PUTMOR-field measurements

a six-months measuring campaign at a lowered dumping pit near Hoek van Holland (The Netherlands)

work document RIKZ/OS-2000.132x
december 2000

S. Hoogewoning

with special thanks to:
Ad Stolk
Marien Boers
Co van de Kreeke

Ministerie van verkeer en Waterstaat

Directoraat-Generaal Rijkswaterstaat

Rijksinstituut voor Kust en Zee/*RIKZ*

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Contents

1. Why field measurements?

1.1. Introduction

The need for sand from the bottom of the North Sea will increase during the next decades. Possible future land reclamation projects, like "Maasvlakte 2" or "Airport on Sea" are under investigation. These projects require large volumes of sand (in the order of 500 million kubic meter or more. This is far more than the annually averaged volumes of around 20 million kubic meter a year. Furthermore, coarse sands required for the building industry, can only be found in sand layers at larger depths. Presently, extraction is only allowed in the upper two meters and in waterdepths beyond 20 m with respect to NAP (Dutch Ordnance Level), according to the Regional Extraction Plan for the North Sea (RON).

To determine whether large scale sand extraction and extraction deeper than presently allowed in RON is feasible, insight in the expected morphological and ecological adaptation of large scale sand extraction areas is required. In assignment of Ad Stolk of DNZ, the morphological issues have been studied within the framework of the coastal research programme Coast*2000 (1995 - 1999). Results have already been used in RON 2, the successor of the present RON. Studies are presently continued within the framework of the Coast*2005 (2000 - 2004) programme, the successor of the Coast*2000 programme.

*1.2. Background of Coast*2000*

As a starting point, one single enclosed sand extraction area up to 500 million kubic meter was considered at waterdepths below 20 m with respect to NAP. The hypothetical extraction depth varied between two and twenty meters. Moreover, a distinction was made between local effects (in and around the sand extraction area) and global effects (up to the nearshore zone).

A quick scan of the possible physical effects, related to the watermovement, sediment transport and resulting morphological developement can be found in **Hoogewoning (1997)**. Subsequently, the local water movement and related morphological effects were studied in more detail. For this the morphological developement of the shipping channel IJgeul and Euromaasgeul to the ports of respectively Amsterdam and Rotterdam was studied **(Hoitink, 1997 and Walstra et al., 1998)**. These studies were a first attempt to determine the possible morphological developement of large scale sand extraction areas. A relatively simple one-dimensional approach to the long term morphological developement of the shipping channels is given by **Hoogewoning and Van de Kreeke (2000)**.

Since the shipping channels are almost perpendicular to the tidal currents (quasi one-dimensional), further studies of the two-dimensional horizontal effects were carried out using a modeling approach. Numerical studies of the two-dimensional water movement were performed without the influence of coriolis **(Labeur, 1998)** and later with the influence of coriolis and the resulting morphological developement **(Klein, 1999)**. In addition to this, a theoretical study of the morphological stability of a large scale sand extraction area was compared with a numerical approach to the morphological stability **(Nemeth, 1998)**. The sand extraction area was considerd a disturbance of the seabottom comparable with large scale tidal sandbanks in the North Sea. A full overview of the results of the forementioned studies is presented in **Hoogewoning (1999)**.

The numerical results of the studies of the two-dimensional water movement showed that the dimensions of the large scale sand extraction area have a significant influence on the tidal flow. In case of a sand extraction area with the longitudinal axis in the direction of tidal flow, the tidal flux per unit width is larger in- than outside the sand extraction area. The extraction area seems to guide the tidal flow. This will result in a quicker flattening of the (up- and downstream) slopes of the extraction area and a larger surrounding area will be morphologically influenced. Moreover, theoretically a small deepening of the center of the extraction area is to be expected.

Whether the two-dimensional approach - in which the horizontal tidal flow dominates the water movement - holds for sand extraction areas with large depths needs verification; the predicted increase of tidal flux should be verified. Of particular interest is the question whether the mixing of water near the bottom in the pit is different from outside the pit; a lower mixing rate may result in lower oxygen values near the bottom. The vertical mixing rate decreases due to vertical stratification, caused by vertical differences in salinity and/or temperature. The horizontal mixing rate depends on the velocity-field near the bottom. Espescially in case of increasing local depth of the extraction area, information about the (vertical and horizontal) mixing rates is relevant to estimate ecological recovery.

In the next paragraph the field site and set up of the field measurements will be explained.

2. Project description

2.1. Perfect opportunity

In 1999, a perfect chance to carry out field measurements did arise. A lowered dumping area (LDA) was to be created, as an alternative to the present dumping place "Loswal North", where dredged sediment from the harbour of Rotterdam and its rivermouth is dumped. The LDA is situated just seaward of the shoreface, at 10 km west of Hoek van Holland and just north of the Euromaas channel. Local waterdepth is 22 m with respect to NAP **(see Figure 2.1 a)**.

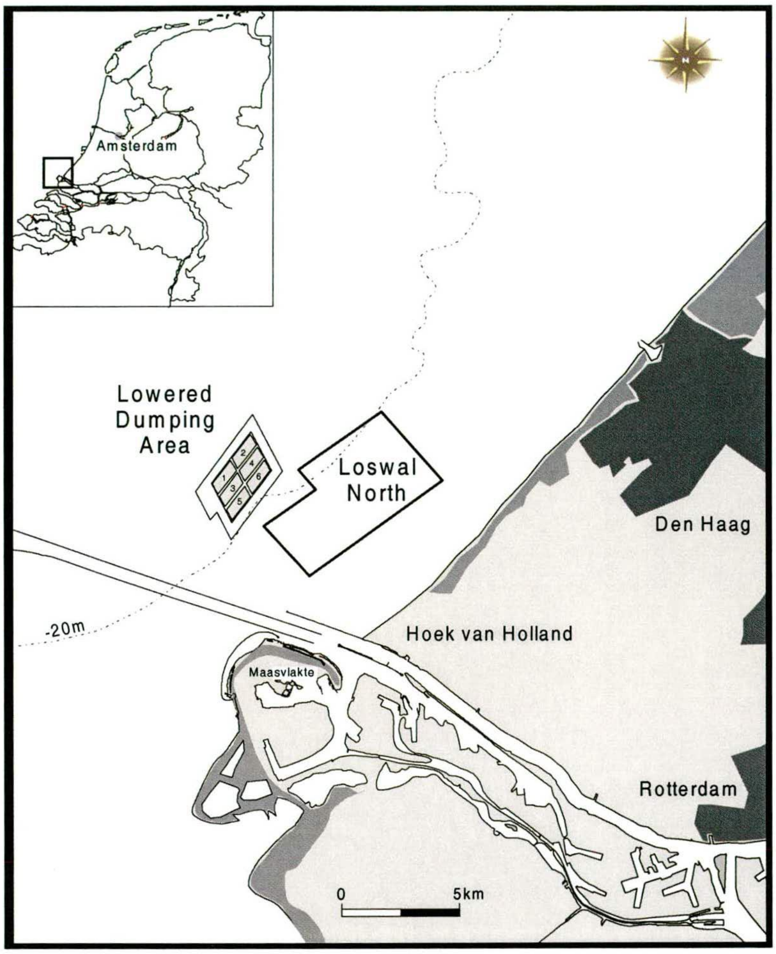


Figure 2.1 a. Overview of the Lowered Dumping Area (LDA) in front of the Dutch Coast, near Hoek van Holland. To the east of the LDA the former dumping place "Loswal North" is shown.

The LDA covers six future lower dumping pits (LDP). Each LDP will have a volume of about five million kubic meters, an average depth of about 10 meters below the surrounding seabottom, an alongshore length of about 1300 m and a cross-shore length of about 500 m (**see Figure 2.1.b**).

The first LDP, situated in the southwest corner of the area, was finished at the end of September 1999. With the approval of the Directorate North Sea (DNZ), Directorate South Holland (DZH) and the Communal Harbour Company of Rotterdam (GHB), this first LDP could be used for field measurements during a 6-months period, from the 1st of October until the 31st of March 2000. After this period the LDP is filled with harbour mud.

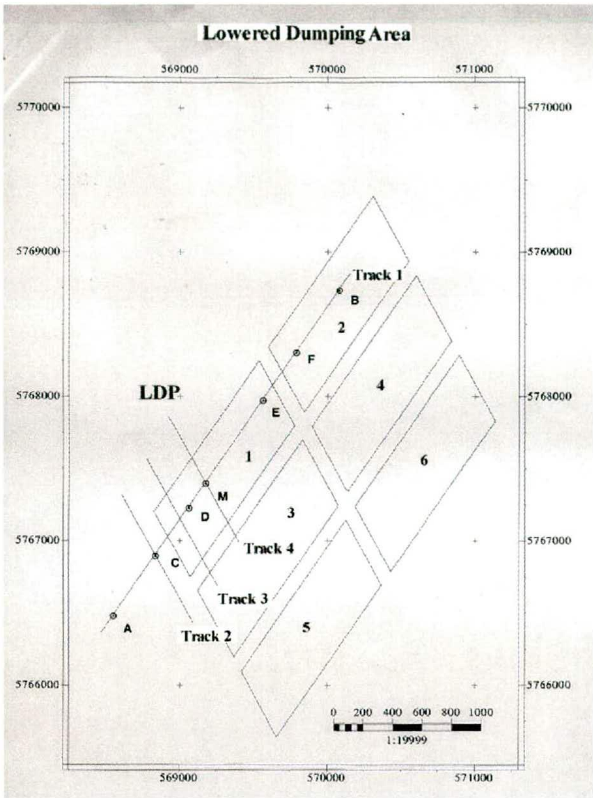


Fig 2.1 b. An overview of the lowered dumping area covering six lowered dumping places. The LDP under investigation is situated in the southwest-corner (indicated with LDP).

2.2. Organization

Preparation and execution of the measurements took place as part of the DNZ-project PUTMOR. Measurements were carried out by the survey department of DNZ, with the cooperation of RIKZ. A flow-diagram (**Figure 2.2**) illustrates the organization.

Progress was discussed monthly with the persons from DNZ-AM, DNZ-MT and RIKZ involved and documented in reports. Persons involved were:

- **Ad Stolk** (DNZ AM), projectmanager of the PUTMOR project;
- **Jos Kamphuis** (DNZ MT), project leader, in charge of the measuring campaign;
- **Marcel Kints** (DNZ MT), preparation of the measuring instruments and collection of the data;
- **Chris Dijkshoorn** (DNZ AM) and Ton Haksteen (DNZ MT), respectively responsible for information about the mining activities and the bathymetric surveys;
- **Sander Hoogewoning** (RIKZ), project leader, involved with the preparation and guidance of the measurements and forthcoming processing and analysis of the data
- **Marien Boers** (RIKZ), project leader starting from October 2000, responsible for the forthcoming processing and analysis of the data
- **Co van de Kreeke**, external advisor for the measurement campaign, involved with the preparation and forthcoming processing and analysis of the data;

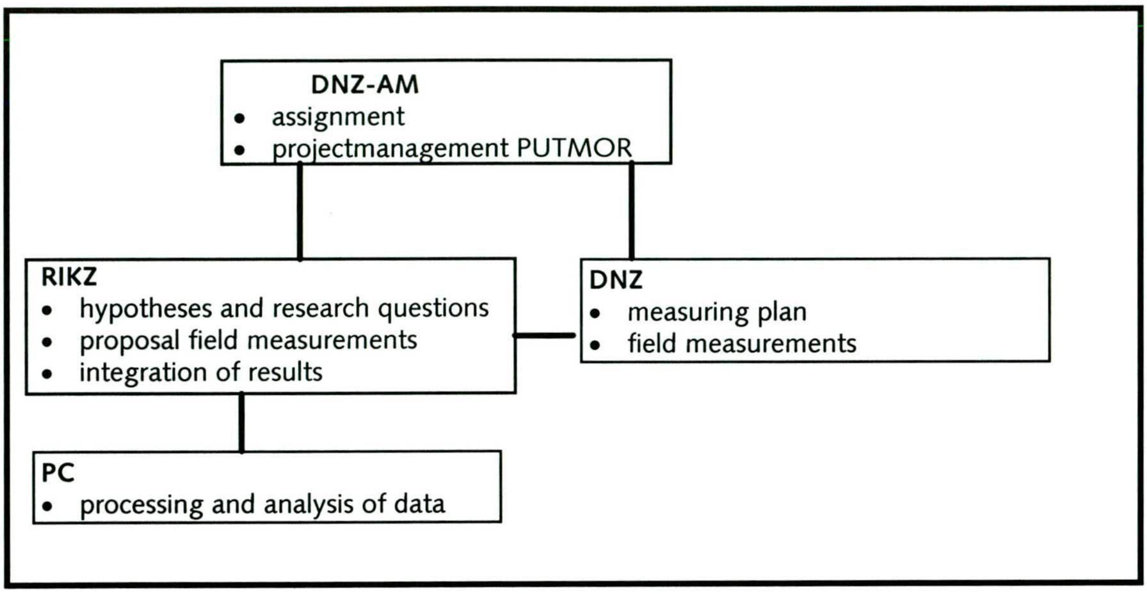


Figure 2.2. Overview of the PUTMOR organization, with DNZ-AM = Directorate North Sea, department Water Management; DNZ-MT = Directorate North Sea, department Marine Technique; RIKZ = National Institute for Coastal and Marine Management and PC = Private Companies.

2.3. Preparation of the measuring campaign

2.3.1. Hypotheses and research questions

Given the opportunity to carry out field measurements, five hypotheses and several related research questions were formulated by RIKZ, based on the earlier results of studies as part of the Coast*2000 programme. The formulated hypotheses are:

H1: Since the main direction of the longest dimension of the LDP nearly coincides with the main direction of the tidal flow and beacause the length to width-ratio of the LDP amounts about 2.5, an increase of the tidal flux through the LDP is expected. The maximum depth-averaged tidal velocity in the LDP is expected to be smaller than outside the LDP due to the limited dimensions of the LDP.

H2: Due to the increased waterdepth, a reduction of the vertical mixing rate in the LDP is expected. Consequently an increase of the present vertical stratification is expected in the LDP.

H3: Tidal velocties near the bottom in the LDP are expected to be smaller than outside the LDP. As a result of this, oxygen-rates in the lower part of the watercolumn of the LDP might be smaller than those outside the LDP.

H4: Given the expected behaviour of the water movement, sedimentation of fine sand and silt is expected in the LDP.

H5: The expected morphological changes of the LDP are charactarised by the flattening of the slopes and a shallowing of the LDP. Largest changes are of course expected after storms.

To be able to validate these hypotheses, in total 26 research-questions were formulated for the distinctive parameters *water level, flow velocity, temperature, salinity, density, turbidity and oxygen-rate.*

A proposal for field measurements, in which the hypotheses and the research-questions related to the parameters to be measured are described, is given in **Hoogewoning and Van de Kreeke (1999)**.

2.3.2. Measuring plan

The forementioned proposal proved to be a good basis for the measuring plan of DNZ-MT (**Kamphuis, 1999**).

The measuring plan describes the configuration of the measurements. It considers:
- the measuring periods,
- the measuring method and equipment,
- the locations of the instruments and
- the products.

The measuring plan comprises measurements *at fixed locations* and *shipmounted* measurements. The configuration for both type of measurements is summarized in the **Tables 2.1.A and.2.1.B** below.

Table 2.1.A. Measurements at fixed locations

Parameter(s)	Measuring position(s)	Location (see fig. 2.1 b)	Instrument Type
V	vertical profile	A, M	ADCP
T, C, D, Tu	1 m above the bottom	A, M	Hydrolab
T, C	five vertical positions: 2, 7, 12, 22 and 28 m above the bottom	near M	Aandera-string
T, P	1 m above the bottom	B	MORS

With V = velocity (u,v,w), T = temperature, C = conductivity, D = waterdepth, Tu = turbidity and P = pressure.

Additional comments:
- the measuring period at the fixed measuring locations lasts at least 30 subsequent days (to be able to detect the relevant tidal frequencies from the data);
- four measuring periods have taken place;
- data-storage intervals are 10 minutes; depending on the instrument a momentary value or a 10-minute averaged value was stored;
- Because the depth at location M is larger than at location A, a 600 kHz ADCP was placed at location M, while a 1200 kHz ADCP was sufficient at location A;

Table 2.1.B Shipmounted measurements

Parameter(s)	Measuring position(s)	location (see Fig. 2.1 b.)	Frequency	Instrument Type
T, C, Tu, O, D	vertical profile	A, M	once or twice a week	Seabird (CTD)
V	vertical profile	along four defined tracks through LDP	two times, near spring-tide	ADCP
B	position of bottom	along tracks (LDP and surrounding area)	once a month	Multi-beam sounding
S	upper bottom layer	four locations outside and five locations inside the LDP	twice	"Van Veen-happer" or box-cores

With T = temperature, C = conductivity, Tu = turbidity, O = oxygen, D = waterdepth ,V = velocity (u,v,w), B = bathymetry with respect to NAP (Dutch Ordnance Level) and S = sediment sampling

Additional comments:
- the configuration of the shipmounted ADCP-measurements was defined by: (a) the sequence of measuring tracks 1 to 4, (b) the ship's speed along tracks 1 to 4, (c) the definition of the parts C-D and E-F along track 1 (where the ship speed is lower) and (d) the frequency of data-storage (around every 10 seconds); **see Fig. 2.1b.**

The products of the field measurements are:
- raw datafiles, including documentation
- background information (reports of field surveys etc.)

Validation of the data and further analysis of the data was not part of the measuring plan. The latter will be performed by private companies (PC) under contract with RIKZ, as part of the Coast*2005 programme (2000 - 2004).

In addition to the forementioned project-related measurements, background data was gathered by RIKZ. These data concerned:
- windspeed
- waveheight and direction
- air pressure
- fresh water influx form the river Rhine
- temperature of the fresh water from the river Rhine

3. Carrying out the field measurements

The field measuring campaign formally started at the 1st of October 1999 and finished on the 31st of March 2000, six months in total. A complete chronological description of the actions that took place within this period is given in **Appendix I.** In the following two paragraphs an overview of the measurements is given.

3.1. Measurements at fixed locations

3.1.1.General description

Measurements at fixed locations were carried out during four subsequent periods:
- from 14 October 1999 until 24 November 1999 (period 1)
- from 13 December 1999 until 14 January 2000 (period 2)
- from 14 January 2000 until 21 February 2000 (period 3)
- from 22 February 2000 until 28 May 2000 (period 4)

After each period, the instruments were retrieved, data was collected and the instruments were cleaned on land. No recalibration of the instruments took place and the instruments were replaced at their original locations.

To protect the instruments against fishing boats or other vessels travelling in the area, buoys were placed at approximately 100 m east and west of the fixed measuring locations. The buoys served their purpose well. No instruments were lost, although the Aandera-string and the MORS seem to have collided both once with a ship. During the measuring periods all instruments kept functioning well, only in the first period the ADCP-measurements from location A were not stored. A first inspection of the collected raw data shows that hardly any gaps are present and just a few spikes exist. In other words the data return seems to be very high. Further details of each measuring period are summarized in tables given in **Appendix II.**

3.1.2. Preliminary results

In this paragraph results for each instrument are shown as an example of the collected data. The presented measurement results, ADCP excluded, cover a full week **(15-21 October 1999)** within the first period.

<u>ADCP data: Vertical velocity-profiles at locations A and M</u>
With the ADCP looking upward at locations A and M, a vertical velocity profile is measured. The ADCP's doesn't cover a complete vertical profile. Near the bottom data is lacking or not reliable over a distance of 2 m. Near the watersurface data is not reliable over the last 2 m (about 6 % of the total waterdepth). Extrapolation is needed to complete the vertical profile. At this state no vertical velocity profiles are available yet. Instead, the ADCP, fixed to its frame and ready to be placed at location M, is shown in **Figure 3.1**.

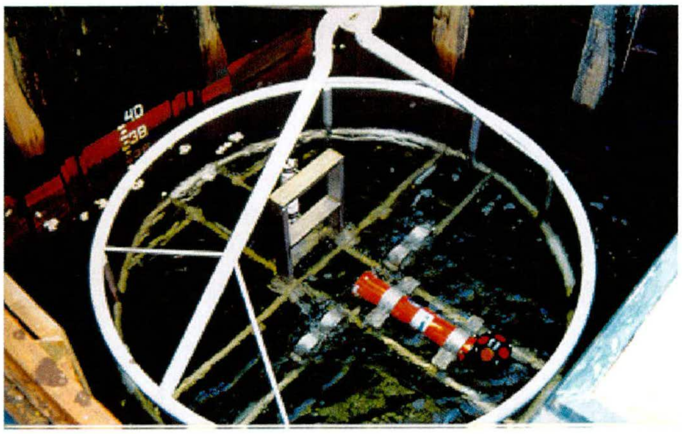


Figure 3.1. The ADCP (in red) fixed to its frame and ready to be placed at location M.

Hydrolab data: Near bottom values of temperature, conductivity, waterdepth and turbidity at locations A and M

The sensors of the hydrolab are situated around 1 m above the bottom. Therefore only single point information is available. With a Hydrolab at location A outside the LDP and one at location M near the middle of the LDP, differences between "outside"en "inside" can be quantified. The instruments registered momentary values once every 10 minutes during a maximum period of 29 days. The latter is related to the limited battery capacity. Examples of the time series of measured temperature, conductivity, waterdepth and turbidity at location M are given below.

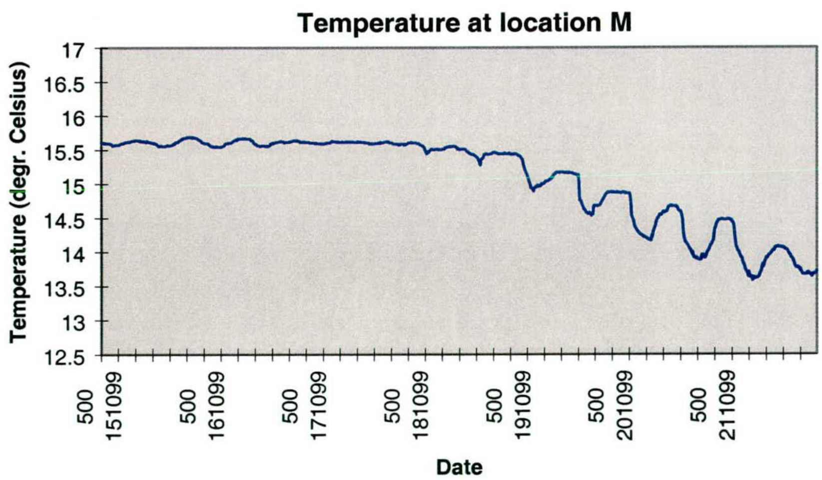


Figure 3.2. The temperature (degree Celsius) at location M near the bottom (+ 1 m), from 15 until 21 October 1999, measured with the Hydrolab. The value 500 refers to 5 minutes past midnight.

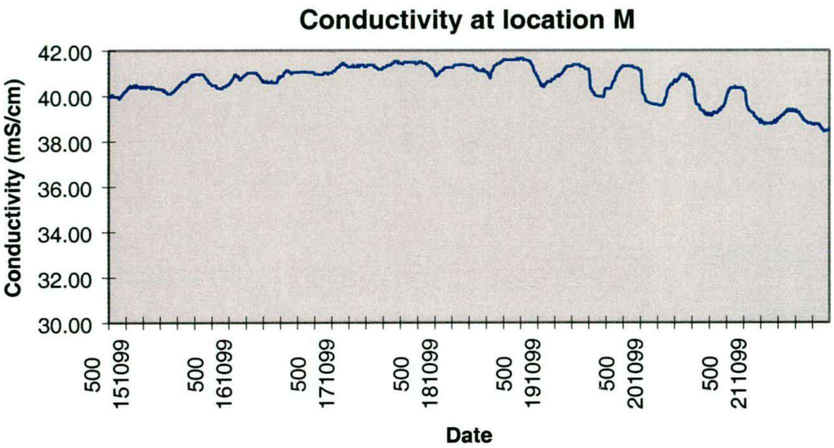


Figure 3.3. The conductivity (milliSiemens/centimeter) at location M near the bottom (+ 1 m), from 15 until 21 October 1999, measured with the Hydrolab. The value 500 refers to 5 minutes past midnight

The conductivity setting of the hydrolabs changed twice. The first change was accidental, the second change restored the original settings. This resulted in measurements of the conductivity during the period 1 (A) and 4 (A, M), while during periods 1 (M), 2 (A, M) and 3 (A, M) specific conductivity (temperature compensated) was measured.

Combined information of temperature and conductivity will lead to values of the salinity and subsequently to values of the local density of the water. More information about the further processing and analysis of the data is given in **Chapter 4**.

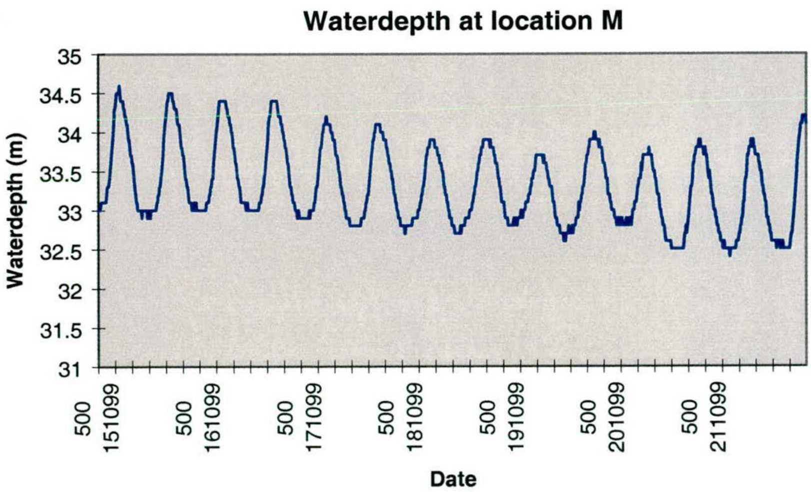


Figure 3.4. The waterdepth (m) at location M (sensor near +1 m above the bottom), from 15 until 21 October 1999, measured with the Hydrolab. Clearly visiable is the neap tide around the 19th of october 1999. The value 500 refers to 5 minutes past midnight.

The hydrolab contains a pressure sensor. Together with the information of conductivity and temperature a waterdepth value was produced. No raw data of pressure is available.

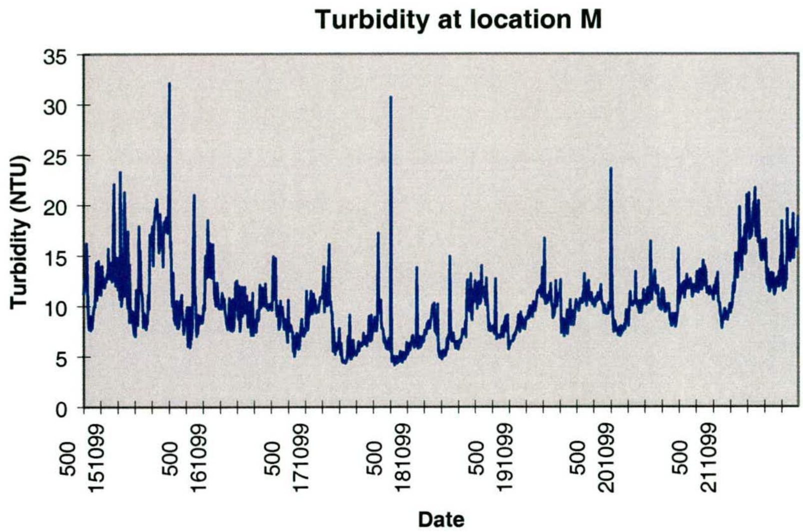


Figure 3.5. The turbidity (NTU) developement at location M, from 15 until 21 October 1999, measured with the Hydrolab. The value 500 refers to 5 minutes past midnight.

The turbidity sensor is sensitive to fouling. This is probably the reason for the observed trend in the turbidity measurements at the end of the first period (not shown here).

<u>Aandera-string data: measurements of temperature and conductivity at five different vertical positions near location M</u>

Temperature and conductivity were measured with the use of a so called Aandera-string. At five different vertical positions these parameters were measured, which are approximately: 2 m, 7 m, 12 m, 22 m and 28 m above the bottom. The Aandera -string uses a taut-wire mooring system (at the bottom first a heavy stone was used, later an anchor chain). Since the wire cannot be kept perfectly straight in the water column, the vertical position of the sensors are known to some extend. Examples of the measured temperature and conductivity at the different vertical positions are given below.

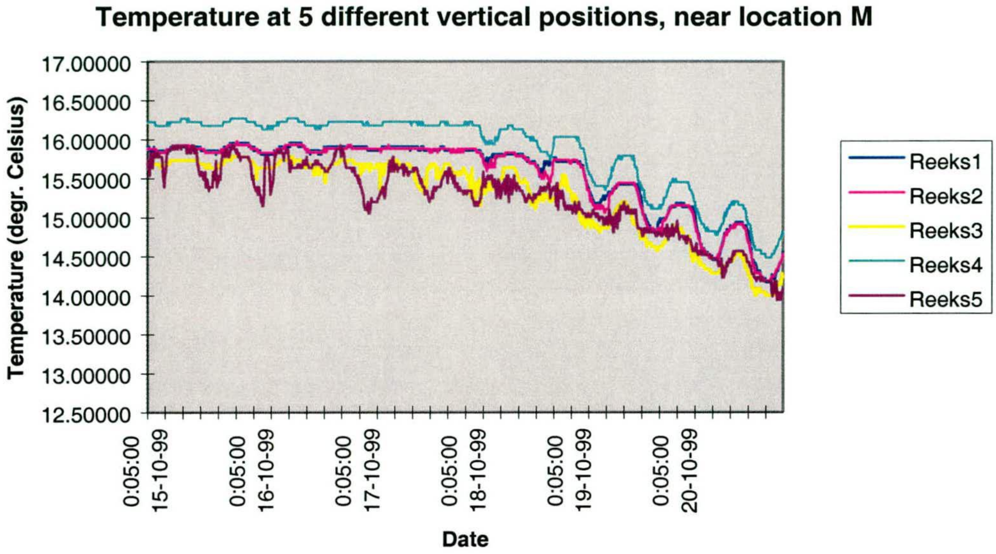


Figure 3.6. Temperature (degree Celsius) at five different positions near location M, from 15 until 21 October 1999, measured with the Aandera-string. "Reeks 1 to reeks 5" in the legenda respectively refer to values at heights above the seabed of +2 m, +7 m, +12 m, + 22 m and + 28 m. The displayed 0:05:00 refers to 5 minutes past midnight.

With the time series at five different depths a vertical distribution of the temperature can be derived. The analysis of the temperature series needs special attention. Temperature values of the sensor + 2 m ("reeks 1") can be compared with the ones from the hydrolab at location M. Time series of air temperature above the water surface, as well as time series of the river flow temperature (of the river Rhine) may be needed to explain the observed vertical temperature distribution. Moreover one should be aware of possible systematic errors in the temperature sensors. The deviation in the temperature series 4, at 22 m above the bottom, is a good example of such a systematic error.

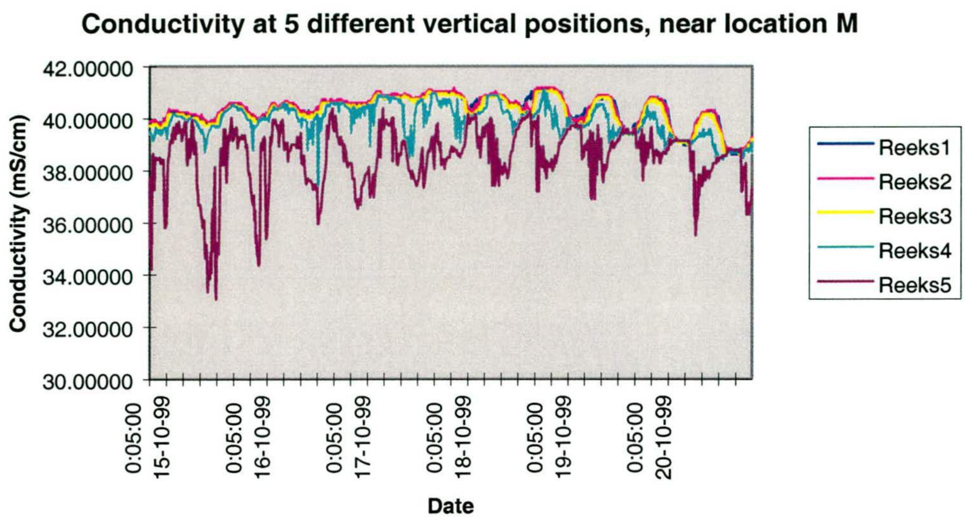


Figure 3.7. The conductivity (milliSiemens per centimeter) measured with the Aandera-string at five different vertical position near location M, from 15 until 21 October 1999. "Reeks 1 to reeks 5" in the legenda refers to values at the heights +2 m, +7 m, +12 m, + 22 m and + 28 m respectively. The displayed 0:05:00 refers to 5 minutes past midnight

Mors data: near bottom measurement of temperature and pressure

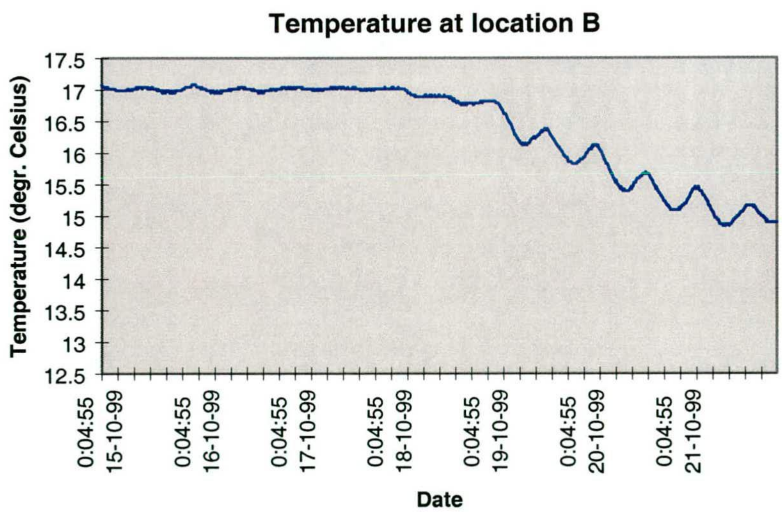


Figure 3.8. The temperature at location B (+ 1 m above the bottom) measured with the MORS, from 15 until 21 october 1999, where 0:04.55 stands for 4 minutes and 55 seconds past midnight.

Values of the temperature with the MORS are less reliable than the other temperature measurements. The values should be regarded as extra background information, not directly usefull for quantitative comparison with the temperature values from the Hydrolab and Aandera-string.

The main purpose of the placement of the MORS, is its relatively precize and reliable measurement of local pressure.

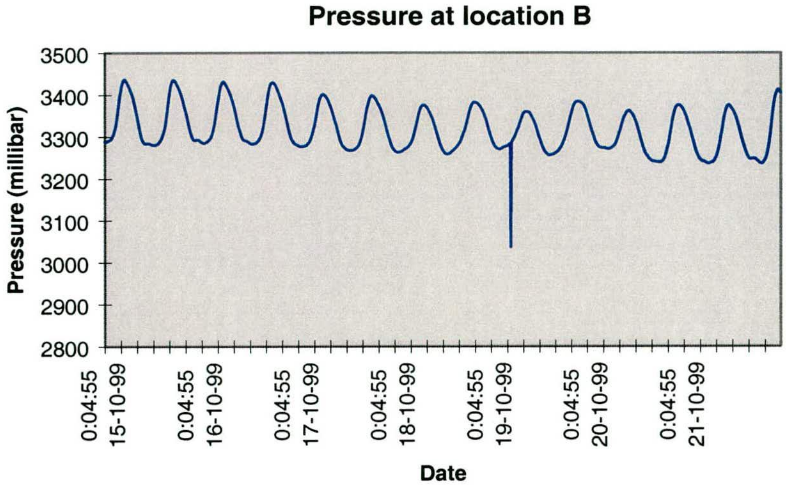


Figure 3.9. The pressure (millibar) at location B (+ 1 m above the bottom) measured with the MORS, where 0:04.55 stands for 4 minutes and 55 seconds past midnight

Clearly visible from the time series of the pressure is the tidal variation of water level, with neap tide around the 19th of october 1999. When looking in more detail, a local maximum appears around low water near spring tide. This is the so called "agger" and originates from the interaction of the principal tides with its higher harmonics.

If the position of the MORS pressure sensor with respect to the local bottom level is known, a mean sealevel (MSL) can be derived from the pressure data. For that purpose time series of the local air pressure are needed, since a change of 10 millibar in the air pressure is roughly equal to 10 cm of waterheight. When the MSL is estimated from the MORS measurements, the bathymetric surveys, containing the values of the local bottomdepth with repsect to MSL, can be checked. Since the relationship between mean sealevel and NAP (Dutch ordnance level) is not known for the LDP and surrounding area, results cannot be coupled to NAP.

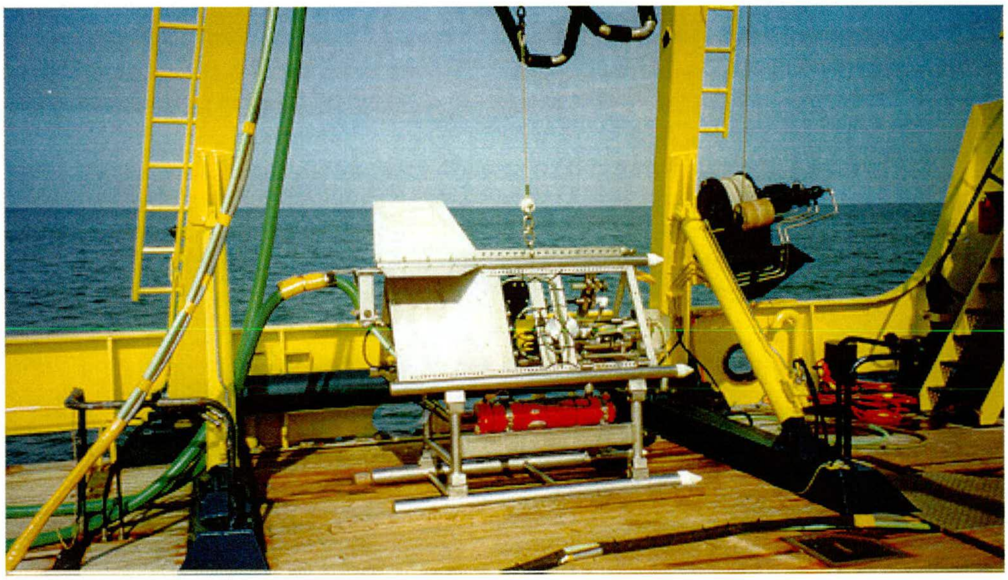
3.2. Shipmounted measurements

Four types of shipmounted measurements were carried out (**see Table 2.1.B**). Each type of measurement is further explained.

3.2.1. Shipmounted velocity measurements

General description
Shipmounted velocity measurements took place twice, the first series on the 22nd and 23rd of November 1999, the second series on the 20th of March 2000. Both measurement periods are selected to coincide with spring tide conditions. Around spring tide, the most pronounced differences of water movement are expected between the area outside and inside of the LDP.

The measurements itself are performed with an ADCP, mounted within a frame, a so called "measuring fish" on board of the vessel "MITRA" (**see Figure 3.10**). The steel fish, which contains additional measuring instruments, is not fixed to the ship. It is kept next to the ship, just beneath the water surface with the help of steel cables and outriggers. In this way the fish remains aligned with the ship, although (small) differences in heading of the fish with respect to the heading of the ship, as well as roll of the fish is possible.



Figures 3.10. The "measuring fish" with ADCP on deck at the 22nd of November 1999, ready for measuring.

With the downward looking ADCP, a vertical velocity profile - at a depth interval of 0,5 m - is measured every 10 seconds. For a distance of roughly 2 m near the bottom and the surface, the data is not reliable and will therefore be disregarded in the data-analysis. By moving along four predefined tracks (**see Figure 2.1 b**), the tidal flux along and perpendicular to the tracks can be determined. In this way, differences between the tidal flux outside and inside the LDP can be established. The four tracks are sailed, once during maximum flood and once during maximum eb. The tidal flow is the most constant around high and low tide and the vertical velocity profile is fully developed.

During the first measuring period (22nd and 23rd of November 1999) the ADCP contained a magnetic flux-compass. The values of this compass are not reliable due to the disturbing influence of the presence of the steel ship, resulting in unreliable data with respect to the direction of the flow. During the second measuring period, a gyro-compass was hired and coupled to the ADCP, which resulted in reliable values of the direction of the flow.

Preliminary results

Results of the ship-mounted ADCP-measurements are comparable with those of the fixed locations. In the shipmounted case, velocities are larger due to the movement of the ship (only against or perpendicular to the tidal flow). The velocities must be corrected for this movement. Navigational information of the ship is produced in seperate data files. An example of a corrected velocity profile is given in **Figure 3.11**.

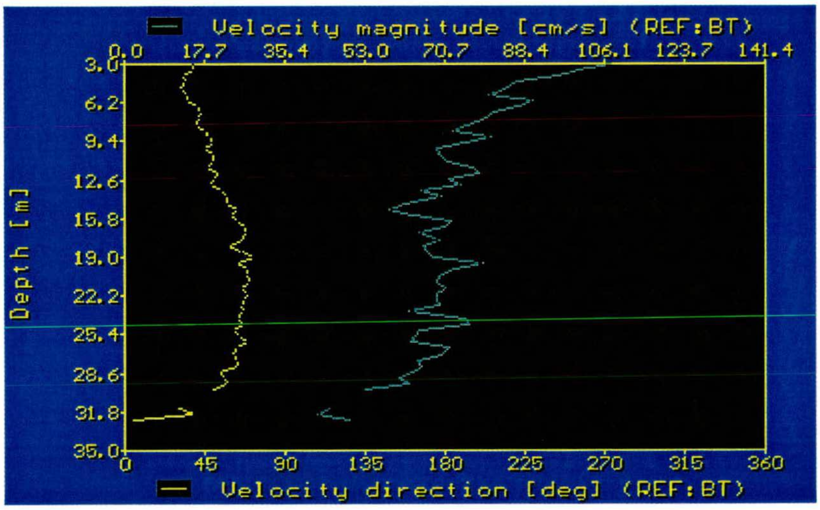


Figure 3.11. A momentarily measured vertical velocity profile during maximum flood - corrected for the movement of the ship - as measured at the 20th of march 2000. The profile is situated along track 1, above the LDP, as can be seen from the maximum waterdepth. The blue line gives the velocity in centimeters a second, as indicated on the upper horizontal scale, while the yellow line represents the direction of the flow in degrees with respect to the north, as indicated on the lower horizontal scale.

Especially in case of strong perpendicular currents it is difficult to exactly follow the shiptrack. This can be seen in **Figure 3.12**, which shows the shiptrack and the measured velocity-vectors at 15 m below the water level.

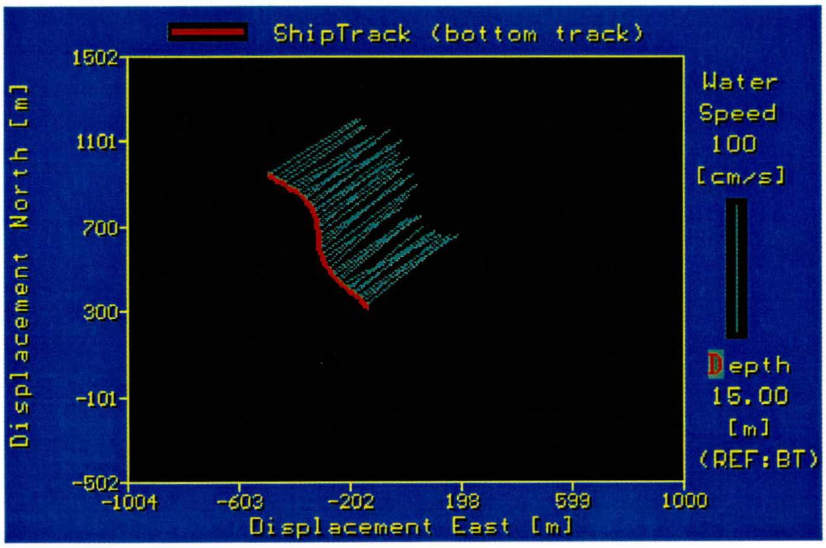


Fig 3.12. Visualization of the shiptrack and velocity vectors measured at 15 m below the water level.

3.2.2 Shipmouted measurements of temperature, conductivity, turbidity and oxygen

General description
From the vessel "MITRA", at most twice a week vertical profiles of temperature, conductivity, turbidity and oxygen were measured at locations A and M. For this use was made of a Seabird CTD. The frequency of measurements depended on the weather conditions and the planned activities for the MITRA. For the same reason measurements could not always be carried out at the same tidal phase.

During 15 of the in total 26 available weeks, measurements took place. During 9 weeks, the vertical profiles are measured once. In the other 6 weeks the vertical profiles were measured twice. The result is a collection of 20 vertical profiles at both location A and M and one vertical profile at location M only, all measured under different tidal, meteorological and river flow conditions.

Preliminary results
An example of the momentarily measured vertical profiles of oxygen (absolute and relative values), temperature and salinity is shown in **Figure 3.13**.

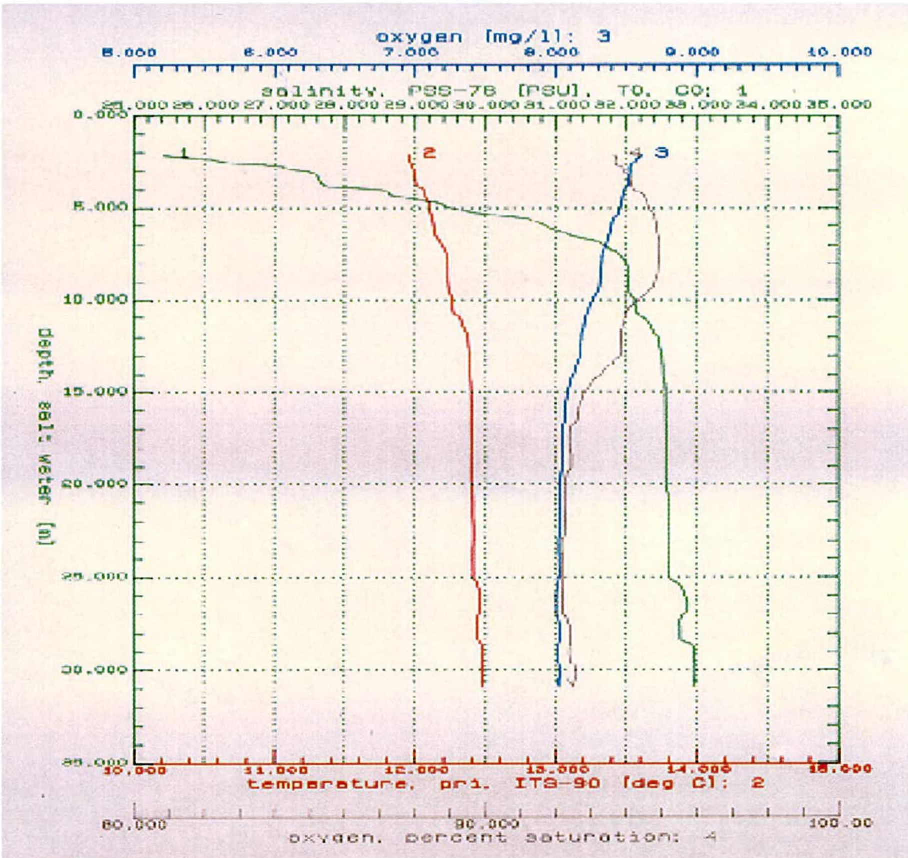


Figure 3.13. Vertical profiles of oxygen (absolute and relative values) in mg/l, temperature in degrees Celsius and salinity in PSU, measured at location M on the 3rd of November 1999, with Seabird CTD equipment.

3.2.3. Bathymetric surveys

General description

Due to bad weather conditions, the number of bathymetric surveys is limited. Monthly sureveys were scheduled. However, in the 6-month period from October 1999 until April 2000, just 3 bathymetric surveys were carried out. The first in October 1999, which can be considered as T_0, a second one at the beginning of January 2000 and the third one at the end of Februari till the middle of March. In April a fourth survey took place, which can be considered as the T_{end}. The surveys are performed with multibeam equipment, which provides a high density of depth data. With the use of locally placed pressure sensors at the bottom of the LDA, correction for tidal waterlevel variation has been performed. The resulting bathymetry-data are presented with respect to Mean Sealevel (MSL) and will be interpolated to a rectilinear grid of 5 x 5 m.

Dumping of dredged sediment at the LDP didn't start before half of August 2000. This means that the bathymetric surveys untill July 2000 can be used as additional information for the analysis of the morphological developement of the LDP. From then on, the monthly bathymetric surveying activities continue within the framework of the MAL-projekt concerning "the monitoring of the alternative dumping areas". The MAL-projekt will need the bathymetry-values to evaluate the spreading of sediment that is dumped at the LDA.

<u>Preliminary results</u>
An example of the bathymetry of the LDA is given in figure 3.14 at the next page. The bathymetry is based on the surveys on the 1st and 2nd of July 1999, two months before the start of the measuring campaign.

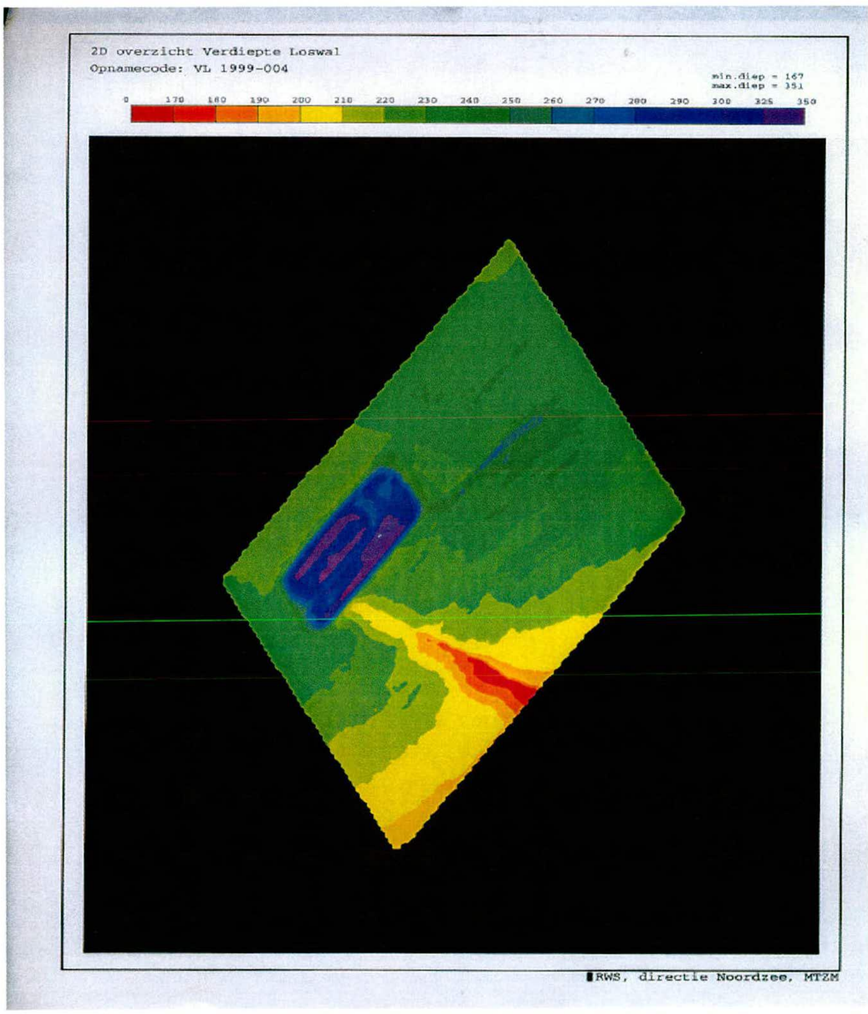


Figure 3.14. Bathymetry of the lowered dumping area (LDA), measured with the multibeam-equipment from the vessel "Octans" at the 1st and 2nd of July 1999. The LDP is visible as the blue rectangle in the soutwest corner.

3.2.4. *Sediment sampling*

General description
Information about the sediment size distribution (important for future modeling activities) is obtained by means of sediment sampling. First sampling took place at the beginning of January 2000, second sampling took place at the end of March 2000. In both cases at nine locations samples where taken of the uppermost layer of around 25 cm. Four of those locations were in undisturbed area outside the LDP, while five locations were inside the LPD (**see Figure 3.15**). Furthermore, at the same 9 location, cores have been taken. Analysis of the cores gives an impression of the vertical structure of the upper 0.5 m of the bottom in- and outside the LDP.

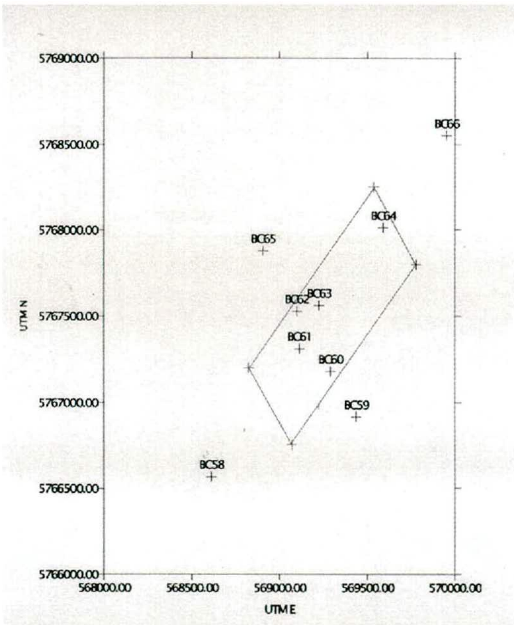


Fig 3.15. Locations of sediment sampling, in- and outside the LDP.

The sediment size distribution of both sampling series was determined by the Lab of RIKZ at Middelburg. Information about the sediment size distribution will be used to detect differences in the sediment between the area inside and outside the LDP. A coarsening or refinement of the distribution in time might be related to erosional or accretional processes. Interpretation of the results should be taken with care, because differences can also be due to very local erosional or accretional events or might be due to differences in sampling location.

4. Processing and analysis of the field data

4.1. General description

The next step involves the processing and analysis of the data. This will be done by third parties under contract with RIKZ. As part of the processing, raw data will be validated and corrected if necessary. The analysis will provide answers to the predefined research-questions, which formed the basis for the field measurements. Finally, the five hypotheses will be tested. The work will start in October 2000 and will probably be finished by September 2001.

The validated field data will be stored at the DONAR database of Rijkswaterstaat. In this way data will be available for other interested parties (with permisson by).

4.2. Processing of the data

Processing of the field data includes:
- removal of spikes,
- restoring small data gaps
- correction of changes in calibration values
- check of physical consistency

Also some additonal information, like time series of wave height and wind speed from existing measuring stations, in the vicinity of the LDP will be processed.

The processing of the raw field (and additional) data will be presented in a "data-report". The validated and corrected data will be produced in a data format, suitable for storage at the DONAR data base.

4.3. Analysis of the data

Analysis of the field data includes:
- deduction of physical relevant parameters (salinity and density)
- harmonical analysis of watermovement (water level, water velocity)
- determination of dominant energy in environmental parameters (temperature, salinity etc.)
- correlation between the driving forces and the repsonse
- determination of morphological changes (volume, slope, centre of mass etc.) of the LDP from the bathymetric measurements

Results of the analysis will be presented in an "analysis report".

Analysis of the data will lead to answers at the predefined research-questions. Together with process-knowlegde and knowlegde of the local system, the hypotheses will be tested.

A final report will be produced, which summarizes the data processing and analysis and describes the answers to the research-questions as well as the testing of the hypotheses.

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Appendix I.

Chronological overview of the measuring campaign

Formal start of the measuring campaign: 1st of october 1999

- 12 and 13 of October 1999: bathymetric measurements of the LDA with the vessel "OCTANS"
- 14 October 1999: the measuring equipment is placed at the fixed measuring locations A, M and B with the vessel "ZIRFAEA". Furthermore, a redefinition of location M took place.
- a week later, buoys are placed at 100 m to the east and the west of the fixed measuring locations A, M and B. These buoys should protekt the instruments against fishing boats and other vessels travelling through the area.
- 3 November 1999: the first verticale profile measurements with the vessel "MITRA" takes place at locations A and M
- 4 November 1999, the proposal for field measurements is made definite
- 22 and 23 of November 1999: tests with the ADCP mounted in the "measuring fish"are performed at the 22nd of November 1999. At th 23rd of November 1999 ADCP-measurements takes place during one tidal cycle (around spring tide). The flux-compass of the ADCP produced wrong directional information. Coupling to the compass of the ship is not possible, since the "measuring fish" is not attached to the ship.
- 24 November 1999: the instruments are removed from the fixed measuring locations. The instruments are taken to Scheveningen Harbour, where servicing and data collection takes place. All instruments have functioned well, but the ADCP at position A didn't collect any data.The total length of measuring period of the hydrolabs (at position A and M) is maximum 29 days, while the Aandera-string measures maximum 37 days. Both are related to the available battery capacity.
- 14 December 1999: the instruments are replaced at their fixed measuring locations. Due to bad weather conditions the instruments could not be replaced earlier.
- 3, 4 and 5 Januari 2000: bathymetric measurements of the LDA are carried out with the vessel "ZIRFAEA". There are doubts about the reliability of the measurements because the results differ too much from the foregoing measurements with the vessel "OCTANS"
- 7 Januari 2000: sediment sampling takes place. The samples will be analysed for sediment size by the lab of RIKZ at Middelburg.
- 14 Januari 2000: the instruments from the fixed measuring locations are retrieved. Data is collected, instruments are serviced. All instruments have functioned well. The instruments were not recalibrated before start of the third period.
- 20 Januari 2000: the instruments are replaced at their fixed measuring locations. The Aandera-string is fixed with an anchor-chain instead of a stone. The anchor-chain is easier to lift from the bottom.
- 15 Februari 2000: a quick scan is made of the results of the first two measuring periodes. This revealed differences in the way the conductivity is measured. A clear distinction has to be made between measurement of conductivity and specific conductivity.
- 21 and 22 February 2000: the instruments at the fixed measuring locations have been picked up on the 21st of February and are replaced again for the last measuring period (number four) on the 22nd of February. The conductivity setting of both

hydrolabs are changed a little. During the last period conductivity is measured (no compensation for temperature) instead of specific conductivity

- 22 and 23 February, 10, 16 and 17 March bathymetric measurements of the LDA takes place with the vessel "Octans".
- 20 March 2000: The second series of ship-mounted ADCP measurements takes place. This time a gyro-compass is installed (especially hired for this purpose) on the ADCP. This time there is confidence about the directional information from the ADCP. The condition are ideal: hardly any wind, small waves, spring-tide. In this seried the vessel will keep a constant speed along track 1 (no smaller speed along the parts C-D and E-F).
- 24, 29 and 30 March 2000: the second series of sediment sampling takes place. Again, the samples are analysed for sediment size by the lab of RIKZ at Middelburg
- 27 March 2000: the instruments are retrieved from the fixed measuring locations. The last ship-mounted vertical profile measurements at locations A and M take place. The Aandera-string is found to be displaced 150 m to the north of its fixed measuring location near M.
- 29 March 2000: the hydrolabs and Aandera-string are brought to the LIB lab of RIKZ for calibration of the instruments. This was performed at the 6th of April 2000.

Formal end of the measuring campaign 1st of April 2000.

Until July 2000 the following bathymetric surveys were taken:

- 6, 10, 11, 12, 13 April 2000, vessel Octans
- 16, 22,23 and 25 May 2000, vessel Octans
- 20,21,27,28 June 2000, vessel Octans
- 31 July, 1,2 and 4 August, vessel Octans

From then on bathymetric surveying activities and sediment sampling continue within the framework of the MAL-projekt concerning "the monitoring of the alternative dumping areas".

Appendix II.

Specifics of the measurements at fixed locations

Tables with specifics of each of the four measuring periods concerning the fixed measuring locations A, M and B are given below.

Data collection

Tabel II.A. Measuring period 1: 14 oktober 1999 - 24 november 1999

Instrument type	*Location*	*Measured parameters*	*Data collection*	*Perc.*	*Remarks*
ADCP	A	V	no data	0	
ADCP	M	V	whole period	100	period to be checked
Hydrolab	A	T, C, D, Tu	untill 13/11/99	100	C =conductivity uncompensated?!
Hydrolab	M	T, C, D, Tu	untill 13/11/99	100	C = conductivity uncompensated
Aandera-string	near M	T, C	untill 21/11/99	100	
MORS	B	T, P	whole period	100	

Table II.B. Measuring period 2: 14 december 1999 - 14 januari 2000

Instrument type	*Location*	*Measured parameters*	*Data collection*	*Perc.*	*Remarks*
ADCP	A	V	whole period	100	period to be checked
ADCP	M	V	whole period	100	period to be checked
Hydrolab	A	T, C, D, Tu	untill 13/01/00	100	C = specific conductivity; Turbidity sensor shows signs of algae
Hydrolab	M	T, C, D, Tu	untill 13/01/00	100	C = specific conductivity; Turbidity sensor shows signs of algae
Aandera-string	near M	T, C	whole period	100	placing a little different from period 1?
MORS	B	T, P	whole period	100	collision with MORS at 17 december 1999?

Table II.C. Measuring period 3: 20 january 2000 - 21 february 2000					
Instrument type	*Location*	*Measured parameters*	*Data collection*	*Perc.*	*Remarks*
ADCP	A	V	whole period	100	period to be checked
ADCP	M	V	whole period	100	period to be checked
Hydrolab	A	T, C, D, Tu	untill 18/02/00	100	C = specific conductivity;
Hydrolab	M	T, C, D, Tu	untill 18/02/00	100	C = specific conductivity
Aandera-string	near M	T, C	whole period	100	
MORS	B	T, P	whole period	100	

Table II.D. Measuring period 4: 22 february 2000 - 27 march 2000					
Instrument type	*Location*	*Measured parameters*	*Data collection*	*Perc.*	*Remarks*
ADCP	A	V	whole period	100	period to be checked
ADCP	M	V	whole period	100	period to be checked
Hydrolab	A	T, C, D, Tu	untill 23/03/00	100	C = conductivity uncompensated
Hydrolab	M	T, C, D, Tu	untill 23/03/00	100	C = conductivity uncompensated
Aandera-string	near M	T, C	whole period	100	The string is picked up at around 150 m to the north of its original placing position
MORS	B	T, P	whole period	100	