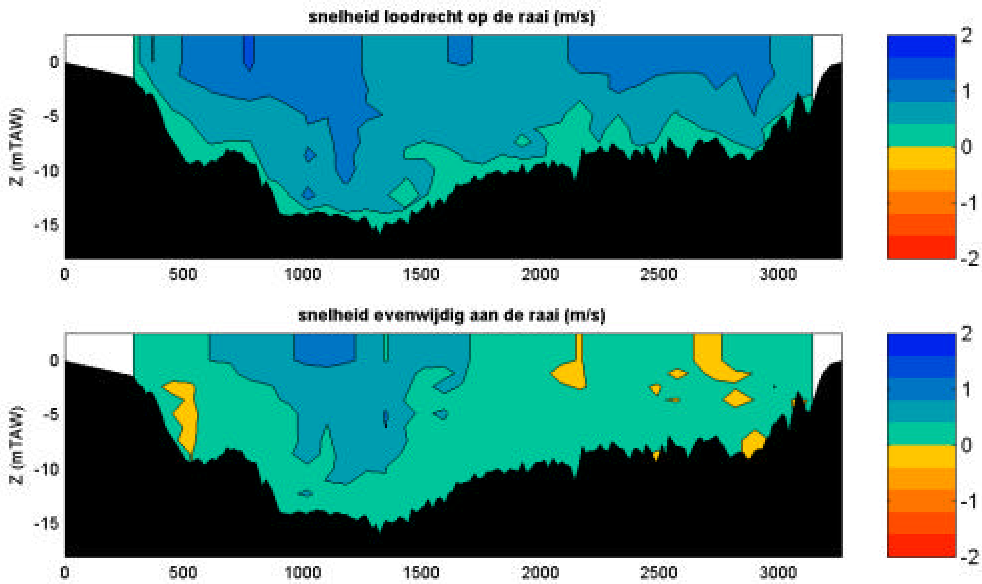
Ministerie van de Vlaamse Gemeenschap
Departement Leefmilieu en Infrastructuur
Afdeling Waterwegen en Zeewezen
Afdeling Waterbouwkundig Laboratorium en Hydrologisch Onderzoek



STUDIE DENSITEITSSTROMINGEN IN HET KADER VAN LTV

STROOM- EN SALINITEITSMETING TE WAARDE UITGEVOERD OP 12/06/2002

I/RA/11216/02.038/CMA
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i.s.m.

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1 INTRODUCTION

1.1 The assignment

On March 1, 2002 the WLHO (Departement Leefmilieu en Infrastructuur, Afdeling Waterwegen en Zeewezen, Afdeling Waterbouwkundig Laboratorium en Hydrologisch Onderzoek) assigned the study " Densiteitsstromingen Schelde in het kader van LTV" (16EB/01/01) to WL | Delft Hydraulics in association with IMDC.
The study consists of the following parts:

- The set up and execution of an extensive measurement campaign
- The building of a physical model, including the access channel to a sluice
- The building of a 3D numerical model
- The writing of a report on future possible actions that can be taken in order to obtain a better understanding of the functioning of sedimentation and silt transport in the Lower Scheldt
- The transfer of the numerical models to the WLHO, including the necessary training sessions.

This report is written as part of sub-assignment 1: the set up and execution of an extensive measurement campaign.

1.2 Purpose of the measurement campaign

The through tide measurement campaign conducted at Waarde is part of the extensive measurement campaign in the study on density currents in the river Scheldt, in the framework of the Scheldt Long Term Vision (LTV). In addition to long term measurement campaigns at certain designated posts along the river Scheldt, the measurement plan also covered two series of through tide measurements at different locations on June 5th and 12th 2002.
The purpose of the measurement campaign was to supply a coherent set of data which will not only be applied in the calibration and validation of the numerical models and the physical model that are being developed in the framework of the study on density currents on the one hand, but which could also contribute to the knowledge of the behaviour of density currens in the river Scheldt, and more specifically around the areas of the Kallo Lock and the future Deurganckdock.

The purpose of the measurement campaign at Waarde was to provide in downstream boundary conditions for the 3D hydrodynamic model.

Table 1 gives a survey of the measurement campaign and the resulting factual data reports. Appendix 4 is a survey of the entire measurement plan, with the locations of the through tide measurement campaigns and the long term measurement locations.

This report is the factual data report of the through tide current and salinity measurements at Waarde on June 12th 2002 . An interpretation and analysis of the measurement data will be made in the data analysis report (I/RA/11216/02.045/CMA), which is in preparation.

Measurement Location	Measurement Period	Type of Measurement	Report number
Waarde	5/06/2002	Through tide current and salinity measurement	I/RA/11216/02.037/CMA
Waarde	12/06/2002	Through tide current and	I/RA/11216/02.038/CMA

		salinity measurement	
Oosterweel	5/06/2002	Through tide current and salinity measurement	I/RA/11216/02.038/CMA
Oosterweel	12/06/2002	Through tide current and salinity measurement	I/RA/11216/02.039/CMA
Deurganckdok	5/06/2002	Through tide current and salinity measurement	I/RA/11216/02.040/CMA
Deurganckdok	12/06/2002	Through tide current and salinity measurement	I/RA/11216/02.041/CMA
Kallo	5/06/2002	Through tide current and salinity measurement	I/RA/11216/02.043/CMA
Kallo	12/06/2002	Through tide current and salinity measurement	I/RA/11216/02.044/CMA
Zandvliet Lillo-Ponton Deurganckdok Schelle Oosterweel Petroleum steiger	June 2002	Long term current and salinity measurement	I/RA/11216/02.046/FDK
Kallo	June 2002	Long term current and salinity measurement	I/RA/11216/02.047/FDK
Merelbeke	June 2002	Discharge measurement	I/RA/11216/02.029/CMA
Analyses of the data			I/RA/11216/02.045/CMA

Table 1 : survey of the measurement campaigns that have been conducted for the study on density currents in the river Scheldt.

1.3 The report

The first chapter forms the introduction, with a short description of the measurement campaign. Chapter 2 describes the measuring equipment used. Chapter 3 includes the proceedings of the measurement campaign. In chapter 4 the processing of the data set and the measurement results are presented.
This report is partly based on the RWS notitie nr. ZLMD-02.N.007. (RWS, 2002).

2 THE MEASUREMENT CAMPAIGN

2.1 Description of the measurement campaign

The current and salinity measurement took place at Waarde on June 12th 2002 from 4:31 MET until 17:30 MET and was conducted by Rijkswaterstaat (meetdienst directie Zeeland). The measurement track is the Rijkswaterstaat measurement track 5B.

From the survey vessel Scaldis ADCP and CTD measurements were conducted. The measurements followed a cyclic pattern. At the start of every hour an ADCP measurement was conducted (sailing from right bank towards the left bank of the river). While sailing back to the starting point of the ADCP measurement track, CTD profiles were measured in the 5 measurement points.

Appendix 4 is a survey of the entire measurement plan, with the locations of the through tide measurement campaigns and the long term measurement locations.
Appendix 7 offers a survey of the measurement location with sailed ADCP tracks, whereas Appendix 8 gives a survey of the location where CTD profiles were measured.
Table 2 displays the average start and end point of the ADCP measurement tracks and the average length and course of the tracks.
Table 3 gives the average positions of the CTD measurement points and the bottom depth at those locations.

name	Start easting	Start northing	End easting	End northing	Average length	Average course
Wan	573322.96	5696647.38	571357.65	5694954.0	2973	216

Table 2 Average start and end point of ADCP measurement tracks

Naam meetpunt	Easting	Northing	Bottom depth (mTAW)
Wc1	571610	5695188	-9
Wc2	572378.1	5695836	-11.6
Wc3	573122.4	5696487	-7.9
Wc4	573499.7	5696815	-3.5
Wc5	571930	5695455	-14.5

Table 3 Average positions of the CTD measurement points

The position of measurement point WC5 (in between measurement points WC1 and WC2) can be explained by the fact that WC5 is an optional measurement point that only had to be added to the measurement cyclus when enough time was available.

2.2 The equipment

The current measurements were conducted with the help of an RDI 600 KHz BB ADCP apparatus which had been build into the vessel SCALDIS. Appendix 2 gives the technical details for the ADCP.
The apparatus was set so as to realize 5 water-profiling pings and 4 bottom-tracking pings per measured ensemble. This results in an average of one ensemble every 3 seconds. The vertical

resolution ("bin size") was 0.5 meters. With Digibar, the sound velocity was registered for every track separately.

The conductivity and salinity pro filing measurements were conducted with the help of an Aquamatic AQUA –16 device, coupled with a measurement fish. Appendix 2 gives the technical specifications for the Aquamatic. While the fish was raised from the bottom to the water level, temperature and conductivity were measured every second.

Positioning was determined by a DGPS. The bathymetric survey of the measurement track was realized with the software program QINSY.

3 THE MEASUREMENTS

3.1 Measurement periods

3.1.1 ADCP measurements

In all, 14 ADCP measurements have been conducted along the measurement track. With exception of track wan-58, all measurement tracks were sailed from the right bank of the river to the left bank of the river, the average course was229° with respect to North. The different data for track wan-58 can be explained by the fact that the original data could not be recuperated and instead measurements made during the ctd profiling were used . Appendix 7 gives a graphic survey of the sailed ADCP tracks, Appendix 5 gives the start and end points of the tracks, the sailed length and the course.

3.1.2 CTD measurement

On five CTD measurement points measurements were conducted during 14 cycles.
The measurements were conducted as profiling measurements, with the profiles being measured from the bottom up at a velocity that allowed for one measurement value every 10 to 20 centimeters (1 measurement per second).
Appendix 6 gives the X and Y coordinates (UTM-ED50) of the every measurement point , the bottom depth in mTAW, the maximum and minimum depth on which measurements took place and the depth averaged temperature and salinity.
Appendix 8 is a graphic overview of the locations of the CTD measurements.

3.2 Hydro-meteorological conditions during the measurement campaign.

3.2.1 Vertical tide during the measurement

The vertical tide was measured at the tidal measuring station (HANS, location number 120 of the RMI measurement net). The values were converted by RWS to a location at the middle of the measurement track. A graphical representation of the tide , together with the tidal registrations for the other measurement locations of the through tide measurements can be found in Appendix 1.
Table 4 gives the most important characterisations (high and low tide) of the tide at Hansweert on the day of the measurements

	Time (hh:mm MET)	**Water level (mTAW)**
HW(1)	03:30	5.02
LW(2)	10:00	0.17
HW(3)	15:50	5.19
LW(4)	22:40	0.06

Table 4 high tide and low tide at Hansweert on 12 /06/2002

Table 5 compares the tidal characteristics of the measurement day to the average tide, the neap tide and the spring tide over the decade 1981-1990 (Claessens and Meyvis, 1994).

The tidal coefficient of 1.09 to 1.16 for the tidal data of 12/06/2002 indicates a spring tide with a tidal difference that is slightly lower than the average spring tide.

Hansweert	**Neap tide ('81-'90)**	**Average Tide ('81-'90)**	**Spring Tide ('81-'90)**	**Tide 12/06/2002**
Water level (mTAW)				
HW (1)	0.52	0.30	-0.02	5.02
LW (2)	4.43	4.71	5.46	0.17
HW (3)	-	-	-	5.19
LW (4)	-	-	-	-0.06
Tidal difference (m)				
Rising(1→2)	3.91	4.41	5.48	4.85
Falling(2→3)	3.91	4.41	5.48	5.02
Rising(3→4)	-	-	-	5.13
Duration (hh:mm)				
Rising(1→2)	06:07	05:47	05:35	6:30
Falling(2→3)	06:35	06:38	06:44	5:50
Rising(3→4)	-	-	-	6:50
Tide (1→3)	12:42	12:25	12:20	12:20
Tide (2→4)	-			12:40
Tidal coefficient				
Rising (1→2)	0.81	1	1.14	1.0
Falling (2→3)	0.81	1	1.14	1.04
Rising (3→4)	-	-	-	1.06

Table 5 comparison of the tidal characteristics of 12/06/2002 with the average tide, the average neap tide and the average spring tide over the periode 1981-1990.

3.2.2 Meteorological data

The wind velocity and direction was measured at the HAWI measurement location (Hansweert, RMI-measurement number 876).
During the entire measurement period, a SE wind with an average speed of 15m/s was measured.

3.3 Naval Traffic

A survey of the naval traffic is given in Appendix 3.

4 PROCESSING OF THE DATASETS

4.1 Methodology of processing

In the following chapter the results of the ADCP and CTD measurements will be discussed, as wel as the processing of the data.

4.1.1 Processing of the ADCP dataset

A survey of the ADCP measurements has already been given in Table 2.
The results of the ADCP measurements can be found in Appendix 9. The processing of the ADCP data was done partially by RWS, department Zeeland.

In the processing of the ADCP data, both the bottom track information collected by the ADCP as well as the velocity data were used.
The movement of the ADCP sensor during the recording has been calculated with the “bottom track” information. This “ bottom track” information is recorded by the ADCP itself during the measurements. Flow velocity and direction were calculated with the help of the “bottom track” information.
The validation of the ADCP data has been conducted on a visual basis and on the basis of the calculated discharge data per measured cel (“bin”): in cases where the value given for this discharge was the dummy value, it was supposed that the velocity information for this particular cel was unreliable. Cells with unreliable data were deleted.
The values for the bottom depth were deduced from the ADCP dataset. The values for the tidal data are measured at the measurement station Hansweert and converted by RWS to a point in the middle of the measurement track.

Further processing of the ADCP data included :

- Drawing a contouring map over the section of the perpendicular velocity
- Drawing a contourig map over the section of the parallel velocity
- Drawing the variation in depth averaged velocity and the discharge along the measurement line
- Drawing the velocity magnitude and direction along the measurement line
- Calculation of the total discharge over the sailed section
- Calculation of the area of the sailed cross-section
- Calculation of the cross-sectional averaged velocity over the sailed cross-section

For the processing of the ADCP data, all measured data were projected on an “theoretical measurement track”, in order to make comparisons between the different measurement cycles more straightforward. This “theoretical measurement track” was defined as the track between the two outermost measurement points. Table 6 gives the coordinates of start and ending point of the track.

	Start Easting	Start Northing	End Easting	End Northing
	571119.1	5694748	573588.8	5696886

Table 6 Coordinates (UTM-ED50) of the "theoretical measurement track"

The velocity measurements have been extrapolated upwards and downwards. In case when the last depth cell was located at more than 3 meters distance of the bottom the data were not extrapolated.
The upward extrapolation was done using a constant extrapolation. Upwards, a layer of ca. 2.5 meters was extrapolated, downwards ca. 1 m. The downward extrapolation was conducted using equation 4-1.(Van Rijn,1993).

$$v = v_1 \left(\frac{z}{z_1} \right)^{0.25} \qquad (4\text{-}1)$$

in which v_1= current velocity in the first measurement point above the bottom
z_1=height of the first measurement point above the bottom

For the drawing of the contouring maps, the data was interpolated on a regular 40*15 points grid.

For the drawing of the contouring maps, the data was interpolated on a regular 40*15 points grid. The bathymetry used in the presentation is the bathymetry measured by the ADCP.

The current velocities are negative in the flood direction and positive in the eb direction. The discharge was calculated by multiplying the depth-averaged velocity per ensemble with the distance to the following ensemble,multiplied by the thickness of the ensemble.

4.1.2 Processing of the CTD results

In Appendix 6 a survey has been given of the CTD measurement points and the average coordinates of these points. The results of the CTD processing can be found in Appendix 10. The processing of the CTD data was done partially by RWS, department Zeeland.
The salinity was calculated from the temperature and conductivity using the pps-78 formula (UNESCO,1991). Appendix 11 gives the calculation.

The validation of the CTD data was done visually : data that showed strong deviations were deleted from the profiles.
The values for the bottom depth were deduced from the bathymetric survey Zli0000.250.Lod. that was conducted by RWS. The values for the tidal data are measured at the measurement station Hansweert.

For every CTD profile a measurement report was made. Besides general information, this report contains a graphical representation of the conductivity, the temperature and the salinity in function of the depth. The measurement values are represented in table (in the case of measurements at relatively deep points not all measurement values are notated) and the depth averaged values for salinity, temperature and conductivity are given.

4.2 Storage of the data

The contents of the folder "Waarde 1206" in the CDROM 11216-1 are the following directories:
-RA02038-Waarde12062002 : de electronic version of this report
-"processed adcp data"
Wa51 to Wa64n.txt : validated data, in the agreed format
-"processed ctd data" :
Wc1 to 5 – 51 to 64n.txt : validated data

Appendix 12 gives the organisation of the files.

5 REFERENCES

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KMI maandbericht (2002) Klimatologische waarnemingen juni

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RWS, directie Zeeland (2002): Stroom- en Saliniteitsmeting Westerschelde Raai-5B Waarde,notitie nr. ZLMD-02.N.007

Unesco (1991) Processing of Oceanographic Station Data

Van Rijn, L. (1993) Principles of Sediment Transport in rivers, estuaries and coastal seas.

APPENDICES

Appendix 1 :Tidal data for all through tide measurement locations on 12/06/2002

Appendix 2:The Equipment

Appendix 3 : Survey of the naval traffic

Appendix 4: Plan of the measurements

Appendix 5 : Start and endpoint of the sailed ADCP lines, sailed length and course

Appendix 6: Coordinates of CTD measurement points, bottom depth,and maximum & minimum measurement depth

Appendix 7 : Graphic survey of the sailed ADCP measurement tracks

Appendix 8 : Graphic survey of CTD measurement locations

Appendix 9 : Processing of the ADCP data set

Appendix 10 : Processing of the CTD data set

Appendix 11 : Calculation of the salinity (pps-78 formula)

Appendix 12 : Organisation of the files