REPORT

**Vlaamse overheid Departement Mobiliteit en Openbare werken**

Afdeling Maritieme Toegang

# Evaluation of the external effects on the siltation in Deurganckdok

Report 2.13: Calibration of stationary instruments on June 1st, 2012

15 October 2012 - version 2.0

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## Abstract

This report is one of a set of reports that gains insight in sediment and water transport between Deurganckdok and the river Scheldt, which belongs to the second part of this project. This report describes the calibration measurement performed on 01/06/2012 near Deurganckdok. The goal is to calibrate all the stationary instruments that were used in the course of this project.

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# 0. SUMMARY

Stationary instruments were calibrated for turbidity, temperature and conductivity.

For turbidity, instruments were calibrated relative to a reference instrument, of which the relation between turbidity and SSC was determined precisely during the calibration campaign. Only low concentrations were found in the water column at various tidal phases during the incoming tide. The highest concentration sampled was approximately 300 mg/l. RMSE values for the SSC calibration are acceptable (about 30 mg/l).

For instruments with a very high turbidity range, such as an Argus ASM IV, 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. Therefore, the Argus ASM IV probe has been calibrated in laboratory conditions and been cross checked afterwards with the in-situ calibration.

The conductivity and the temperature cross-check are limited due to the small range of conductivities/temperatures that were measured. Conductivity of CTD-divers is accurate, but the conductivity sensors of OBS 3A and RCM 9 instruments are showing higher variations and will therefore not be used for salinity measurements during the project.

Temperature measurements show no large discrepancies between the different instruments, except for RCM 9 s/n 1225.

# GLOSSARY

| | |
|---|---|
| BIS | Dredging Information System used in the Lower Sea Scheldt |
| d | Density of dredged sediment [kg/dm³] |
| DGD | Deurganckdok |
| HCBS | High Concentration Benthic Suspensions |
| M | Mass of dry solids [ton] |
| $\rho_s$ | Density of the solid minerals [kg/dm³] |
| $\rho_w$ | Density of clear water [kg/dm³] |
| $t_{0d}$ | Reference situation for densimetric analysis (empty dock) |
| $t_{0e}$ | Reference situation for volumetric analysis (24 March 2006) |
| TDS | Ton of dry solids [ton] |
| V | Volume of dredged sediment [m³] |

# 1. INTRODUCTION

## 1.1 THE ASSIGNMENT

This report is part of a set of reports concerning the project 'Evaluation of the external effects on the siltation in Deurganckdok'. The terms of reference were prepared by 'Departement Mobiliteit en Openbare Werken van de Vlaamse Overheid, Afdeling Maritieme Toegang (16EF/2009/14). The study was awarded to International Marine and Dredging Consultants NV in association with Deltares and Gems International on 8 December 2009.

This study is a follow-up study on the study 'Opvolging aanslibbing Deurganckdok' that ran from January 2006 till March 2009.

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 provided depth sounding and density profile measurements.

## 1.2 PURPOSE OF THE STUDY

The purpose of this study entails evaluating the external effects on the siltation in the Deurganckdok. External effects are those effects caused by recent or near-future human operations near Deurganckdok:

- The construction of the Current Deflecting Wall downstream of the entrance of the Deurganckdok.
- The deepening and widening of the navigational channel in the Lower Sea Scheldt between the entrance of the Deurganckdok and the access channels to the locks of Zandvliet-Berendrecht.
- The deepening of the entrance to the Deurganckdok by removing the sill at the entrance.

## 1.3 OVERVIEW OF THE STUDY

This study constitutes of 3 parts:

- Reporting and analysis of existing documents and measurement data.
- Execution of specific measurement campaigns to map the siltation and its environmental factors.
- Support in numerical modeling efforts.

## 1.4 STRUCTURE OF THE REPORT

Reports of the project 'Evaluation of the external effects on the siltation in the Deurganckdok' are summarized in Table 1-1.

This report is one of a set of reports that gains insight in sediment and water transport between Deurganckdok and the river Scheldt, which belongs to the second part of this project. This report describes the calibration measurement performed on 01/06/2012 near Deurganckdok. The goal is to calibrate all the stationary that will be used in the course of this project.

*Table 1-1: Overview of the External Effects Deurganckdok Reports*

| Report | Description |
|---|---|
| **1.** | **Reporting** |
| **I.1 Annual Sediment Balance: Bathymetry surveys, Density measurements, Maintenance and construction dredging activities** | |
| 1.1 | Annual Sediment Balance: year 1: 1/4/2009-31/3/2010 (I/RA/11354/10.067/NZI) |
| 1.2 | Annual Sediment Balance: year 2: 1/4/2010-31/3/2011 (I/RA/11354/10.100/MBO/ANF) |
| 1.3 | Annual Sediment Balance: year 3: 1/4/2011-31/3/2012 (I/RA/11354/10.101/MBO/ANF) |
| **I.2 Boundary Conditions: Upriver Discharge, Salt concentration Scheldt, Bathymetric evolution in access channels, dredging activities in Lower Sea Scheldt and access channels** | |
| 1.4 | Boundary Conditions year 1: 01/04/2009 – 31/3/2010 (I/RA/11354/10.102/MBO/ANF) |
| 1.5 | Boundary Conditions year 2: 01/04/2010 – 31/3/2011 (I/RA/11354/10.103/MBO/ANF) |
| 1.6 | Boundary Conditions year 3: 01/04/2011 – 31/3/2012 (I/RA/11354/10.104/MBO/ANF) |
| **I.3 Synthesis of CDW research** | |
| 1.7 | Synthesis report of research on Current Deflecting Wall (I/RA/11354/10.063/MBO) |
| **I.4 Analysis: evaluation of external effects on siltation in Deurganckdok** | |
| 1.8 | Analysis of external effects on siltation processes and factors (I/RA/11354/10.105/MBO/ANF) |
| **2.** | **Measurement campaigns: Factors contributing to salt and sediment distribution in Deurganckdok: Salt-Silt (OBS3A) & Frame measurements, Through tide measurements (SiltProfiling & ADCP) & Calibrations** |
| **II.1 Through tide measurements fixed transects** | |
| 2.1 | Through tide Sediview measurement: Entrance DGD during spring tide Autumn 2011 (I/RA/11354/10.106/MBO/ANF) |
| 2.2 | Through tide Sediview measurement: Entrance DGD during neap tide Autumn 2011 (I/RA/11354/10.107/MBO/ANF) |
| 2.3 | Through tide Sediview measurement: Entrance DGD during spring tide Spring 2012 (I/RA/11354/10.108/MBO/ANF) |
| 2.4 | Through tide Sediview measurement: Entrance DGD during neap tide Spring 2012 (I/RA/11354/10.109/MBO/ANF) |
| **II.2 Through tide measurements eddy currents** | |
| 2.5[2] | Through tide measurements: Eddy Currents DGD 02/03/2010 (I/RA/11283/10.051/MSA) |
| 2.6 | Through tide measurements: Eddy Currents DGD Autumn I/RA/11354/10.110/MBO/ANF) |
| 2.7 | Through tide measurements: Eddy Currents DGD Spring 2012 (I/RA/11354/10.111/MBO/ANF) |
| **II.3 Salt Silt Distribution entrance Deurganckdok** | |
| 2.8[3] | Salt-Silt distribution Deurganckdok 1/4/2009-31/3/2010 (I/RA/11354/10.068/NZI) |
| 2.9 | Sal-Silt distribution Deurganckdok 1/6/2011-31/05/2012 (I/RA/11354/10.112/MBO/ANF) |
| **II.4 Current Salt Silt Distribution CDW Deurganckdok** | |
| 2.10 | Salt Silt & Current Distribution entrance Deurganckdok: frame measurements and throughtide measurements: Autumn 2011 (I/RA/11354/11.131/BQU) |
| 2.11 | Salt Silt & Current Distribution entrance Deurganckdok: frame measurements and throughtide measurements: Spring 2012 (I/RA/11354/10.114/MBO/ANF) |
| **II.5 Quality Control instruments** | |
| 2.12 | Calibration stationary & mobile equipment 16/03/2011 (I/RA/11354/10.113/MBO/ANF) |
| 2.13 | Calibration stationary equipment 01/06/2012 (I/RA/11354/12.011/JCA) |

[2]: this report is part of the project Siltation Deurganckdok (11283)

[3]: this report contains report 2.35 of project Siltation Deurganckdok (I/RA/11283/09.085/MSA)

# 2. SEDIMENTATION IN DEURGANCKDOK

## 2.1 PROJECT AREA: DEURGANCKDOK

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

- The dock has a total length of 2750 m and is 450 m wide at the Scheldt end and 400 m wide at the inward end of the dock.
- The bottom of Deurganckdok is provided at a depth of –17m TAW in the transition zones between the quay walls and the central trench and of –19m TAW in the central trench.
- The quay walls reach up to +9m TAW.

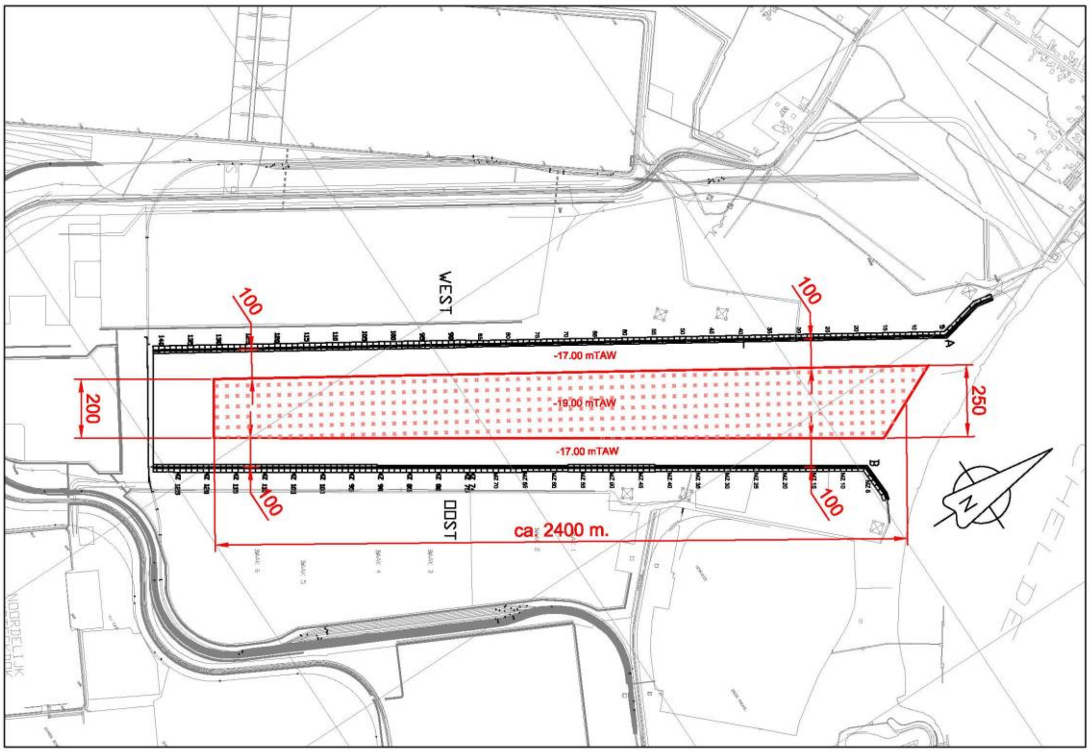


*Figure 2-1: Overview of Deurganckdok*

The dredging of the dock is performed in 3 phases. On 18 February 2005 the dike between the Scheldt and the Deurganckdok was breached. On 6 July 2005 Deurganckdok was officially opened. The second dredging phase was finalized a few weeks later. The first terminal operations have started since. In February 2007, the third dredging phase started and is finalized by February 2008.

## 2.2 OVERVIEW OF THE STUDIED PARAMETERS

The first part of the study aims at determining a sediment balance of Deurganckdok and the net influx of sediment. The sediment balance comprises a number of sediment transport modes: deposition, influx from capital dredging works, internal replacement and removal of sediments due to maintenance dredging (Figure 2-2 & Figure 2-1).

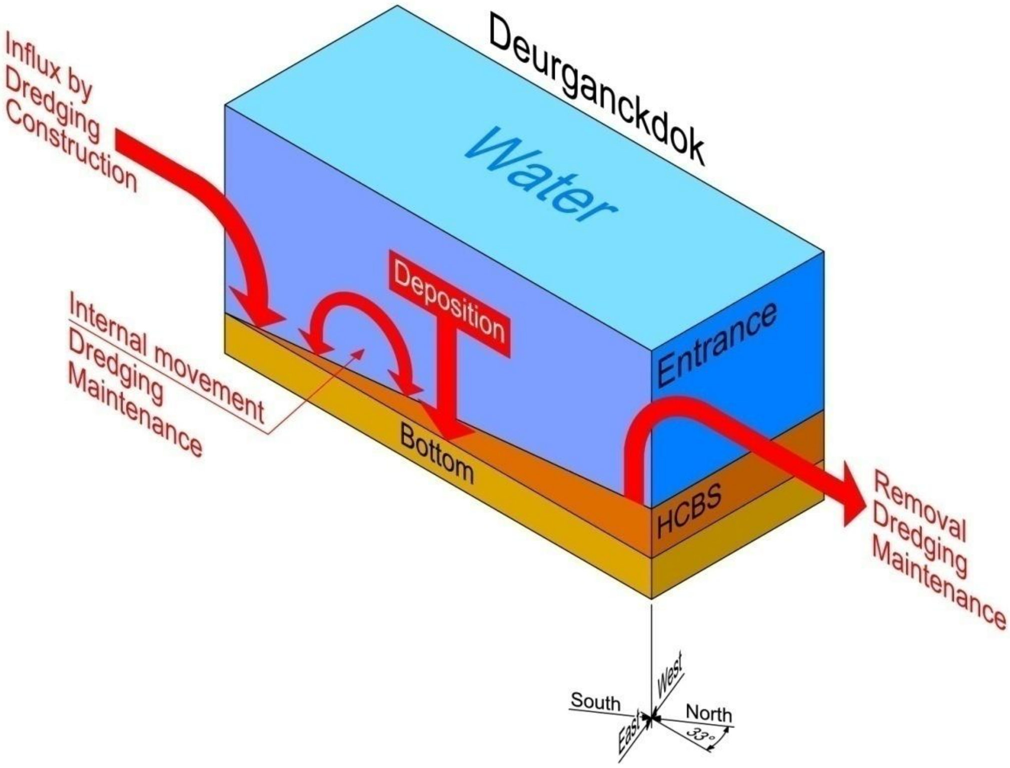


*Figure 2-2: Elements of the sediment balance*

A net deposition can be calculated from a comparison with a chosen initial condition t0 (Figure 2-3). The mass of deposited sediment is determined from the integration of bed density profiles recorded at grid points covering the dock. Subtracting bed sediment mass at t0 leads to the change in mass of sediments present in the dock (mass growth). Adding cumulated dry matter mass of dredged material removed since t0 and subtracting any sediment influx due to capital dredging works leads to the total cumulated mass entered from the river Scheldt since t0.

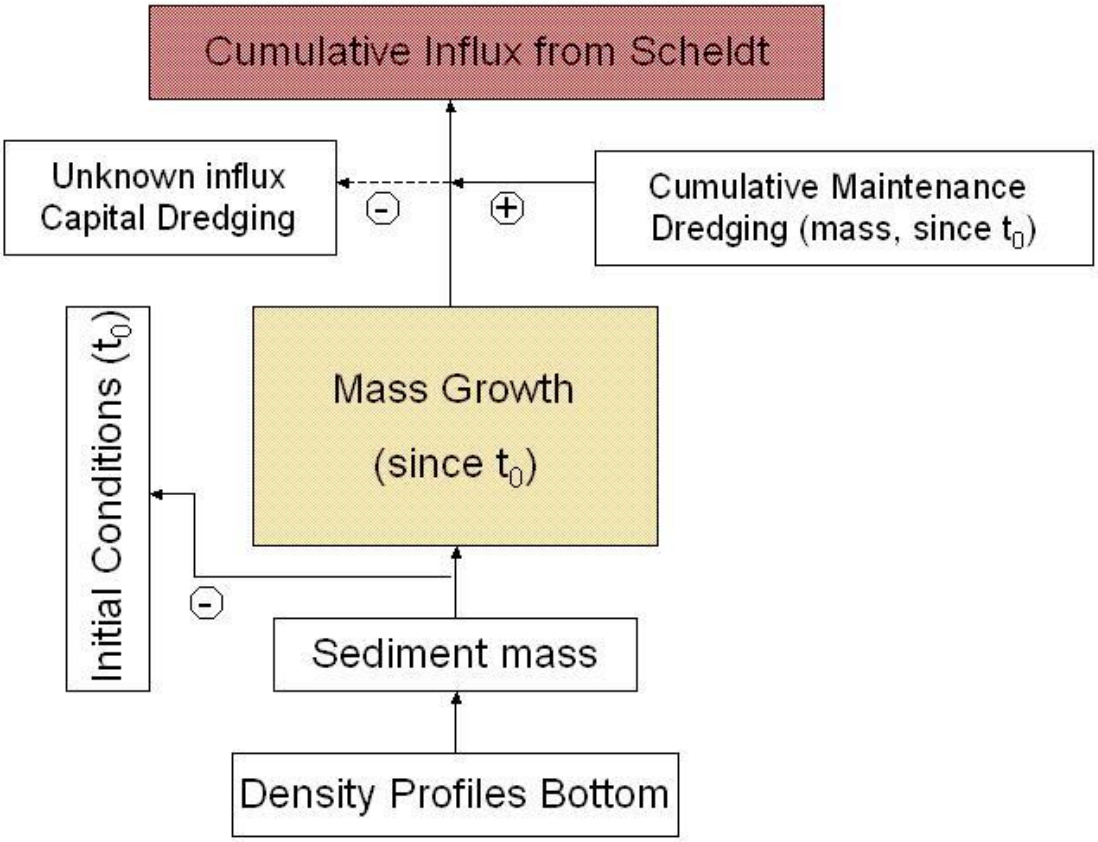


*Figure 2-3: Determining a sediment balance*

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

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

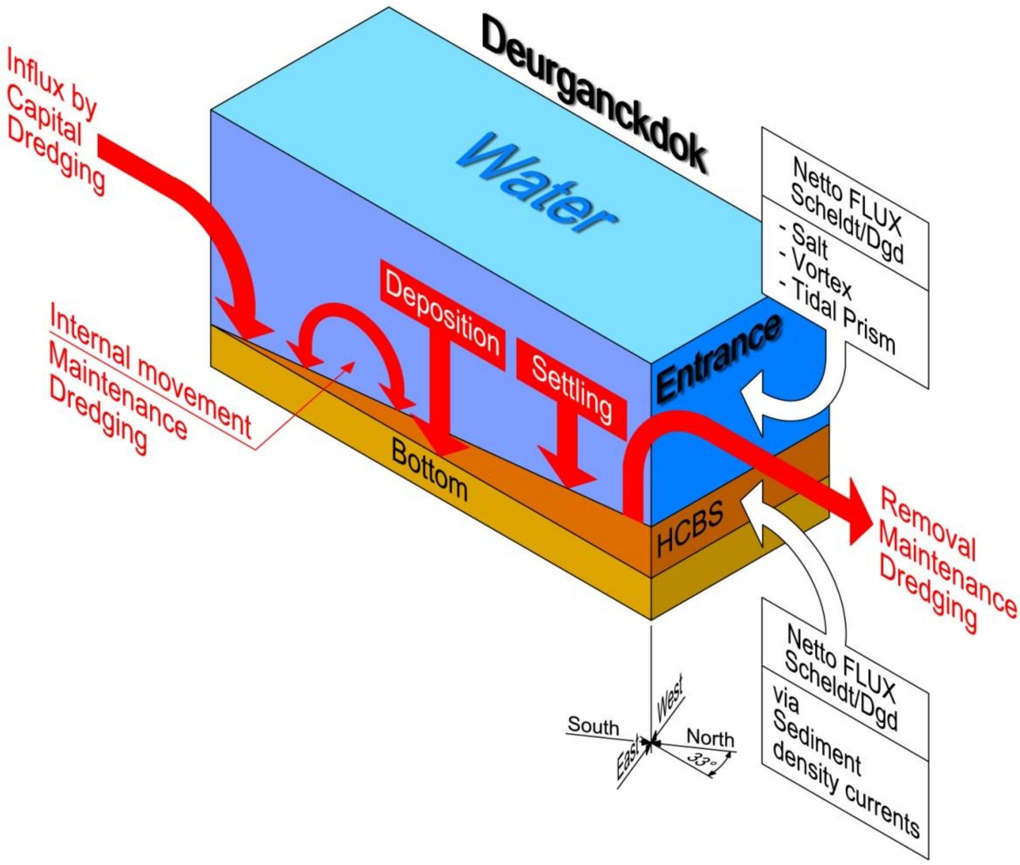


*Figure 2-4: Transport mechanisms*

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

Following data are being collected to understand these mechanisms:

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

# 3. THE MEASUREMENT CAMPAIGN

## 3.1 CALIBRATION STRATEGY

### 3.1.1 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 3-1 gives an overview of all the instruments used for measurement of SSC in long term and through tide measurement campaigns during this project.

*Table 3-1: Overview of instruments measuring SSC*

| ***Instrument*** | ***Quantity*** | ***Principle*** | ***Long term (LT) /Through Tide (TT)*** |
|---|---|---|---|
| D&A Instruments OBS 3A* | 7 | Turbidity Backscatter Sensor | TT / LT |
| SiltProfiler* (Extinction Sensors) | 2 | Turbidity Extinction sensor | TT |
| SiltProfiler* (Seapoint Sensor) | 1 | Turbidity Backscatter Sensor | TT |
| Aanderaa RCM-9* (0-500 NTU ) | 2 | Turbidity Backscatter Sensor | LT |
| Aanderaa RCM-9* (Seapoint sensor ) | 1 | Turbidity Backscatter Sensor | LT |
| Argus ASM IV | 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 and 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.

### 3.1.2 Salinity

Salinity is not measured directly but calculated using a UNESCO formula that incorporates conductivity, temperature and depth measurements (Unesco, 1991, see Annex A). 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.

## 3.2 CALIBRATION SET UP

### 3.2.1 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 3-1: Calibration frame with pump set-up*

A pump has been used to calibrate the turbidity sensors. The pump discharge velocity has been tested in advance with dye.

*Table 3-2: Set up for calibration on 01/06/2012*

| ***Calibration day 01/06/2012*** |
|---|
| 1 Argus ASM IV |
| 6 CTD-divers |
| 4 OBS 3A |
| 1 RBR |
| 3 RCM-9 |
| 1 pump |

### 3.2.2 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 in a place with high gradients in SSC; at the entrance of Deurganckdok (downstream).

### 3.2.3 Calibration protocol

The aim was to calibrate the turbidity sensors at 8 predetermined SSC levels:

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

During the survey one instrument which has already been used in previous surveys and recently been sent to the manufacture for inspection, was chosen as reference instrument. This instrument was connected with an external data cable and as such 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 watersamples were taken from a pump sampler for laboratory analysis. This procedure was carried out twice for each concentration.

All the remaining turbidity sensors are mounted at the same height as the reference turbidity sensor and the inlet of the pump bowel.

The reference sensor will be calibrated from NTU to mg/l by defining a linear relationship between the measured NTU values and the collected watersamples.

All the remaining turbidity sensors will be crosscalibrated from NTU to reference NTU by defining a linear relationship between the measured NTU values of each sensor and the measured NTU values of the reference sensor. These calculated reference NTU values can then be converted to mg/l by using the first obtained calibration curve of the reference sensor.

The advantages of this method are:

- No errors due to any exact time match between low frequency sensor records and time of watersampling.
- Much more points are available to establish calibration equation.
- The relative error between different sensors is minimal.
  - The absolute error is based on the quality of the calibration of the reference sensor; this calibration can be expected to be more accurate since now only one sensor has to be monitored closely.

### 3.2.4 Sample analysis

The NEN 6484 standard for total suspended sediment analysis was used for all water samples.

### 3.2.5 Validation, Drifting and extra Sensors

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.

## 3.3 INSTRUMENTS

### 3.3.1 OBS 3A

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

- temperature (°C),
- conductivity (mS/cm)
- turbidity (counts/NTU)
- absolute depth (m)

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

### 3.3.2 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. The 4 Instruments are from IMDC. The RCM 9 with serial number 1225 (IMDC) is equipped with an additional Seapoint sensor (0-750 NTU).

### 3.3.3 CTD-Diver datalogger

CTD-Diver dataloggers were used. Measured parameters by the CTD-Diver datalogger are:

- temperature (°C),
- conductivity (mS/cm)
- absolute depth (m)

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

### 3.3.4 Argus ASM IV

Argus ASM IV probes were used. Measured parameters by the Argus ASM IV datalogger are:

- temperature (°C),
- 96 turbidity sensors (mg/l)
- absolute depth (m)

IMDC (2008a) gives more details on the ASM IV Argus. During the previous calibration campaign Argus ASM IV s/n 2000 was not calibrated.

### 3.3.5 Pump Sampler

A watersampler was attached nearby the turbidity sensor taking water samples. Samples were collected in 1 liter 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.

# 4. COURSE OF THE MEASUREMENTS

## 4.1 HYDROMETEOROLOGICAL CONDITIONS

Measurements were conducted during flood. The vertical tide is given for the tidal gauge at Prosperpolder (see Table 4-1).

*Table 4-1: High and Low Tide at Prosperpolder Tidal Gauge on 01/06/2012*

| Prosperpolder Tidal Gauge | | |
|---|---|---|
| | 01 June 2012 | |
| | Time [MET] | Water level [m TAW] |
| **LW (1)** | 06:30 | -0.06 |
| **HW (2)** | 12:20 | 5.13 |
| **LW (3)** | 18:50 | 0.05 |
| **HW (4)** | 00:40 | 5:30 |

Meteorological data at Woensdrecht was obtained from the Weather Underground website (Wunderground, 2012). Information of the Royal Meteorological Institute is not yet available.

On the 1st of June, the air temperature varied between 12 and 18 °C. The wind blew at an average velocity of 12 km/h from W. There was no rain.

## 4.2 LOCATIONS

The location where the calibration was performed is situated near de Current Deflecting Wall at the entrance of Deurganckdok (see Figure 4-1).

*Table 4-2: Coordinates Calibration locations [UTM ED50]*

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

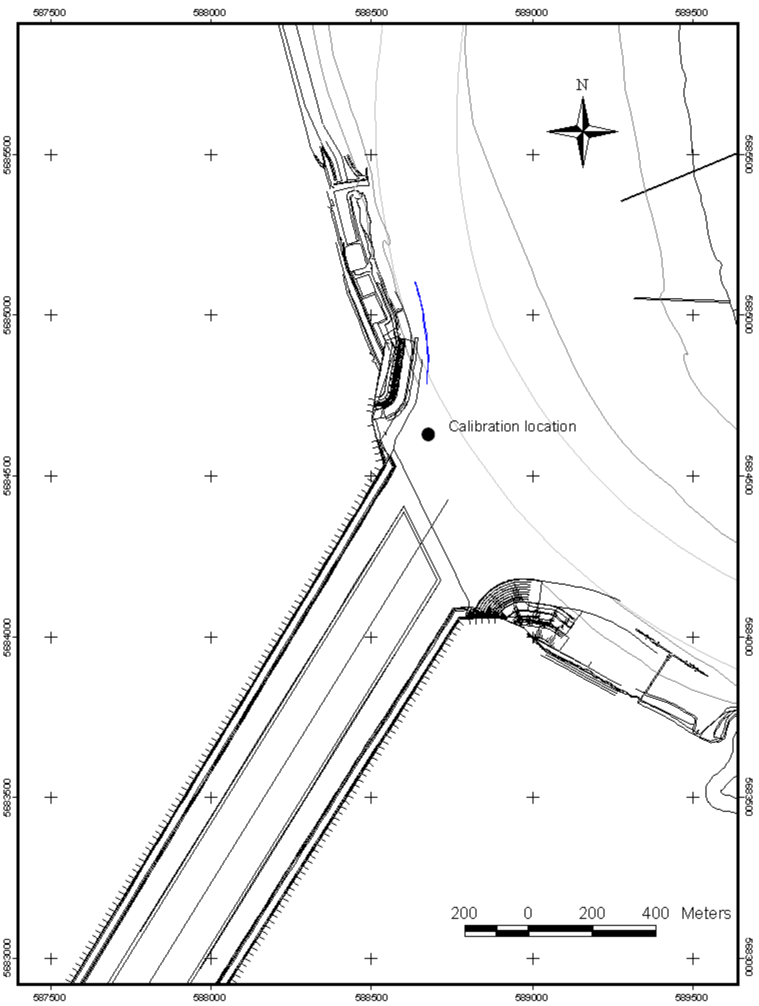


Figure 4-1: Calibration Location

## 4.3 MEASURED CONCENTRATIONS

Direct read out of one of the instruments allowed to aim for the predetermined concentrations (see § 3.2.3).

The following concentration ranges were obtained:

30 – 40 – 60 – 100 - 150 – 200 – 250 – 300 mg/l.

# 5. PROCESSING OF DATASETS

## 5.1 INTRODUCTION

The SSC calibration results are given in the next paragraph (§5.2). Conductivity and temperature comparisons are made in §**Error! Reference source not found.**5.3.

## 5.2 SSC CALIBRATION RESULTS

OBS3A sn 307 turbidity sensor has been selected as reference instrument on June1st, because this instrument was used as reference instrument in the previous calibration campaign. This sensor was logged by direct reading at a high frequency (2 measurements per sec). The calibration curve for this reference sensor from NTU to mg/l has been derived from the collected watersamples and is presented in Figure 5-1.

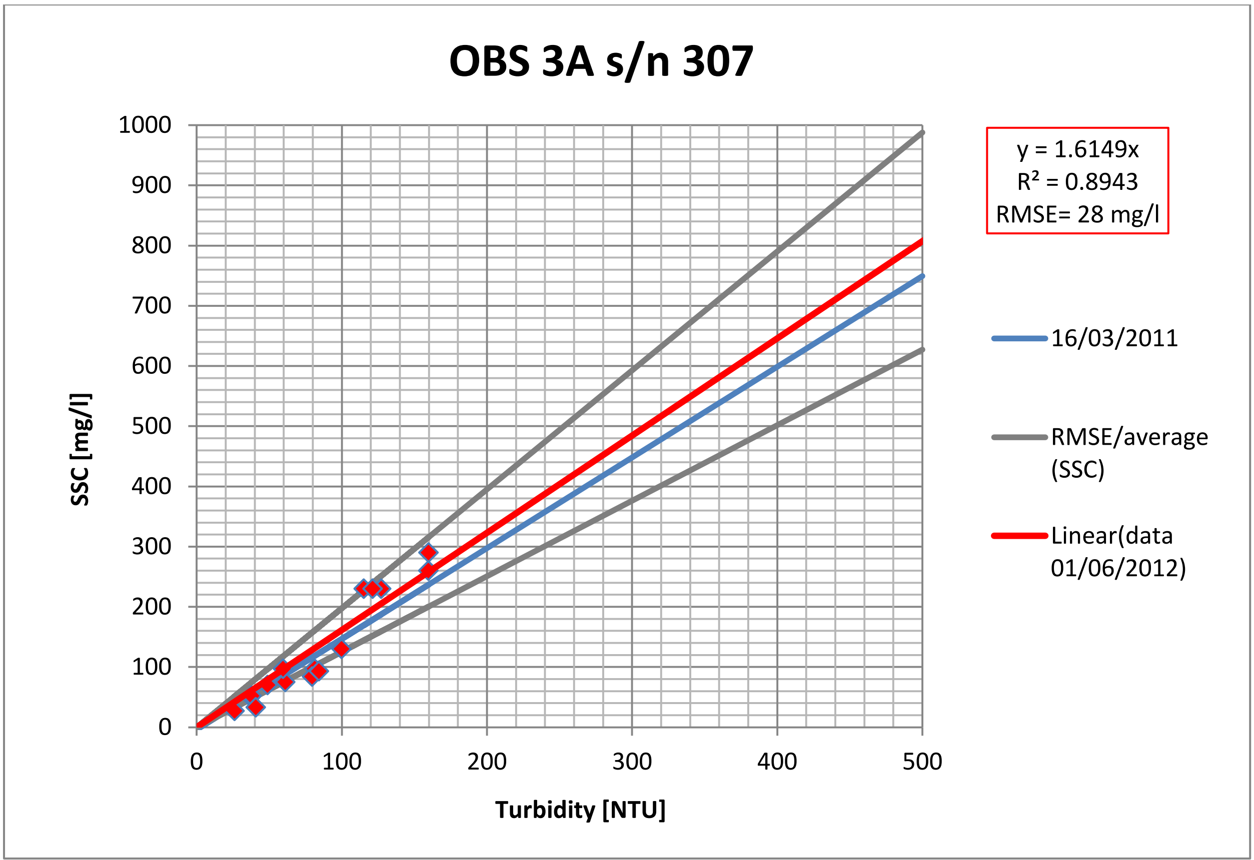


*Figure 5-1: Calibration of reference turbidity sensor OBS3A s/n 307*

The RMSE (root mean square error) has been calculated for low turbidity values (0-100 NTU), high turbidity values (> 100 NTU) and for all the points. These RMSE values are presented in Table 5-1. To estimate the error on the estimation of SSC the total RMSE is divided by the total averaged sampled

SSC which results in 22%. This calculated error is also illustrated in Figure 5-1 and will increase when the estimated SSC values are higher than 300 mg/l.

*Table 5-1 RMSE values calculated from the calibration curve for the reference turbidity sensor*

| ***Class*** | ***RMSE (mg/l)*** | ***Average SSC (mg/l)*** |
|---|---|---|
| 0-100 NTU | 26 | 66 |
| >100 NTU | 31 | 228 |
| Total | 28 | 124 |

For OBS3A and RCM 9 turbidity sensors, raw FTU/NTU values are cross calibrated to reference NTU. For Argus ASM IV s/n 2000 turbidity sensors, raw mg/l values can only be extracted from the instruments. These raw values are based on a calibration performed by the manufacturer in a tank with sediment scraped from the bottom in Deurganckdok. These raw mg/l values are cross calibrated with the mg/l values of the reference instrument, which is presented in Figure 5-2.

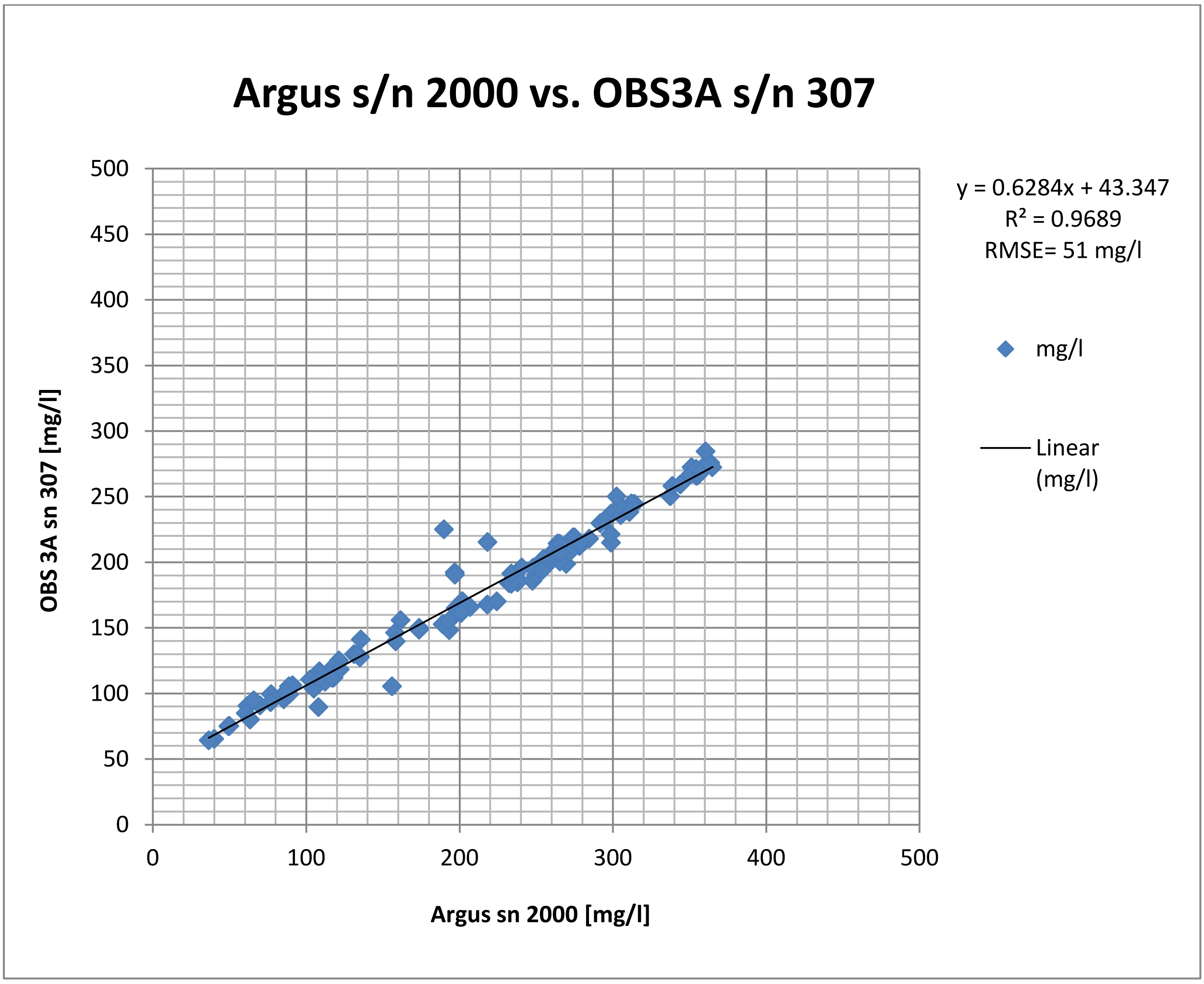


*Figure 5-2 Calibration graph of Argus ASM IV s/n 2000*

The calibration results for all sensors are given in Table 5-2. In this table the conversion formulas are given to convert turbidity counts, NTU, FTU to reference NTU. The R square value and the RMSE is added as well.

The calibration graphs show the reference NTU values on the Y-axis and the instrument readout in AD counts, or Turbidity Units (NTU/FTU) on the X-axis. These graphs can be found in Annex B.

The final calibration equations, which convert the raw value (FTU/NTU/raw mg/l) to mg/l are given in

Table 5-3.

*Table 5-2: Overview of Calibration Results to reference instrument for 01/06/2012 including instrument description, formulas, $R^2$ and RMSE values and remarks*

| Instrument | Serial no. | Range | Unit | Function | $R^2$ | RMSE | Unit RMSE | Remarks |
|---|---|---|---|---|---|---|---|---|
| OBS3A | 221 | 0-500 | NTU to NTU reference | y = 0.9302x | $R^2 = 0.8168$ | 10 | FTU | IMDC |
| OBS3A | 222 | 0-500 | NTU to NTU reference | y = 0.9911x | $R^2 = 0.8429$ | 10 | FTU | IMDC |
| OBS3A | 224 | 0-2000 | NTU to NTU reference | y = 0.8454x | $R^2 = 0.9050$ | 8 | FTU | IMDC |
| OBS3A | 225 | 0-2000 | NTU to NTU reference | y = 0.9471x | $R^2 = 0.8464$ | 10 | FTU | IMDC |
| OBS3A | 307 | 0-2000 | NTU to mg/l | y = 1.6149x | $R^2 = 0.8943$ | 28 | mg/l | IMDC |
| RCM-9 | 1165 | 0-500 | NTU to FTU reference | y = 1.112x | $R^2 = 0.914$ | 7 | FTU | IMDC |
| RCM-9 | 1166 | 0-100 | NTU to FTU reference | y = 1.2743 | $R^2 = 0.6882$ | 14 | FTU | IMDC |
| RCM-9 | 1225 | 0-500 | NTU to FTU reference | y = 0.6999x | $R^2 = 0.8182$ | 11 | FTU | IMDC |
| RBR | 17136 | 0-5000 | FTU to FTU reference | y = 0.659x | $R^2 = 0.8961$ | 8 | FTU | IMDC |
| Argus | 2000 | 0-5000 | mg/l to mg/l reference | y = 0.6842x+43.347 | $R^2 = 0.9689$ | 51 | mg/l | IMDC |

*Table 5-3: Overview of Calibration Results to mg/l for 01/06/2012 including instrument description and formulas*

| Instrument | Serial no. | Range | Unit | Function |
|---|---|---|---|---|
| OBS3A | 221 | 0-500 | NTU to mg/l | y = 1.50x |
| OBS3A | 222 | 0-500 | NTU to mg/l | y = 1.60x |
| OBS3A | 224 | 0-2000 | NTU to mg/l | y = 1.37x |
| OBS3A | 225 | 0-2000 | NTU to mg/l | y = 1.53x |
| OBS3A | 307 | 0-2000 | NTU to mg/l | y = 1.61x |
| RCM-9 | 1165 | 0-500 | FTU to mg/l | y = 1.79x |
| RCM-9 | 1166 | 0-100 | FTU to mg/l | y = 2.05 |
| RCM-9 | 1225 | 0-500 | FTU to mg/l | y = 1.13x |
| RBR | 17136 | 0-5000 | FTU to mg/l | y = 1.06 |
| Argus | 2000 | 0-5000 | mg/l to mg/l | y = 1.10x-70.0 |

## 5.3 CONDUCTIVITY AND TEMPERATURE 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.

The CTD Diver s/n Z060 sensor was chosen as a reference.

### 5.3.1 Conductivity

Figure 5-3 shows the conductivity read out of all CTD diver instruments deployed at the same level on the measurement frame. All these conductivity sensors measure in a close range of the reference CTD Diver s/n Z060.

Figure 5-4 shows the conductivity read out of the OBS3A instruments, RCM-9 instruments and the RBR deployed at the same level on the measurement frame. OBS3A s/n 221 & 225 were not equipped with a conductivity sensor. The RBR instrument and reference CTD Diver Z060 measure similar conductivity values. OBS3A s/n 224 measures a much higher value and OBS3A s/n 222 a much lower value. In the first two hours of the measurements the RCM 9's show a similar trend as CTD Diver Z060, but after that the conductivity levels drop and remain on a constant lower level. In general, OBS3A and RCM 9 conductivity sensors are more sensitive to pollution; therefore, conductivity measurements will always be performed together with CTD Divers. The RSME values of these types of sensors vary between 0.47 and 5.21, which is quite high.

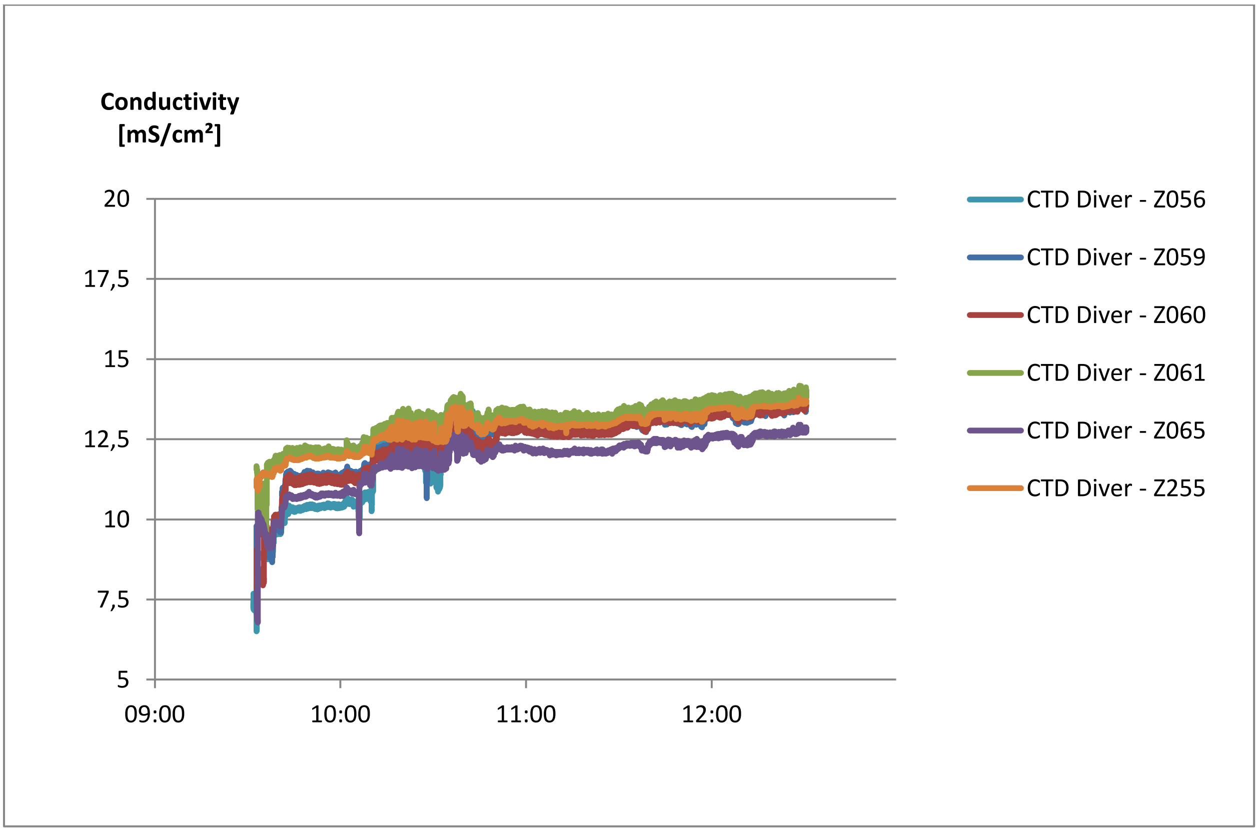


*Figure 5-3: CTD Diver conductivity measurements 01/06/2012*

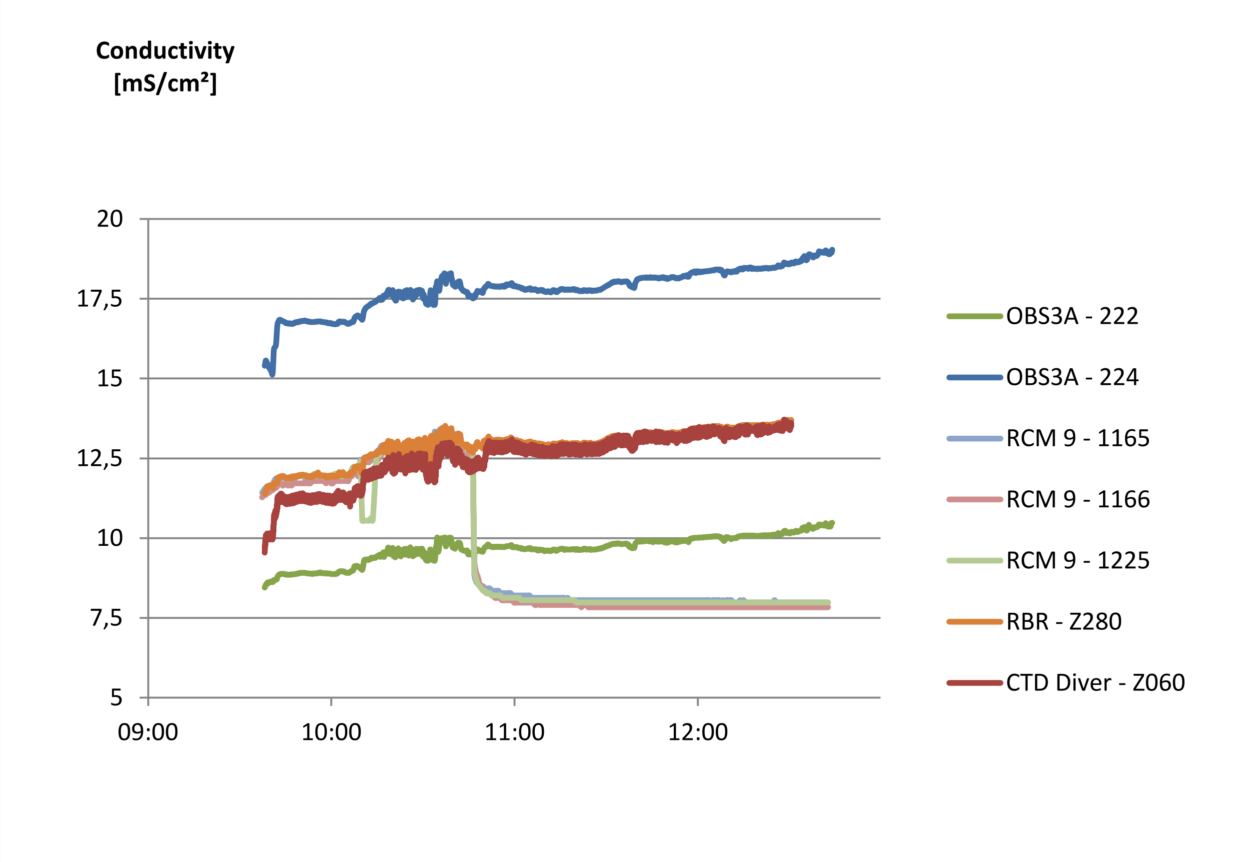


*Figure 5-4: OBS 3A, RCM 9, RBR and Reference CTD diver conductivity measurements 01/06/2012*

The Root Mean Square Error (RMSE) was calculated for each correctly working instrument. The RMSE was calculated for each instrument comparing its measurement to the reference conductivity measurement (CTD diver Z060). (see

Table 5-4).

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

$X_i$ = measured conductivity value for a given instrument

$\overline{X}$ = CTD diver Z060 conductivity value for each measurement

n = number of measurements

*Table 5-4: RMSE values [mS/cm] for conductivity sensors*

| ***Instrument*** | ***RMSE*** | ***Instrument*** | ***RMSE*** |
|---|---|---|---|
| CTD diver Z056 | 0.37 | OBS3A sn 222 | 3.04 |
| CTD diver Z059 | 0.13 | OBS3A sn 224 | 5.21 |
| CTD diver Z060 | 0.00 | RCM 9 sn 1165 | 0.68 |
| CTD diver Z061 | 0.39 | RCM 9 sn 1166 | 0.47 |
| CTD diver Z065 | 0.73 | RCM 9 sn 1225 | 0.69 |
| CTD diver Z255 | 0.17 | RBR sn 17136 | 0.42 |

### 5.3.2 Temperature

Temperature measurements were compared as well. Figure 5-5 and Figure 5-6 show the temperature measurements of the OBS 3A, RBR, RCM-9 and the CTD-Diver instruments. The OBS3A sensor s/n 222 doesn't measure correct temperature. This sensor will be rejected from further measurements. The other temperature sensors are showing a spread which is acceptable. All measurements follow the same trend, except RCM 9 s/n 1225. All the RCM 9's have a drop in temperature around 10:50h.Nothing happened during the calibration campaign which can explain this drop in temperature; therefore, temperature measurements will always be performed together with CTD Divers. RMSE values are given in Table 5-5 and are calculated with reference to the CTD diver s/n Z060 temperature sensor.

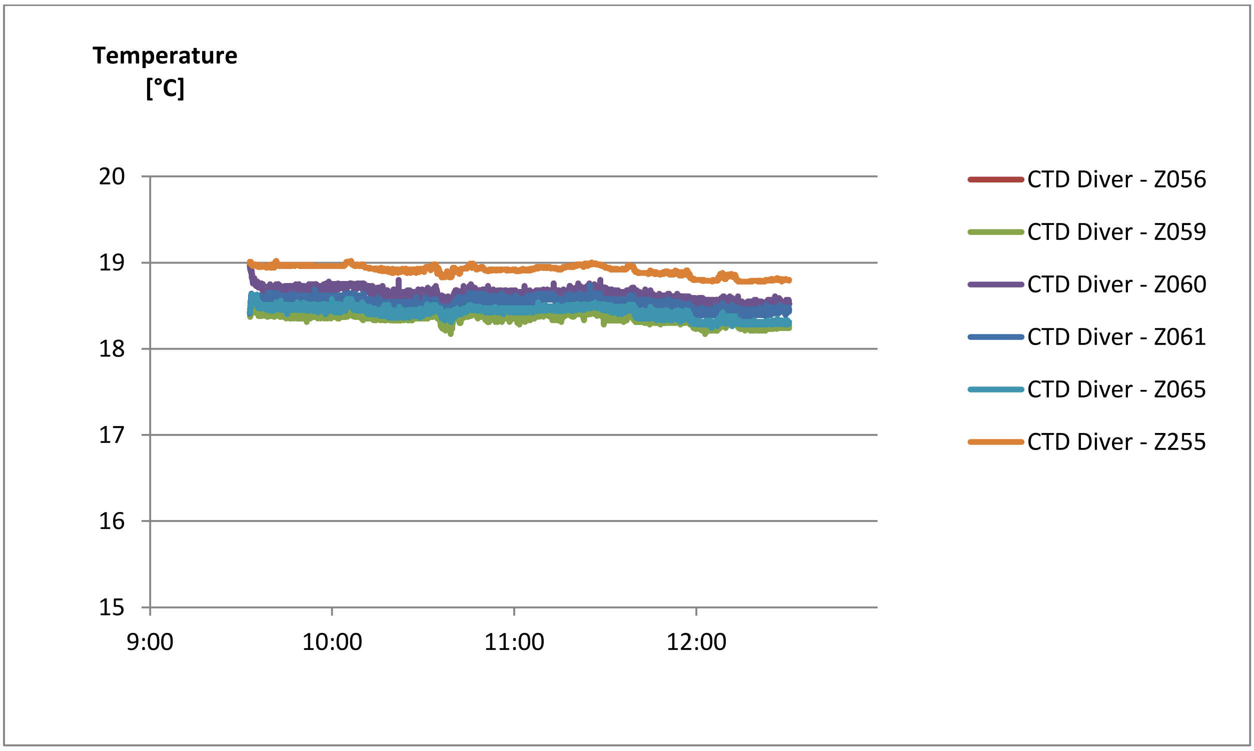


*Figure 5-5: CTD Diver temperature measurements 01/06/2012*

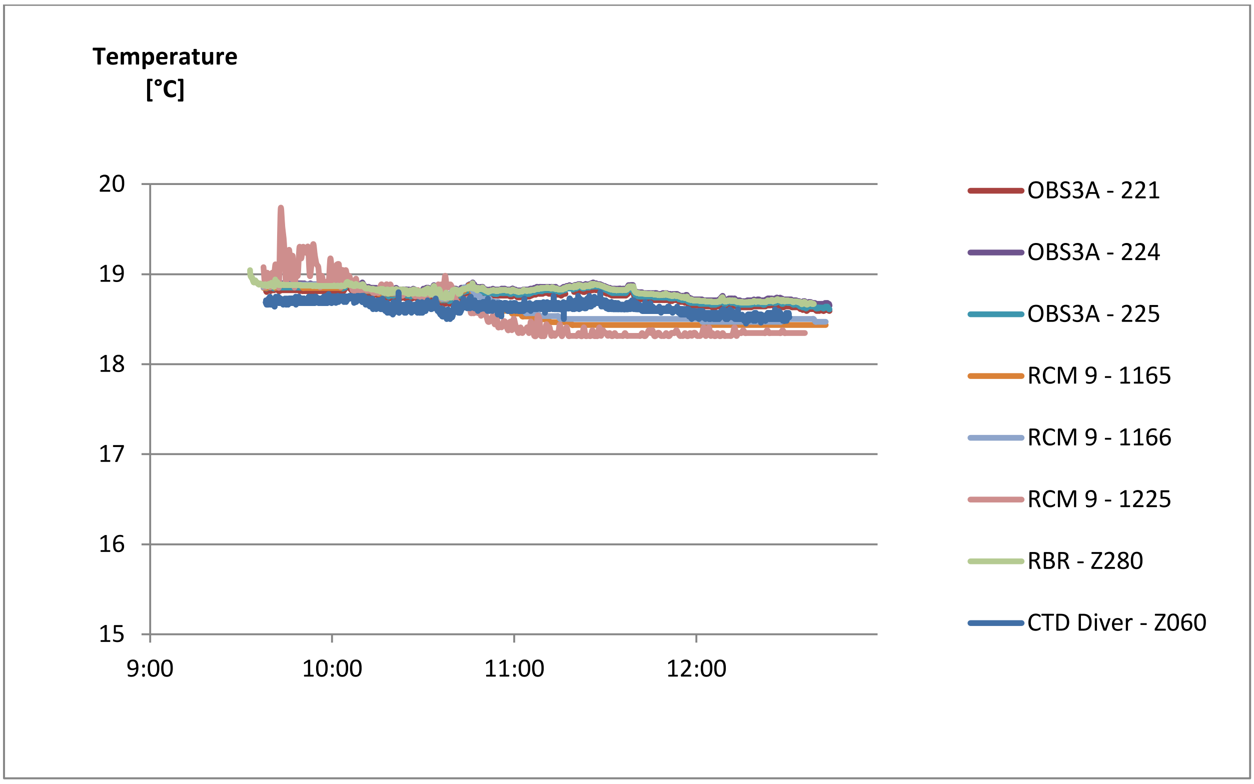


*Figure 5-6: OBS 3A, RCM 9, RBR and reference CTD Diver temperature measurements 01/06/2012*

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

| ***Instrument*** | ***RMSE*** | ***Instrument*** | ***RMSE*** |
|---|---|---|---|
| CTD diver Z056 | 0.11 | OBS3A sn 222 | 15.62 |
| CTD diver Z059 | 0.28 | OBS3A sn 224 | 0.84 |
| CTD diver Z060 | 0.00 | OBS3A sn 225 | 0.83 |
| CTD diver Z061 | 0.11 | RCM 9 sn 1165 | 0.15 |
| CTD diver Z065 | 0.21 | RCM 9 sn 1166 | 0.13 |
| CTD diver Z255 | 0.27 | RCM 9 sn 1225 | 0.27 |
| OBS3A sn 221 | 0.83 | RBR sn 17136 | 0.18 |

## 5.3.3 Salinity

Salinity is calculated according to the UNESCO pps-78 formula (see Annex A), using the measured conductivity, temperature and depth. Therefore, no calibration is necessary since all the input parameters have been cross checked.

# 6. CONCLUSION OF THE CALIBRATION ON JUNE 1ST 2012

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 around 300 mg/l.

RMSE values for the SSC are acceptable (around 30 mg/l). Only for the Argus ASM IV s/n 2000 instrument the RMSE offset value for SSC is rather high (51 mg/l). This could be due to a higher sand content of the samples with high SSC. The sand content of the suspended sediment samples is negligible in general. But 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. 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.

The conductivity cross-check is limited due to the small range of conductivities that were measured. The conductivity comparison of the CTD-Divers and RBR are showing similar trends, the range of values during each measurement is about 0.5 mS/cm. The conductivity of the OBS3A instruments and RCM 9 instruments have a much higher variation and will therefore not be used for salinity measurements during the project. Salinity will be measured by CTD-divers or the RBR, attached to the OBS3A instruments.

Temperature measurements are also compared. No large discrepancies were found, except for RCM 9 s/n 1225, which shows more variation in temperature data. This instrument wasn’t used during the measurement campaigns in Deurganckdok. All RMSE values for the remaining instruments are lower than 0.50 °C.

# 7. REFERENCES

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

Unesco (1983). Algorithms for computation of fundamental properties of seawater, UNESCO Technical Papers in Marine Science, 44. UNESCO, France.

Wunderground (2012), Weather Underground: www.wunderground.com

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# Annex A UNESCO PPs-78 formula for calculating salinity

## Practical Salinity Scale (PPS 78) Salinity in the range of 2 to 42

**Constants from the 19th Edition of Standard Methods**

| | | | |
|---|---|---|---|
| R cond.ratio | 0.0117 | $R = \frac{C}{42.914 mS/cm}$ | |
| **C Cond at t** | **0.5** | | **Input conductivity in mS/cm of sample** |
| **t deg. C** | **22.00** | | **Input temperature of sample solution** |
| **P dBar** | **20** | | **Input pressure at which sample is measured in decibars** |
| Rp | 1.0020845 | $R_p = 1 + \frac{p(e_1 + e_2 p + e_3 p^2)}{1 + d_1 t + d_2 t^2 + (d_3 + d_4 t)R}$ | |
| rt | 1.1641102 | $r_t = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4$ | |
| Rt | 0.0099879 | $R_t = \frac{R}{R_p \times r_t}$ | |
| Delta S | -0.0010 | $\text{Delta S} = \frac{(t-15)}{1+k(t-15)}(b_0 + b_1 R_t^{1/2} + b_2 R_t + b_3 R_t^{3/2} + b_4 R_t^2 + b_5 R_t^{5/2})$ | |
| **S = Salinity** | **0.257** | $S = a_0 + a_1 R_t^{1/2} + a_2 R_t + a_3 R_t^{3/2} + a_4 R_t^2 + a_5 R_t^{5/2} + \text{delta S}$ | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| a0 | 0.0080 | b0 | 0.0005 | c0 | 0.6766097 | d1 | 3.426E-02 | e1 | 2.070E-04 |
| a1 | -0.1692 | b1 | -0.0056 | c1 | 2.00564E-02 | d2 | 4.464E-04 | e2 | -6.370E-08 |
| a2 | 25.3851 | b2 | -0.0066 | c2 | 1.104259E-04 | d3 | 4.215E-01 | e3 | 3.989E-12 |
| a3 | 14.0941 | b3 | -0.0375 | c3 | -6.9698E-07 | d4 | -3.107E-03 | | |
| a4 | -7.0261 | b4 | 0.0636 | c4 | 1.0031E-09 | | | | |
| a5 | 2.7081 | b5 | -0.0144 | | | | | | |
| | | k | 0.0162 | | | | | | |

**R** = ratio of measured conductivity to the conductivity of the Standard Seawater Solution

Conductivity Ratio R is a function of salinity, temperature, and hydraulic pressure. So that we can factor R into three parts i.e.

**R = Rt x Rp x rt**

**R = C(S,t,p)/C(35,15,0)**

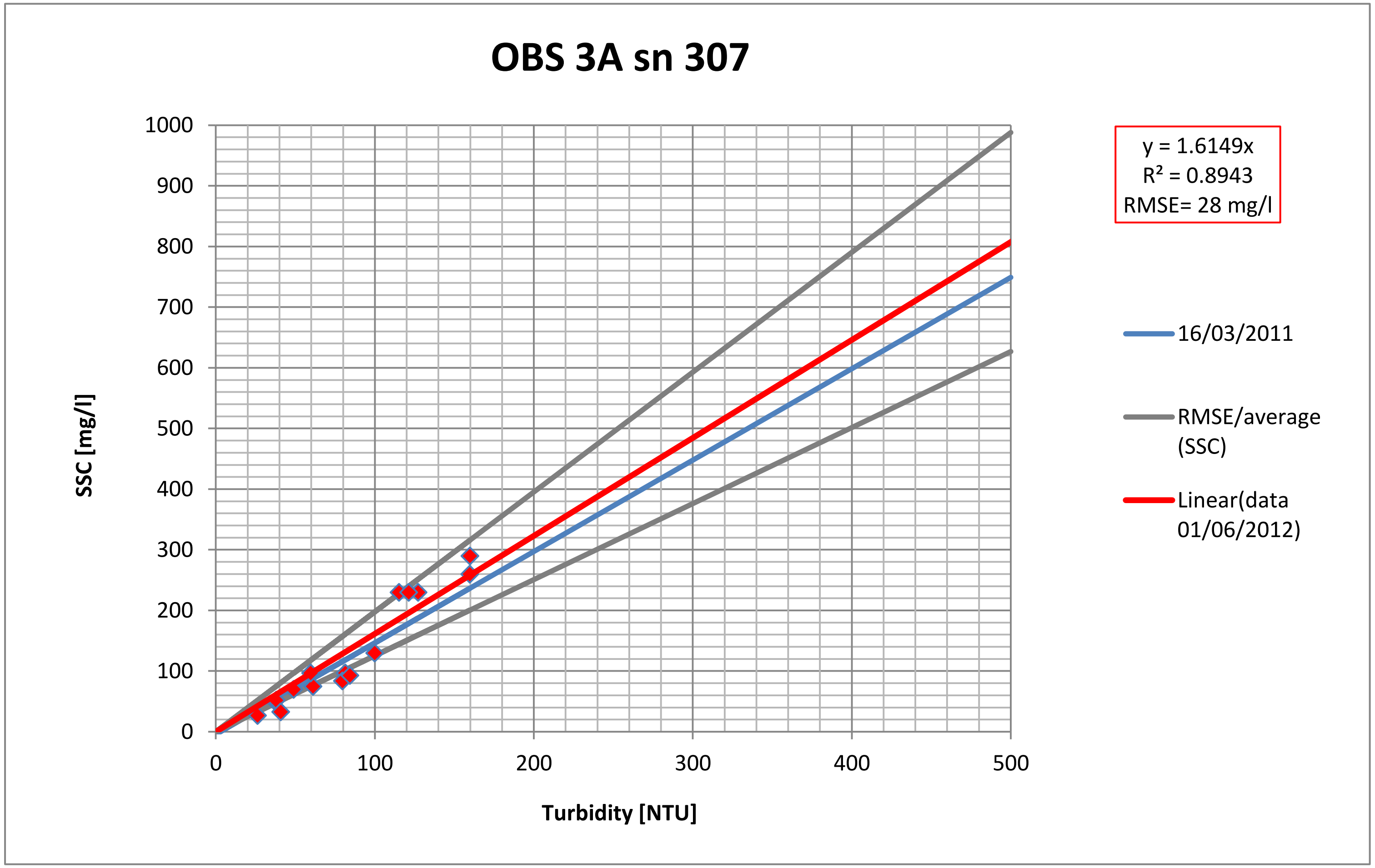
**C = 42.914 mS/cm at 15 deg C and 0 dbar pressure ie C(35,15,0) where 35 is the salinity**

**Ocean pressure is usually measured in decibars. 1 dbar = 10^-1 bar = 10^5 dyne/cm^2 = 10^4 Pascal.**

# Annex B Calibration Graphs

## B.1 In situ Calibration Graphs

# 11354 - Opvolging aanslibbing Deurganckdok




Calibration Graph of reference instrument OBS 3A s/n 307

Location:
Lower Sea Scheldt

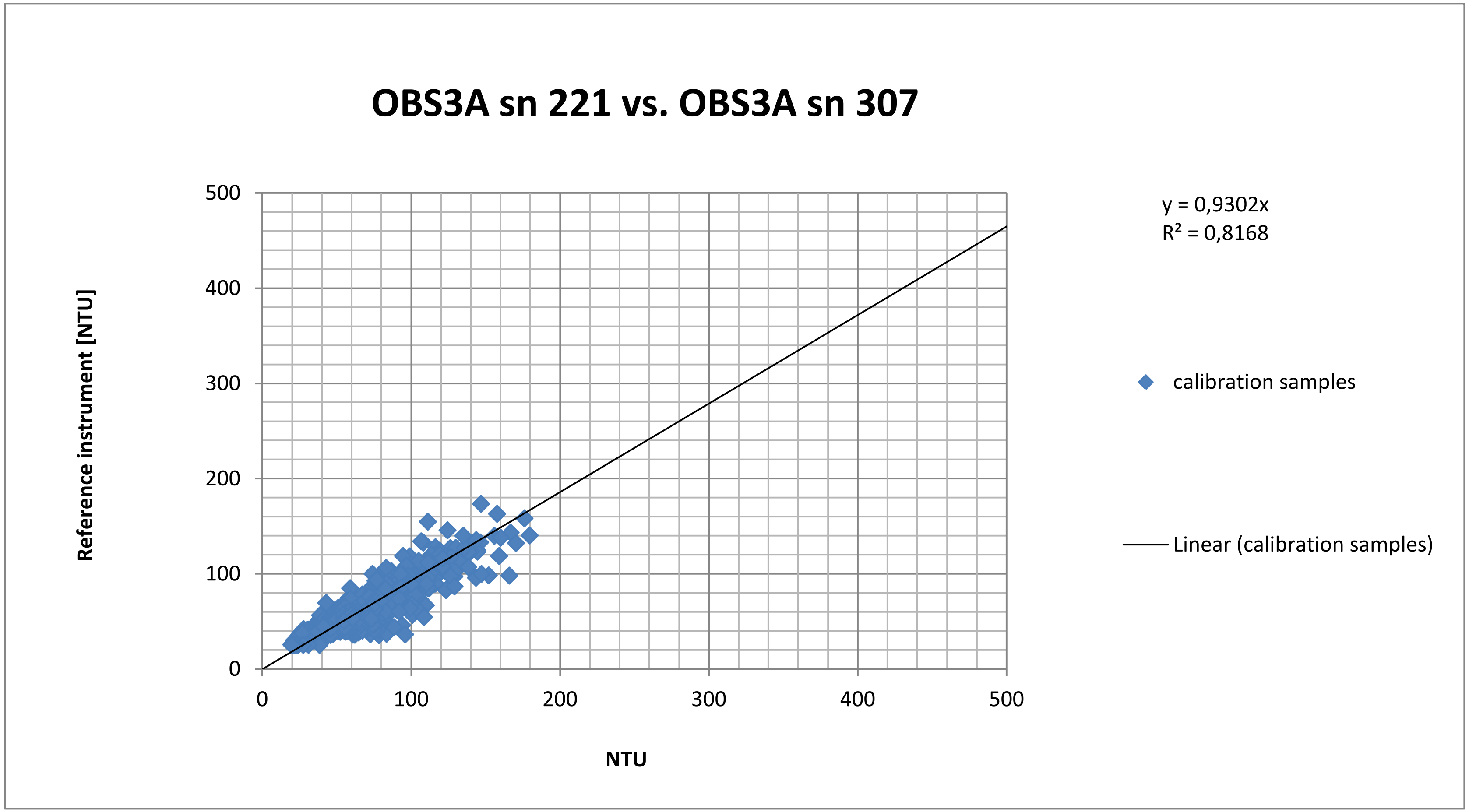
Date:
01/06/2012

*Data processed by:* IMDC International Marine & Dredging Consultants

*In association with:* GEMS International, Deltares

*I/RA/11354/12.011/JCA*

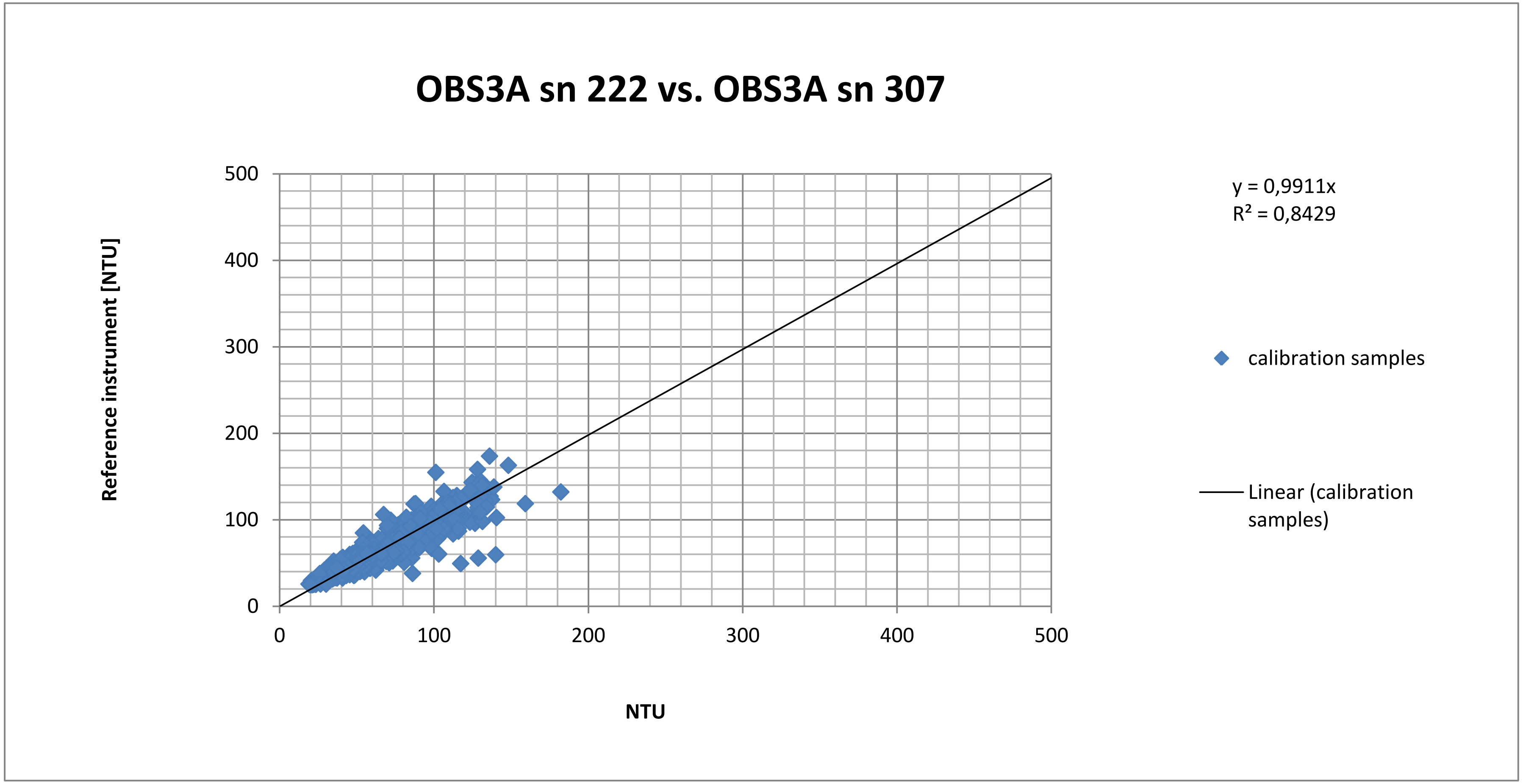
# 11354 - Opvolging aanslibbing Deurganckdok



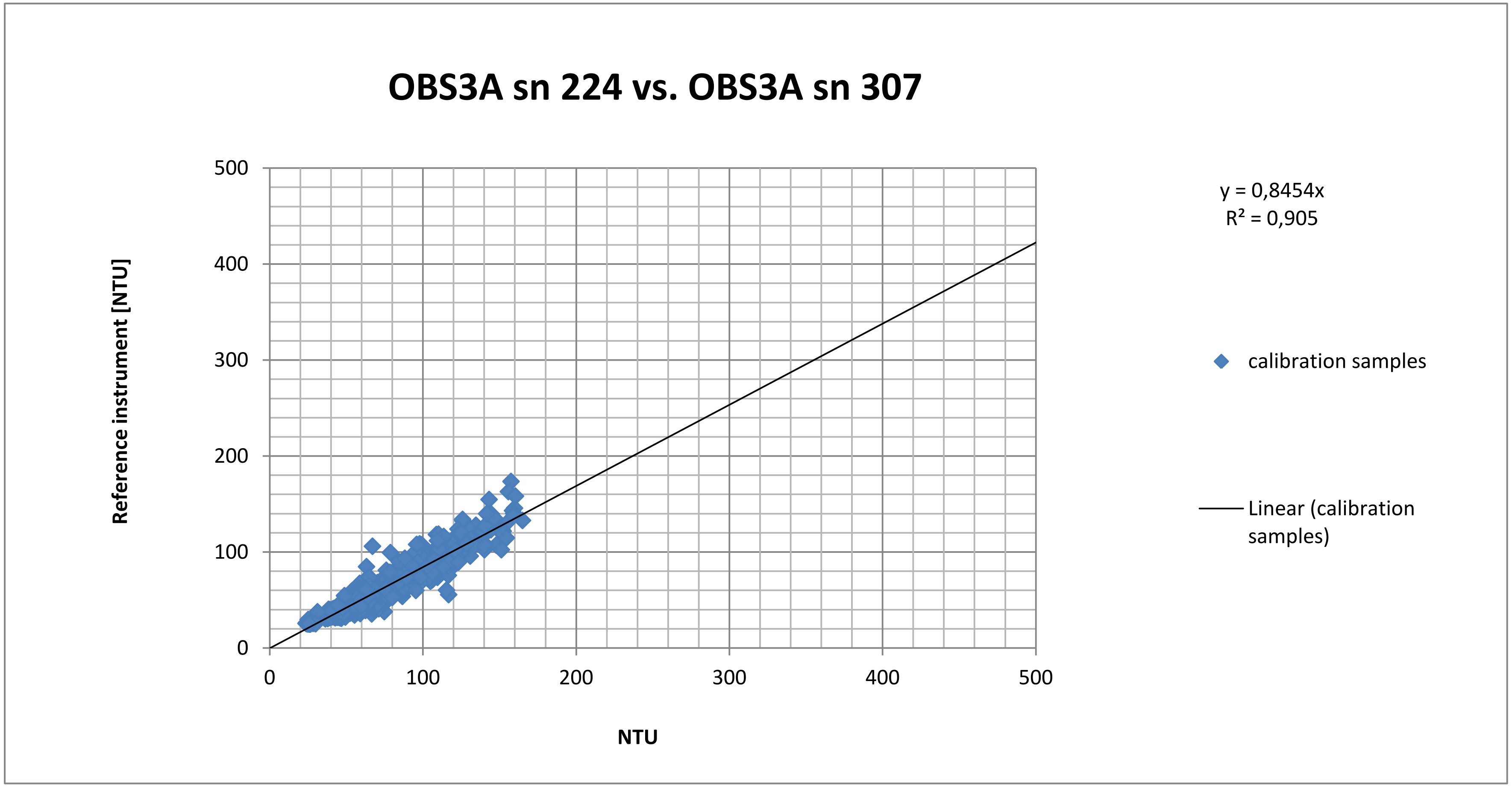

| Calibration Graph of reference instrument OBS 3A s/n 221 | | Data processed by: IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 01/06/2012 | In association with: GEMS International, Deltares Enabling Delta Life |

*I/RA/11354/12.011/JCA*

# 11354 - Opvolging aanslibbing Deurganckdok



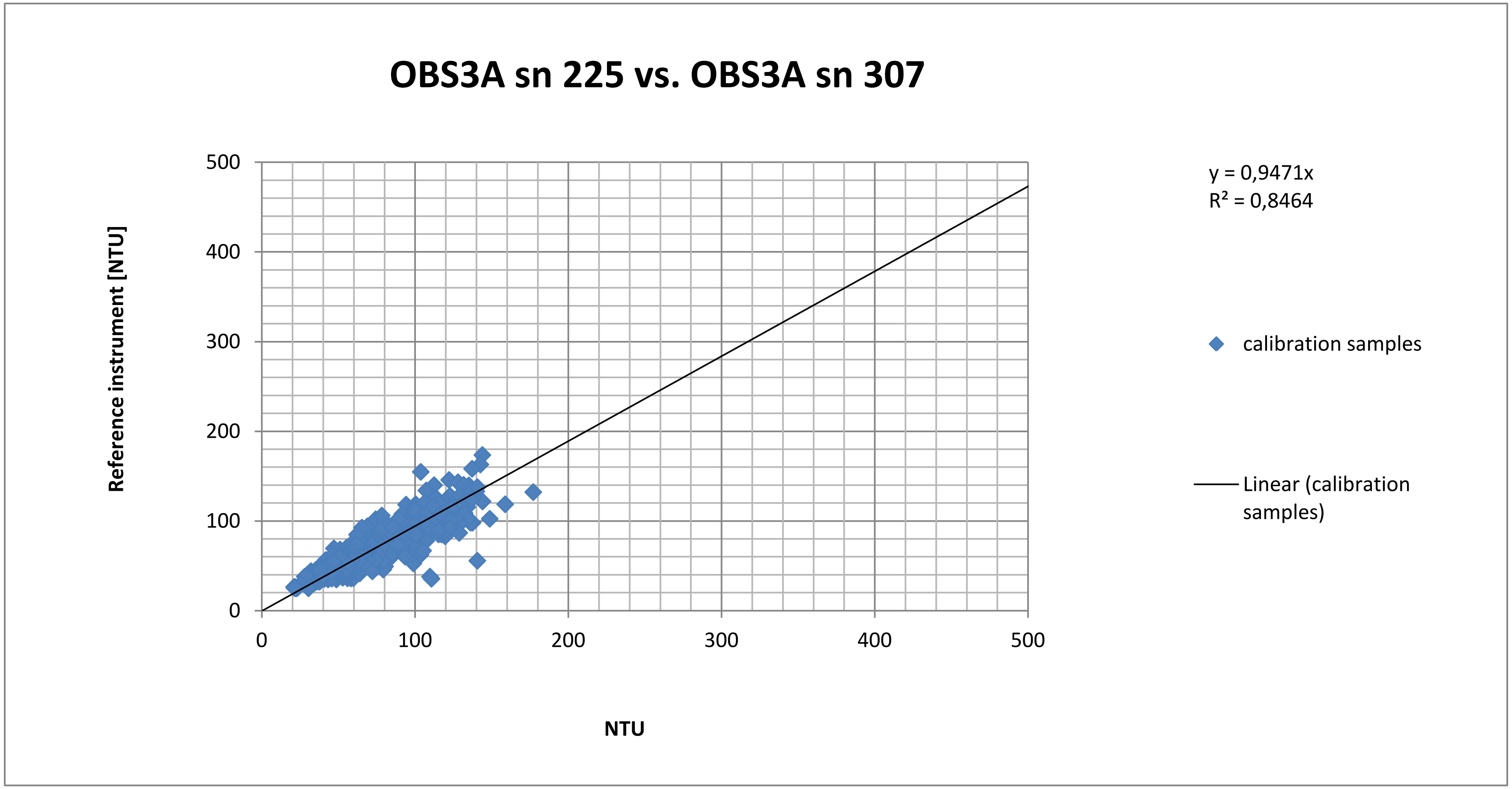

| Calibration Graph of OBS3A s/n 222 | | *Data processed by:* IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 01/06/2012 | *In association with:* GEMS International, Deltares Enabling Delta Life |
| | | *I/RA/11354/12.011/JCA* |




| Calibration Graph of OBS3A s/n 224 | | Data processed by: IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 01/06/2012 | In association with: GEMS International, Deltares Enabling Delta Life |

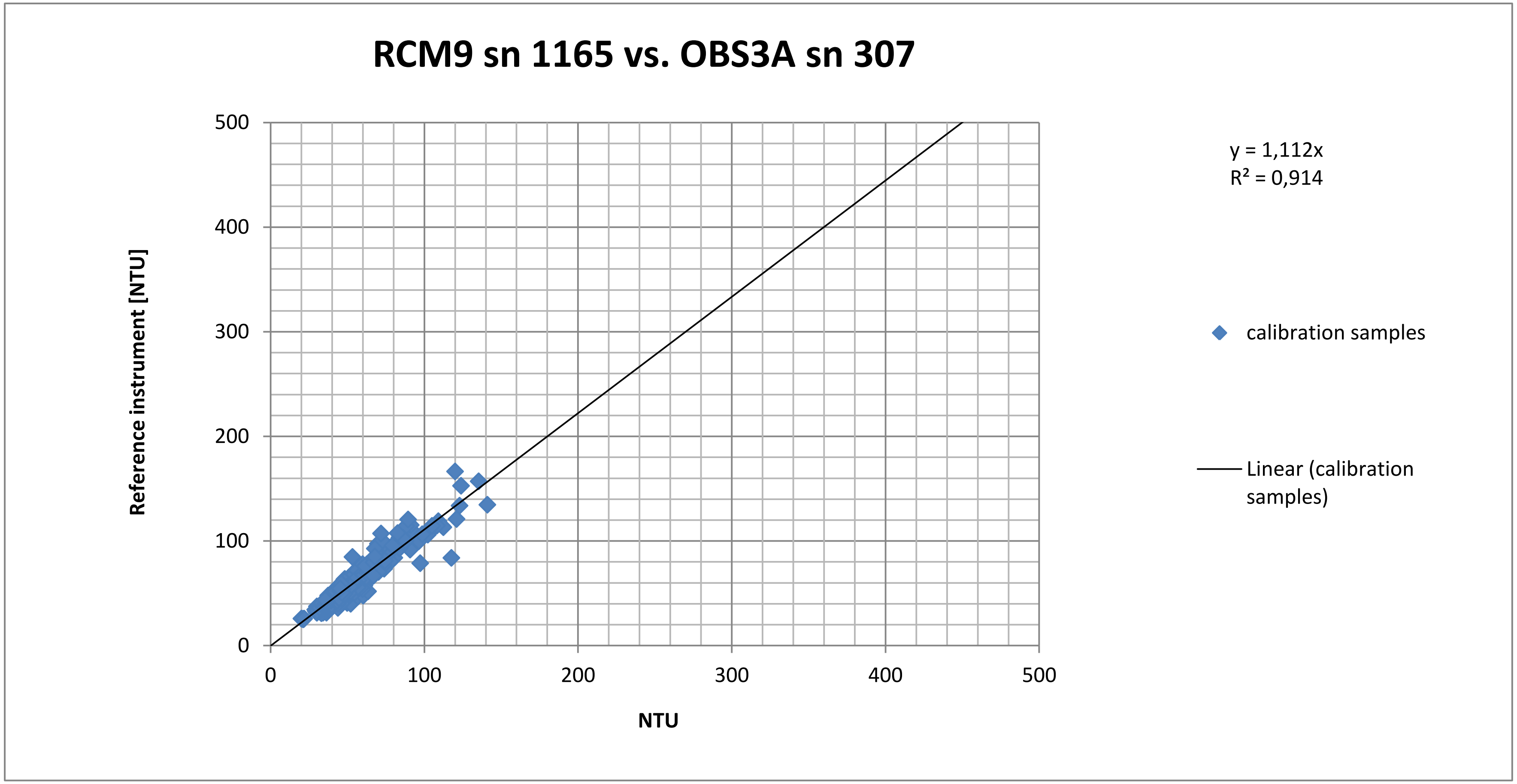
I/RA/11354/12.011/JCA

# 11354 - Opvolging aanslibbing Deurganckdok



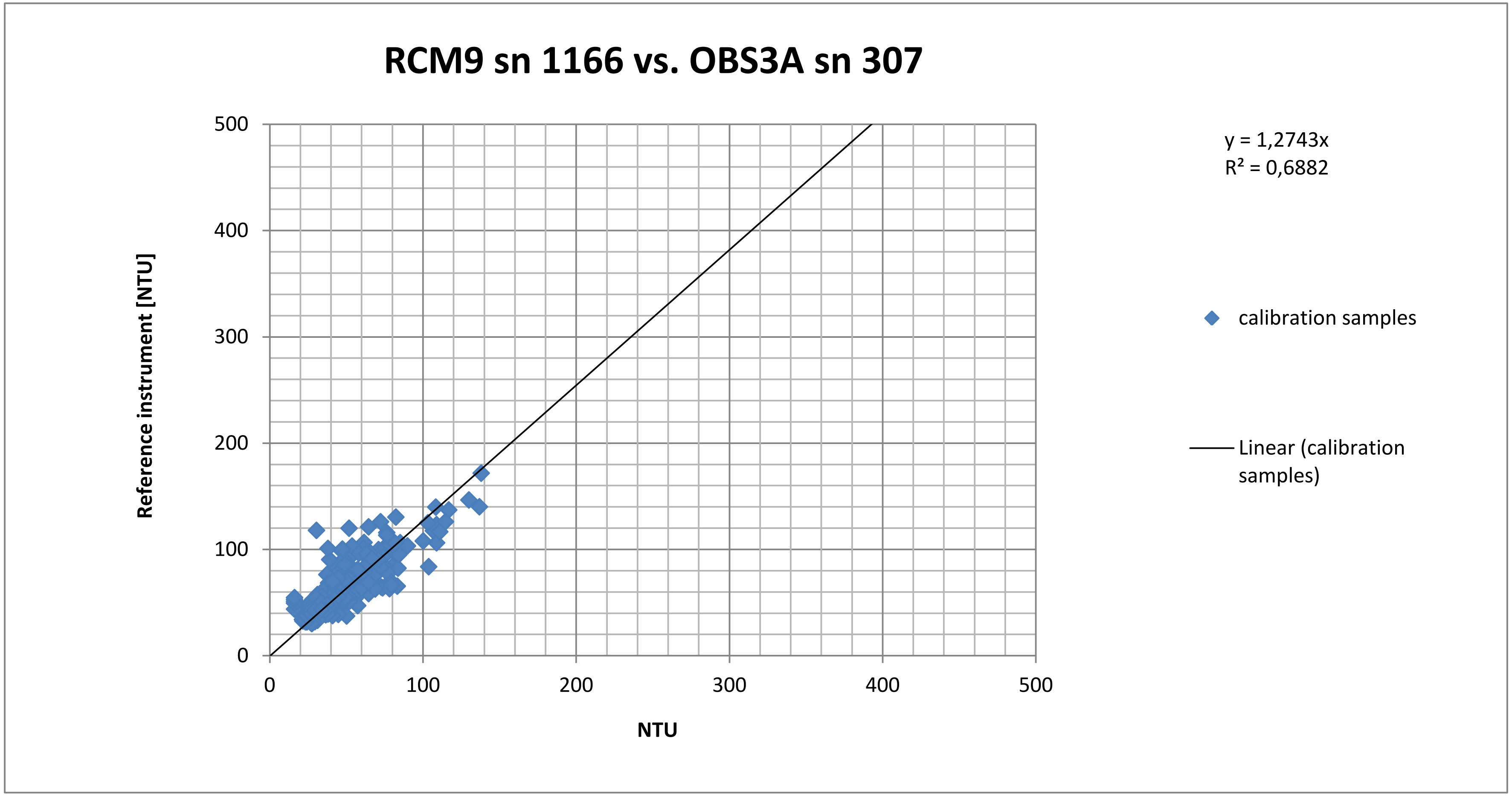

| Calibration Graph of OBS3A s/n 225 | | Data processed by: IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 01/06/2012 | In association with: GEMS International, Deltares Enabling Delta Life |
| | | I/RA/11354/12.011/JCA |

# 11354 - Opvolging aanslibbing Deurganckdok




| Calibration Graph of RCM 9 s/n 1165 | | Data processed by: IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 01/06/2012 | *In association with:* GEMS International, Deltares Enabling Delta Life<br>*I/RA/11354/12.011/JCA* |

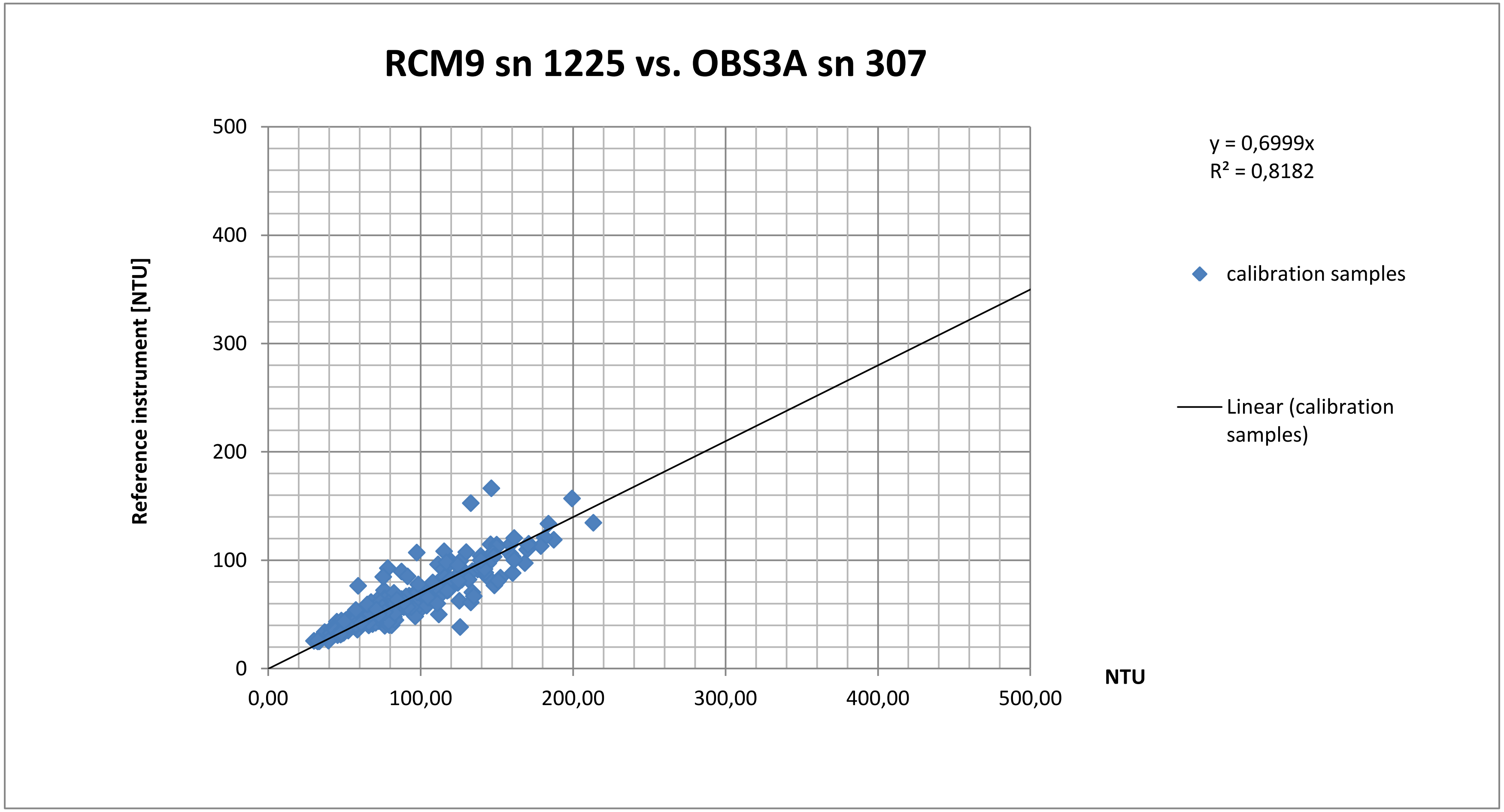
# 11354 - Opvolging aanslibbing Deurganckdok




Calibration Graph of RCM 9 s/n 1166

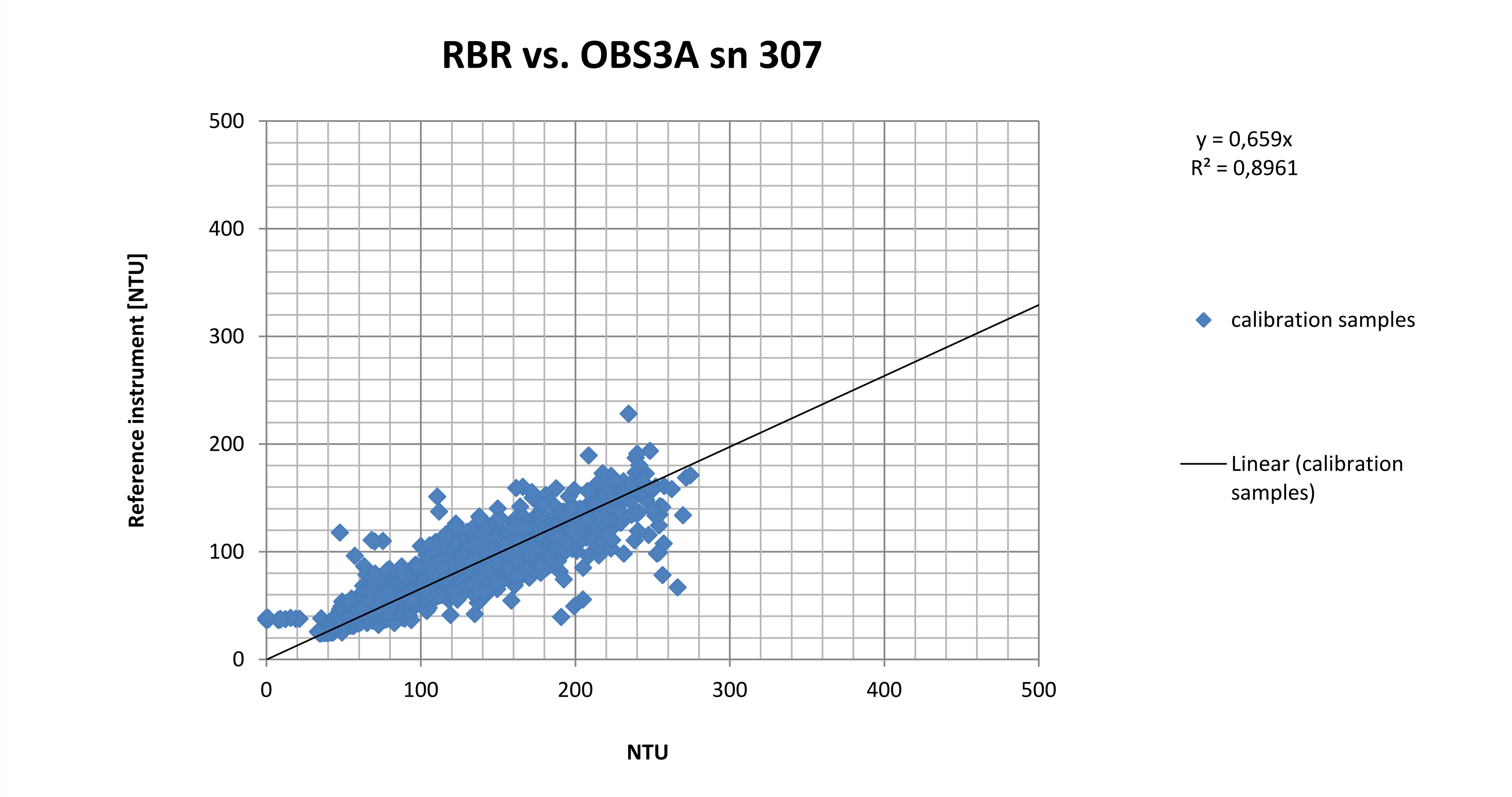
| | | |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 01/06/2012 | *Data processed by:* IMDC International Marine & Dredging Consultants<br>*In association with:* GEMS International, Deltares Enabling Delta Life<br>*I/RA/11354/12.011/JCA* |

# 11354 - Opvolging aanslibbing Deurganckdok



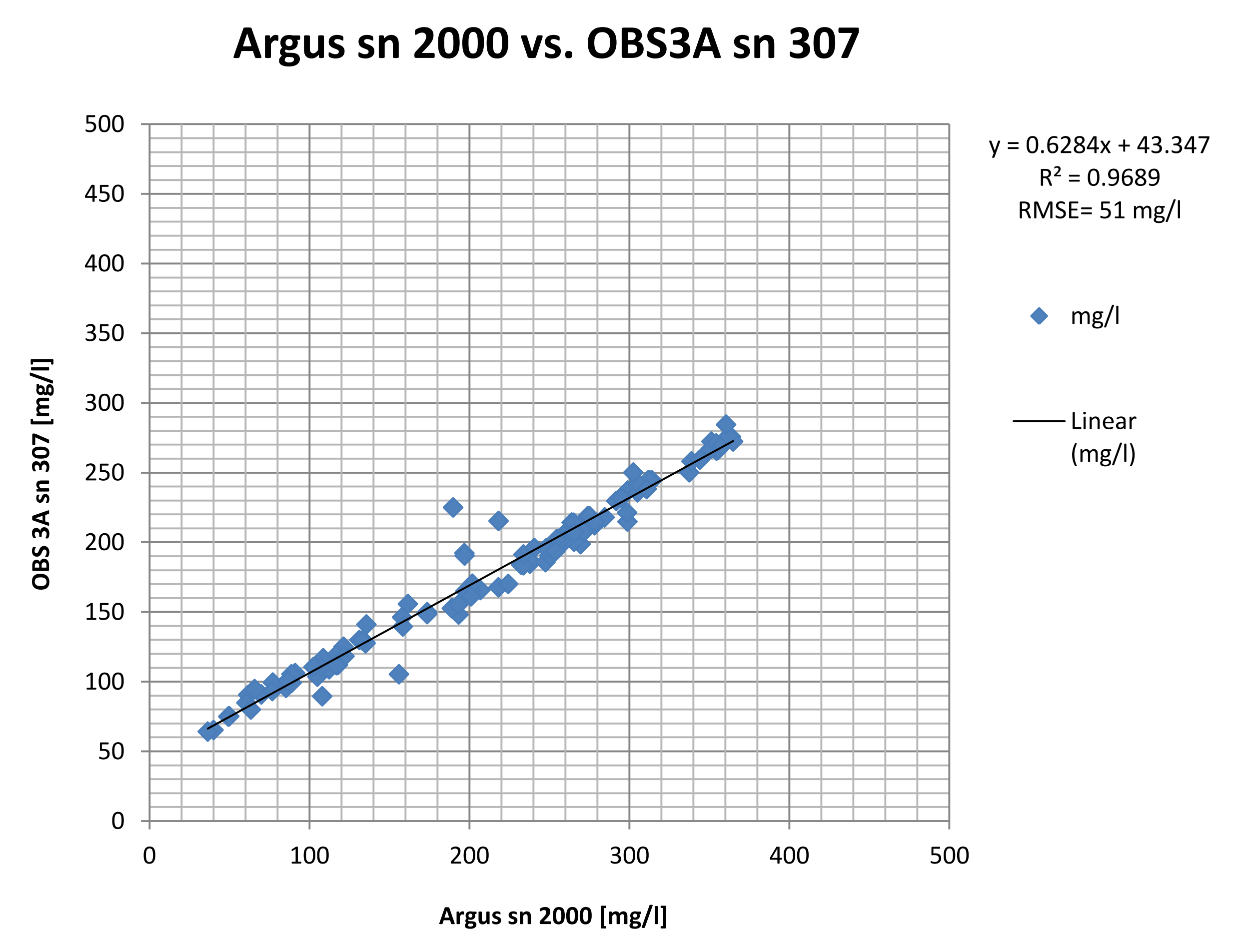

| Calibration Graph of RCM 9 s/n 1225 | | Data processed by: IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 01/06/2012 | In association with: GEMS International, Deltares Enabling Delta Life |
| | | I/RA/11354/12.011/JCA |

# 11354 - Opvolging aanslibbing Deurganckdok




| Calibration Graph of RBR s/n 17136 | | Data processed by: IMDC International Marine & Dredging Consultants |
|---|---|---|
| Location: Lower Sea Scheldt | Date: 01/06/2012 | In association with: GEMS International, Deltares Enabling Delta Life |
| | | I/RA/11354/12.011/JCA |

# 11354 - Opvolging aanslibbing Deurganckdok




Calibration Graph of Argus s/n 2000

Location:
Lower Sea Scheldt

Date:
01/06/2012

*Data processed by:* IMDC International Marine & Dredging Consultants

*In association with:* GEMS International, Deltares Enabling Delta Life

*I/RA/11354/12.011/JCA*