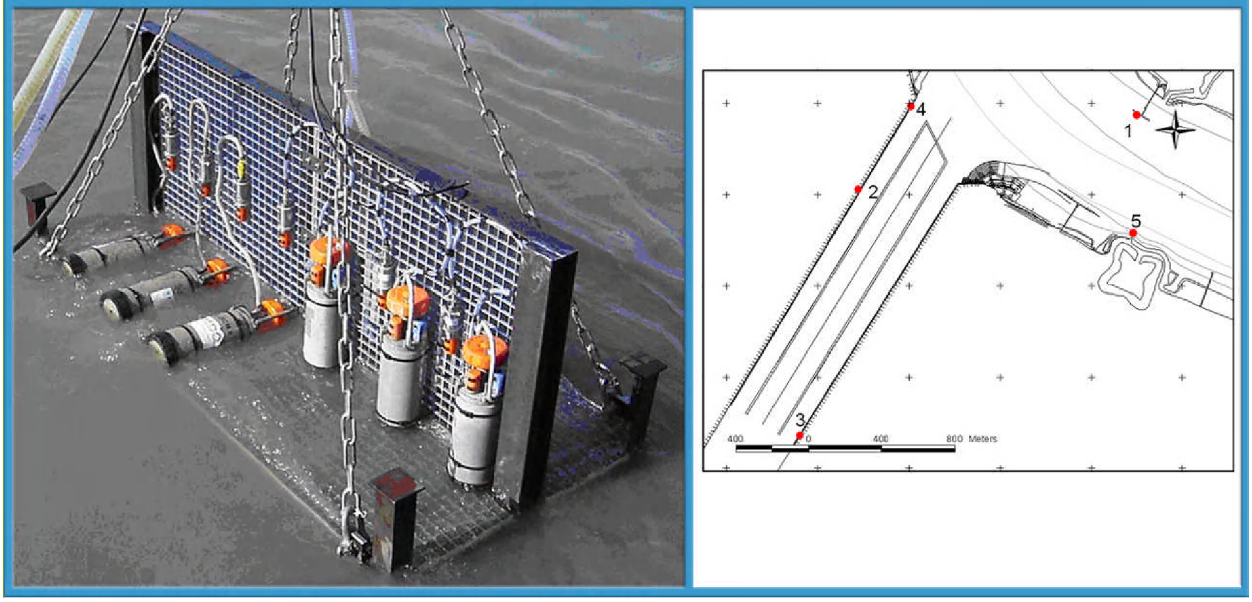
VLAAMSE OVERHEID
DEPARTEMENT MOBILITEIT EN OPENBARE WERKEN

WATERBOUWKUNDIG LABORATORIUM

Langdurige metingen Deurganckdok 2: Opvolging en analyse aanslibbing

Bestek 16EB/05/04

Calibration Frame set-up (left) & Measurement locations (right)



Deelrapport 2.19: Calibratie stationaire en mobiele toestellen Winter 4 – 5 februari 2008

Report 2.19: Calibration stationary an mobile equipment Winter 4 – 5 February 2008

14 July 2008

I/RA/11283/07.096/MSA

IMDC i.s.m. WL | delft hydraulics en GEMS International

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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

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, ‘Opvolging aanslibbing Deurganckdok’.

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

The execution of the study involves a twofold assignment:

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

1.2. Purpose of the study

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

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

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

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

1.3. Overview of the study

1.3.1. Reports

Reports of the project 'Opvolging aanslibbing Deurganckdok 2' for the period April 2007 – March 2008 are summarized in Table 1-1.

Table 1-1: Overview of Deurganckdok Reports

Report	Description
Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities	
1.10	Sediment Balance: Three monthly report 01/04/2007 - 30/06/2007 (I/RA/11283/07.081/MSA)
1.11	Sediment Balance: Three monthly report 01/07/2007 – 30/08/2007 (I/RA/11283/07.082/MSA)
1.12	Sediment Balance: Three monthly report 01/09/2007 – 31/12/2007 (I/RA/11283/07.083/MSA)
1.13	Sediment Balance: Three monthly report 01/01/2007 – 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 winter (I/RA/11283/07.086/MSA)
2.11	Through tide measurement Salinity Profiling winter (I/RA/11283/07.087/MSA)
2.12	Through tide measurement Sediview winter (I/RA/11283/07.088/MSA)
2.13	Through tide measurement Sediview winter (I/RA/11283/07.089/MSA)
2.14	Through tide measurement Sediview winter (I/RA/11283/07.090/MSA)
2.15	Through tide measurement Siltprofiler (to be scheduled) (I/RA/11283/07.091/MSA)
2.16	Salt-Silt distribution Deurganckdok summer (21/6/2007 – 30/07/2007) (I/RA/11283/07.092/MSA)
2.17	Salt-Silt distribution & Frame Measurements Deurganckdok autumn (17/09/2007 - 10/12/2007) (I/RA/11283/07.093/MSA)
2.18	Salt-Silt distribution & Frame Measurements Deurganckdok winter (18/02/2008 - 31/3/2008) (I/RA/11283/07.094/MSA)
2.19	Calibration stationary & mobile equipment winter (I/RA/11283/07.096/MSA)

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

In situ calibrations were conducted on several dates (15/03/2006; 14/04/2006; 23/06/2006; 18/09/2006, 10/9/2007, 04/02/2008 and 05/02/2008) to calibrate all turbidity and conductivity sensors (IMDC, 2006a, IMDC, 2007a & IMDC, 2008).

1.4. Structure of the report

This report is the factual data report of winter calibration measurements on 2008, February 4th and 5th. The first chapter comprises an introduction. The second chapter describes the measurement campaign and the equipment. Chapter 3 describes the course of the actual measurements. The measurement results and processed data are presented in Chapter 4, whereas chapter 5 gives the conclusion of the winter calibrations.

2. THE MEASUREMENT CAMPAIGN

2.1. Calibration Strategy

2.1.1. Suspended Sediment Concentration

A calibration strategy for the Siltation Study in Deurganckdok for the measurement of Suspended Sediment Concentration (SSC) and Salinity was set up.

Table 2-1 gives an overview of all the instruments used for measurement of SSC in long term and through tide measurement campaigns.

Table 2-1: Overview of instruments measuring SS concentration

Instrument	***Quantity***	***Principle***	***Long term (LT) /Through Tide (TT)***
D&A Instruments OBS 3A*	9	Turbidity Backscatter Sensor	TT / LT
Siltprofiler* (Extinction Sensors)	2	Turbidity Extinction sensor	TT
SiltProfiler* (Seapoint Sensor)	1	Turbidity Backscatter Sensor	TT
Argus ASM-IV*	1	Turbidity Backscatter Sensor	LT
Aanderaa RCM-9* 0-500 NTU	9	Turbidity Backscatter Sensor	LT
Aanderaa RCM-9* 0-2000 NTU	1	Turbidity Backscatter Sensor	LT
Valeport Midas* (OBS3+) 0-2000 NTU	2	Turbidity Backscatter Sensor	LT

**These instruments also contain conductivity sensors*

This overview shows that all instruments measure turbidity. Therefore these instruments had to be calibrated to link turbidity to SSC.

This can be done in 2 ways:

- Laboratory calibration
- In Situ calibration

Both methods have advantages and disadvantages. In a laboratory all conditions (concentration, circulation, siltation) are controllable but not identical to the situation in the field. An in situ calibration is more representative of the actual measurement conditions but less controllable. Lab calibrations almost guarantee to cover the whole measurement range of the instrument (very low to very high SSC), which is more difficult to guarantee during field calibrations.

In situ conditions allow all instruments to be calibrated simultaneously and in the same calibration mixture. This is almost unachievable in a laboratory condition.

A good knowledge of the study area can enhance the measurement range that could be attained in an in situ calibration. Knowing where and when certain concentrations are occurring is vital in order to cover a wide range of concentrations. For this reason a preliminary SSC survey was foreseen in Deurganckdok.

2.1.2. Salinity

Salinity is not measured directly but calculated using a UNESCO formula that incorporates conductivity, temperature and depth measurements (Unesco, 1991). All sensors, which measure conductivity and temperature, have also been cross-checked with each other. This means that simultaneous measurements of conductivity and temperature are compared in brackish Scheldt water during the calibration.

2.2. Calibration set up

2.2.1. Frame set-up

A special frame was used to calibrate all stationary and mobile equipment. A rectangular frame, measuring 2 meters by 1 meter, is covered with a wire mesh. In the middle there is a vertical mesh wire wall that divides the frame in 2 parts (2*0.5m), which was used to line up all turbidity sensors to measure at the same vertical level on the frame. All the turbidity sensors were aligned to measure in a horizontal orientation. To avoid interference between backscatter turbidity sensors, a minimum distance between sensors of the same type was respected.

Figure 2-1: Calibration frame with double pump set-up

Because of the amount of sensors 2 calibration days were required, therefore the next set up was realised. In both set ups 2 pumps have been used to calibrate the turbidity sensors. Pump discharge velocities have been tested in advance with dye ($KMnO_4$).

Table 2-2: Set up for calibration both days

Calibration day 1 04/02/2008	***Calibration day 2 05/02/2008***
2 pumps	2 pumps
9 OBS 3A (IMDC) 1 SiltProfiler (IMDC) 10 RCM-9: 6 IMDC (0-500 NTU) 3 FHR (0-500 NTU) 1 FHR (0-2000 NTU) 2 Valeport Midas 1 Argus ASM IV (IMDC)	9 OBS 3A (IMDC) 1 SiltProfiler (IMDC) 10 RCM-9: 6 IMDC (0-500 NTU) 3 FHR (0-500 NTU) 1 FHR (0-2000 NTU) 1 Argus ASM IV (IMDC) 10 CTD-diver (IMDC)

2.2.2. Measurement locations

Previous measurement campaigns in the Lower Sea Scheldt demonstrate what concentration ranges can be expected at certain locations, depths and tidal phases. It was decided to measure during incoming tide and at places with high gradients in suspended sediment concentrations between Deurganckdok (downstream) and Liefkenshoek (upstream).

2.2.3. Calibration protocol

The aim was to calibrate the turbidity sensors at 8 predetermined SS concentrations.

25 – 50 – 100 - 200 – 400 – 800 – 1200 – 1600 mg/l.

During the survey one instrument which has already been used in previous surveys and which as such can be considered as pre-calibrated had real time read-out facilities, so that the frame could be positioned in the appropriate SSC environment as mentioned above. One OBS 3A was used for this purpose.

When the instruments are positioned in the layer with the required SSC, 1 liter water samples were taken from each pump sampler for laboratory analysis. This procedure was carried out twice for each concentration.

2.2.4. Sample analysis

The NEN 6484 standard for total suspended sediment analysis was used for all water samples. On a limited number of samples the sample was sieved over a 63 µm filter to determine the sand content of these samples.

2.2.5. Validation, Drifting and extra Sensors

It has to be mentioned that the SiltProfiler and the Argus have been calibrated in a laboratory set up by the manufacturer using wet mud of the measurement location (Lower Sea Scheldt). The calibration mixtures were analysed using the NEN 6484 standard.

These instruments have a high concentration range and are difficult to calibrate in situ, therefore these instruments were not be calibrated as such, and were only be validated by the calibration procedure described above.

Long term measuring equipment (i.e. RCM-9; OBS 3A) will be tested for drifting by IMDC at each redeployment, by performing a zeroing measurement in clean tap water.

While processing the data it appeared that one of the OBS 3A instruments (sn 221) did not measure during the calibration measurements. However when the instrument was set up this didn't show. Consequently this instrument was not calibrated on 04/02/2008 and 05/02/2008 and will be calibrated during the next calibration.

2.3. Instruments

2.3.1. D & A OBS 3A

D&A Instruments type OBS-3A were calibrated. Measured parameters by the OBS 3A sensor:

- temperature (°C),
- conductivity (µS/cm)
- turbidity (counts/FTU)
- absolute depth (m)

IMDC (2006a) gives more technical details on the OBS 3A sensors.

2.3.2. SiltProfiler

For the HCBS measurements on the river Scheldt a new instrument has been developed, the SiltProfiler.

The SiltProfiler has the following general specifications. The data collection is executed locally (i.e. on the profiler) by an integrated data logger. Sensor cables are kept very short and connect to the interfacing electronics of the data logger. The data logger collects the sensor signals and records the same in internal memory. Simultaneously the data are transmitted via a serial communication cable (if connected). Emphasis is on fast data collection and less on the absolute accuracy of the sensors.

In case the communication cable is not connected, the data can be retrieved upon recovery of the profiler via a short range wireless connection. As soon as the profiler breaks the water surface the data can be accessed and transferred to the operator's PC, whereupon the profiler is ready for a new profiling session. The retrieved profile data are visualised immediately in depth profile graphs. This operational mode requires no electrical cables to be attached to the profiler. However, a small box (diameter in the order of 20 cm) with electronics, data logger and batteries is attached to the profiler. The hoisting cable is attached to sturdy structure above the electronics box.

Figure 2-2: High Resolution SiltProfiler

The sensors are:

- one Conductivity and Temperature sensor with measuring ranges adequate for use in seawater.
- multiple turbidity sensors to cover the entire range of 0 to 35 000 mg/L suspended solids: 2 transmittance sensors (type FOSLIM) are used, in combination with a Seapoint turbidity sensor (0-400 mg/l).
- one pressure sensor.

As such the SiltProfiler is anticipated to rapidly profile the suspended sediment concentration as well as the salinity structure. The SiltProfiler can measure at variable speed up to 100 measurements per second (100 Hz).

The data collection rate is adjustable to optimise for the required vertical / temporal resolution. Further, the data acquisition rate will be depth dependent in such a way that the rate is low in the upper section of the profile and higher in de lower section. Both rates and the changeover depth are user adjustable. The duration of data retrieval depends upon the amount of collected data and the effective data transfer rate.

2.3.3. Argus ASM-IV

The Argus ASM-IV is used to detect the vertical structure of the suspended sediment concentration in the zone of 0-1 meter above the bed.

The ARGUS ASM-IV was developed for high resolution measuring of accretion and erosion of the riverbed. (ARGUS UMWELT-MEATECHNIK, 2005). The instrument operates with backscatter infrared laser sensors embedded in a stainless steel rod. The 96 sensors are placed on an active board at a distance of 0.01m of each other. There are three additional sensors: an inclinometer, a pressure gauge and a on board temperature sensor.

A battery powered central unit in the head of the instrument controls activation and power supply of the sensors as well as the transmission of the signals. The sealed in unit consists of a microprocessor, a data memory, the additional sensors and the energy supply.

The measurement range of the ARGUS ASM-IV is from 0 to 5000mg/l. The instrument was calibrated by the manufacturer in a laboratory set up as mentioned in § 2.2.5.

IMDC (2008)gives more details on the ARGUS ASM-IV (ARGUS UMWELT-MEATECHNIK, 2005; Gilpin 2003).

Figure 2-3: ARGUS ASM-IV

2.3.4. Aanderaa RCM-9

The Aanderaa Recording Current Meter RCM-9 MkII is a multi-parameter instrument that consists of a CTD probe, Doppler Current Sensors and a Turbidity Sensor. This instrument is used in a moored set up for long term measurements in this project. IMDC (2006a) gives more details on the RCM-9.

2.3.5. CTD-Diver datalogger

CTD-Diver dataloggers were used.

Measured parameters by the CTD-Diver datalogger are:

- temperature (°C),

- conductivity (µS/cm)
- absolute depth (m)

IMDC (2008) gives more details on the CTD-Diver datalogger.

2.3.6. Pump Sampler

A water sampler was attached nearby the turbidity sensor taking water samples. Samples were collected in 1 litre sampling bottles. The pumping speed of the water sampler was tested at the start of the measurement campaign on board. Dye was used to time the duration between the intake of the dye and exit at the sampling end of the sampler on board.

3. COURSE OF THE MEASUREMENTS

3.1. Hydrometeorological conditions

Measurements were conducted during flood. The vertical tide is given for the tidal gauge at Liefkenshoek (see Table 3-1).

Table 3-1: High and Low Tide at Liefkenshoek Tidal Gauge on 04/02/2008 & 05/02/2008

Liefkenshoek Tidal Gauge				
	10 september 2007			
	Time [MET]	***Water level [m TAW]***	***Time [MET]***	***Water level [m TAW]***
HW (1)	1:10	4.27	2:10	4.80
LW (2)	7:50	0.22	9:10	-0.22
HW (3)	13:50	4.84	14:30	4.85
LW (4)	20:30	0.50	21:00	0.39

Meteorological data at Deurne was obtained from the Weather Underground website (Wunderground, 2007). Information of the Royal Meteorological Institute is not yet available.

On the 4th of February, the air temperature varied between 2 and 9 °C. The wind blew at an average velocity of 15 km/h from S. There was no rain (Wunderground, 2007).

On the 5th of February, the air temperature varied between 4 and 12 °C. The wind blew at an average velocity of 14 km/h from S. There was some rain and it was cloudy (Wunderground, 2007).

3.2. Locations

On both days the same location was visited to obtain the necessary concentrations. The location is situated near de current deflecting wall at the entrance of Deurganckdok (see Figure 3-1).

Table 3-2: Coordinates Calibration locations [UTM ED50]

Name	***EASTING***	***NORTHING***
Deurganckdok Entrance	588672	5684623

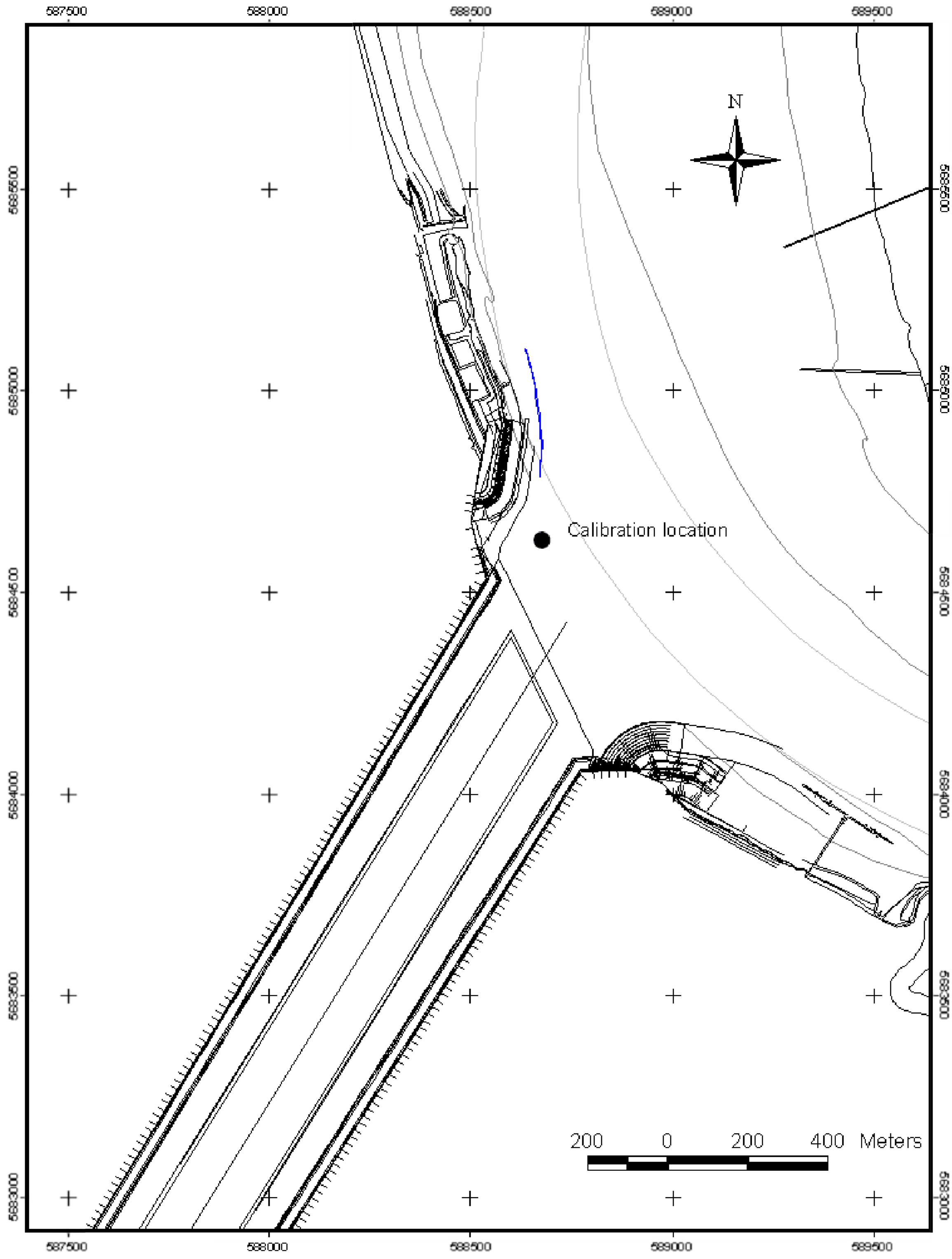


Figure 3-1: Calibration Location

3.3. Measured Concentrations

Direct read out of one of the instruments allowed to aim for the predetermined concentrations (see § 2.2.3).

The following concentration ranges were obtained:

20 – 35 – 100 – 150 – 200 – 300 – 350 – 400 – 500 mg/l.

4. PROCESSING OF DATASETS

4.1. Introduction

Sand content of samples will be discussed in §4.2. The SSC calibration results are given in the next paragraph (§4.3). Paragraph 4.4 and 4.5 covers SiltProfiler calibration checks, respectively Argus ASM IV calibration checks. Conductivity and temperature comparisons are made in §4.6.

4.2. Sand content of samples

A number of water samples (varying concentrations) taken on the 4th and the 5th of February 2008 were analysed for sand content. Figure 4-1 and Table 4-1 show the results of this analysis. It can be seen that the sand content (mg/l) is negligible compared to the SSC (mg/l), except for the samples where relatively high concentrations of SSC were obtained.

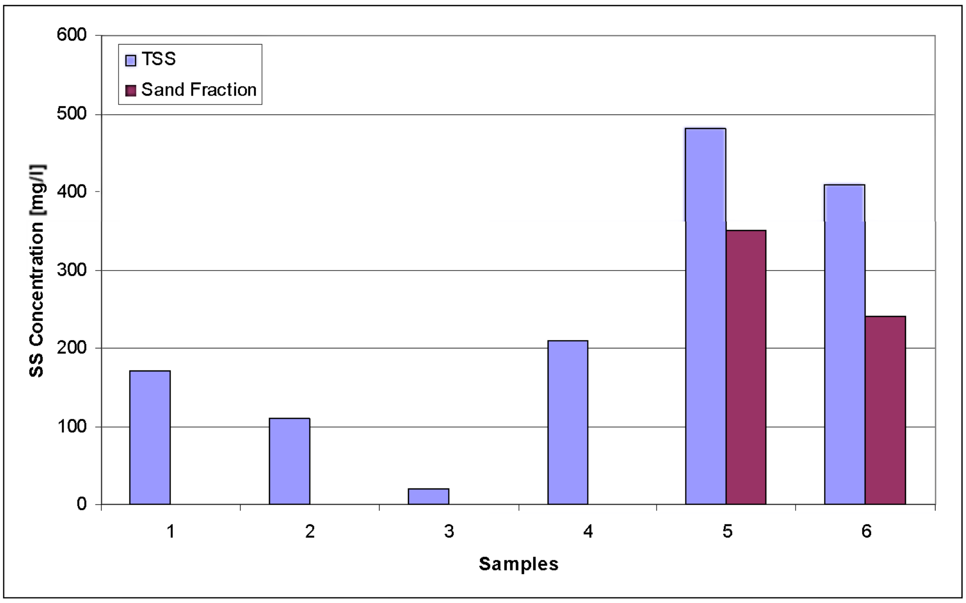


Figure 4-1: Sand content of Selected Samples

Table 4-1: Overview of Total SS Concentration [mg/l], Sand Concentration [>63 µm mg/l] and mass percentage sand in samples

Suspended Sediment Concentration [mg/l]		***% Sand***
Total SS Conc.	***Sand Content(>63µm)***	
110	< 5.0	-
170	< 5.0	-
21	< 5.0	-
210	< 5.0	-
480	350	72.9
410	240	58.5

4.3. SSC Calibration results

The calibration results for all sensors are given in Table 4-2. In this table the conversion formulas are given to convert turbidity counts, NTU, FTU to SSC [mg/l]. The formulas are determined based on the data collected on both days. To verify that considering the two calibration days as two separated calibrations would not result in large differences for the conversion formulas a check up was done. It could be concluded that there are no problems when both days are considered as one calibration.

It was chosen to use second order fits to define the calibration curves. The R square value is added as well.

The calibration graphs show the suspended sediment sample concentration in mg/l on the Y-axis and the instrument readout in AD counts, or Turbidity Units (NTU/FTU) on the X-axis and can be found in APPENDIX A.

Table 4-2: Overview of Calibration Results for 04-05/02/2008 including instrument description, formulas, R^2 and RMSE values and remarks

Instrument	Serial no.	Range	Unit	Function	R^2	RMSE	Remarks
OBS3A	185	0-2000	FTU	$y = 0.3074x^2 - 0.6258x + 1.1806$	$R^2 = 0.9147$	43.95	IMDC
OBS3A	222	0-500	FTU	$y = 0.0113x^2 + 0.589x - 5.4444$	$R^2 = 0.9232$	46.19	IMDC
OBS3A	223	0-500	FTU	$y = 0.0125x^2 + 0.8389x - 10.423$	$R^2 = 0.9285$	40.26	IMDC
OBS3A	224	0-2000	FTU	$y = 0.0114x^2 + 0.4843x - 3.5132$	$R^2 = 0.9552$	31.85	IMDC
OBS3A	225	0-2000	FTU	$y = 0.0091x^2 + 0.8159x - 12.126$	$R^2 = 0.9704$	25.90	IMDC
OBS3A	247	0-2000	FTU	$y = 0.0117x^2 + 0.4071x - 6.0937$	$R^2 = 0.9197$	42.66	IMDC
OBS3A	261	0-500	FTU	$y = 0.0109x^2 + 1.1557x - 15.753$	$R^2 = 0.9345$	38.54	IMDC
OBS3A	262	0-2000	FTU	$y = 0.0156x^2 - 0.2608x + 8.001$	$R^2 = 0.9239$	41.53	IMDC
RCM-9	0149_1316	0-500	NTU	$y = 0.0237x^2 - 0.4592x + 2.897$	$R^2 = 0.9869$	20.26	FHR
RCM-9	0152_1317	0-500	NTU	$y = 0.0206x^2 - 0.0637x + 1.3583$	$R^2 = 0.9783$	24.58	FHR
RCM-9	0243_255	0-2000	NTU	$y = 0.0436x^2 - 1.0699x + 8.0671$	$R^2 = 0.9104$	51.64	FHR
RCM-9	0579_560	0-500	NTU	$y = 0.009x^2 + 1.6192x - 22.882$	$R^2 = 0.9618$	29.40	FHR
RCM-9	1165_1025	0-500	NTU	$y = 0.0125x^2 + 0.3389x - 3.4111$	$R^2 = 0.9755$	22.52	IMDC
RCM-9	1168_1021	0-500	NTU	$y = 0.0156x^2 + 0.1686x + 5.3221$	$R^2 = 0.9710$	29.19	IMDC
RCM-9	1170_1026	0-500	NTU	$y = 0.025x^2 - 0.6407x + 7.8249$	$R^2 = 0.9628$	33.27	IMDC
RCM-9	1171_1028	0-500	NTU	$y = 0.0231x^2 - 0.5246x + 6.2216$	$R^2 = 0.9741$	27.73	IMDC
RCM-9	1220_1052	0-500	NTU	$y = 0.0239x^2 - 0.9641x + 12.717$	$R^2 = 0.9716$	28.93	IMDC
RCM-9	1229_1054	0-500	NTU	$y = 0.0209x^2 + 0.0004x - 1.8378$	$R^2 = 0.9720$	28.92	IMDC

Instrument	Serial no.	Range	Unit	Function	R^2	RMSE	Remarks
MIDAS OBS-3+	24163_2565	0-1500	FTU	$y = 0.0334x^2 - 1.0263x + 1.1023$	$R^2 = 0.9801$	9.43	IMDC
MIDAS OBS-3+	24164_2564	0-1500	FTU	$y = 0.0084x^2 + 0.6181x - 5.0769$	$R^2 = 0.9786$	9.57	IMDC
OBS-3+	2556	0-5	V	$y = 72.001x - 31.551$	$R^2 = 0.9043$	38.57	IMDC
SiltProfiler	Seapoint	0-700	mg/l	comparison calibrated concentrations			
	Long Range	400-5000	mg/l	comparison calibrated concentrations			
	Short Range	4500 – 38300	mg/l	comparison calibrated concentrations			
ARGUS ASM IV	61			horizontal variation, timeseries, comparison calibrated concentrations			
ARGUS ASM IV	79			horizontal variation, timeseries, comparison calibrated concentrations			

4.4. Manufacturer's Calibration & Cross-check of Siltprofiler

4.4.1. Manufacturer's calibration of Silt Profiler

The manufacturer's calibration was done at WL|Delft Hydraulics following a procedure set forward by IMDC. This procedure is set up as follows: The sediment was sieved with a 63 µm filter. The filtrate was desalinated, and was allowed to settle and to evaporate. The resulting mud was used as base material. It was analysed for dry content, which resulted in a ratio of 0.28386 grams of dry material per gram base material.

The calibration was done in a 5 L solution of DEMI (demineralised) water in which the base material was dissolved and kept in suspension. This was done for increasing concentrations. From every calibration mixture a sample was taken to be analysed for suspended sediment concentration. Samples were filtered over a preweighed desiccated 0.45 micron filter, after which the filter is dried in an oven at 105°C, cooled and weighed (NEN 6484).

This approach was chosen for its close resemblance to an in situ calibration. Manipulation of the basis material was limited.

The calibration graphs can be found in APPENDIX A.

Table 4-3: Calibration Equations as derived for both Seapoint and SiltProfiler sensors (low and high range), x=AD counts, y=sample suspended sediment concentration

Instrument	***Equation***	***R^2***
Siltprofiler – Seapoint	$Y= 0.000026x^2+ 0.594246x+1.5$	0.999
SiltProfiler – Low range	$Y = 0.000277x^2 + 0.233989x –182.9$	0.999
SiltProfiler – High range	$Y=0.0.001698x^2 + 4.429417x –332.6$	0.999

4.4.2. Cross-check of SiltProfiler

The Siltprofiler was cross-checked during the in situ calibration. Figure 4-2 shows the comparison of the Siltprofiler measurement for 4 and 5 February 2008. The X-axis shows the sample SSC, the Y-axis shows the Siltprofiler SSC (determined by the manufacturer's calibration).

Turbidity values were converted to suspended sediment concentration using the equation of the calibration curve determined at the pre-calibration done by WL|Delft. These were compared to sample concentrations. Only Seapoint measurements were used, because of the low concentrations. It can be seen that the higher the concentration the higher de deviation.

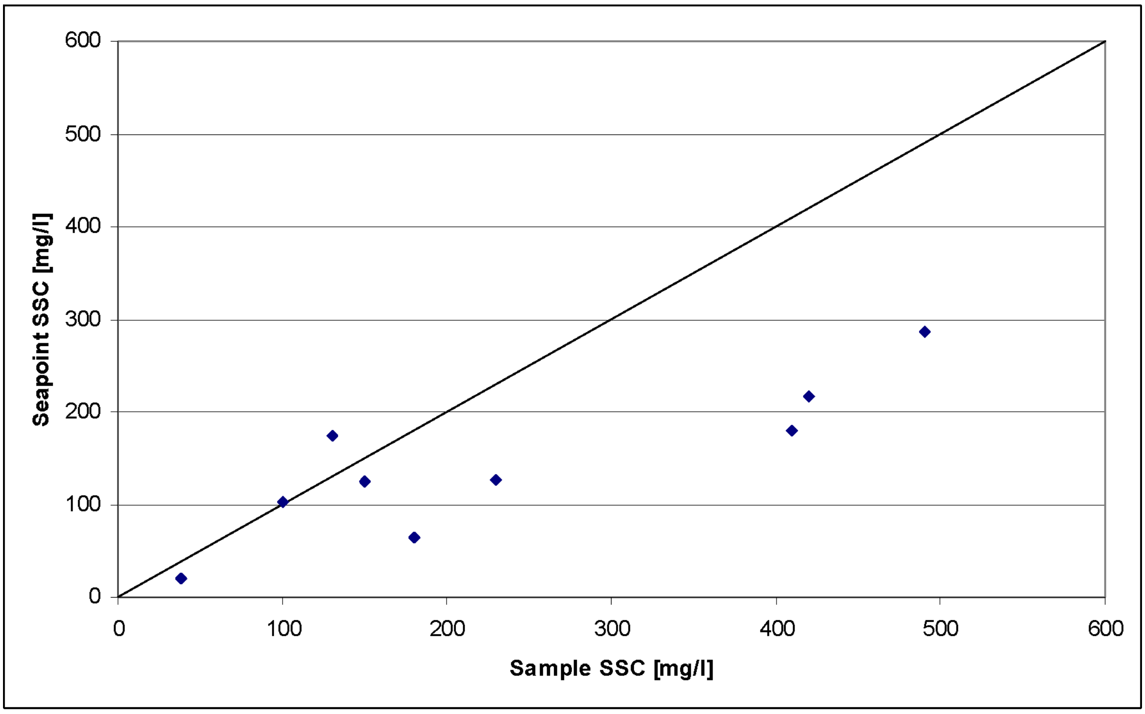


Figure 4-2:Comparison of Sample SSC to SiltProfiler SSC for 4 and 5 February 2008

4.5. Manufacturer's Calibration & Cross check of Argus ASM-IV

4.5.1. Manufacturer's calibration of Argus ASM IV

The manufacturer's calibration was completed by Argus GESELLSCHAFT FUER UMWELTMESSTECHNIK MBH. Because of the special nature of this instrument, 96 OBS sensors spread out over a length of a meter a specialized calibration tank was used, that can be seen in IMDC(2008).

Wet sediment was sieved with a 63 µm filter. The resulting mud was used as base material. In the calibration tank measurements were made at various concentrations between 0-10000 mg/l for the ARGUS ASM IV sn 61. Calibration tank measurements for the ARGUS ASM IV sn 79 were made at various concentration between 0-5000 mg/l.

From every calibration mixture a sample was taken to be analysed for suspended sediment concentration. Samples were filtered over a preweighed desiccated 0.45 micron filter, after which the filter is dried in an oven at 105°C, cooled and weighed (NEN 6484).

The calibration graphs can be found in APPENDIX A- A.2.

4.5.2. Cross check of Argus ASM IV

The ARGUS ASM IV sn 79 was also tested for cross-checking the manufacturer's calibration. The ARGUS ASM IV sn 61 gave faulty data when read out with the ASMA software. So a cross-checking could not be done this time for this instrument. In the report of the previous calibration measurements (IMDC, 2008) a cross-check of this instrument can be found. It must be mentioned that this instrument is very hard to calibrate in situ, because of its size, shape and the spatial spread of its sensors. Therefore the cross-check was limited to concentrations which were spread homogenously throughout the water column, being low concentrations (stable conditions).

Figure 4-3 shows the comparison of the Argus measurement in stable conditions for 4 and 5 February 2008. The X-axis shows the Sample SSC, the Y-axis shows the average Argus SSC of all the 96 sensors (determined by the manufacturer's calibration).

It can be seen that at low concentrations the manufacturer's calibration and the in situ calibration correspond (near the 1:1 diagonal).

To illustrate the difficulty in this comparison, and its interpretation, the next figure (Figure 4-4) shows a time series in a high concentration for a sensor on the left side, middle and right side of the ARGUS (sn. 79). The ARGUS was positioned horizontally, so this graph shows a temporal variation for 3 sensors, two at each end of the instrument (left (sensor 1) right (sensor 96), and one in the middle (sensor 48). The main trend of the measurements is comparable, but previous calibrations showed that the higher the concentration of suspended sediment, the higher the difference between the measurements of the sensors.

Figure 4-5 shows the horizontal variation of the SSC environment at a low and a high sample concentration. As the Argus was positioned horizontally, this figure shows the horizontal variation between sensor 96 and sensor 1 of Argus s/n 079. Both concentrations show relative constant measurement values for all backscatter sensors except for sensors 85, 87 and 90, which give considerable higher values of SSC due to scratches.

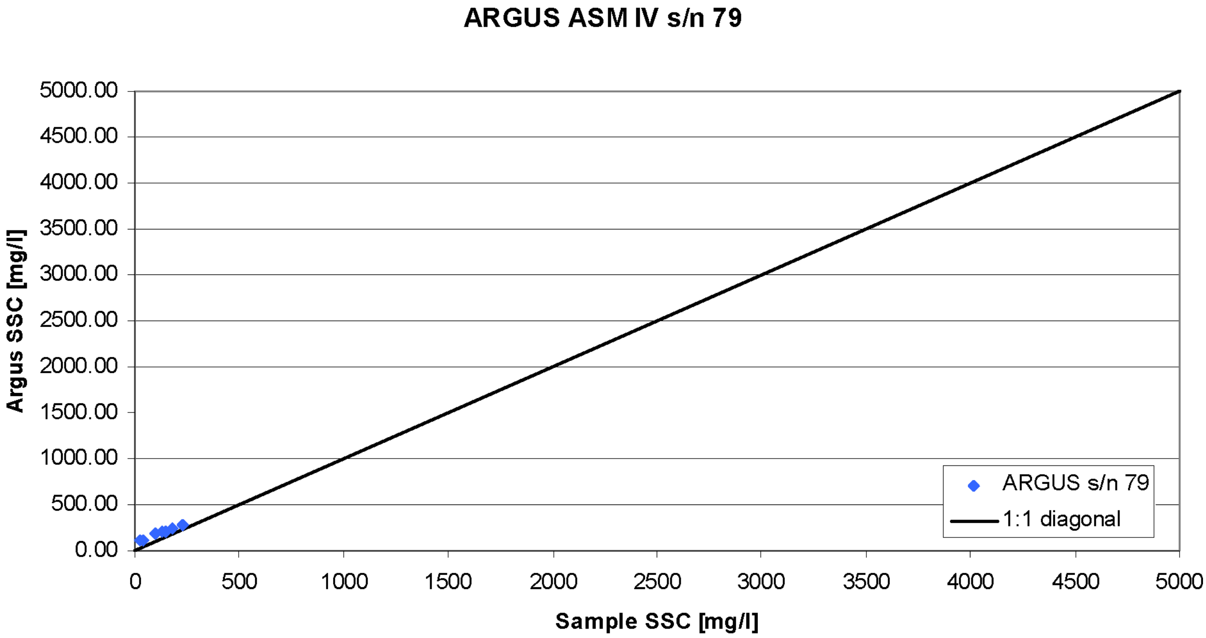


Figure 4-3: Comparison of Sample SSC to Argus SSC for s/n 79

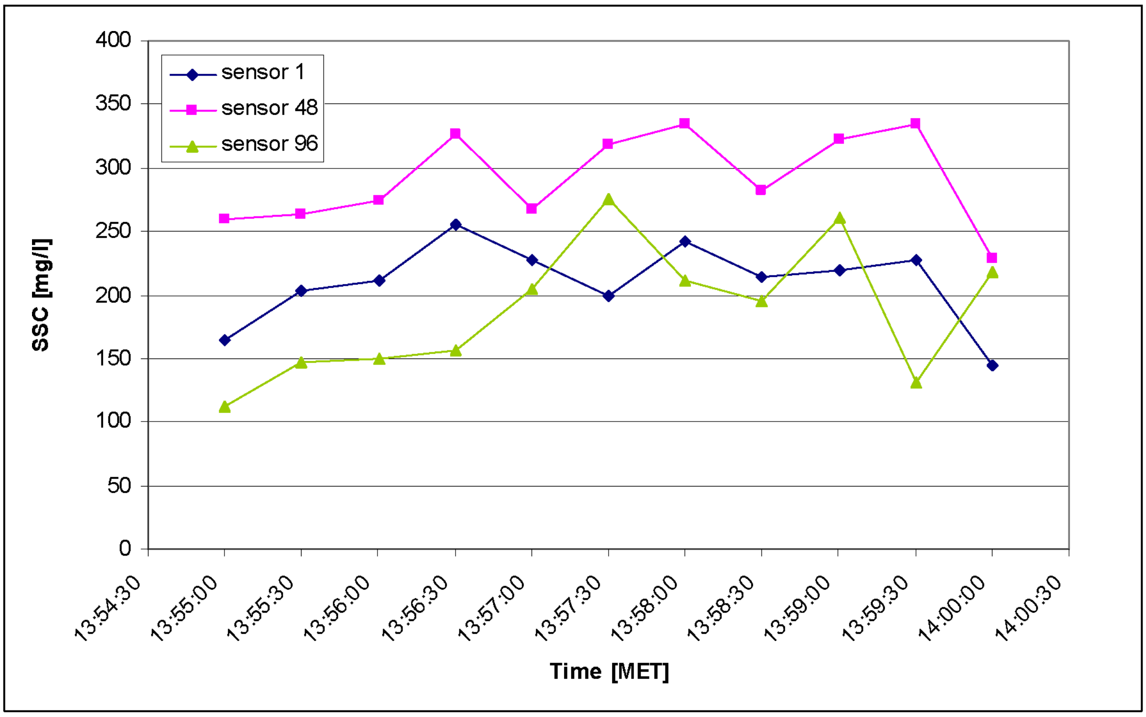
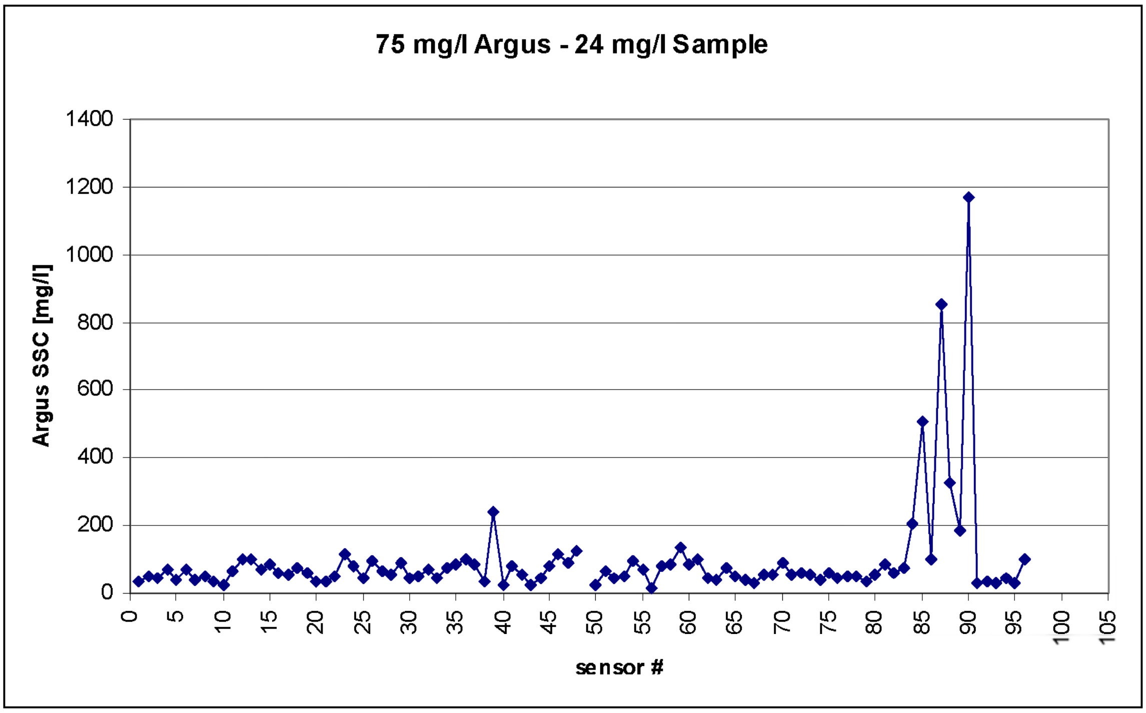


Figure 4-4: Timeseries in a high SSC environment for 3 sensors of Argus: X-axis shows time, Y-axis shows SSC: Argus sn 79.



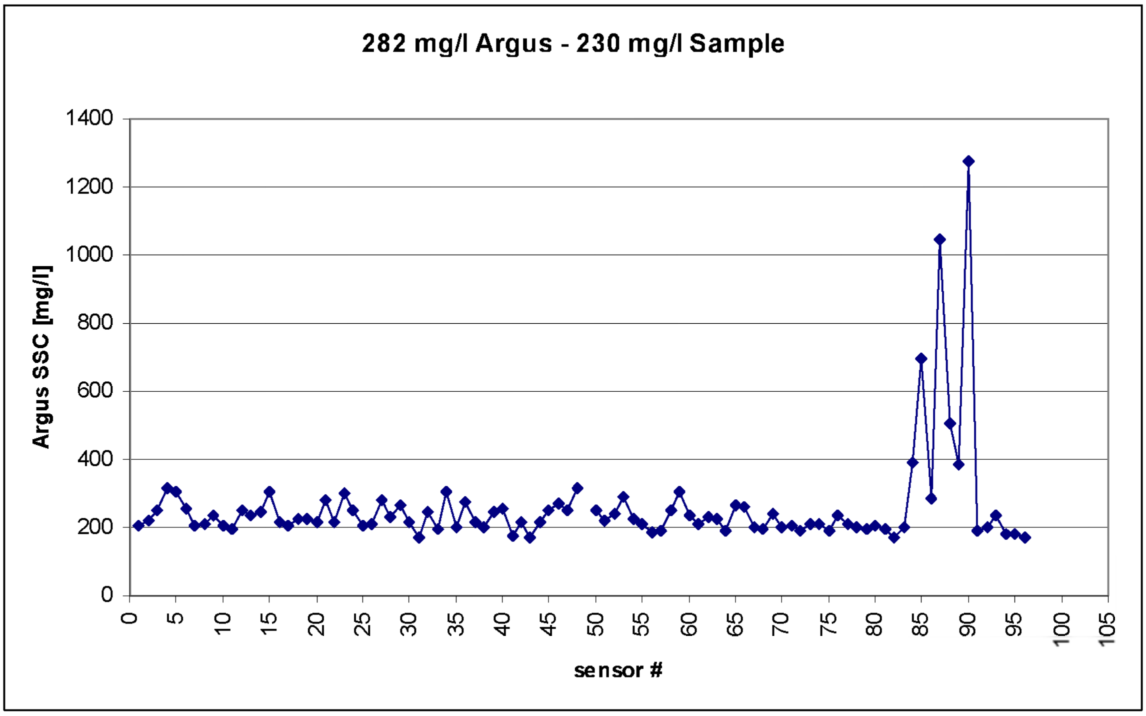


Figure 4-5: Horizontal variation of the SSC during a sampling event at low (top) and high (bottom) concentrations for Argus s/n 79

4.6. Conductivity, temperature and salinity cross-check

Conductivity and temperature measurements were conducted during this measurement campaign, however it was not possible to obtain a wide range of conductivity/salinity levels in the area that was frequented for the calibration. A limited analysis will include a comparison of simultaneous conductivity and temperature measurements by the different instruments that were mounted on the frame.

4.6.1. Calibration days: February 4th and 5th 2008

Figure 4-6 shows the conductivity read out of all OBS 3A instruments deployed at the same level on the measurement frame. Only one OBS 3A instrument measured slightly lower conductivity values.

Figure 4-7 shows the conductivity read out of 9 RCM-9 instruments deployed at the same level on the measurement frame. One RCM-9 of FHR didn't measure conductivity. All IMDC RCM-9 conductivity sensors measure similar conductivity values. One of the RCM-9 conductivity sensors installed on the instruments of FHR give a slightly higher value. RCM-9 sn 0579 is the only one with an old conductivity sensor, which gives a deviation compared to the new conductivity sensors. This behaviour is also seen in previous calibration report (IMDC, 2008) where old conductivity sensors were installed on RCM-9 sn 0579 and 1153.

Figure 4-8 shows the conductivity read out of all the CTD – Divers deployed at the same level on the measurement frame. Notice that the CTD-Divers were only installed on the frame the second calibration day. All sensors measure similar conductivity values.

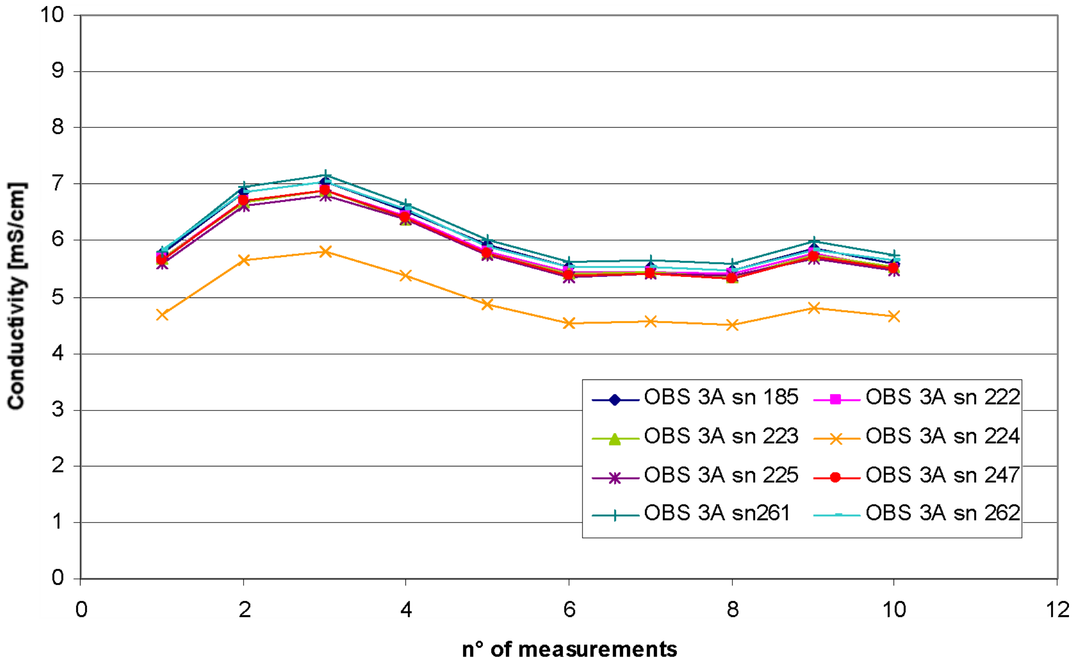


Figure 4-6: OBS 3A Conductivity Measurements 04/02/2008 & 05/02/2008

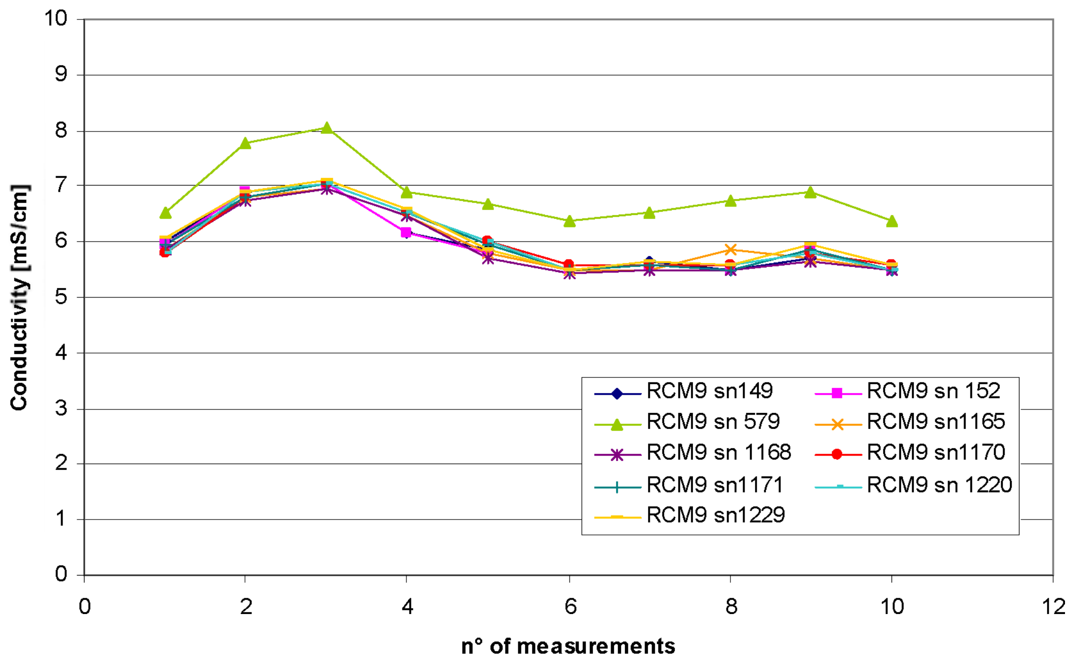


Figure 4-7: RCM-9 Conductivity Measurements 04/02/2008 & 05/02/2008

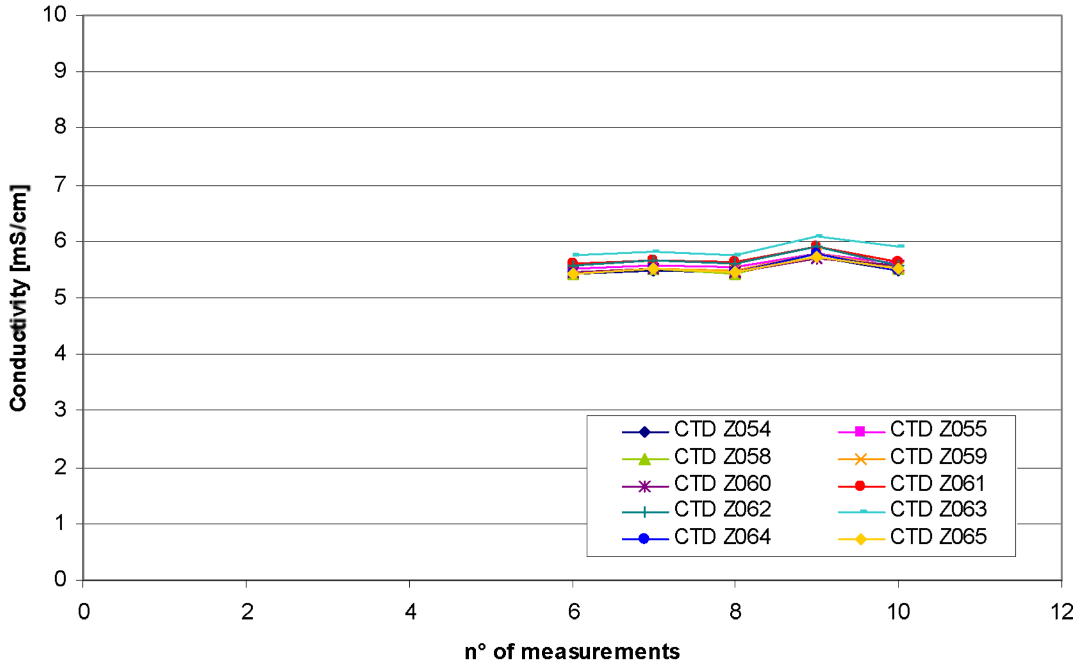


Figure 4-8: CTD-Diver Conductivity Measurements 04/02/2008 & 05/02/2008

Figure 4-9 shows all conductivity measurements and the average conductivity on 04/02/2008 and 05/02/2008. All instruments show similar trends and are spread out over about 2 mS/cm, each instrument is fairly consistent respective to the average.

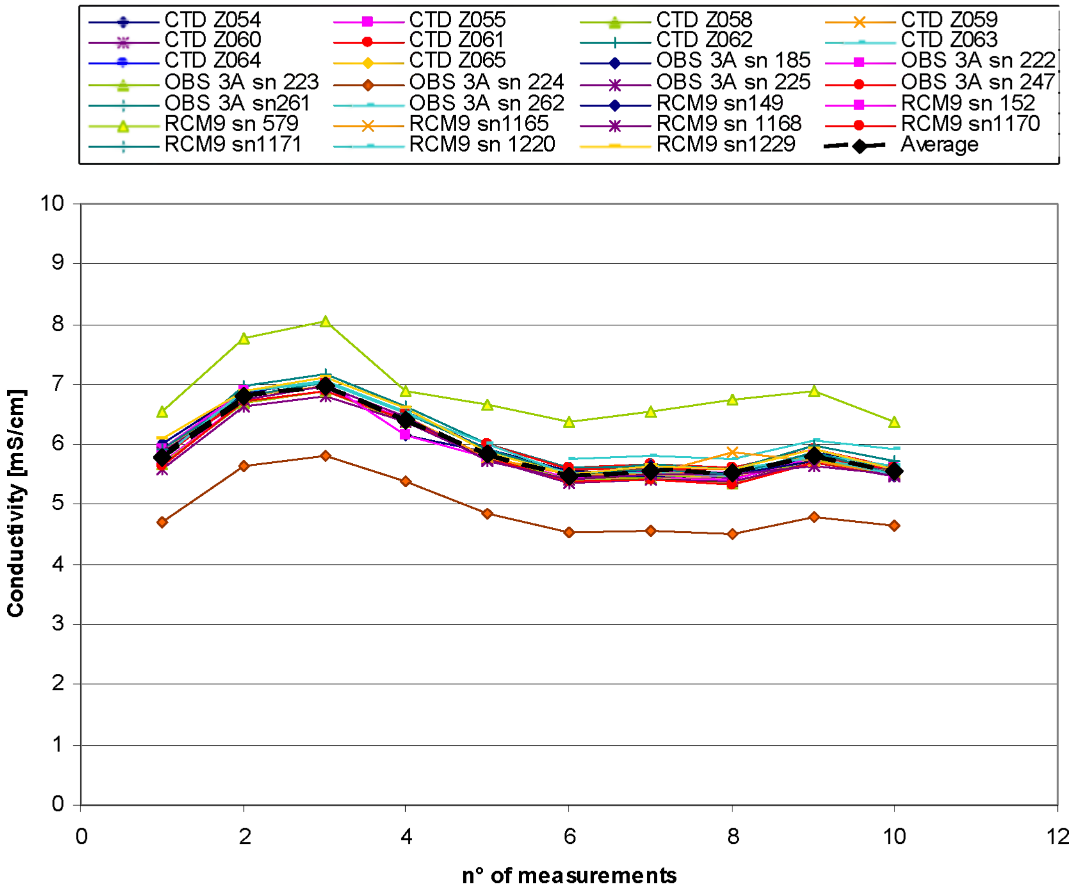


Figure 4-9: All Conductivity Measurements 04/02/2008 & 05/02/2008

When comparing the conductivity measurements a good resemblance can be seen. Only the OBS 3A sn 224 and the RCM-9 sn 0579 measure slightly lower, respectively higher values.

The Root Mean Square Error (RMSE) was calculated for each correctly working instrument. The average of every conductivity measurement was calculated using all correctly working conductivity sensors. The RMSE was calculated for each instrument comparing its measurement to the average conductivity measurement (this average is based on all CORRECT measurements).

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i - \overline{X})^2}$$ in which

X_i = measured conductivity value for a given instrument

$\overline{X}$ = average conductivity value for each measurement

n = number of measurements

Table 4-4: RMSE values [mS/cm] for Conductivity sensors

Instrument	***RMSE***	***Instrument***	***RMSE***
OBS3A 185	0.19	**CTD Z054**	0.09
OBS3A 222	0.09	**CTD Z055**	0.02
OBS3A 223	0.06	**CTD Z058**	0.08
OBS3A 224	0.88	**CTD Z059**	0.04
OBS3A 225	0.03	**CTD Z060**	0.07
OBS3A 247	0.05	**CTD Z061**	0.09
OBS3A 261	0.29	**CTD Z062**	0.07
OBS3A 262	0.20	**CTD Z063**	0.27
RCM-9 sn 0149	0.15	**CTD Z064**	0.07
RCM-9 sn 0152	0.15	**CTD Z065**	0.08
RCM-9 sn 0579	0.86	**RCM-9 sn 1171**	0.11
RCM-9 sn 1165	0.15	**RCM-9 sn 1220**	0.10
RCM-9 sn 1168	0.18	**RCM-9 sn 1229**	0.08
RCM-9 sn 1170	0.11		

Temperature measurements were compared as well. Figure 4-10, Figure 4-11 and Figure 4-12 show the temperature measurements of the OBS 3A, the RCM-9 and the CTD-Diver instruments. The CTD-Diver temperature measurements show a spread of 0.2°C up to 0.3 °C, which is the largest but still is small. One OBS 3A gives slightly higher temperature values (0.2°C higher). All temperature sensors are compared in Figure 4-13. All measurements follow the same trend. RMSE values are given in Table 4-5.

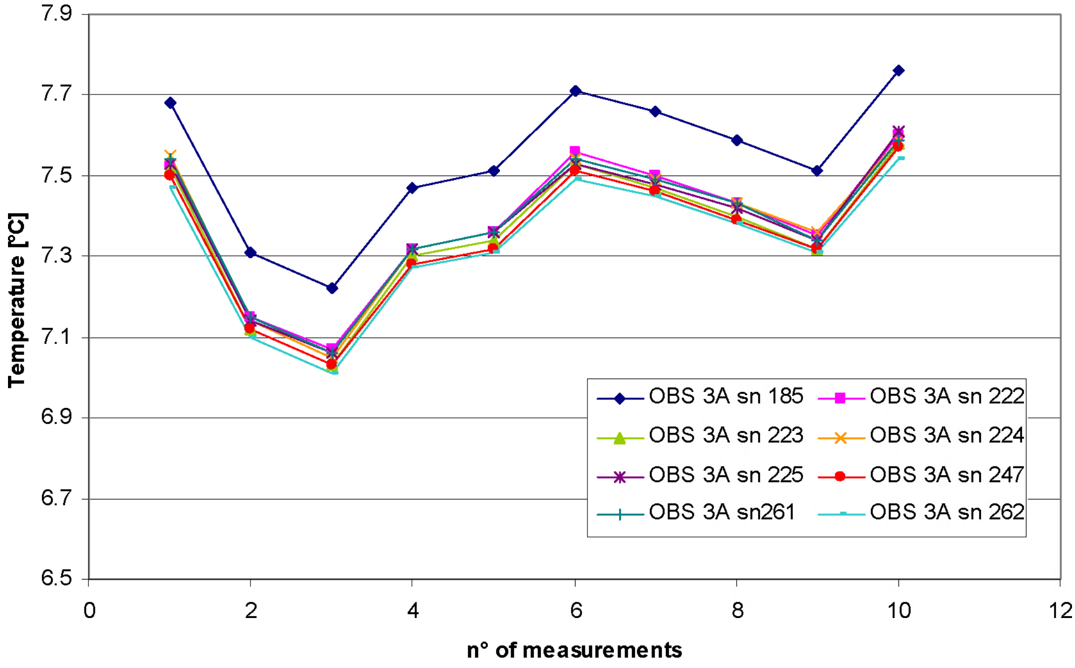


Figure 4-10: OBS 3A Temperature Measurements 04/02/2008 & 05/02/2008

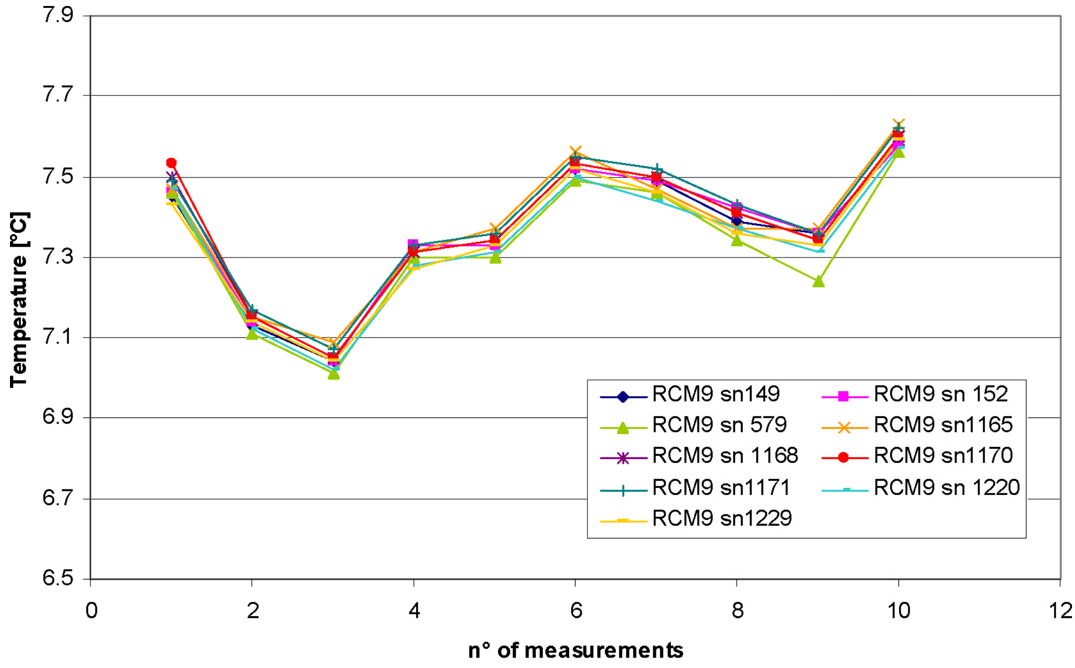


Figure 4-11: RCM-9 Temperature Measurements 04/02/2008 & 05/02/2008

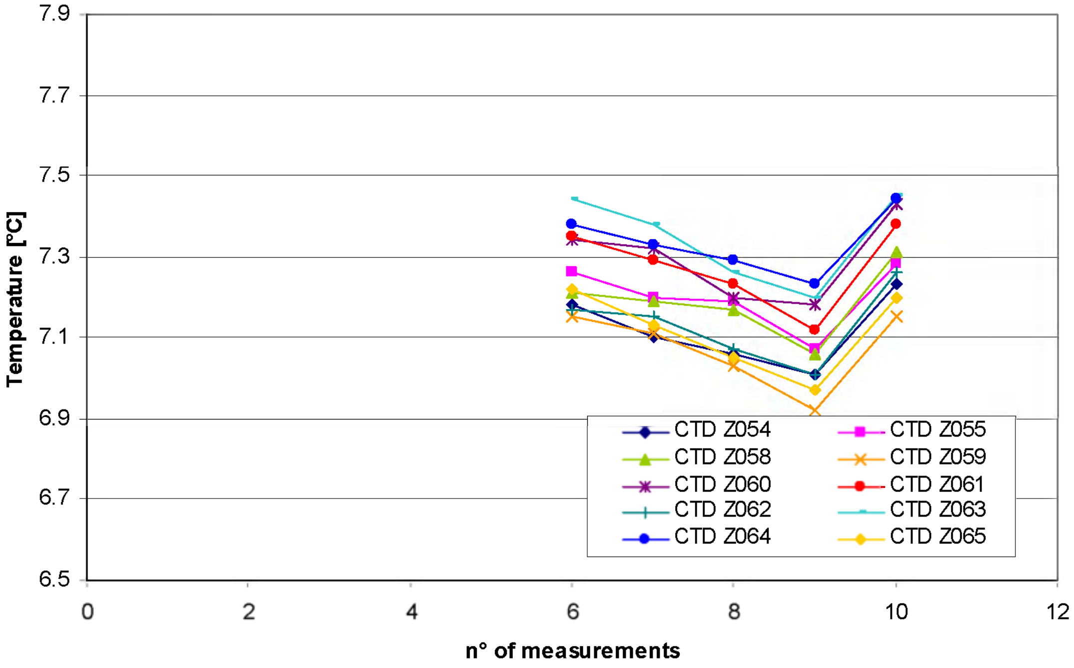


Figure 4-12: CTD-Diver Temperature Measurements 04/02/2008 & 05/02/2008

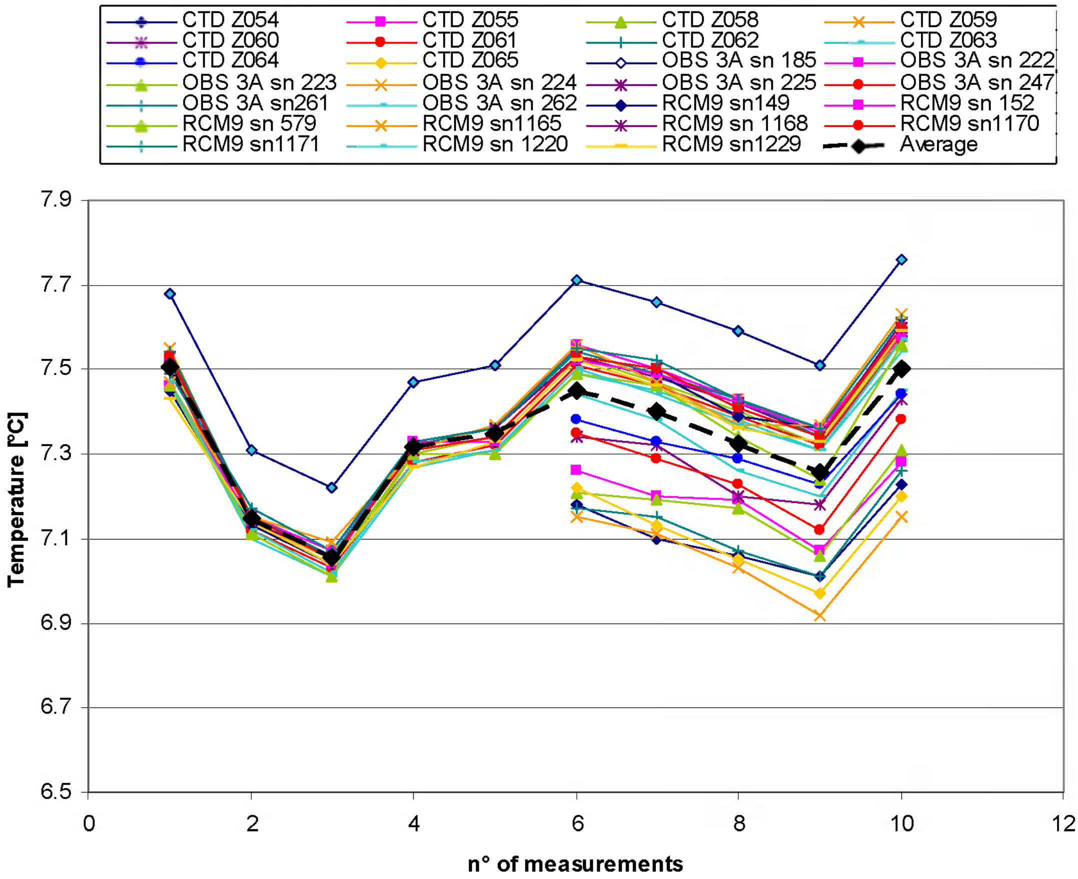


Figure 4-13: Temperature measurements 04/02/2008 & 05/02/2008

Table 4-5: RMSE values [°C] temperature sensors

Instrument	***RMSE***	***Instrument***	***RMSE***
OBS3A 185	0.15	**CTD Z054**	0.09
OBS3A 222	0.01	**CTD Z055**	0.02
OBS3A 223	0.03	**CTD Z058**	0.03
OBS3A 224	0.01	**CTD Z059**	0.14
OBS3A 225	0.01	**CTD Z060**	0.07
OBS3A 247	0.04	**CTD Z061**	0.09
OBS3A 261	0.01	**CTD Z062**	0.08
OBS3A 262	0.06	**CTD Z063**	0.14
RCM-9 sn 0149	0.01	**CTD Z064**	0.13
RCM-9 sn 0152	0.02	**CTD Z065**	0.10
RCM-9 sn 0579	0.04	**RCM-9 sn 1171**	0.03
RCM-9 sn 1165	0.03	**RCM-9 sn 1220**	0.02
RCM-9 sn 1168	0.01	**RCM-9 sn 1229**	0.02
RCM-9 sn 1170	0.02		

Salinity is also calculated and compared between the different instruments. The RMSE values are given in Table 4-6. A graph with calculated salinity values is given together with the average salinity value in Figure 4-14.

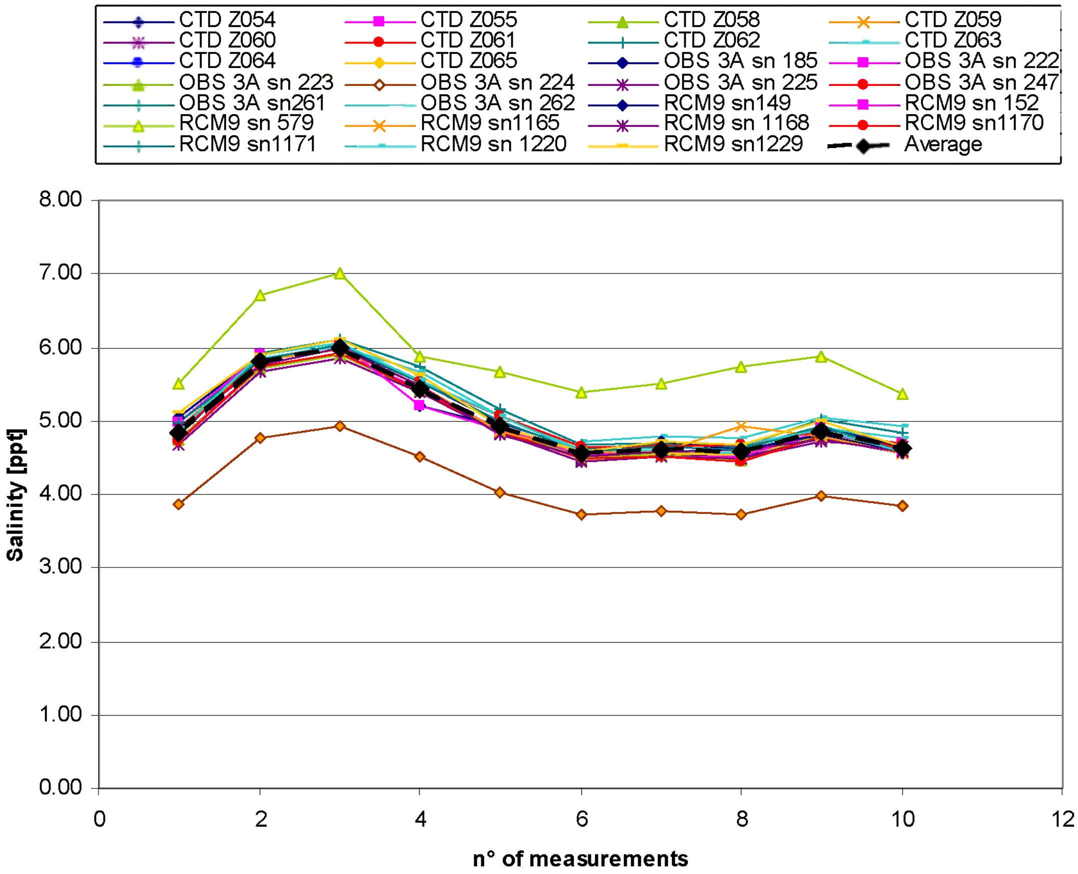


Figure 4-14: Salinity values 04/02/2008 & 05/02/2008

Table 4-6: RMSE values [ppt] salinity

Instrument	***RMSE***	***Instrument***	***RMSE***
OBS3A 185	0.15	**CTD Z054**	0.07
OBS3A 222	0.07	**CTD Z055**	0.02
OBS3A 223	0.06	**CTD Z058**	0.07
OBS3A 224	0.79	**CTD Z059**	0.02
OBS3A 225	0.02	**CTD Z060**	0.07
OBS3A 247	0.05	**CTD Z061**	0.07
OBS3A 261	0.27	**CTD Z062**	0.07
OBS3A 262	0.20	**CTD Z063**	0.22
RCM-9 sn 0149	0.14	**CTD Z064**	0.08
RCM-9 sn 0152	0.14	**CTD Z065**	0.06
RCM-9 sn 0579	0.74	**RCM-9 sn 1171**	0.10
RCM-9 sn 1165	0.14	**RCM-9 sn 1220**	0.09
RCM-9 sn 1168	0.17	**RCM-9 sn 1229**	0.08
RCM-9 sn 1170	0.10		

4.6.2. Cross-calibration SiltProfiler

During analysing the data it seemed that conductivity measurements of the SiltProfiler were erroneous. Cross calibrating the measurements was also impossible. Usually a CTD – Diver is installed on the SiltProfiler during measurements, so conductivity values can be obtained this way.

5. CONCLUSION OF WINTER CALIBRATION

The technical realization of the in situ calibration for turbidity measurements was carried out with variable success. Only low concentrations were found in the water column at various tidal phases during the incoming tide. The highest concentration sampled was 490 mg/l.

RMSE values for the SSC were rather high (from 20 to 50 mg/l). This was mainly due to the samples with the highest concentration, but deviation of the calibration graphs is not noticed for these samples. This could be due to a higher sand content of the samples with high SS concentrations. The sand content of the suspended sediment samples is negligible in general. But as mentioned before, the sand content runs up when aiming for high concentrated samples.

High concentrations can only be found near the bottom. Disturbance of the soft bottom at these depths is inevitable and therefore not recommended for calibration. For instruments with a very high turbidity range (SiltProfiler) an in situ calibration is not recommended. It is very hard to find very high concentrations in a homogenous mixture in the Lower Sea Scheldt. Only in situ cross-checks are useful in this case, with the widest range of concentrations possible.

When compared to the previous calibration in autumn (IMDC, 2008) it can be seen that the calibration graphs in this calibration are more parabolic in nature than the previous calibration, which was more linear. This implies higher SSC in the higher range of NTU and FTU. This can be related to the higher sand content for the higher concentrations, or to different sediment characteristics between winter and autumn conditions.

The conductivity cross-check was limited due to the small range of conductivities that were measured. The conductivity comparison of 10 CTD-Divers, 8 OBS 3A instruments and 9 RCM-9 instruments showed similar trends, the range of values during each measurement was about 0.5 mS/cm, except for one OBS 3A and one RCM-9. These two instruments measured about 1mS/cm lower, respectively higher compared to the other instruments. These deviations must keep at the back of one's mind interpreting the conductivity (or salinity) values of these two instruments. The instrument OBS 3A sn 224 was used from 20/02/2008 till 31/03/2008 at the N-entrance of Deurganckdok (PSA-HNN bottom) and the RCM-9 sn 579 at buoy 84 (3.3m above the bottom) from 09/05/2007 till 31/03/2008. The RMSE of all the instruments varied between 0.02 and 0.88 mS/cm. It can be seen in Figure 4-9 that every instrument is quite consistent in relation to the average of the conductivity measurements.

Temperature measurements were also compared. No large discrepancies were found. All RMSE values for the instruments were lower than 0.15 °C. All together the temperature measurements by each instrument are acceptable.

The salinity RMSE values were a bit smaller when compared to the conductivity RMSE values. Again the same two instruments (OBS 3A sn 224, RCM-9 sn 0579) had lower/higher values compared to the other instruments measuring conductivity and temperature.

6. REFERENCES

ABB Instrumentation (2005) Principles of a Nephelometric Turbidity Monitor.

ARGUS UMWELT-MEATECHNIK (2005), ASM-IV-laser, ARGUS surface meter manual, 31p.

IMDC (2006a). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 6.1 Winter Calibration (I/RA/11291/06.092/MSA), in opdracht van AWZ.

IMDC (2006b). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 7.4 23/3 Parel 2 – Schelle (I/RA/11291/06.097/MSA), in opdracht van AWZ.

IMDC (2007a). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 6.2 Summer Calibration (I/RA/11291/06.093/MSA), in opdracht van AWZ.

IMDC (2007). Uitbreiding studie densiteitsstromingen in de Beneden Zeeschelde in het kader van LTV Meetcampagne naar hooggeconcentreerde slibsuspensies Deelrapport 12 Report concerning the presence of HCBS layers in the Scheldt river (I/RA/11291/06.109/MSA), in opdracht van AWZ.

IMDC (2008). Langdurige metingen Deurganckdok: Opvolging en analyse aanslibbing. Deelrapport 2.9 Autumn Calibration (I/RA/11283/07.095/MSA)

Unesco (1991). Processing of Oceanographic Station Data.

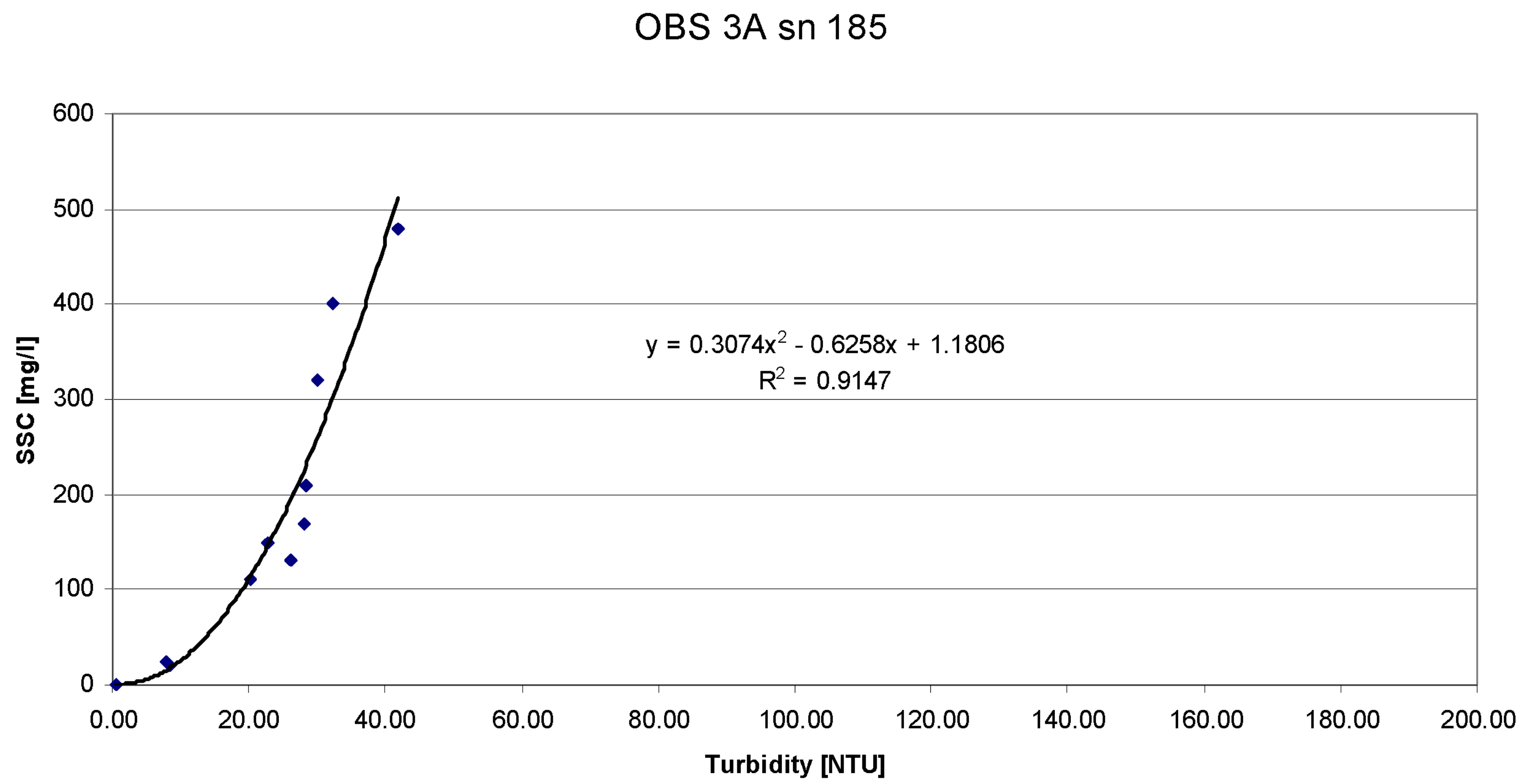
Wunderground (2007).Weather Underground: www.wunderground.com.

APPENDIX A.

CALIBRATION GRAPHS

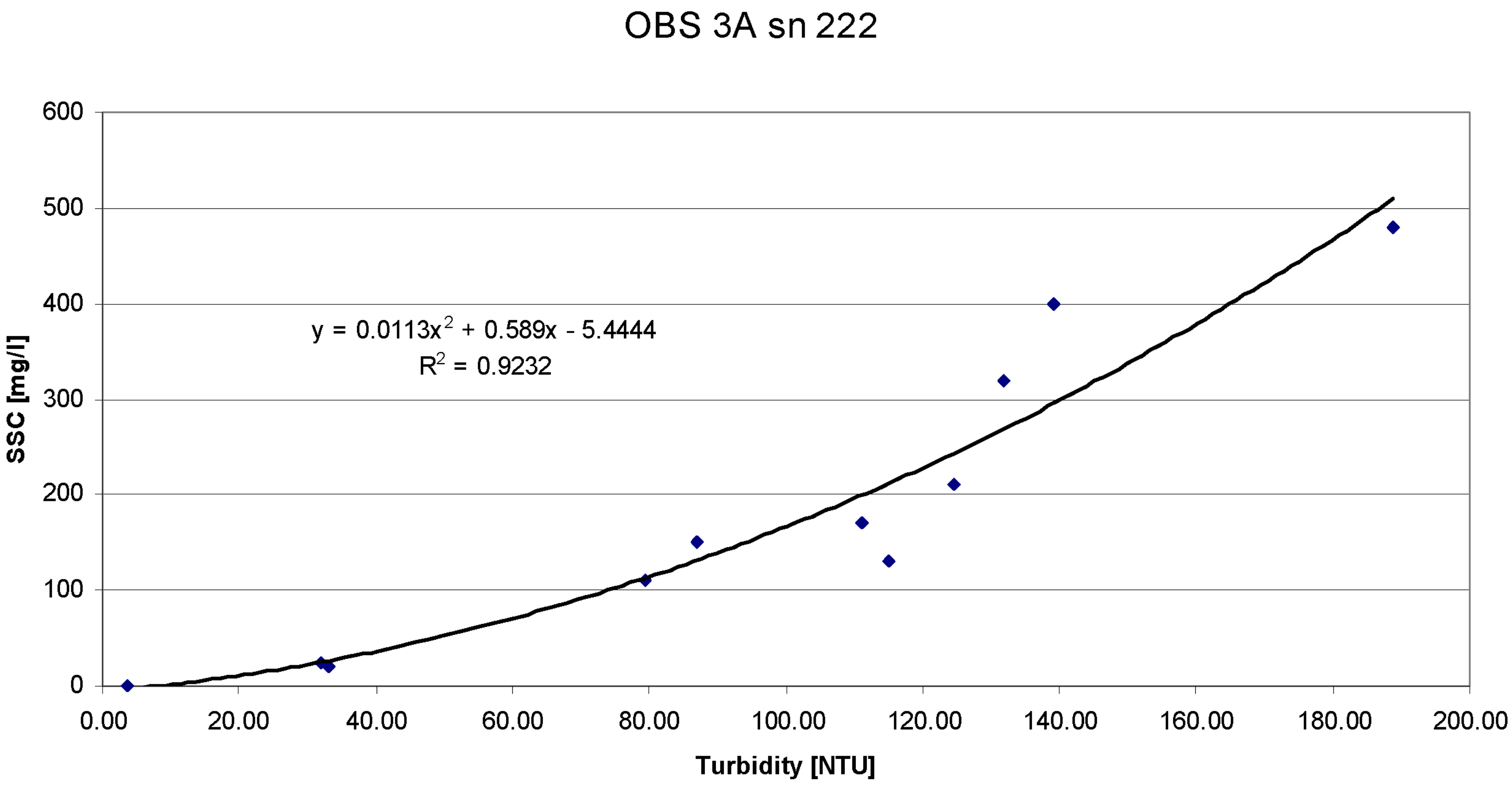
A.1 In situ Calibration Graphs

11283 DGD2 – CALIBRATION WINTER



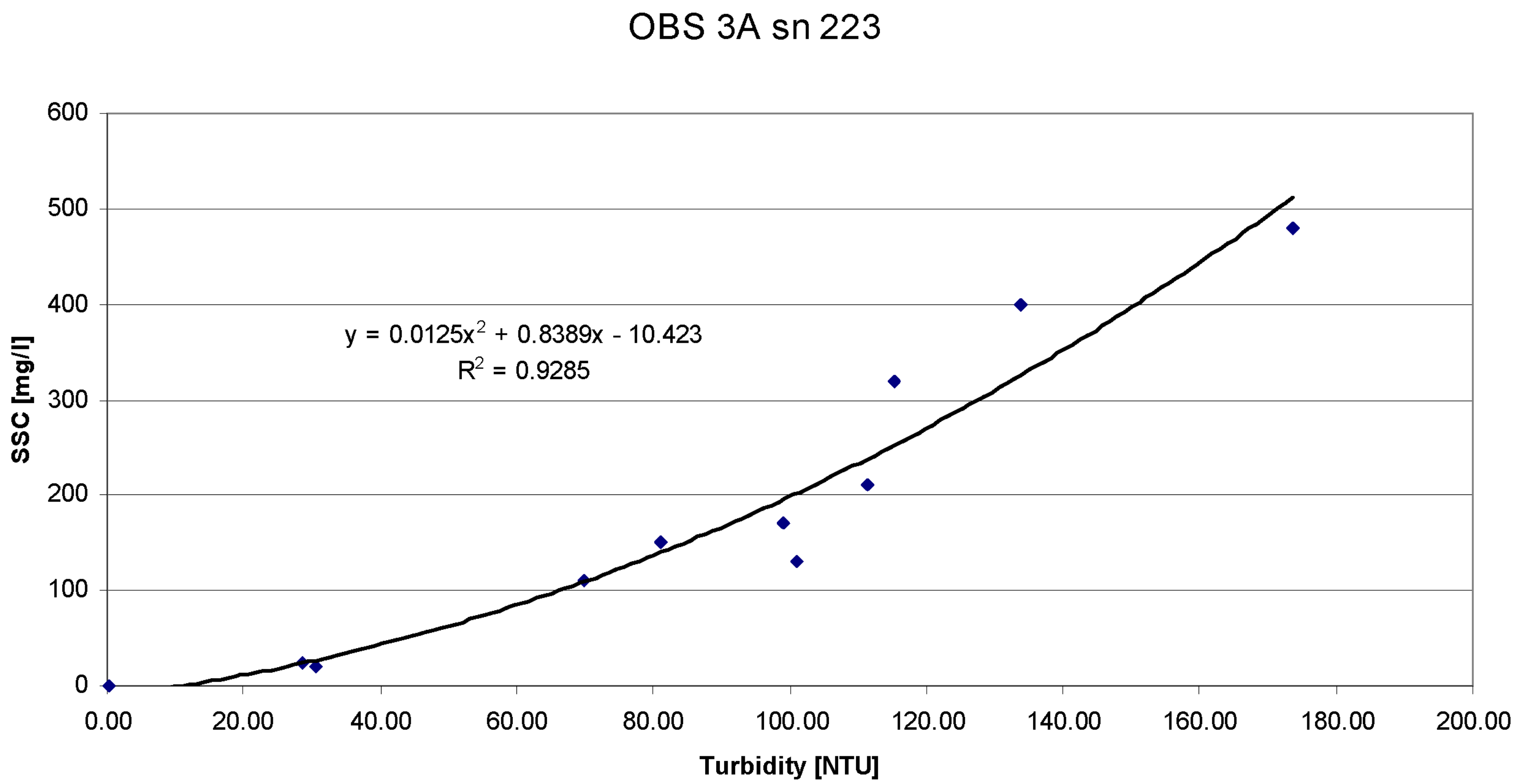
Calibration Graph of OBS 3A s/n 185		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	*In association with:* WL | delft hydraulics, GEMS International *I/RA/11283/07.096/MSA*

11283 DGD2 – CALIBRATION WINTER



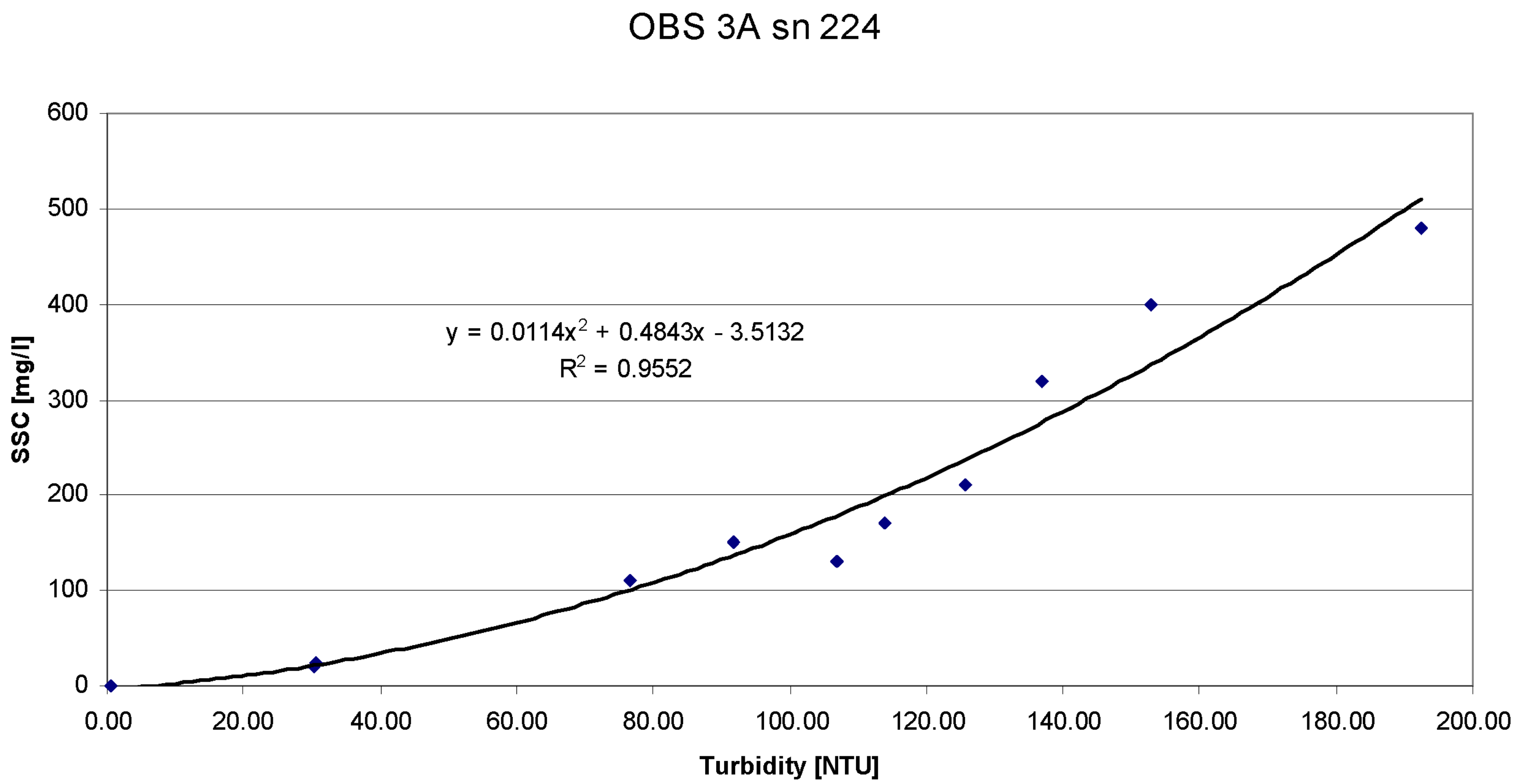
Calibration Graph of OBS 3A s/n 222		Data processed by:
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	*In association with:*
		I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of OBS3A s/n 223		Data processed by: IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	In association with: WL | delft hydraulics, GEMS International
		I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of OBS 3A s/n 224

Location:
Lower Sea Scheldt

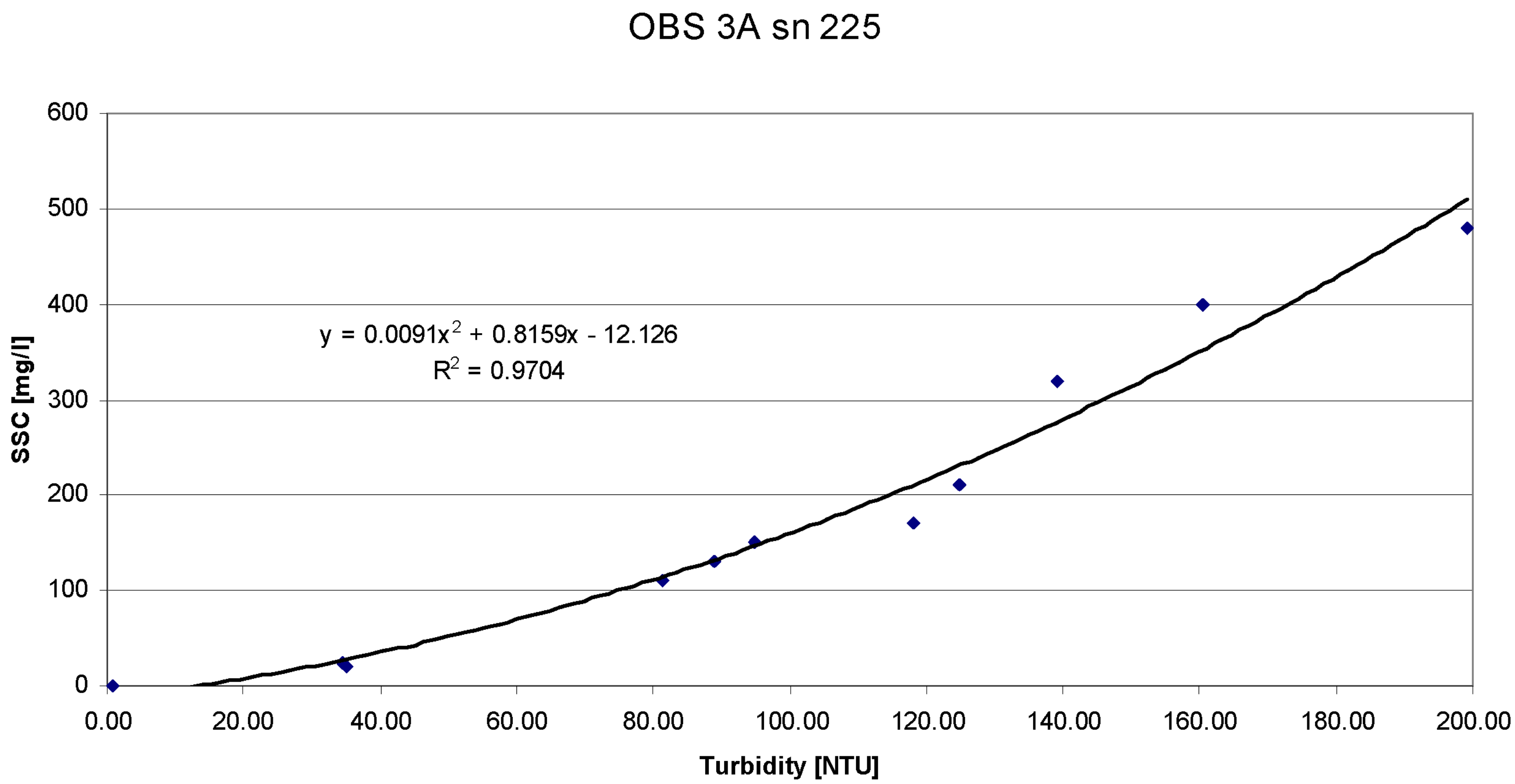
Date:
04/02/08 & 05/02/08

Data processed by: IMDC

In association with: WL | delft hydraulics, GEMS International

I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of OBS 3A s/n 225

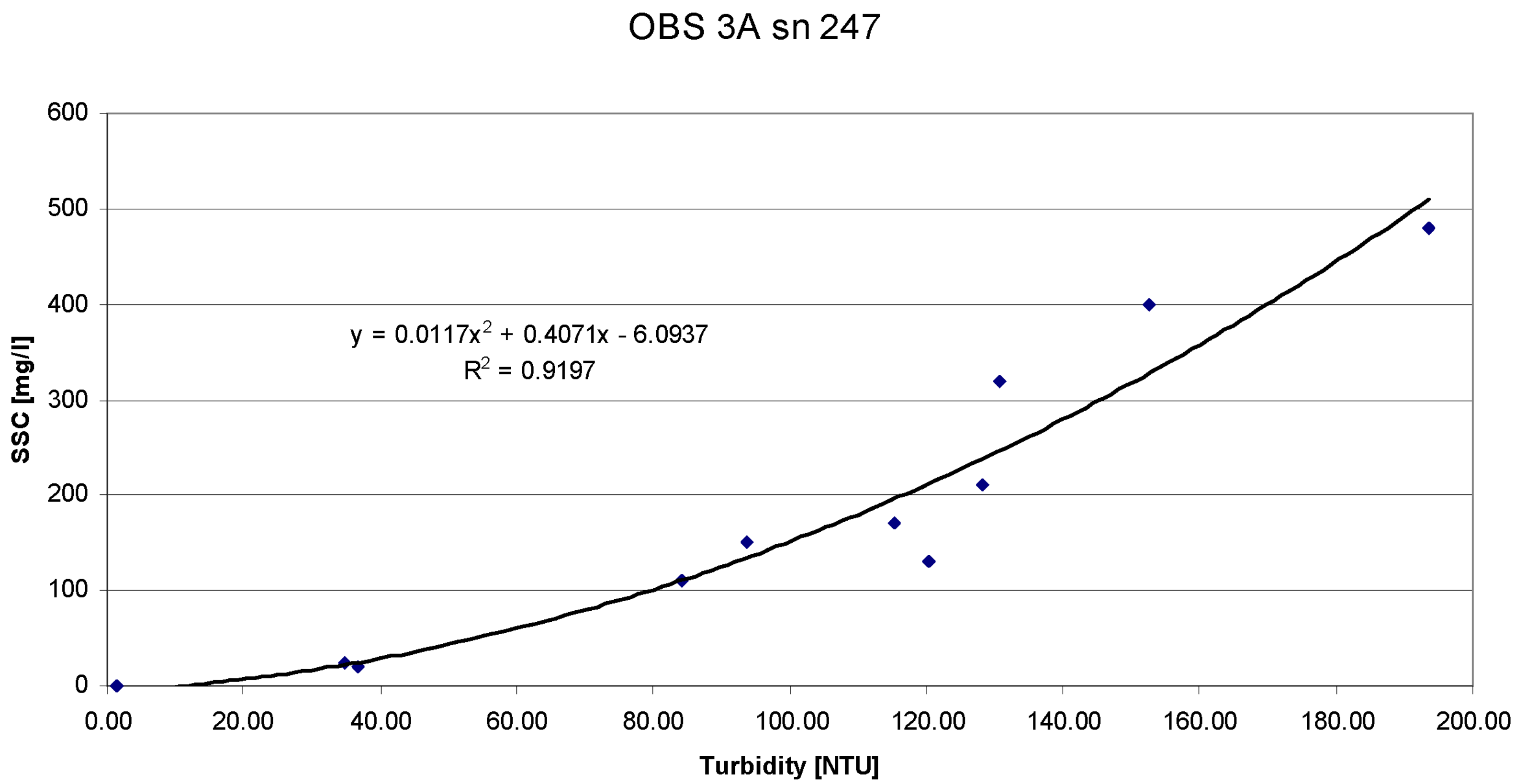
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08

Data processed by: IMDC

In association with: WL | delft hydraulics, GEMS International

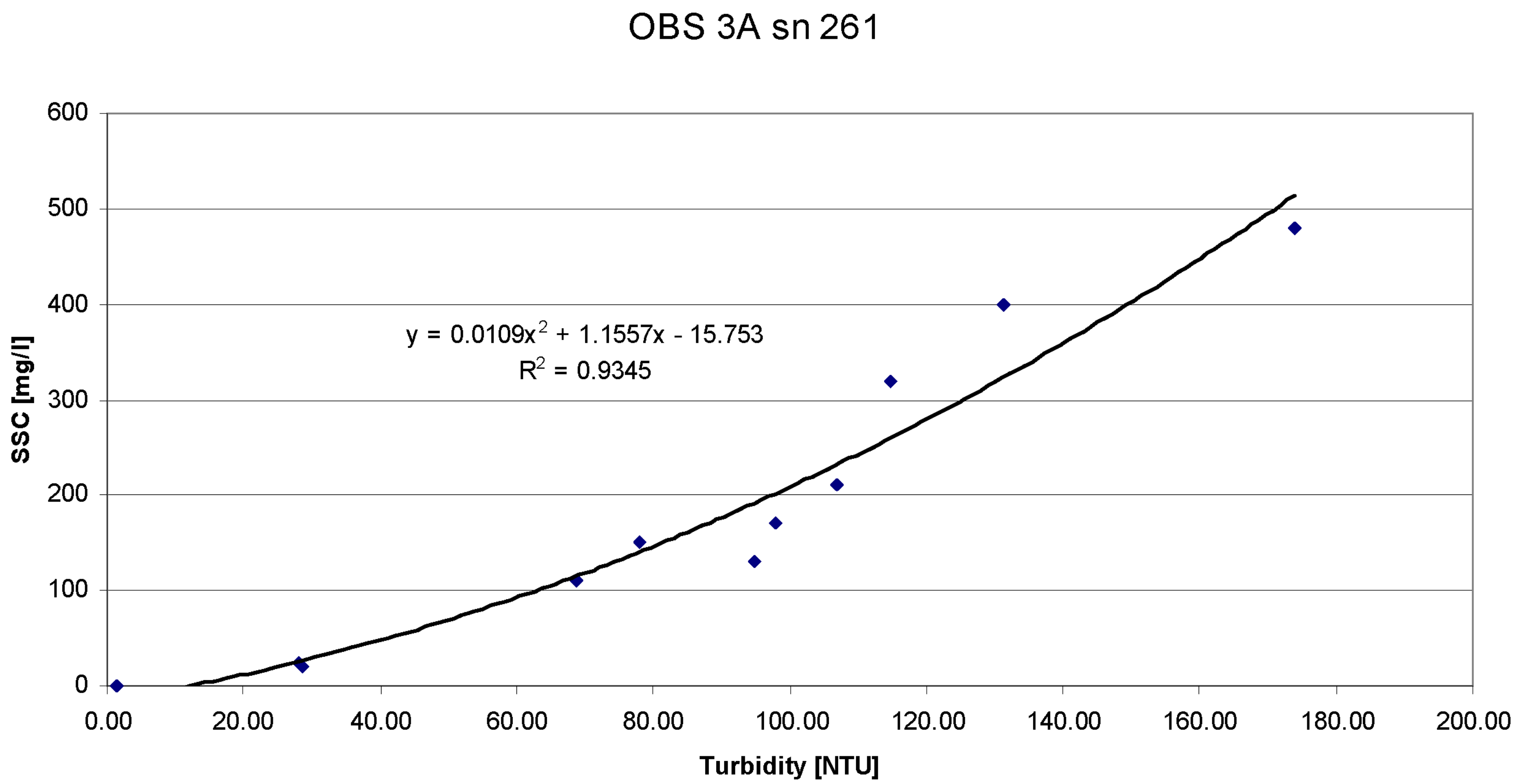
I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



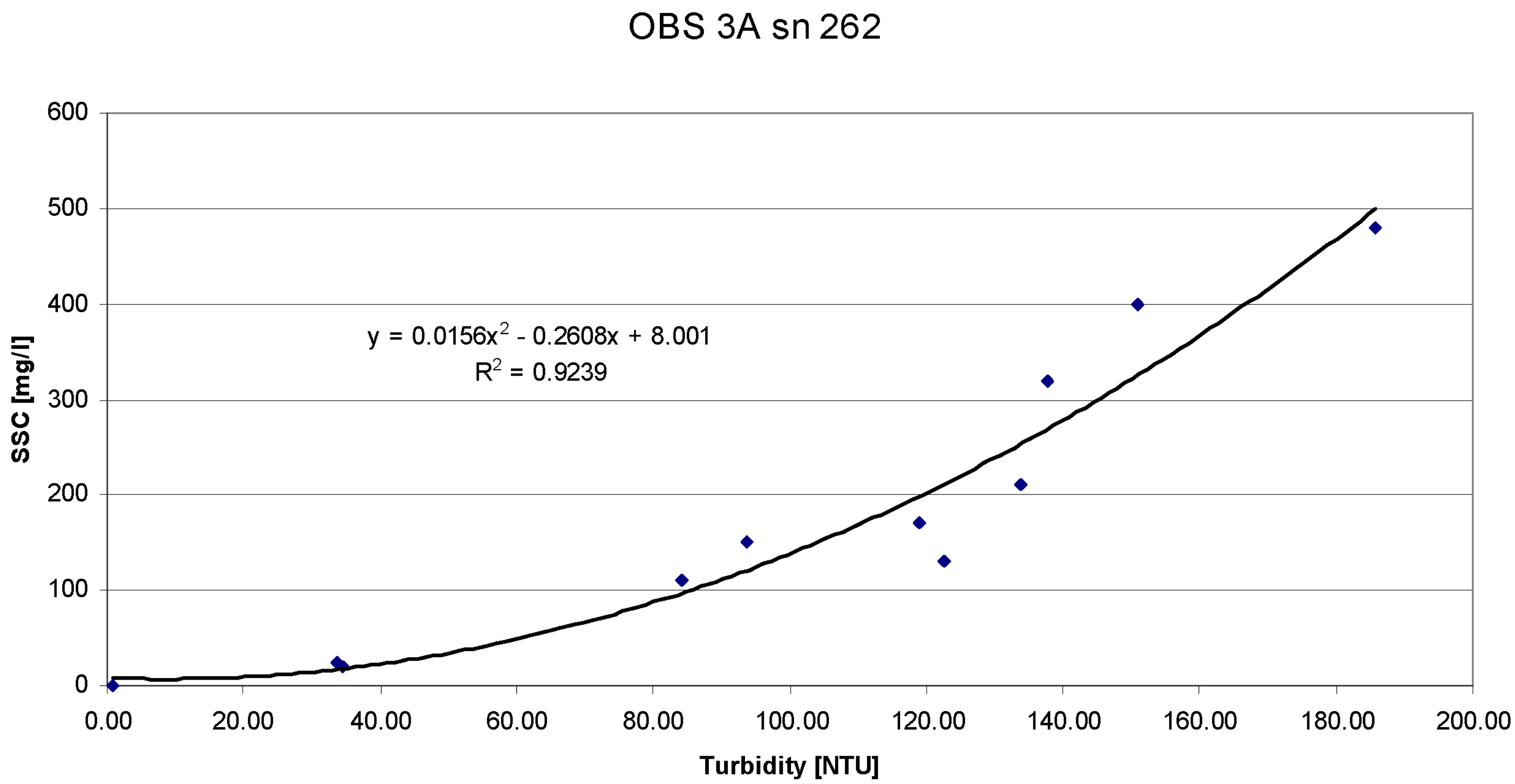
Calibration Graph of OBS 3A s/n 247		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	*In association with:* wl | delft hydraulics, GEMS International
		I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



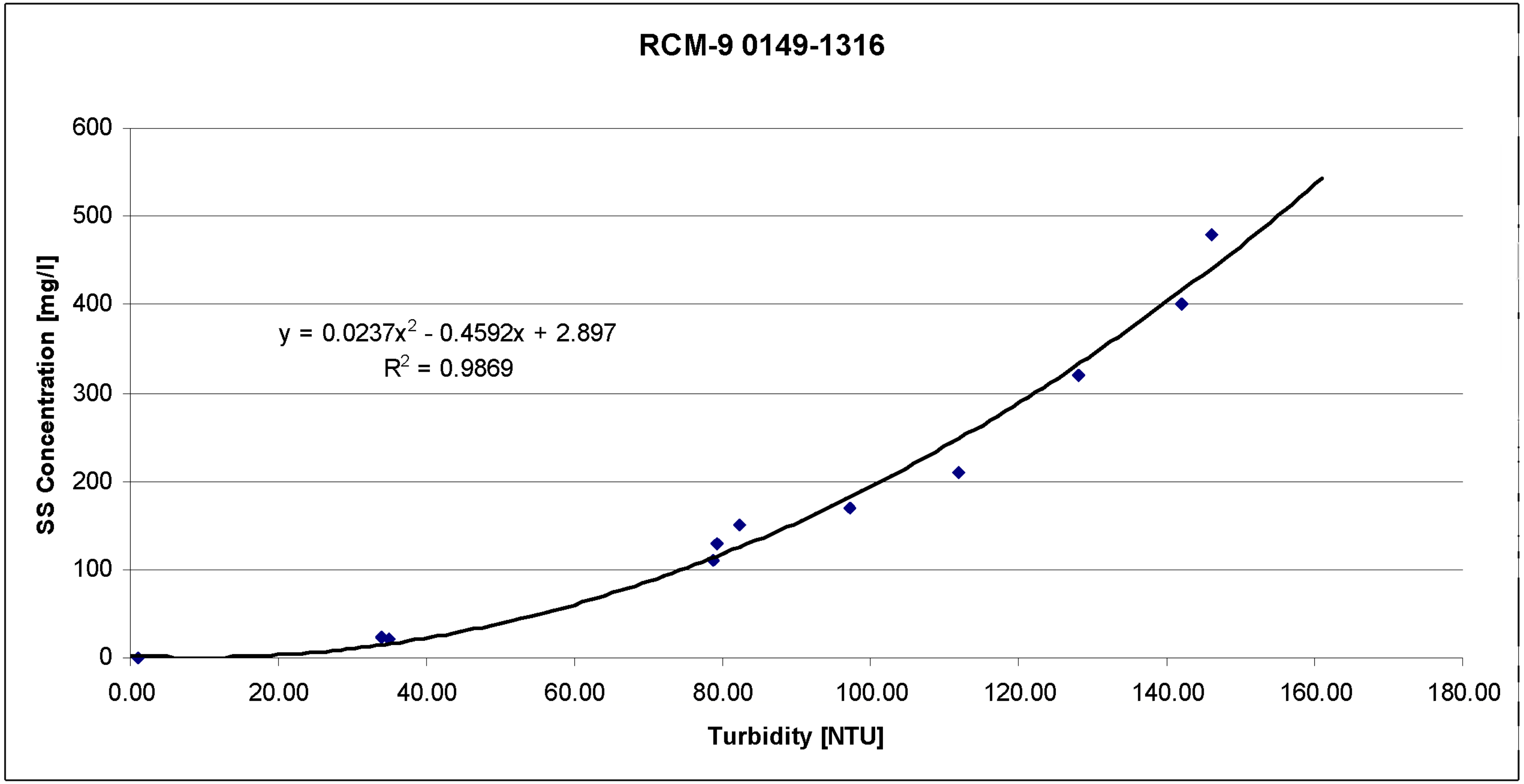
Calibration Graph of OBS 3A s/n 261		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	*In association with:* WL | delft hydraulics, GEMS International
		I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



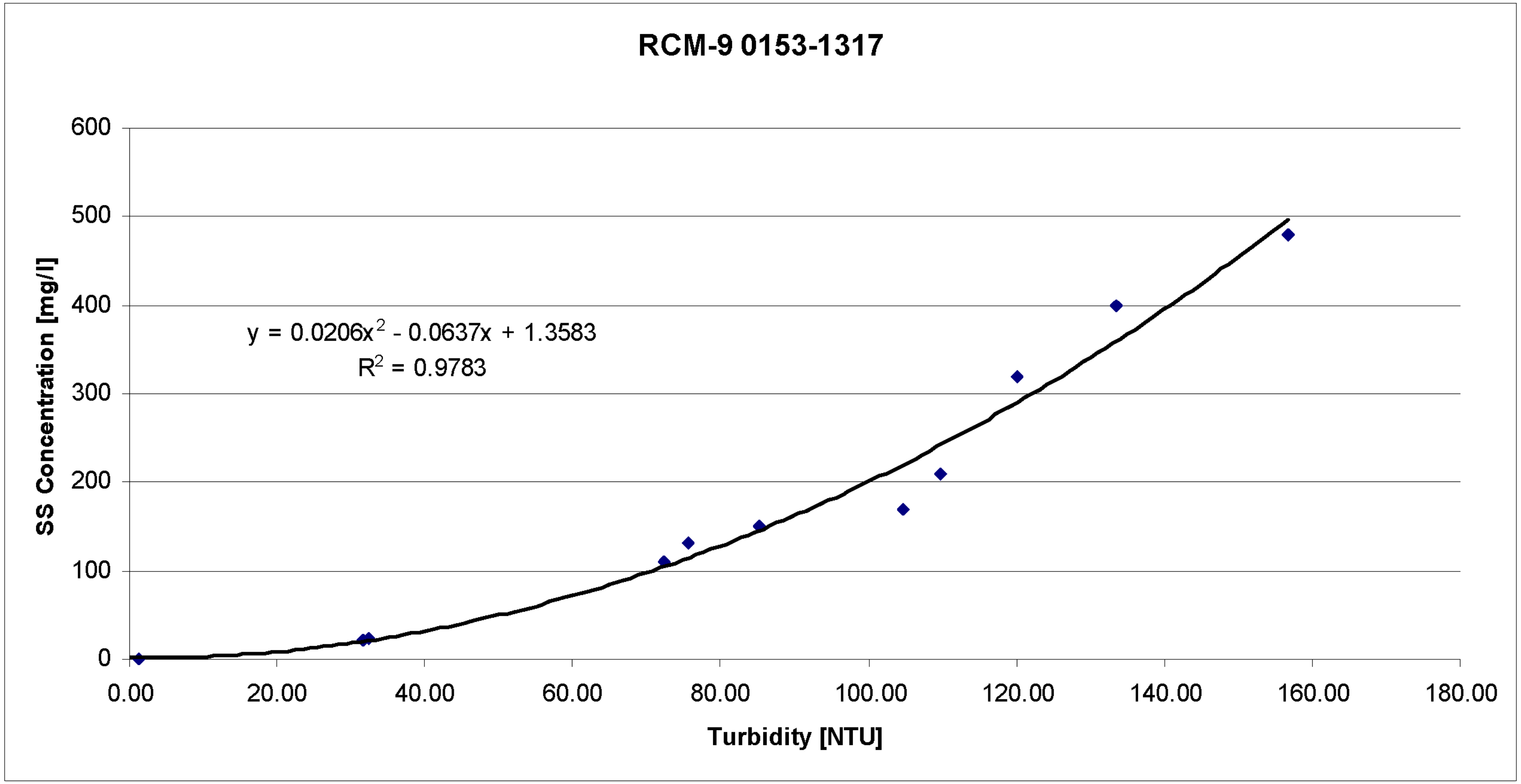
Calibration Graph of OBS 3A s/n 262		Data processed by: IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	In association with: WL | delft hydraulics, GEMS International I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



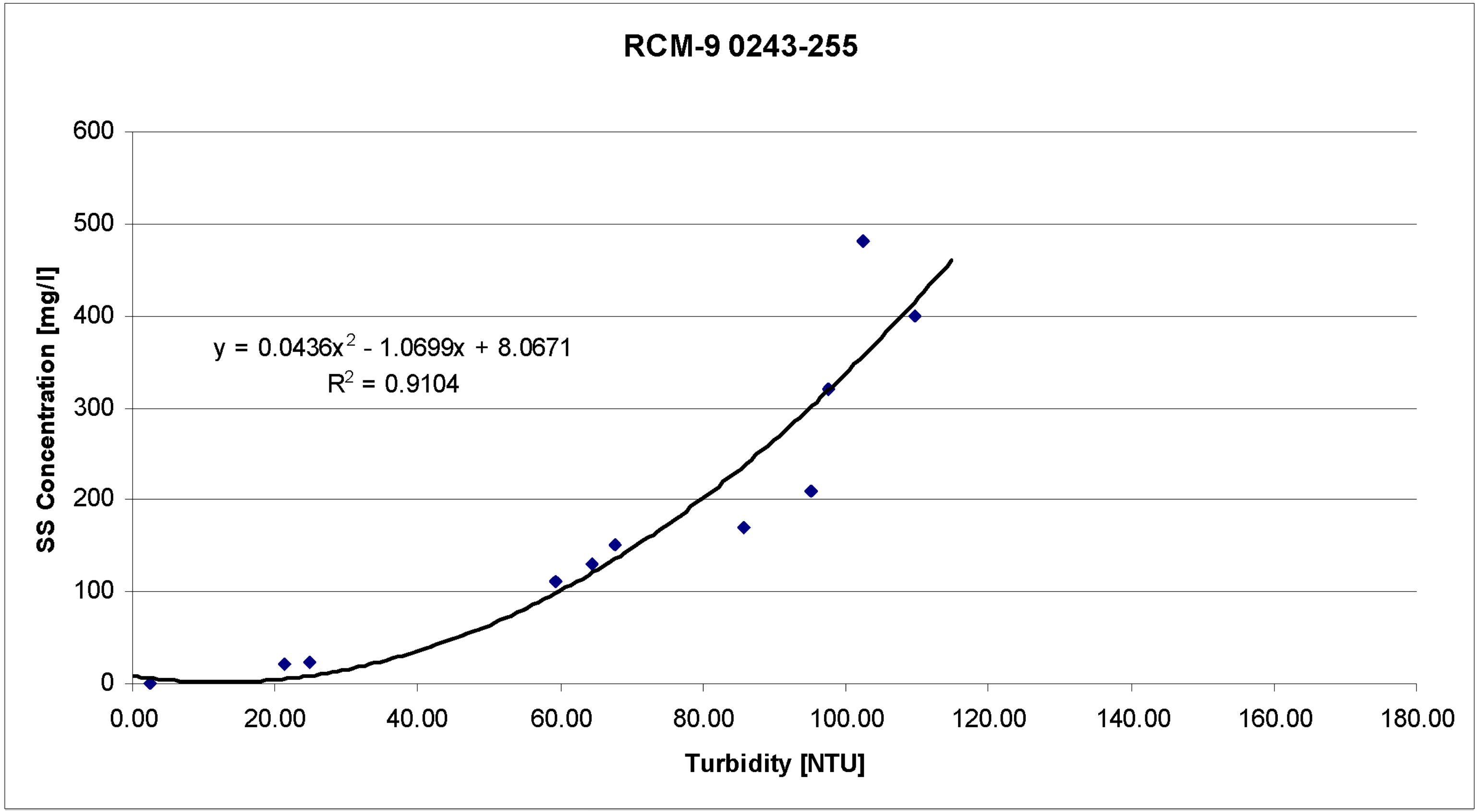
Calibration Graph of RCM-9 0149-1316		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	*In association with:* WL | delft hydraulics, GEMS International
		I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of RCM-9 0153-1317		Data processed by: IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	In association with: WL | delft hydraulics, GEMS International I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of RCM-9 0243-255

Location:
Lower Sea Scheldt

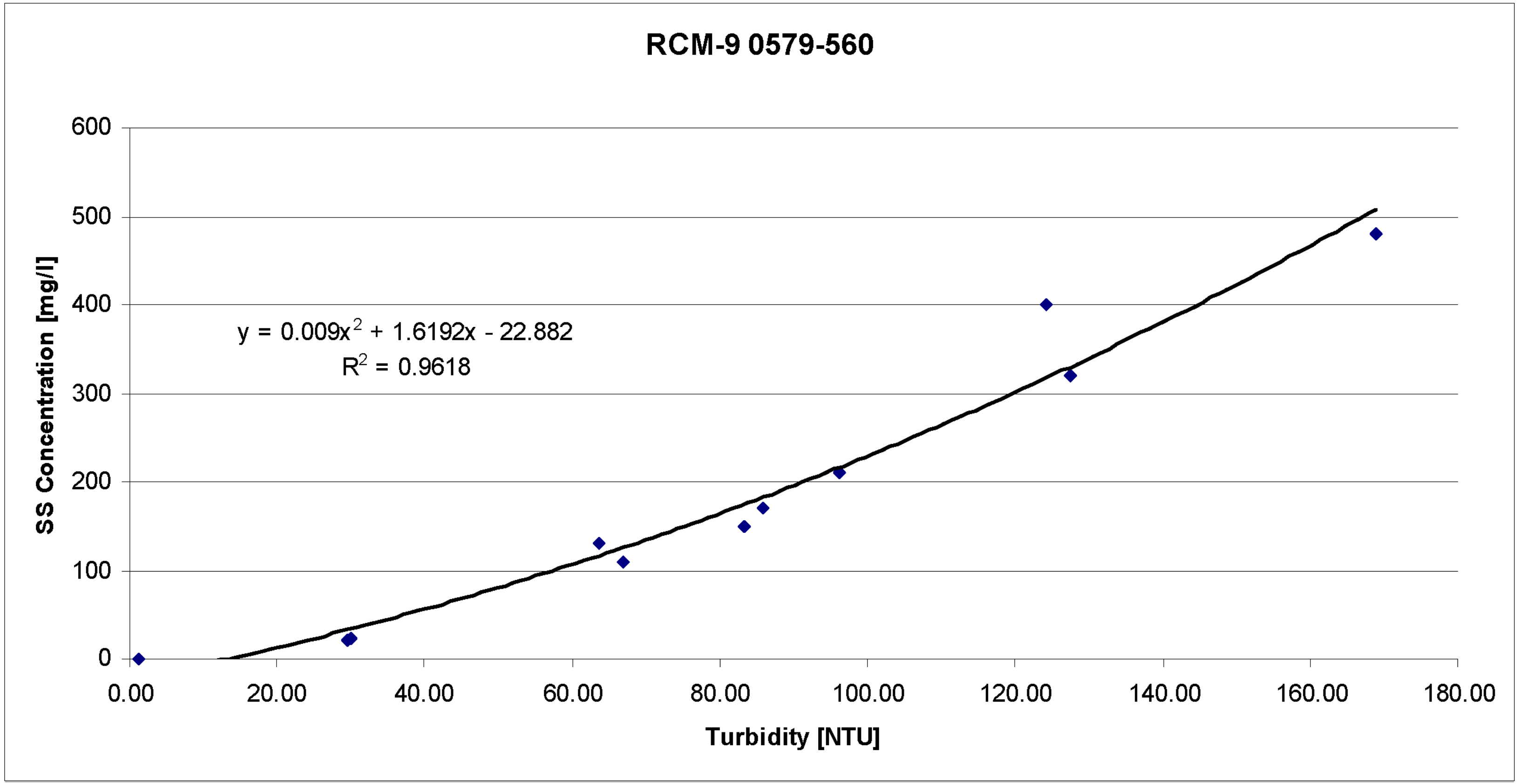
Date:
04/02/08 & 05/02/08

Data processed by:

In association with:

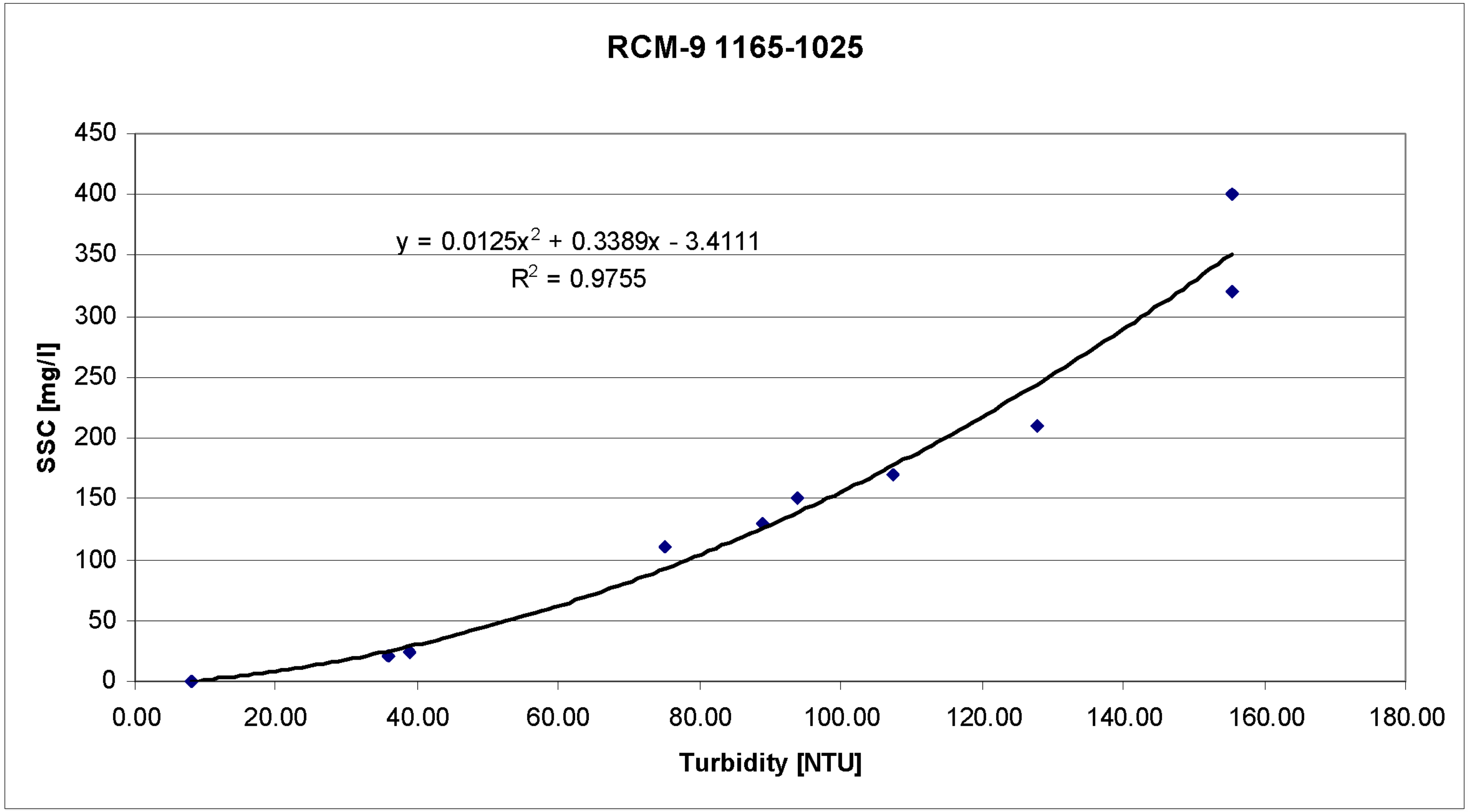
I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



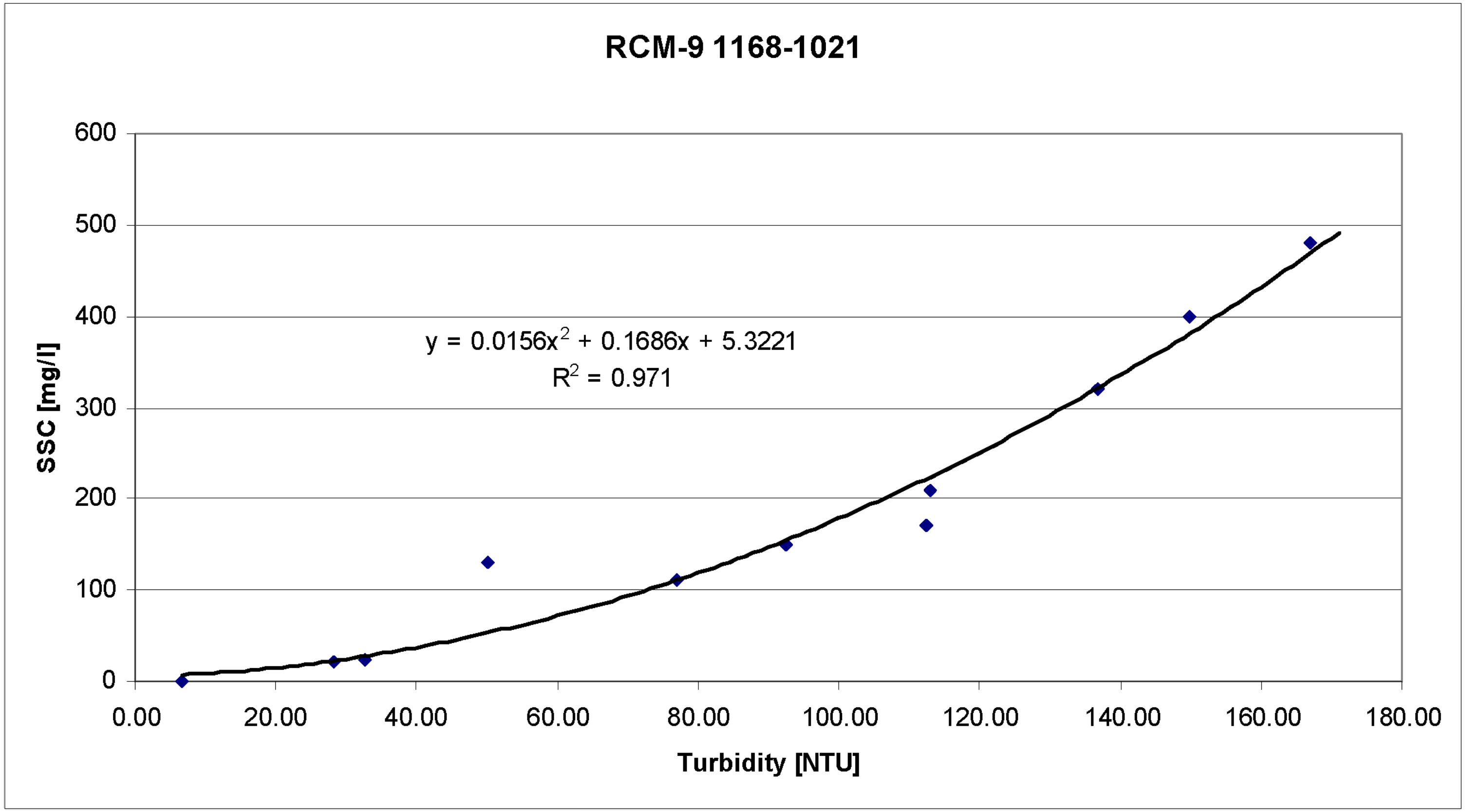
Calibration Graph of RCM-9 0579-560		Data processed by: IMDC In association with: WL | delft hydraulics, GEMS International I/RA/11283/07. 096/MSA
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of RCM-9 1165-1025		Data processed by: IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	In association with: WL | delft hydraulics, GEMS International
		I/RA/11283/07. 096/MSA

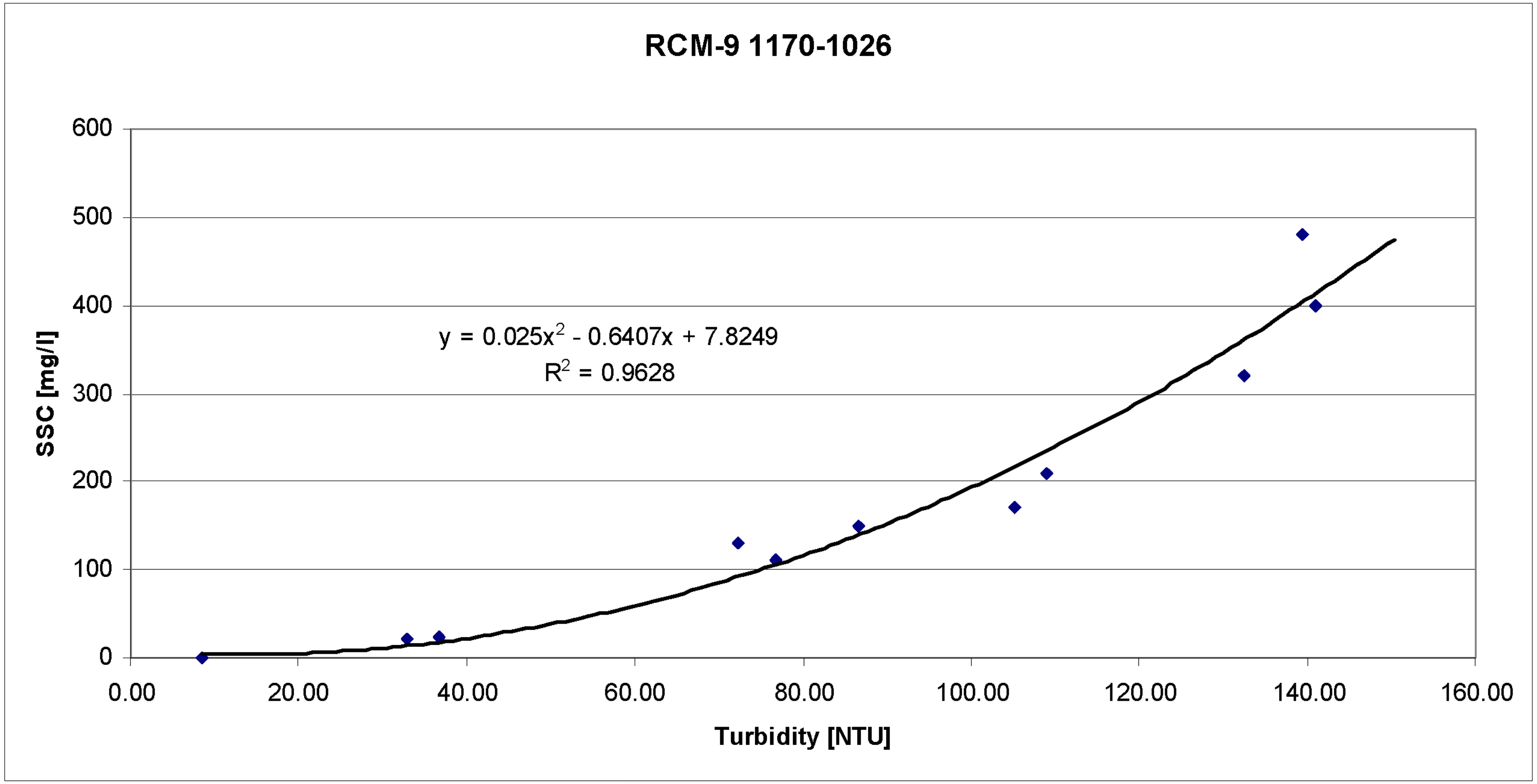
11283 DGD2 – CALIBRATION WINTER



Calibration Graph of RCM-9 1168-1021

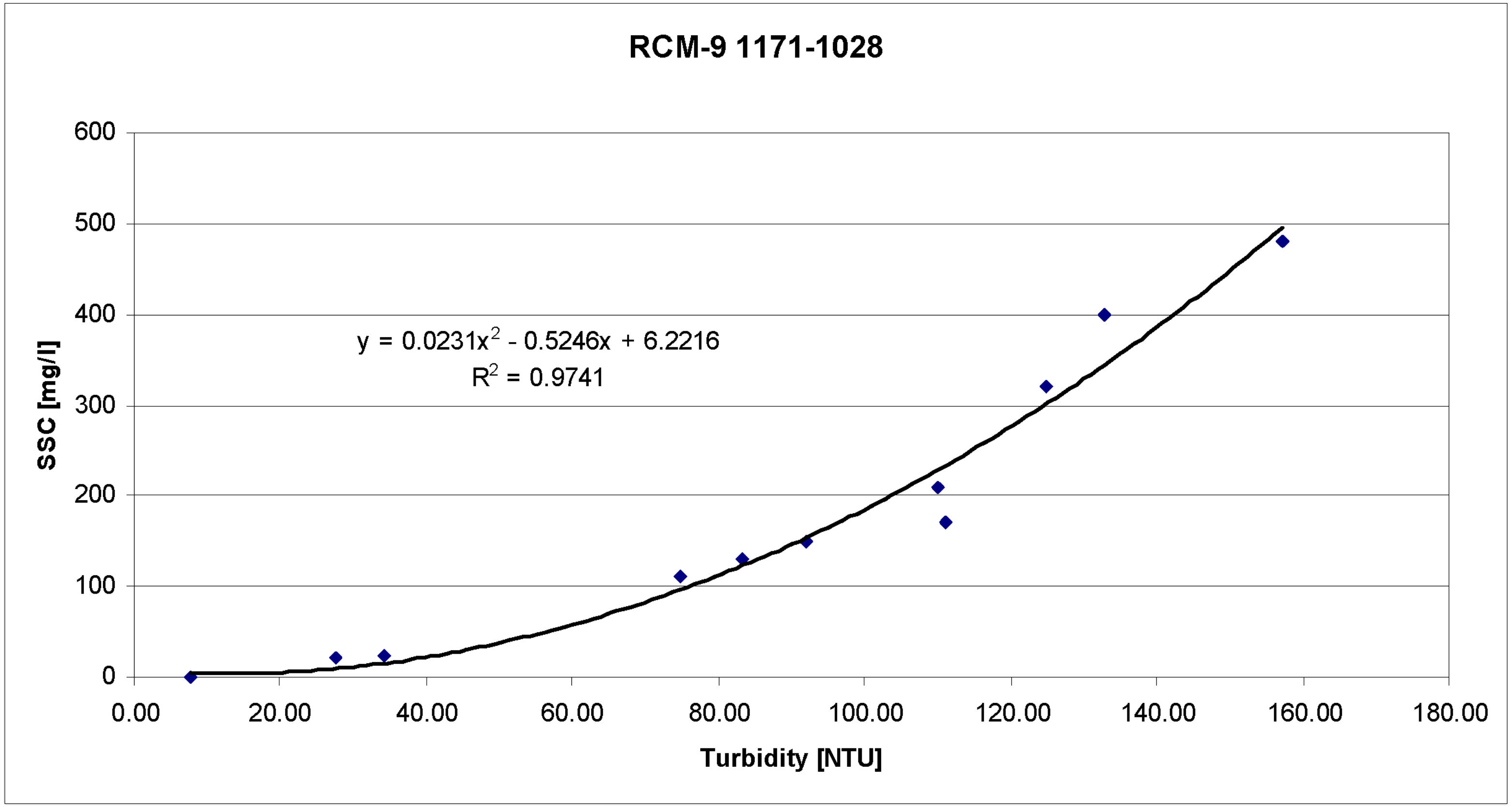
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	*Data processed by:* IMDC *In association with:* WL | delft hydraulics, GEMS International *I/RA/11283/07. 096/MSA*

11283 DGD2 – CALIBRATION WINTER



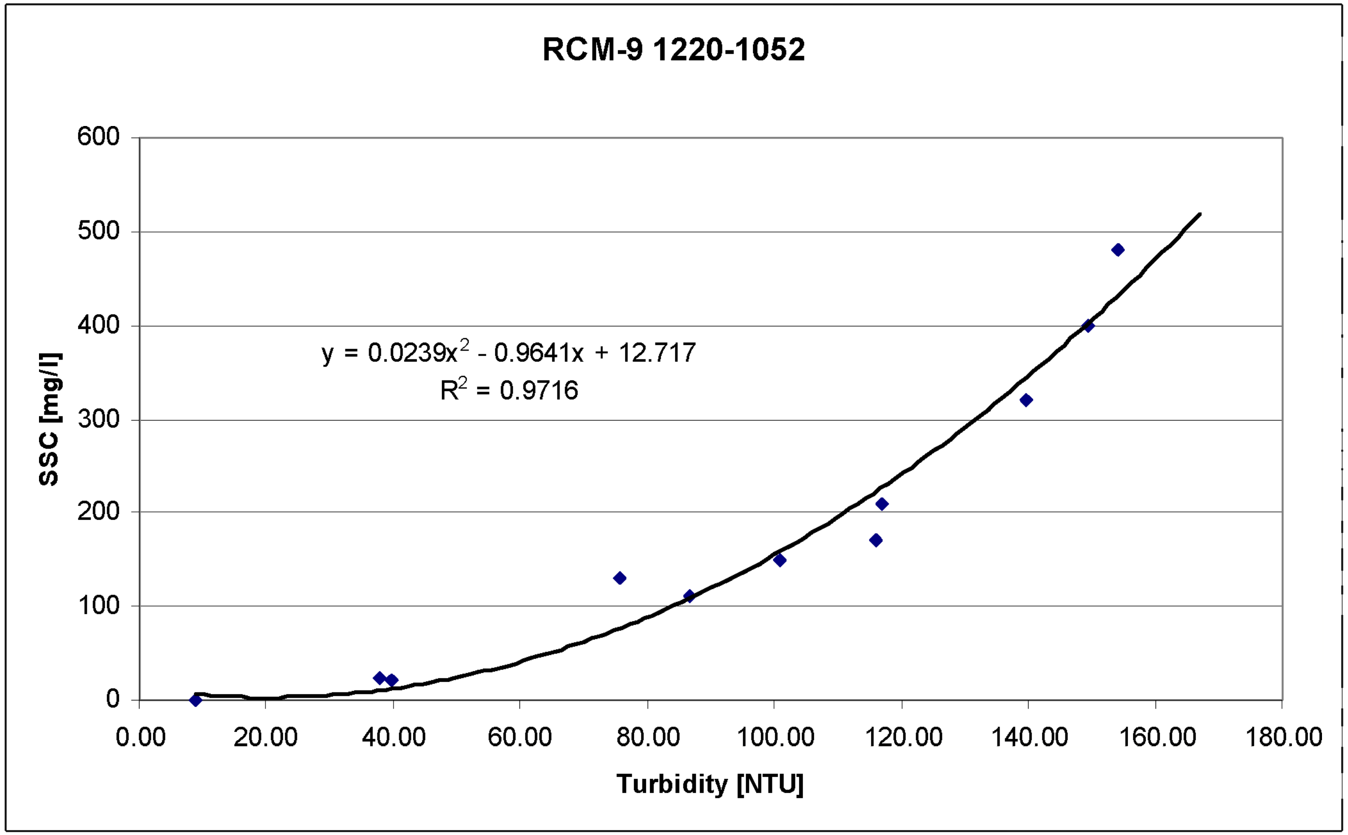
Calibration Graph of RCM-9 1170-1026		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	*In association with:* WL | delft hydraulics, GEMS International
		I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of RCM-9 1171-1028		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	*In association with:* WL | delft hydraulics, GEMS International
		I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of RCM-9 1220-1052

Location:
Lower Sea Scheldt

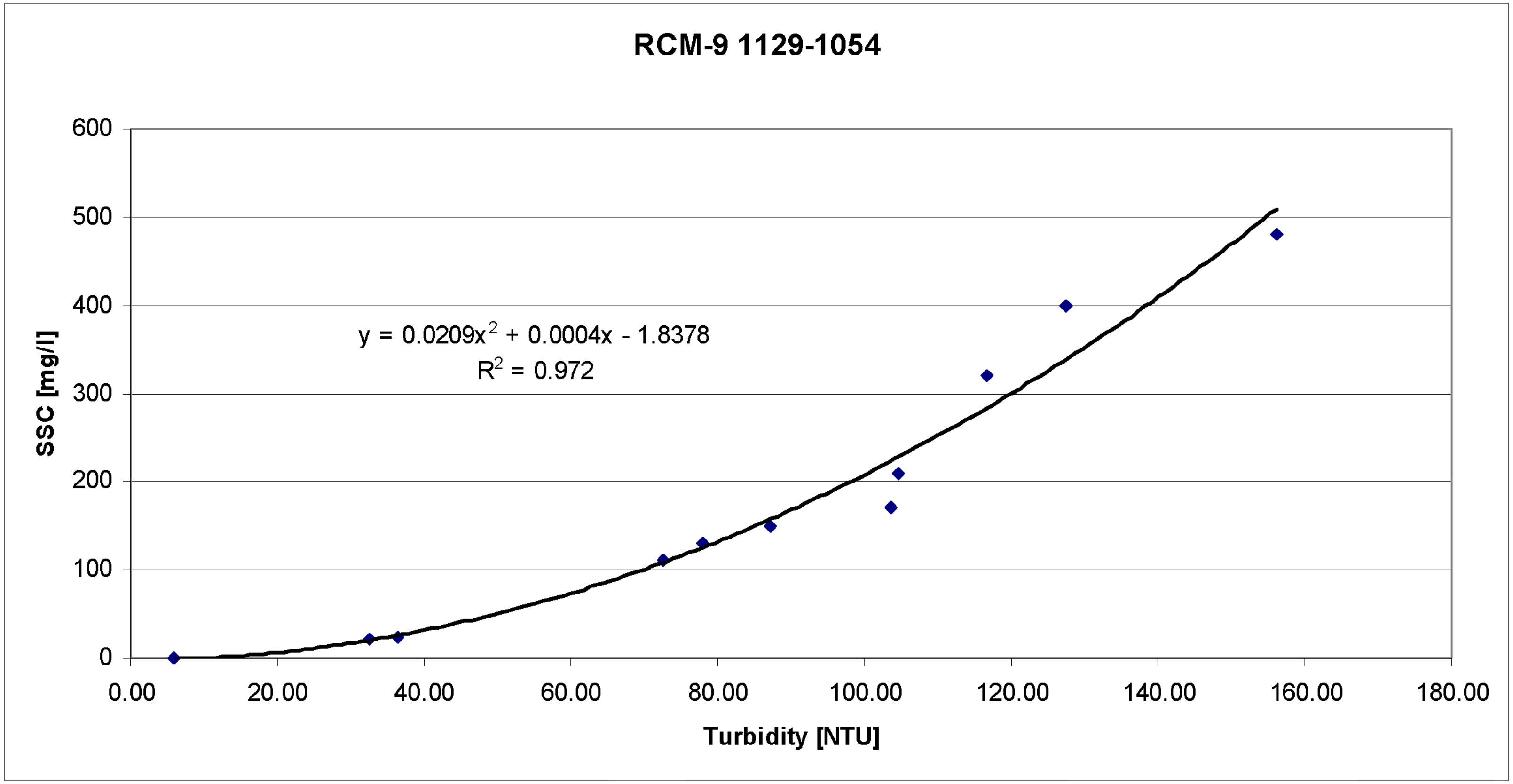
Date:
04/02/08 & 05/02/08

Data processed by:

In association with:

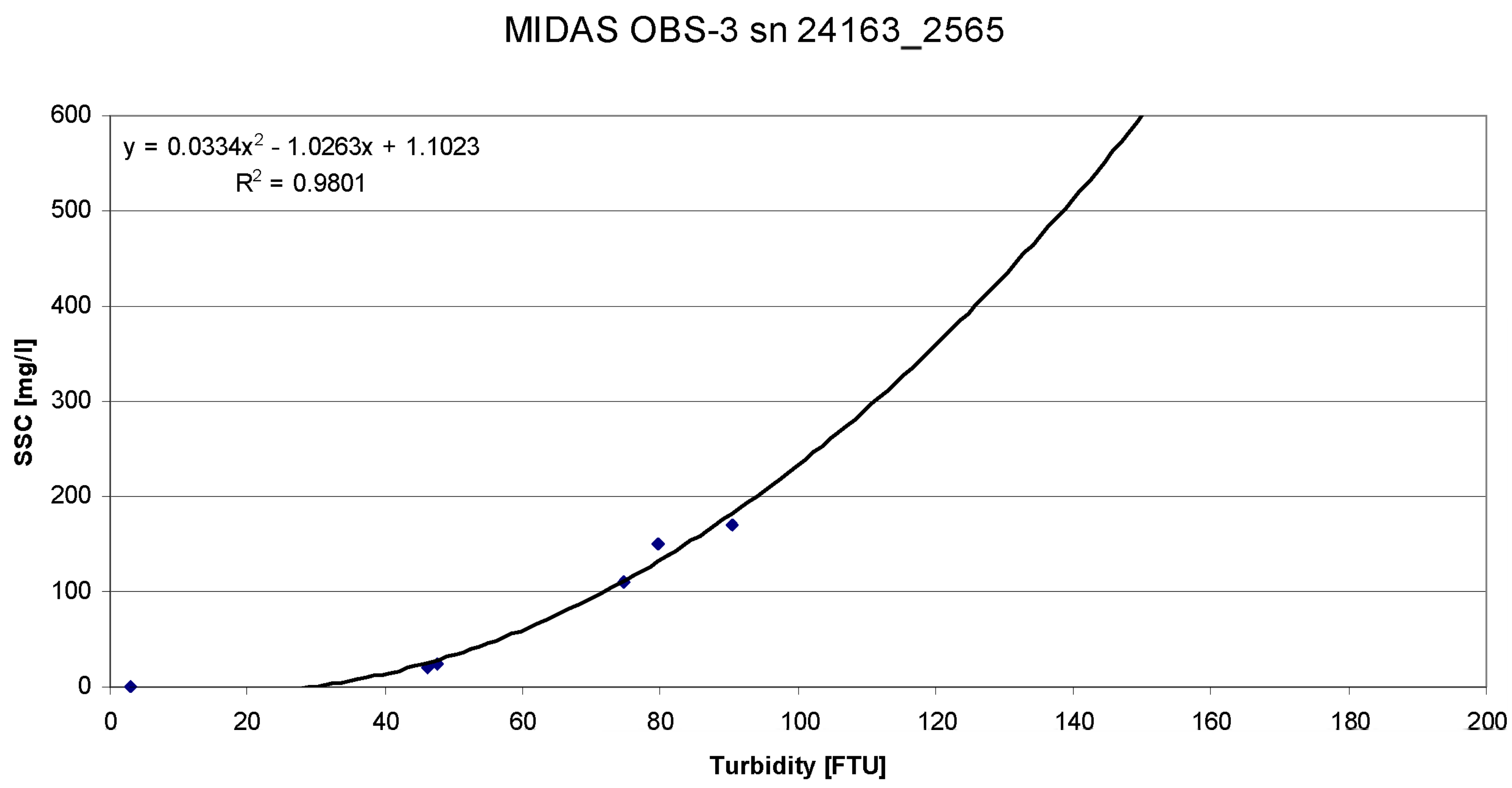
I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER



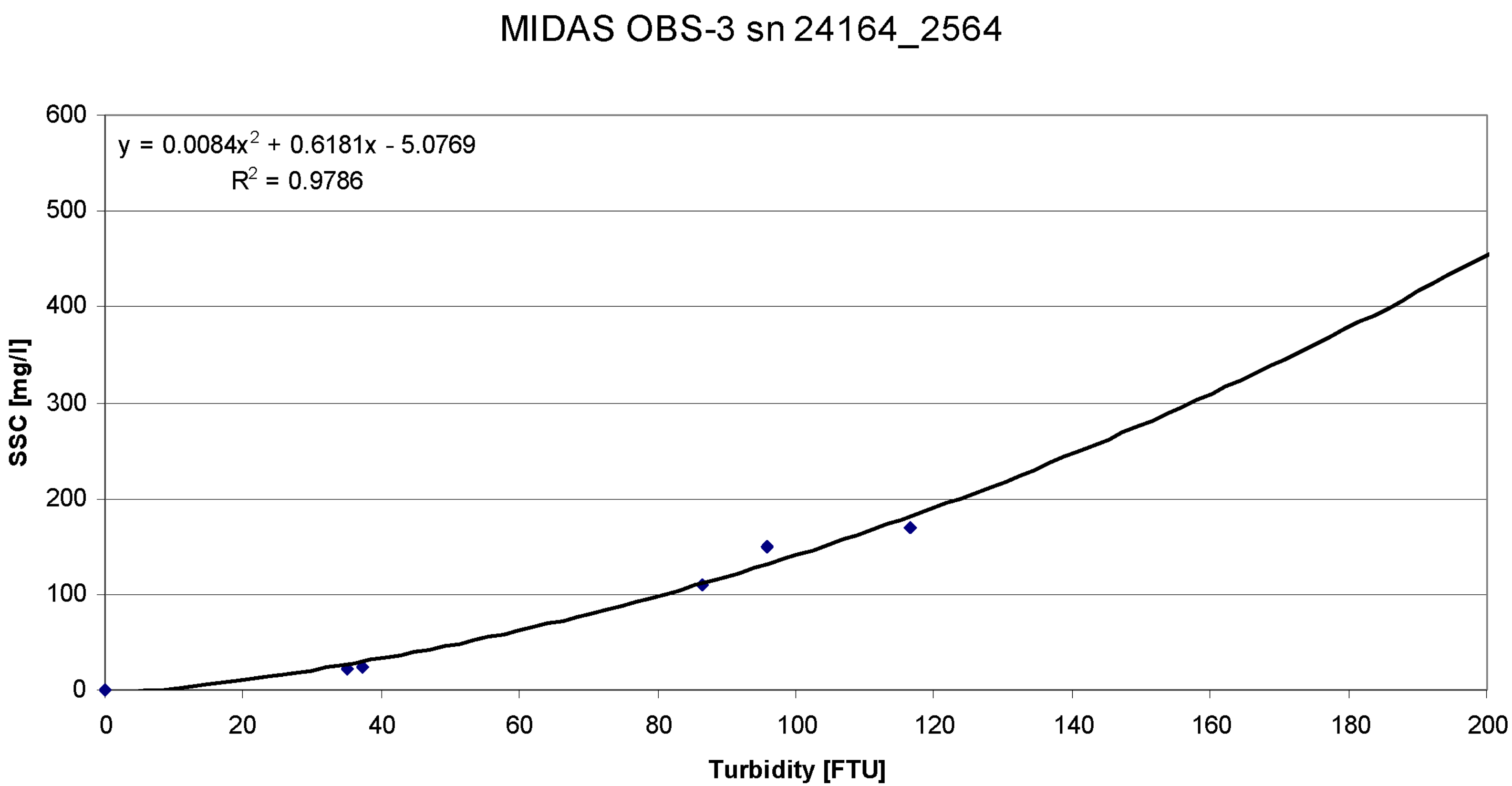
Calibration Graph of RCM-9 1229_1054		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 04/02/08 & 05/02/08	*In association with:* wl | delft hydraulics, GEMS International *I/RA/11283/07. 096/MSA*

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of OBS 3+ 2565		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 04/02/08	*In association with:* wl | delft hydraulics, GEMS International
		I/RA/11283/07. 096/MSA

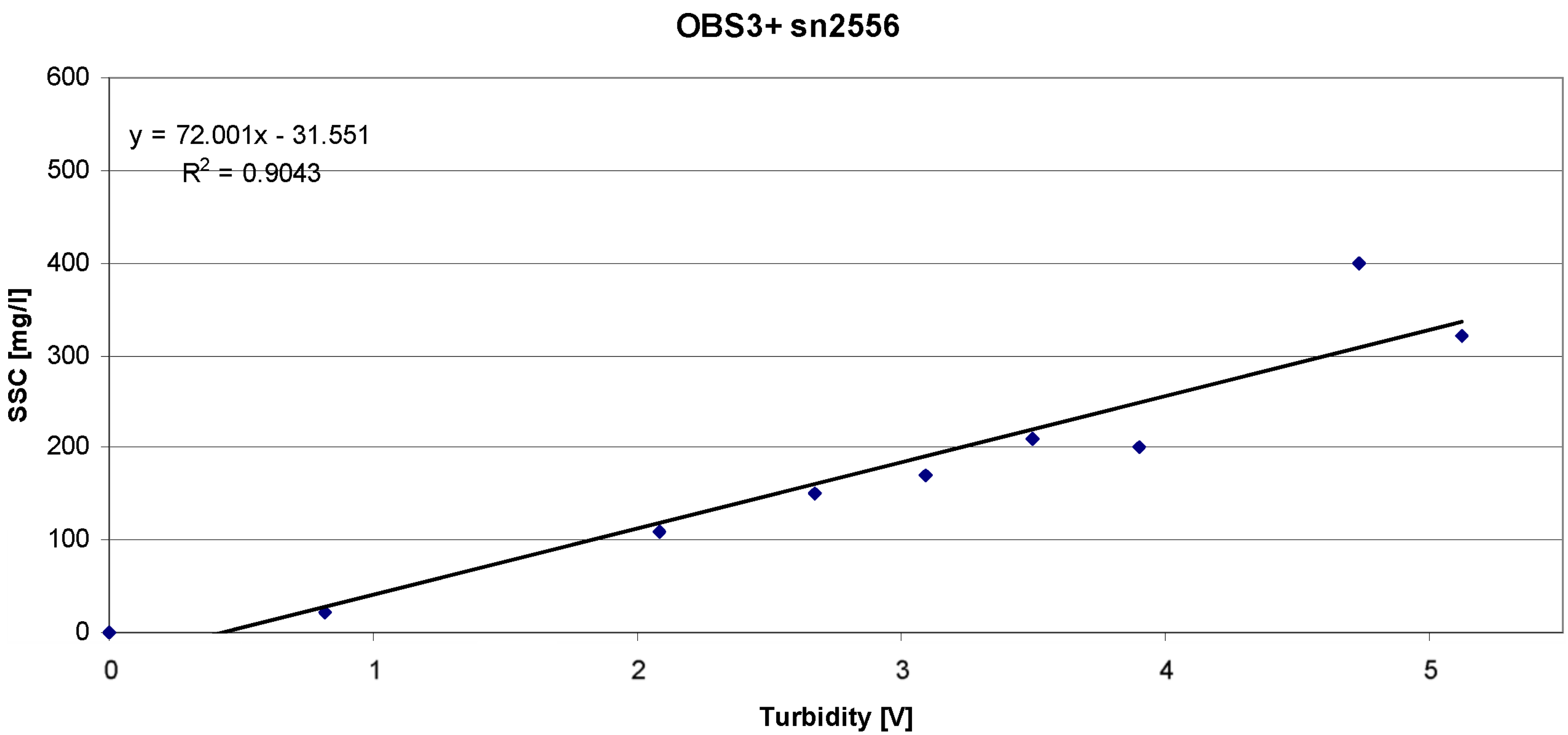
11283 DGD2 – CALIBRATION WINTER



Calibration Graph of OBS 3+ 2564		Data processed by: IMDC
Location: Lower Sea Scheldt	Date: 04/02/08	In association with: WL | delft hydraulics, GEMS International

I/RA/11283/07. 096/MSA

11283 DGD2 – CALIBRATION WINTER

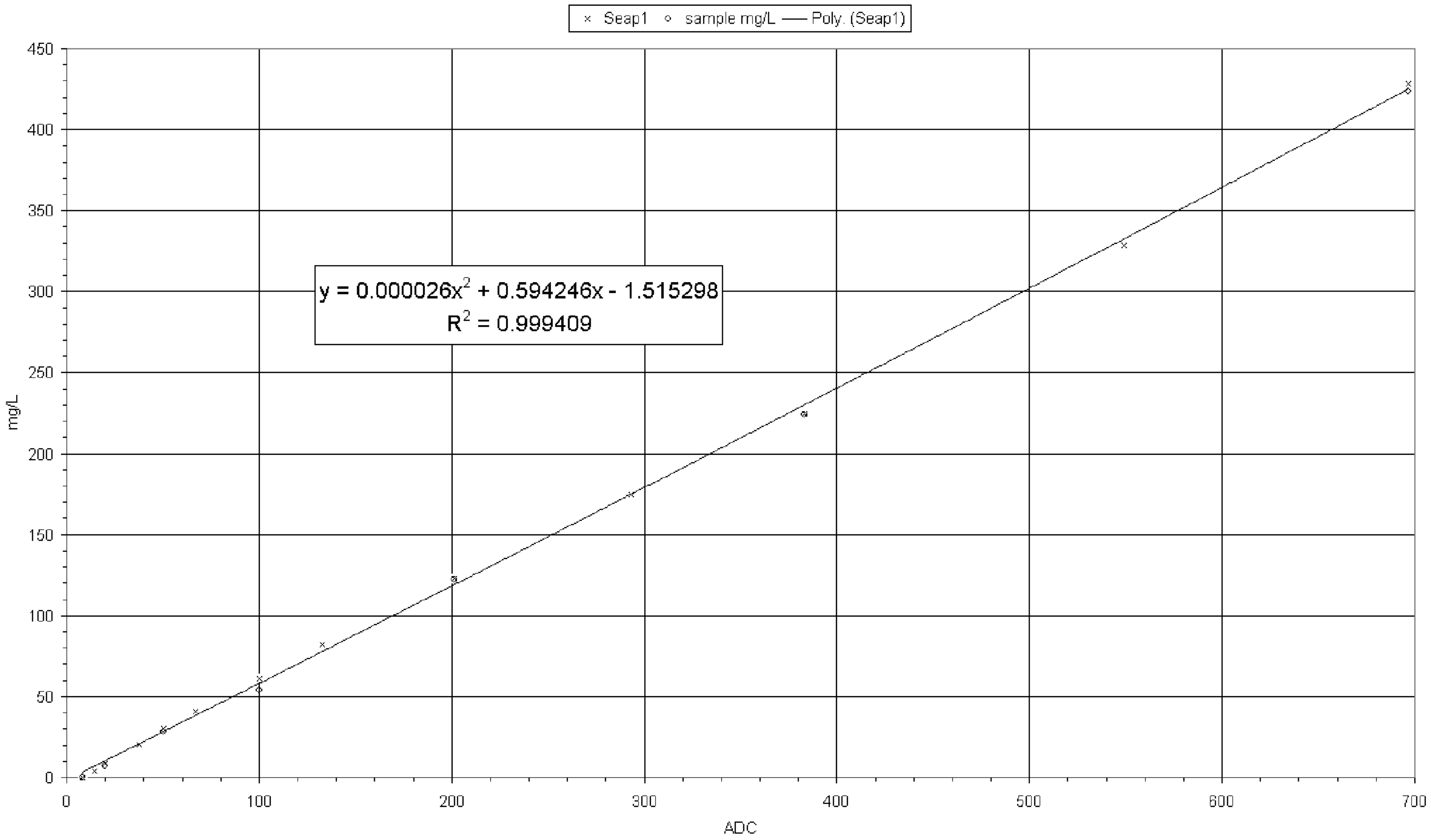


Calibration Graph of OBS 3+ 2556		*Data processed by:* IMDC
Location: Lower Sea Scheldt	Date: 04-05/02/08	*In association with:* wl | delft hydraulics, GEMS International

I/RA/11283/07. 096/MSA

A.2 Manufacturers Calibration

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of Siltprofiler - Seapoint

Location: WL|Delft Hydraulics

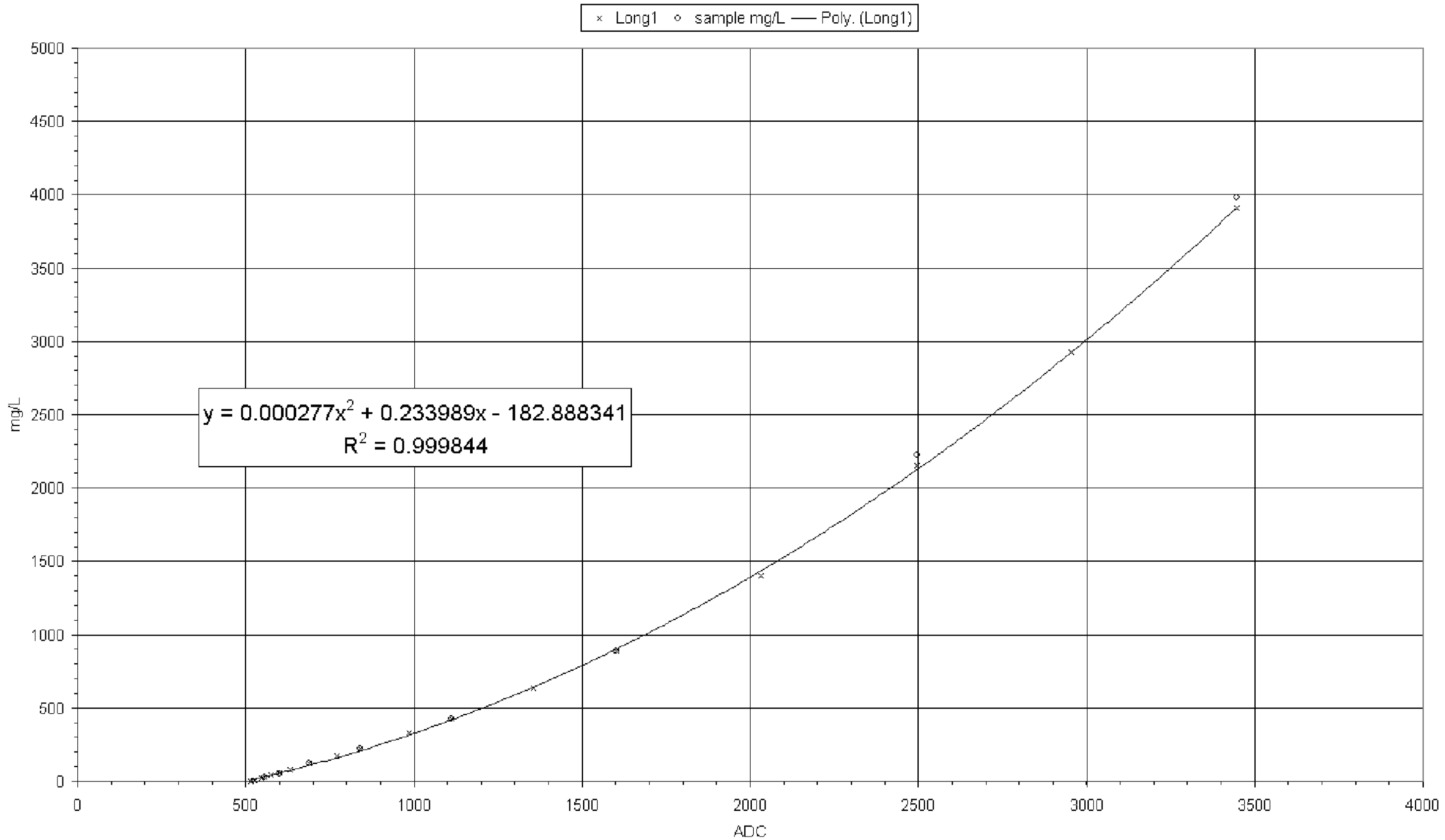
Date: 10/01/2007

Data processed by: IMDC

In association with: WL | delft hydraulics, GEMS International

I/RA/11283/07.096/MSA

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of Siltprofiler – Long Range

Location:
WL|Delft Hydraulics

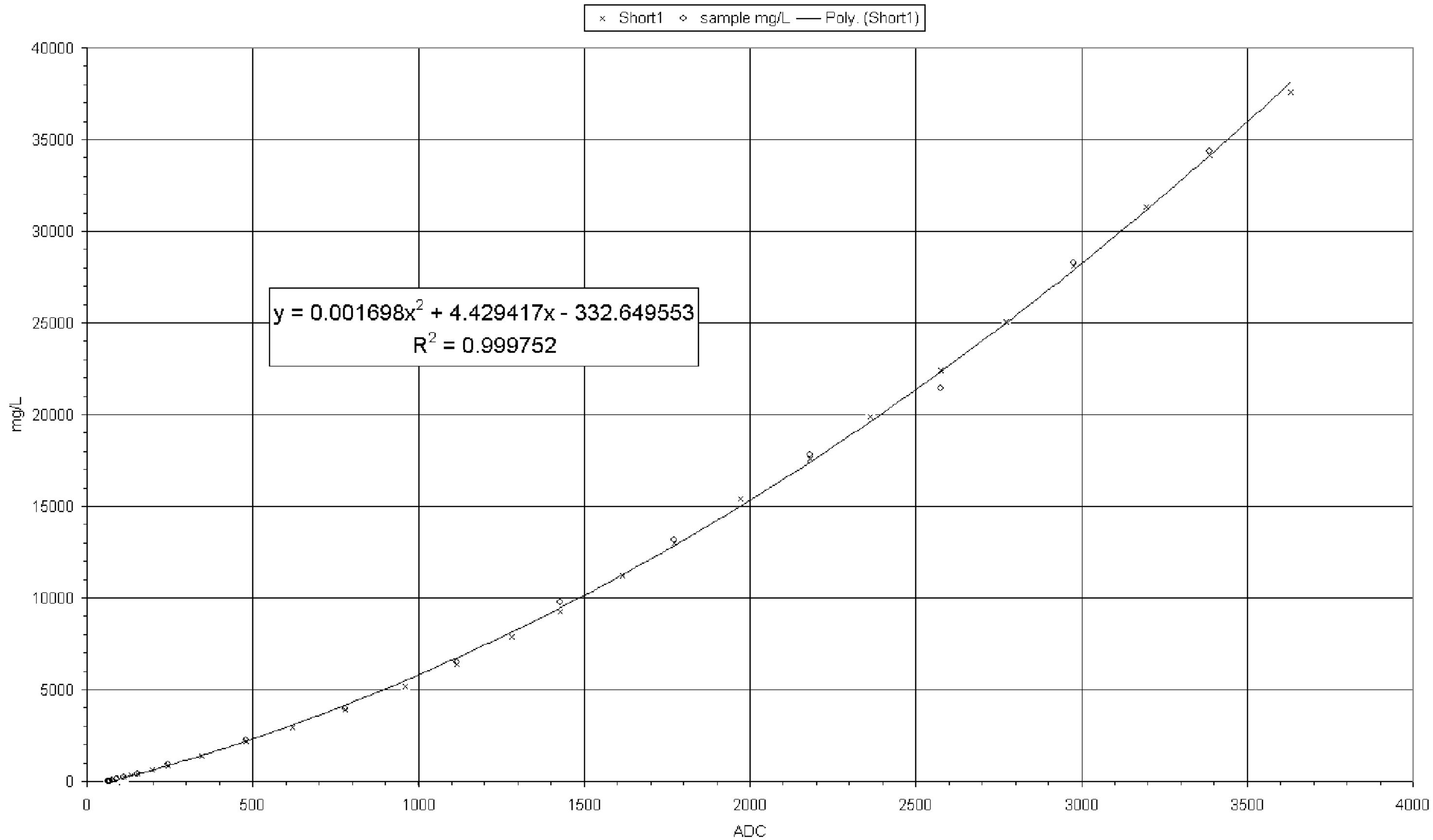
Date:
10/01/2007

Data processed by:

In association with:

I/RA/11283/07.096/MBO

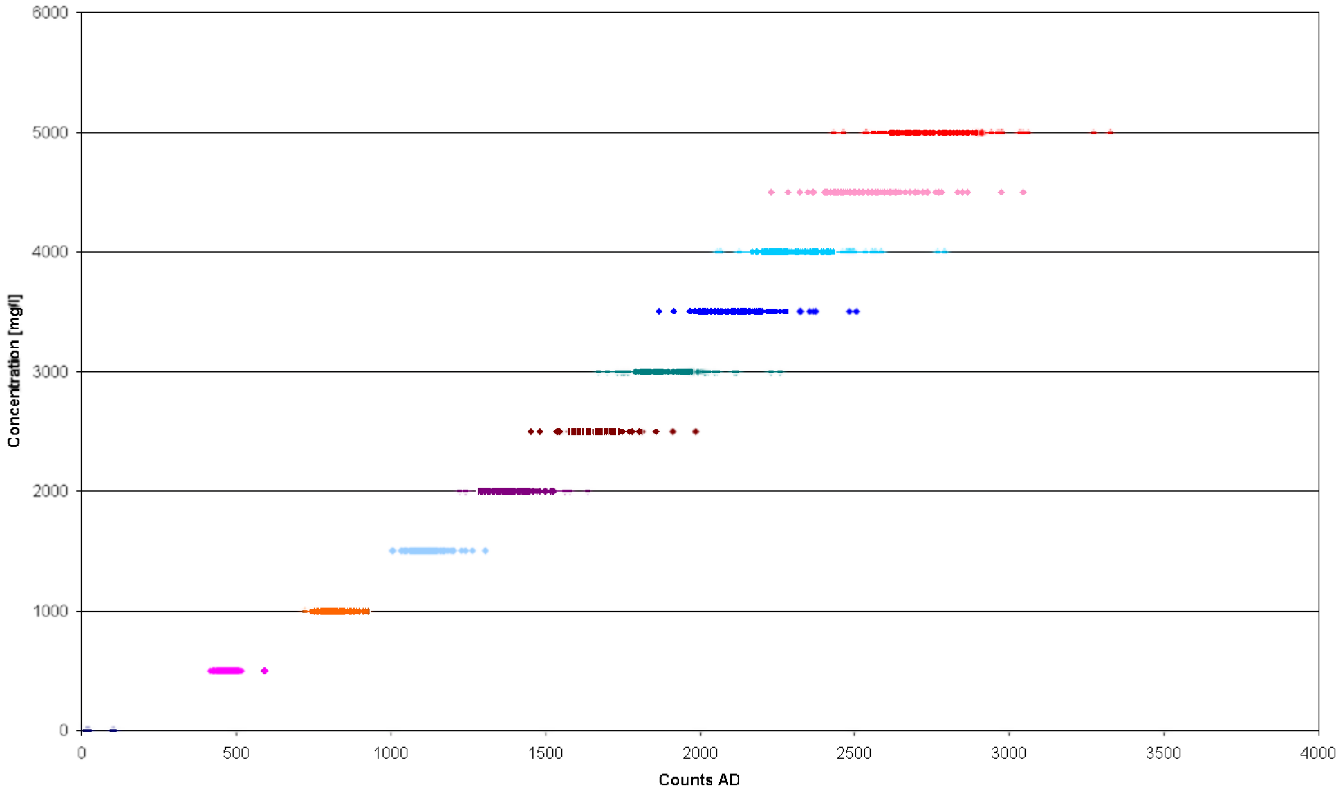
11283 DGD2 – CALIBRATION WINTER



Calibration Graph of Siltprofiler – Short Range		*Data processed by:* IMDC
Location: WL|Delft Hydraulics	Date: 10/01/2007	*In association with:* WL | delft hydraulics, GEMS International

I/RA/11283/07.096/MBO

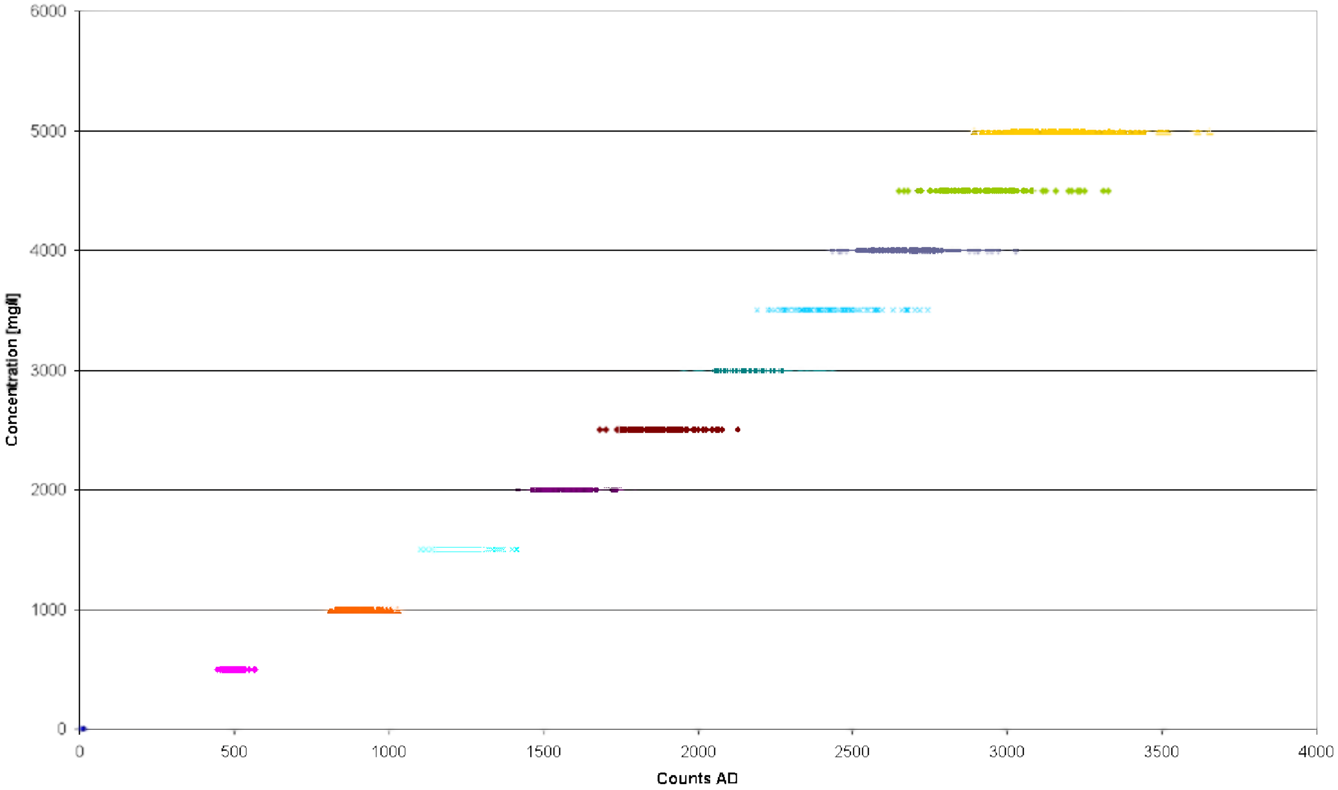
11283 DGD2 – CALIBRATION WINTER



Calibration Graph of ARGUS ASM IV sn 61		Data processed by:
Location: ARGUS gMBH	Date: 02/02//2007	*In association with:*

I/RA/11283/07.096/MSA

11283 DGD2 – CALIBRATION WINTER



Calibration Graph of ARGUS ASM IV sn 79		Data processed by:
Location: ARGUS gMBH	Date: 21/05/2007	In association with:
		I/RA/11283/07.096/MSA