LIP 11D Delta Flume Experiments

A dataset for profile model validation

Data Report

January 1995

LIP 11D Delta Flume Experiments

A dataset for profile model validation

J.A. Roelvink and A.J.H.M. Reniers

Contents

List of tables

List of figures

List of figures (continued)

1 Introduction

Within the framework of the European Large Installation Plan (LIP) a programme of detailed measurements of hydrodynamics and sediment transport in the surf zone has been carried out in DELFT HYDRAULICS' Delta Flume (see Figure 1.1).

The objective of the study was the generation of high quality and high resolution data on hydrodynamics and sediment transport dynamics on a natural 2DV beach under equilibrium, erosive and accretive conditions. Special attention was paid to long-wave effects and near-bottom resolution.

During the project, DELFT HYDRAULICS made available the Delta Flume and took care of expert assistance in running the facility and carrying out the experiments.

The team from DELFT HYDRAULICS was led by Dr. J.A. Roelvink (project manager) and A.J.H.M. Reniers (project engineer).

The Universities of Catalunya, Liverpool, Padova and Thessaloniki sent researchers to design and oversee the experiments in the flume, and to further process and analyse the data. The University of Trento had to withdraw.

The researchers are:

> Prof. A. Sánchez-Arcilla (Principal Investigator), J. Gomez, J. Jimenez of the University of Catalunya;
> Prof. B.A. O'Connor, Dr. J. Nicholson of the University of Liverpool;
> Prof. G. Matteotti, Dr. P. Ruol of the University of Padova;
> Dr. Th. Karambas of the University of Thessaloniki.

The preparation of the Delta Flume and the positioning and testing of the instruments took place from April 5 until April 23 1993. The actual experiments were carried out in the period of April 26 until June 25 1993.

In the week of 2-9 June 1993, 13 researchers active in MaST-G8M were invited to join the experiments. Since data processing was performed directly after each wave hour, processed results were available for analysis and model comparisons, and a fruitful workshop could be held.

The researchers will use the results of these experiments to validate and improve hydrodynamic, sediment transport and morphodynamic models. This will lead to improved understanding and prediction of profile- and bar-generating processes.

A first overview of the experiments is presented in Arcilla et al. (1994).

The data have been used in model validation studies presented in:

Roelvink (1993)
Wallace (1993)
Reniers (1993)
Wallace and Southgate (1993)
O'Connor and Nicholson (1993)
Arcilla et al. (1994)
Hamm and Roelvink (1994)
Rivero et al. (1994)
Stive and De Vriend (1994)
Southgate and Wallace (1994)
Collado et al. (1994)
Mocke et al. (1994)
Nicholson and O'Connor (1994)
Reniers and Roelvink (1994)
Walstra et al. (1994)
Beyer (1994)
Boers (1994)

In this report, first the experimental set-up is described in Chapter 2. Standard data analysis and checking is described in Chapter 3. Here the reader is also instructed on how to extract the parameters computed from the raw data from the data set accompanying this report.

In Chapter 4, a number of dedicated sub-datasets are described which have been tailored specifically for the validation of coastal profile models. A part of the data, concerned with the wave decay and kinematics, has been entered into the G8M database distributed by Dr. L. Hamm of SOGREAH.

This report was drawn up by Dr. J.A. Roelvink and A.J.H.M Reniers of DELFT HYDRAULICS, with valuable support by Dr. L. Hamm at SOGREAH.

A substantial part of the data validation and tailoring for profile model validation has been carried out in the framework of DELFT HYDRAULICS' research cluster "Validation of computer models", focused on the validation of computer models using experimental and other techniques. An example of a specific validation study is found in DELFT HYDRAULICS (1995), in which the validation of the profile model UNIBEST-TC against this data set is described.

2 Experimental set-up

2.1 Initial beach geometries

The first geometry consisted of a Dean-type beach with constant slope near and above the water line. Given the grain diameter of 220 μ, a so-called equilibrium parabolic beach profile of Bruun-Dean-Moore was adopted. This profile has an unrealistic gradient of the bottom profile near the water line, which was modified. The modified profile (Stive et al., 1992) is given by:

$$h = Ax^{\frac{2}{3}} \qquad \text{for } \frac{dh}{dx} < m$$

$$h = h' - m\,(x' - x) \qquad \text{for } \frac{dh}{dx} > m$$

where h is the water depth, x a horizontal coordinate (positive seawards), m the beach slope and (x',h') the coordinates of the point where $dh/dx = m$. A is a (dimensional) constant.

The two parameters are mainly determined by the flume boundary conditions. Given the grainsize diameter this yields for A:

$$A = 0.10 \quad m^{\frac{1}{3}}$$

The profile is restricted by the DELTA-flume geometry. The coordinates of the concrete bottom are given in Table 2.1.

Distance x (m)	Bottom height z (m)
0.0	0.00
180.0	0.00
192.0	3.00
210.0	6.00
225.0	6.75

Table 2.1 Concrete bottom

Here $x = 0$ corresponds to the middle position of the wave paddle and $z = 0$ to the flume bottom. In view of the wave generation, it was advisable to have at least the first *20 m* from the wave paddle without sand. The height of the walls in the DELTA-flume is *7 m*. Depending on maximum wave height, run-up and dune height the actual water depth was then between *4* and *5 m*.

Using a waterdepth of *+4.1 m* with a length of water line of approximately *183 m*, the bottom slope was chosen to be:

$$m = \frac{1}{30} \qquad for \quad z > 3.7\ m$$

$$m = \frac{1}{20} \qquad for \quad z < 1.6\ m$$

The resulting initial bottom profile is presented in Table 2.2 and Figure 2.1.

Distance x (m)	Bottom height z (m)
0.00	0.00
20.00	0.00
52.00	1.60
87.56	2.10
118.91	2.60
145.38	3.10
156.46	3.35
165.82	3.60
169.00	3.70
181.00	4.10
196.00	4.60
203.00	4.83

Table 2.2 Initial profile

The second geometry differed from the first only in the presence of a low dune, see Figure 2.1. The dunefoot was chosen to be just above the still water level. The purpose of this second geometry was to investigate the effect of the upper boundary condition on the profile development.

2.2 Wave conditions

The test set-up for both geometries was made up of the following sub-tests:

- slightly erosive wave conditions,
- highly erosive wave conditions,
- strongly accretive wave conditions.

Narrow-banded, random waves were chosen such that the wave steepness at the peak frequency in combination with the water level were expected to result in a stable, erosive and accretive beach, consecutively. During each of these stages the water level and wave conditions were kept constant. This sequence of conditions could be interpreted as a schematization of the natural development of a storm, represented by the different sea states. The duration (number of wave hours) of each state was determined by the test duration and number of possible wave hours per day, but was chosen to be at least long enough to obtain accurate sediment transport estimates from profile measurements.

The incident wave height, wave period, water level and sub-test duration for the different sub-tests are presented in Table 2.3.

Test code	Initial geometry	H_{m0} [m]	T_p [s]	Water level (m)	Duration (h)
1a	Dean-type	0.9	5	4.1	12
1b	result of 1a	1.4	5	4.1	18
1c	result of 1c	0.6	8	4.1	13
2a	Dean-type with dune	0.9	5	4.1	12
2b	result of 2a	1.4	5	4.1	12
2e	result of 2b	1.4	5	4.6	18
2c	result of 2e	0.6	8	4.1	21

Table 2.3 Incident wave conditions

2.3 Instrumentation

The following instruments were deployed:

- One measurement carriage equipped with:
  — automatic sounding system (see below),
  — sediment concentration sampler (10 suction tubes),
  — 5 electro-magnetic current meters,
  — 4 Optical Backscatter Sensors,
  — bottom sediment transport meter (HARK),
  — video camera.
- Two surface-following wave gauges near the wave generator
- One resistance type wave gauge near the carriage
- Ten pressure sensors attached to flume wall
- Five velocity meters attached to the wall

The technical data concerning the instruments are given in Table 2.4 below.

Description	Instrument type	Sampling freq.	Accuracy
pressure	PDCR10/D/F-01	10 Hz	0.15%
velocity	EMF	10 Hz	2 cm/s
water level	surface follower	10 Hz	2.5 cm
	resistance type	10 Hz	1. cm
bottom	provo	25 Hz (1/cm)	.2 cm
suspended load	Pumping sampler	twice per hour	10%
grain size	VAT	all samples	

Table 2.4 Instrument characteristics

Note that the surface following wave gauges could not be used in case of breaking waves.

PROVO

The PROVO (PROfiel vOlger, Dutch for Profile Follower) presented in Figure 2.2 is used to measure the bottom profile in the wave flume. During measuring the following signals are obtained:

- echo sounding (only for underwater measurements),
- angle of wheel arm,
- vertical displacement of rod,
- electronic pulse for indication of horizontal displacement.

The angle of the wheel arm was used to steer the vertical displacement of the rod. An echo sounder was attached to the rod, in a position just in front of the wheel. This echosounder hovered over the bottom at a distance of approx. 10-20 cm. The combination of echo sounding and rod displacement yielded a very accurate and undisturbed profile measurement under water; near the water line and above it the combination of wheel angle and vertical displacement of the rod provided an accurate profile measurement as well. The two measurements were combined by a computer program in such a way, that echo data were used where possible; erroneous echo data were replaced by the wheel recording, which also provided data above water. The time-series were converted to spatial data on a 0.01 m grid.

Layout of fixed instruments

The selection of the positions of the various instruments along the wave flume was based on computational results obtained with UNIBEST-TC. The EMF current meters were positioned at one third of the water depth. The resulting positions are given in Table 2.5 and Figure 2.3.

EMF number	x (m)	z (m)
1	65	2.55
2	100	2.90
3	130	3.25
4	145	3.44
5	160	3.70

Table 2.5 Positions of fixed EMS current meters

The pressure sensors attached to the flume walls were positioned as high as possible, but below the expected lowest wave trough level. The positions are given in Table 2.6 and Figure 2.3. An example of the configuration of fixed EMF and pressure sensor is given in Figure 2.4

	x (m)	z (m)
1	20	3.00
2	65	3.00
3	100	3.20
4	115	3.30
5	130	3.55
6	138	3.50
7	145	3.70
8	152	3.60
9	160	3.44
10	170	3.70

Table 2.6 Positions of pressure sensors

Layout of instruments on measurement carriage

The layout of the instruments on the measurement carriage is presented in Figure 2.5. The EMF current meters attached to the carriage (numbers 6-10) were applied at the following distances from the actual bed:

EMF number	Height above bed (m)
6	0.10
7	0.20
8	0.40
9	0.70
10	1.10

Table 2.7 Vertical positions of EMF current meters 6-10

The OBS sensors were applied at the distances above the actual bed:

OBS number	Height above bed (m)
01	.45
02	.40
05	.05
06	.10
07	.20

Table 2.8 Vertical positions of Optical Backscatter Sensors (OBS)

The suction samples were positioned at the following distances above the actual bed:

Sampler number	Height above bed (m)
1	.05
2	.075
3	.100
4	.130
5	.180
6	.255
7	.400
8	.650
9	1.050
10	1.550

Table 2.9 Vertical positions of suction tubes

2.4 Acquisition of data

Each sub-test (1a - 2c) was subdivided in a number of "wave hours". During each wave hour, a time series of exactly one hour of waves was generated. Sampling started just before the wave paddle was started and continued until after the last waves had died away. Measurements were taken by instruments attached to the flume wall, to the movable carriage and by the three movable wave gauges. All movable instruments remained in a fixed position during the wave hour.

All instruments were sampled simultaneously at 10 Hz. In order to avoid aliasing, each signal was low-pass filtered by an analog filter at 5 Hz before storage.

The profile was measured by an automatic sounding system which was operated in between the wave hours. Three profiles were measured each time: one in the middle of the flume and two at a distance of 0.85 m from the flume walls. The profile data were stored at 0.01 m intervals.

In Appendices A 1 through A 7, an overview is given of the measurements carried out, the measuring positions and conditions per wave hour and the corresponding code (and file-) names.

In order to facilitate further analyses, the EMF and OBS timeseries were divided into a number of series pertaining to the total signal, the high-frequency part, the low-frequency part or the interaction between low- and high-frequency parts. The coding of these series is given in Table 2.10.

EMF	1	2	3	4	5	6	7	8	9	10
u-signal	emf01	emf03	emf05	emf07	emf09	emf11	emf13	emf15	emf17	emf19
w-signal	emf02	emf04	emf06	emf08	emf10	emf12	emf14	emf16	emf18	emf20
u-low	emf101	emf103	emf105	emf107	emf109	emf111	emf113	emf115	emf117	emf119
w-low	emf102	emf203	emf106	emf108	emf110	emf112	emf114	emf116	emf118	emf120
u-high	emf201	emf203	emf205	emf207	emf209	emf211	emf213	emf215	emf217	emf219
w-high	emf202	emf204	emf206	emf208	emf210	emf212	emf214	emf216	emf218	emf220
interaction	emf301	emf302	emf303	emf304	emf305	emf306	emf307	emf308	emf309	emf310

OBS	1	2	5	6	7
c-signal	obs01	obs02	obs05	obs06	obs07
c-low	obs101	obs102	obs105	obs106	obs107
c-high	obs201	obs202	obs205	obs206	obs207

Table 2.10 Coding of EMF and OBS time series

3 Standard data analysis and checking

3.1 Measured parameters derived from raw time series

A number of integral parameters were computed from the raw time series directly after each test. This enabled the researchers to use the results almost immediately after each test. The integration interval for these parameters was chosen from 10 minutes to 60 minutes after the start of each test. Standard plots of some parameters were made after each wave hour, which allowed a visual check of the data. Examples of these plots are given in Figures 3.1.1 through 3.7.6; these Figures are included here to allow the reader a quick overview of the measurement conditions and of the data. The results shown are uncorrected values; for a discussion of the data validation see Section 3.6. The following Figures are shown, per test:

- Profile development over the entire test;
- Sediment transport rates derived from profile measurements;
- Surface elevation spectra derived from fixed pressure sensors[1];
- Integral surface elevation and velocity data based on fixed instruments;
- A compilation of the velocity profiles measured during the test;
- A compilation of the concentration profiles measured during the tests.

The list of computed parameters was agreed on beforehand, and is given below; the names that are used in the data files are given first, followed by the symbol and a brief description.

zb	z_b	:	bottom profile

statistical wave parameters[2]:

setup	η	:	mean water level
Hrms,d	H_{rms}	:	root mean square wave height (zero downcrossing)
H1/3	$H_{1/3}$	:	mean of highest *1/3*
H1/10	$H_{10\%}$	:	*10%* exceeded wave height
H1/100	$H_{1\%}$	:	*1%* exceeded wave height
Hmax	H_{max}	:	maximum wave height in a record
N	N	:	number of waves in a record
TH1/3,d	$T_{H1/3}$	:	mean wave period of $\frac{1}{3}^{rd}$ of waves
Tz,d	T_z	:	mean wave period (zero downcrossing)
skewness	$\dfrac{\langle(\eta-\bar{\eta})^3\rangle}{\langle(\eta-\bar{\eta})^2\rangle^{\frac{3}{2}}}$		skewness
kurtosis	$\dfrac{\langle(\eta-\bar{\eta})^4\rangle}{\langle(\eta-\bar{\eta})^2\rangle^2} - 3$		kurtosis

---

1 Time series over the interval 10 min - 60 min were transformed by FFT to periodegrams. From this the power spectrum was computed. Figures represent spectra averaged over .01 Hz bins.

2 Obtained from zero-down crossing analysis; no smoothing was applied other than the 5 Hz analog filter (see Section 2.4)

spectral wave parameters[3]:

m0 etc.	m_i	:	spectral moments, $i = -1, 0, 1, 2, 4$
Hmø	$4\sqrt{m_0}$	:	spectral H_{m0}
TpD	T_pD	:	spectral peak wave period
kappa	κ	:	spectral parameter kappa
	$4\sqrt{m_{0_{low}}}$	:	spectral low frequency H_{m0}
	$4\sqrt{m_{0_{high}}}$	:	spectral high frequency H_{m0}

wave envelope analysis:

GF	GF	:	groupiness factor
Cr	C_r	:	correlation between low-frequency waves and high-frequency wave envelope

velocity related parameters:

mean	$\bar{u}$	:	mean velocity in x-direction
mean	$\bar{w}$	:	mean velocity in z-direction
rms	u_{rms}	:	root mean square orbital velocity in x-direction
rms	w_{rms}	:	root mean square orbital velocity in z-direction
gu2,gu3,gu5	$<\|u(t)\|^n>$	:	total even velocity moments, $n = 2,3,5$
gu2ux,gu3ux	$<u(t)\|u(t)\|^n>$		total odd moments, $n = 2,3$
guss	$<u_s(t)\|u_s(t)\|^2>$		third order velocity moment (short waves)
guls	$<3u_l(t)\|u_s(t)\|^2 + u_l(t)\|u_l(t)\|^2>$	:	third order velocity moment (long-short wave interaction)
gusc	$<3\bar{u}\|u_s(t) + u_l(t)\|^2>$	:	third order velocity moment (mean current - wave interaction)
guc	$\bar{u}\|\bar{u}\|^2$	:	third order velocity moment (mean current only)
guzx	$<u_s w_s>$	:	wave induced Reynolds stress
st-dev-pos	$\sigma_{u_{s,crest}}$	:	standard deviation short wave velocity in x-direction at crest
st-dev-neg	$\sigma_{u_{s,trough}}$	:	standard deviation short wave velocity in x-direction at trough
st-dev-pos	$\sigma_{w_{s,crest}}$	:	standard deviation short wave velocity in z-direction at crest
st-dev-neg	$\sigma_{w_{s,trough}}$	:	standard deviation short wave velocity in z-direction at trough

3) For parameters computed from pressure time series, the pressure spectrum was first transformed to a surface elevation spectrum using linear theory. For comments see Appendix B.

3.2 Sediment and concentration related parameters

The mean sediment concentration was measured by the method of transverse suction. Water-sediment samples of 10 l were taken at 10 vertical positions simultaneously. The sediment content was determined by measuring the volume in pre-calibrated glass tubes.
The samples showed that there was a fair amount of peat present at some locations along the flume. The sediment concentrations were obtained from the sand fraction only, by separating the peat from the sand, using the difference in fall velocity. This procedure was performed twice during each wave hour. The difference between the two measurements gives an indication of the maximum error which may occur at that specific location. In general the differences are small, in the order of 10%.

conc	$\bar{c}$:	mean concentration

Bottom and suction samples were taken at various locations along the flume and for different tests. The fall velocity of these samples was measured in DELFT HYDRAULICS' Visual Accumulation Tube (VAT). Grain diameters were computed from these fall velocities using standard conversion formulae (Van Rijn, 1989).

w10	w_{10} :	fall velocity not exceeded by 10% of sample volume
w50	w_{50} :	fall velocity not exceeded by 50% of sample volume
w90	w_{90} :	fall velocity not exceeded by 90% of sample volume
d10	D_{10} :	grain diameter not exceeded by 10 % of sample volume
d50	D_{50} :	grain diameter not exceeded by 50 % of sample volume
d90	D_{90} :	grain diameter not exceeded by 90 % of sample volume

3.3 Bottom profiles and sediment transport

Bed level changes

As has been mentioned before the bottom profile was measured along a number of lines in the longshore direction (see Chapter 2). The measurements show variations in the bed-level in various sections (see Figure 3.8).

Because the model computations assume longshore uniformity, we have used a representative bottom profile. This profile is given by a parabolic fit to the measurements:

$$z=0.407z_1 + 0.186z_3 + 0.407z_5$$

where the indices refer to the lines along which the bottom profile was measured.

Total sediment transport

The total sediment transport has been obtained from the bed-level changes in consecutive representative bottom profiles. The procedure is described below.

Using the balance equation between bed-level changes and sediment transport gradient:

$$\frac{\partial z}{\partial t} + \frac{\partial S}{\partial x} = 0$$

The sediment transport can be obtained by integrating:

$$S(x) = -\int_{19m}^{x} \frac{\Delta z - \Delta \bar{z}}{\Delta t} dx$$

where

$$\Delta \bar{z} = \frac{1}{L} \int_{19m}^{L+19m} \Delta z_{t-1} dx$$

and L is the distance to a point where there is no sediment transport (ie. outside the swash zone). The time step was taken to be 6 hours, in order to have significant differences in the measured bottom profiles. Comparing the results for a single test indicate that the error in the total sediment transport is in the order of 25% of the peak value.

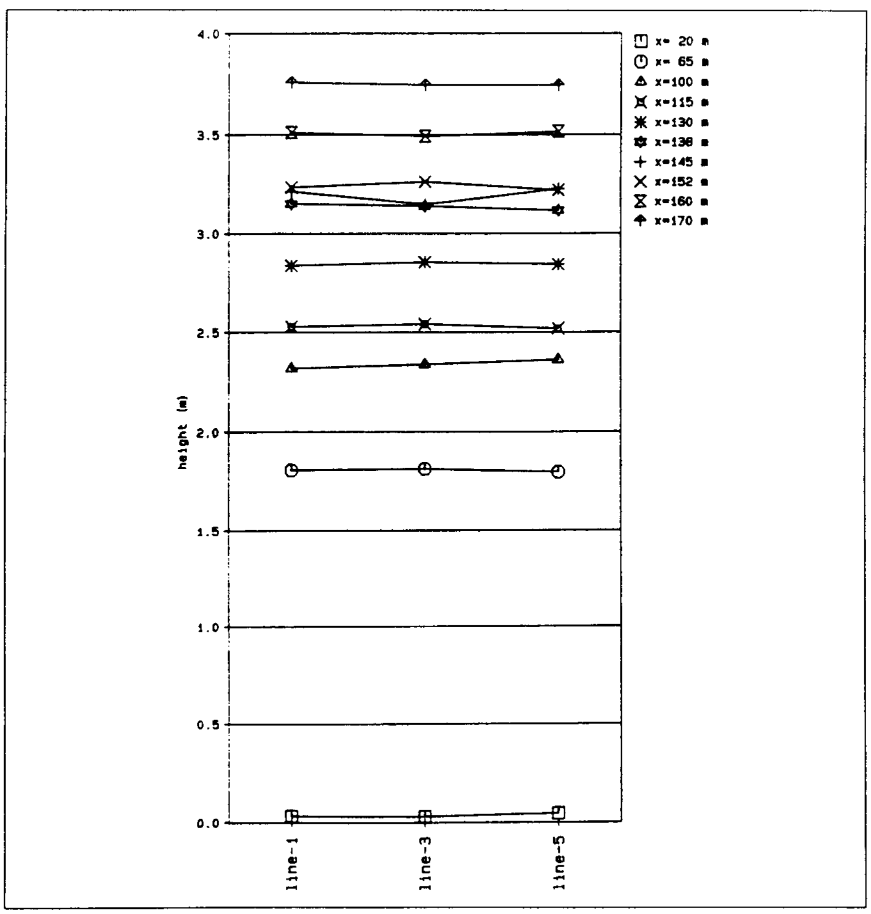


Figure 3.8 Variation bottom profiles

3.4 Bottom roughness and bed forms

The bottom roughness was obtained from the measured bottom profile by spectral analysis using a non-causal band-pass filter (Boers, 1994). An example of the results obtained is shown in Figure 3.9. This shows the wave length and amplitude of the ripples present during test 2A, B, E and C in a section near the wave paddle.

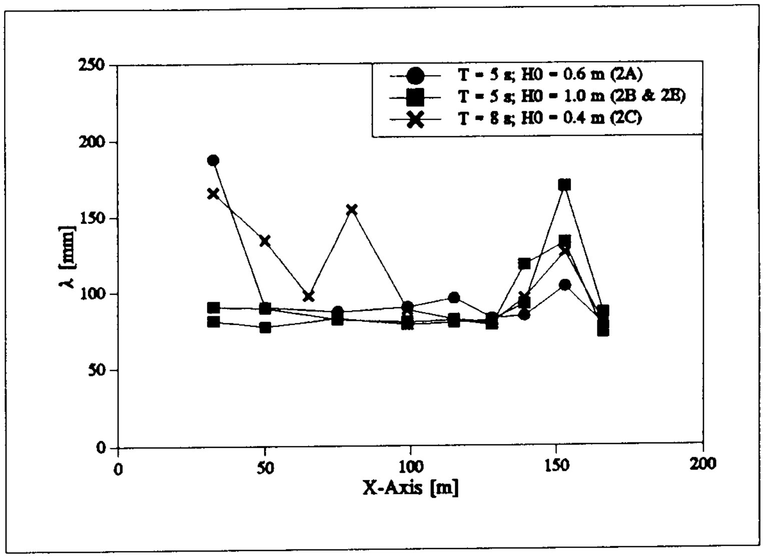


Figure 3.9 Ripple length and amplitude Test 2 A, B, E and C (from Boers,1994)

Similar results have been obtained for the other tests.

3.5 Fraction of breaking waves

The fraction of breaking waves was obtained from detailed analyses of the video recordings (Beyer, 1994). At every location two estimates of Qb were made, at ten minutes and thirty minutes after the start of the video record, respectively. The first ten minutes of every video record have been skipped because this is a transient period after the start of wave generation. Per estimate 100 waves have been counted. Both breaking and non-breaking waves were marked on a paper. As a criterion for a breaking wave the following was adopted: If a wave crest passing a fixed point shows air-entrainment, the wave is breaking or broken. An indication of the possible error in the thus determined fraction of breaking waves is indicated by the difference in Qb for the two counts. The difference proved to be in the order of 15%.

3.6 Data validation

Introduction

The validation of the measurement data consists of two parts, the pre- and post-validation. First a description of the tests performed before during and after the actual measurements are described. This can be described as a pre-validation of the data. In case any of these tests failed, adequate actions (eg. replacing an instrument) were taken.

The post-validation of the data-set is along the lines as described in Van Vledder (1993). The key-elements in this procedure are graphs and numbers; i.e. visual inspection of the data in combination with statistical parameters.

Instrument performance tests

After the initial deployment of the instruments in the Delta flume some basic tests were performed. To test the pressure sensors the water level was lowered by 1 meter. The values obtained by subtracting the pressure values before and after lowering the water level should then be the same for all pressure sensors (allowable differences in values between the various pressure sensors in the order of millimetres) showing a pressure drop corresponding to 1 meter lowering of the water level.
A similar test was performed for the current velocity meters attached to the measurement carriage. The carriage was moved with a velocity of 25 cm/s. Comparison of the velocities (allowable differences in values in the order of a centimetre per second) again shows whether or not the instruments operate correctly.
As for the profile-follower used to measure the bottom profile, a trapezoid, of known dimensions, was fixed to the bottom. Comparison with the measured values (allowable differences in the order of millimetres) again shows whether or not the instrument is working correctly.

In addition before, during and afterwards the actual measurements a number of tests were performed to check on the validity of the measured data obtained with the various instruments:

prior to test:
- pre-calibration of profile follower,
- zero-levelling of all EMF's and pressure sensors,
- zero-level measurement.

during:
- plotting first 80 s. of all time series.

after the test:
- zero-level measurement after tests,
- plotting results of preliminary analysis (wave height, set-up, return flow, sediment concentration).

Statistical analysis

Prior to the inspection of the actual data, as described previously, the measured time series have been analysed. For this the following parameters have been used:

mean

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

standard deviation

$$s_x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

skewness

$$Skew_x = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{x - \bar{x}}{\sigma_x}\right)^3$$

kurtosis

$$Kurt_x = \left[\frac{1}{N}\sum_{i=1}^{N}\left(\frac{x - \bar{x}}{\sigma_x}\right)^4\right] - 3$$

These parameters give information about the statistical distribution of the measurement data (time series). Where the standard deviation yields information on the spreading of the data around its mean value, the skewness characterises the degree of asymmetry around its mean. The kurtosis gives an indication of the relative peakedness or flatness of a distribution compared to the normal distribution. The results for all instruments per test are given in Tables in Appendix C. In case of malfunctioning of the instrument, the results for some of the statistical parameters differ significantly from the results obtained with other instruments.

The next step is to compute the mean and standard deviation of these parameters per test. So this will yield info on the statistical distribution per test. This is only useful in case the hydrodynamic conditions are constant during the test. This is the case for the fixed instruments, but not so for the instruments attached to the carriage. The results are presented in Tables in Appendix D. Comparing the individual values with the overall mean enables us to detect outliers (also presented in Appendix D). An outlier is defined by:

value(x) > mean(x) + 2.5 * standard deviation(x),
value(x) < mean(x) - 2.5 * standard deviation(x).

The data obtained with the instruments on the carriage have been checked using only the statistical parameters obtained from the time series. Because the current velocity meters on the carriage have a different position in the vertical only, the results should be of similar order per wave-hour. If this is not the case, the result is taken to be an outlier.

Inspection

Detected outliers are analysed one by one to see what might be the cause. Given the tests described earlier there are a number of possible data-checks:

1 visual inspection of part of the time series,
2 comparing the zero-level measurements before and after a wave hour.

The criterion in case of visual inspection of the time series is that all time series should give similar results (corresponding to progressing waves travelling from the wave board to the water line). Differences occur in case of malfunctioning:

- breakdown: no signal;
- in case where the instrument is buried in the sand due to bed level changes: no signal;
- in case instruments are outside fluid domain (eg. EMF above wave trough level): signal stays at cut-off value.

The criterion in the second case is that the zero-level value before and after a wave hour should be of the same order for all instruments. If one of the criteria is not met the measurement data has been omitted from the set. The resulting set of outliers is presented in Appendix E, where the following codes have been used:

0: no measurements performed
1: instrument not deployed
2: instrument break down
3: instrument (sometimes) above water level
4: instrument buried
5: wandering offset
6: parameter not computed
7: series too short

3.7 Data storage and retrieval

The data described above are stored on the accompanying disk 1. This is a MS-DOS compatible 1.44 MB HD disk. To install the data on your hard disk, you need approx. 6 MB of disk space. The following steps unwrap the disk:

- Make a directory on your hard disk. Type:
  c:
  md \LIPDATA
- Type **a:** to go to the diskette.
- Copy the whole disk including sub-directories to your directory by typing:
  xcopy /S a:*.* c:\LIPDATA

The files on the disk are archived in .ARC files using the program PKARC. The .ARC files can be un-archived using the program PKXARC which is included on Disk 1. Copy this program to your utilities directory. To un-archive the .ARC files in a specific directory go to the directory and type:

pkarc -e *.arc *.*

The disk contains the sub-directories:

- TRANSP; this directory contains files which each have two measured bottom profiles, averaged over three sections, the differences between the two mean profiles and the transport rates derived from these differences, as in Section 3.3. Results are given at 0.5 m intervals, although the full sets have been used to derive the transport rates.

- VAT; this directory contains self-descriptive files with the results of the analysis of suction and botton samples in the Visual Accumulation Tube.

- HYDRODAT; this directory contains parameter files which collect all parameters derived from the time series.

Data from the parameter files in HYDRODAT can be selected quite conveniently by a utility program COLLEC.EXE. The program assumes that it is run from the directory immediately above sub-directory HYDRODAT. (This is the case if you have followed the instructions above). To make a selection of data go to the main directory LIPDATA and type:

collec

The program asks for a test name. Type the code for the test you want. Legal codes are given in the file "tests". The code you type may include one ore more "*" as wild-characters, i.e.

2B0506	to get data from just this test, or
2B****	to get data from all tests in series 2B, or
******06**	to get data from all measurements at position 06, or
2*****	to get data from all tests in series 2, or
********	to get data from all tests.

Note that the input is case-sensitive; only capital letters are allowed here.
Next, the program asks for an instrument name. Legal names are given in the file "instrum". Again the input is case-sensitive (capitals only) and "*" is allowed as wild-character. For instance, type

EMF11	to get data from the lowest current meter, or:
EMF1*	to get data from all current meters on the carriage.

Finally, the program asks for a variable name; legal variable names are listed in the file "varnames". The input is still case-sensitive. No wild-characters are allowed. For instance, type

mean	to get the average value of each selected instrument in each selected test.

The program writes the X, Y and Z values, the parameter values, the instrument and test codes to the file "collec.out". This file is overwritten each time the program is run. To save your results, copy them to another filename.

4 Tailoring for model validation

Even after reduction of the raw time series to integrated parameter values, the available amount of data is still overwhelming. For the use of the data in the validation of coastal profile models it is therefore convenient to generate sub-sets of the data, dedicated to specific aspects or sub-models. We will first discuss the model components. In Section 4.2, we describe the data requirements of each sub-model, and in Section 4.3 we explain the structure of the dedicated data files. In Section 4.4, the inclusion of part of the data in a G8M database is treated.

4.1 Model components

Although the existing process-based profile models vary in a number of aspects, their general structure is very similar (see e.g. Roelvink & Brøker, 1993); a wave model provides the translation from offshore boundary conditions to local conditions, where 1DV sub-models translate these conditions to near-bed velocity and transport. This boils down to the following sub-models which can be tested against data:

- wave model
- return flow model
- sediment concentration model
- near-bed orbital motion
- sediment transport model

4.2 Data required

In the next part we describe the measurement data required for the various sub-models, either as input or as data to be used for the validation (comparison between measurements and computations).

1) *Wave propagation model*

input data:
- H_{m0} (offshore boundary)
- T_p
- bottomprofile
- bottom roughness

measurement data for comparison:
- H_{m0} (x)
- set-up (x)
- fraction of breaking waves (x)

2) *return flow model*

input data:
- H_{m0}, T_p
- bottom roughness
- wave dissipation
- fraction of breaking waves
- orbital motion
- water depth

measurement data for comparison:
- mean velocity (z)
- mass flux

3) *sediment concentration model*
- mean velocity (z)
- D_{50}, D_{90}
- bottom roughness
- orbital motion
- water depth
- wave dissipation
- fraction of breaking waves

data for comparison:
- sediment concentration (z)
- reference concentration

4) *velocity moments (orbital motion model)*

input:
- H_{m0}
- water depth
- T_p
- fraction of breaking waves

data for comparison:
- third order short wave velocity moment
- third order bound long wave velocity moment
- U_{rms}

5) *Total sediment transport model*

input:
- mean velocity in the vertical
- time series of near-bed velocity
- D_{50}, D_{90}
- bottom roughness
- bottom level

data for comparison:
— transport obtained from measured bottom level changes

6) *Morphodynamic model*

input:
— time series H_{m0}, T_p, water depth
— bottom profile

output:
— bottom changes

Not all of the required input-data can be obtained from the measurements. Some of it because it was not measured during a specific test (eg. malfunction of instrument, video recordings not available for analysis) others because it can not be measured directly (e.g. wave dissipation). If this is the case the required input data will have to be computed with another model. To minimise the possible error in the input, these models will be calibrated using the measurement data.

4.3 Data presentation

All the data used for the validation is collected on accompanying disk 2. Examples for each type of file are presented in Appendices F, G, H and I. The format of the Tables, which have been divided into a number of data-blocks, is described below.

Appendix F

Data for wave-propagation model (subdirectory WAVEMOD).

The first block (BL0) contains:

- peak period, f 1/T
- ratio.

The second block (BL1):

- distance from wave paddle,
- bottom profile,
- ~~set-up data.~~ WATER LEVEL (m)

The third block (BL2)

- position w.r.t. wave paddle,
- significant wave height. H_{m0} (m)

The fourth block (BL3)

- position w.r.t. wave paddle
- mean water level set-up

Appendix G

Data for return flow model (subdirectory RTF)

The first block in each table gives:

- root mean square wave height,
- spectral peak period,
- D_{50} grain size,
- ripple height,
- measured fraction of breaking waves,
- estimated fraction of breaking waves,
- standard deviation of near -bed velocity,
- estimated dissipation,
- water depth,

The second block:

- height above bed-level,
- height wrt (concrete) bottom,
- return flow velocity.

Appendix H

Data for the sediment concentration model (subdirectory CONC)

Block 1 gives:

- mean velocity at 0.1 m above bed level,
- standard deviation of velocity at 0.1 m above bed level,
- 50% grain diameter,
- 90% grain diameter,
- ripple height,
- water depth,
- ~~estimated dissipation.~~ rms wave height
- peak period

The second block:

- height w.r.t. bed level,
- height w.r.t. (concrete) bottom,
- sediment concentration.

Appendix I

Data for the velocity moments (subdirectory VLM)

In this case there is a single block containing:

- root mean square wave height,
- spectral peak period,
- water depth,
- standard deviation of velocity at 0.1 m above bed level,
- estimated fraction of breaking waves,
- measured fraction of breaking waves,
- third order velocity moment associated with wave asymmetry,
- third order velocity moment associated with bound long waves.

4.4 Inclusion in G8M database

A summary of the hydrodynamic data has been built from the different data files and stored in a convenient way for modellers interested in the simulation of wave haights (spectral and statistical representations), set-up, undertow and velocity moments. Seven files corresponding to the seven tests (from 1A to 2C) have been created and included into the database wave and associated currents for coastal profile modelling set up during the MAST-G8M project (Hamm and Peronnard, 1995).

In each file, the following data could be found:

a) Three smoothed representative bottom profiles are provided corresponding to the initial, mid and final states of each test,

b) Mean values of Hm0, TpD and set-up together with their standard deviations. Mean and Std. have been computed after elimination of sub-tests performed with incident wave conditions too far from the mean (for instance, runs 1 to 6 of test 1B) and after elimination of spurious data (for instance, erroneous values of set-up from DRO08 in runs 2 and 8 in test 1C, see Appendix E). An example of such a computation is shown in Table 4.1 for test 1C,

c) Statistical and spectral parameters computed from the wave gauges records after elimination of sub-tests performed with incident wave conditions too far from the mean and after elimination of spurious data (see b above). The stored parameters are those discribed in Paragraph 3.1 except m2, m4, Tz, GF, Cr, skewness and kurtosis,

d) Fraction of breaking waves estimated from video records,

e) Vertical profiles of undertow

f) Near-bottom velocity moments estimated from the mobile electromagnetic currentmeters located at 0,10 m from the bottom. The file includes short-waves velocity moments gu2, gu3, gu5, gu2ux, gu3ux and guzx and the different contributions of the total third order odd moment gu2ux, guss, guls,gusc and guc (see Paragraph 3.1 for the = notations).

Table 4.1: Mean values and standard deviations of the measured significant wave height, peak period and set-up at fixed locations
TEST 1C with erroneous data ignored

Hm0

Fixed pressure sensors

	X(m)	1C0102D	1C0204D	1C0313D	1C0405D	1C0514D	1C0615D	1C0706D	1C0807D	1C0908D	1C1009D	1C1110D	1C1200D	1C1300D	Mean	Std	Std (%)
DR001	20	0.584	0.585	0.581	0.583	0.577	0.582	0.579	0.580	0.577	0.578	0.581	0.580	0.578	0.580	0.002	0.41
DR002	65	0.628	0.629	0.624	0.625	0.619	0.626	0.621	0.621	0.618	0.621	0.623	0.624	0.622	0.623	0.003	0.51
DR003	100	0.631	0.635	0.632	0.631	0.629	0.632	0.629	0.632	0.628	0.629	0.631	0.630	0.628	0.631	0.002	0.31
DR004	115	0.627	0.633	0.626	0.627	0.624	0.625	0.620	0.626	0.619	0.619	0.620	0.621	0.617	0.623	0.004	0.69
DR005	130	0.629	0.633	0.628	0.624	0.621	0.618	0.611	0.618	0.612	0.610	0.607	0.604	0.601	0.617	0.010	1.58
DR006	138	0.572	0.591	0.594	0.590	0.606	0.608	0.612	0.627	0.629	0.632	0.632	0.634	0.635	0.612	0.020	3.27
DR007	145	0.510	0.526	0.518	0.505	0.515	0.507	0.495	0.510	0.503	0.496	0.496	0.488	0.481	0.504	0.012	2.37
DR008	152	0.472	0.000	0.480	0.475	0.486	0.472	0.466	0.000	0.467	0.467	0.466	0.461	0.454	0.470	0.008	1.80
DR009	160	0.457	0.478	0.472	0.459	0.473	0.464	0.459	0.477	0.470	0.462	0.460	0.453	0.450	0.464	0.009	1.87
DR010	170	0.326	0.345	0.338	0.328	0.343	0.331	0.325	0.342	0.337	0.333	0.336	0.332	0.327	0.334	0.007	1.98

TpD

Fixed pressure sensors

	X(m)	1C0102D	1C0204D	1C0313D	1C0405D	1C0514D	1C0615D	1C0706D	1C0807D	1C0908D	1C1009D	1C1110D	1C1200D	1C1300D	Mean	Std	Std (%)
DR001	20	7.99	7.97	7.99	7.98	7.97	7.98	7.97	7.97	7.98	7.97	7.97	7.97	7.97	7.975	0.006	0.07
DR002	65	7.95	7.94	7.96	7.97	7.96	7.98	7.99	7.98	7.99	8.00	8.00	8.01	8.01	7.981	0.021	0.26
DR003	100	7.98	7.98	8.01	8.01	8.00	8.03	8.03	8.03	8.04	8.05	8.05	8.05	8.05	8.025	0.023	0.28
DR004	115	7.98	8.00	8.02	8.01	8.00	8.02	8.01	8.01	8.02	8.02	8.02	8.01	8.01	8.009	0.010	0.12
DR005	130	7.91	7.93	7.95	7.93	7.93	7.94	7.93	7.94	7.95	7.94	7.94	7.93	7.93	7.936	0.008	0.10
DR006	138	7.81	7.84	7.84	7.80	7.82	7.80	7.79	7.81	7.81	7.79	7.80	7.79	7.78	7.806	0.017	0.22
DR007	145	7.92	7.92	7.93	7.92	7.93	7.92	7.93	7.93	7.92	7.93	7.93	7.93	7.94	7.928	0.006	0.07
DR008	152	7.91	0.00	7.93	7.92	7.94	7.92	7.91	0.00	7.93	7.92	7.93	7.93	7.93	7.925	0.009	0.11
DR009	160	10.48	9.21	8.78	10.00	8.75	9.09	9.11	9.05	8.80	9.03	9.11	9.24	10.11	9.288	0.529	5.69
DR010	170	19.76	19.64	19.63	19.62	19.55	19.66	19.65	19.62	19.69	19.67	19.70	19.71	19.79	19.668	0.061	0.31

Set-Up

Fixed pressure sensors

	X(m)	1C0102D	1C0204D	1C0313D	1C0405D	1C0514D	1C0615D	1C0706D	1C0807D	1C0908D	1C1009D	1C1110D	1C1200D	1C1300D	Mean	Std	Std (%)
DR001	20	-0.013	-0.013	-0.012	-0.011	-0.010	-0.013	-0.010	-0.013	-0.009	-0.010	-0.011	-0.011	-0.011	-0.011	0.001	11.05
DR002	65	-0.016	-0.018	-0.010	-0.014	-0.014	-0.016	-0.015	-0.021	-0.001	-0.004	-0.014	-0.026	-0.022	-0.015	0.007	44.83
DR003	100	-0.022	-0.023	-0.008	-0.026	-0.029	-0.021	-0.019	-0.022	0.036	0.011	-0.050	-0.064	-0.065	-0.023	0.026	113.25
DR004	115	-0.018	-0.018	-0.012	-0.016	-0.016	-0.019	-0.016	-0.019	-0.014	-0.012	-0.016	-0.015	-0.015	-0.016	0.002	13.13
DR005	130	-0.021	-0.020	-0.009	-0.017	-0.018	-0.021	-0.018	-0.022	-0.013	-0.014	-0.018	-0.017	-0.015	-0.017	0.003	19.12
DR006	138	-0.021	-0.024	-0.016	-0.021	-0.021	-0.026	-0.023	-0.028	-0.022	-0.021	-0.024	-0.024	-0.023	-0.023	0.003	12.13
DR007	145	-0.012	-0.016	-0.006	-0.008	-0.009	-0.013	-0.010	-0.013	-0.006	-0.007	-0.010	-0.006	-0.006	-0.009	0.003	33.42
DR008	152	-0.008	0.000	0.000	-0.005	-0.004	-0.008	-0.016	0.000	-0.002	-0.000	-0.005	0.004	-0.001	-0.004	0.005	123.17
DR009	160	-0.012	-0.015	-0.009	-0.010	-0.009	-0.013	-0.009	-0.011	-0.010	-0.009	-0.008	-0.006	-0.009	-0.010	0.002	21.84
DR010	170	0.018	0.012	0.016	0.017	0.016	0.013	0.018	0.014	0.015	0.017	0.018	0.018	0.017	0.016	0.002	11.56

underlined figures: erroneous data (see MALFUN file)

References

Arcilla, A.S.-, J.A. Roelvink, B.A. O'Connor, A. Reniers and J.A. Jimenez (1994) The Delta Flume '93 Experiment. Proc. Coastal Dynamics Conf., UPC, Barcelona, Feb. 1994, pp. 488-502.

Beyer, D. (1994) Energy dissipation in random breaking waves: the probability of breaking. M.Sc. Thesis, Delft Univ. of Technology, June 1994.

Boers, M. (1994) Bed forms and bed roughness in the surf zone. Proc. Int. Symp. Waves - Physical and numerical modelling, Univ. of British Columbia, Vancouver, Canada, August 1994.

Collado, F., A.S.-Arcilla, M.G. Coussirat and J. Prieto (1994) 2DV Circulation pattern: wave decay and undertow modelling with NEARCIR code. Proc. Coastal Dynamics Conf., UPC, Barcelona, Feb. 1994, pp. 556-570.

DELFT HYDRAULICS, (1995). Validation study of UNIBEST-TC, DELFT HYDRAULICS, Jan. 1995.

Hamm, L. and C. Peronnard (1995). Database waves and associated currents for coastal profile modelling. Internal report MAST-G8M, SOGREAH report n=B052184R6, February 1995.

Hamm, L. and J.A. Roelvink (1994) Short and long wave transformation modelling in a large scale flume. Proc. Coastal Dynamics Conf., UPC, Barcelona, Feb. 1994, pp. 503-517.

Mocke, G., A. Reniers and G. Smith (1994) A surfzone parameter sensitivity analysis on LIP11D suspended sediment and return flow measurements. Proc. Coastal Dynamics Conf., UPC, Barcelona, Feb. 1994, pp. 571-585.

Nicholson, J. and B.A. O'Connor (1994) Calibration and validation of a cross-shore transport model. Proc. Coastal Dynamics Conf., UPC, Barcelona, Feb. 1994, pp. 586-598.

O'Connor, B.A. and J. Nicholson (1993) Calibration and validation of a Watanabe-type cross-shore transport model. In: G8M Coastal Morphodynamics Overall Workshop, Abstracts in-depth, September 1993, Delft Hydraulics.

Reniers, A.J.H.M. (1993) The use of UNIBEST-TC in LIP-experiment. In: G8M Coastal Morphodynamics Overall Workshop, Abstracts in-depth, September 1993, Delft Hydraulics.

Reniers, A.J.H.M and J.A. Roelvink (1994) Validation of cross-shore hydrodynamic modelling. In: G8M Coastal Morphodynamics Overall Workshop, Abstracts in-depth, September 1994, Delft Hydraulics.

Rivero, F.J., A.S.-Arcilla and D. Beyer (1994) Comparison of a wave transformation model with LIP-11D data. Proc. Coastal Dynamics Conf., UPC, Barcelona, Feb. 1994, pp. 518-532.

Roelvink, J.A. (1993) Surface roller effect in a surf beat model. In: G8M Coastal Morphodynamics Overall Workshop, Abstracts in-depth, September 1993, Delft Hydraulics.

Roelvink, J.A. and I. Brøker (1993) Cross-shore profile models. Coastal Engineering, 21 (1993) pp. 163-191.

Southgate, H.N. and H.M. Wallace (1994) Breaking wave persistence in parametric surf zone models. Proc. Coastal Dynamics Conf., UPC, Barcelona, Feb. 1994, pp. 543-555.

Stive, M.J.F. and H.J. de Vriend (1994) Verification of the shearstress boundary condition in the undertow problem. Proc. Coastal Dynamics Conf., UPC, Barcelona, Feb. 1994, pp. 533-542.

Stive, M.J.F., H.J. de Vriend, R.J. Nicholls and M. Capobianco (1992) Shore nourishment and the active zone: a time scale dependent view. Proc. 23rd Int. Conf. on Coastal Eng., ASCE, pp. 2464-2473.

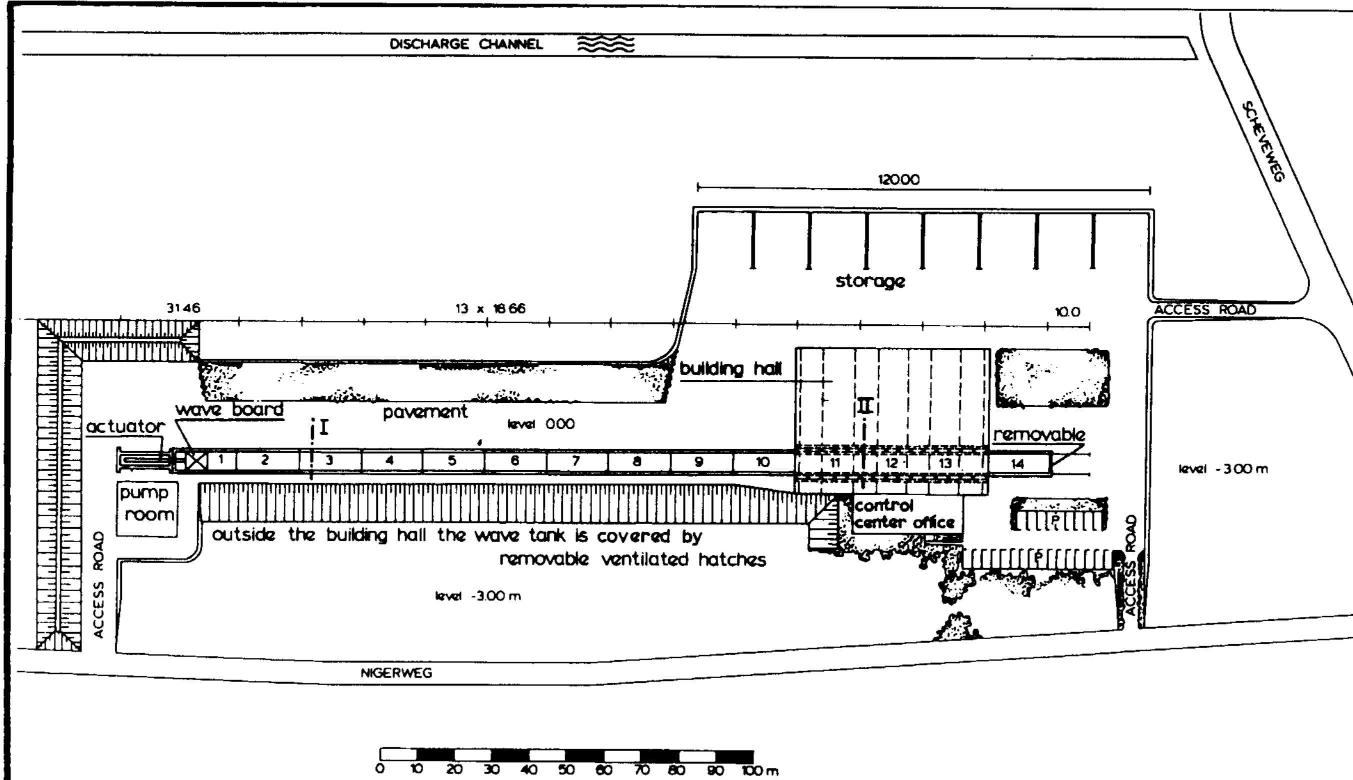
Van Rijn (1989) Handbook Sediment transport by currents and waves. Delft Hydraulics Report H461, June 1989.

Van Vledder (1993) Evaluation of model performance. DELFT HYDRAULICS report H1224, 1993.

Wallace, H. (1993) Comparison of a three-layer undertow model with data. In: G8M Coastal Morphodynamics Overall Workshop, Abstracts in-depth, September 1993, Delft Hydraulics.

Wallace, H. and H.N. Southgate (1993) Comparisons of COSMOS-2D profile results with LIP11D data. In: G8M Coastal Morphodynamics Overall Workshop, Abstracts in-depth, September 1993, Delft Hydraulics.

Walstra, D.J., M. Piepers, J.A. Roelvink and G.S. Stelling (1994) 2-DV modelling of surfzone currents. In: G8M Coastal Morphodynamics Overall Workshop, Abstracts in-depth, September 1994, Delft Hydraulics.



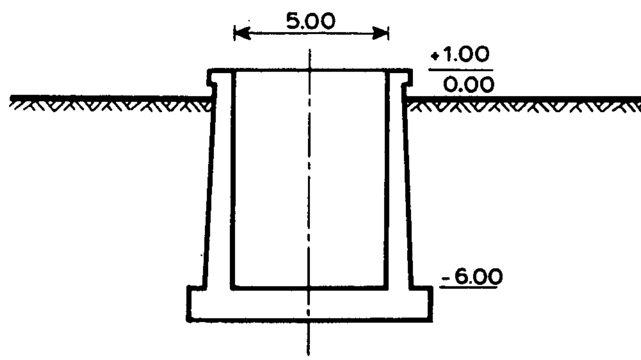
wave tank : length 233 m
(1...14) width 5 m
depth 7 m

deep section : length 50 m
(11, 12, 13) width 5 m
depth 9.5 m

wave board : piston-type with water on one side only

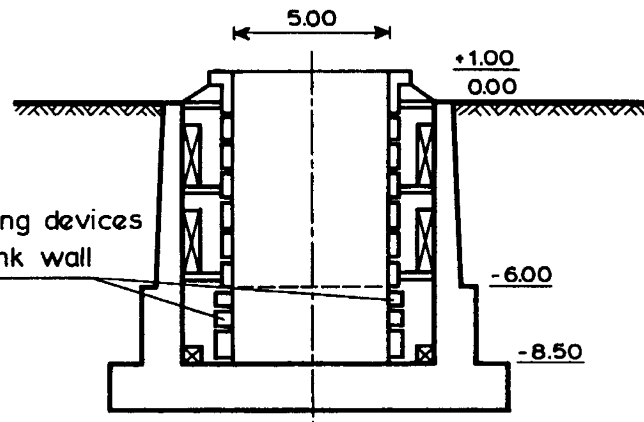
wave frequency range ~0.1 - 0.5 Hz

max. wave height at 5 m water depth :
periodic ~2.5 m
random ~1.75 m significant



CROSS-SECTION I (1...10,14)

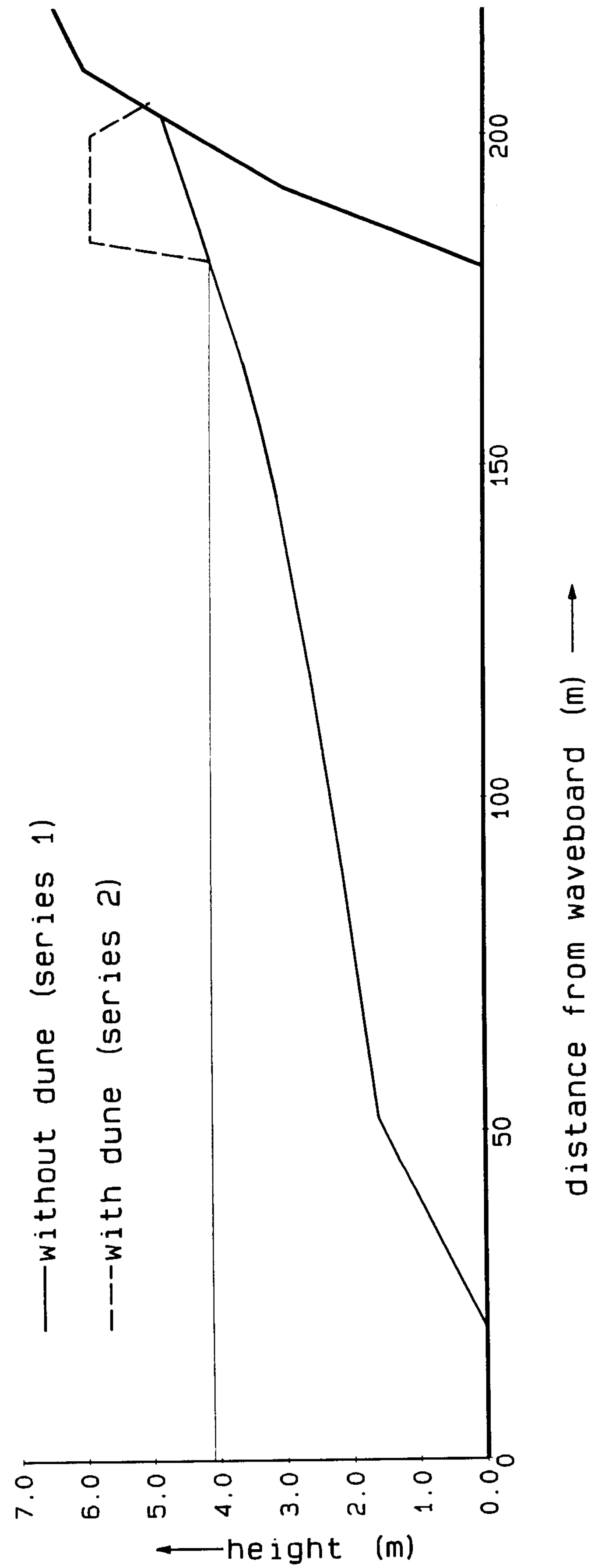
possibility to mount measuring devices or windows through the tank wall



CROSS-SECTION II (11, 12, 13)

DELTA FLUME

DELFT HYDRAULICS LABORATORY | H 2130 | FIG. 1.1

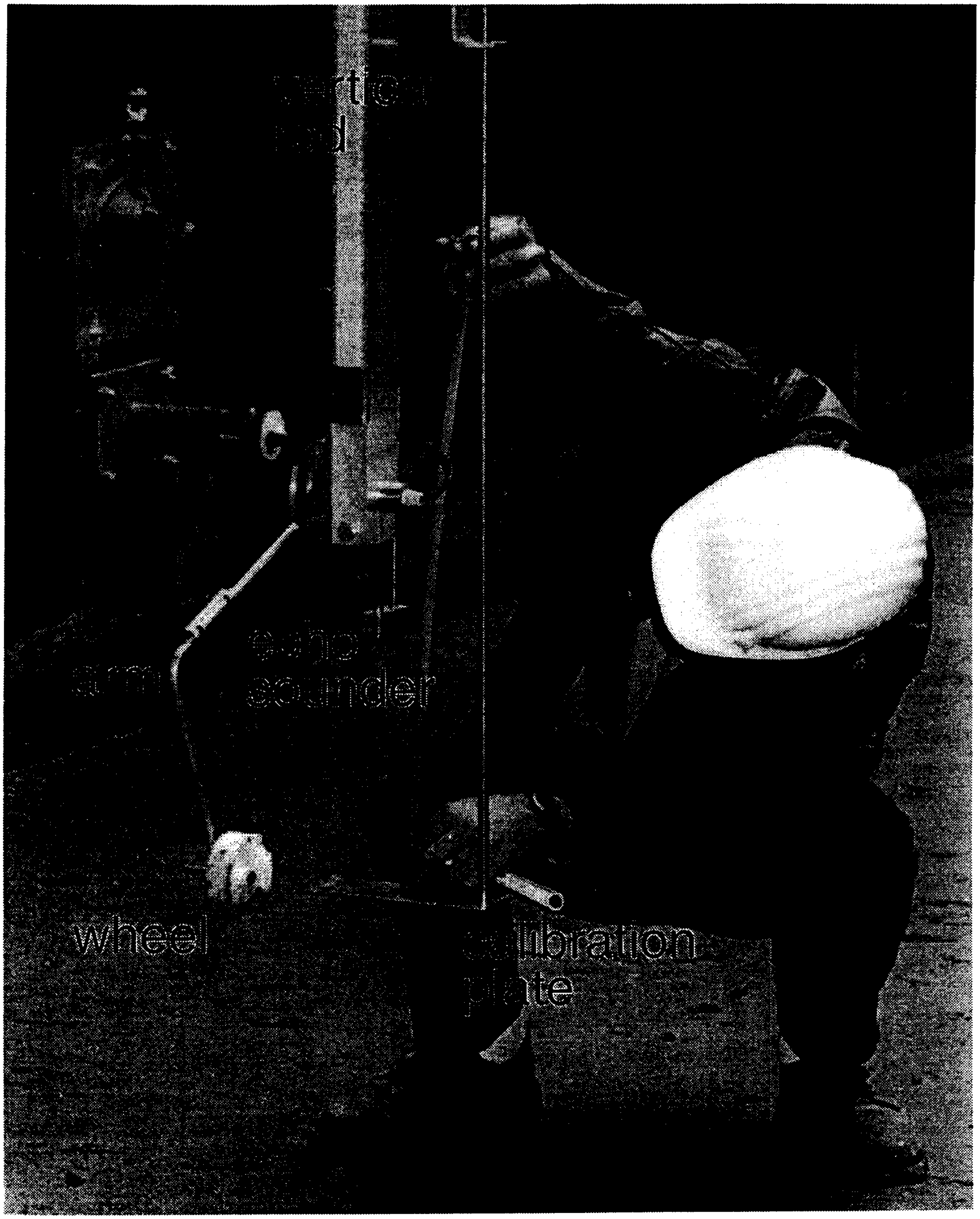


INITIAL BOTTOM PROFILE

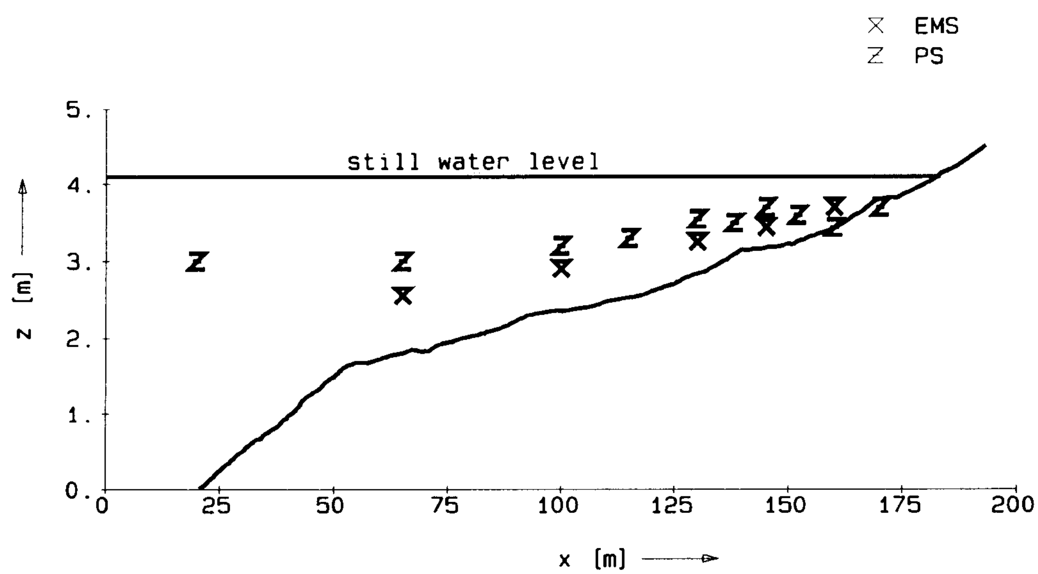
DELFT HYDRAULICS

H 2130

FIG. 2.1

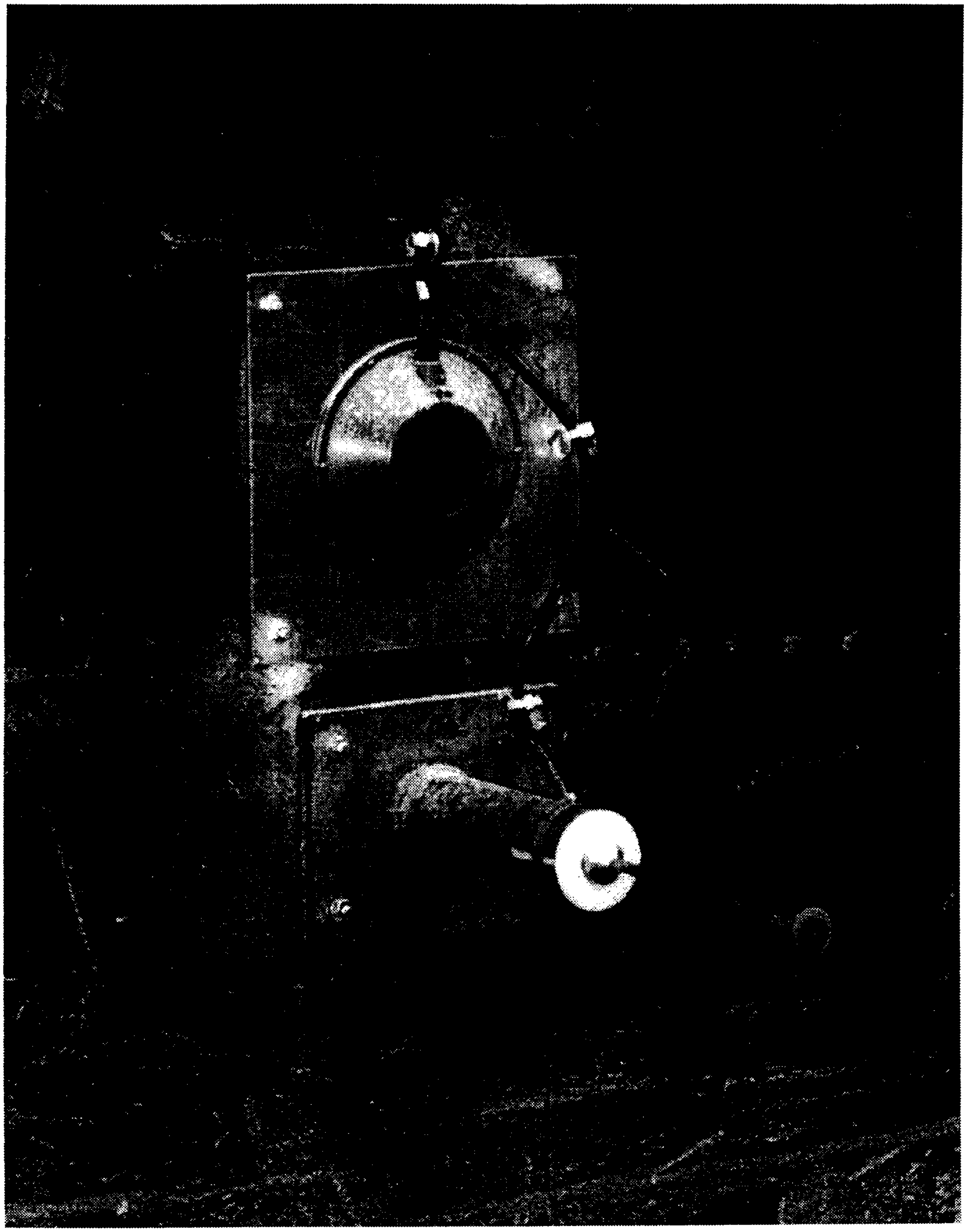


Profile follower (PROVO)



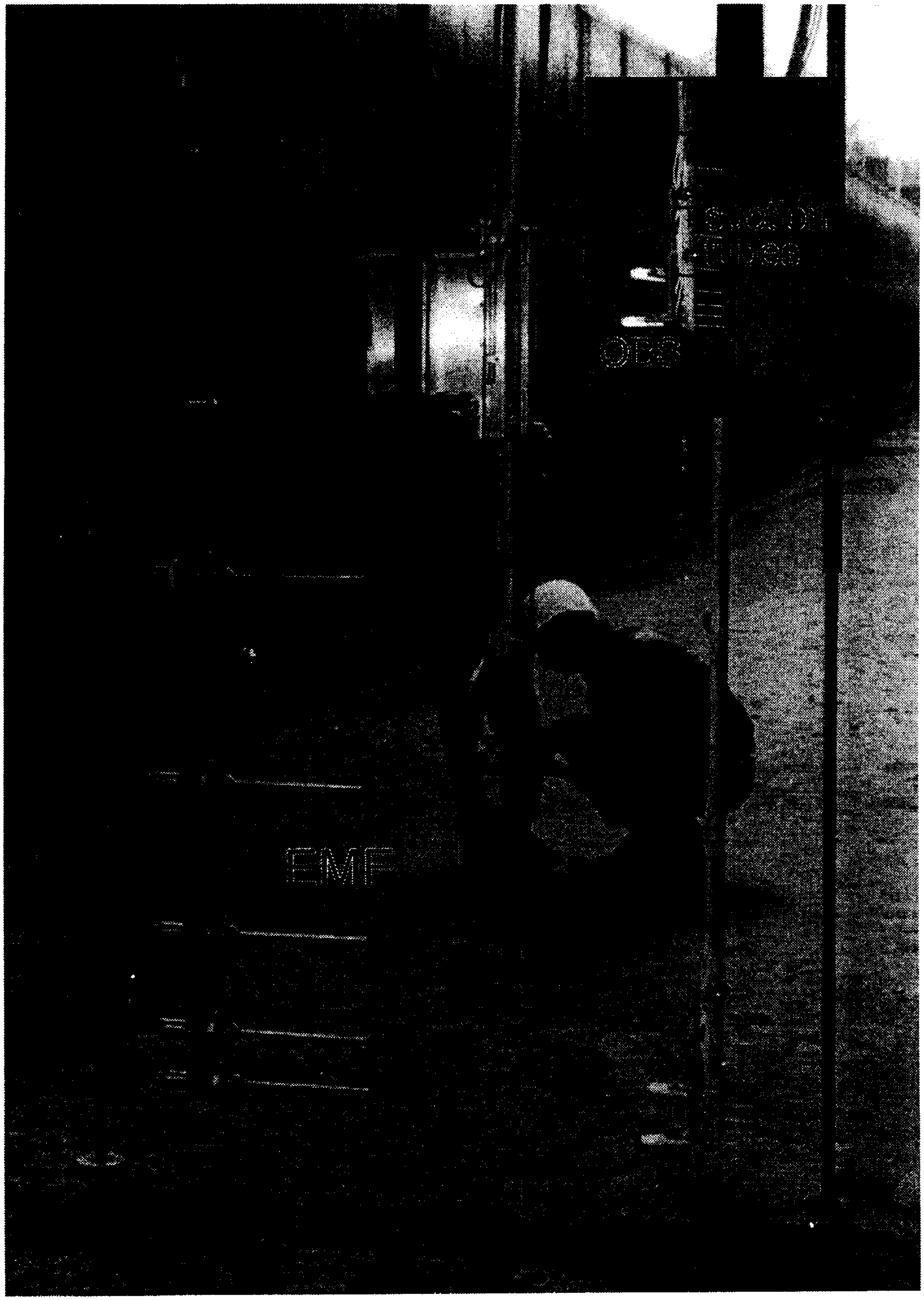
POSITIONS OF FIXED INSTRUMENTS

DELFT HYDRAULICS | H 2130 | FIG. 2.3

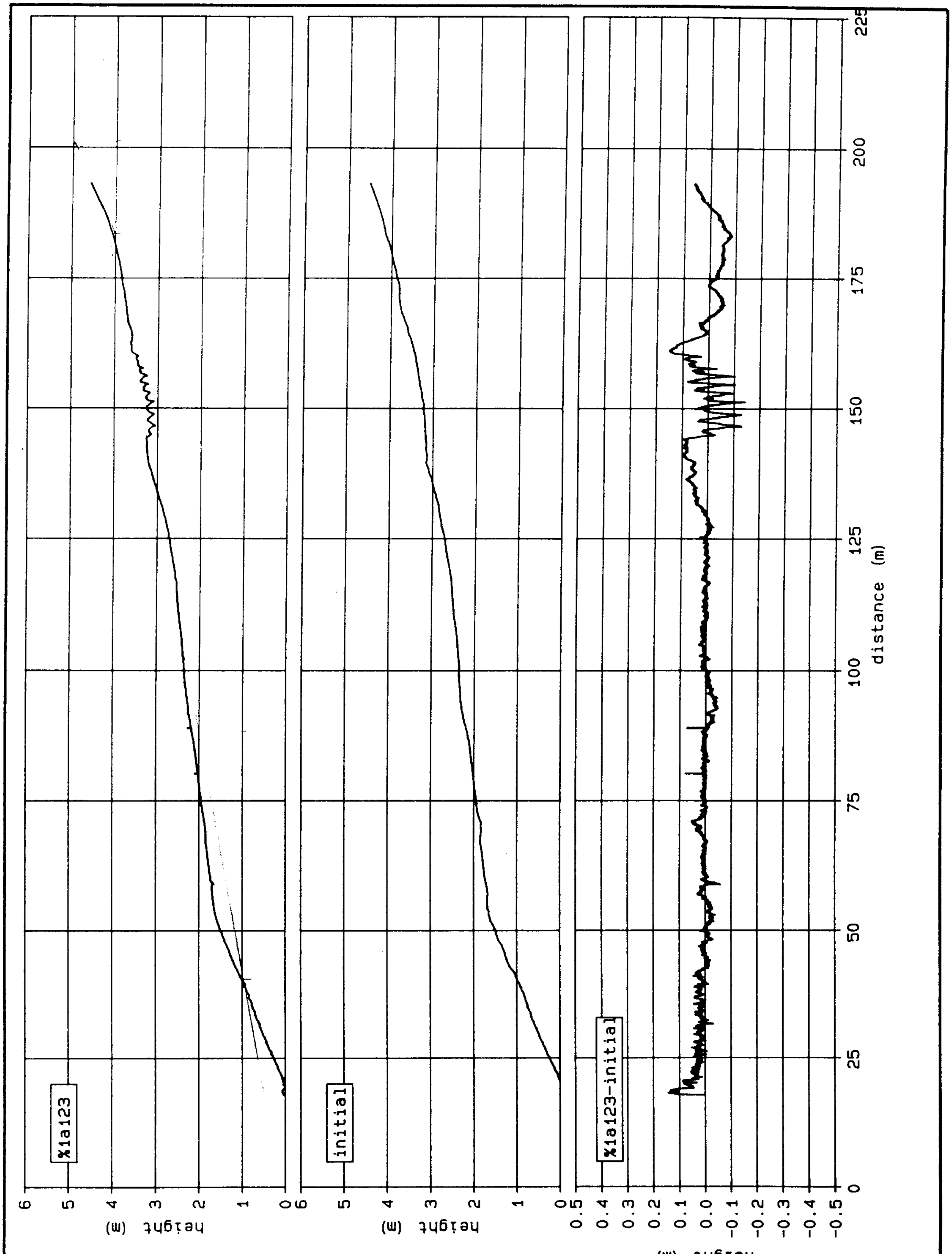


Layout of fixed pressure sensor
and EMF current meter

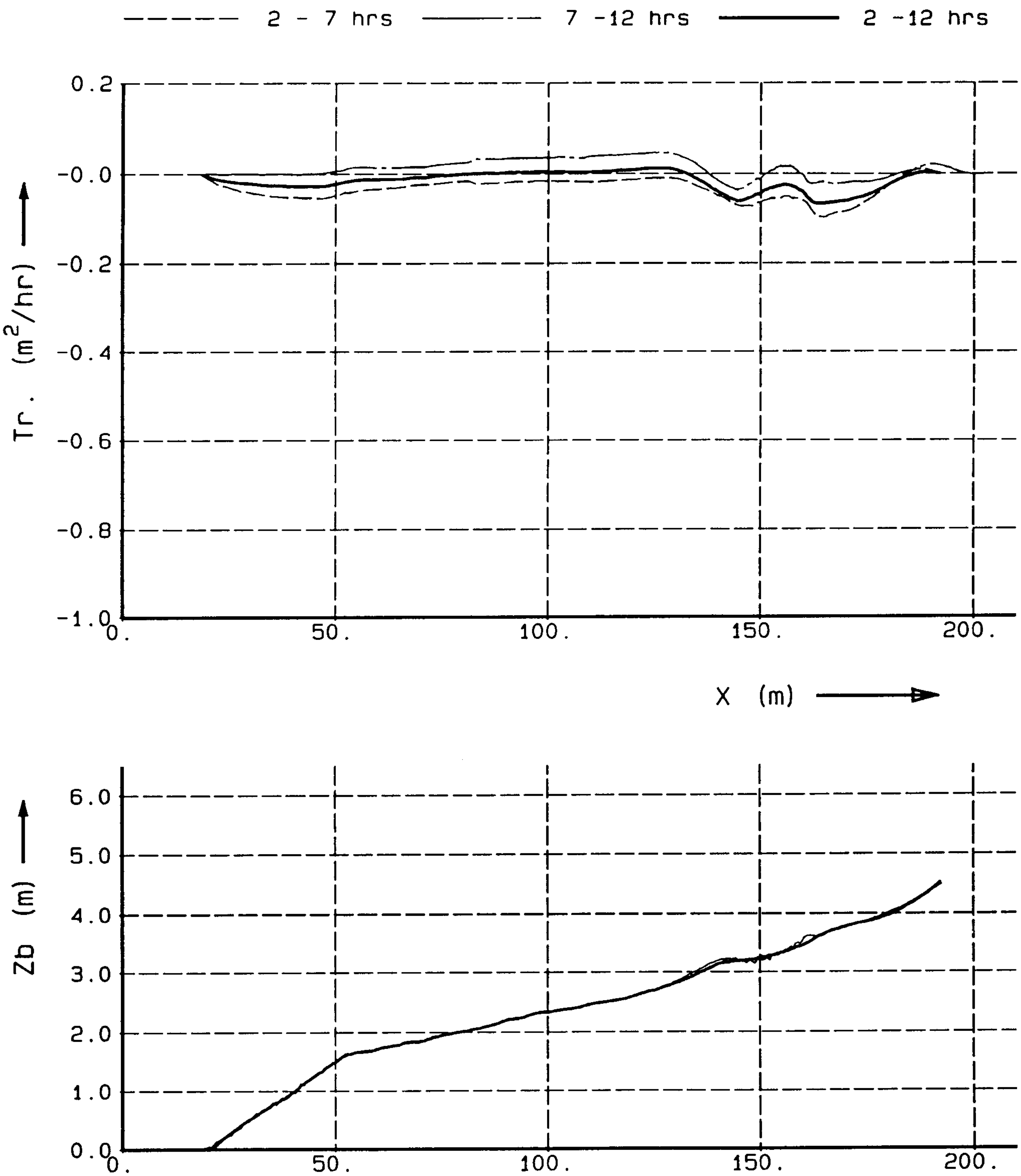
DELFT HYDRAULICS	H2130	FIG. 2.4



Layout of instruments attached to carriage

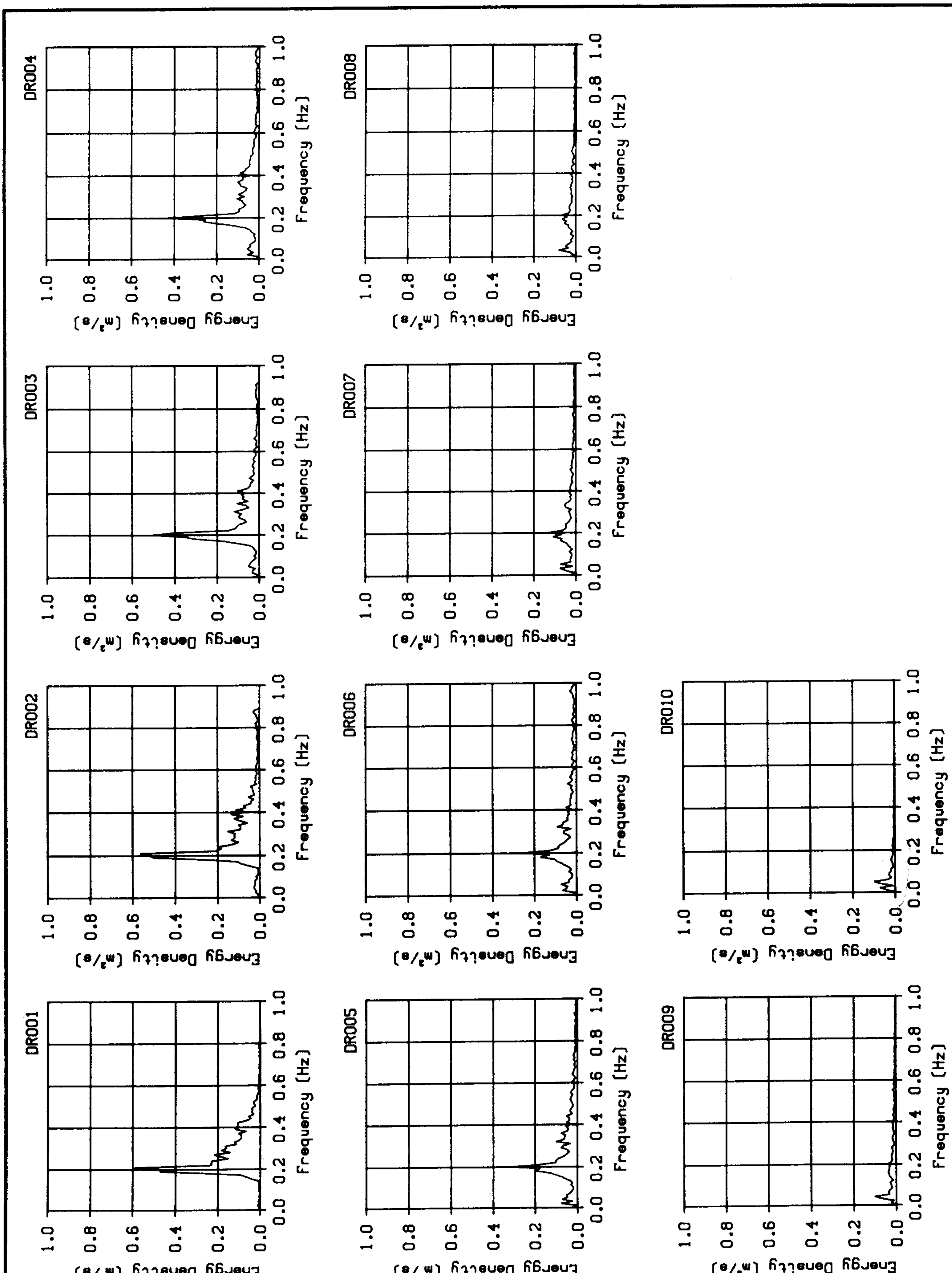


Profile development after 12 hours : line 3 : test 1a	%1a123
DELFT HYDRAULICS	H1572	FIG. 3.1.1

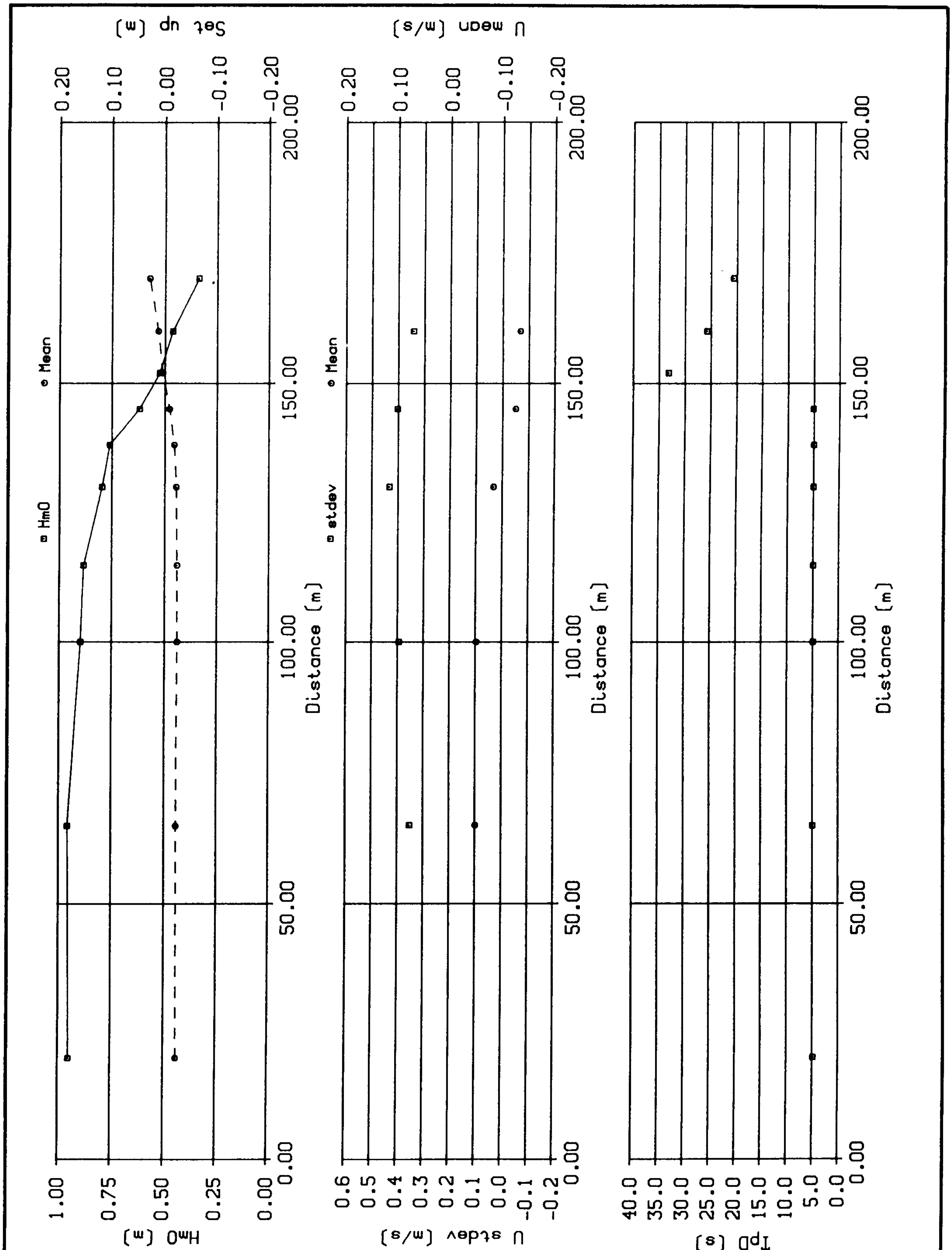


INFERRED TRANSPORT RATES, TEST 1A

DELFT HYDRAULICS | H 2130 | FIG. 3.1.2

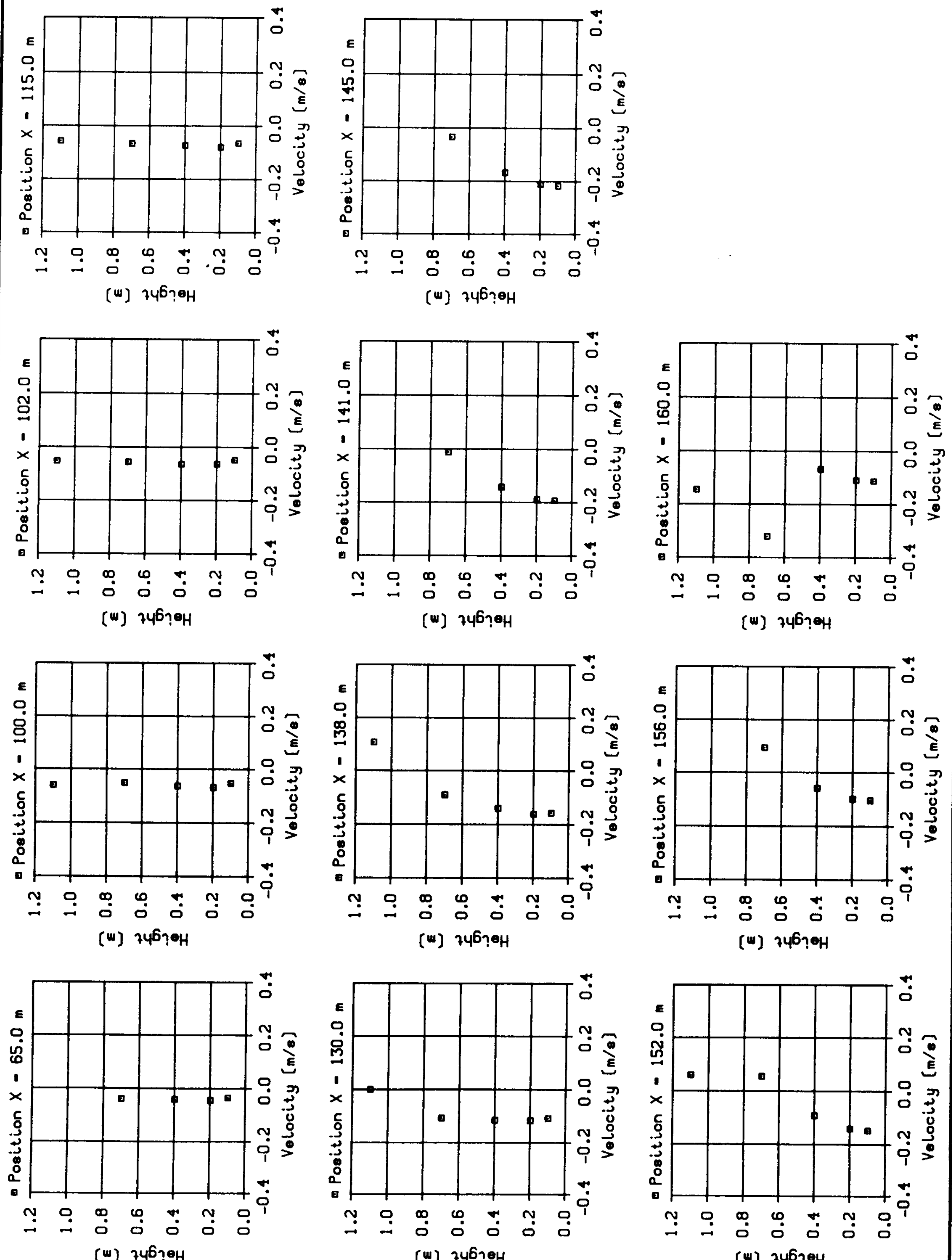


SURFACE ELEVATION SPECTRA BASED ON PRESSURE SENSORS	1A0607	
DELFT HYDRAULICS	H1572	FIG. 3.1.3

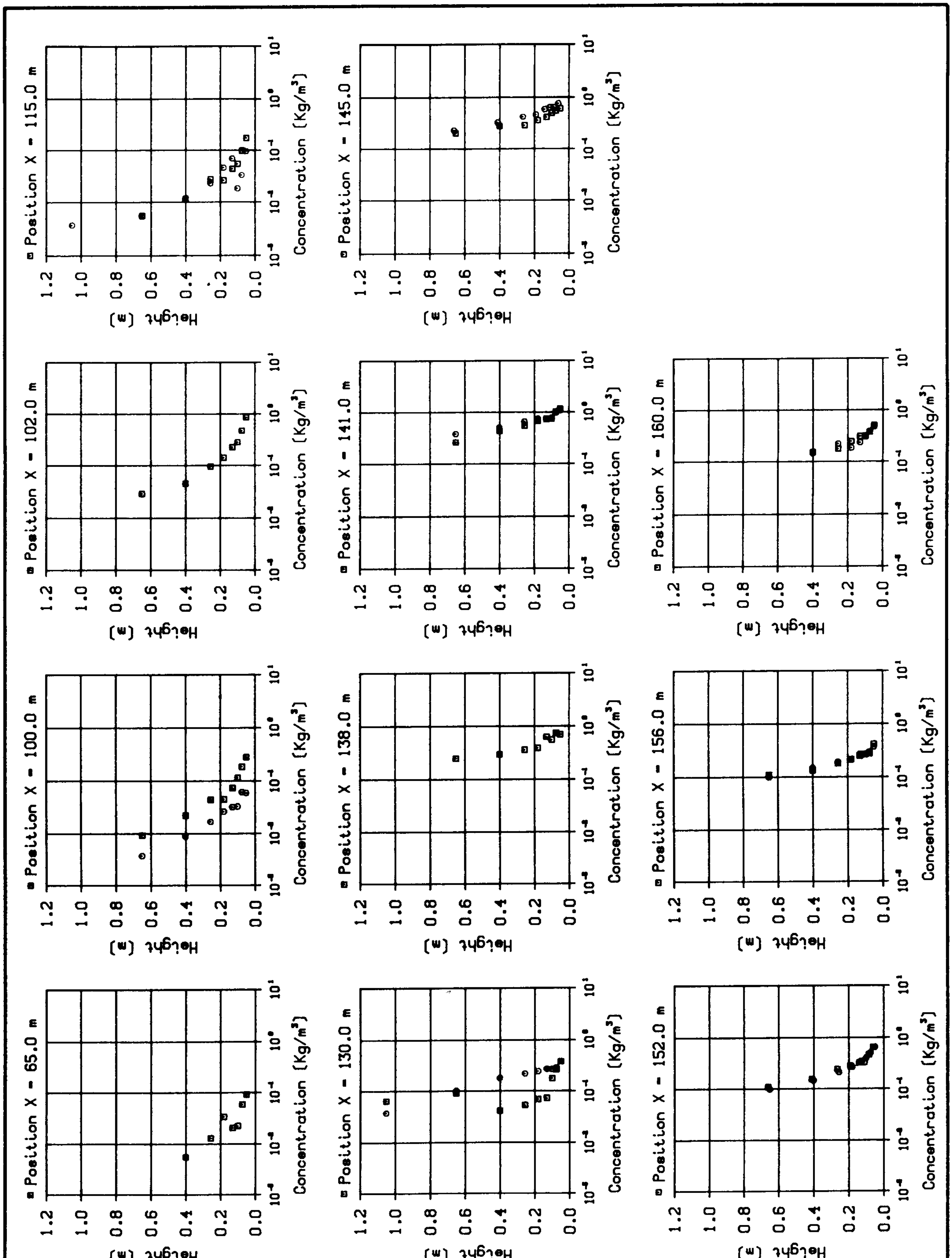


INTEGRAL SURFACE ELEVATION AND VELOCITY DATA
BASED ON FIXED INSTRUMENTS, TEST 1A

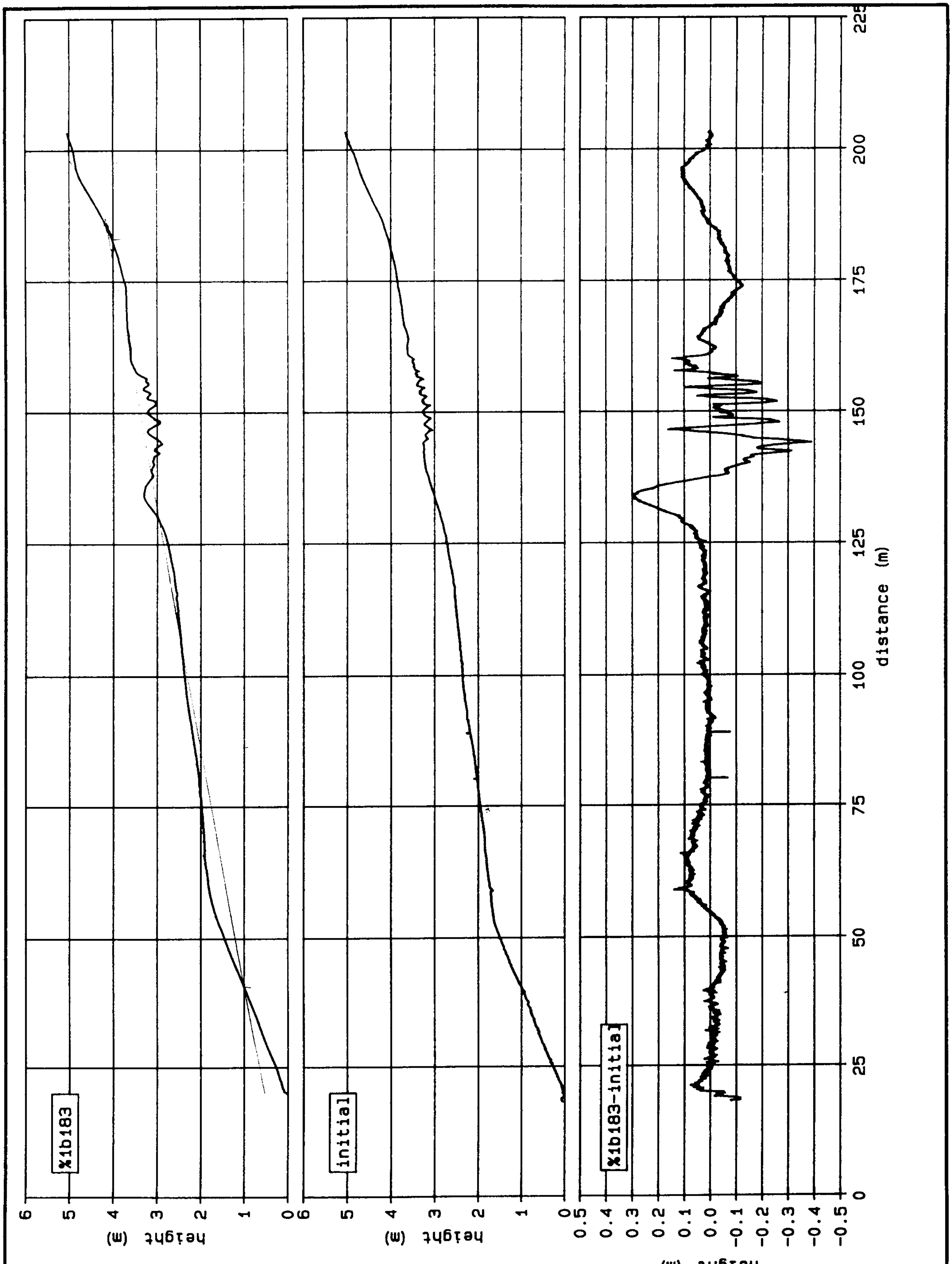
	#1A0607	
DELFT HYDRAULICS	H1572	FIG. 3.1.4



VELOCITY RESULTS	1A	
DELFT HYDRAULICS	H1572	FIG. 7.1.5



CONCENTRATION RESULTS	1A	
DELFT HYDRAULICS	H1572	FIG. 3.1.6



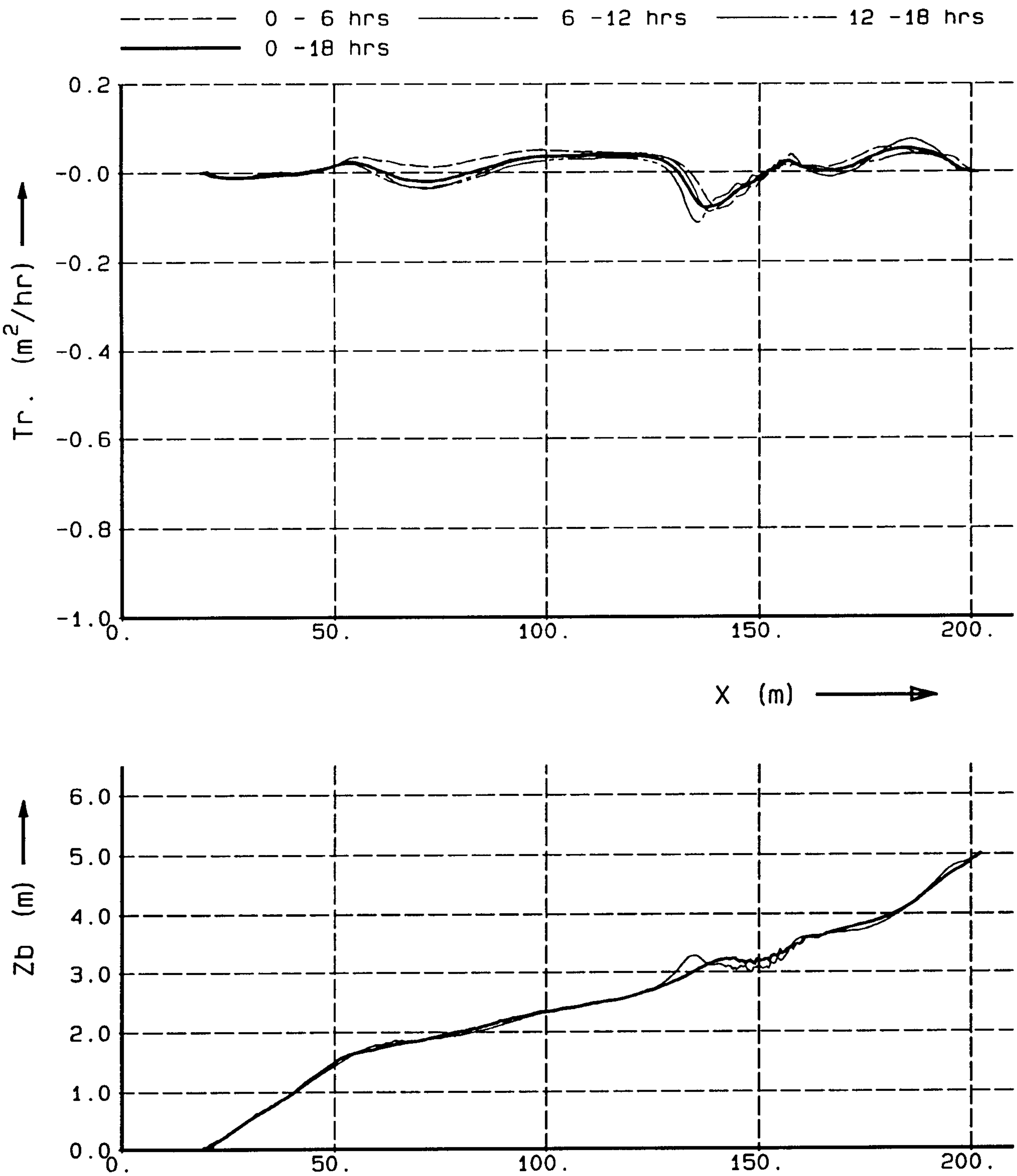
Profile development after 18 hours :
line 3 : test 1b

%1b183

DELFT HYDRAULICS

H1572

FIG. 3.2.1

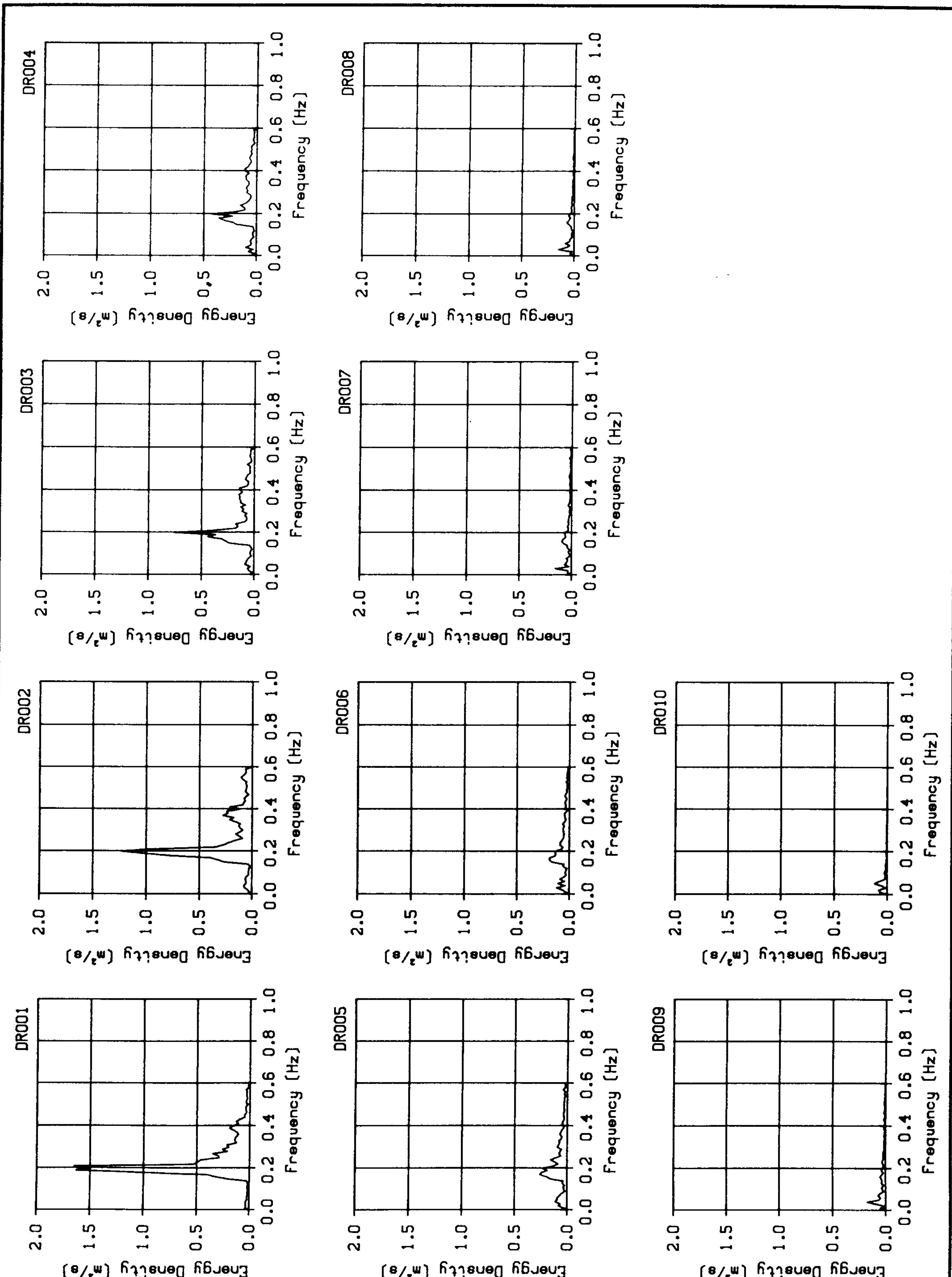


INFERRED TRANSPORT RATES, TEST 1B

DELFT HYDRAULICS

H 2130

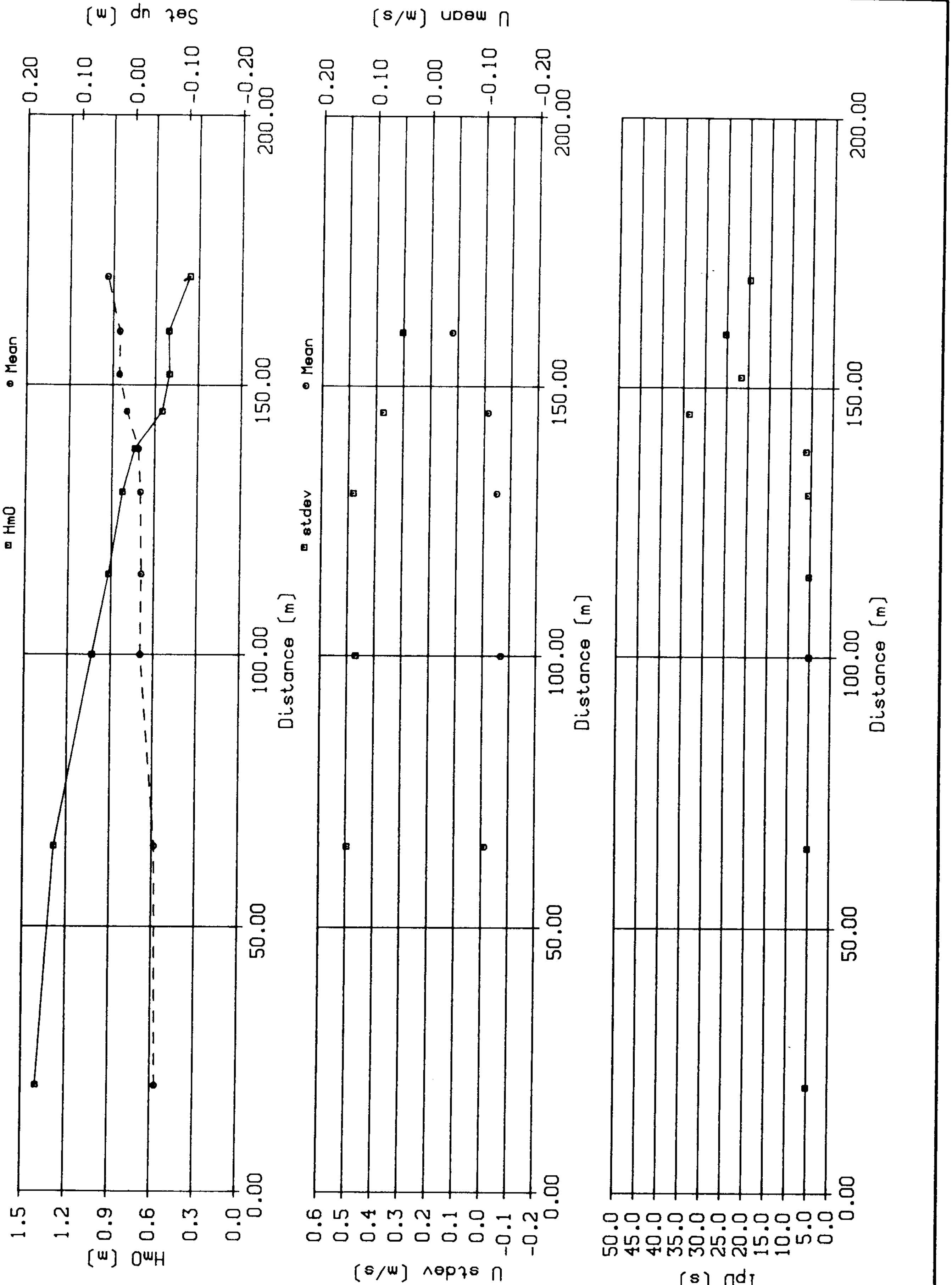
FIG. 3.2.2



SURFACE ELEVATION SPECTRA
BASED ON PRESSURE SENSORS

1B0909	

DELFT HYDRAULICS | H1572 | FIG. 3.2.3



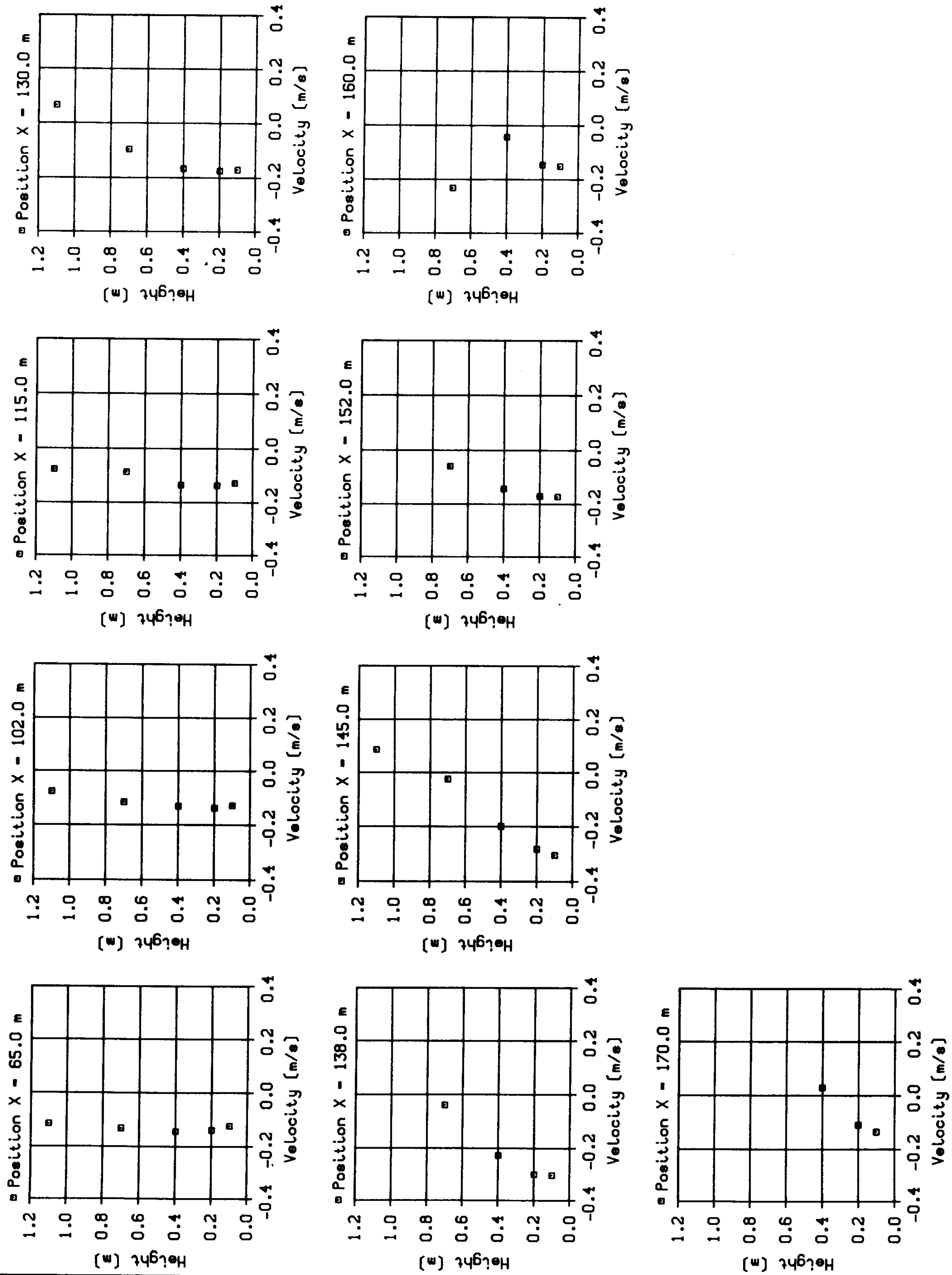
INTEGRAL SURFACE ELEVATION AND VELOCITY DATA
BASED ON FIXED INSTRUMENTS, TEST 1B

#1B0909

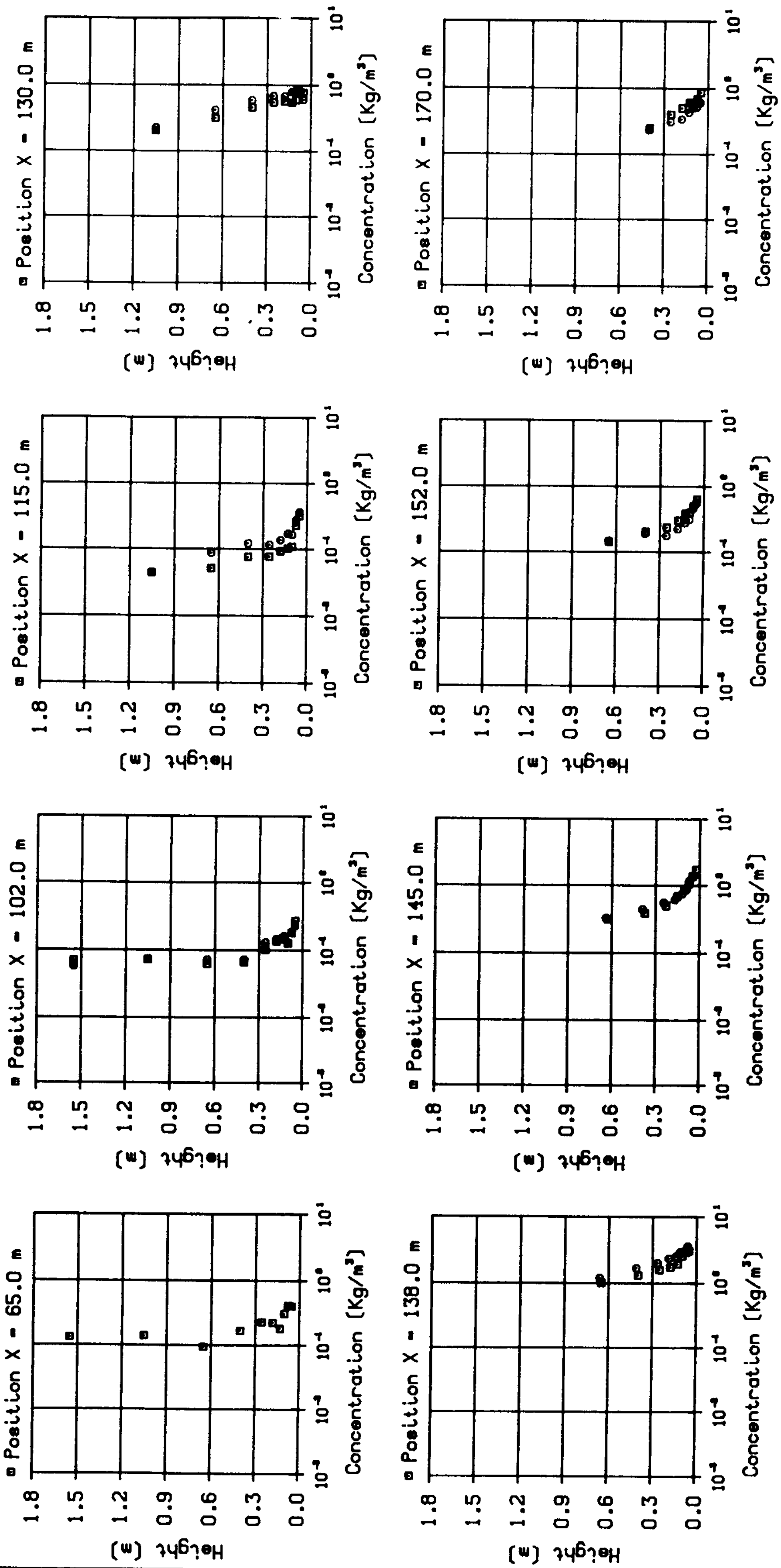
DELFT HYDRAULICS

H1572

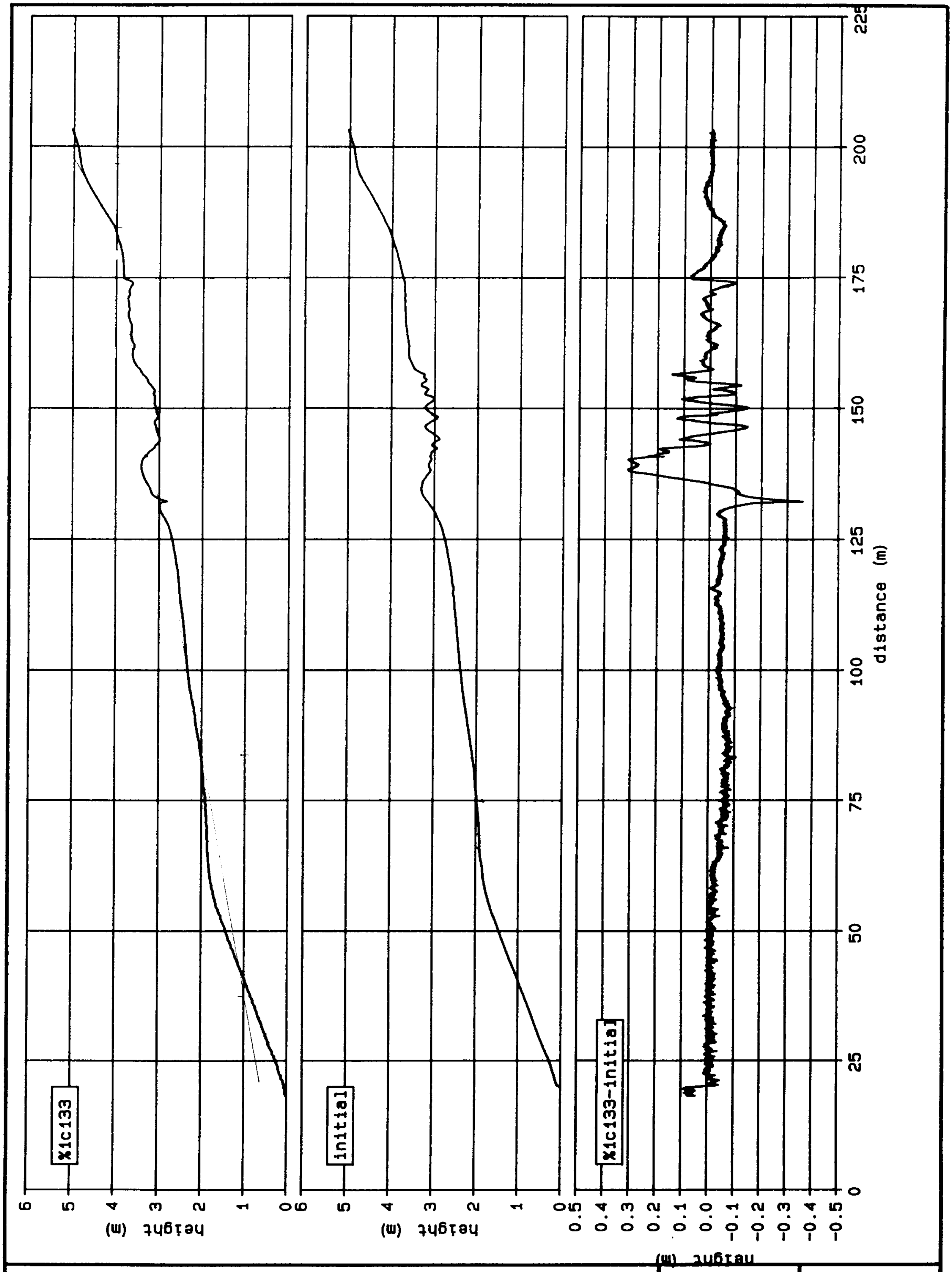
FIG. 3.2.4



VELOCITY RESULTS	1b	
DELFT HYDRAULICS	H1572	FIG. 3.2.5



CONCENTRATION RESULTS	1B	
DELFT HYDRAULICS	H1572	FIG. 3.2.6



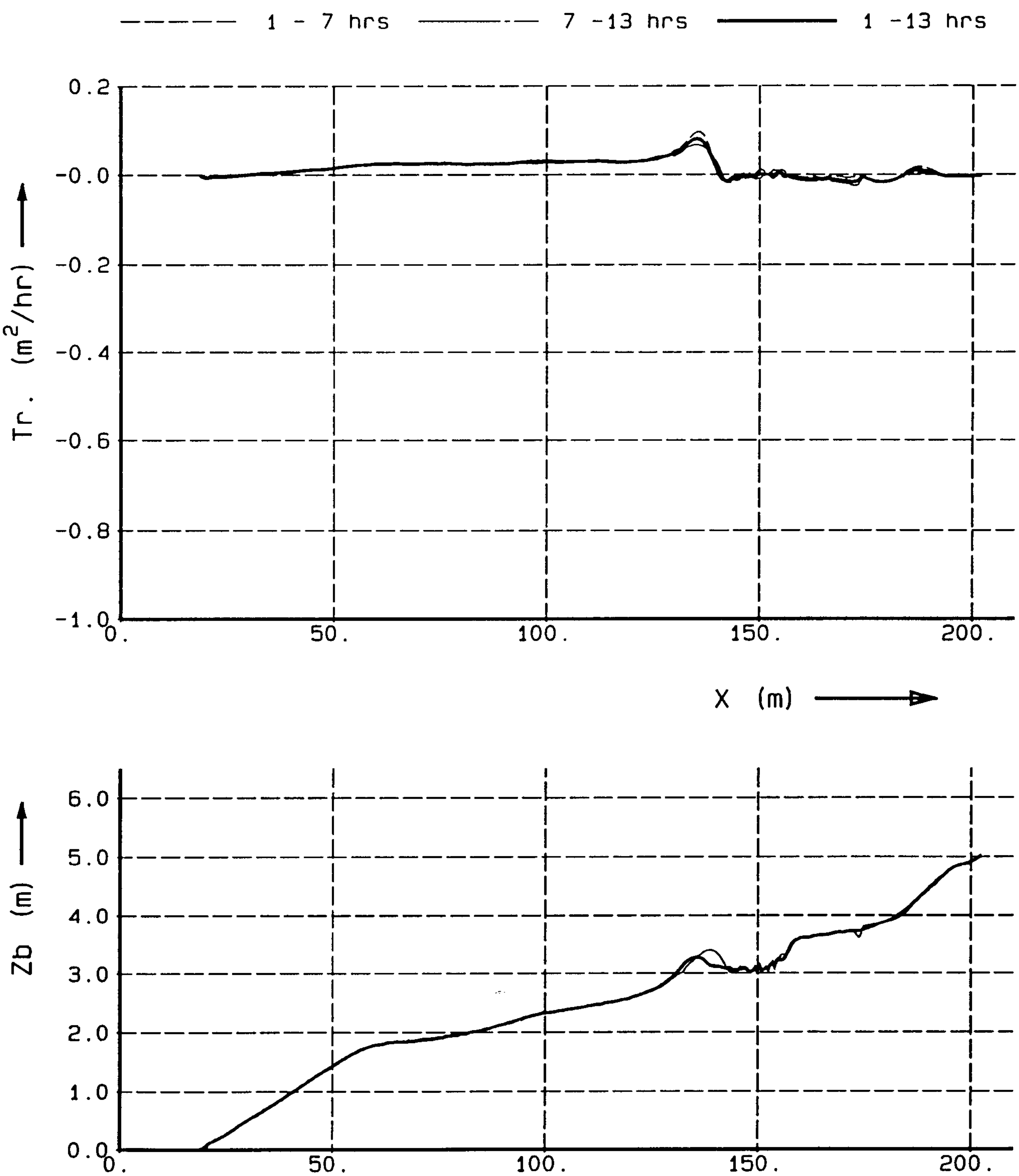
Profile development after 13 hours :
line 3 : test 1c

%1c133

DELFT HYDRAULICS

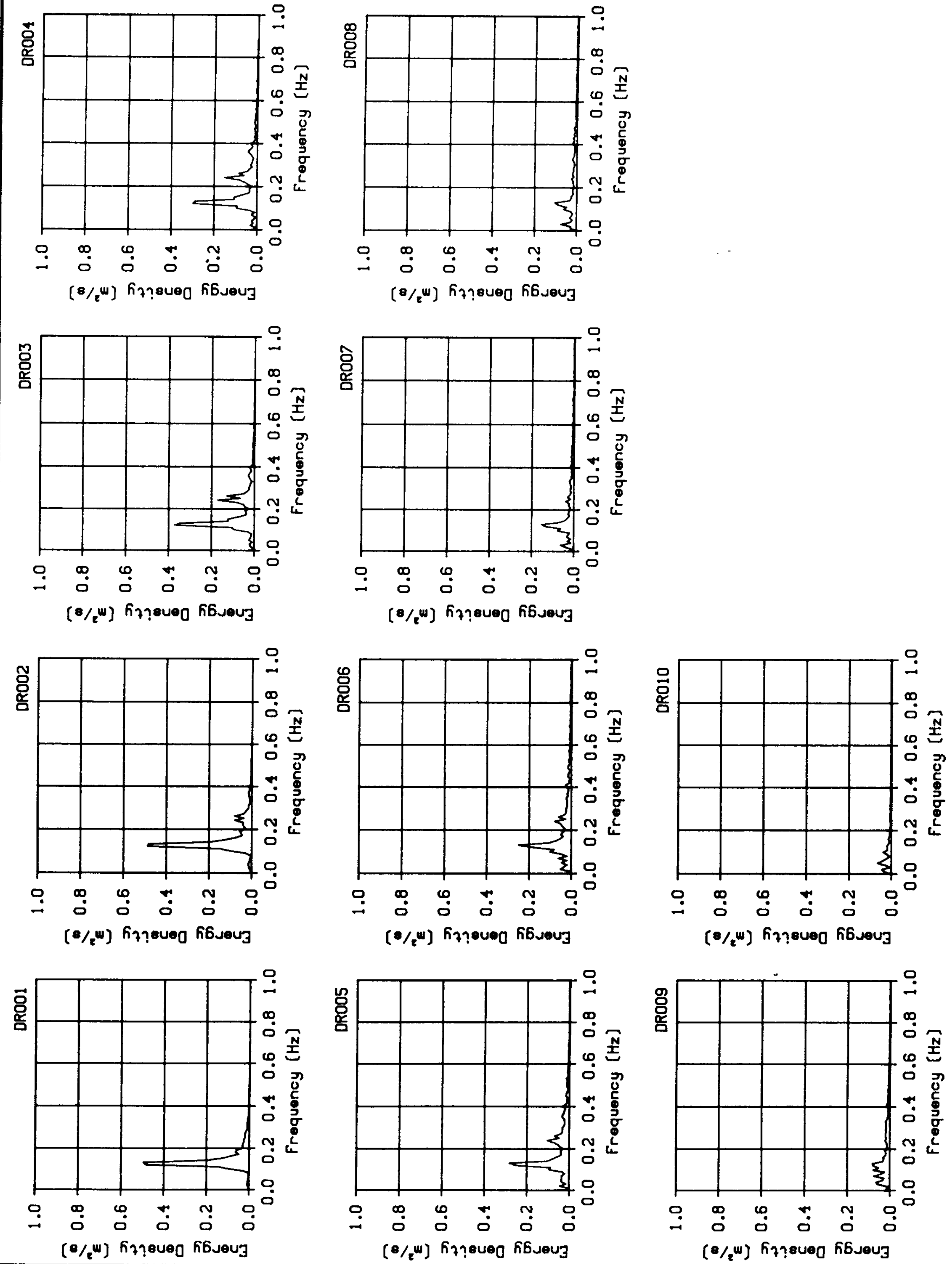
H1572

FIG. 3.3.1



INFERRED TRANSPORT RATES, TEST 1C

DELFT HYDRAULICS	H 2130	FIG. 3.3.2



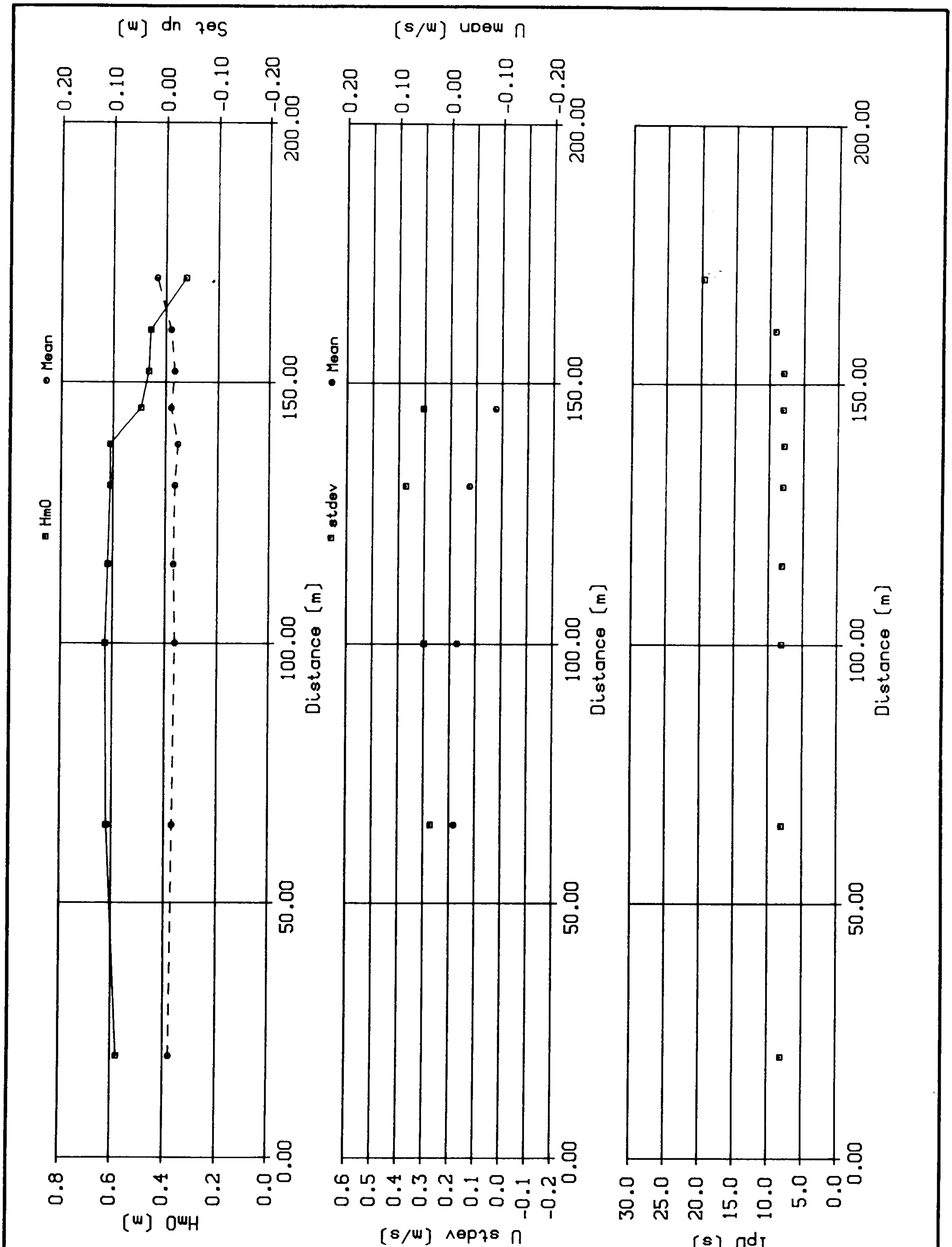
SURFACE ELEVATION SPECTRA
BASED ON PRESSURE SENSORS

1C0706

DELFT HYDRAULICS

H1572

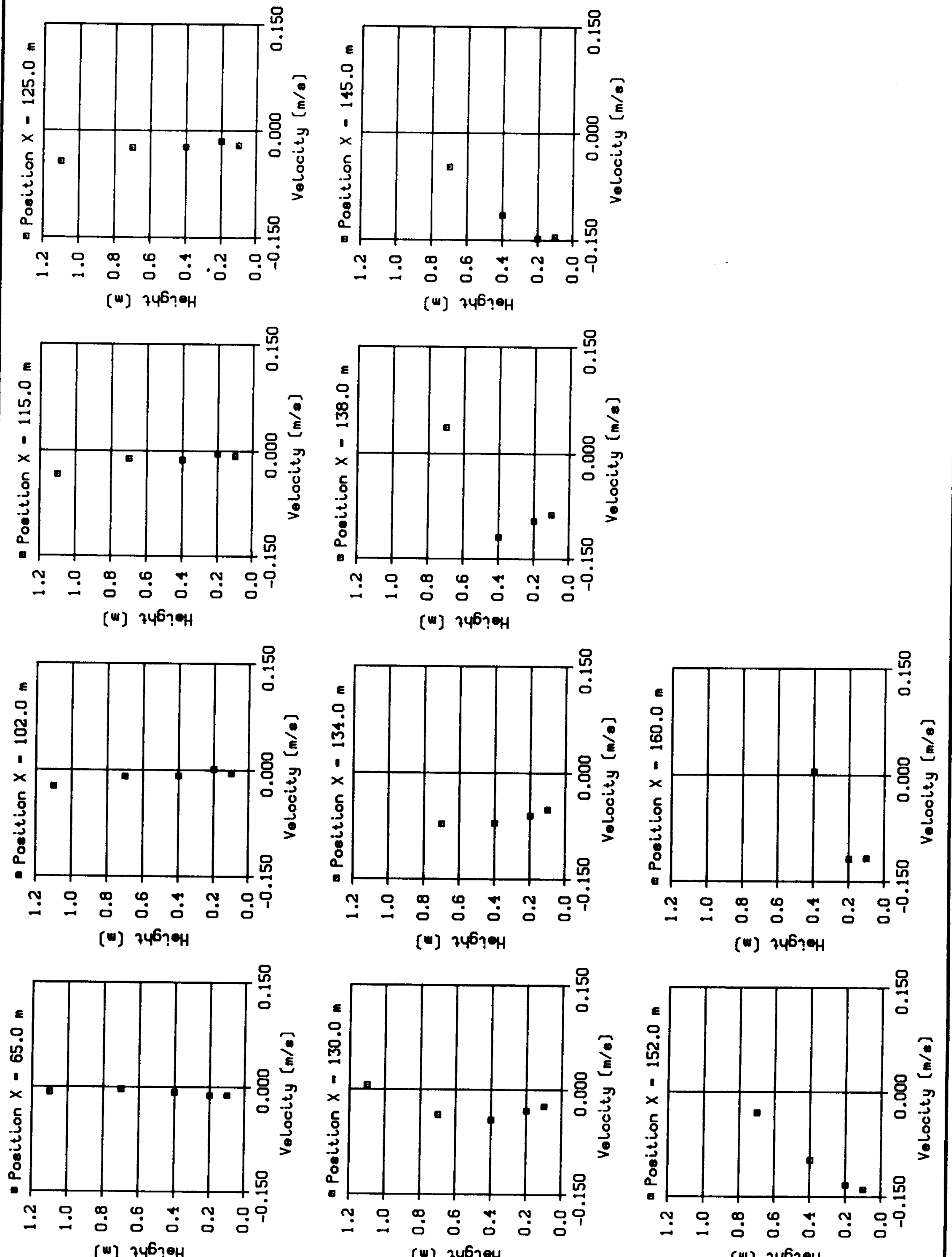
FIG. 3.3.3



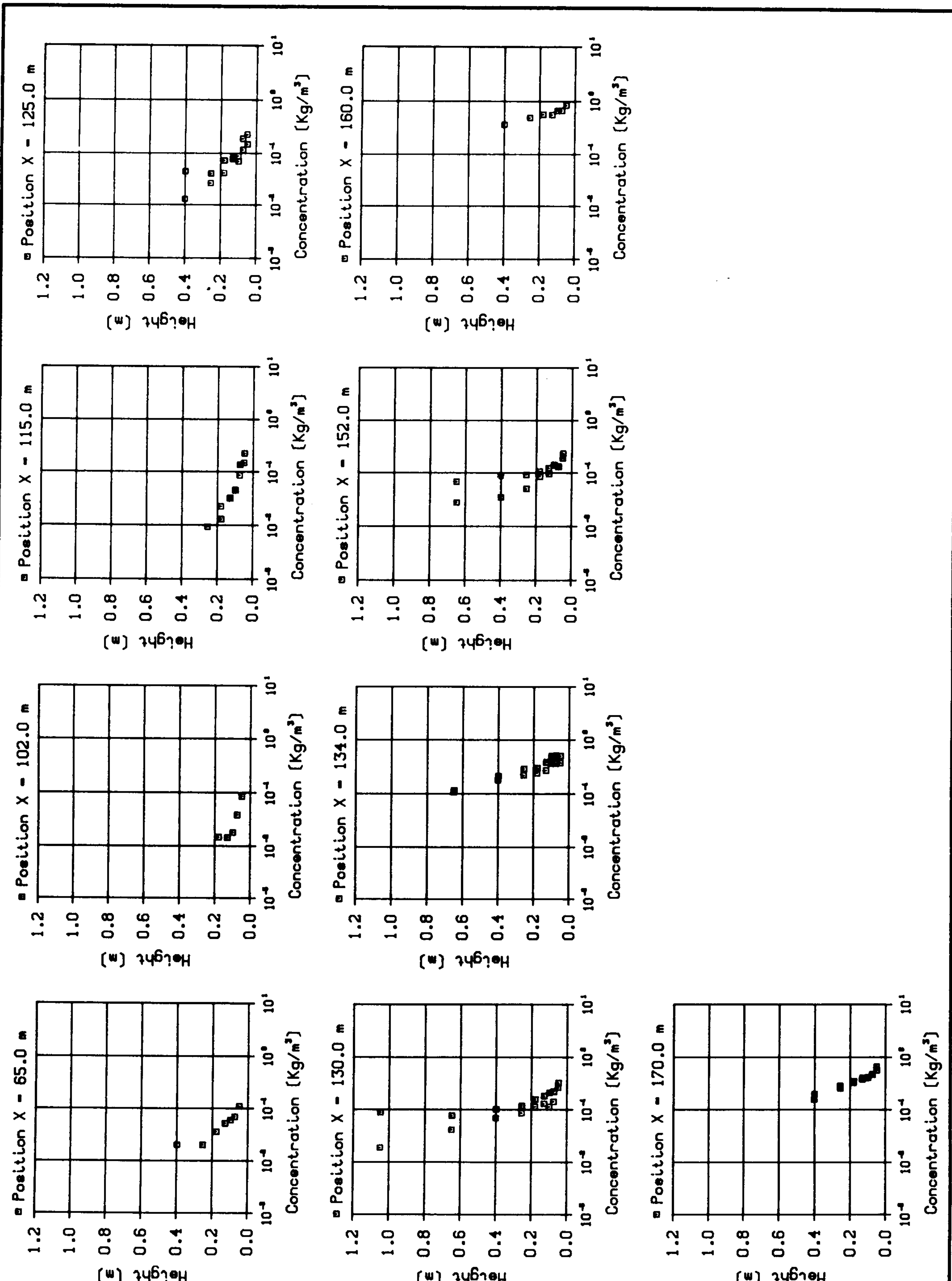
INTEGRAL SURFACE ELEVATION AND VELOCITY DATA BASED ON FIXED INSTRUMENTS, TEST 1C

#1C0706	

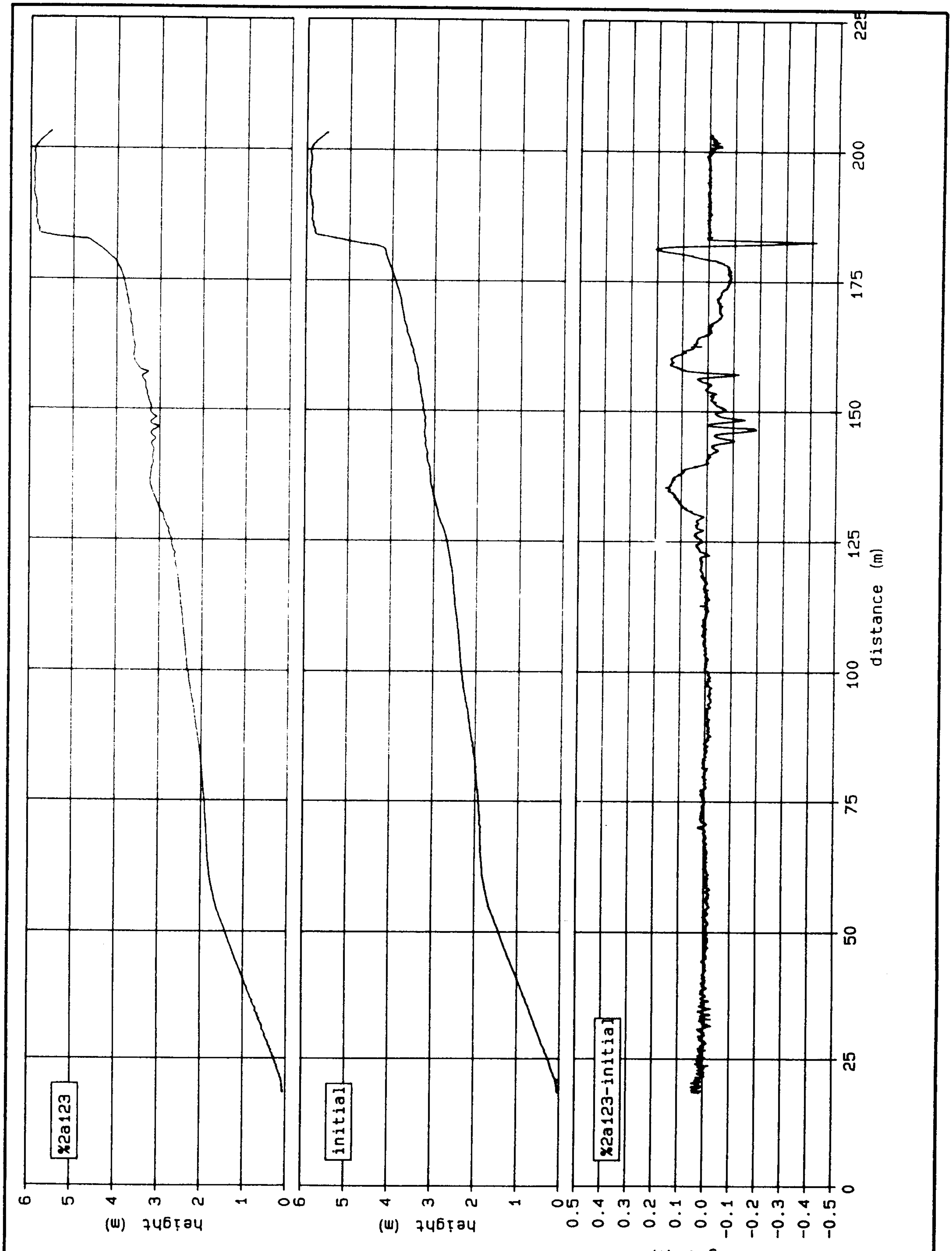
DELFT HYDRAULICS	H1572	FIG. 3.3.4



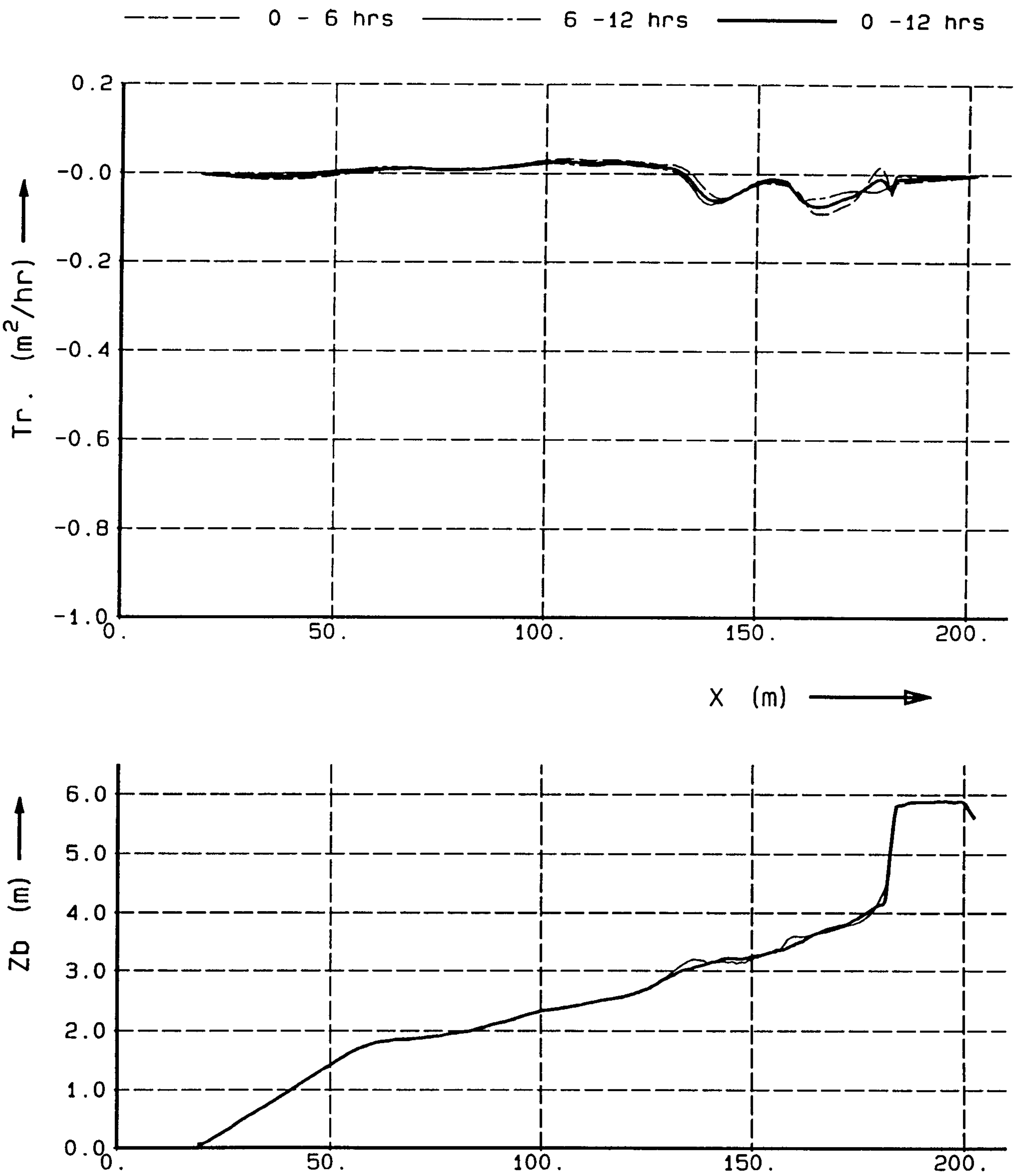
VELOCITY RESULTS	1C	
DELFT HYDRAULICS	H1572	FIG. 3.3.5



CONCENTRATION RESULTS	1C	
DELFT HYDRAULICS	H1572	FIG. 3.3.6

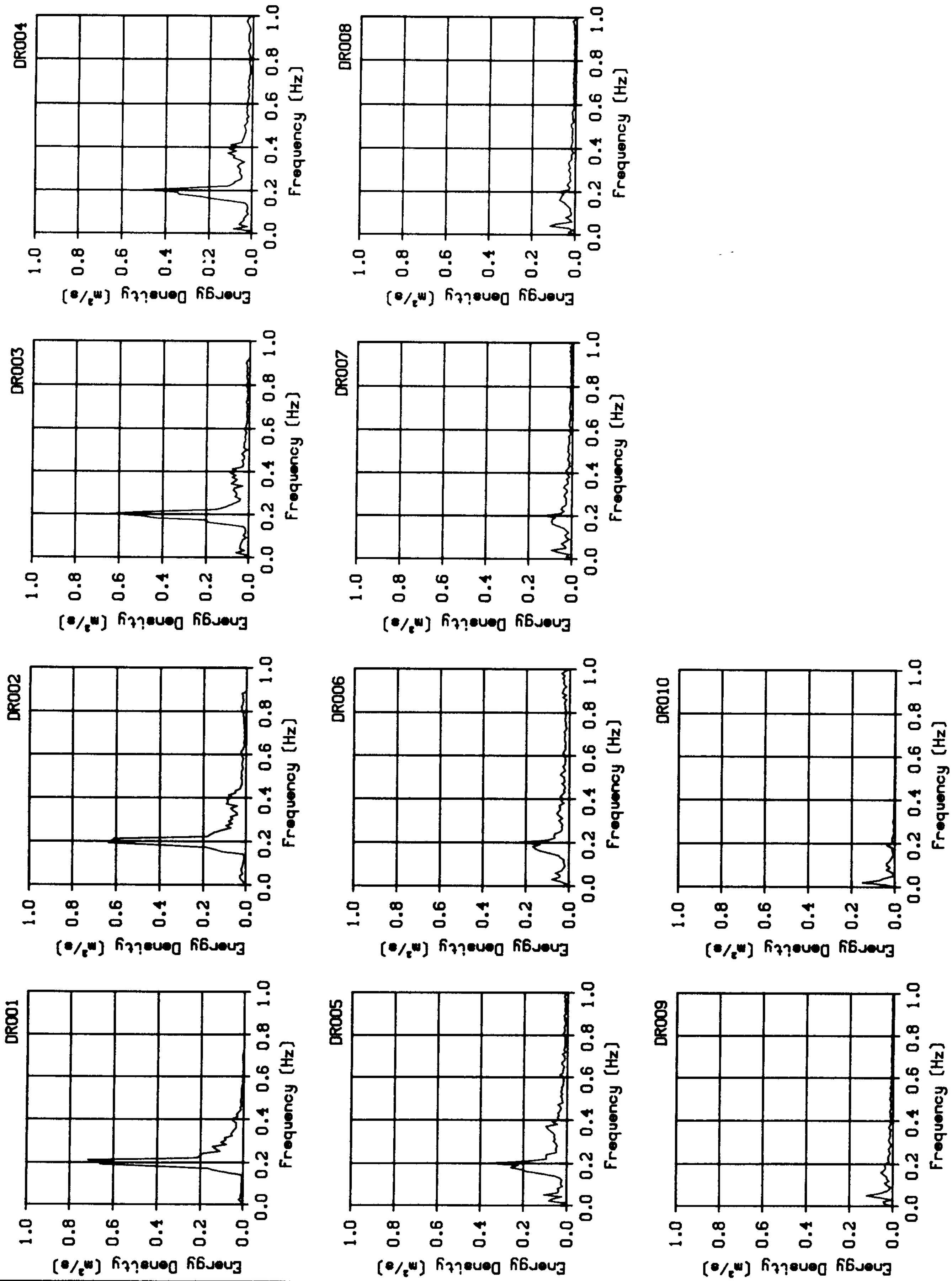


Profile development after 12 hours : line 3 : test 2a	%2a123	
DELFT HYDRAULICS	H1572	FIG.3.4.1



INFERRED TRANSPORT RATES, TEST 2A

DELFT HYDRAULICS | H 2130 | FIG. 3.4.2

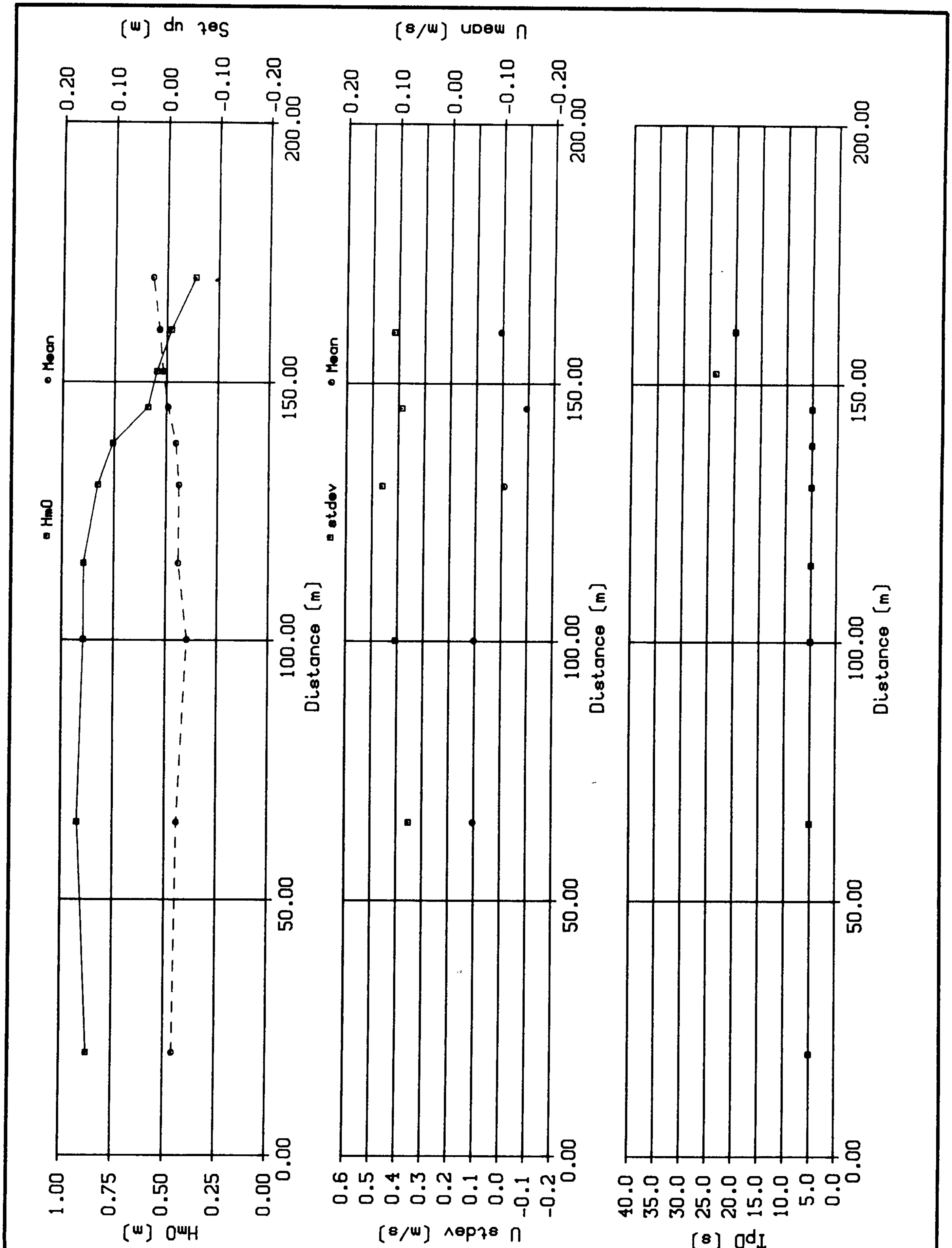


SURFACE ELEVATION SPECTRA
BASED ON PRESSURE SENSORS

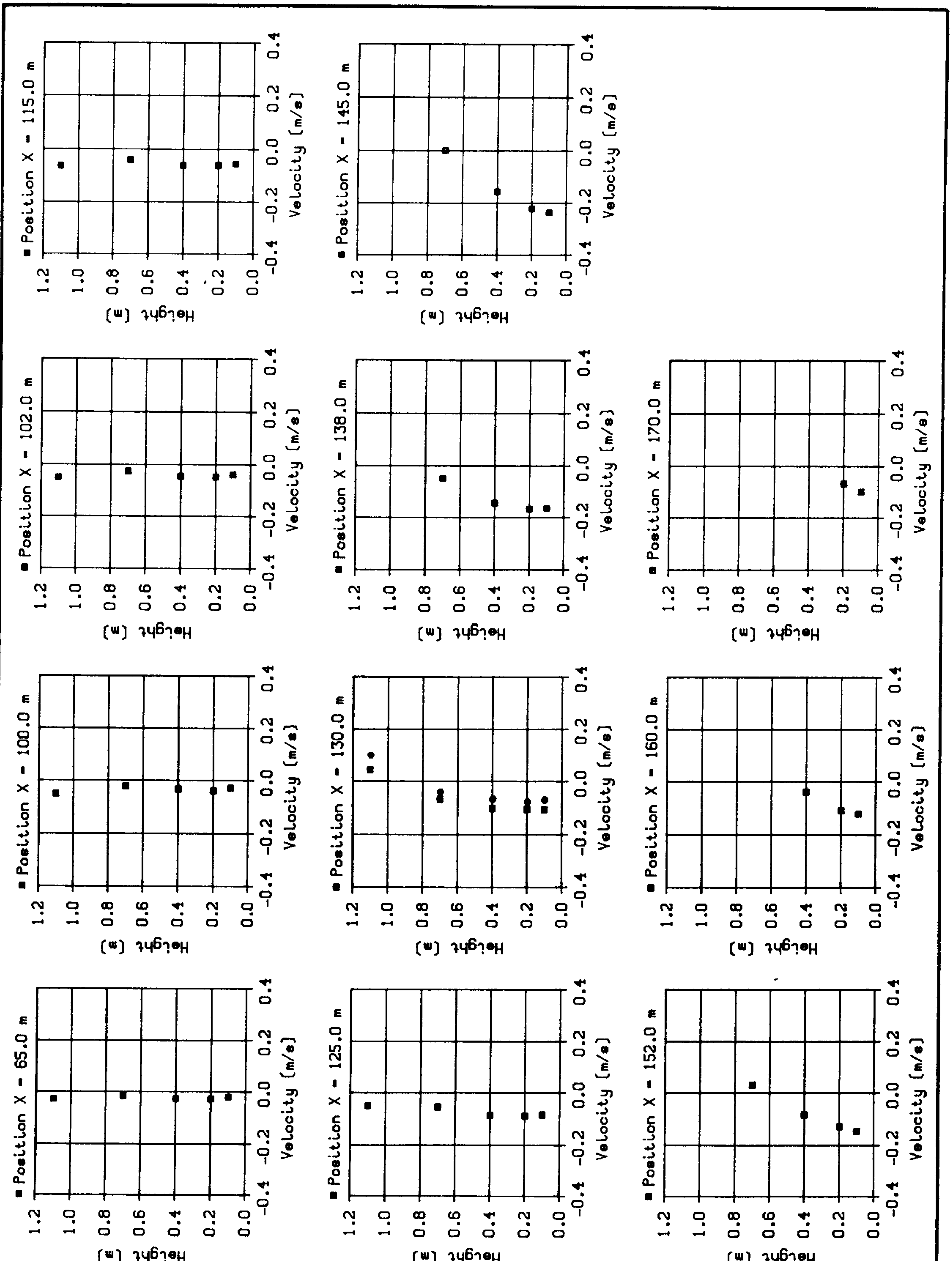
2A0607	

DELFT HYDRAULICS

H1572	FIG. 3.4.3



INTEGRAL SURFACE ELEVATION AND VELOCITY DATA BASED ON FIXED INSTRUMENTS, TEST 2A	#2A0607	
DELFT HYDRAULICS	H1572	FIG. 3.4.4



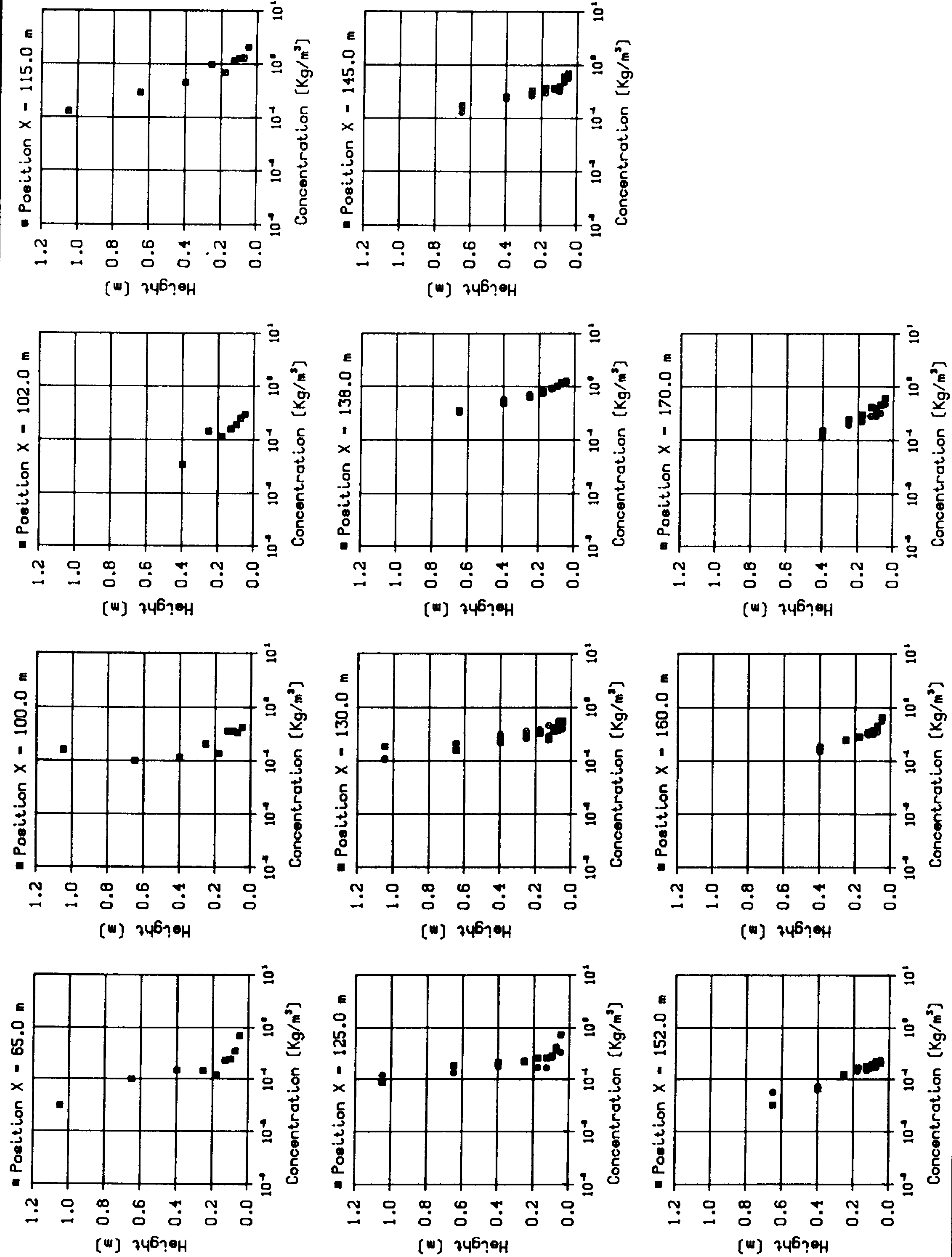
VELOCITY RESULTS

2A

DELFT HYDRAULICS

H1573

FIG. 3.4.5



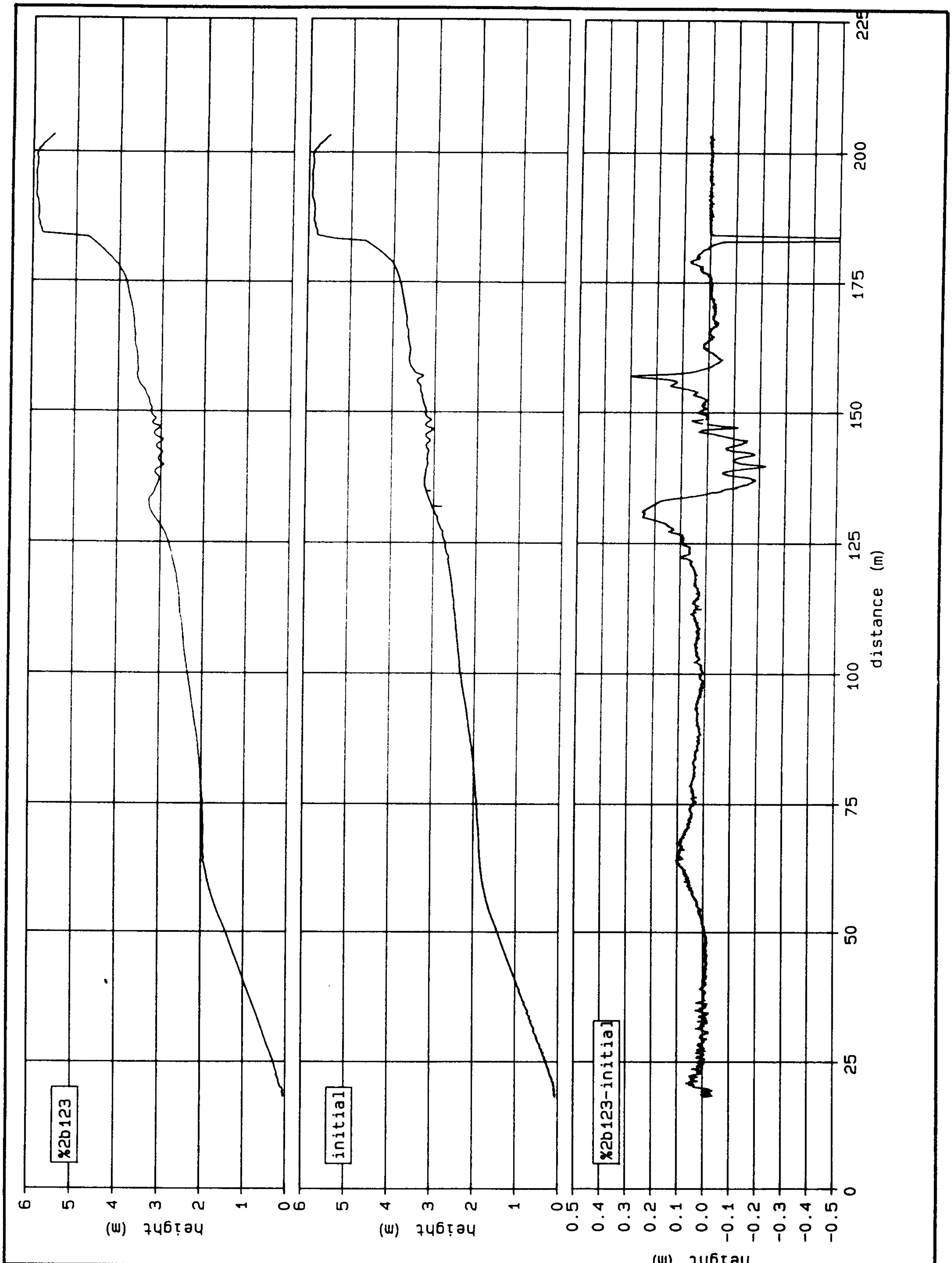
CONCENTRATION RESULTS

2A

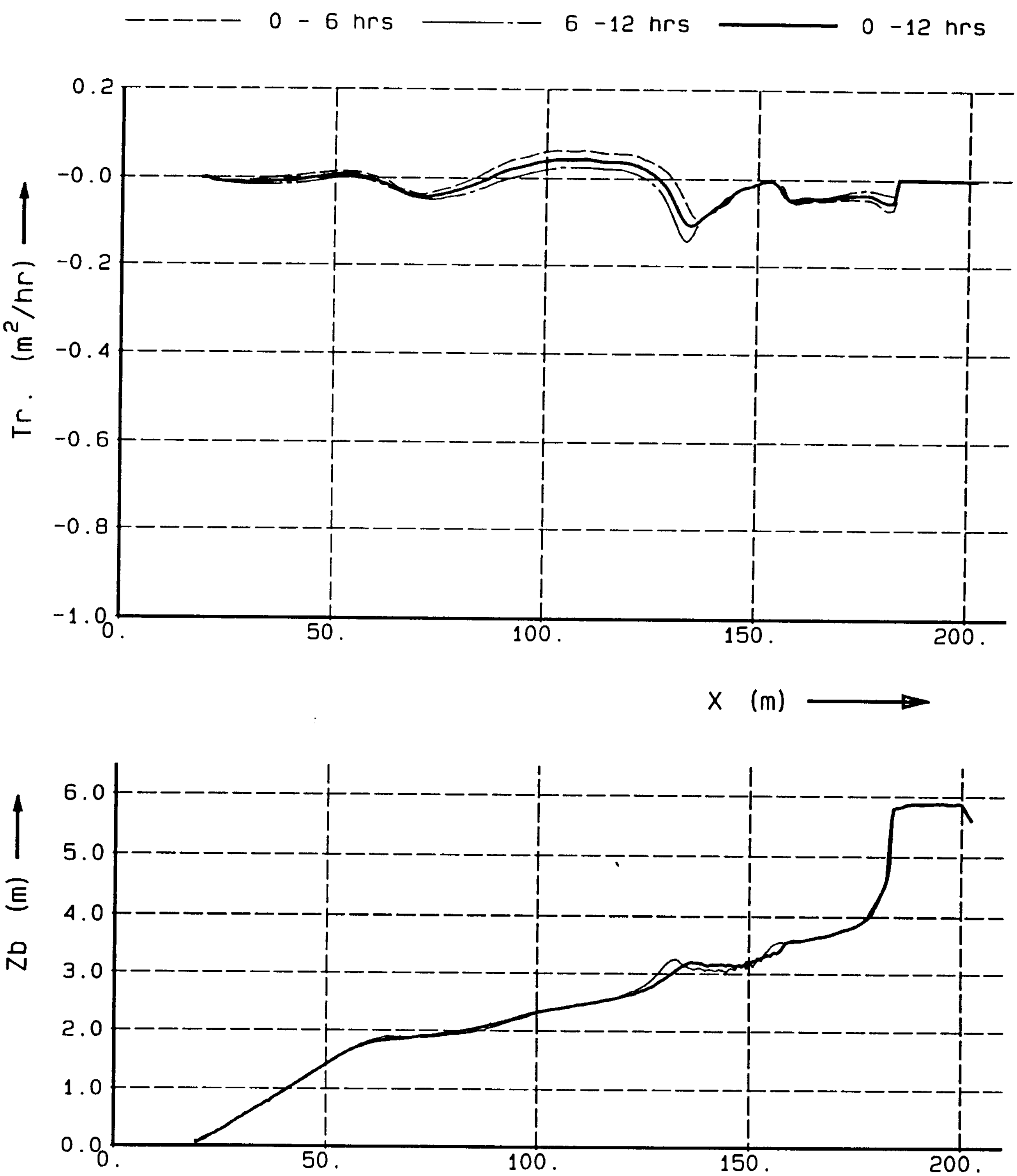
DELFT HYDRAULICS

H1572

FIG. 3.4.6

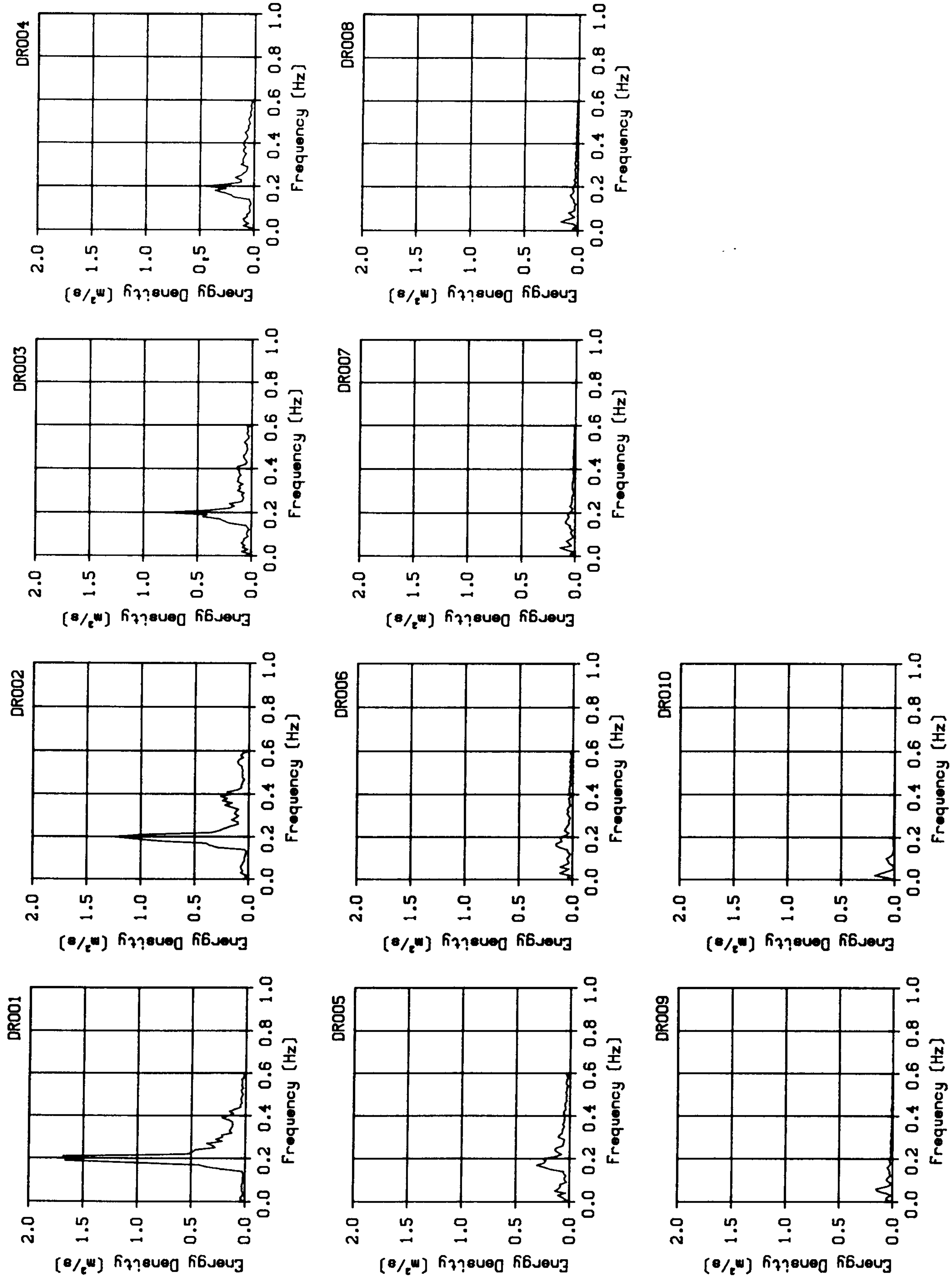


Profile development after 12 hours : line 3 : test 2b	%2b123	
DELFT HYDRAULICS	H1572	FIG. 3.5.1

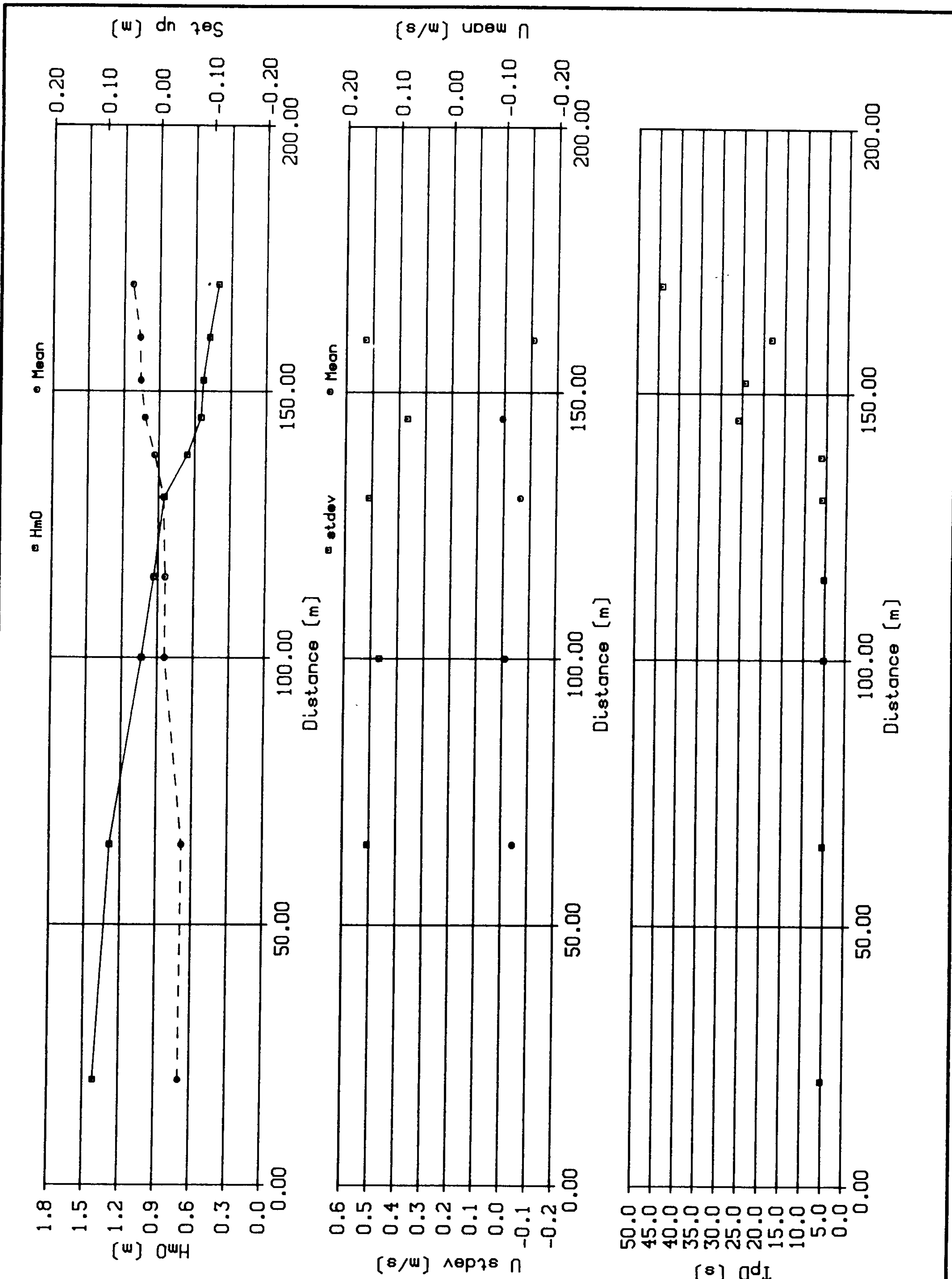


INFERRED TRANSPORT RATES, TEST 2B

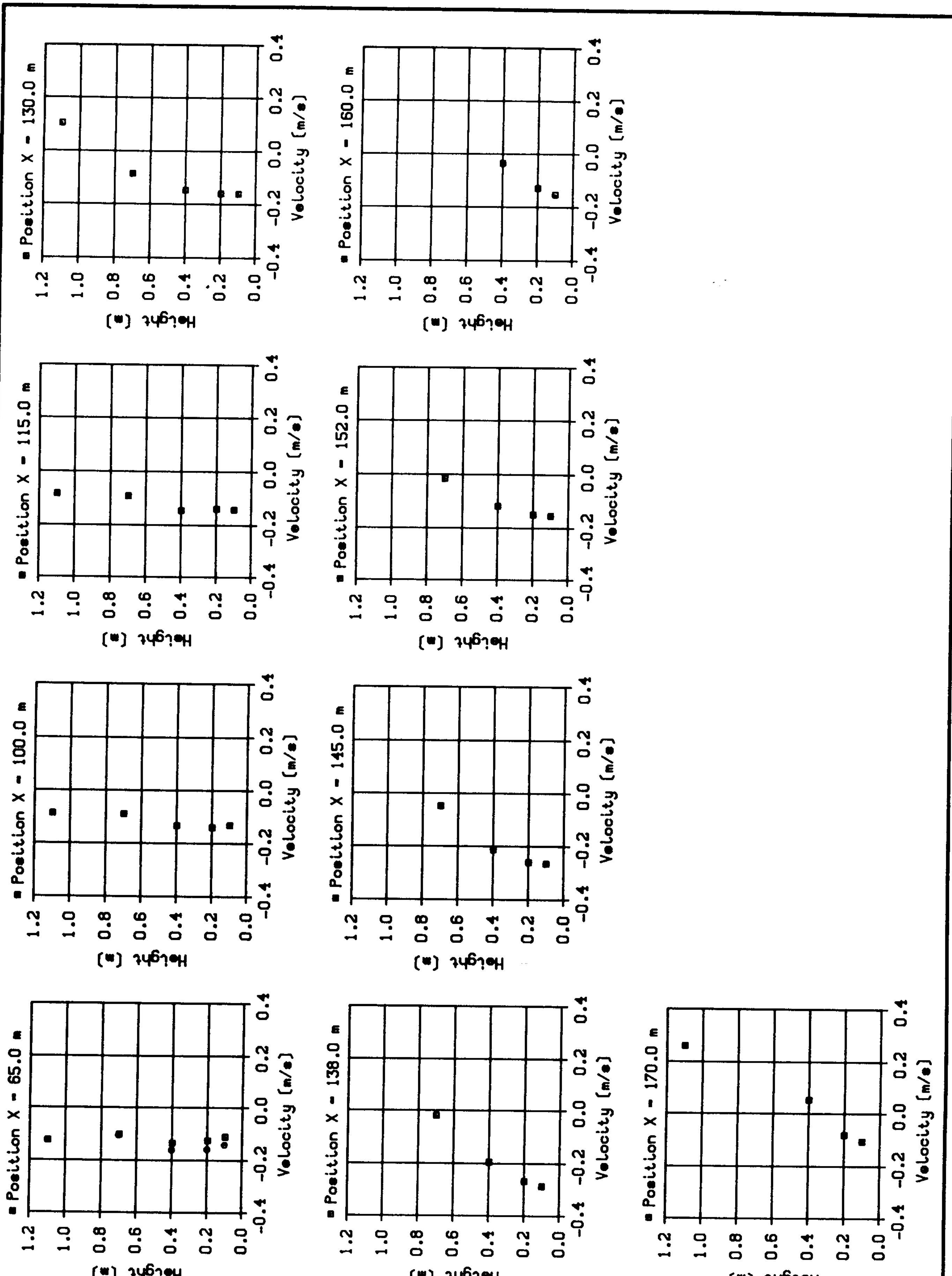
DELFT HYDRAULICS | H 2130 | FIG. 3.5.2



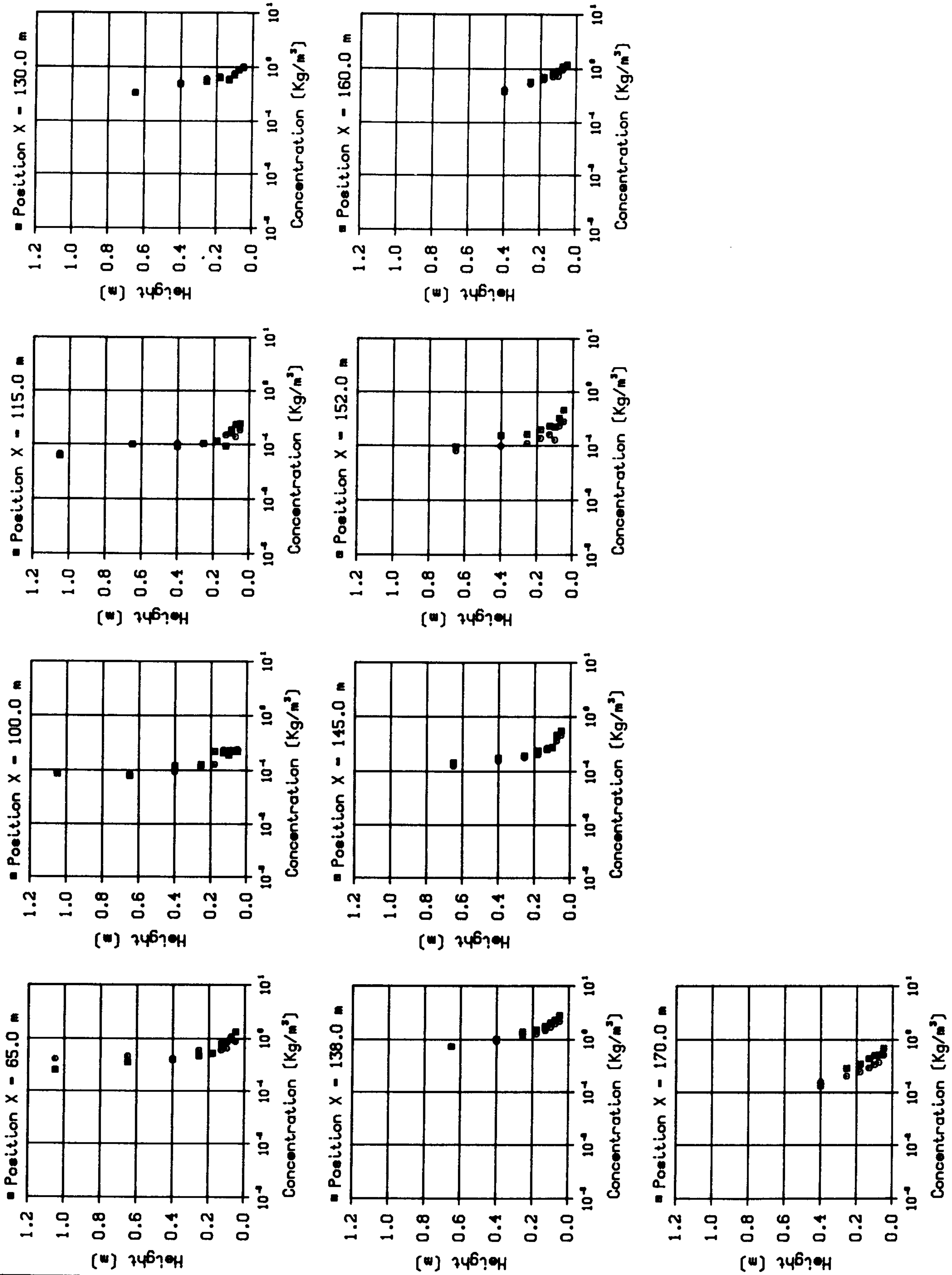
SURFACE ELEVATION SPECTRA BASED ON PRESSURE SENSORS	2B0506	
DELFT HYDRAULICS	H1572	FIG. 3.5.3



INTEGRAL SURFACE ELEVATION AND VELOCITY DATA BASED ON FIXED INSTRUMENTS, TEST 2B	#2B0506
DELFT HYDRAULICS	H1572 / FIG. 3.5.4

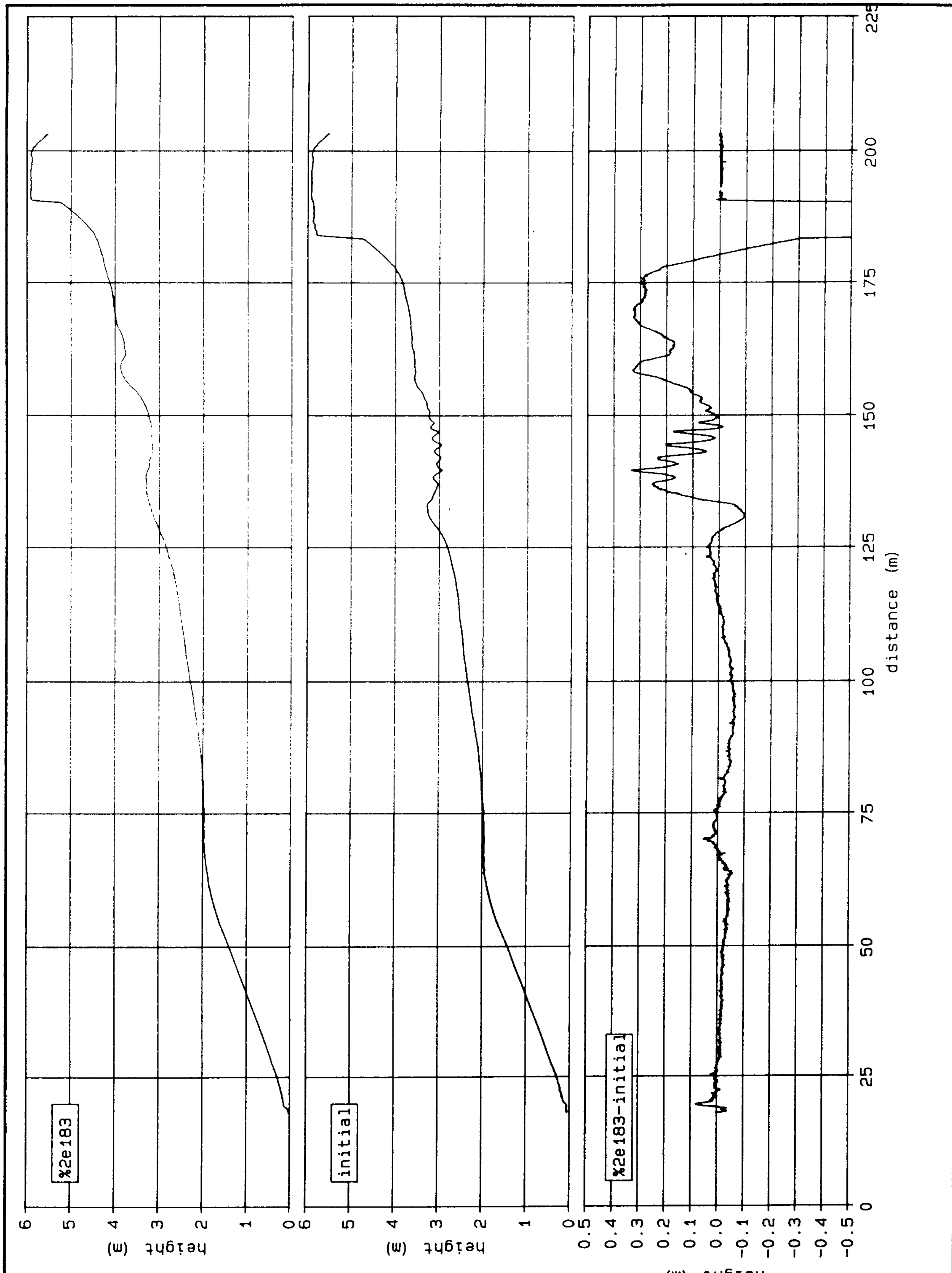


VELOCITY RESULTS	2B	
DELFT HYDRAULICS	H1572	FIG. 3.5.5



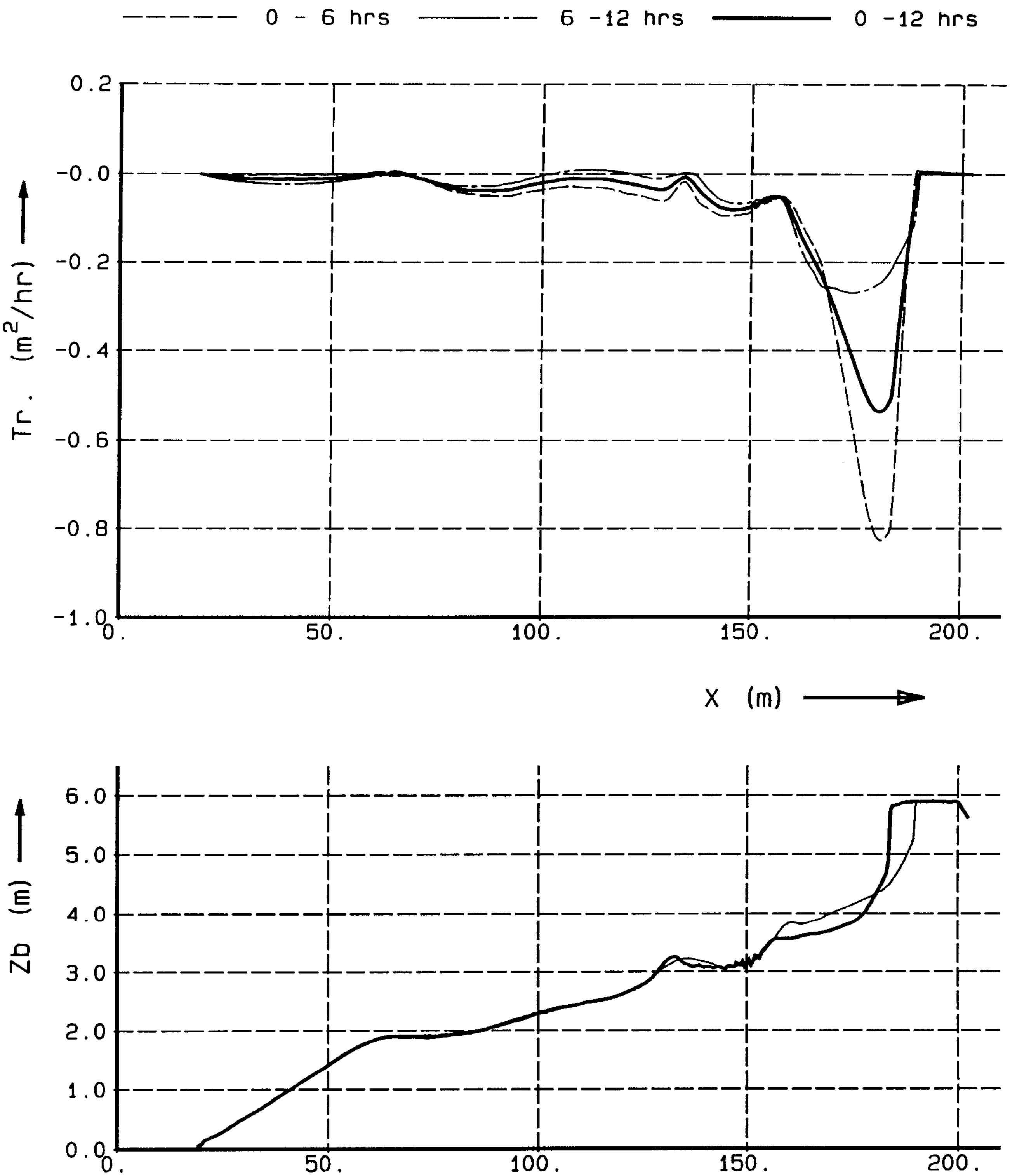
CONCENTRATION RESULTS

2B	



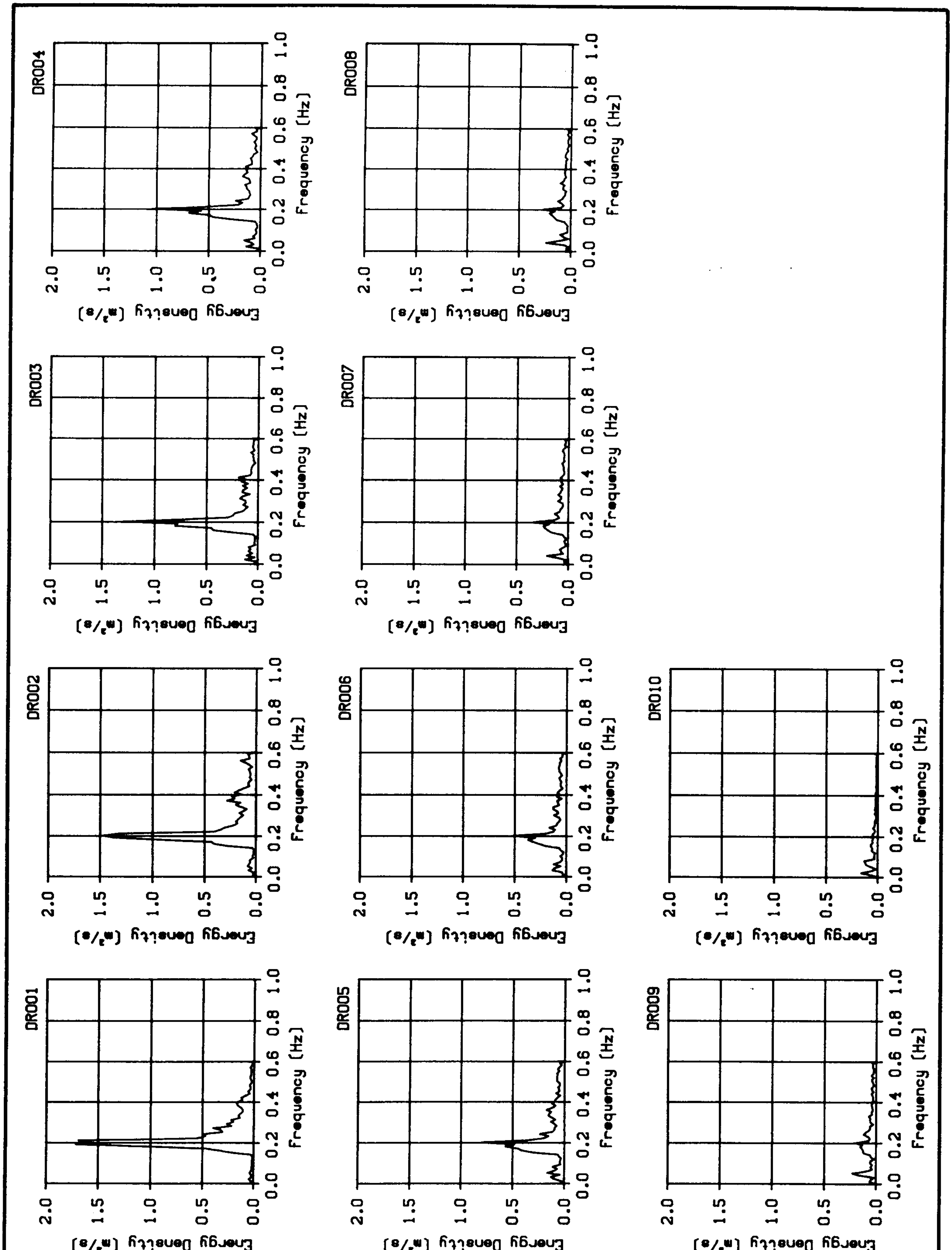
Profile development after 18 hours :
line 3 : test 2e

	%2e183	
DELFT HYDRAULICS	H1572	FIG. 3.6.1



INFERRED TRANSPORT RATES, TEST 2E

DELFT HYDRAULICS | H 2130 | FIG. 3.6.2



SURFACE ELEVATION SPECTRA
BASED ON PRESSURE SENSORS

2E0809	

DELFT HYDRAULICS | H1572 | FIG. 3.6.3