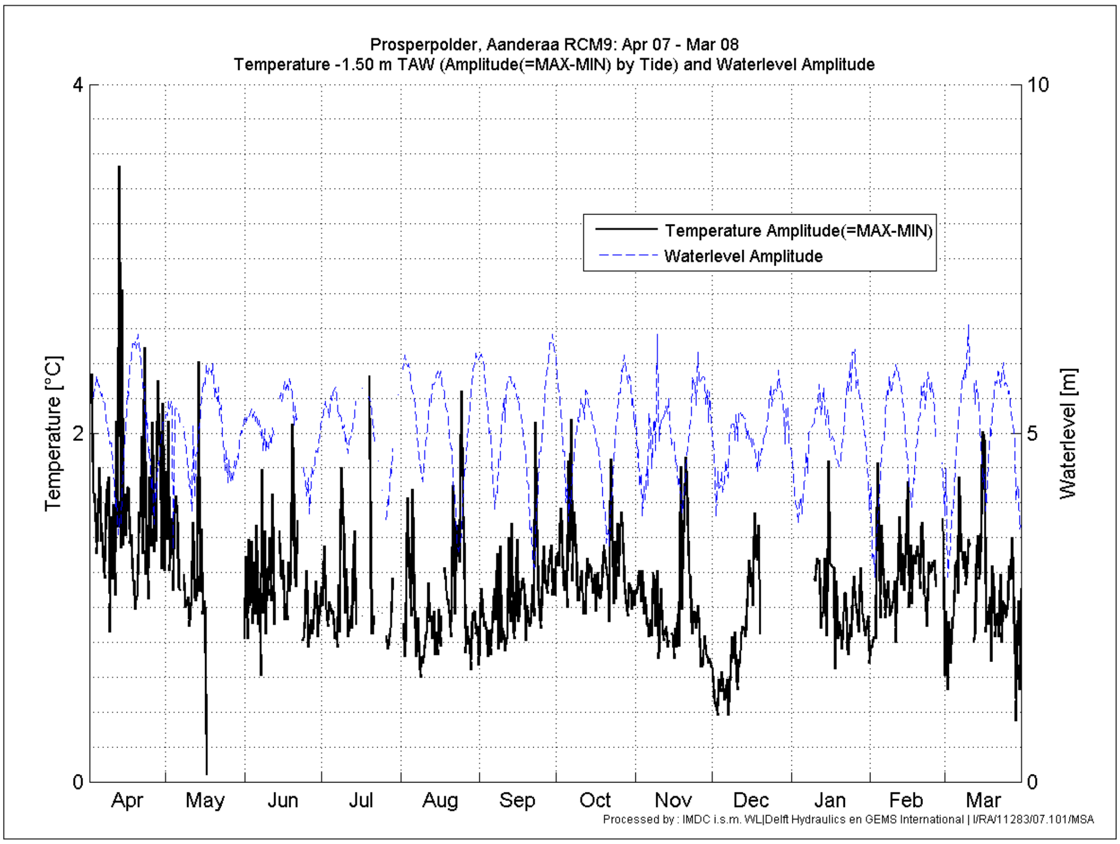
Annex-Figure E-5: Oosterweel (-2.1m TAW), April 2007 – March 2008, (a) tidal maximum and minimum temperature, (b) tidal temperature and water level amplitude



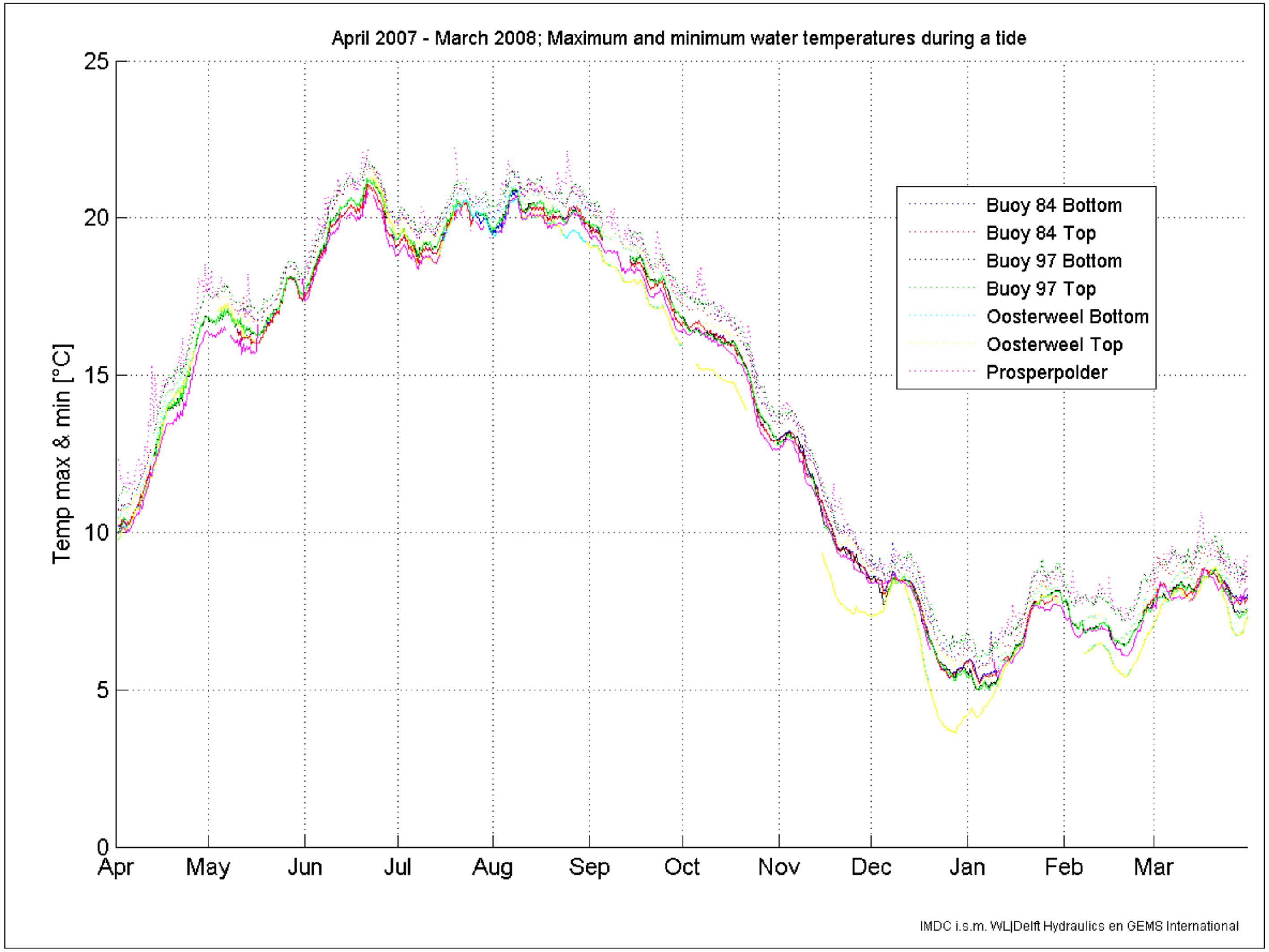


Annex-Figure E-6: Oosterweel (-5.7m TAW), April 2007 – March 2008, (a) tidal maximum and minimum temperature, (b) tidal temperature and water level amplitude

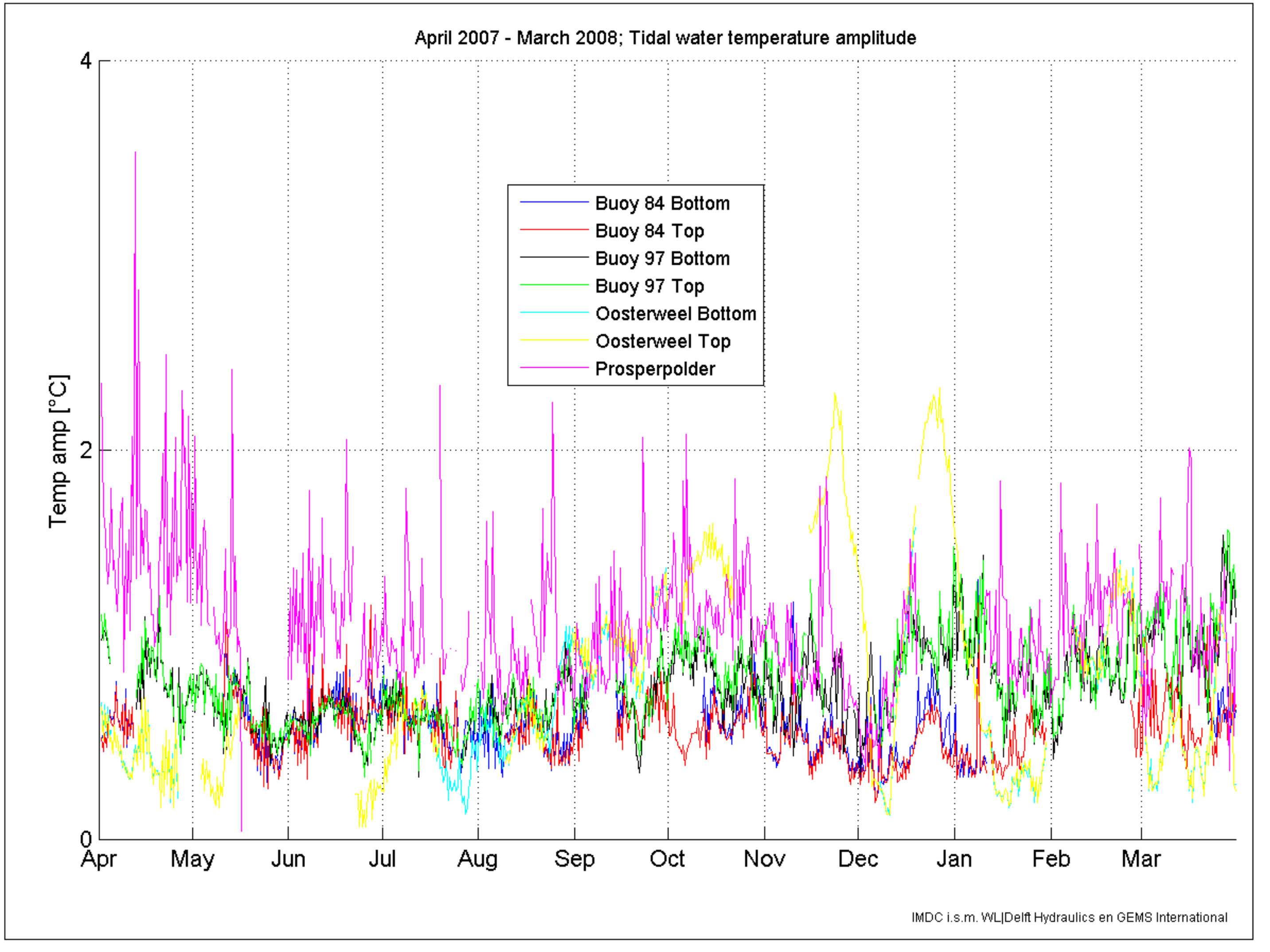




Annex-Figure E-7 Prosperpolder (-1.5m TAW), April 2007 – March 2008, (a) tidal maximum and minimum temperature, (b) tidal temperature and water level amplitude



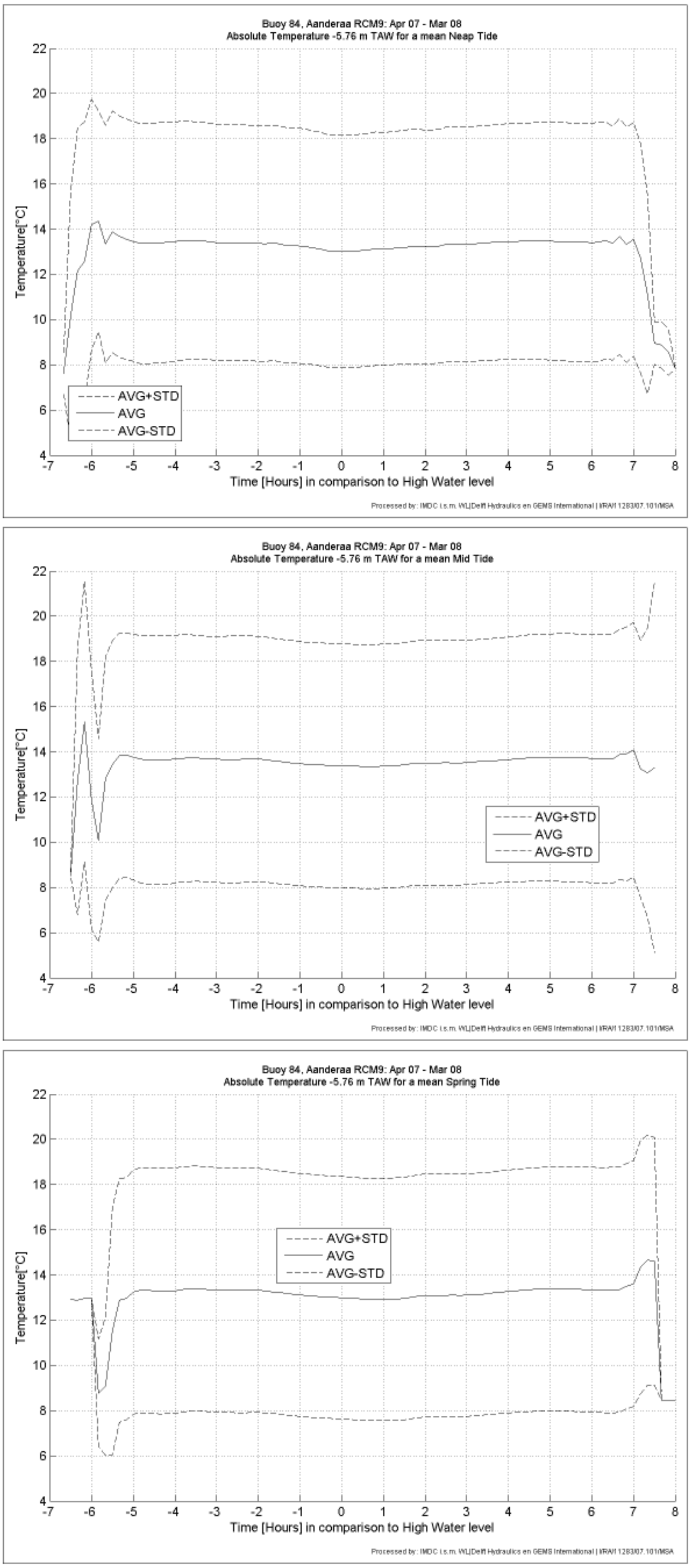
Annex-Figure E-8 Maximal (__) en minimal (…) tidal temperature for all measurement stations



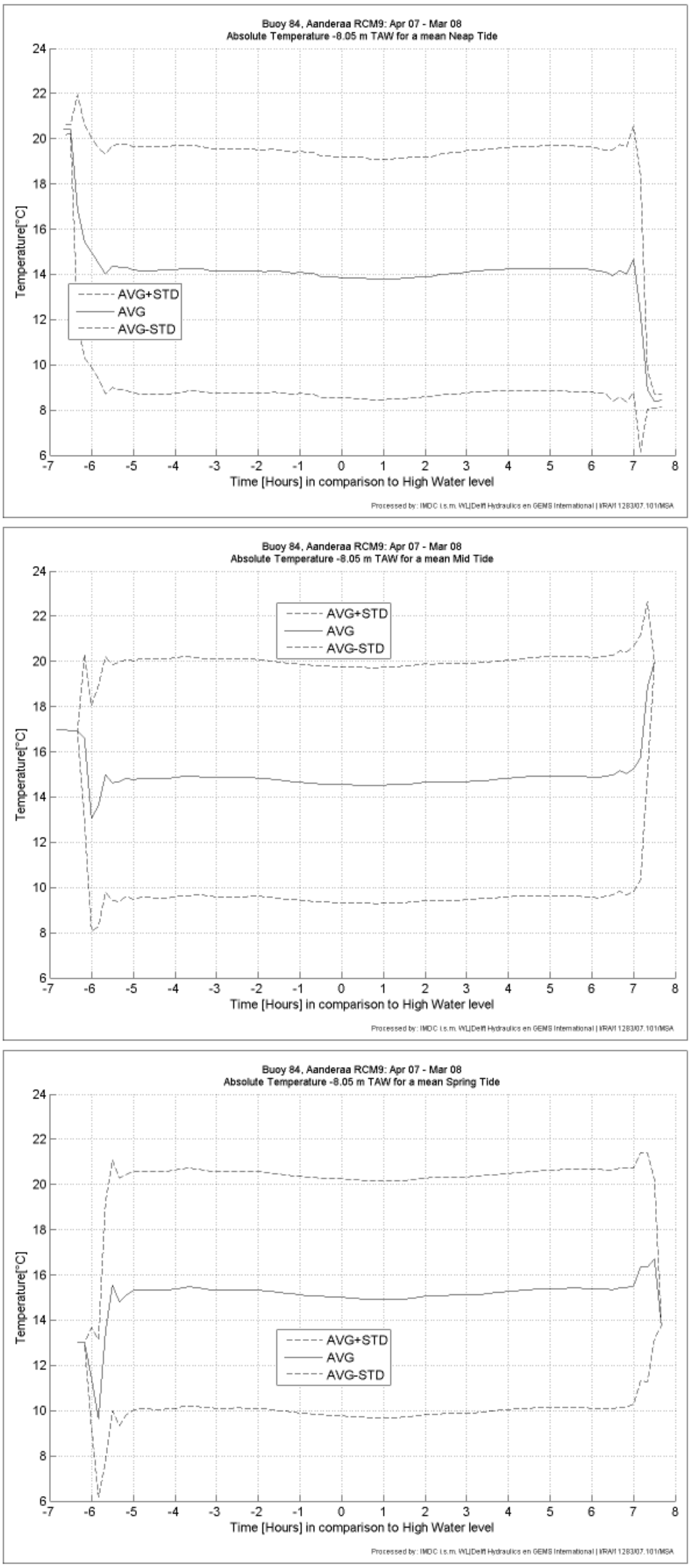
Annex-Figure E-9 Tidal temperature amplitude for all measurement stations.

Annex-Table E-1: Averaged tidal temperature amplitude [°C] (ΔT), standard deviation (σ), and amount of tide in the sample (N) for every measurement station during considered period (Summer: Apr 2007-Sep 2007, Winter: Oct 2007-Mar 2008, Year: Apr 2007-Mar 2008)

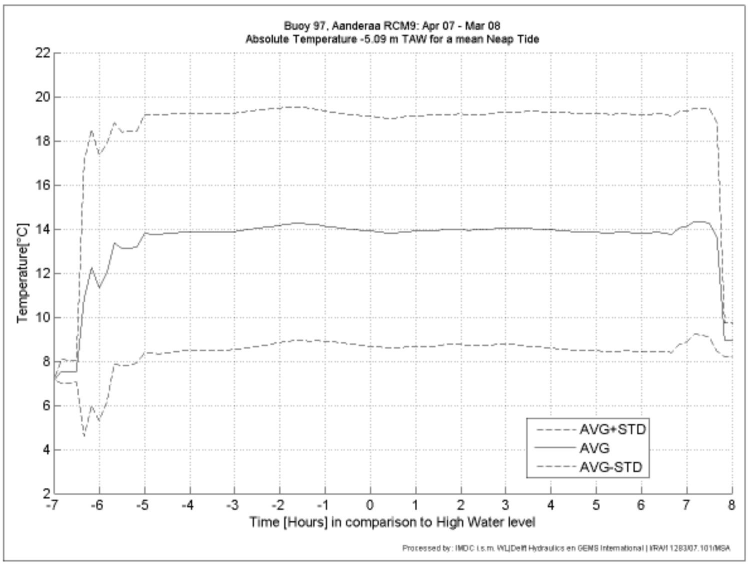
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year		
			ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N	ΔT	σ	N
Buoy 84		Neap	0.57	0.15	27	0.49	0.10	18	0.47	0.13	39	0.46	0.16	16	0.54	0.14	45	0.47	0.14	55	0.50	0.14	100
	-8.1 m	Avg	0.61	0.16	58	0.60	0.14	44	0.55	0.17	78	0.56	0.28	12	0.61	0.15	102	0.55	0.19	90	0.58	0.17	192
	TAW	Spring	0.67	0.12	35	0.60	0.14	52	0.62	0.17	42	0.65	0.09	11	0.63	0.13	87	0.63	0.16	53	0.63	0.14	140
		All	0.62	0.15	120	0.58	0.14	114	0.55	0.17	159	0.55	0.20	39	0.60	0.15	234	0.55	0.18	198	0.58	0.16	432
		Neap	0.61	0.23	25	0.54	0.11	22	0.46	0.11	46	0.56	0.19	31	0.58	0.18	47	0.50	0.15	77	0.53	0.17	124
	-5.6 m	Avg	0.61	0.17	58	0.60	0.13	46	0.49	0.13	83	0.50	0.18	43	0.60	0.15	104	0.50	0.15	126	0.54	0.16	230
	TAW	Spring	0.64	0.12	37	0.60	0.13	54	0.57	0.15	48	0.60	0.16	41	0.62	0.13	91	0.58	0.16	89	0.60	0.14	180
		All	0.62	0.17	120	0.59	0.13	122	0.50	0.14	177	0.55	0.18	115	0.60	0.15	242	0.52	0.16	292	0.56	0.16	534
Buoy 97		Neap	0.56	0.13	32	0.60	0.12	27	0.77	0.17	49	0.94	0.24	45	0.57	0.13	59	0.85	0.22	94	0.75	0.24	153
	-7.8 m	Avg	0.66	0.11	73	0.67	0.10	50	0.85	0.22	80	0.94	0.25	54	0.67	0.11	123	0.89	0.24	134	0.78	0.22	257
	TAW	Spring	0.81	0.16	51	0.74	0.12	58	0.85	0.17	47	0.89	0.19	67	0.77	0.15	109	0.87	0.18	114	0.82	0.17	223
		All	0.69	0.16	156	0.68	0.13	135	0.83	0.20	176	0.92	0.22	166	0.69	0.15	291	0.87	0.22	342	0.79	0.21	633
		Neap	0.59	0.14	32	0.61	0.12	31	0.84	0.16	35	0.99	0.24	47	0.60	0.13	63	0.93	0.22	82	0.78	0.25	145
	-5.3 m	Avg	0.64	0.12	73	0.67	0.11	56	0.96	0.18	64	0.96	0.25	50	0.66	0.12	129	0.96	0.21	114	0.80	0.23	243
	TAW	Spring	0.83	0.17	51	0.73	0.11	55	0.89	0.16	35	0.92	0.19	69	0.78	0.15	106	0.91	0.18	104	0.84	0.18	210
		All	0.69	0.17	156	0.68	0.12	142	0.91	0.18	134	0.95	0.23	166	0.69	0.15	298	0.93	0.21	300	0.81	0.22	598
Oosterweel		Neap	0.38	0.12	11	0.60	0.26	40	1.22	0.62	4	0.56	0.30	28	0.55	0.25	51	0.64	0.40	32	0.59	0.32	83
	- 5.8 m	Avg	0.47	0.16	14	0.77	0.26	47	0.66	0.43	19	0.60	0.38	50	0.70	0.27	61	0.62	0.39	69	0.66	0.34	130
	TAW	Spring	0.44	0.13	18	0.91	0.26	48	0.28	0.00	1	0.70	0.36	60	0.78	0.32	66	0.69	0.36	61	0.74	0.34	127
		All	0.43	0.14	43	0.77	0.29	135	0.73	0.50	24	0.63	0.36	138	0.69	0.30	178	0.65	0.38	162	0.67	0.34	340
		Neap	0.30	0.16	27	0.76	0.21	21	1.24	0.47	34	0.68	0.33	36	0.50	0.29	48	0.95	0.49	70	0.77	0.47	118
	- 2.3 m	Avg	0.35	0.13	31	0.76	0.26	49	1.38	0.56	59	0.57	0.33	51	0.60	0.30	80	1.00	0.62	110	0.83	0.55	190
	TAW	Spring	0.47	0.15	32	0.90	0.27	42	1.77	0.58	31	0.74	0.37	68	0.72	0.31	74	1.06	0.66	99	0.91	0.56	173
		All	0.38	0.16	90	0.82	0.26	112	1.44	0.58	124	0.67	0.36	155	0.62	0.31	202	1.01	0.60	279	0.85	0.54	481
Prosperpolder		Neap	1.34	0.62	33	1.11	0.38	34	1.07	0.43	45	1.03	0.39	38	1.22	0.52	67	1.05	0.41	83	1.13	0.47	150
	- 1.5 m	Avg	1.28	0.35	64	0.99	0.22	55	0.99	0.27	71	1.14	0.25	49	1.15	0.33	119	1.05	0.27	120	1.10	0.31	239
	TAW	Spring	1.36	0.42	44	1.02	0.28	67	1.03	0.23	37	1.09	0.19	65	1.16	0.38	111	1.07	0.21	102	1.11	0.31	213
		All	1.32	0.45	141	1.03	0.29	156	1.02	0.32	153	1.09	0.27	152	1.17	0.40	297	1.06	0.30	305	1.11	0.35	602

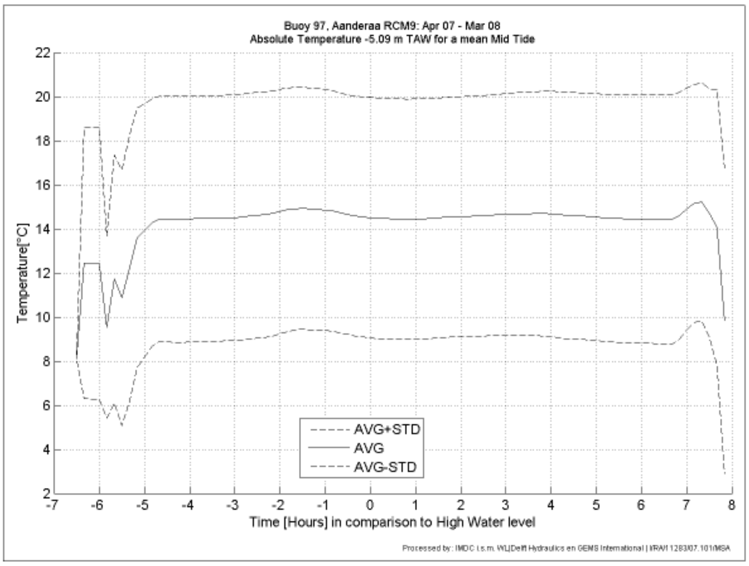


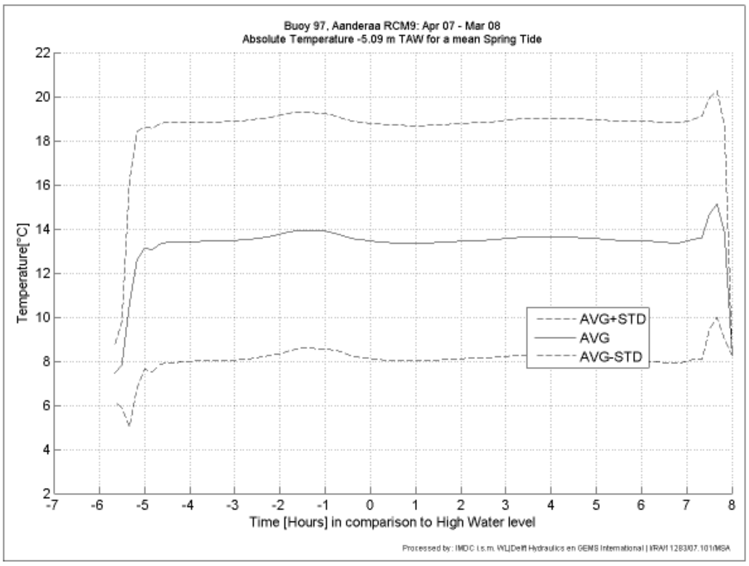
Annex-Figure E-10: Buoy 84 (-5.8m TAW), April 2007-March2008, average tidal curve of the temperature for a (a) neap, (b) average, (c) spring tide



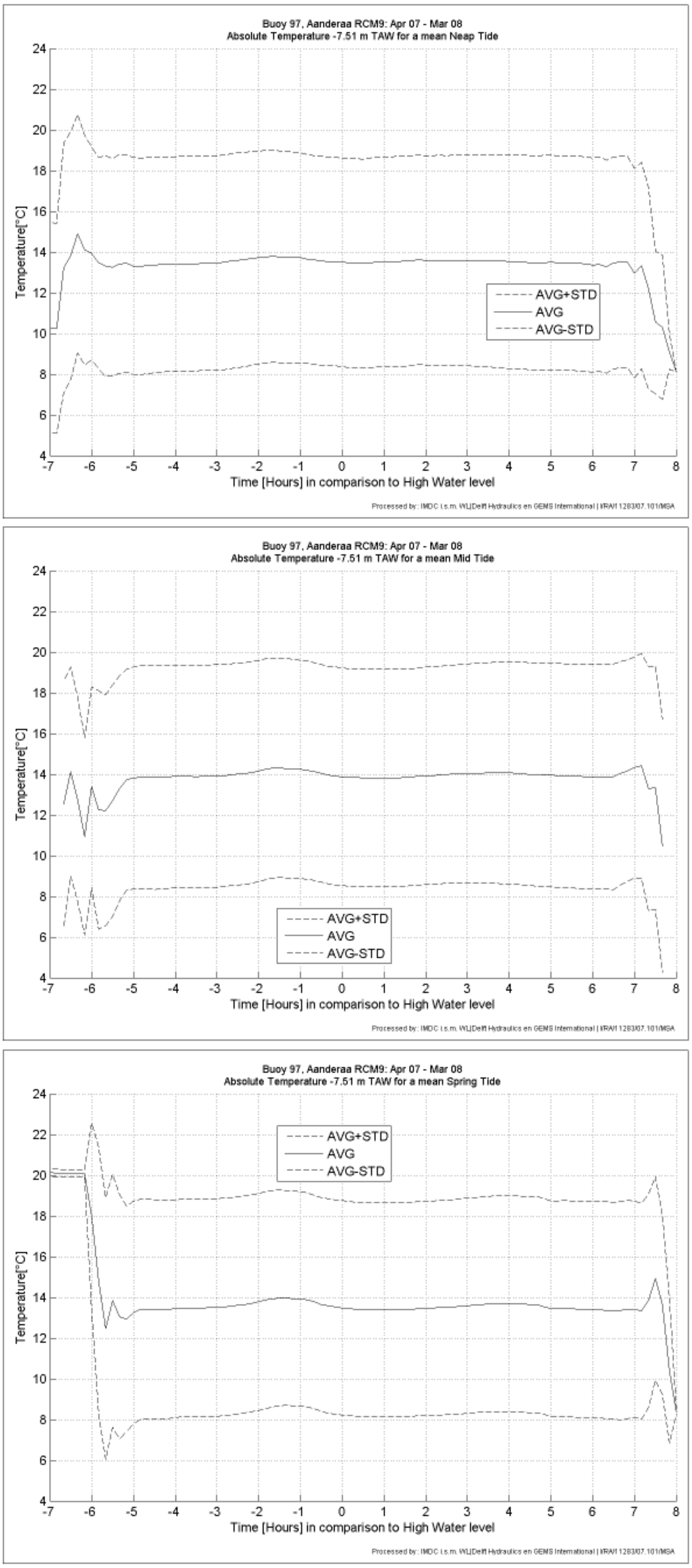
Annex-Figure E-11: Buoy 84 (-8.1m TAW), April 2007-March2008, average tidal curve of the temperature for a (a) neap, (b) average, (c) spring tide



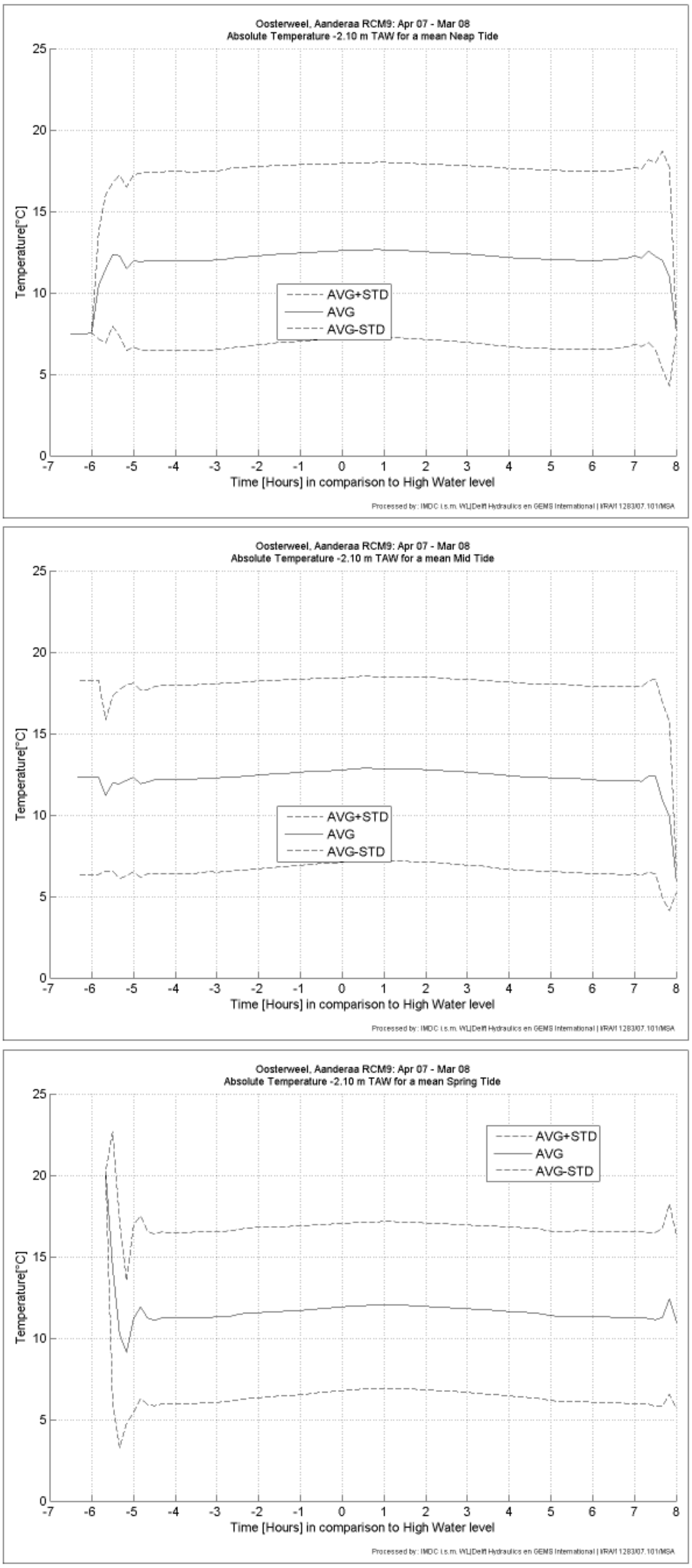




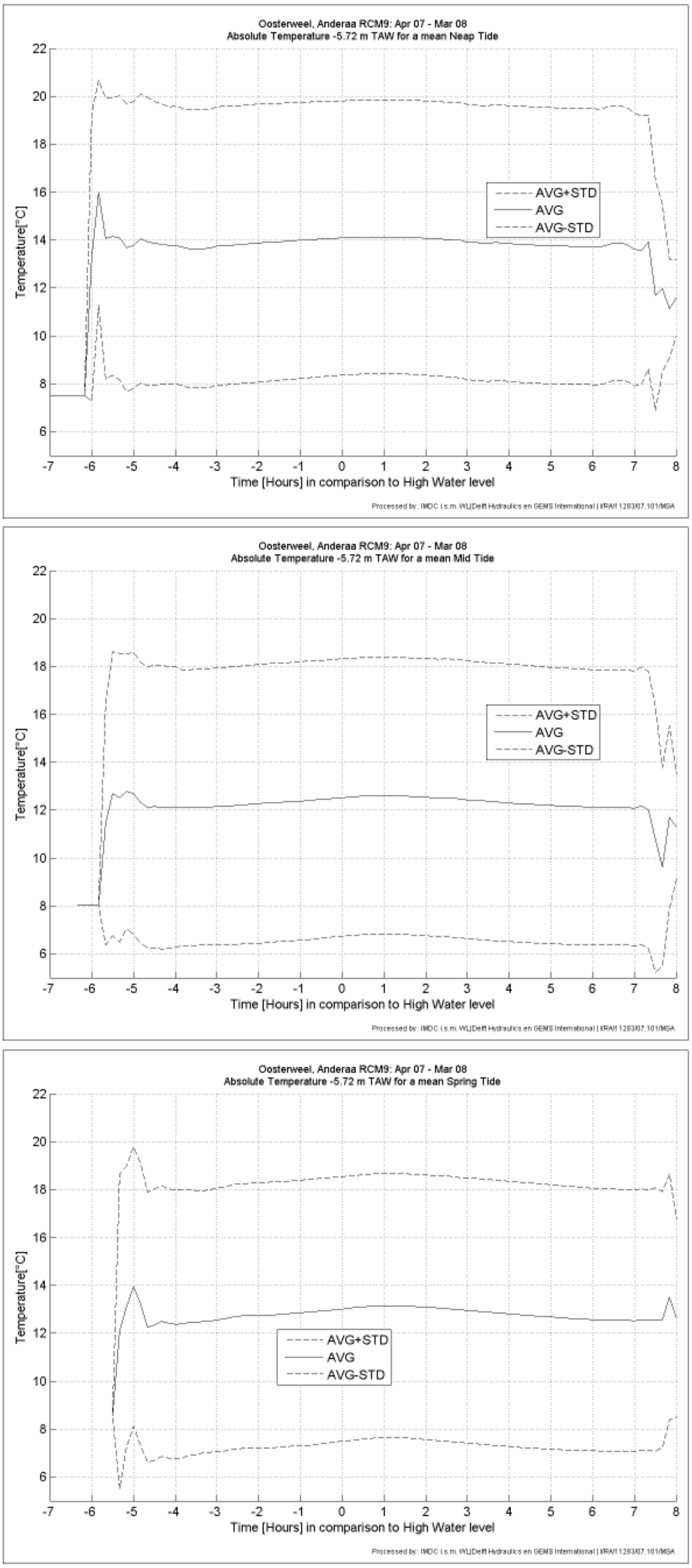
Annex-Figure E-12: Buoy 97 (-5.1m TAW), April 2007-March2008, average tidal curve of the temperature for a (a) neap, (b) average, (c) spring tide



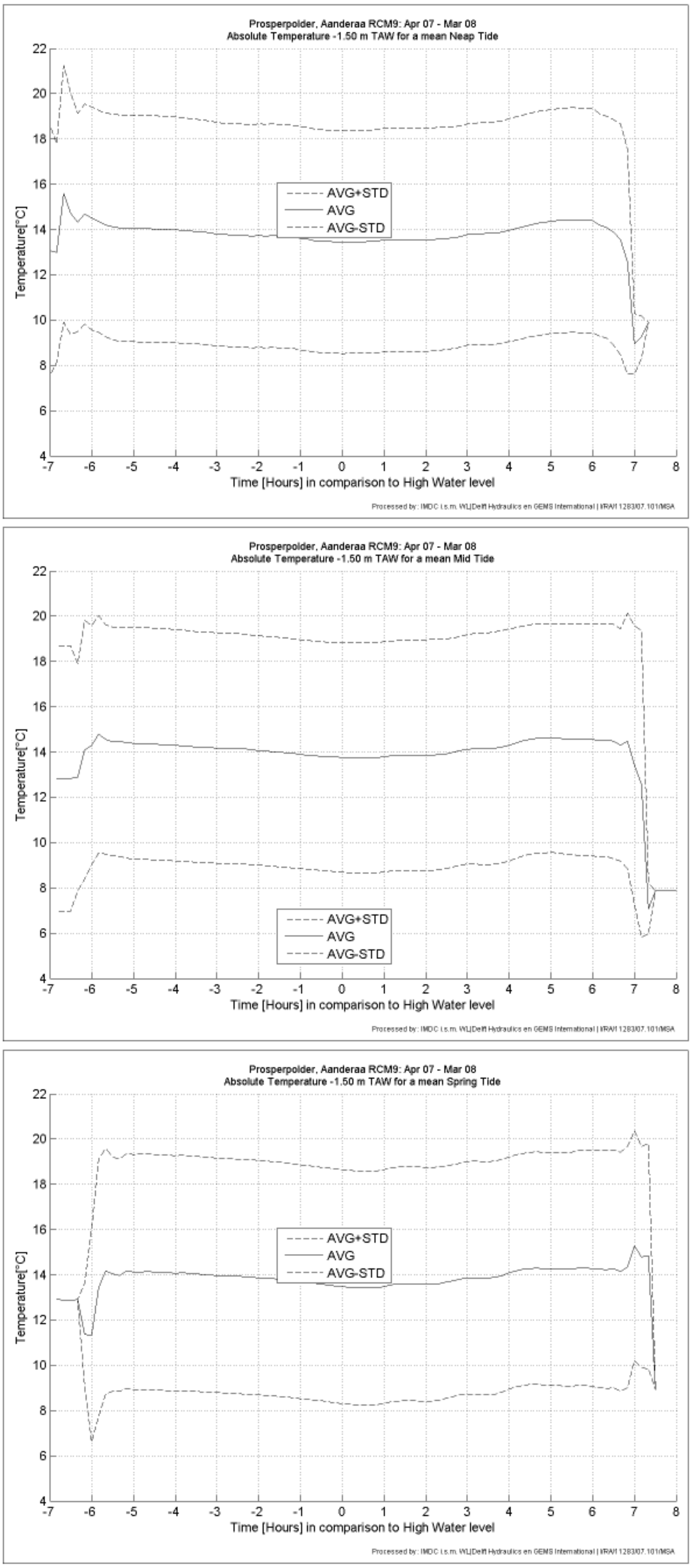
Annex-Figure E-13: Buoy 97 (-7.5m TAW), April 2007-March2008, average tidal curve of the temperature for a (a) neap, (b) average, (c) spring tide



Annex-Figure E-14: Oosterweel (-2.1m TAW), April 2007-March2008, average tidal curve of the temperature for a (a) neap, (b) average, (c) spring tide

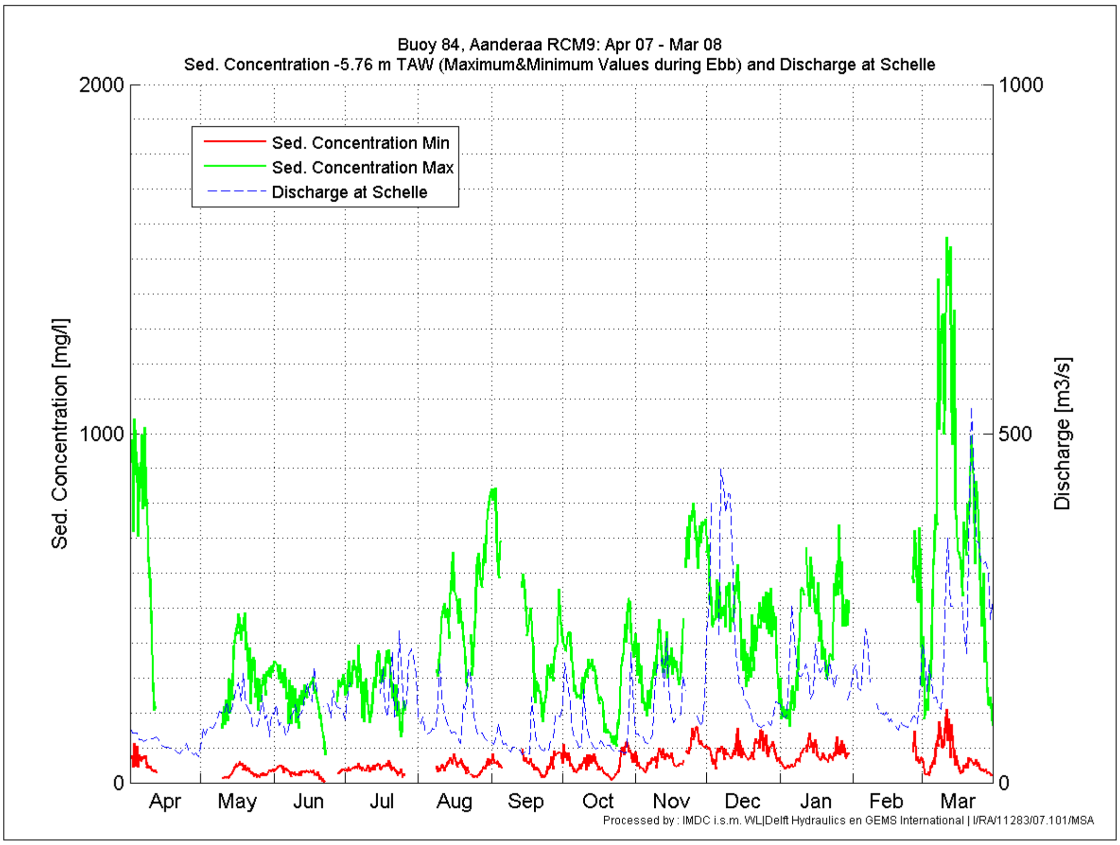


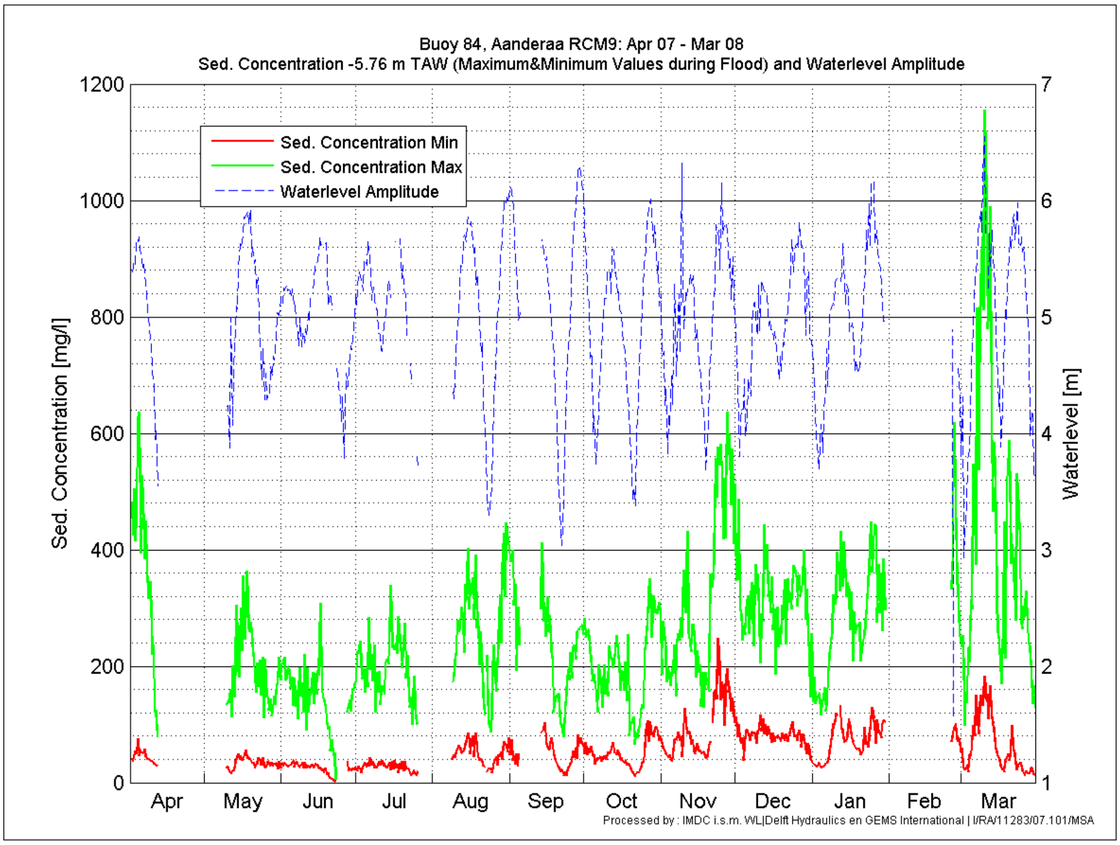
Annex-Figure E-15: Oosterweel (-5.7m TAW), April 2007-March2008, average tidal curve of the temperature for a (a) neap, (b) average, (c) spring tide



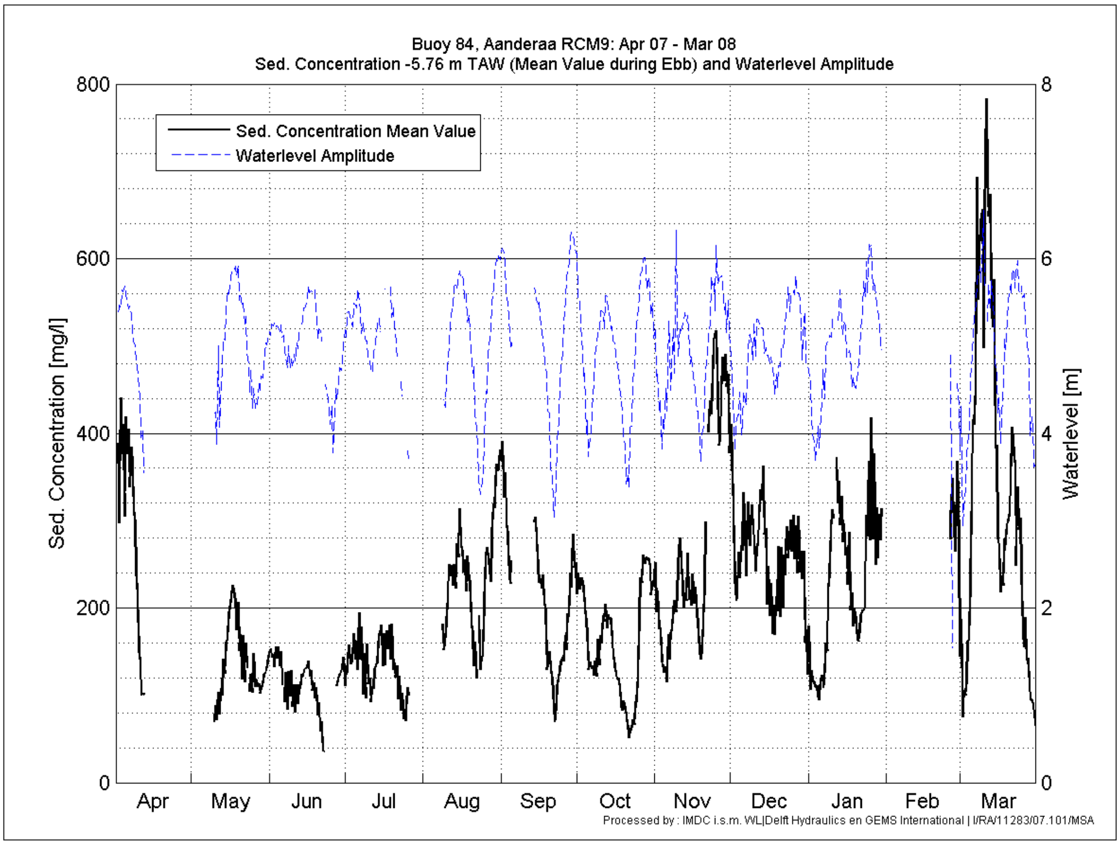
Annex-Figure E-16 prosperpolder (-1.5m TAW), April 2007-March2008, average tidal curve of the temperature for a (a) neap, (b) average, (c) spring tide

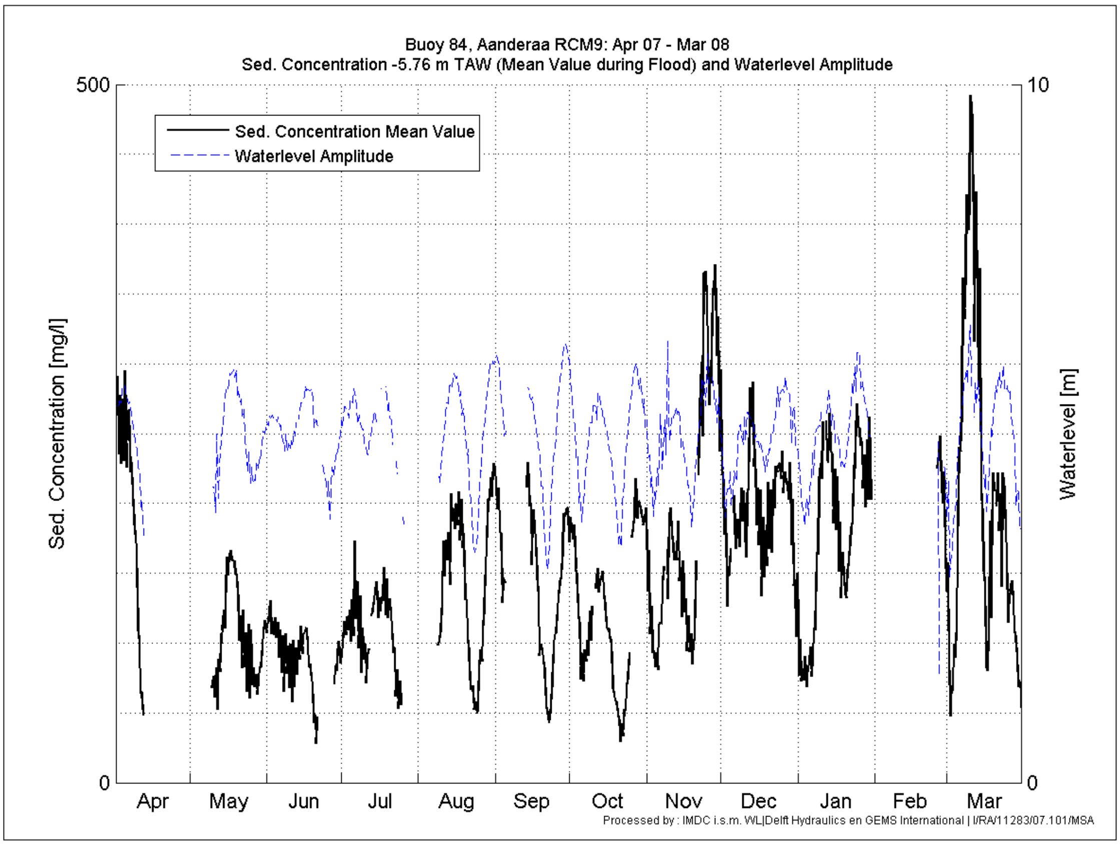
ANNEX F.: FIGURES FOR SUSPENDED SEDIMENT CONCENTRATION



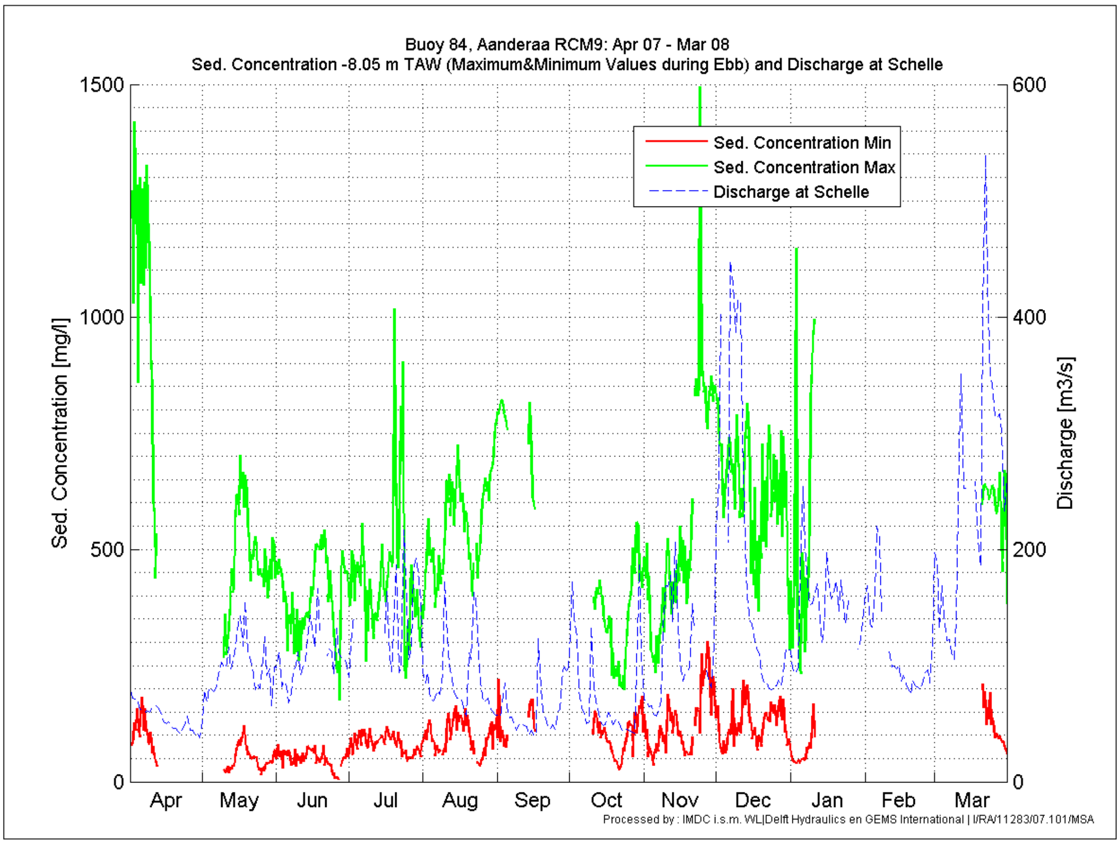


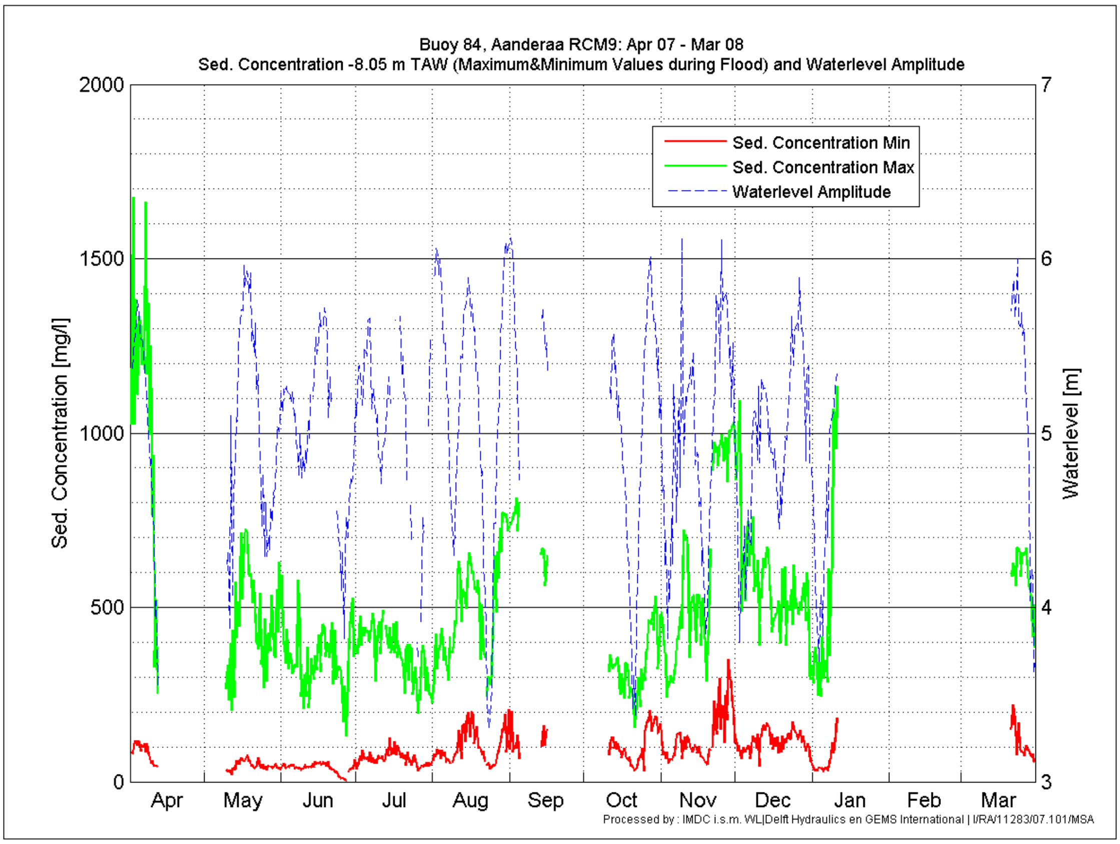
Annex-Figure F-1: Buoy 84 (-5.8m TAW), April 2007 - March 2008, maximal and minimal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration



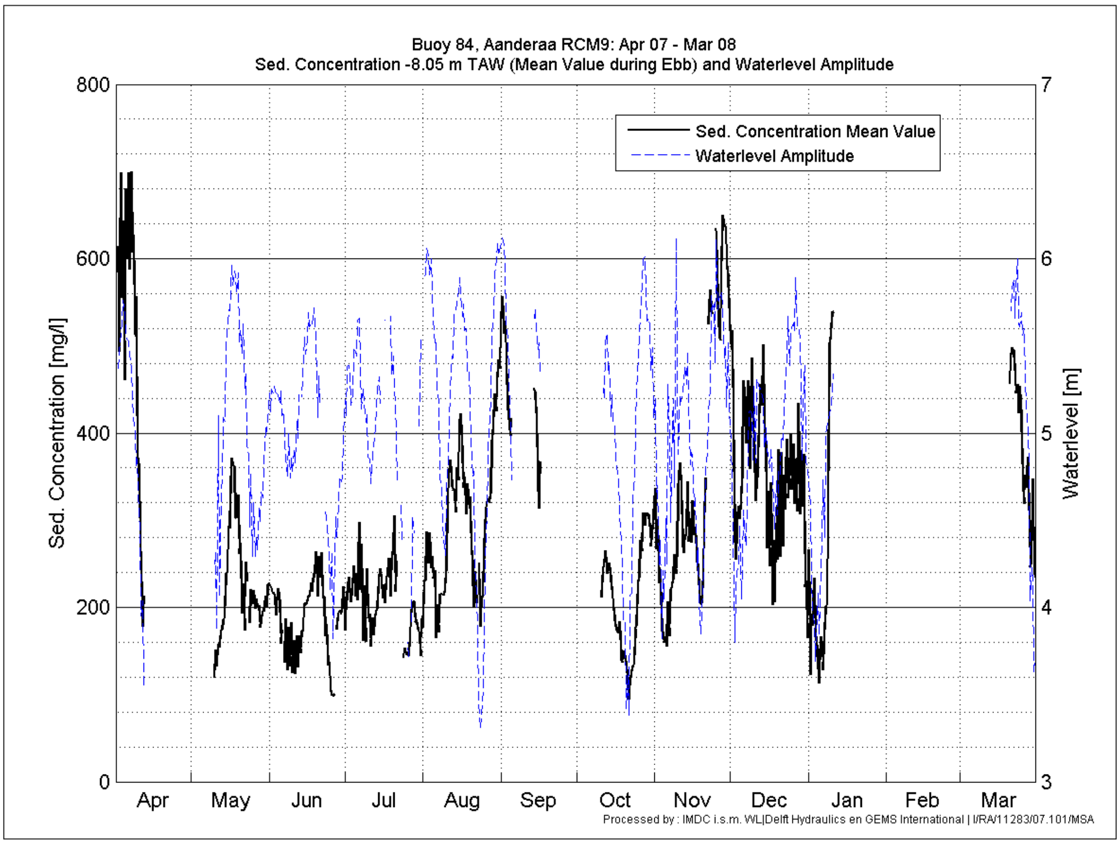


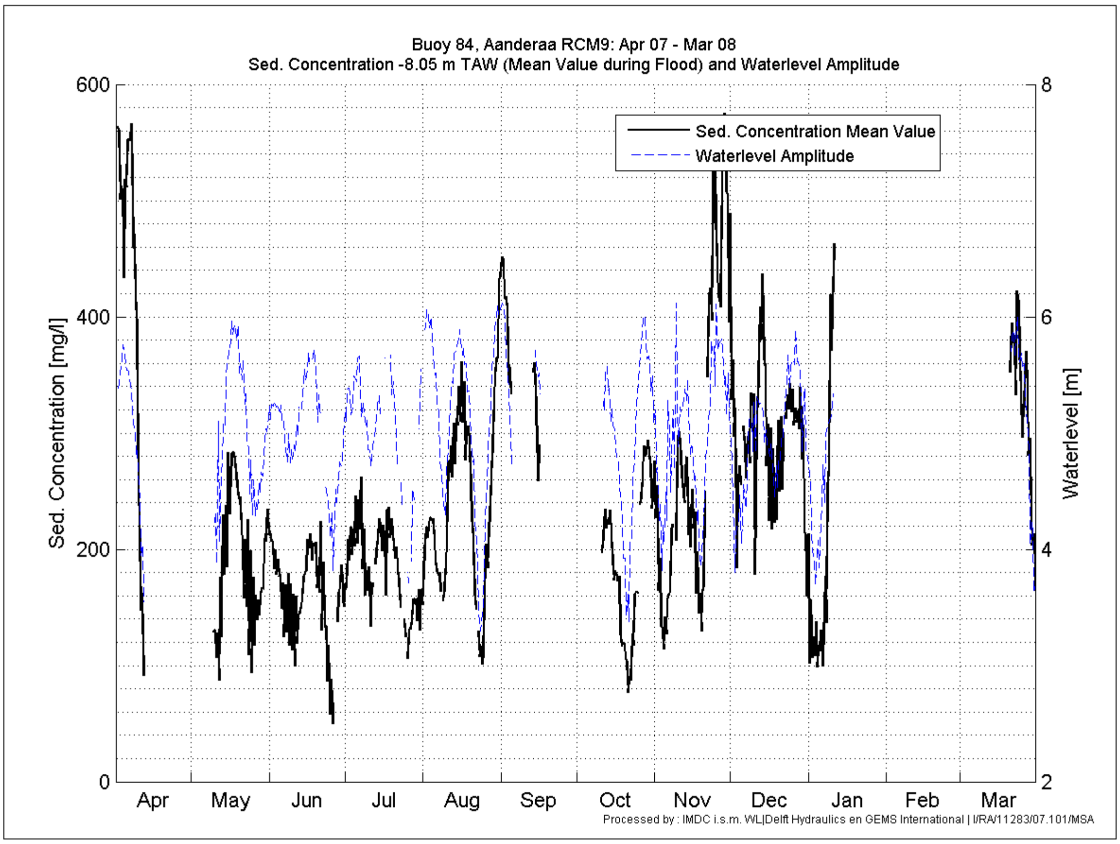
Annex-Figure F-2: Buoy 84 (-5.8m TAW), April 2007 - March 2008, average (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration



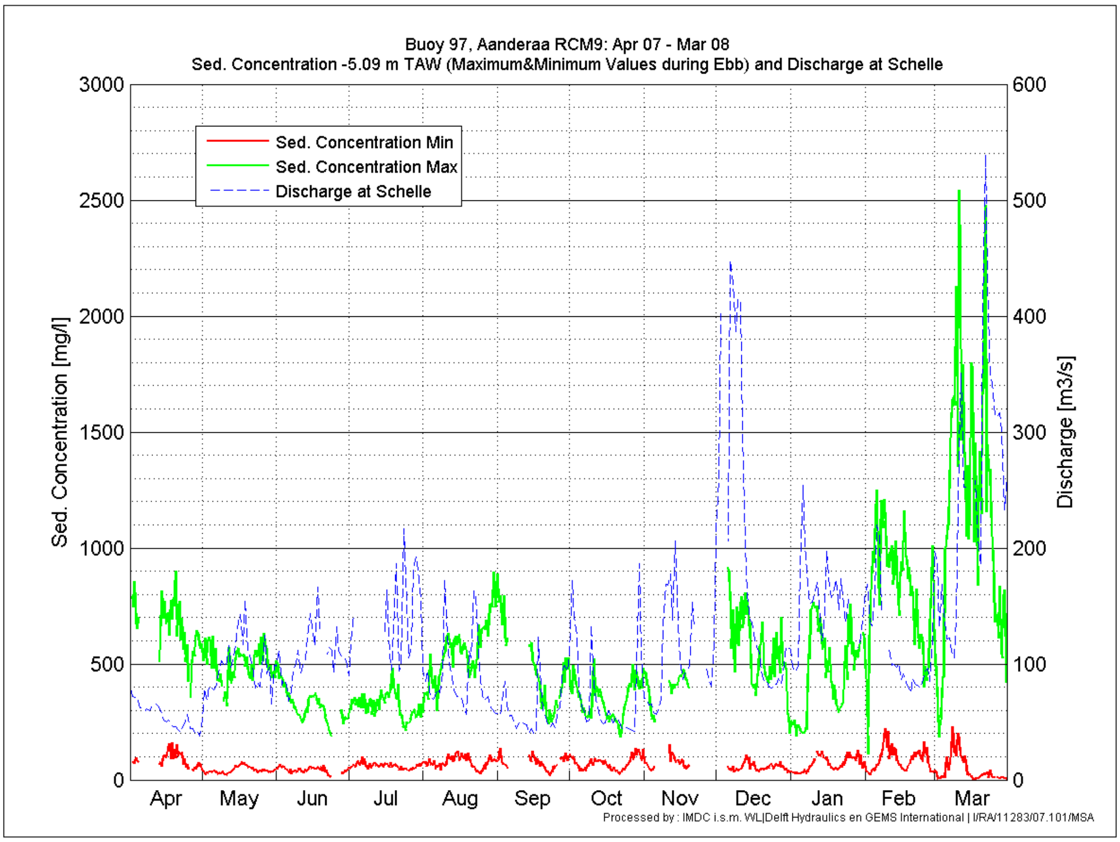


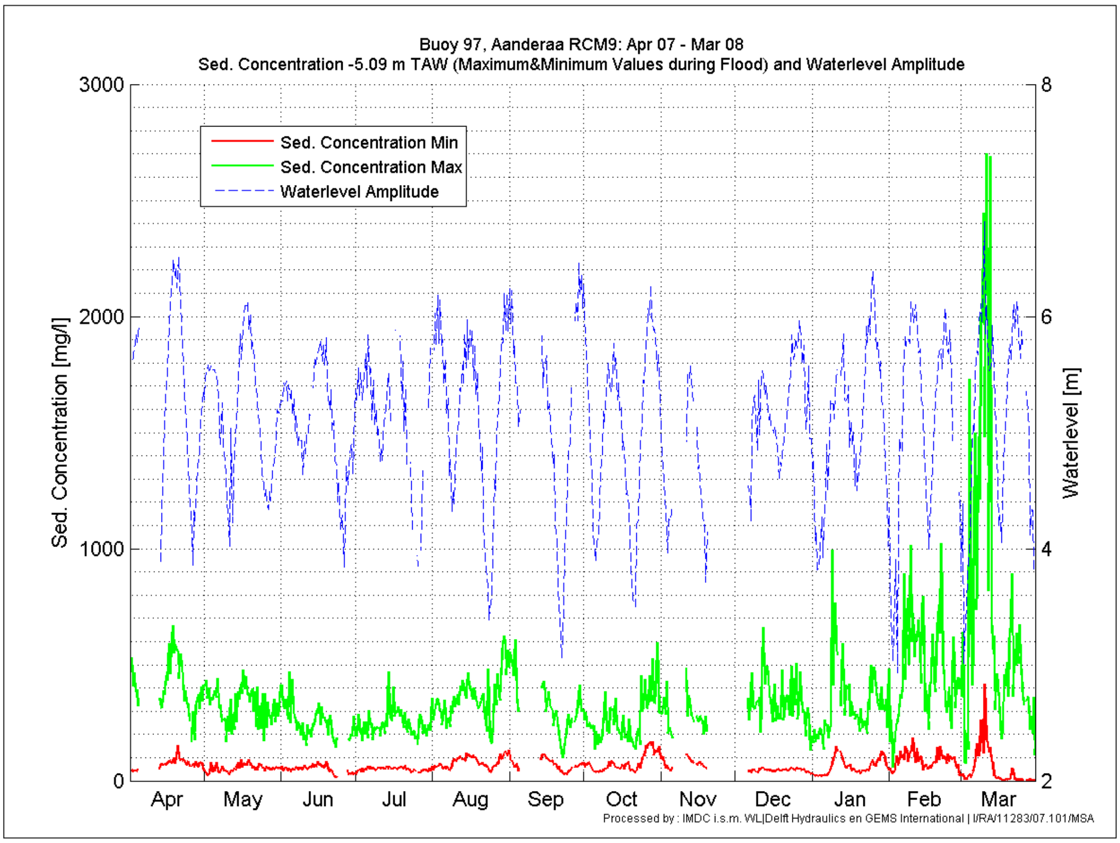
Annex-Figure F-3: Buoy 84 (-8.1m TAW), April 2007 - March 2008, maximal and minimal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration



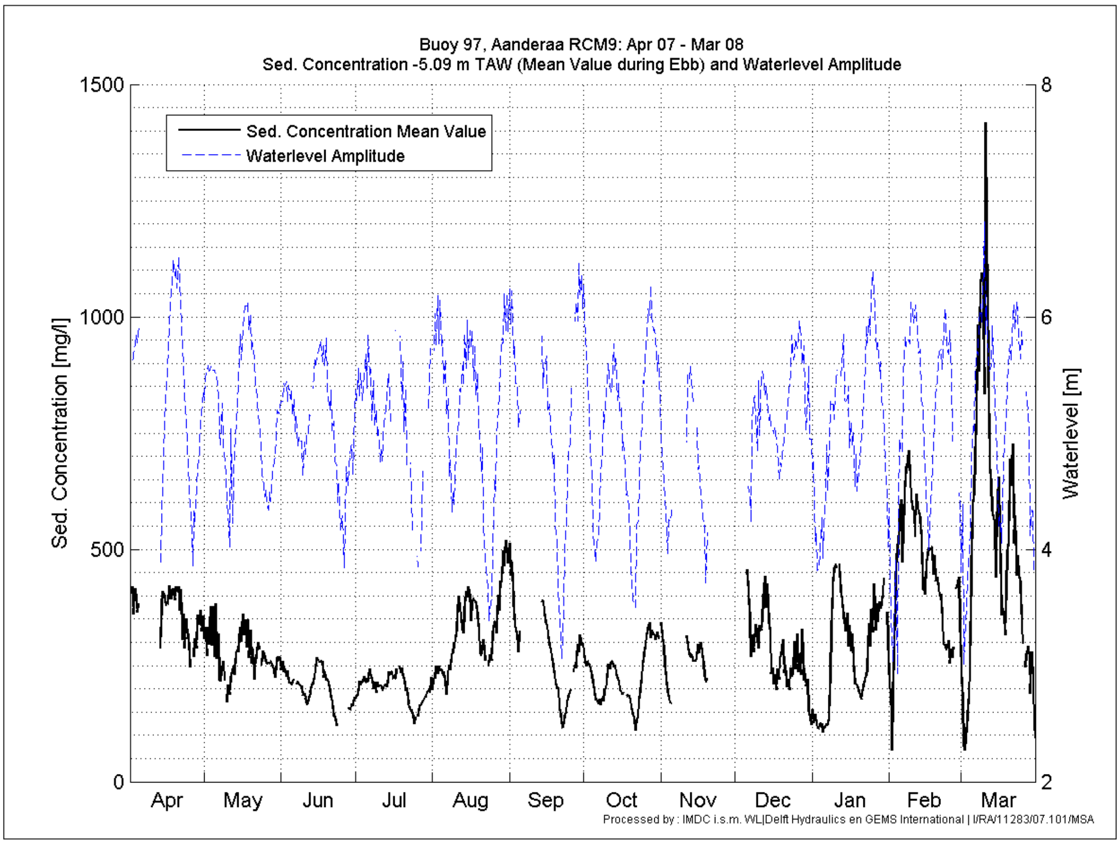


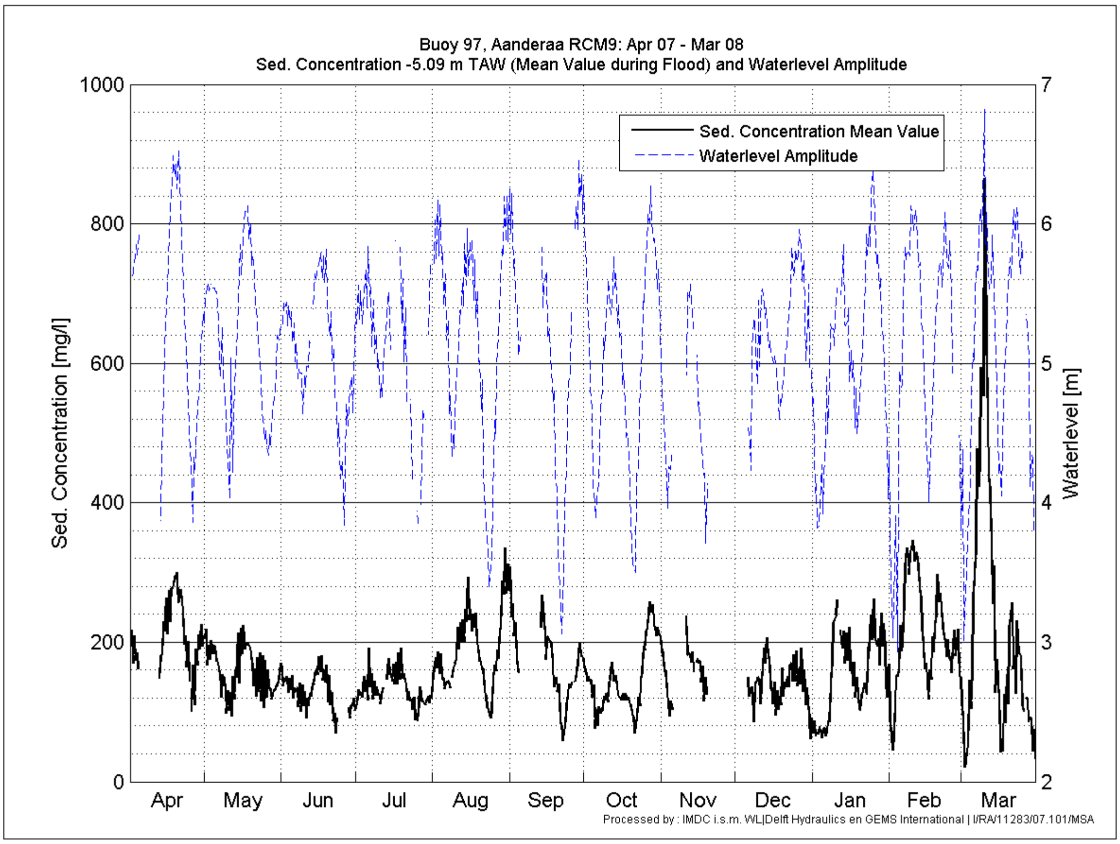
Annex-Figure F-4: Buoy 84 (-8.1m TAW), April 2007 - March 2008, averaged (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration



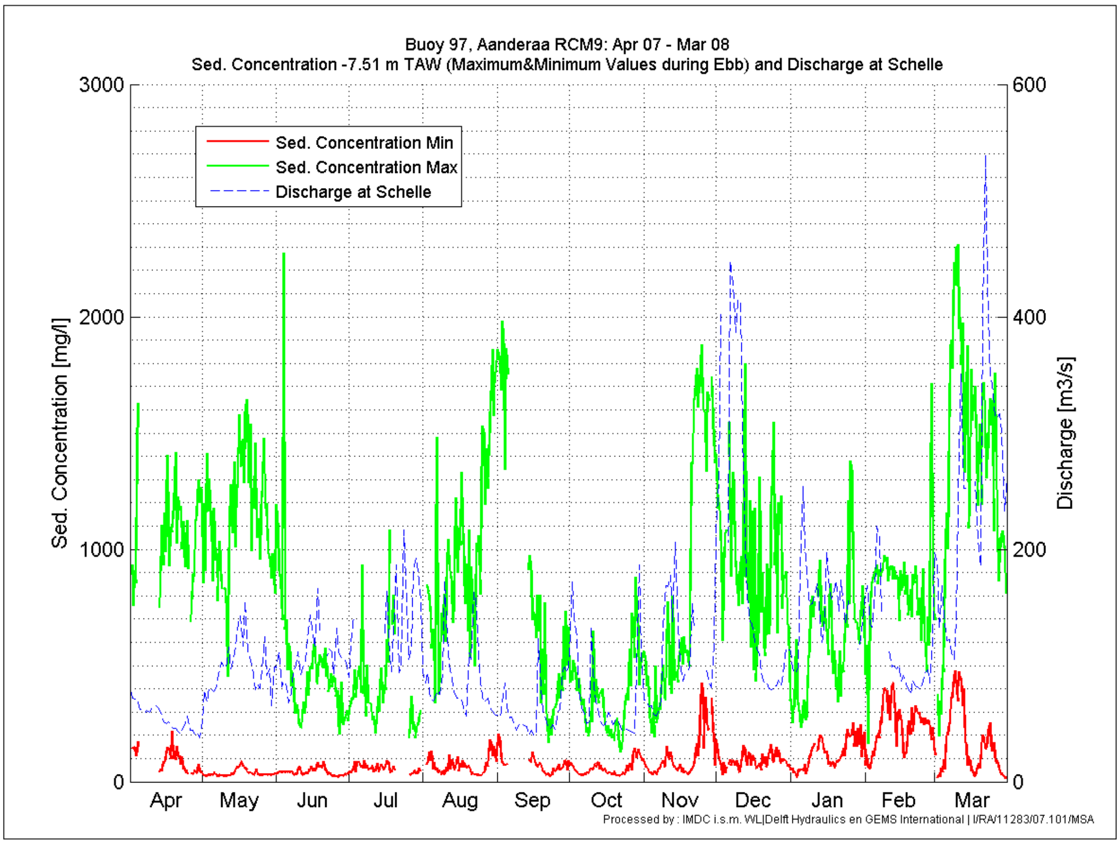


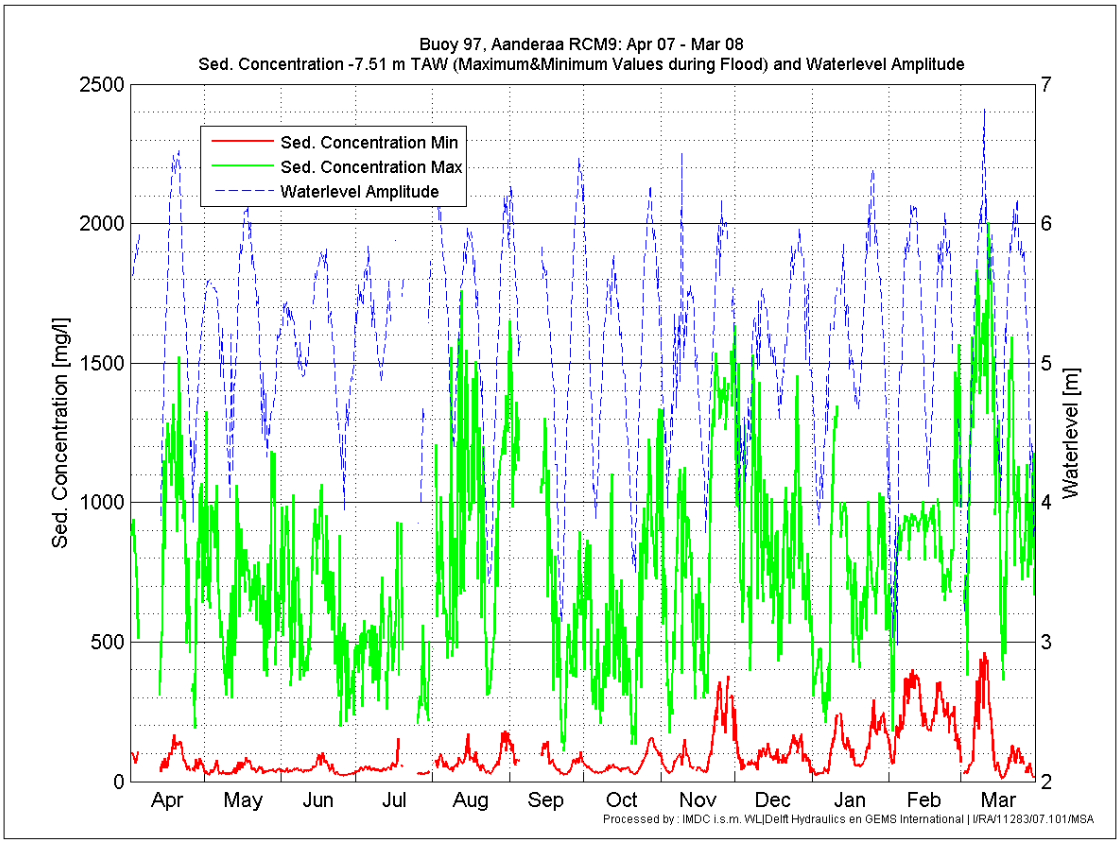
Annex-Figure F-5: Buoy 97 (-5.1m TAW), April 2007 - March 2008, maximal and minimal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration



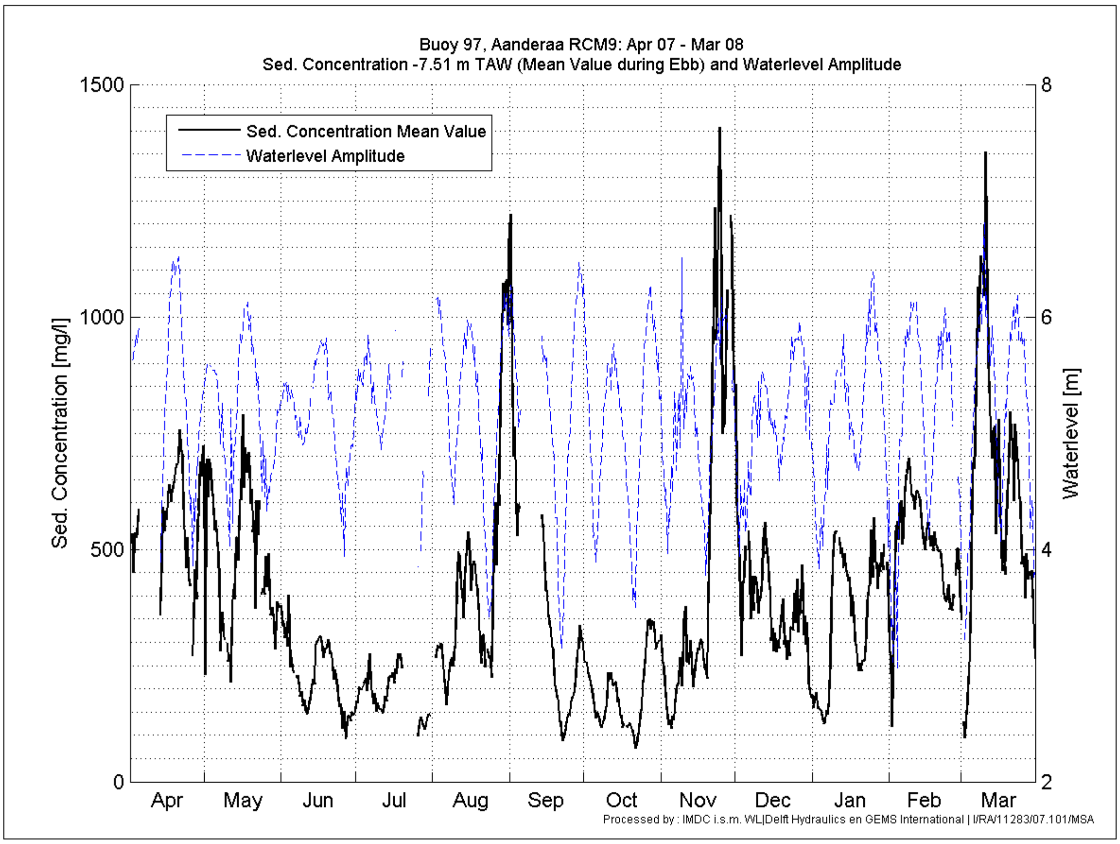


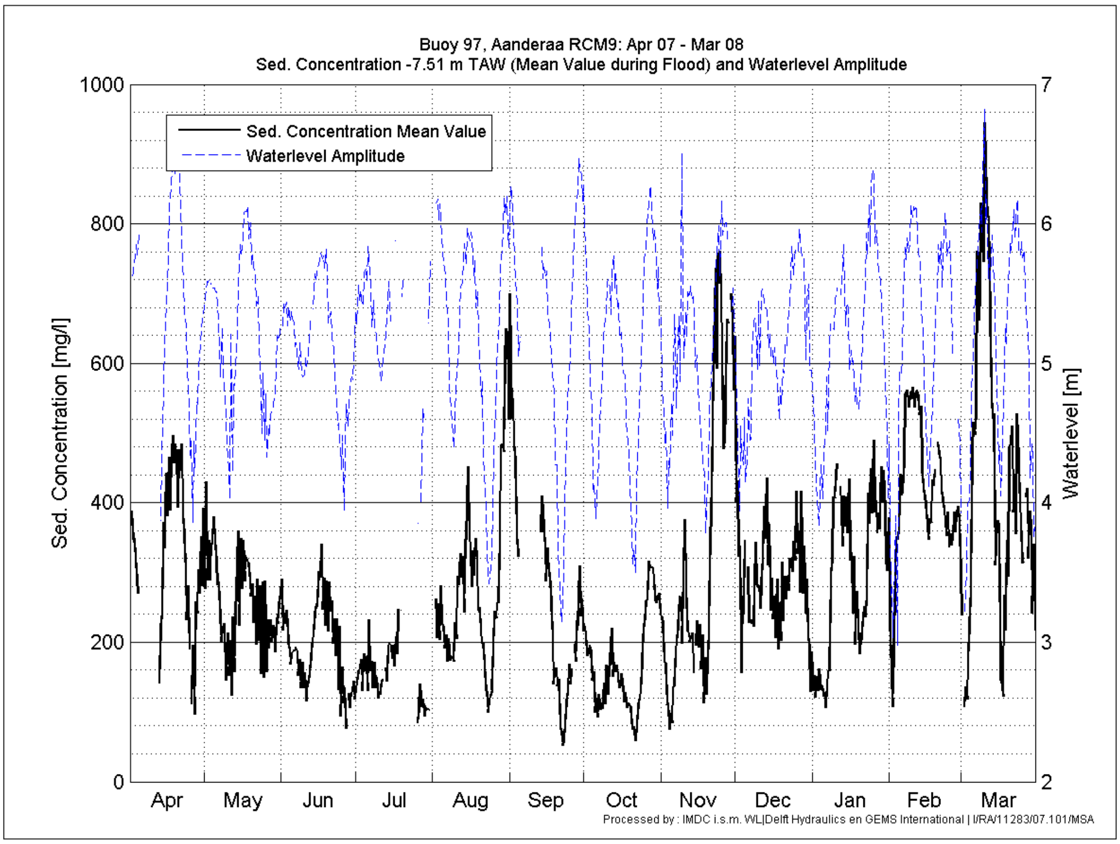
Annex-Figure F-6: Buoy 97 (-5.1m TAW), April 2007 - March 2008, averaged (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration



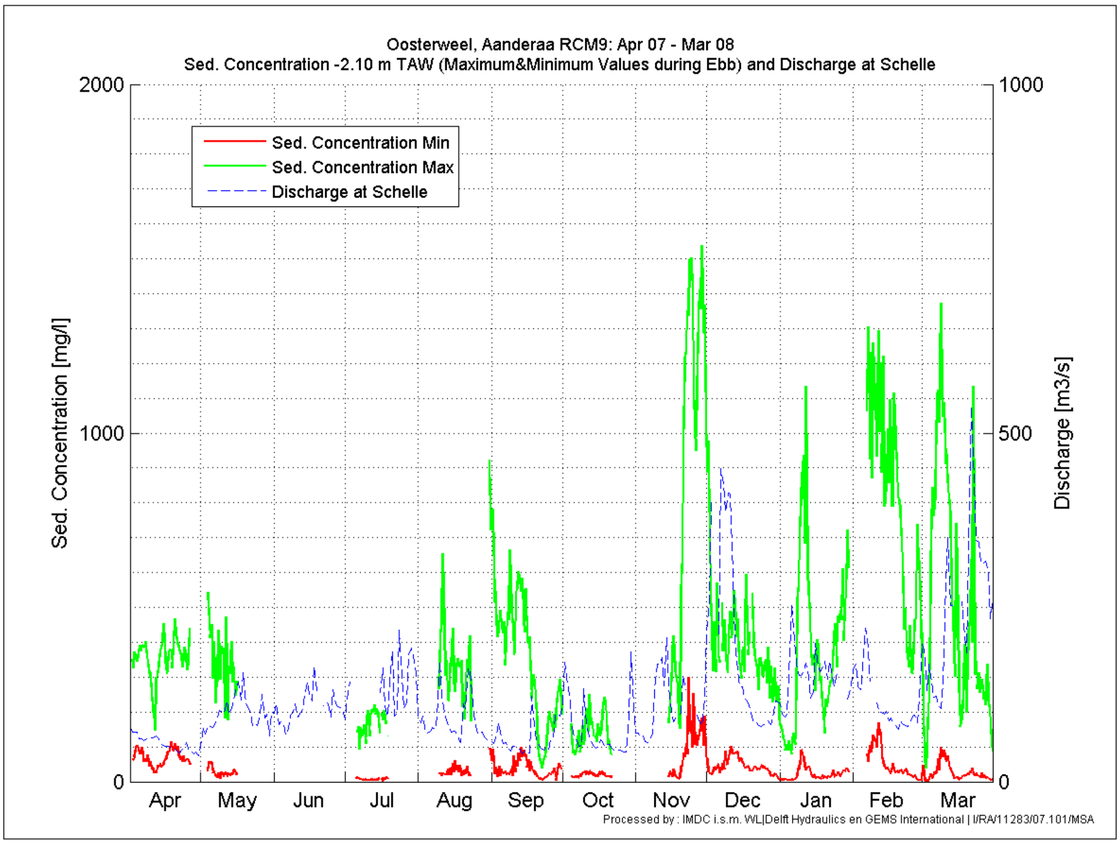


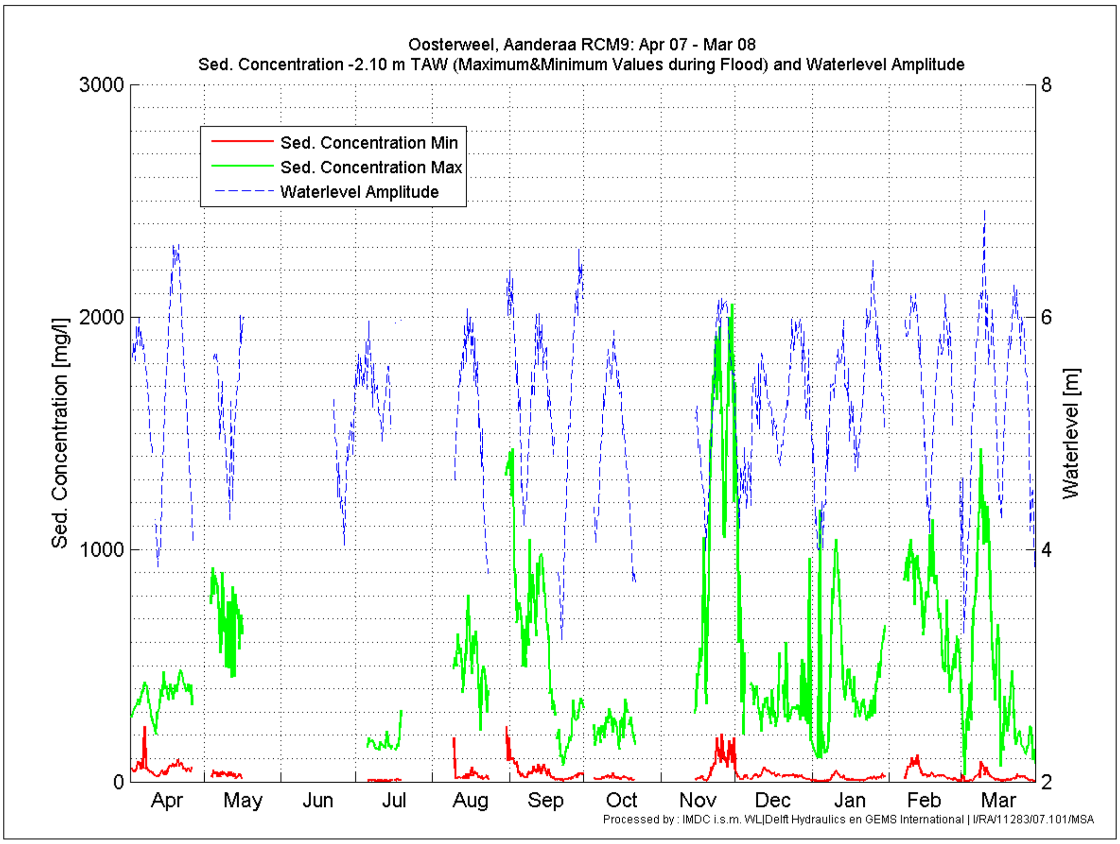
Annex-Figure F-7: Buoy 97 (-7.5m TAW), April 2007 - March 2008, maximal and minimal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration



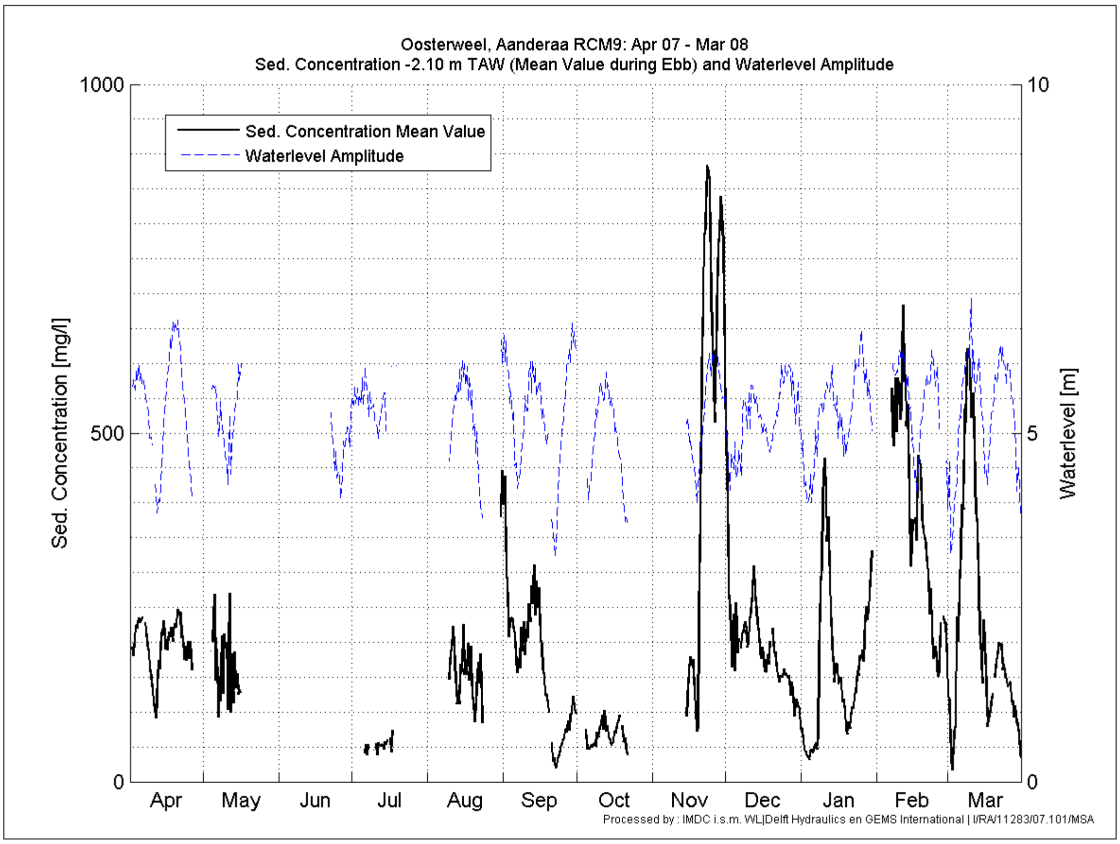


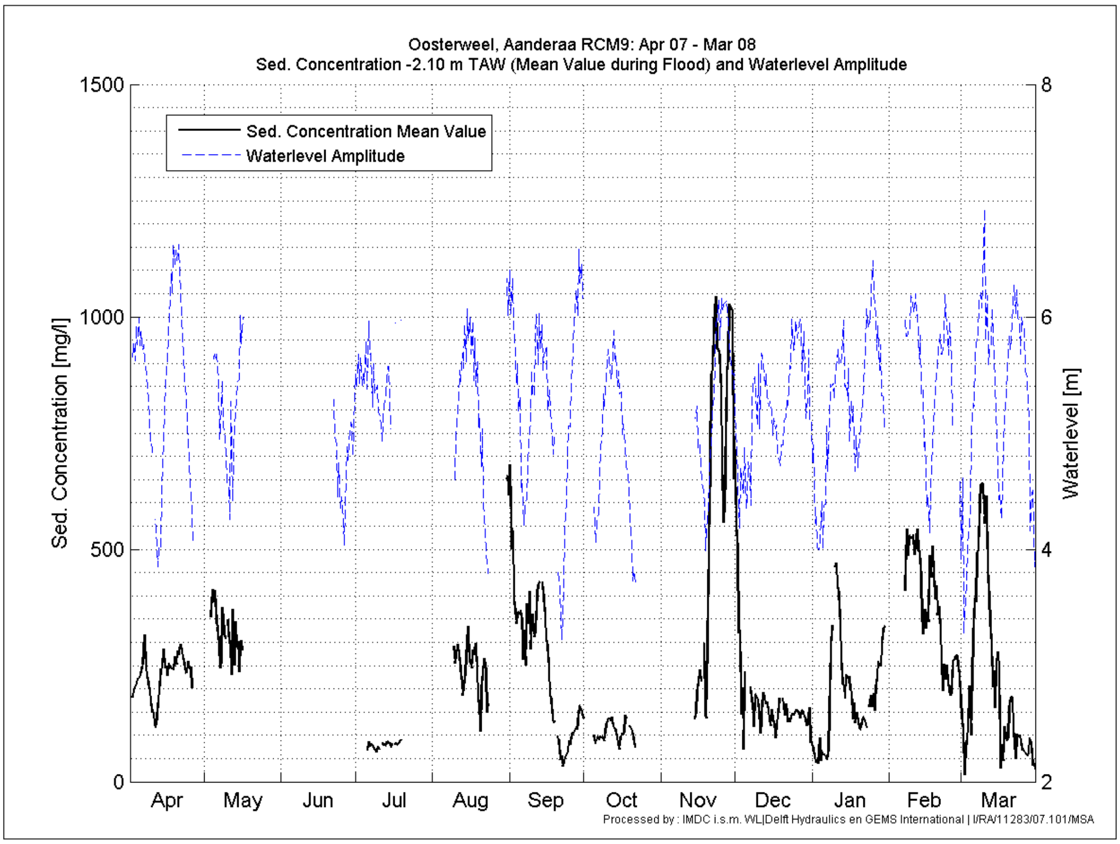
Annex-Figure F-8: Buoy 97 (-7.5m TAW), April 2007 - March 2008, averaged (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration



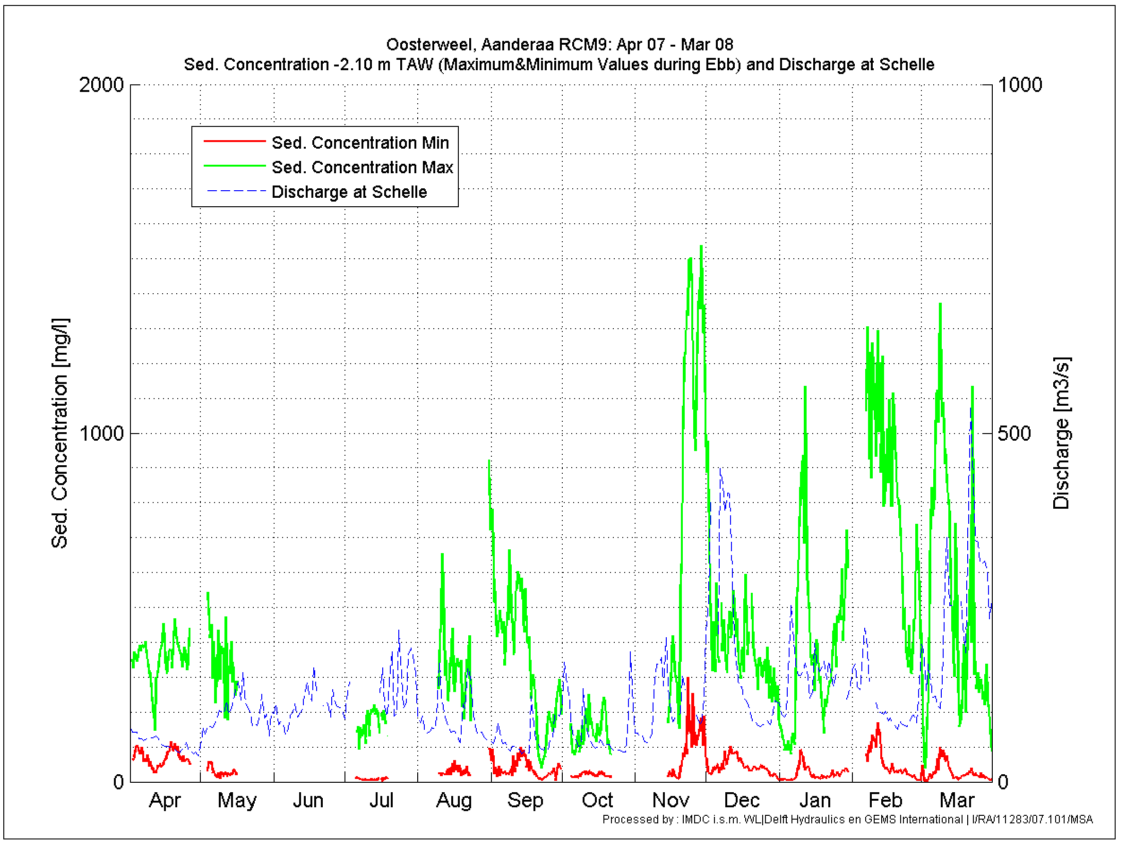


Annex-Figure F-9: Oosterweel (-2.1m TAW), April 2007 - March 2008, maximal and minimal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration

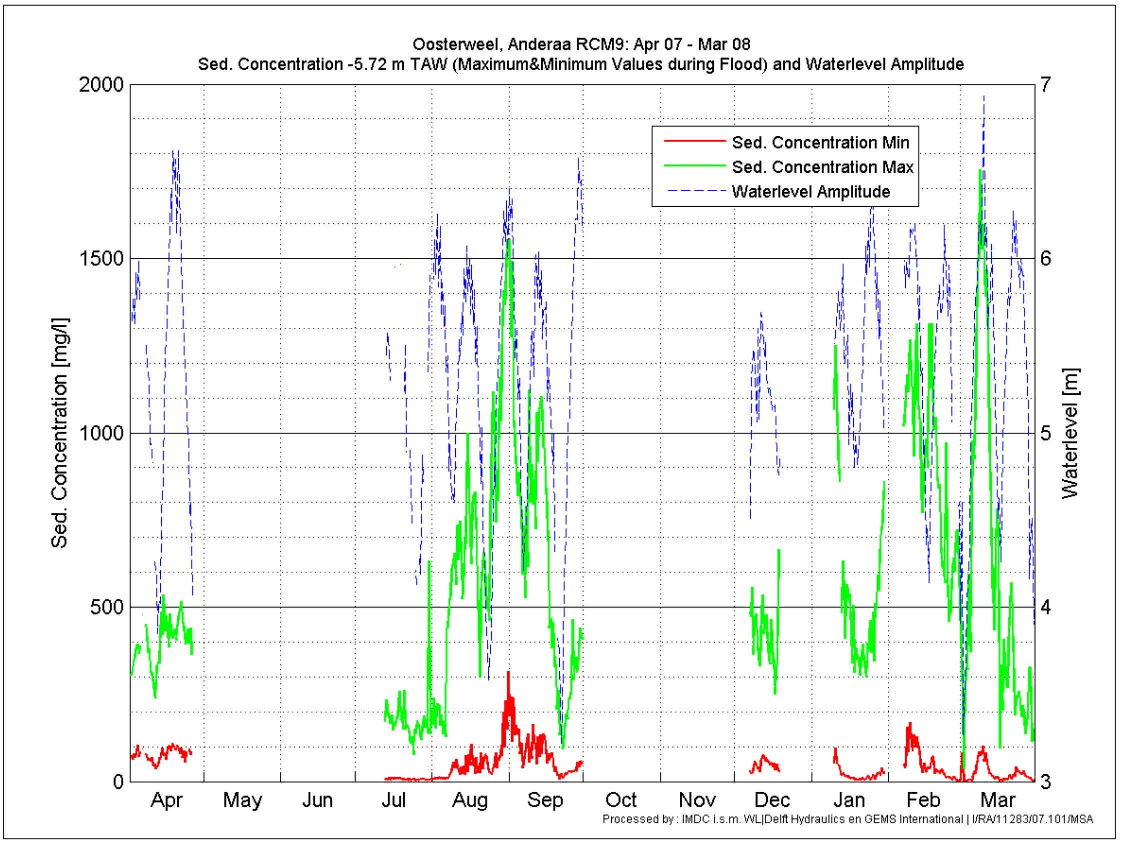




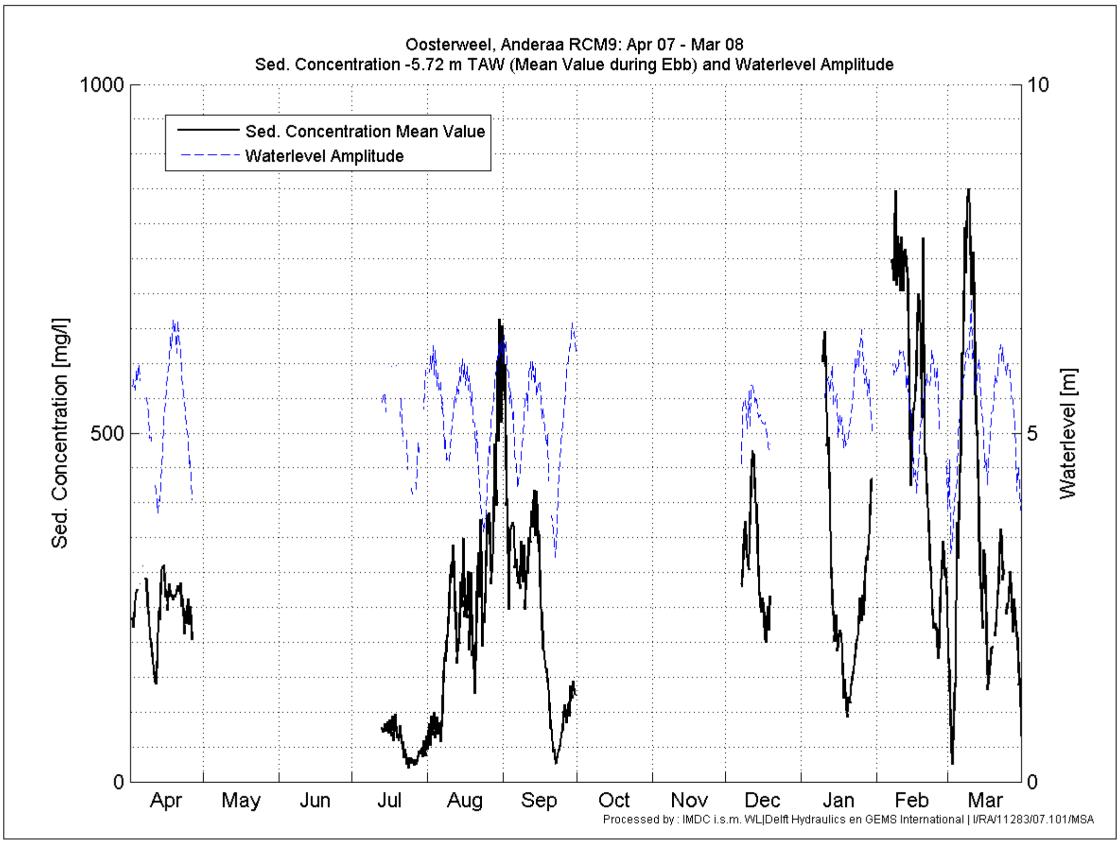
Annex-Figure F-10: Oosterweel (-2.1m TAW), April 2007 - March 2008, averaged (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration

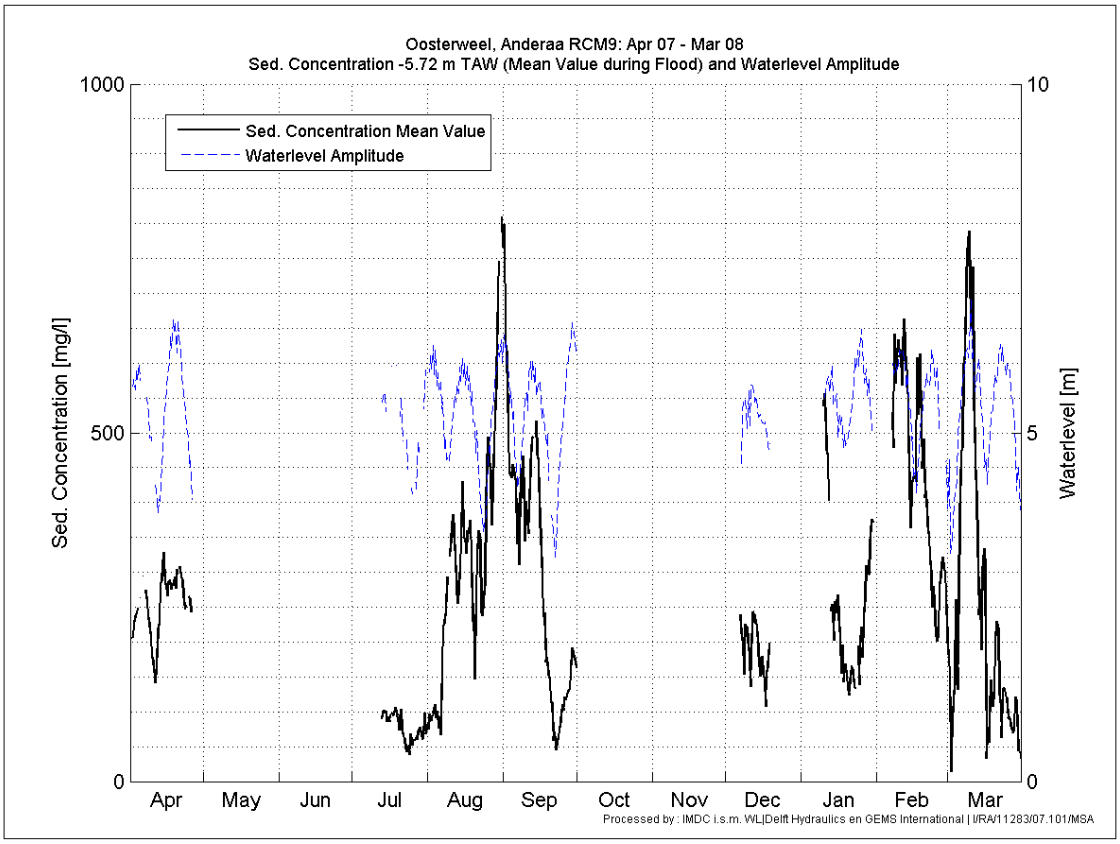


ipf



Annex-Figure F-11: Oosterweel (-5.7m TAW), April 2007 - March 2008, maximal and minimal (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration





Annex-Figure F-12: Oosterweel (-5.7m TAW), April 2007 - March 2008, averaged (a) ebb phase (and Scheldt discharge) and (b) flood phase (and tidal amplitude) suspended sediment concentration

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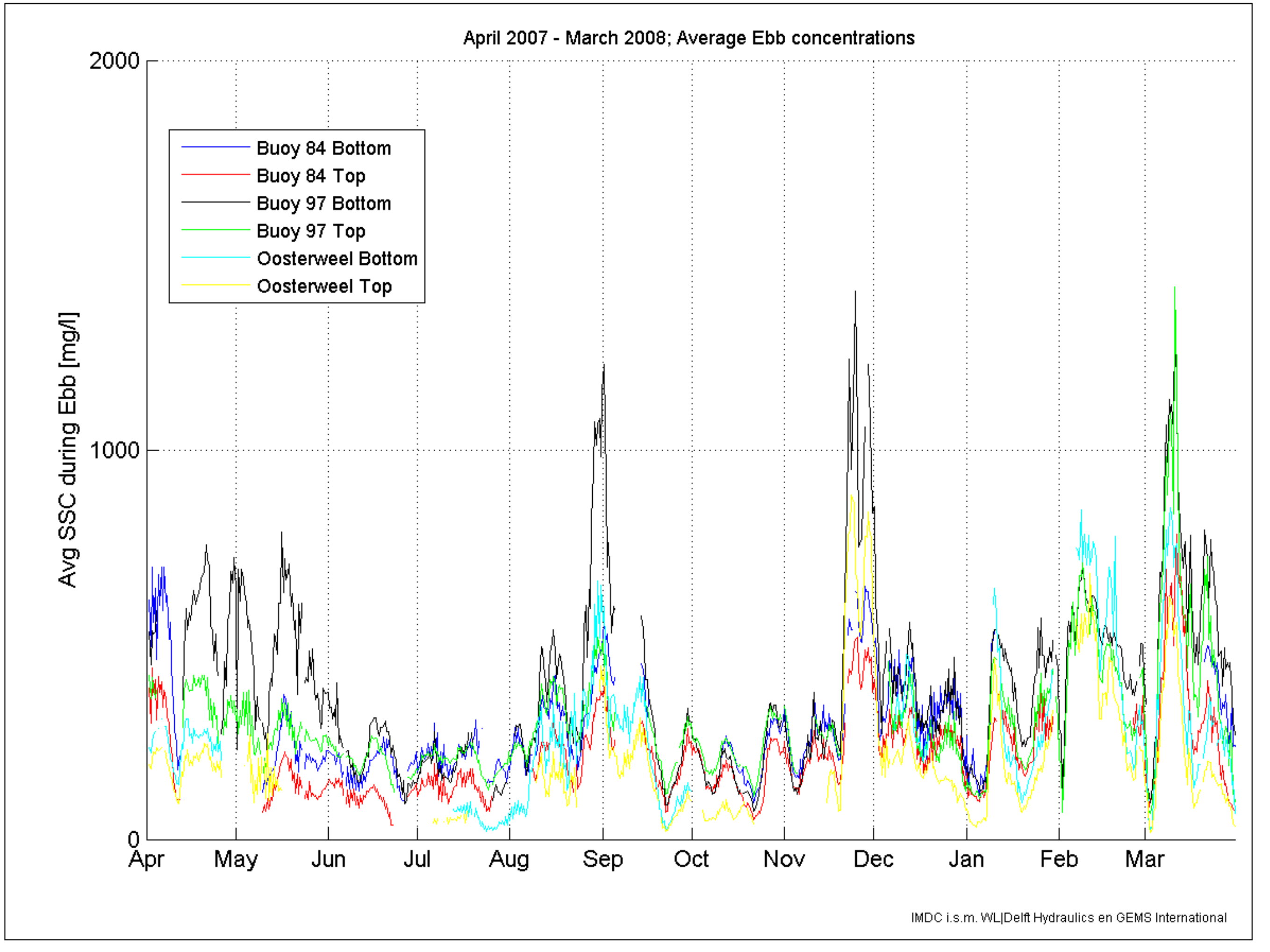
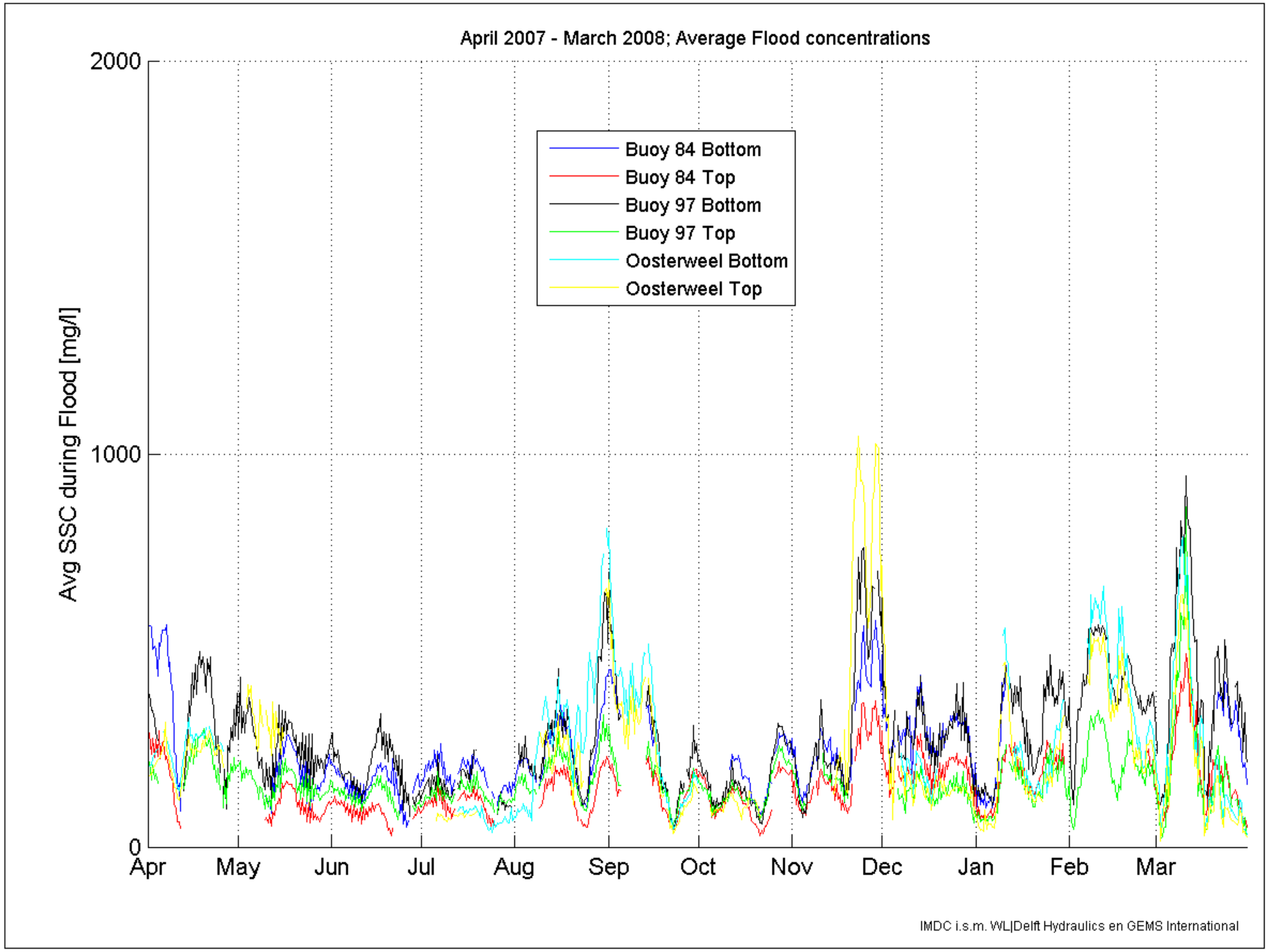


Annex-Figure F-13 Tidally averaged sediment concentrations during Ebb in all measurement stations. April 2007 to March 2008.



Annex-Figure F-14 Tidally averaged sediment concentrations during Flood in all measurement stations. April 2007 to March 2008.

Annex-Table F-1: Averaged ebb phase suspended sediment concentration, average value (C [mg/l]), standard deviation (σ) and amount of considered ebb phases (N) during considered period (Summer: Apr 2007-Sep 2007, Winter: Oct 2007-Mar 2008, Year: Apr 2007-Mar 2008)

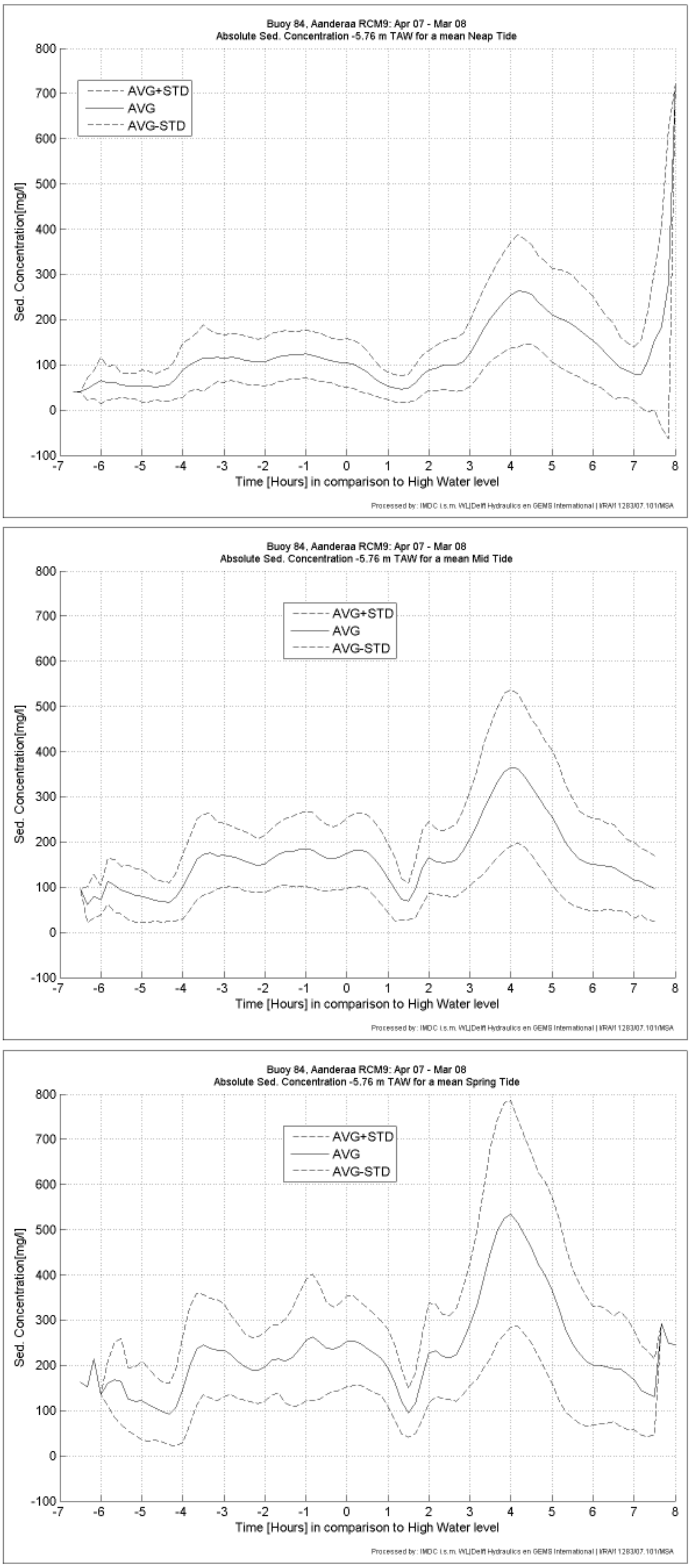
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year		
			C	σ	N	C	σ	N	C	σ	N	C	σ	N	C	σ	N	C	σ	N	C	σ	N
Buoy 84		Neap	177	59	26	221	49	16	233	93	39	194	61	16	194	59	42	222	87	55	210	77	97
	-8.1 m	Avg	231	120	55	254	74	45	315	106	77	357	141	12	241	102	100	321	111	89	279	113	189
	TAW	Spring	359	175	35	336	106	52	387	138	41	437	58	11	345	137	87	398	127	52	365	136	139
		All	257	147	116	287	99	113	313	124	157	313	138	39	272	126	229	313	127	196	291	128	425
		Neap	106	23	17	142	51	23	166	70	46	150	72	31	127	44	40	160	70	77	148	64	117
	-5.6 m	Avg	134	56	54	168	52	47	229	80	82	264	115	43	150	57	101	241	95	125	200	92	226
	TAW	Spring	222	110	37	245	74	54	293	110	49	383	154	42	235	90	91	334	139	91	285	127	182
		All	160	88	108	196	76	124	230	99	177	277	152	116	179	84	232	248	124	293	218	113	525
Buoy 97		Neap	309	139	32	221	129	26	231	132	48	338	171	45	269	141	58	283	160	93	277	153	151
	-7.8 m	Avg	349	159	70	280	141	51	347	226	78	455	132	53	320	155	121	391	200	131	357	183	252
	TAW	Spring	545	157	51	470	295	57	465	319	47	634	228	67	506	242	108	565	280	114	536	263	222
		All	406	183	153	350	242	134	347	250	173	496	222	165	380	214	287	420	248	338	401	234	625
		Neap	254	60	24	221	69	29	209	63	35	260	159	47	236	66	53	238	129	82	237	108	135
	-5.3 m	Avg	240	62	69	259	68	57	252	63	62	370	131	49	249	66	126	304	115	111	275	96	237
	TAW	Spring	330	65	51	321	97	55	283	48	35	543	251	69	326	83	106	456	240	104	390	190	210
		All	274	75	144	276	90	141	249	65	132	411	229	165	275	82	285	339	194	297	308	153	582
Oosterweel		Neap	219	57	11	169	129	39	255	28	4	253	198	28	180	119	50	253	185	32	208	152	82
	- 5.8 m	Avg	248	31	14	209	109	47	319	80	19	339	175	49	218	98	61	333	154	68	279	142	129
	TAW	Spring	267	16	17	267	182	48	427	0	1	458	235	59	267	156	65	458	233	60	358	218	125
		All	248	40	42	218	149	134	313	79	24	373	221	136	225	132	176	364	207	160	291	185	336
		Neap	161	44	17	111	69	21	134	76	32	127	127	36	133	64	38	130	105	68	131	92	106
	- 2.3 m	Avg	173	43	21	139	75	42	216	191	59	213	121	50	150	68	63	215	162	109	191	138	172
	TAW	Spring	208	35	30	187	112	37	388	309	31	324	172	68	196	87	67	344	225	99	284	195	166
		All	185	44	68	151	94	100	238	227	122	242	166	154	165	79	168	240	195	276	212	165	444

Annex-Table F-2: Averaged flood phase suspended sediment concentration, average value (C [mg/l]), standard deviation (σ) and amount of considered flood phases (N) during considered period (Summer: Apr 2007-Sep 2007, Winter: Oct 2007-Mar 2008, Year: Apr 2007-Mar 2008).

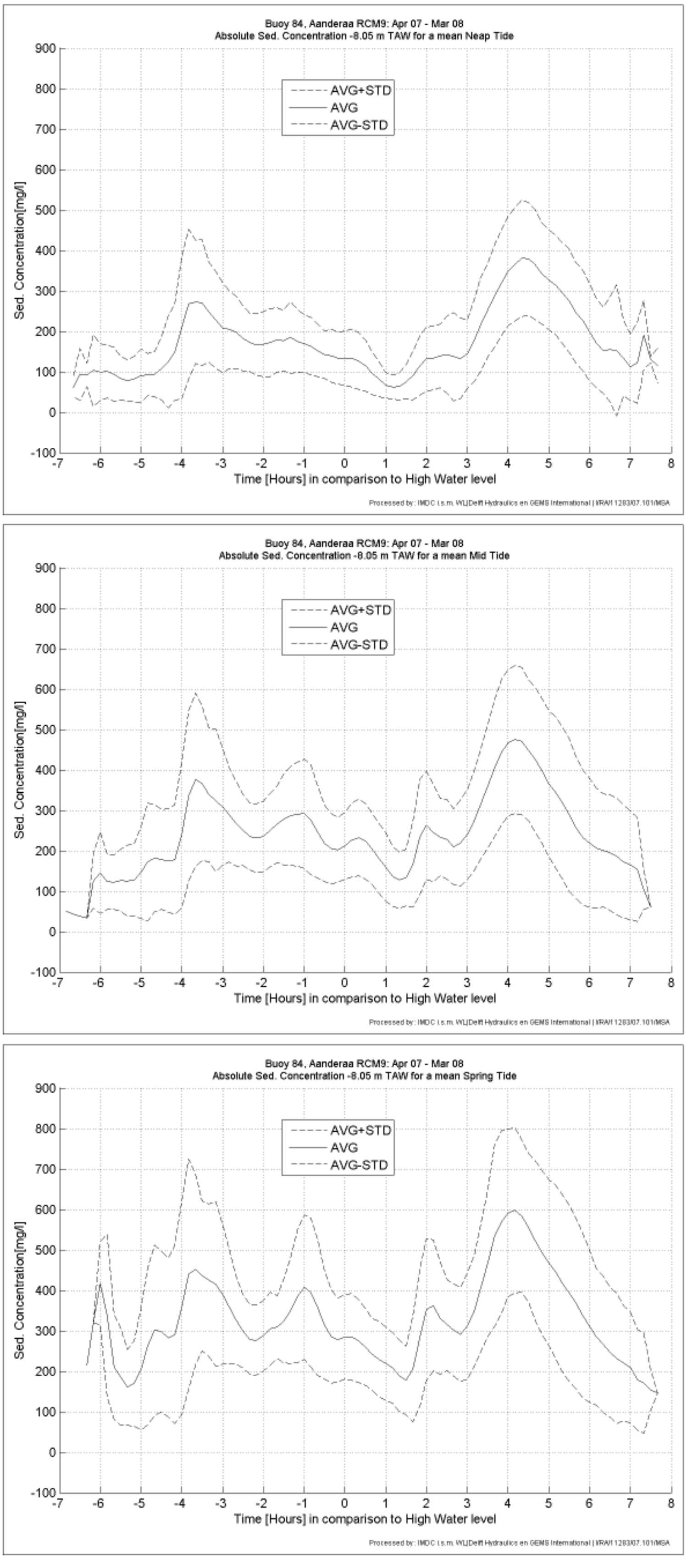
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year		
			C	σ	N	C	σ	N	C	σ	N	C	σ	N	C	σ	N	C	σ	N	C	σ	N
Buoy 84		Neap	125	46	25	140	29	15	181	73	38	153	57	16	131	41	40	173	69	54	155	62	94
	-8.1 m	Avg	204	101	58	218	54	44	267	80	75	288	105	12	210	84	102	270	83	87	237	89	189
		Spring	308	141	35	285	82	52	340	107	41	363	41	11	295	109	87	345	97	52	313	107	139
		All	218	125	118	239	83	111	265	103	154	254	114	39	228	107	229	263	105	193	244	107	422
		Neap	73	19	16	72	21	21	108	46	45	103	42	31	72	20	37	106	44	76	95	41	113
	-5.6 m	Avg	100	36	57	122	31	45	170	53	81	186	68	43	110	36	102	175	59	124	146	60	226
	TAW	Spring	161	69	37	171	37	54	224	71	47	254	87	41	167	52	91	238	80	88	202	76	179
		All	117	58	110	135	49	120	169	71	173	188	91	115	126	54	230	176	80	288	154	74	518
Buoy 97		Neap	173	50	32	131	47	26	163	80	48	248	104	45	154	53	58	204	102	93	185	89	151
	-7.8 m	Avg	226	67	73	207	70	49	260	121	79	346	110	52	219	69	122	294	123	131	258	107	253
	TAW	Spring	340	80	51	321	143	56	351	177	47	493	155	67	330	117	107	434	178	114	384	160	221
		All	253	94	156	241	128	131	258	147	174	379	164	164	247	111	287	317	166	338	285	148	625
		Neap	135	31	26	120	31	29	121	28	35	101	47	47	127	31	55	110	41	82	117	38	137
	-5.3 m	Avg	145	36	72	163	38	55	142	34	64	166	59	50	153	38	127	152	48	114	153	43	241
	TAW	Spring	203	45	51	197	55	55	177	41	35	281	138	69	200	50	106	246	125	104	223	98	210
		All	163	48	149	168	53	139	146	40	134	195	124	166	165	50	288	173	99	300	169	79	588
Oosterweel		Neap	221	54	11	209	148	39	190	38	4	220	161	28	212	133	50	216	151	32	213	139	82
	- 5.8 m	Avg	254	35	13	268	138	47	190	37	19	287	158	49	265	123	60	260	142	68	262	133	128
	TAW	Spring	274	27	16	339	224	46	136	0	1	372	218	59	322	195	62	368	218	60	344	207	122
		All	253	43	40	275	182	132	188	37	24	310	195	136	270	161	172	292	185	160	280	173	332
		Neap	230	75	17	183	121	21	178	98	30	143	126	36	204	104	38	159	115	66	175	112	104
	- 2.3 m	Avg	268	50	21	205	120	44	232	242	59	220	129	50	225	107	65	227	198	109	226	169	174
	TAW	Spring	265	58	32	280	180	38	434	370	31	315	177	67	273	138	70	353	258	98	320	219	168
		All	258	62	70	228	149	103	270	274	120	244	165	153	240	122	173	255	220	273	249	188	446

Annex-Table F-3: Averaged tide suspended sediment concentration, average value (C [mg/l]), standard deviation (σ) and amount of considered tides (N) during considered period (Summer: Apr 2007-Sep 2007, Winter: Oct 2007-Mar 2008, Year: Apr 2007-Mar 2008)

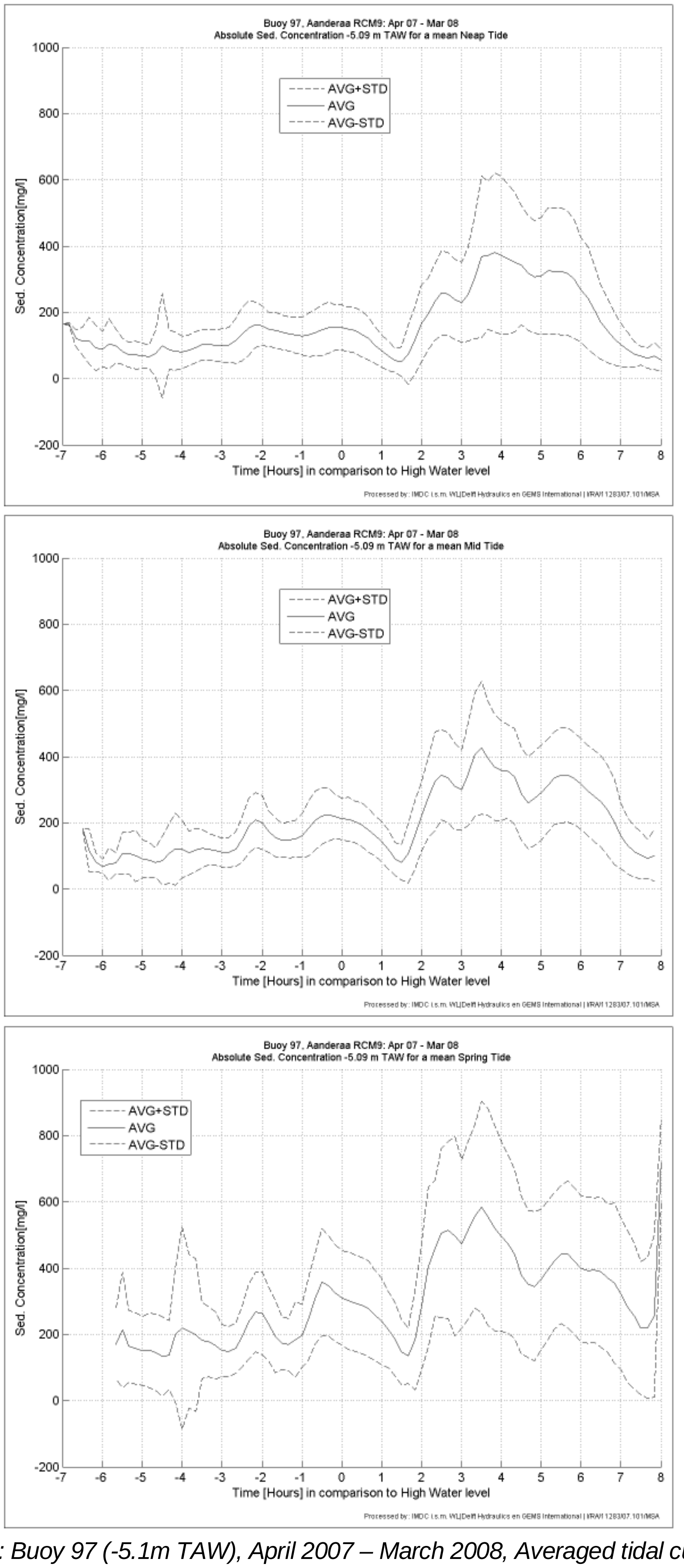
			Apr-Jun			Jul-Sep			Oct-Dec			Jan-Mar			Summer			Winter			Year		
			C	σ	N	C	σ	N	C	σ	N	C	σ	N	C	σ	N	C	σ	N	C	σ	N
Buoy 84		Neap	150	50	25	179	33	15	205	80	38	173	55	16	161	47	40	196	74	54	181	66	94
	-8.1 m	Avg	218	110	56	238	61	43	291	92	75	324	120	12	227	92	99	296	96	87	259	100	186
	TAW	Spring	335	156	35	311	93	52	364	121	40	399	45	11	320	122	87	371	109	51	339	119	138
		All	238	135	116	265	89	110	289	112	153	283	124	39	251	115	226	288	114	192	268	116	418
		Neap	89	20	16	107	30	21	136	57	45	126	54	31	99	27	37	132	55	76	121	50	113
	-5.6 m	Avg	117	46	55	145	38	45	199	66	81	224	89	43	130	45	100	208	75	124	173	74	224
	TAW	Spring	191	88	37	207	54	54	260	90	47	318	119	41	201	70	91	287	108	88	243	100	179
		All	138	73	108	166	59	120	199	84	173	231	120	115	153	67	228	212	101	288	186	92	516
Buoy 97		Neap	240	81	31	172	82	25	198	104	48	292	130	45	209	88	56	244	126	93	231	114	149
	-7.8 m	Avg	287	107	71	246	101	49	307	173	77	401	116	51	270	106	120	344	159	128	308	141	248
	TAW	Spring	445	106	51	393	203	56	409	246	47	566	188	67	418	165	107	501	226	114	461	203	221
		All	330	131	153	295	175	130	304	197	172	439	190	163	314	154	283	370	205	335	344	185	618
		Neap	199	39	23	170	46	28	166	43	35	180	95	47	183	45	51	174	77	82	177	67	133
	-5.3 m	Avg	193	48	70	213	52	55	197	46	62	269	89	49	202	50	125	229	77	111	215	65	236
	TAW	Spring	268	50	51	261	75	55	231	40	35	414	193	69	264	64	106	353	181	104	308	142	210
		All	221	59	144	223	70	138	198	49	132	304	174	165	222	64	282	257	143	297	240	113	579
Oosterweel		Neap	220	54	11	188	140	38	222	32	4	236	177	28	195	126	49	234	165	32	211	143	81
	- 5.8 m	Avg	250	32	13	239	123	47	257	56	19	316	163	48	241	109	60	299	143	67	272	131	127
	TAW	Spring	270	19	15	298	201	46	284	0	1	422	223	58	291	175	61	419	222	59	354	209	120
		All	249	41	39	245	164	131	253	53	24	345	206	134	246	145	170	331	194	158	287	175	328
		Neap	195	53	17	146	93	21	155	83	30	135	125	36	168	81	38	144	108	66	153	99	104
	- 2.3 m	Avg	219	35	21	178	96	41	224	214	59	216	122	49	192	83	62	220	178	108	210	150	170
	TAW	Spring	233	33	30	236	143	36	411	338	31	321	173	67	235	107	66	350	239	98	303	205	164
		All	219	42	68	192	119	98	255	249	120	243	165	152	203	96	166	248	206	272	231	174	438



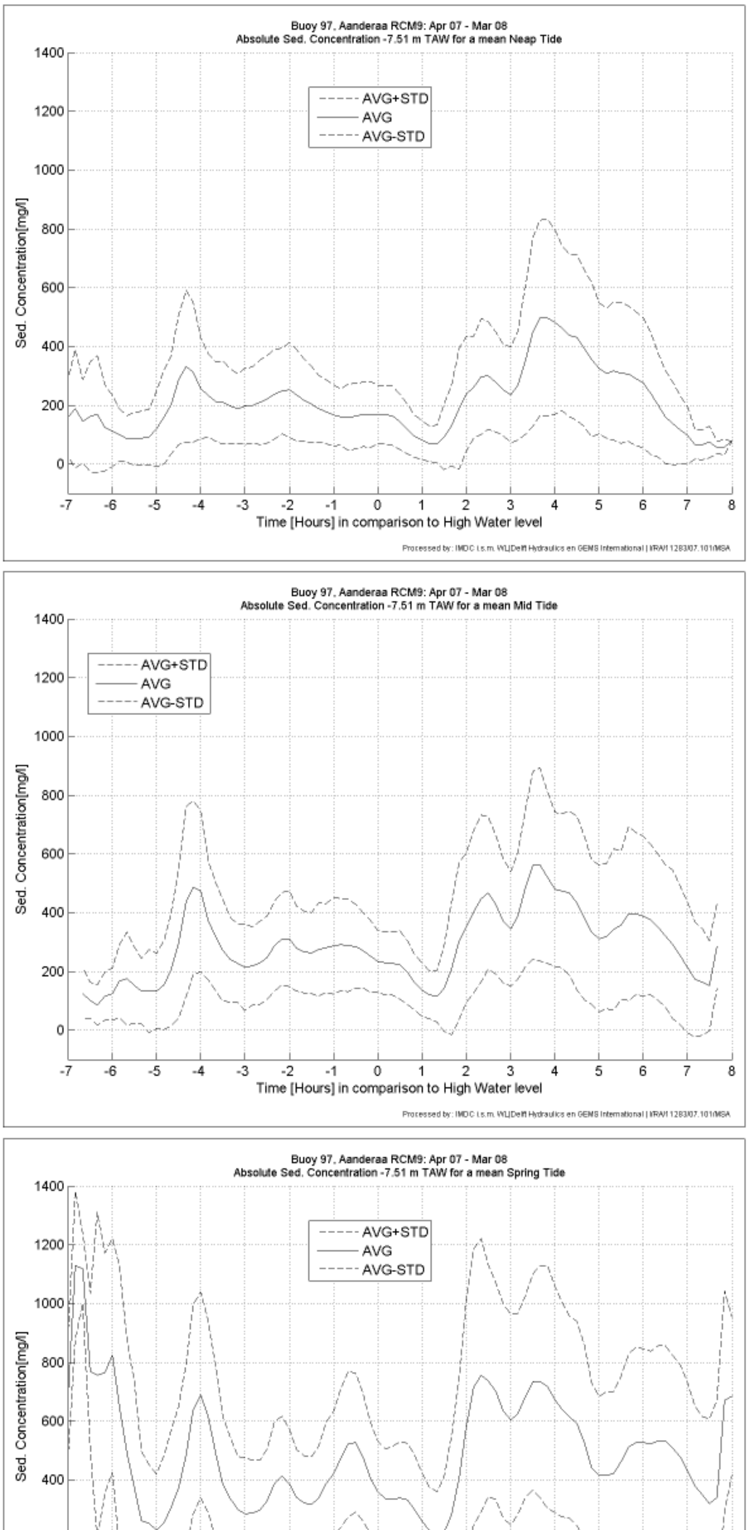
Annex-Figure F-15: Buoy 84 (-5.8m TAW), April 2007 – March 2008, Averaged tidal curve of the relative suspended sediment concentration for an averaged (a) neap, (b) average (c) spring tide



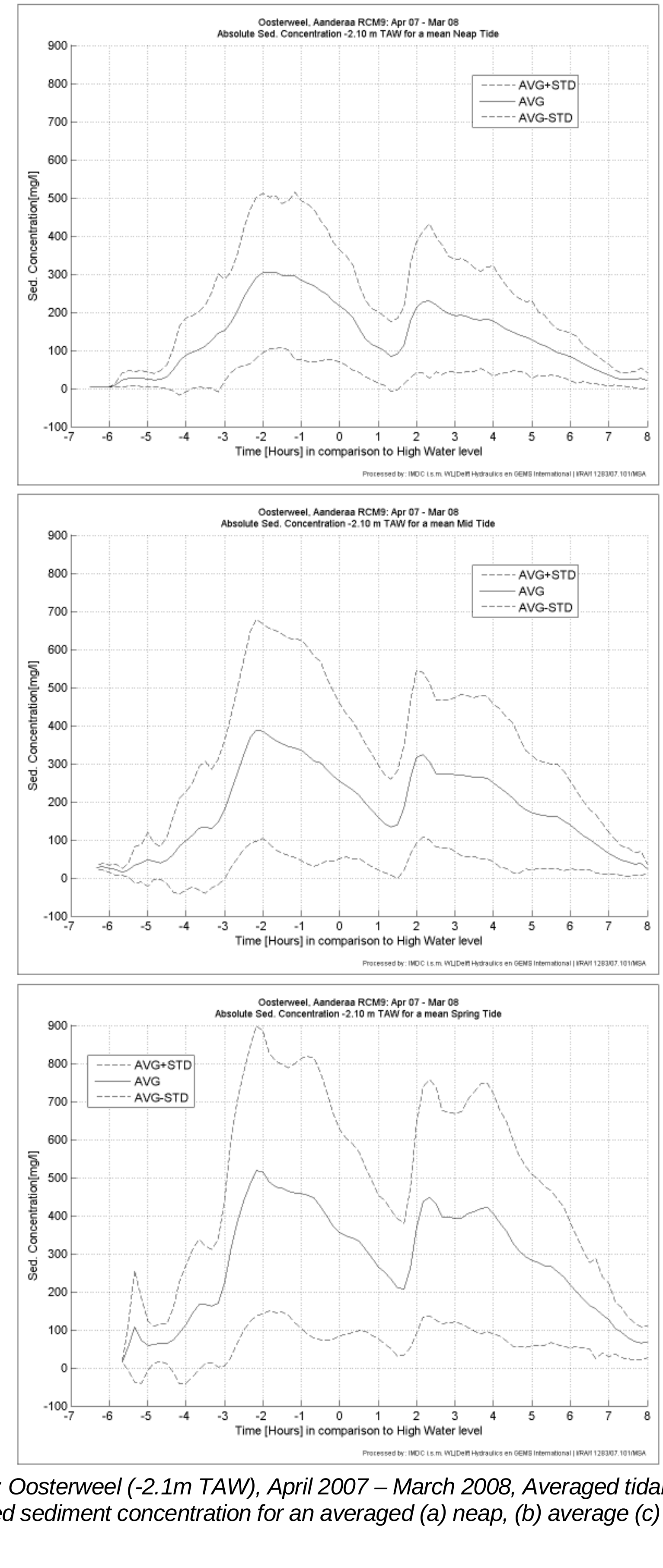
Annex-Figure F-16: Buoy 84 (-8.1m TAW), April 2007 – March 2008, Averaged tidal curve of the relative suspended sediment concentration for an averaged (a) neap, (b) average (c) spring tide



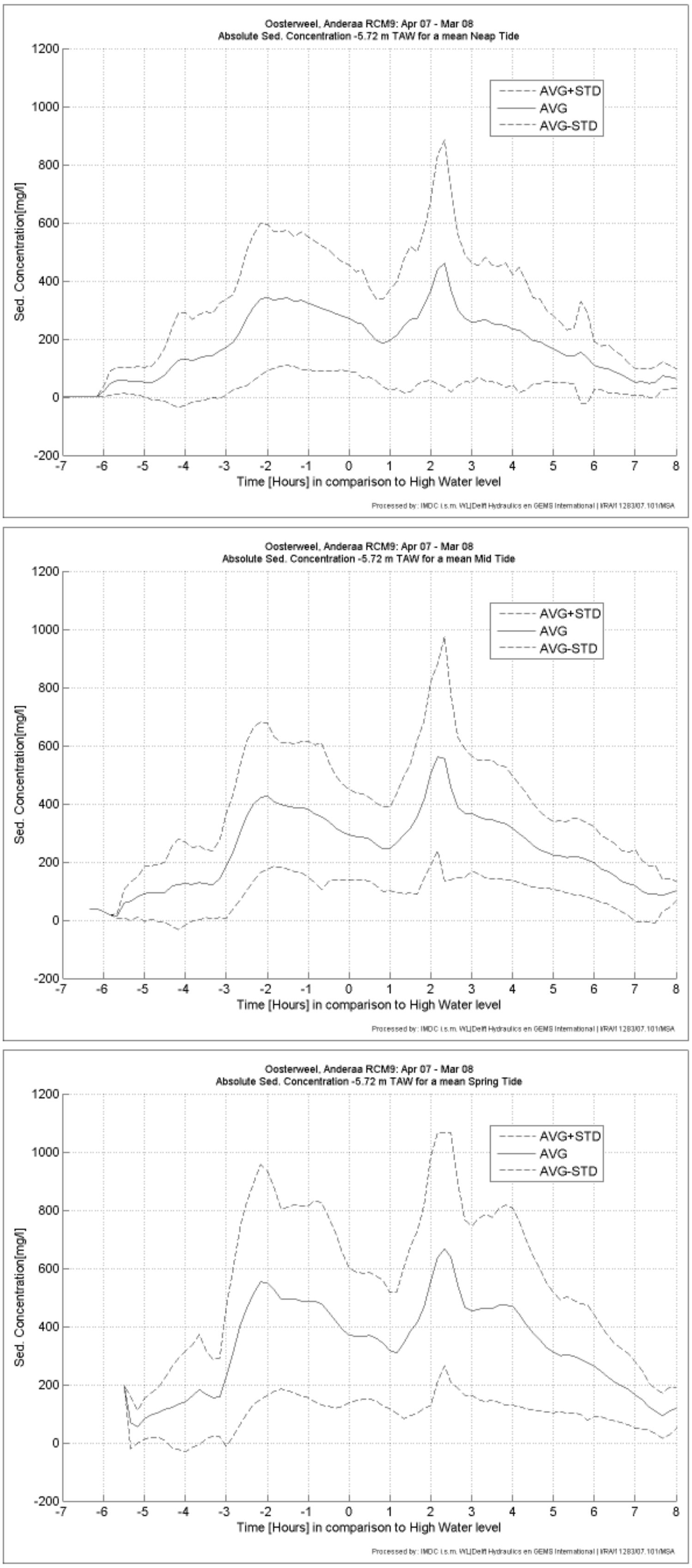
Annex-Figure F-17: Buoy 97 (-5.1m TAW), April 2007 – March 2008, Averaged tidal curve of the relative suspended sediment concentration for an averaged (a) neap, (b) average (c) spring tide



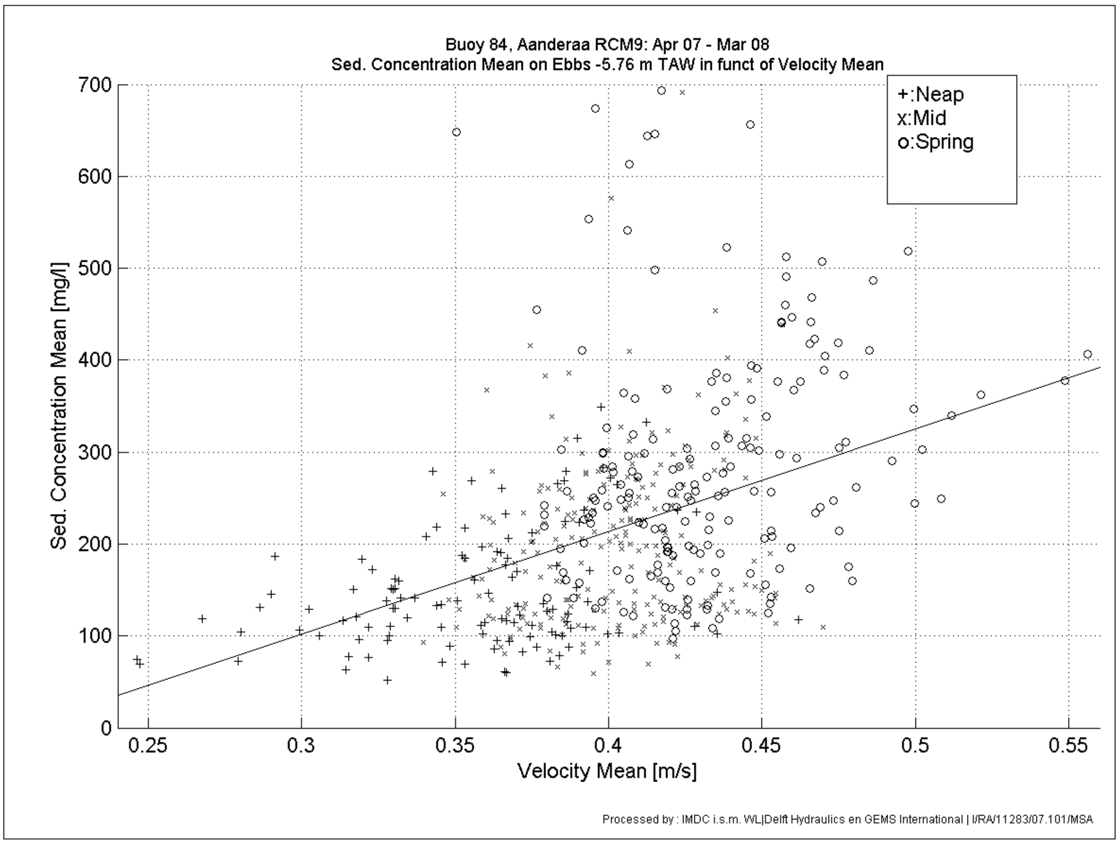
Annex-Figure F-18: Buoy 97 (-7.5m TAW), April 2007 – March 2008, Averaged tidal curve of the relative suspended sediment concentration for an averaged (a) neap, (b) average (c) spring tide

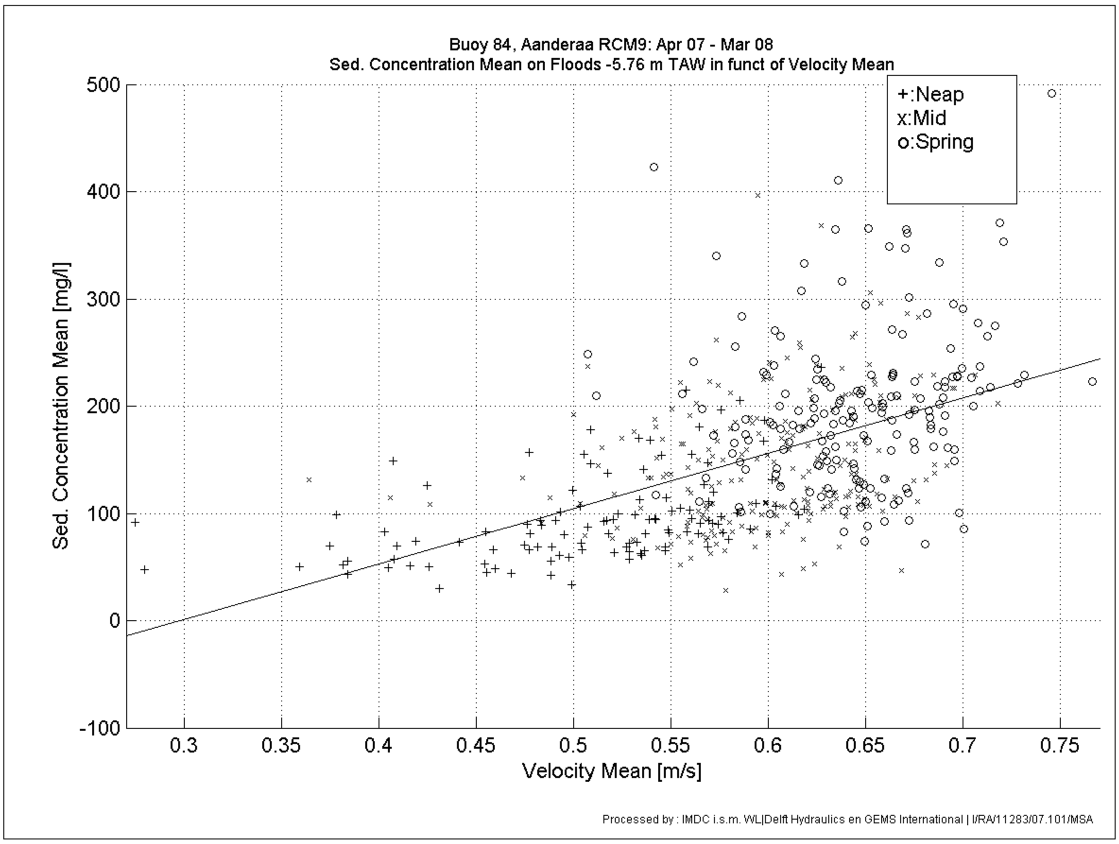


Annex-Figure F-19: Oosterweel (-2.1m TAW), April 2007 – March 2008, Averaged tidal curve of the relative suspended sediment concentration for an averaged (a) neap, (b) average (c) spring tide

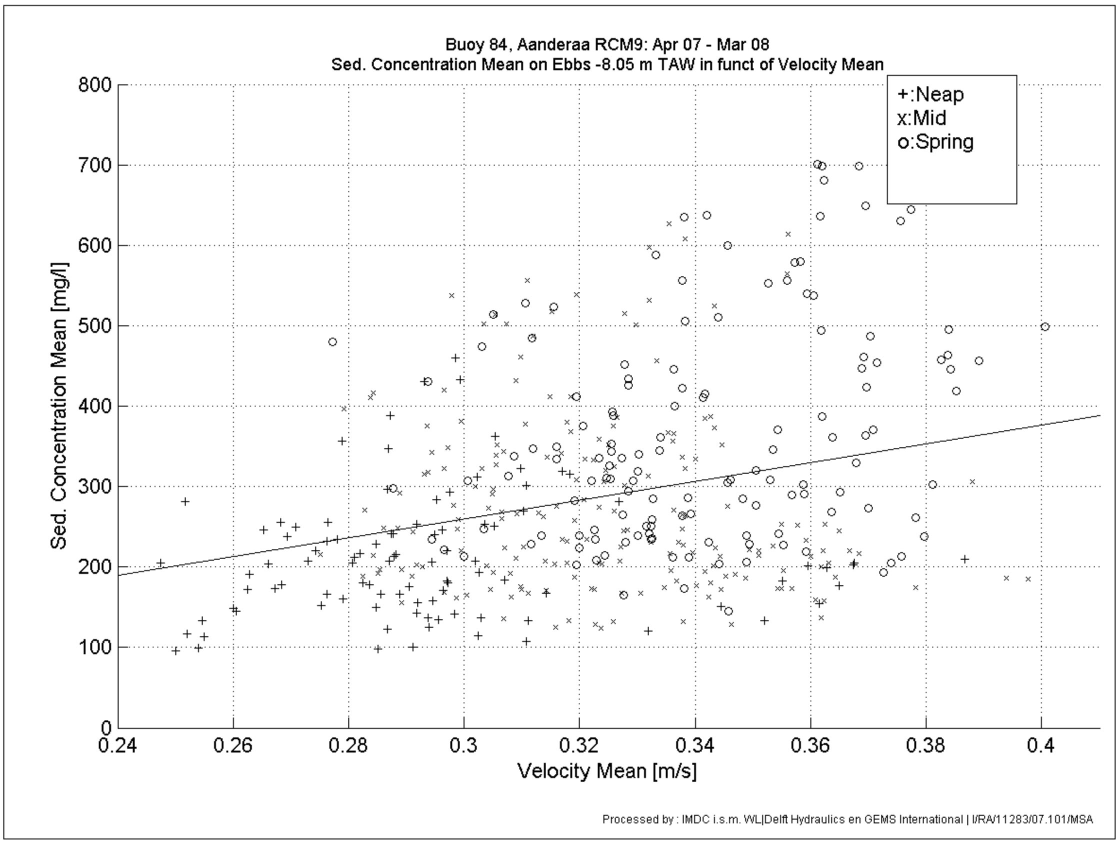


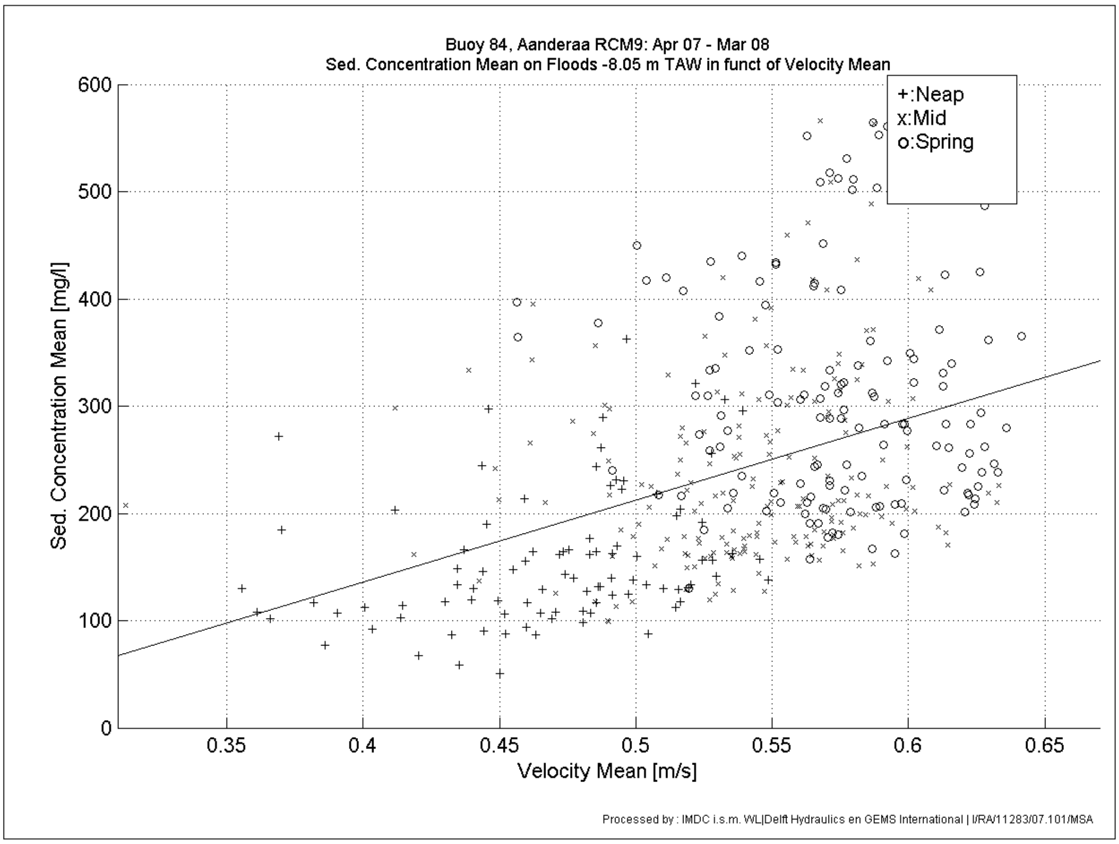
Annex-Figure F-20: Oosterweel (-5.7m TAW), April 2007 – March 2008, Averaged tidal curve of the relative suspended sediment concentration for an averaged (a) neap, (b) average (c) spring tide



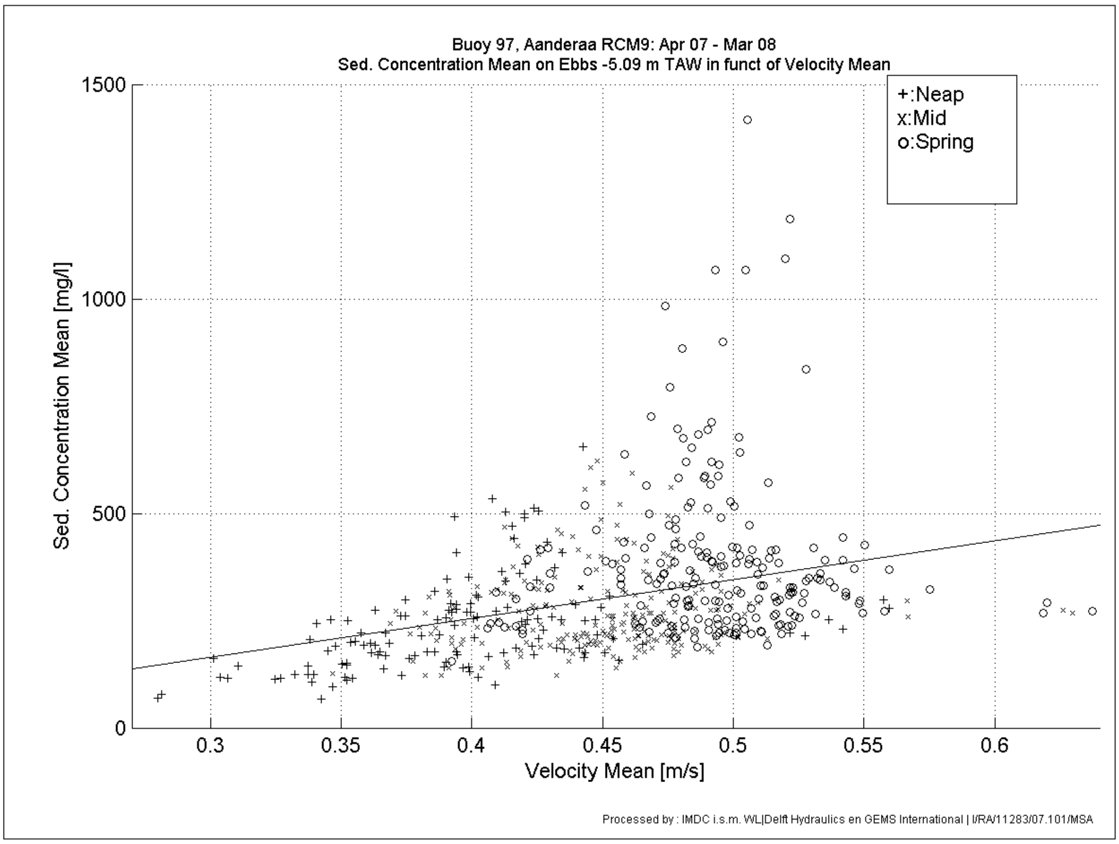


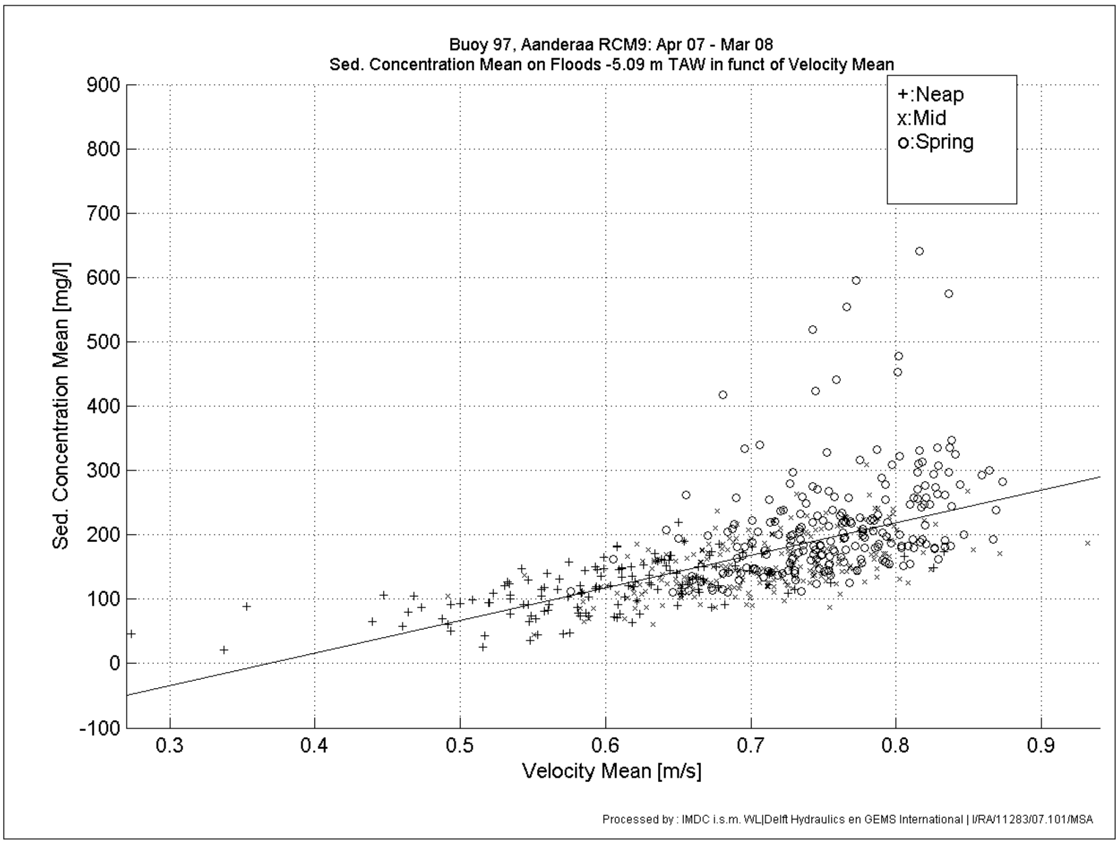
Annex-Figure F-21: Buoy 84 (-5.6m TAW), ebb phase (R = 0.41; sig = 0.00; n = 547;) and flood phase (R = 0.50; sig = 0.00; n = 537;) average suspended sediment concentration vs flow velocity



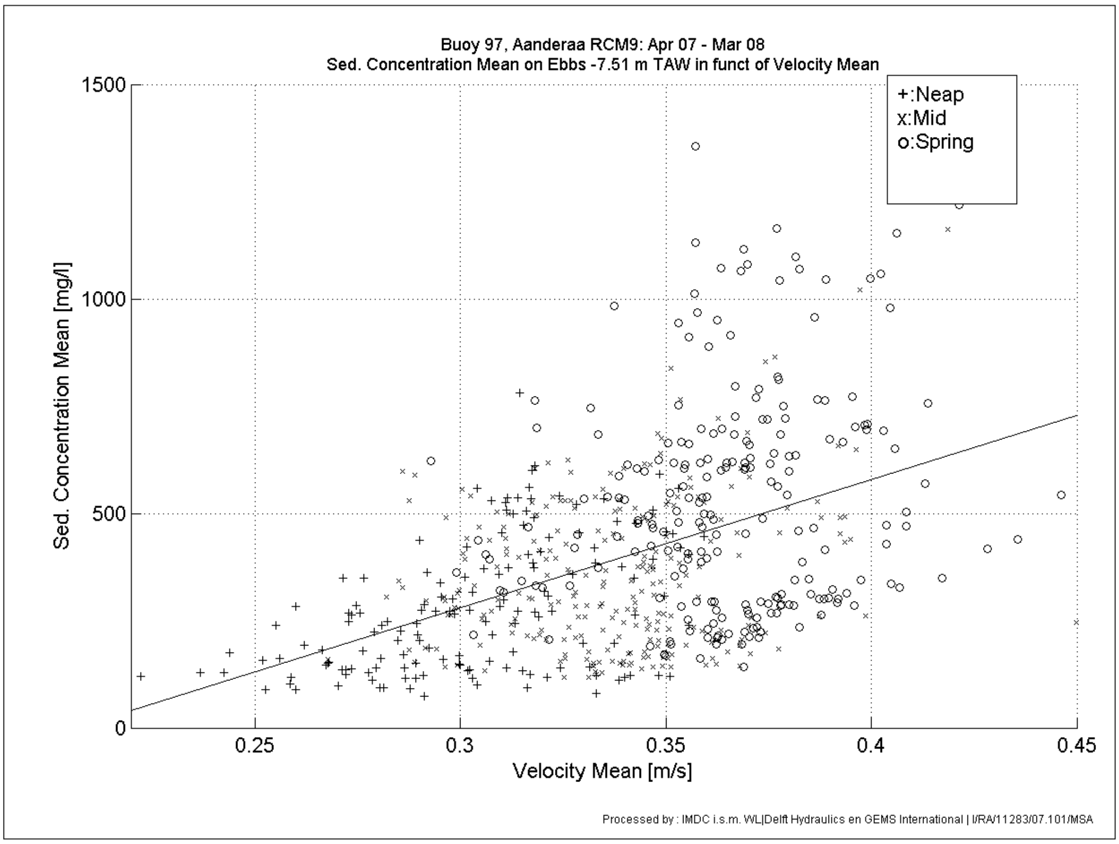


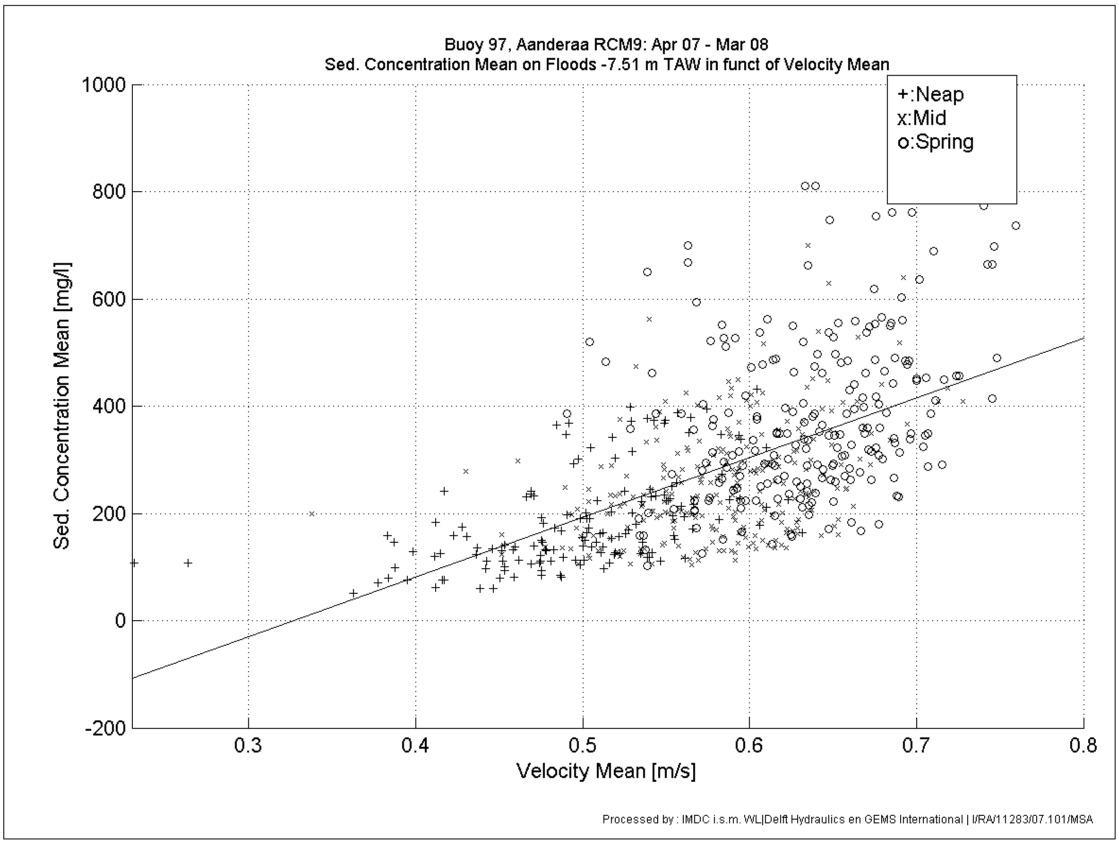
Annex-Figure F-22: Buoy 84 (-8.1m TAW), ebb phase (R = 0.28; sig = 0.00; n = 447;) and flood phase (R = 0.41; sig = 0.00; n = 443;) average suspended sediment concentration vs flow velocity



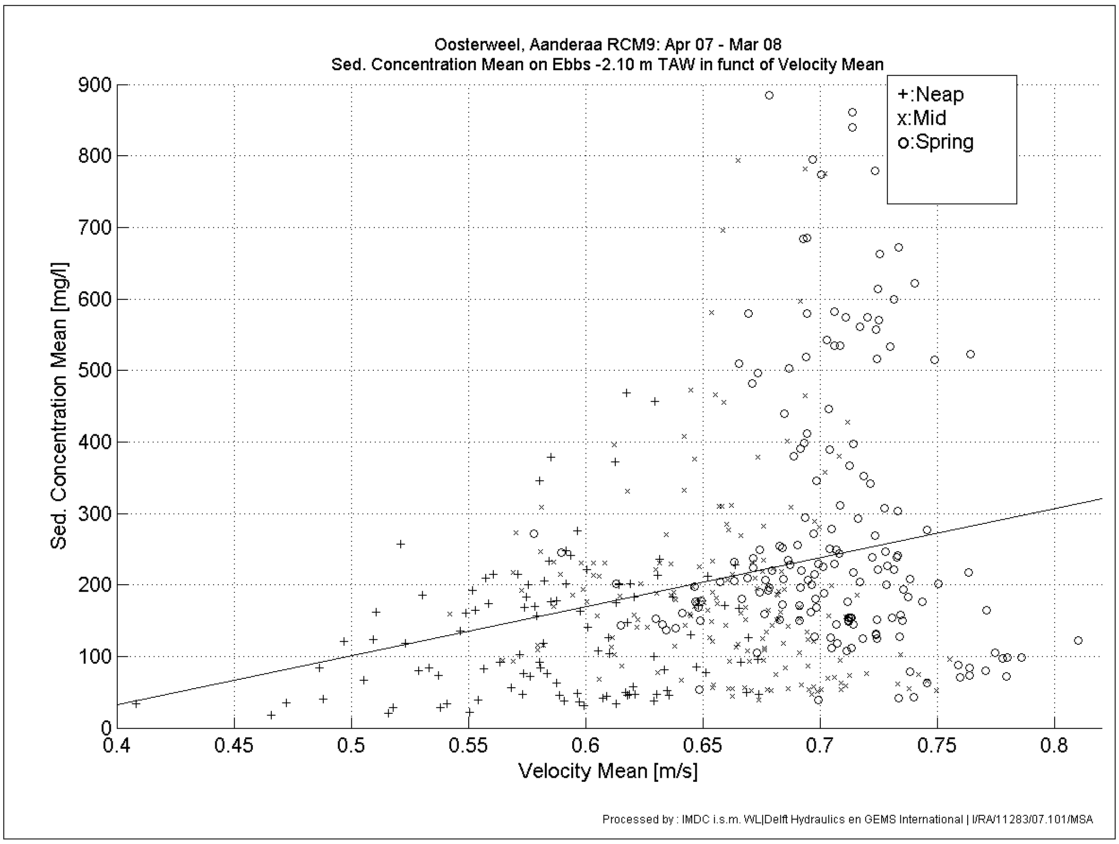


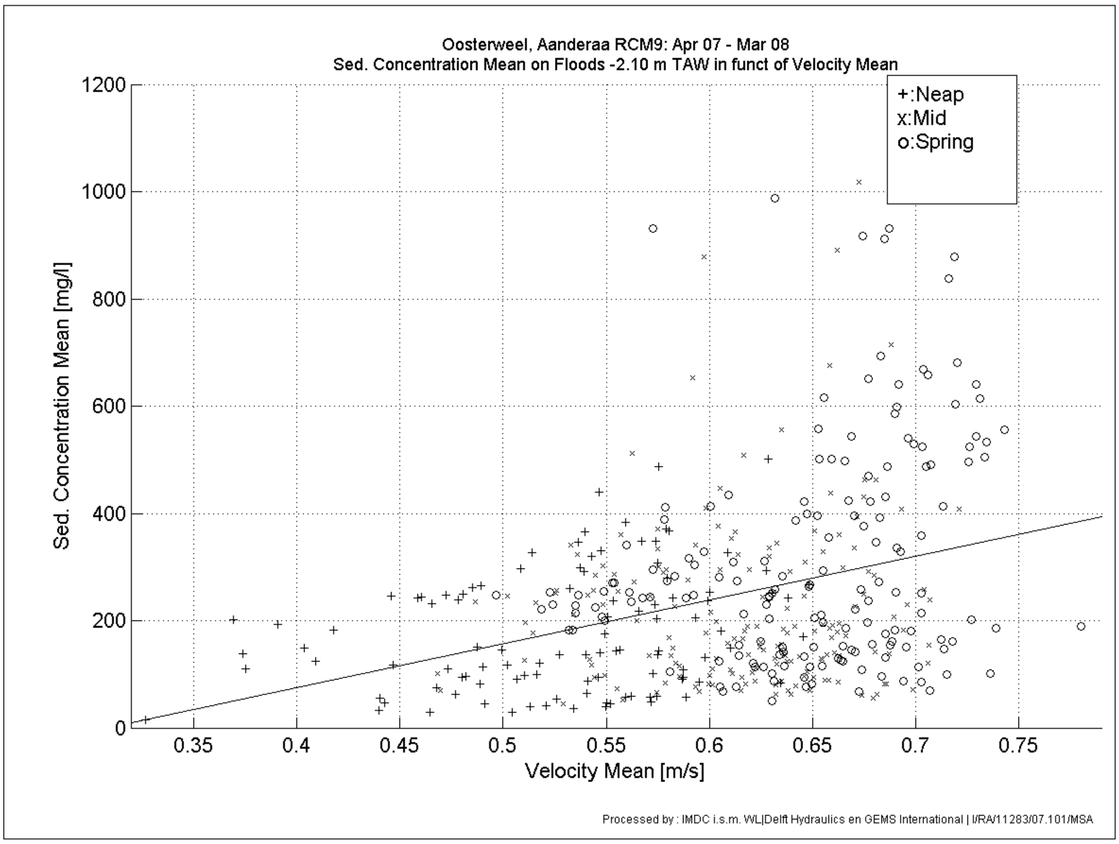
Annex-Figure F-23: Buoy 97 (-5.1m TAW), ebb phase (R = 0.32; sig = 0.00; n = 609;)and flood phase (R = 0.57; sig = 0.00; n = 617;) average suspended sediment concentration vs flow velocity



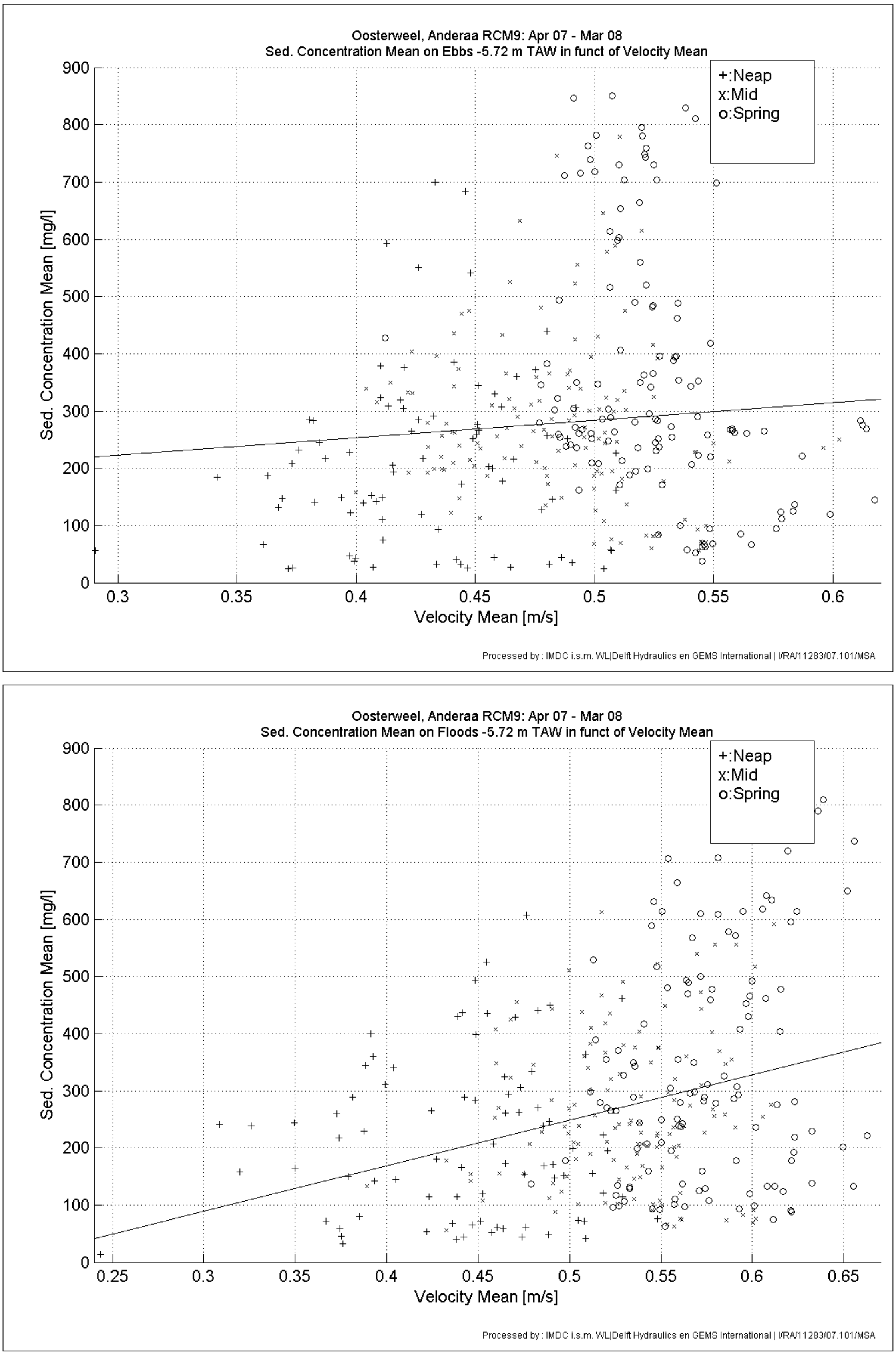


Annex-Figure F-24: Buoy 97 (-7.5m TAW), ebb phase (R = 0.46; sig = 0.00; n = 644;) and flood phase (R = 0.58; sig = 0.00; n = 645;) average suspended sediment concentration vs flow velocity

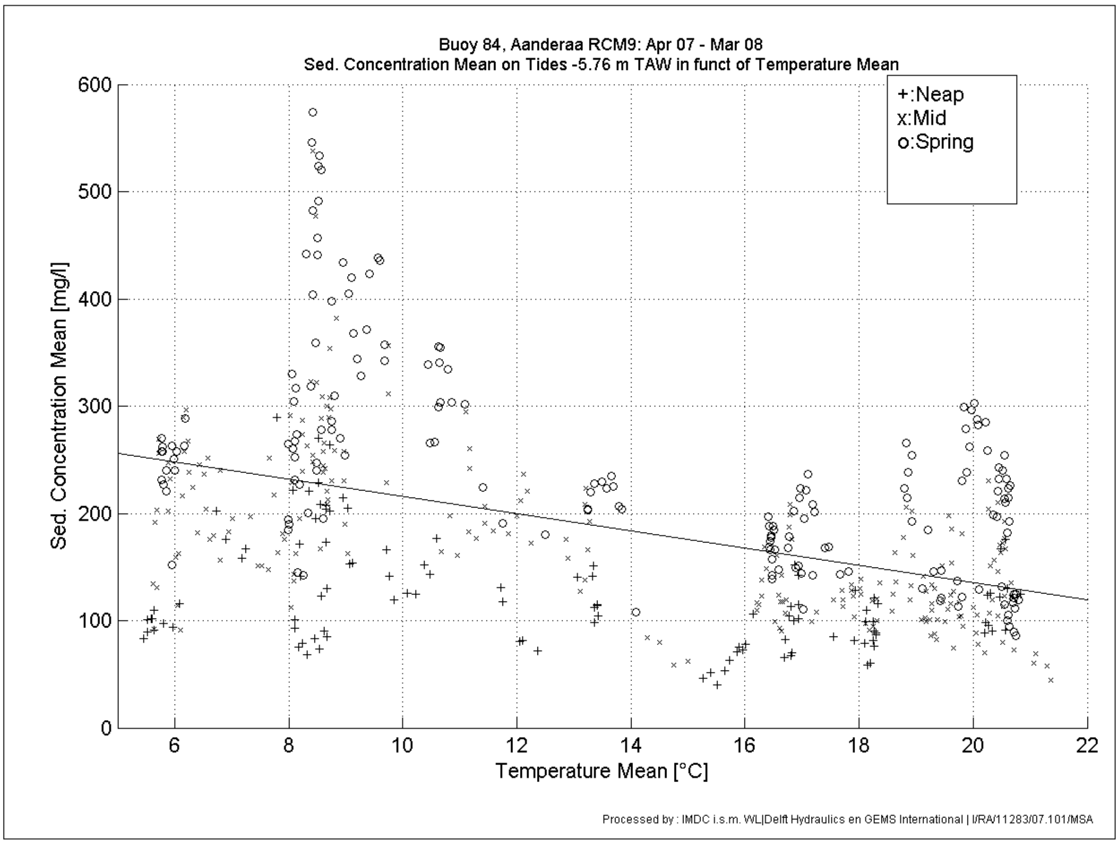




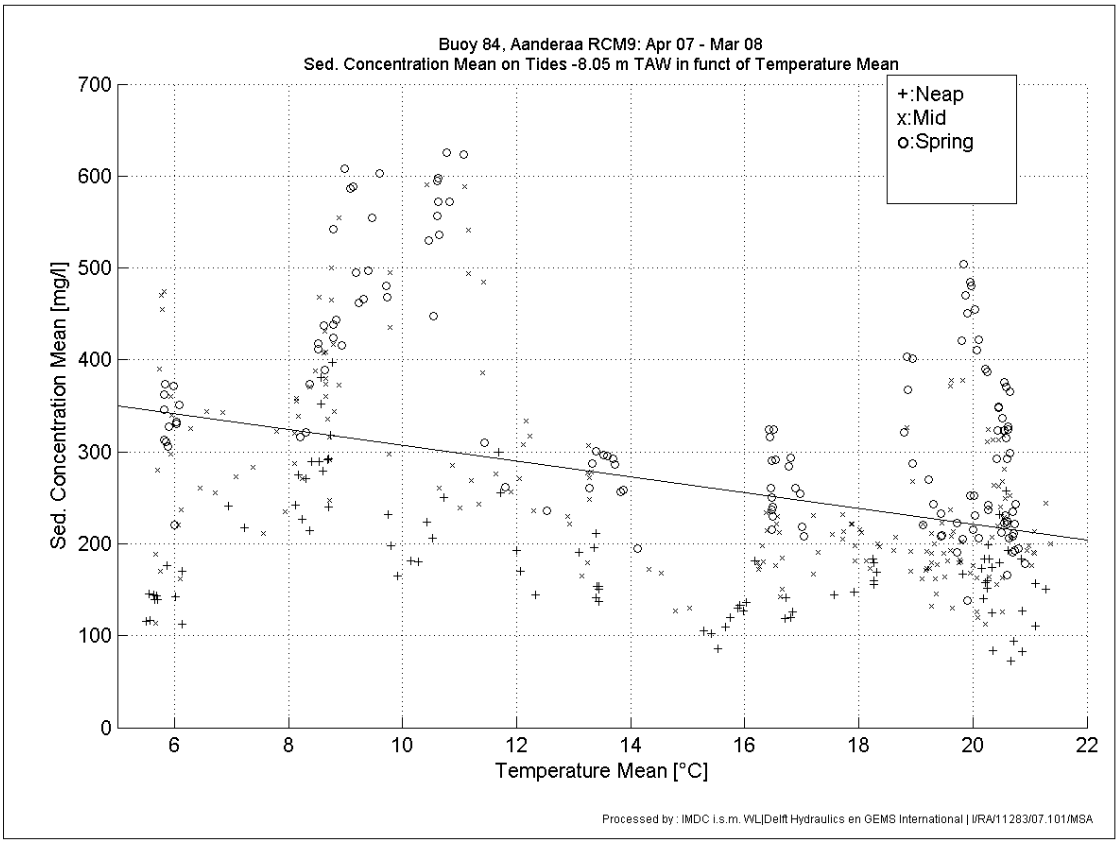
Annex-Figure F-25: Oosterweel (-2.1m TAW), ebb phase (R = 0.26; sig = 0.00; n = 456;) and flood phase (R = 0.33; sig = 0.00; n = 463;) average suspended sediment concentration vs flow velocity



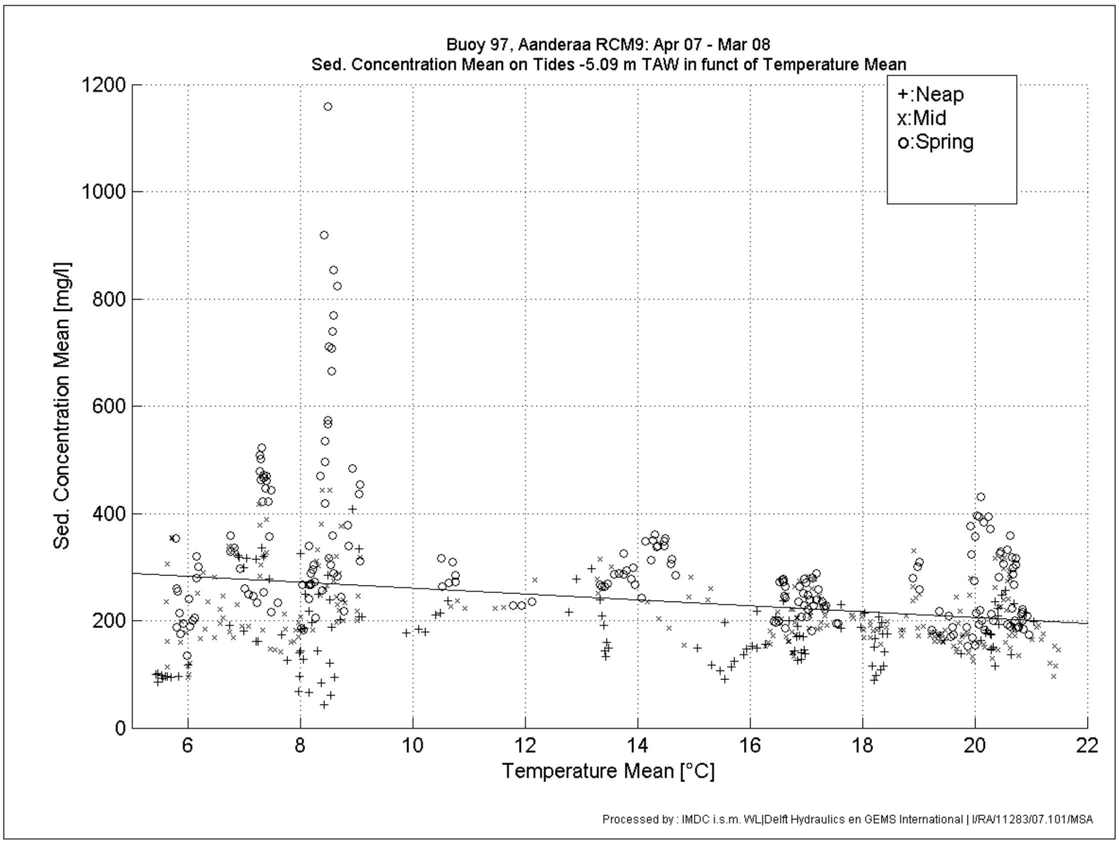
Annex-Figure F-26: Oosterweel (-5.7m TAW), ebb phase (R = 0.09; sig = 0.10; n = 365;) and flood phase (R = 0.31; sig = 0.00; n = 361;) average suspended sediment concentration vs flow velocity



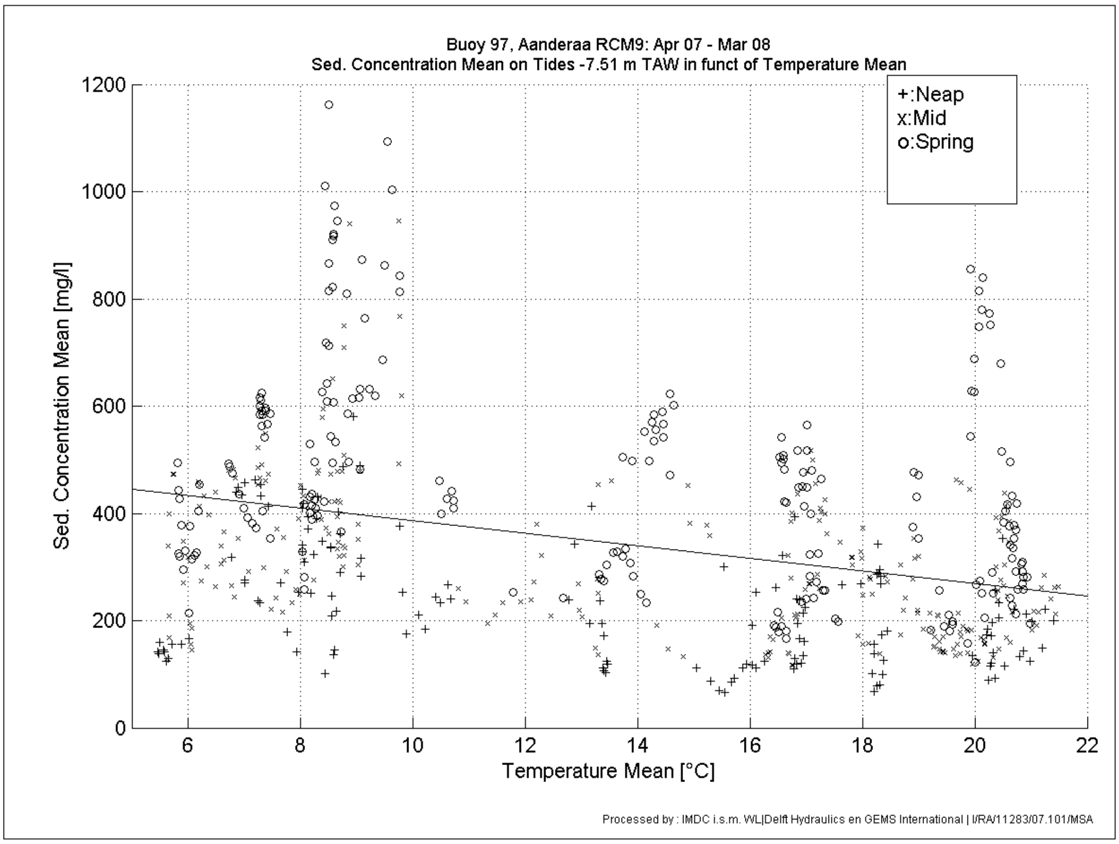
Annex-Figure F-27: Buoy 84 (-5.6m TAW), tidal average sediment concentration vs temperature (R = -0.45; sig = 0.00; n = 532;)



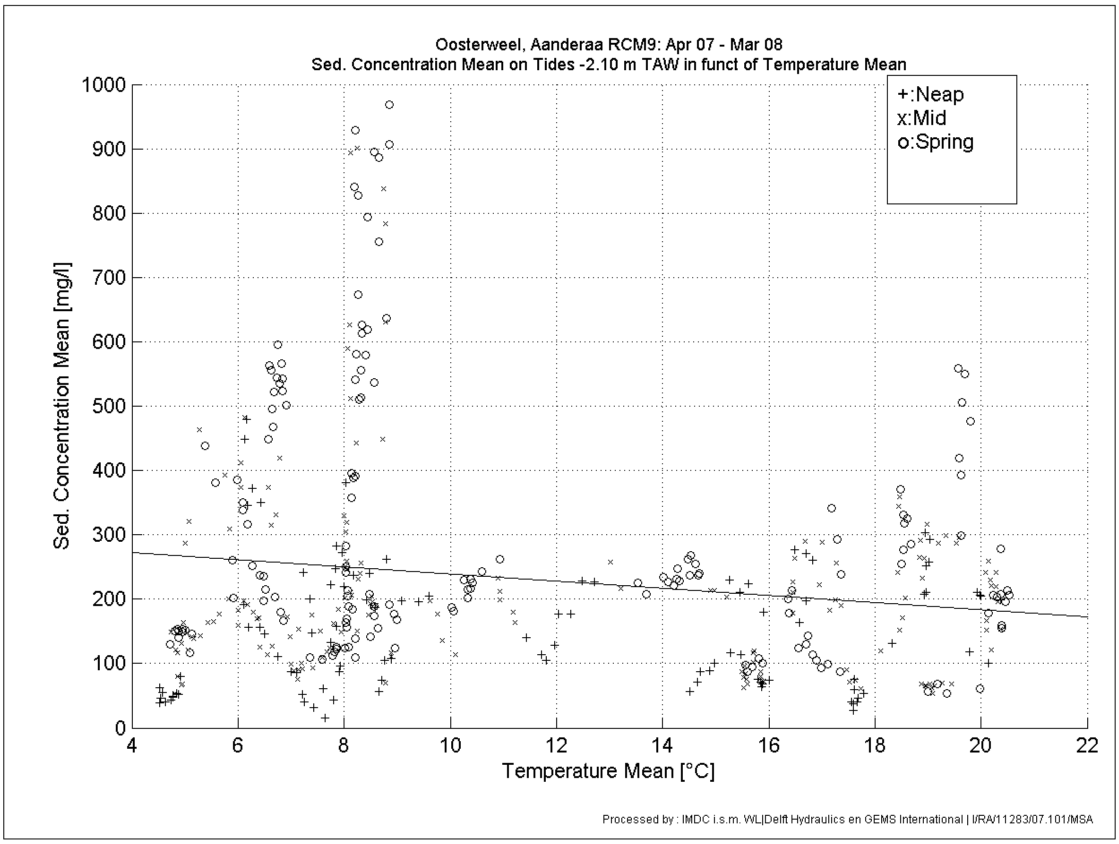
Annex-Figure F-28: Buoy 84 (-8.1m TAW), tidal average sediment concentration vs temperature (R = -0.39; sig = 0.00; n = 436;)



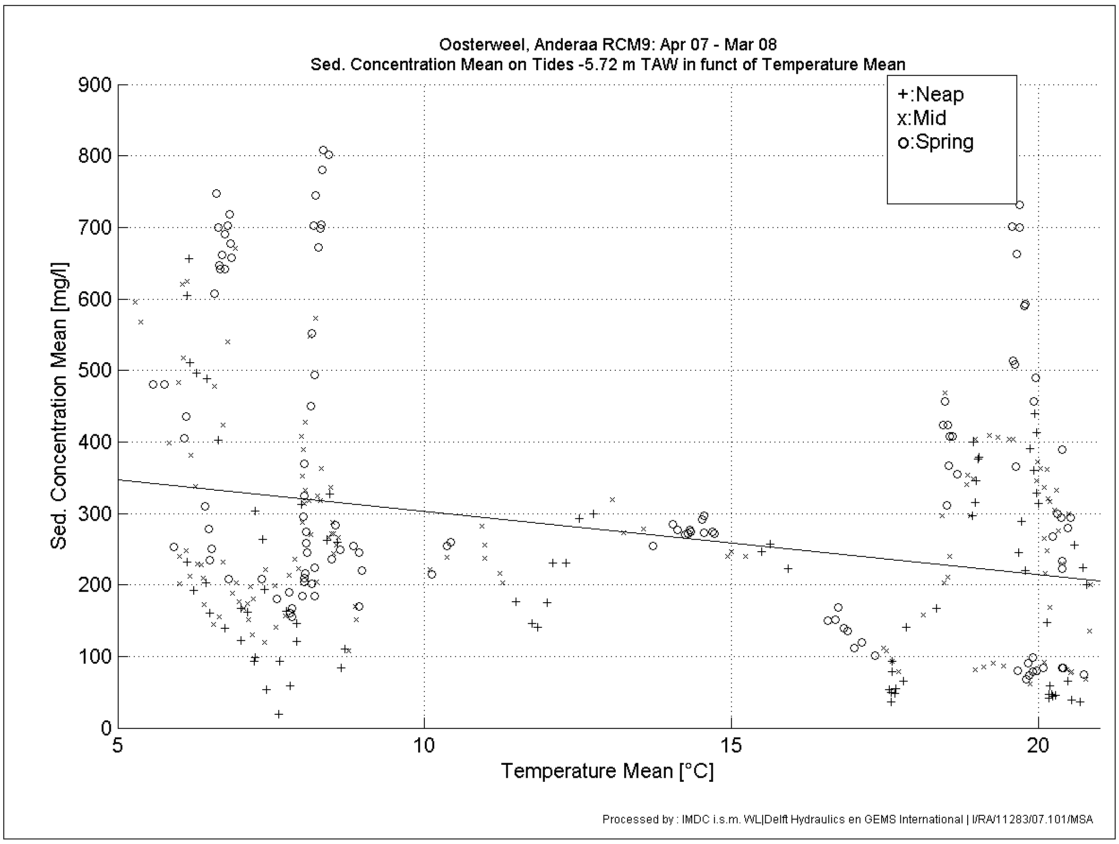
Annex-Figure F-29: Buoy 97 (-5.1m TAW), tidal average sediment concentration vs temperature (R = -0.27; sig = 0.00; n = 600;)



Annex-Figure F-30: Buoy 97 (-7.5m TAW), tidal average sediment concentration vs temperature (R = -0.34; sig = 0.00; n = 632;)



Annex-Figure F-31: Oosterweel (-2.1m TAW), tidal average sediment concentration vs temperature (R = -0.17; sig = 0.00; n = 446;)



Annex-Figure F-32: Oosterweel (-5.7m TAW), tidal average sediment concentration vs temperature (R = -0.29; sig = 0.00; n = 351;)