European SANDPIT Project
Sand Mining Experiments

SANDPIT Field deployments of ADCP
Spring and Autumn 2003

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Summary

SANDPIT Field Deployments of ADCP - Spring and Autumn 2003

Report TR 140
April 2004

Current speed and direction measurements were made in the Spring and Autumn 2003 at a distance of 2km off the North Sea coastal town of Noordwijk in the Netherlands. They were carried out as part of the SANDPIT project funded partly by the European Commission's research programme (Contract No. EVK3-2001-00056), and partly through national funding from the UK Department for Environment, Food and Rural Affairs (CSA5995, FD1912).

Multiple seabed instrumentation deployments were simultaneously undertaken at four seabed locations at the site within a co-operative deployment exercise between the data collection partners HR Wallingford (HRW, UK), University of Utrecht (UU, Netherlands), University of Caen (UCa, France), and the University of East Anglia (UEA, UK). The well-equipped and efficient facility at the Rijkswaterstaat (RWS) depot at Scheveningen harbour supplied all other on-site local logistical resources for the storage, preparation, deployment and servicing of the various complex seabed instrumentation systems.

The results of the partners measurements are contained in full within the Work Package 3 section of EC Project No.EVK3-2001-00056, which is being produced by UU.

The HRW job number for this work was CBS0312/03. This report was written, and the field measurements undertaken, by Mr S J Hearn the Principal Surveyor in the Environmental Measurements and Assessments Group.

All time given in this report are to UTC, but it should be noted that Middle European Time (MET) may be used in the full EC report. The full data-set is given on the CD-ROM included with this report.

Contents

1. Field campaigns

During the Spring and Autumn of 2003 two deployments of an HRW seabed-mounted upward looking Nortek 1.5mHz NDP acoustic doppler current profiler (ADCP) were made on the 10m contour 2km off of the town of Noordwijk in the Netherlands, at positions 596043E, 5791189N (Spring) and 596069E, 5791157N (Autumn).

This was one of four seabed instrument packages, of varying complexity, deployed at and near the same location as part of the EC funded sand-mining SANDPIT data collection and numerical modelling study.

All deployments and recoveries of the project seabed instrumentation were undertaken from the 56m LOA RWS vessel "Mitra" under the supervision RWS surveyors and crew, with the assistance of UU personnel.

The ADCP recorded current speed and direction every 10-minutes at 0.5m intervals throughout the water column, with the centre of the measurement cells starting at 2.1m above the seabed, and finishing near the sea surface. A diagram of the measurement positions throughout the depth profile is given in Figure 1.

Examples of velocity profiles throughout a tidal cycle are given in Figures 2 and 3, and an inter-comparison with UCa data is given in Figure 4.

The ADCP was mounted in a 3m-diameter tubular stainless steel frame (Plate 1) provided by RWS at Scheveningen, which is the base for the "Mitra". This large frame was required, as the "Mitra" could not handle the much smaller frame that was usually used to mount the ADCP. Due to the large size of the seabed frame the transducer face of the ADCP was 1.22m above the seabed.

The Spring deployment provided a full data set, but the Autumn deployment had a reduced data return due to a faulty fuse connector within the battery canister for the ADCP.

The speed and direction data recovered were:

- Spring 2003 – 3/03/03 17:50 to 7/04/03 14:30 - 100% data return – 5019 velocity profiles
- Autumn 2003 – 16/10/03 08:20 to 7/11/03 11:40 - 43% data return – 3189 velocity profiles

2. Data quality

Velocity profiles in depth cells (bins) at 0.5m intervals were collected starting at 2.12m above the seabed. The Nortek 1.5MHz NDP transducer face being at 1.22m above the seabed.

The data collection consisted of the average of a 60-second sample, with water temperature also measured and water salinity assumed to be 34psu.

The instrument sampled the following parameters every 10-minutes:

- Current speed
- Current direction
- Water depth over sensor head
- Temperature
- Signal to Noise (SNR) for beams 1, 2 and 3
- Platform heading, pitch and roll
- Battery voltage.

The ADCP data is read into and Excel spreadsheet, and filtered for total water depth over the ADCP transducer face to remove any incomplete 0.5m depth cells. However, the top 10 to 20% of any ADCP data series should be considered an area of lesser reliability due to the effects of wave action.

The active spreadsheets for both Dep1 and Dep2 can produce time series plots, frequency bar charts, and tidal ellipses of speed and direction for any selected depth cell. It also computes the "depth averages" using the method detailed in the SANDPIT Database Conventions Ver.4 (Appendix 1). Spreadsheet data tabs marked "v" and "u" are Database Conventions for "long-shore" and cross-shore" currents respectively.

The data CD provides Excel sample graphical plots for depth cell at 3.12m above the seabed only, but lists all depth cell data for all heights in an Excel tabular format.

A summary of the all ADCP platform parameters are given in Appendix 2.

3. *Data comparisons*

Due to the differing seabed frame sizes the heights of the ADCP transducer faces in each of the partners seabed frames also differed slightly, hence it was not possible to directly compare identical profile levels sampled. The relationship between "burst" numbering, a UU convention at the projects start, and UTC is identified on the data CD in file "Burst IDs.xls".

Sampling regimes were hourly (UCa) centred on "hour +10 minutes", and every 10 minutes (HRW) centred on hour +10, +20, +30 minutes etc. All current directions use the convention "flowing towards".

3.1 HORIZONTAL TIME SERIES

Data inter-comparison between the HRW 1.5MHz Nortek NDP and the UCa 1.0MHz Nortek Aquadopp profiler at the 3.12 and the 3.25m depth cells respectively provides, in periods of both calm and stormy weather, the following typical differences:

Burst No.	Date & UTC	U Caen speed m/s	HRW speed m/s	Difference m/s
1510.167	4/3/03 20:10	0.40	0.36	0.04
1705.167	12/3/03 23:10	0.08	0.11	0.03
2201.167	2/4/03 15:10	0.69	0.59	0.10

Burst No.	Date & UTC	U Caen direction True North	HRW direction True North	Difference Degrees
1510.167	4/3/03 20:10	202	198	004
1705.167	12/3/03 23:10	030	077	047
2201.167	2/4/03 15:10	028	020	008

It should be noted that the above tables only represent "snapshots" of the data comparison, and that burst 1705 occurs during a "storm" neap tide event, while bursts 1510 and 2201 occur on spring tides in much calmer conditions. For a more detailed comparison refer to the 6 Excel plots in files "Burst 1484to3195_near3m.xls" on the data CD.

3.2 VERTICAL PROFILES

The vertical profiles of speed and direction, between 2.1 and 12.1m above the seabed, appear similar at burst 1510. Speeds agree to within 0.05 or 0.10m/sec, and directions to between 0° and 20°.

However, for burst 1705 the speeds and directions agree within 0.01 to 0.09m/s, and 10° to 40° respectively. These larger differences are considered to be due to the turbulence during burst 1705, and spatial separation of the two sensors, which is estimated to be 75m in an east to west direction.

For a more detailed comparison refer to the 2 plots in "Bursts_1510_1705_verticals.xls".

4. *Data accuracy*

For the measured standard deviations of each 60-second average, collected by the Nortek 1.5MHz NDP identified in this report, refer to the tabs "SD1, SD2, SD3" in the files Sand1001_v4b.xls and Sand2006_v2c.xls. These respectively refer to the velocity "East", "North" and "Up" components.

4.1 VELOCITY RESOLUTION AND ACCURACY

Velocity resolution	0.1cm/sec
Velocity accuracy	+/- 1% of measured velocity, +/-0.5cm.sec

4.2 VELOCITY PRECISION

Velocity precision for 60 second sample 1.56cm/sec

4.3 STANDARD DEVIATION

Standard deviation of velocity is provided in the raw ADP data files, and is another indicator of instrument performance and profiling range.

Each velocity profile recorded by the ADCP is the average of a number of pings, each of which provides an estimate of the velocity profile. Standard deviation as recorded by the ADCP, shows the precision of the mean velocity estimates for each depth cell. This precision represents both instrument-generated noise, and the real variation of the velocity profile with time.

For a Nortek 1.5MHz NDP measuring 0.50m depth cells, and the theoretical estimate of Doppler noise, the standard deviations are as follows:

Single ping SD	Averaging interval For 5cm/s sV (# of samples)	Averaging Interval for 2cm/s sV (# of samples)	Averaging Interval for 1.56cm/s sV (# of samples)	Averaging Interval for 1cm/s sV (# of samples)
28cm/s	4 s (35 samples)	20 s (200 samples)	60 s (525 samples)	80 s (800 samples)

5. Conclusion

Two periods of current speed and direction were recorded during the Spring and Autumn of 2003 at a near shore location off of the Netherlands coast. This was one element of a multi-system data collection exercise undertaken by field data gathering partners comprising HR Wallingford, University of Utrecht, University of Caen, and the University of East Anglia.

Figures

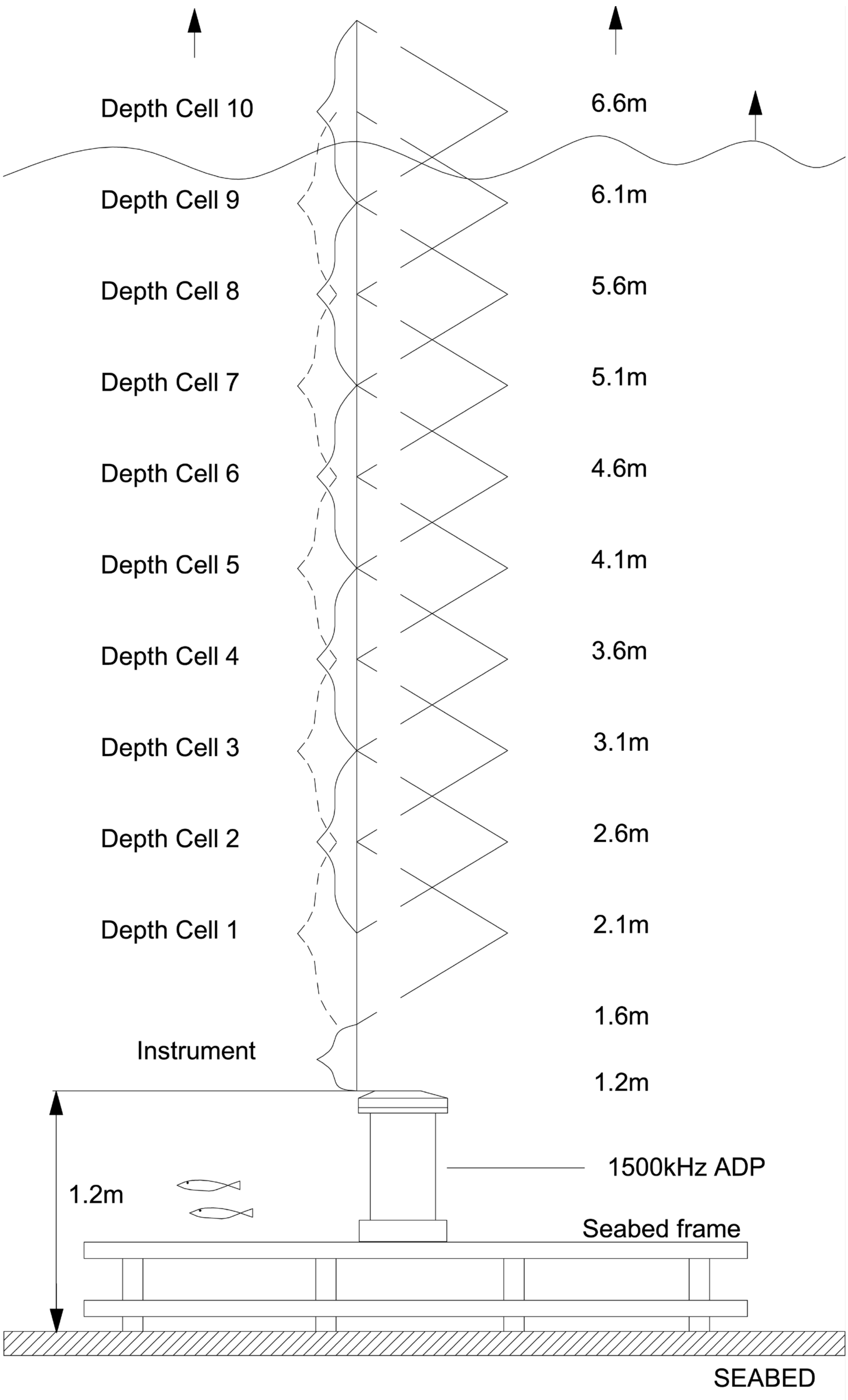


Figure 1 ADCP depth cells (bins) showing mid-point and triangular weighting around the mid-point

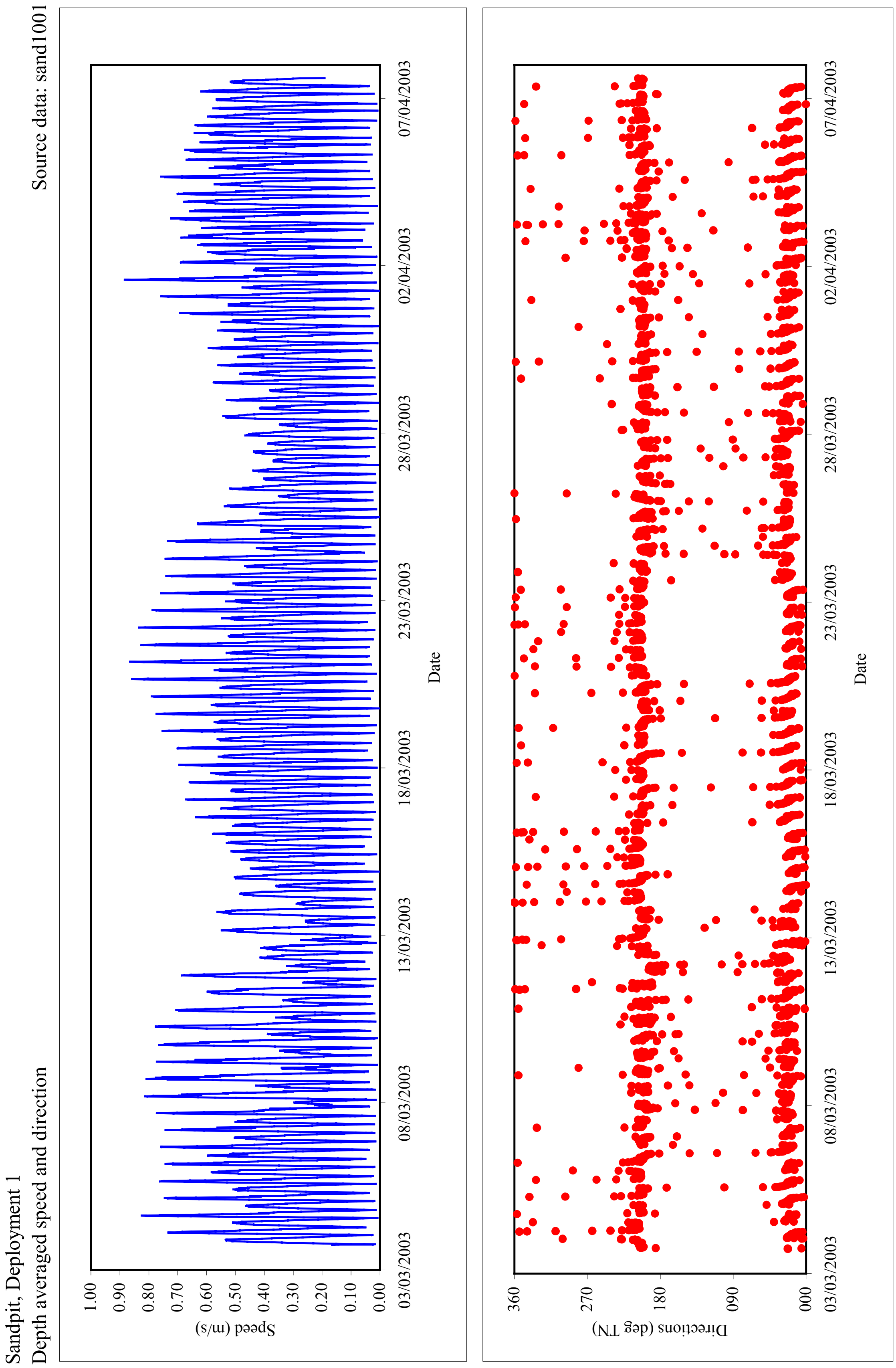


Figure 2 Depth averages for the 3.12m depth cell - Spring campaign

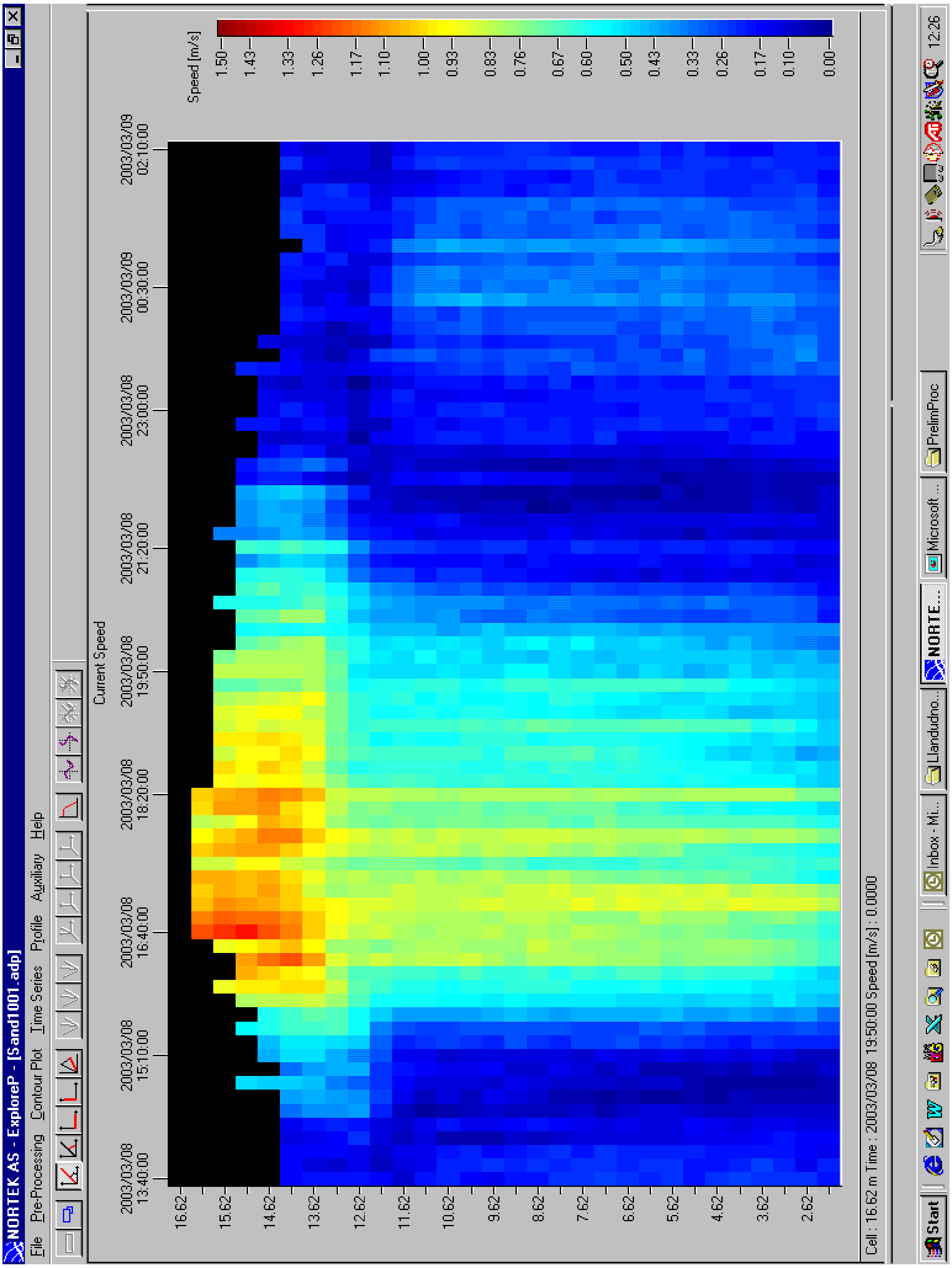
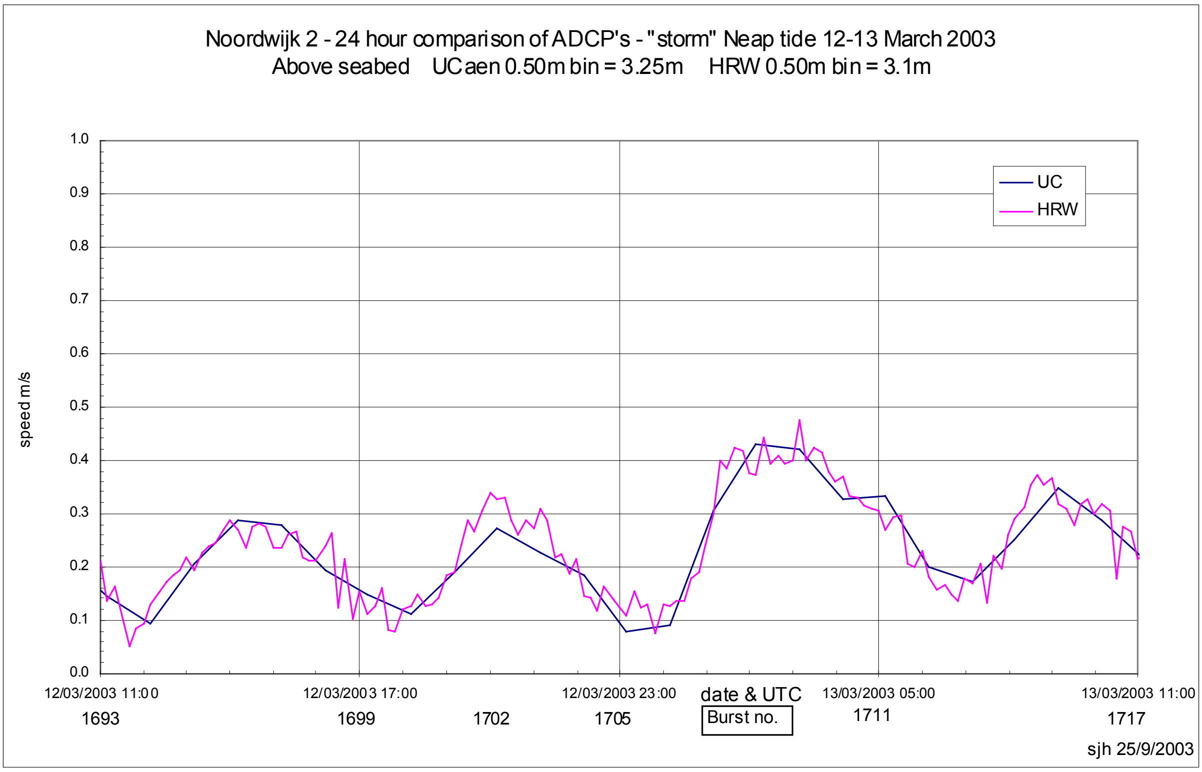


Figure 3 Raw current speeds 8-9th March 2003 - depth filter not applied



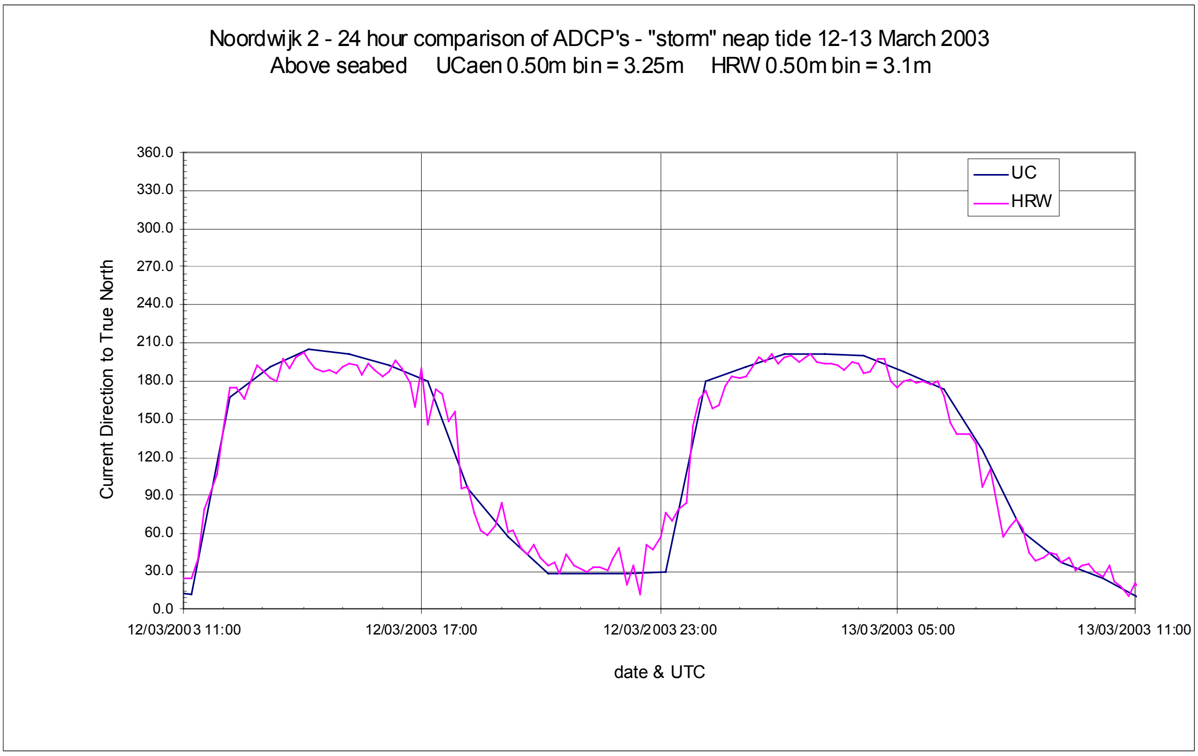
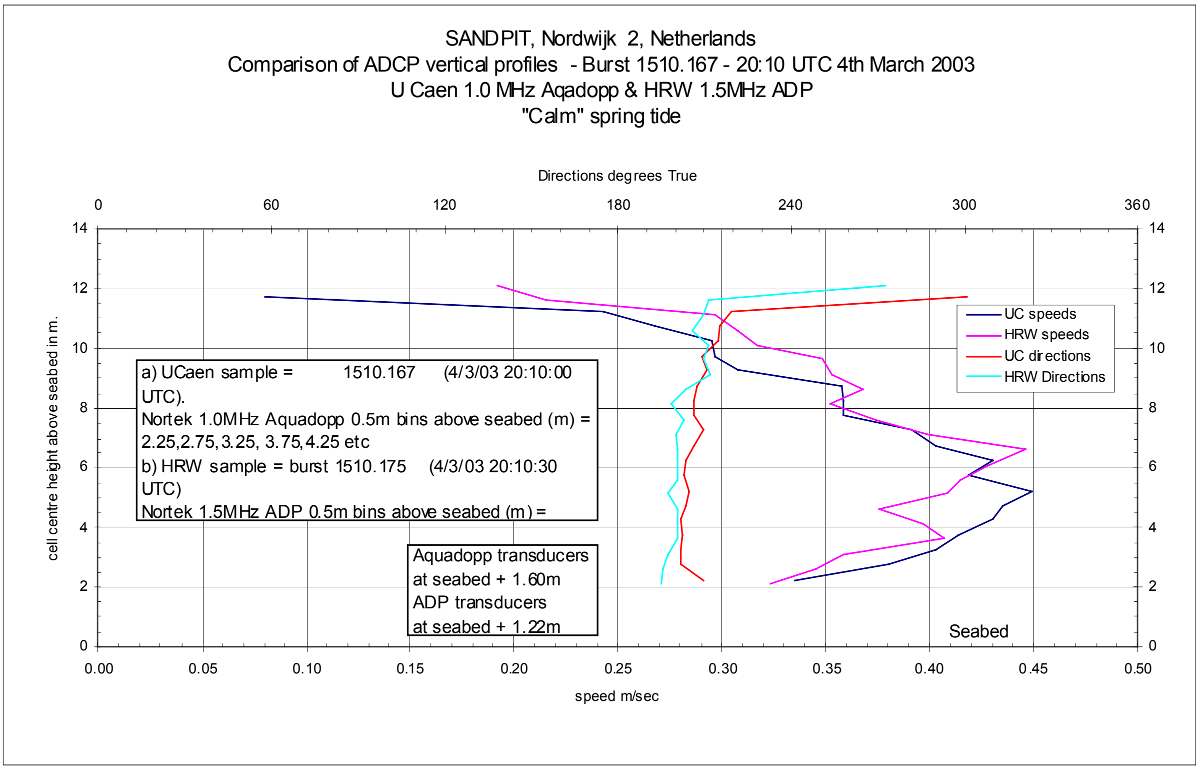


Figure 4 Near 3m depth cell 12th–13th March 2003 - inter-comparison between HR Wallingford and University of Caen ADCP's



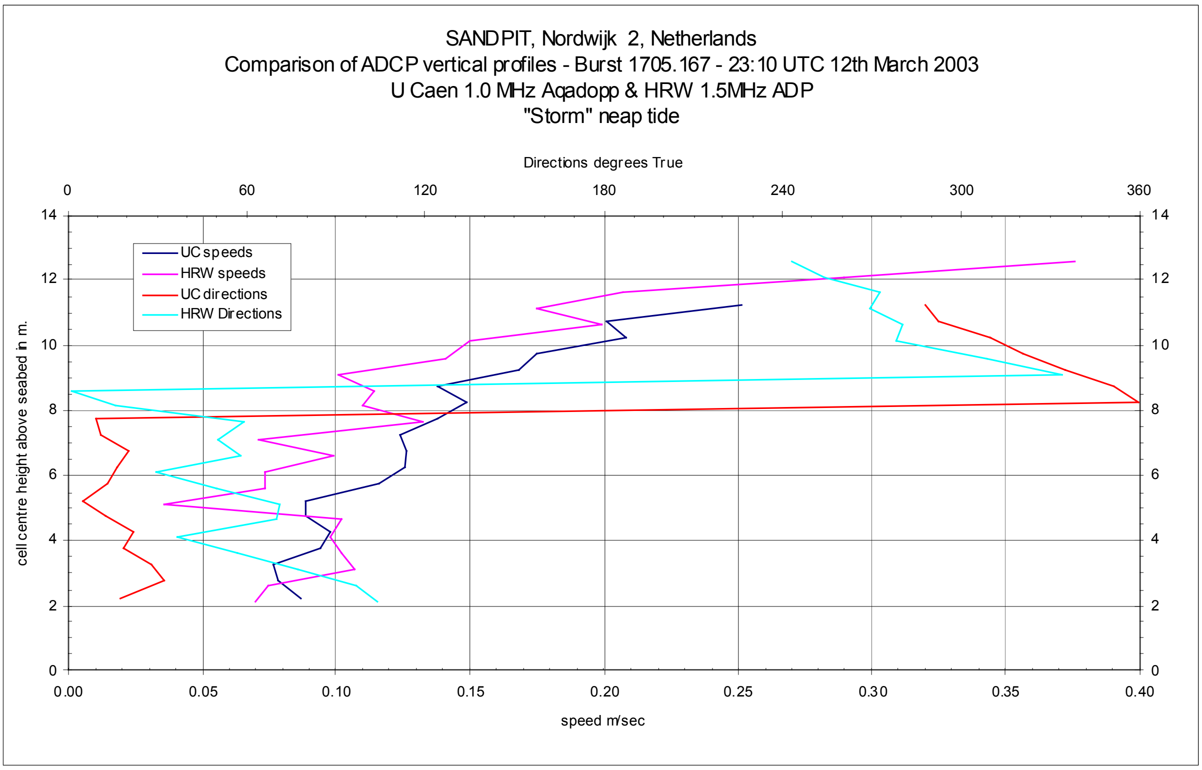


Figure 5 **Vertical profile 12th March 2003 - inter-comparison between HR Wallingford and University of Caen ADCP's**

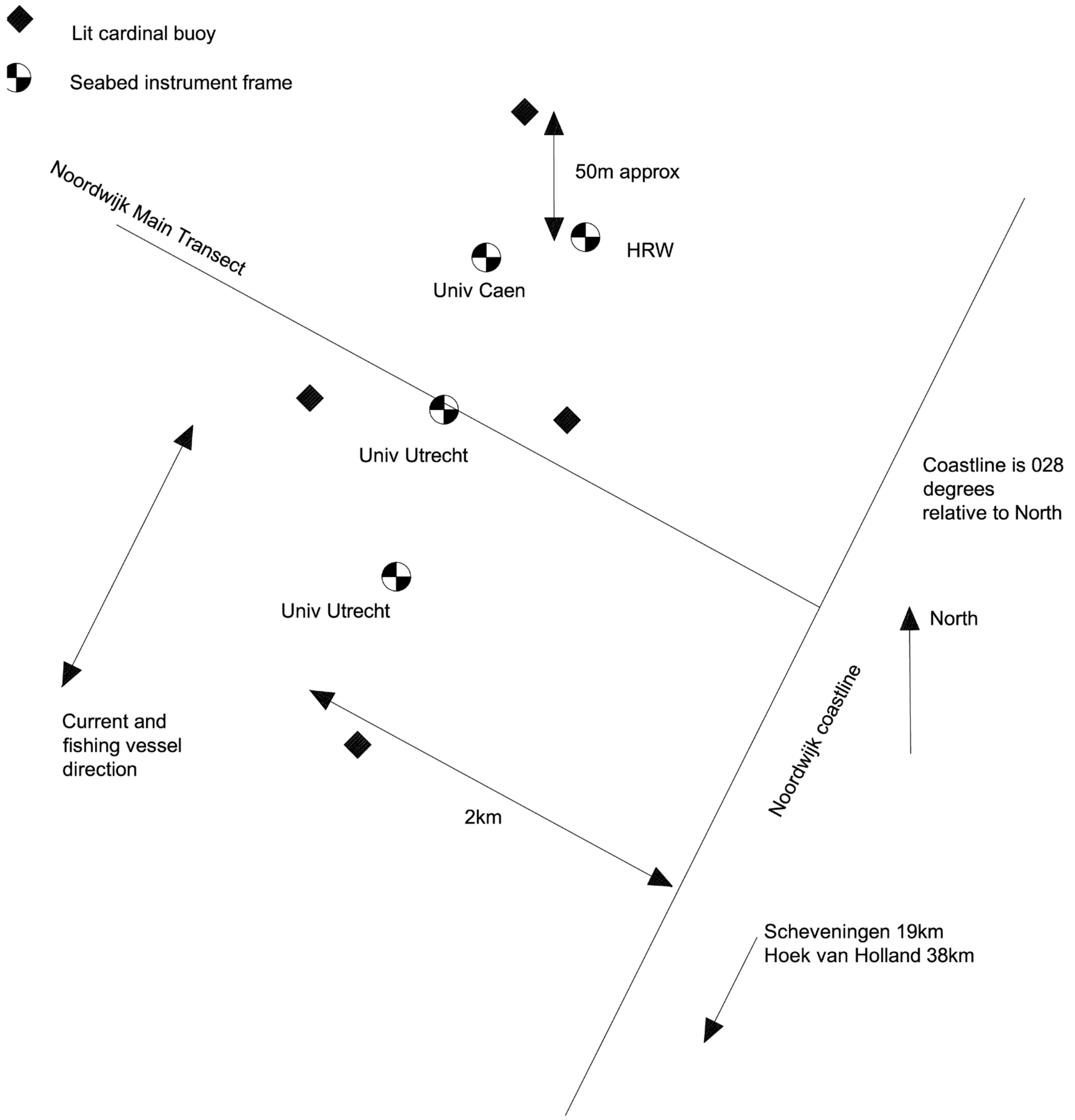


Figure 6 Project partners seabed instrumentation locations (Noordwijk) schematic

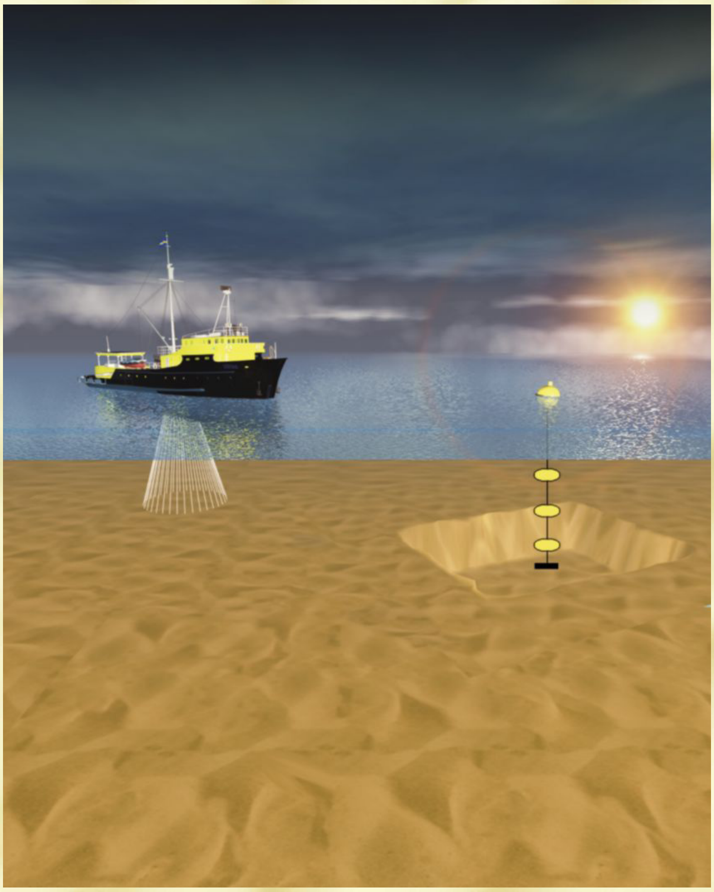
Plate

Plate 1 ADCP in seabed frame 7th November 2003 – end of Deployment 2

Appendices

Appendix 1 SANDPIT Database Conventions Ver.4

Database Conventions
Version 4



BART GRASMEIJER

UNIVERSITY OF UTRECHT

APRIL 2002

1. INTRODUCTION

This document describes the database conventions as suggested for the European Sandpit project.

2. SANDPIT DATABASES (BED AND SED)

The Sandpit database consists of two databases:

1. Basic Experimental Data (BED), contains basic parameters and time series of all tests.
2. SEdiment transport Data (SED), contains detailed parameters and transport rates of clustered tests.

2.1. BASIC EXPERIMENTAL DATA (BED)

The BED database contains basic information on all measured time series. It consists of four sub-modules, i.e.

- Background database (B-module)
- Time-series database (T-module)
- Parameter database (P-module)

The sub-modules are described below.

2.1.1. BACKGROUND DATA (B-MODULE)

The B-module contains important background information and tools to facilitate handling of the data available in Sandpit database.

- Offshore wind, wave and current conditions
- Name (unique identification) and description of instruments
- Locations of data collection
- Conventions and definitions
- Bed material data, bed profile data, etc
- Bed level soundings (profiles normal to coast)
- Time-series analyses tools (software or matlab routines)

2.1.2. TIME-SERIES (T-MODULE)

The T-module contains the basic validated data such as time series of

- Water surface elevation (in meters to MSL)
- Water pressure near bed (in N/m^2)
- Fluid velocity (m/s) and sand concentration (kg/m^3) at various elevations above bed

But also

- Bed form dimensions (in m) and bed level (in meters to MSL)
- Bed material and suspended material composition (sieve curve results)

The data are stored as compressed ASCII files (software for unpacking available in the Background database).

2.1.3. PARAMETERS (P-MODULE)

Experimenters will provide the parameters from their validated time series. Procedures for computation of these parameters are given in this document. All experimenters will make software to compute the selected parameters. Software will also be available for download on the Sandpit website. A test file is available for download on the Sandpit website.

List of basic parameters

The standard parameters that will be included in the P-module are described here. More detailed parameters can be derived from the available time series (T-module) or are available in the SED database. Parameters derived from measured time series are based on the entire burst length of the time series. All parameters should be available as ASCII files no later than 6 months after the end of each experiment.

It is suggested to decompose the surface elevation, velocity and concentration time series into time-averaged, and high- and low-frequency oscillatory components. To discriminate between high- and low-frequency, a split frequency f_{split} = 0.05 Hz (T_{split} = 20 s) is suggested for the field measurements and $f_{split} = 0.5f_p$ ($T_{split} = 2T_p$) for the laboratory measurements.

- Location of data (x,y,z) and burst number (time)
- Water level (tide + wave set-up + wind set-up, in meters to MSL)
- Water depth (bed to surface, in m.)
- Wave heights and periods (high-frequency and low-frequency)
  - Time domain: H_{rms}, $H_{1/3}$, $T_{1/3}$, T_m and T_z
  - Spectral domain: H_{m0} and T_p
- Mean wave direction (and standard deviation for directional instruments) with respect to topographic north and local coastline (pos angle of 40 degrees to north)
- Velocities (m/s)
  - Time-averaged velocity (cross-shore $\bar{u}$ and longshore components $\bar{v}$; northerly and easterly components); for profiling instruments every 0.1 m in vertical direction over lowest 1 meter and every 0.5 m between 1 meter and water surface
  - Peak orbital velocities $u_{1/3,on}$ and $u_{1/3,off}$ of cross-shore near-bed velocity component; 1 value per hour over available burst length (high-frequency and low-frequency)
  - Root mean square velocity u_{rms} of cross-shore near-bed velocity component; 1 value per hour over available burst length (high-frequency and low-frequency)

- Bathymetry
  - Profiles 100 m apart along main pit axis (bed level in m to MSL); 2x per year
  - Profiles 100 m apart perpendicular to main pit axis (bed level in m to MSL); 2x per year
- Offshore boundary conditions
  - Water level (to MSL); 10 min average values at stations Hoek van Holland and Scheveningen;
  - Offshore wave height, period and direction (time domain and frequency domain parameters); 60 min. average values at Euro-Maas platform and Noordwijk platform

- Wind velocity and direction; 10 min. average values at station Euro Maas
- Water temperature and salinity
- Bed material composition outside and inside pit
- Bed form type and dimensions (height and length) outside and inside pit at all locations;

Procedures to determine parameters

The procedures to determine the basic wave height and periods are standard and are not repeated here. The procedures to compute non-standard parameters are given below. It has been assumed that all time series are properly calibrated and validated. This implies that spikes are removed and that the pressure time series are corrected for barometric pressure. Cross-shore velocity is positive onshore in x-direction, longshore velocity is positive in the y-direction (see Figure 2.1).

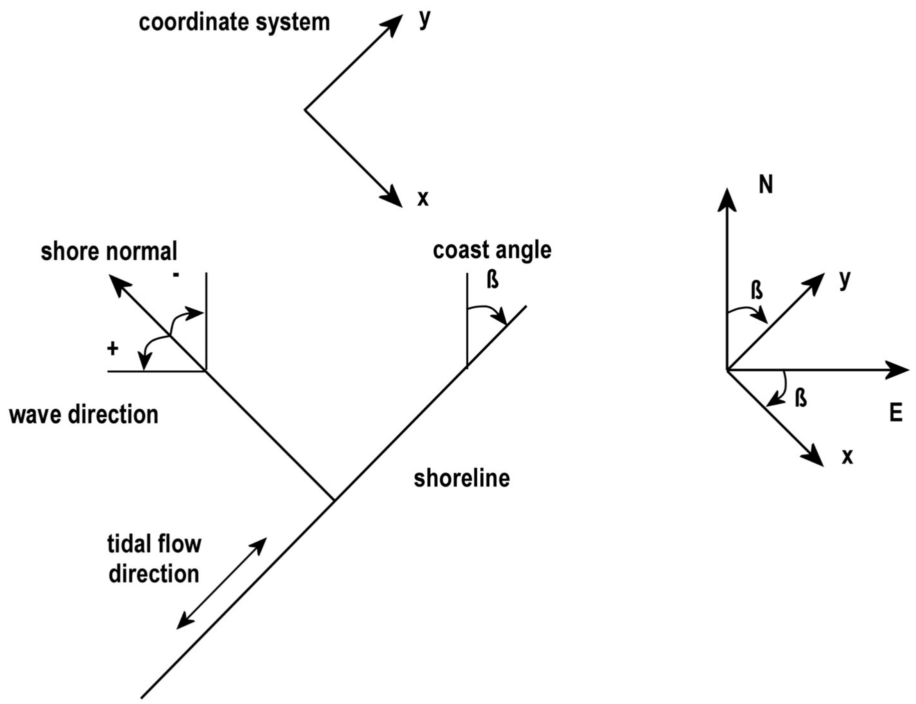


Figure 2.1 Coordinate system Sandpit project

Water depth from pressure sensor data

1. Calculate mean value over burst length
2. Add sensor height above the bed

Example: mean value = 6.5 m; sensor height = 0.3 m, total water depth = 6.5 + 0.3 = 6.8 m

Water level relative to MSL from pressure sensor data

MSL is about 0 m NAP. NAP is Dutch Ordnance Level. The height values provided by the echo soundings are all with respect to NAP. Negative value is below NAP; positive value is above NAP.

Add height of the bottom (in NAP) to total water depth.

Example: bottom location: -5.8 m NAP; water depth = 6.8 m; depth to MSL = 6.8 + (-5.8) = +1.0 m.

Mean wave direction from velocity data

1) Detrend cross-shore velocity over burst length with second-order polynomial
2) Detrend longshore velocity over burst length with second-order polynomial
3) Apply linear correlation technique: x-values are the cross-shore data, y-values are the longshore data. The constant of proportionality (c.o.p.) can be calculated into a direction: c.o.p. = tan (direction). The resulting angle is with respect to the shore-normal
4) This value can be recalculated in degrees relative to the North

Example: a -20 degrees wave direction means that waves are coming in at 20 degrees North of the shore normal. The coast angle near Noordwijk is β = 27.92 degrees relative to the north and hence the shore-normal is 297.92 degrees relative to the North. Thus a wave direction of -20 degrees relative to shore normal corresponds to a wave direction of 317.92 degrees relative to the North.

Time-averaged velocity

1) Calculate mean cross-shore ($\overline{u}$) and longshore ($\overline{v}$) velocity
2) Northerly directions: $\overline{v}_{north} = \overline{v}\cos(\beta) + \overline{u}\cos(180-\beta)$
3) Easterly directions: $\overline{u}_{east} = \overline{v}\sin(\beta) + \overline{u}\sin(180-\beta)$

Cross-shore orbital motion $u_{1/3,on}$ and $u_{1/3,off}$ (high and low-frequency)

1) Detrend cross-shore velocity time series over burst length with second-order polynomial
2) Apply high-pass or low-pass filter
3) Determine all individual onshore flow phases for high-frequency signal, calculate maximum onshore velocity per individual half-wave cycle
4) Determine all individual offshore flow phases, calculate maximum offshore velocity per individual half-wave cycle
5) Sort all observed onshore maximum values, calculate mean value of highest one-third
6) Sort all observed offshore maximum values, calculate mean value of highest one-third
7) Repeat for low-frequency values

Root-mean-square cross-shore velocity u_{rms} (high and low-frequency values)

1) Detrend cross-shore velocity time series over burst length with second-order polynomial
2) Apply high-pass or low-pass filter
3) Determine standard deviation of signal for high and low-frequency values; u_{rms} = standard deviation

Time-averaged sand-concentration

Calculate average value over entire burst length

2.1.4. FILE NAME AND DATA STORAGE CONVENTIONS

File name

The name of the data files (time series) to be banked in the database is based on the 8 characters (+3 in extension) in the MSDOS-format. The filename conventions are as follows

- The first three characters denote the position of the instruments. This coding will be provided in time before the start of measurement campaign. If the coding is less than 3 characters, the remaining characters are replaced by an underscore (_).
- The next five characters denote the burst number. Every hour has in a year has a unique burst number, with 1 January 2002 00:00 MET = burst 1. The burst numbering starts anew every year. Mean European Time (MET) is used as a fixed time reference to prevent problems with summertime to wintertime changes. If the burst number is less than five characters, additional 0's have to be placed in front of it, e.g. burst number 1000 becomes 01000. For the laboratory measurements, it is suggested to use the burst number as a test run follow-up number.
- The file extension is .txt

A few examples:

10a00123.txt file with time series measured at position 10a during burst 123

1__02345.txt file with time series measured at position 1 during burst 2345

3b_13555.txt file with time series measured at position 3b during burst 13555

10e17891.txt file with time series measured at position 10e during burst17891

In this file name convention it is essential to use fixed measurement positions during a campaign. Furthermore, each institute has to be able to transform time information correctly into a burst number.

Data format

The format of the data-files is ASCII. For space reduction, the data is stored in a compressed way (e.g. with PkZip or WinZip). The compressed data files are accompanied by an info-file that provides information on the stored data such as length of the time series, number of columns, description of instruments, measurement frequencies, etc. An example data-file and info-file can be downloaded from the Sandpit website.

Burst length

For the field measurements, each burst starts at the onset of the whole hour. A burst length of 17 minutes is suggested (2048 time-steps if measuring with 2 Hz). All parameters are provided as burst-averaged values. This implies that instruments that store just average values have to store 17-minute average values. For the laboratory measurements the burst length depends on the experimental scale.

Units and coordinate system

The units of the parameters have to be according to the SI-system. Thus, water depths and wave heights in meters, periods in seconds, concentrations in kg/m^3, and so on. The alongshore current is positive in the positive y-direction and the cross-shore current is positive in the positive x-direction as shown in Figure 2.2. Wave direction relative to shore normal is positive for waves coming from southwesterly directions, and negative for waves coming from northwesterly directions (see Figure 2.2).

At Noordwijk, the coastline orientation is 27.92 degrees relative to the North (topographic north; 360-degree system), which results in 297.92 degrees for the shore normal direction. The magnetic north is 2? degrees west of the topographic north.

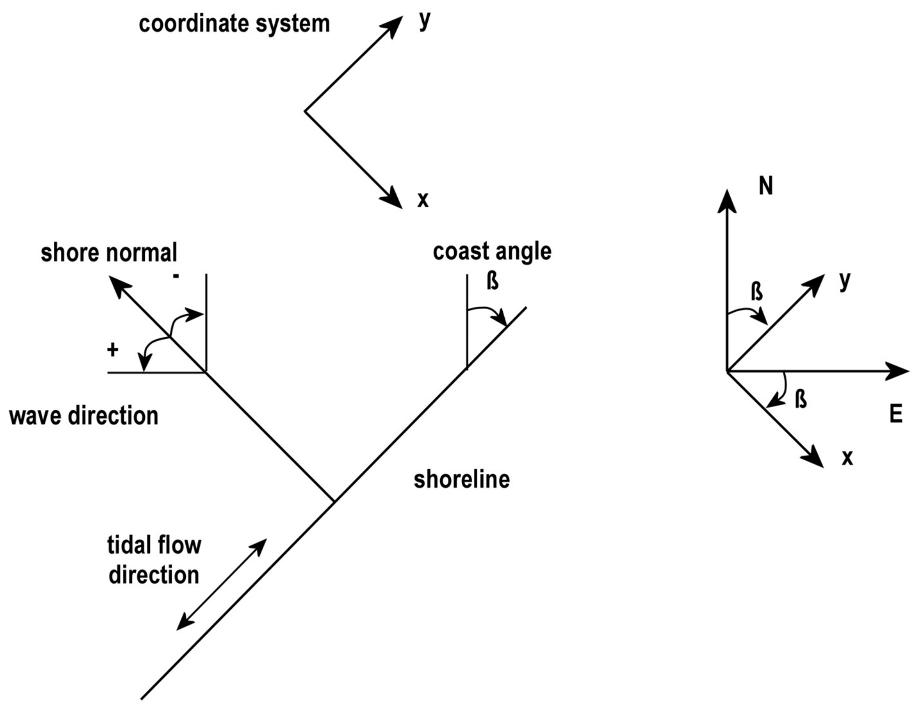


Figure 2.2 Coordinate system Sandpit project

2.2. SEDIMENT TRANSPORT DATA (SED)

The SED database will be based on the SEDMOC Database. Data from both laboratory and field experiments will be included in the SED database.

The SED database contains sediment concentration profiles (particles larger than 50 μm) and fluid velocity profiles (if available) and the relevant hydraulic and sediment parameters for current and/or wave conditions in flume and field conditions. Furthermore, the SED database contains various sediment transport components (mean, low-freq. and high. freq.) of which the mean component is available as extrapolated (using 3 different methods) and non-extrapolated.

2.2.1. INTRODUCTION

The SED system contains the data records of the hydraulic and sediment variables, the velocity profiles, the sediment concentration profiles and the D_{50}-profiles of the suspended sediment. An additional program has been developed to compute the depth-averaged fluid velocity, the depth-integrated suspended sediment load and transport. After computation, these latter variables are stored in the database.

The computation program consists of:

- extrapolation of velocity and concentration profiles,
- numerical computation of depth-averaged fluid velocity (*Vprof*), depth integrated suspended sediment load (*Ls*), suspended sediment transport (*Ss*), and bed concentrations (C_{bed}).

2.2.2. LIST OF PARAMETERS

The SED contains a description of the test (Table 2.1), the sediment and bed form parameters (Table 2.2), the mean hydrodynamic parameters (Table 2.3), the velocity and concentrations profiles per test and the depth-integrated sediment loads and transport rates (Table 2.4).

The surface elevation, velocity and concentration time series should be decomposed into time-averaged (mean), and high- and low-frequency oscillatory components. To discriminate between high- and low-frequency, a split frequency f_{split} = 0.05 Hz (T_{split} = 20 s) is suggested for the field measurements and $f_{split} = 0.5f_p$ ($T_{split} = 2T_p$) for the laboratory measurements.

Table 2.1 Test description in SED.

Parameter	Description	Unit
NR	identity number(NR)	-
STT	set name	-
CODE	code name	-
MODEL	model name	-
TEST	test name	-
LOCATION	location	-
DATE	date	-
TIME	time	-

Table 2.2 Sediment and bed form parameters in SED.

Parameter	Description	Unit
$D_{b,10}, D_{b,50}, D_{b,90}$	grain size bed material	µm
$w_{b,10}, w_{b,50}, w_{b,90}$	fall velocity bed material	m/s
$D_{s,10}, D_{s,50}, D_{s,90}$	grain size suspended material	µm
$w_{s,10}, w_{s,50}, w_{s,90}$	fall velocity suspended material	m/s
$r_{mean}, r_{min}, r_{max}$	mean, min and max bed form height	m
$\lambda_{mean}, \lambda_{min}, \lambda_{max}$	mean, min and max bed form length	m

Table 2.3 Hydrodynamic parameters in SED.

Parameter	Description	Unit
h	water depth	m
η_{slope}	water surface slope	-
$H_{1/3,high}, H_{1/3,low}$	significant wave heights in time domain	m
$H_{mo,high}, H_{mo,low}$	significant wave heights in frequency domain	m
$H_{m,high}, H_{m,low}$	mean wave heights	m
$H_{rms,high}, H_{rms,low}$	rms wave heights	m
$T_{z,high}, T_{z,low}$	zero-cross period	s
$T_{p,high}, T_{p,low}$	wave spectrum peak periods	s
U_m, V_m	depth-averaged velocity in cross- and alongshore dir.	m/s
V_{mr}	depth-averaged result velocity	m/s
V_{prof}	depth-averaged velocity profile	m/s
$u_{rms,high}, u_{rms,low}$	rms velocities near bed	m/s
$u_{1/3,on,high}, u_{1/3,on,low}$	significant orbital velocities near bed in onshore direction	m/s
$u_{1/3,off,high}, u_{1/3,off,low}$	significant orbital velocities near bed in offshore direction	m/s
ϕ	angle between wave propagation vector and current vector	degr.
α	angle between wave propagation vector and shore normal	degr.
Q_b	fraction of breaking waves	-
x_b	distance between measurement location and breaker line	m
BT	breaker type	-
T_e	water temperature	°C

Table 2.4 Velocity and concentration profiles and transport rates in SED

Parameter	Description	Unit
$C_{bed1}, C_{bed2}, C_{bed3}$	bed concentration, method 1, 2 and 3	kg/m^3
$C_{mean}, C_{min}, C_{max}$	mean, min and max concentration at point (x, z)	kg/m^3
$V_{mean}, V_{min}, V_{max}$	mean, min and max alongshore velocity at point (x, z)	m/s
$U_{mean}, U_{min}, U_{max}$	mean, min and max cross-shore velocity at point (x, z)	m/s
D_{50}	median grain diameter D_{50} at point (x, z)	µm
L_{s1}, L_{s2}, L_{s3}	suspended load, method 1, 2 and 3	kg/m^2
$S_{t,x}, S_{t,y}$	total net depth-integrated transport in cross- and alongshore dir.	kg/sm
$S_{b,x}, S_{b,y}$	mean bed load transport in cross- and longshore dir.	kg/sm
$S_{s1,x}, S_{s2,x}, S_{s3,x}$	mean suspended transport, method 1, 2 and 3 in cross-shore dir.	kg/sm
$S_{s1,y}, S_{s2,y}, S_{s3,y}$	net suspended transport, method 1, 2 and 3 in alongshore dir.	kg/sm
$S_{s,x,high}, S_{s,y,high}$	high-frequency suspended transport in cross- and alonghore dir. (not extrapolated)	kg/sm
$S_{s,x,low}, S_{s,y,low}$	low-frequency suspended transport in cross- and alonghore dir. (not extrapolated)	kg/sm
$S_{s,x,mean}, S_{s,y,mean}$	mean suspended transport in cross- and alongshore dir. (not extrapolated)	kg/sm

2.2.3. EXTRAPOLATION OF VELOCITY AND CONCENTRATION PROFILES

To compute the depth-integrated suspended sediment load transport, the velocity and concentration profiles must be fully defined from the bed to the water surface. Since there are always small zones ('unmeasured' zones) near the bed and the water surface where velocity and concentration measurements cannot be performed, extrapolation methods are necessary to complete the data.

Velocity

The velocities between the bed and the first measuring point (Z_1) are represented by the following function (see Figure 2.3):

$$V = V_1 (\frac{Z}{Z_1})^{0.25} \quad \text{for } 0<Z<Z_1 \qquad (1)$$

in which:

V_1 = fluid velocity in first measuring point above the bed
Z_1 = height above bed of first measuring point

The velocities between the last measuring point (Z_L) and the water surface are assumed to be equal to the velocity (V_L) in the last measuring point (see Figure 2.3). Thus:

$$V = V_L \quad \text{for } Z_L < Z < h \qquad (2)$$

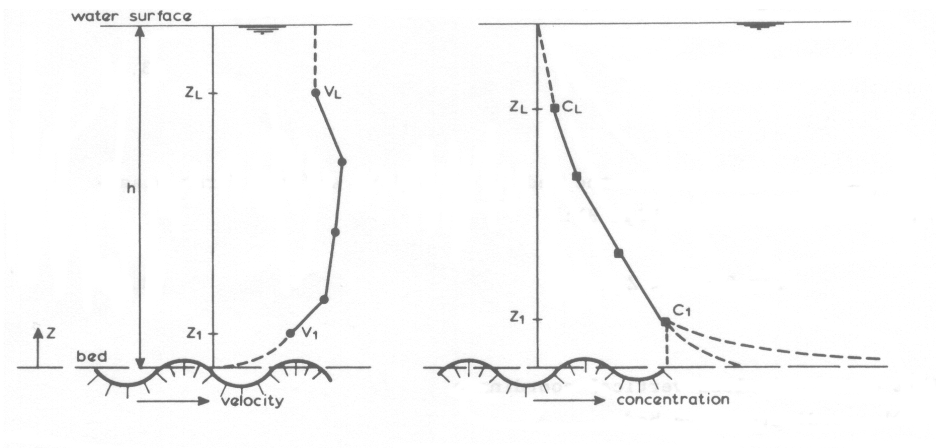


Figure 2.3. Extrapolation of velocity and concentration profiles

Concentration

The sediment concentrations between the last measuring point and the water surface are represented by a linear function giving a zero concentration at the surface, as follows (see Figure 2.3)

$$C = (\frac{h-Z}{h-Z_L}) C_L \quad \text{for } Z_L < Z < h \qquad (3)$$

in which:

C_L = concentration in last measuring point
Z_L = height above bed of last measuring point.

Since the exact distribution of the sediment concentrations in the near-bed zone is not known and considering the relative importance of the concentrations in this zone, three different extrapolation methods are applied to represent the concentration profile between the bed and the first measuring point.

Method 1 is supposed to give a lower limit, while method 2 is supposed to give an upper limit.

Method 1

The sediment concentrations between the bed (Z = 0 m) and the first measuring point ($Z = Z_1$) are assumed to be equal to the concentration (C_1) in the first measuring point (see Figure 2.3). Thus:

$$C = C_1 \quad \text{for } 0 < Z < Z_1 \qquad (4)$$

Method 2

The sediment concentrations between the bed (Z = 0.001 m) and the first measuring point are computed by (See next page Figure 2.4):

$$C = AY^B \quad \text{for } 0.001 < Z < Z_1 \qquad (5)$$

in which:

$Y = (h-Z)/Z$ = dimensionless vertical coordinate
Z = vertical coordinate above bed
h = water depth
A, B = coefficients

The A and B coefficients are determined by a regression method applying the measured concentrations of the first three measuring points above the bed, as follows:

- select $B = 0.1$
- compute $A = \dfrac{\sum_1^3 (Y_k^B C_k)}{\sum_1^3 (Y_k^B Y_k^B)}$
- compute $T = \sum_1^3 (AY_k^B - C_k)$
- select $B = 0.2$ (B is varied over the range 0.1 to 5), repeat procedure

Finally, the A and B coefficients corresponding to a minimum T-value are selected as the 'best' coefficients. Applying Eq. (5), the sediment concentrations are computed in 50 (equidistant) points between the bed (defined at Z = 0.001 m) and the first measuring point ($Z = Z_1$). The maximum concentration is assumed to be 1590 kg/m^3.

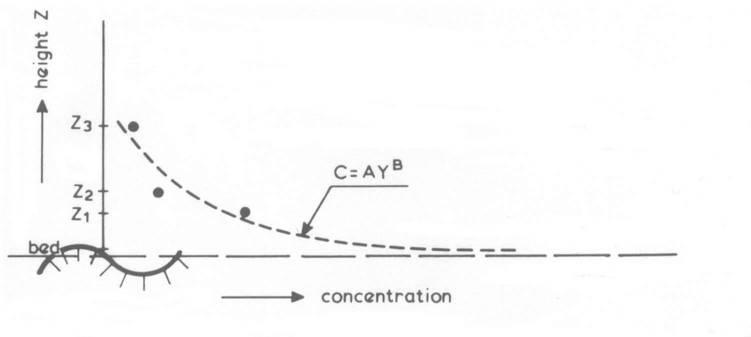


Figure 2.4. Regression of concentration profile (method 2).

Method 3

The sediment concentrations between the bed and the first measuring point are represented by (Figure 2.5):

$$C = e^{AZ+B} \quad \text{for } 0 < Z < Z_1 \tag{6}$$

in which:

Z = height above bed
A, B = coefficients

The A and B coefficients are determined by a linear regression method applying the measured concentrations of the first three measuring points above the bed, as follows:

$$A = \frac{3\sum_1^3 (Z_k \ln C_k) - \sum_1^3 (Z_k)\sum_1^3 (\ln C_k)}{3\sum_1^3 (Z_k Z_k) - (\sum_1^3 Z_k)^2} \tag{7}$$

$$B = \frac{\sum_1^3 (Z_k Z_k)\sum_1^3 (\ln C_k) - \sum_1^3 (Z_k)\sum_1^3 (Z_k \ln C_k)}{3\sum_1^3 (Z_k Z_k) - (\sum_1^3 Z_k)^2} \tag{8}$$

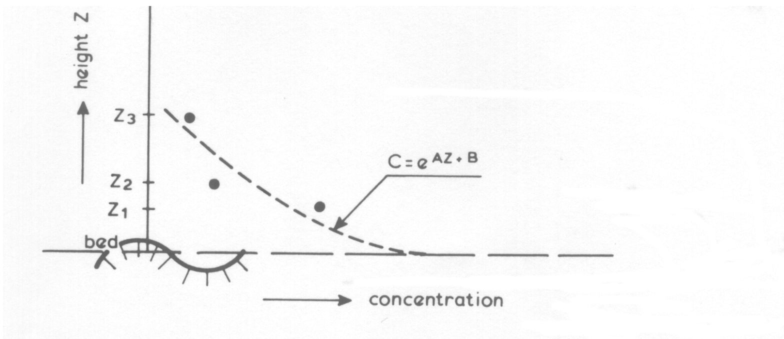


Figure 2.5. Regression of concentration profile (method 3)

Applying Eq. (6), the sediment concentrations are computed in 50 (equidistant) points between the bed (defined at Z = 0 m) and the first measuring point ($Z = Z_1$). The maximum concentration is assumed to be 1590 kg/m^3.

2.2.4. COMPUTATION OF DEPTH-AVERAGED FLUID VELOCITY

The depth-averaged fluid velocity is computed as:

$$V_{prof} = \frac{1}{h}\sum_{i=1}^{N} \frac{1}{2}(V_i + V_{i-1})(Z_i - Z_{i-1}) \tag{9}$$

in which:

h = water depth
V_i = fluid velocity at height Z_i above the bed
N = total number of points (including extrapolated values)

2.2.5. COMPUTATION OF DEPTH-INTEGRATED SUSPENDED SEDIMENT LOAD

The depth-integrated suspended sediment load (*Ls*) is computed as:

$$L_s = \sum_{i=1}^{N} \frac{1}{2}(C_i + C_{i-1})(Z_i - Z_{i-1}) \qquad (10)$$

in which:

C_i = sediment concentration at height Z_i above bed
N = total number of points (including extrapolated values)

Since three different methods are applied to represent the sediment concentrations in the unmeasured zone near the bed, three different values of the suspended sediment load are obtained and implemented the database (L_{s1}, L_{s2} and L_{s3}).

2.2.6. COMPUTATION OF DEPTH-INTEGRATED SUSPENDED TRANSPORT

Numerical computation of the depth-integrated suspended sediment transport (S_s) requires the specification of velocities and concentrations at equal elevations above the bed (at equal *Z*-values). When the *Z*-values of the velocities and concentrations are not corresponding, linear interpolation is applied to obtain the required data.

The depth-integrated suspended sediment transport (S_s) is computed as:

$$S_S = \sum_{i=1}^{N} \frac{1}{2}(V_i C_i + V_{i-1} C_{i-1})(Z_i - Z_{i-1}) \qquad (11)$$

in which:

V_i = alongshore fluid velocity at height Z_i above the bed
C_i = sediment concentration at height Z_i above the bed
N = total number of points (including extrapolated and interpolated values).

Since three different methods are applied to represent the sediment concentrations in the unmeasured zone near the bed, three different values of the suspended sediment transport are obtained and implemented in the database (S_{s1}, S_{s2}, S_{s3}). The transport rates are computed in cross- and alongshore direction.

3. DATA AVAILABILITY

3.1. INSIDE PROJECT

All data will be available 6 months after the end of the experiments.

3.2. OUTSIDE PROJECT

The data from all experiments will be available 6 months after the end of the project. The BED will be provided on cd-rom with data files in directories and subdirectories (per institute, per station, per instrument, etc.). The SED database will be implemented on the internet.

3.3. TRANSFER OF TECHNOLOGY (PART B OF CONTRACT)

The most important points are:

- Foreground information shall be owned by contractors and associate contractors,
- Contractors and associate contractors shall give reasonable information on the project to relevant bodies for up to 2 years after the project,

- Contractors shall grant access rights to outsiders, only if requested and may be subject to confidentiality (foreground information),
- Contractors are free to grant access rights to background information,
- Access rights for background information shall be granted to contractors in same contract if necessary for their own work (on transfer conditions).

4. CONTACT

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Appendix 2 Summary of all ADCP parameters

The full available output of parameters provided by the ADCP (Nortek 1.5mHz NDP) are given under the numerous tabs in the files Sand1001_v4b.xls and Sand2006_v2c.xls, which in summary are:

System parameters:

- Profile no.
- Profile Time - yyyy.mm.dd hh.mm.ss
- Number of samples averaged this profile
- Sound speed used to calculate velocity - m/s
- Mean heading - °
- Mean pitch (rotation about Y-axis) - °
- Mean roll (rotation about X-axis) - °
- Mean temperature - °C
- Mean pressure - metres Sea Water
- Standard deviation of heading - °
- SD of pitch, roll - °
- SD of temperature - °C
- SD of pressure – m SW

Hydrodynamic parameters:

- Current speed
- Current direction
- Velocity components – VE, VN, VUp

Measures of system response:

- Standard deviation of velocity components - sVE, sVN, sVUp
- Raw signal strength data for each beam – A1, A2, A3
- Signal-to-Noise Ratio for each beam – SN1, SN2, SN3

Data CD