Preface

"Experiencing what has been studied." With this idea some students from the Hydraulic Engineering section of the Faculty of Civil Engineering of TUDelft enrolled into a "subject", "Hydraulic Fieldwork Engineering", which had nothing in common from the others (except, maybe, the teacher). Its main point was that the lessons wouldn't be inside any building, looking at the reality as a mere idea reflected into some concepts on a board or a computer screen, but ON TOP of this reality, feeling the stones under their feet if they were on a groin, the sand if they were on a beach… to put it shortly: Hydraulic Engineering IN SITU.

This is the fruit of such an exceptional educative experience. The following pages report the activities and measurements carried out during a field trip to Bulgaria's Black Sea Coast. This took place between the 3rd and 13th of October, 2003. It has an exclusively technical focus, it is not meant to be a detailed description of all the aspects of the trip but merely a compilation and interpretation of data acquired on it.

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List of Symbols

ρ_s	Mass density of concrete	kg/m³
ρ_w	Mass density of water	kg/m³
Δ	$(\rho_s / \rho_w) - 1$ = relative density	-
D_n	Diameter of cube with the same volume as certain tetrapods	m
N_{od}	Number of units displaced out of the armour layer within a strip width of one cube length D_n	-
N_z	Number of waves	-
C	Length of one leg tetrapod	m
V	Volume of one tetrapod	m³
s_{om}	Wave steepness ($=H/gT^2/2\pi$)	-
K_D	Stability coefficient	-
M	Armor unit mass in ton	tons
f_T	Concrete static tensile strength	MPa
C_0, C_1, C_2, C_3	Fitted parameters	-
k	Wave number ($2\pi/L$)	1/m
L	Wave length	m
h	Water depth	m
z	Depth of the pressure gauge	m
H_s	Significant wave height	m
H_0	Wave height deepwater	m
H	Wave height	m
K_s	Shoaling factor	-
K_r	Refraction factor	-
T_m	Mean wave period	s
T_p	Wave period	s
θ	Wave angle	-
g	gravity	m/s²
a	Amplitude	m
p	Pressure	N/m²
BLc	Blockiness	-
BLc_m	Mean blockiness	-
D_n	Nominal grain diameter	m
D_{n50}	Mediam nominal diameter	m
m_1	Mass under water	kg
m_2	'moist' mass	kg
m_3	'dry' mass	kg
C	Average density of rocks	kg/m³
n_v	Porosity	-
k_t	Single layer thickness	m
P	Permeability in Van der Meer formula	-
S_D	Damage level in Van der Meer formula	-
K_D	Damage coefficient in Hudson's formula	-
ξ	Breaker parameter ($=\tan\alpha/\sqrt{s}$)	-
P_f	Failure probability	-
K	Bulk modulus	Pa

1 Introduction

A series of hydraulic measurements were carried out during the field trip, ranging from beach profiles to wave data collection and suitability of stones from local quarries for hydraulic purposes. They are all presented in detail in the following sections.

However, since not only activities that yielded data or were susceptible to be measured and analyzed during the trip, a short chronological list is given with the main activities that filled each day, so that the reader can have a better idea on the whole data gathering process:

Fr. 3rd Oct	Trip from the Netherlands to Varna, via Brussels.
Sa. 4th Oct	General visit to St. Constantine sea-front, up to unfinished marina on its southern tip, in front of Delphin hotel. Wave measurements on nearby pier. Arrival of Bulgarian students.
Su. 5th Oct	Morning: Groyne measurements. Afternoon: Tetrapod measurements on unfinished marina at northern tip of Sunny Day complex and visit to Varna´s harbour breakwater.
Mo. 6th Oct	Visit to Burgas harbour's expansion works, landslides as well as prevention works near Sarafovo and tourist town of Nesebar.
Tu. 7th Oct	Morning: Visit to industrial port in Varna's lake and stone measurements at Marciana Quarry. Afternoon: Visit of Sini Vir quarry after lunch by Conevo reservoir.
We. 8th Oct	Beach measurements at St. Constantine
Th. 9th Oct	Morning Short theoretical analyze of previous dates' data with CRESS, short explanation on GPS by University of Sofia personnel. Afternoon: GPS measurements on beach contour.
Fr. 10th Oct	Morning: Bathymetric survey and beach measurements at St. Constantine. Afternoon: Lab work at Eskana office in Varna.
Sa. 11th Oct	Morning: Visit to landslides and corrective measures near Golden Sands. Afternoon: Boat outing in front of St. Constantine
Su. 12th Oct	Departure of most of the Bulgarian students. Visit to the northern stretch of Bulgaria's coast, including the port of Balcik, Cape Kaliakra, Cape Shabla and surrounding oil fields.
Mo. 13th Oct	Return trip to the Netherlands.

In all cases the departure/ base point was hotel Ralitsa, in the St. Constantine tourist complex northeast of Varna.

It must be stressed that the techniques and equipment used were (mainly) purposely non-high tech, so that a more intuitive approach to the problem could be taken, as well as serving as possible training for a "worst case scenario" in future work in developing countries.

The chronology of this report is evaluated below.
In chapter 2 something is told about the tetrapods. At Sunny Day Beach in St. Constantine some sightseeing has been done on a breakwater. The quality of the concrete and the breakwater was inspected and some measurements have been done on the tetrapods.
Chapter 3 deals with the beach measurements. In order to get an idea about the sand transport along the coast, some measurements have been done on the beach profile. This chapter also discusses the GPS measurements and the sieve analysis of the beach sand.

In chapter 4 the wave measurements are discussed. Some measurements on the wave height and wave period and length were done. The results have been checked to see if the waves were Gauss distributed and if the data were reliable.
There is also something told about the groyne measurements in chapter 5. In order to get a view on the stability and change in volume some results of measurements are discussed. By measuring different profiles, the volume could be calculated. And this volume has been compared to the groyne volume of last year.
In chapter 6 the distribution of stones from a quarry are discussed. The distribution has also been plotted in a log and log Gauss graph to be able to draw conclusions. Finally a new design has been made for the groyne at St. Constantine by using the distribution of the stones from the quarry in the calculations.
Chapter 7 finally discusses the bathymetry Survey. With an echo sounder and DGPS depth-position measurements have been done. With the data of these measurements volume calculations have been done. With these calculations it will be easy to compare the bottom profile in the coming years. These measurements have been done along the same coast as the beach measurements.

Figure 1-1 Group picture in the harbor of West-Varna

No attention has been given to the excursions. In the personal reports however information about this part of the study tour can be found. This report only discusses the technical part of the fieldwork in Bulgaria.
While reading the report backgrounds (Annexes) on the subjects can be found. These Annexes can not be found in this report because most of it consist only of data with are used within this report. Only a digital version of all of these data is handed over with this report.

2 Tetrapods on Sunny day breakwater

2.1 Preface

In this exercise we looked at tetrapods at the breakwater near the Sunny Day beach.
This breakwater is composed as a caisson type breakwater with tetrapods in front of the caisson. The breakwater was built in 1984 and has been exposed to storm waves for a large number of years. It was clearly visible that quite some tetrapods were damaged, so it can be concluded that the quality of the tetrapods is below standard. The purpose of this exercise is to measure the tetrapods and to determine the number of broken tetrapods by sight. Afterwards we calculate the design wave height, the expected breakage according to CEM and compare these with our observations.

2.2 Sample Descriptions and Results

The dimensions of the tetrapods are determined by measuring one leg with a measuring tape. With the following formula the mass of the tetrapod can be calculated:

$$H = 2.096 * C$$

$$V = 0.280 * H^3$$

In which C is the length of one leg, H the overall height and V the volume.

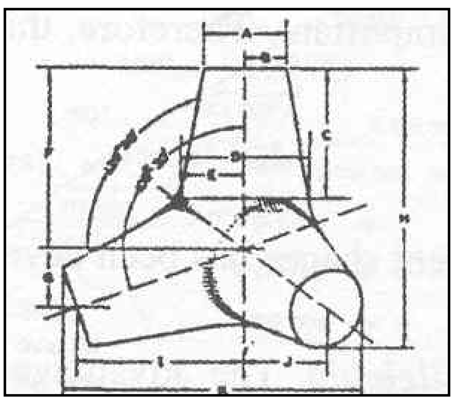


Figure 2-1 Dimensions Tetrapod

This leads to the following:

	C (m)	H (m)	V (m^3)	M (kg)
1	1.12	2.34752	3.622312665	8693.550395
2	1.17	2.45232	4.129423752	9910.617006
3	1.22	2.55712	4.68178384	11236.28122
4	1.22	2.55712	4.68178384	11236.28122
5	1.23	2.57808	4.797855905	11514.85417
6	1.25	2.62	5.03572384	12085.73722
7	1.25	2.62	5.03572384	12085.73722
8	1.25	2.62	5.03572384	12085.73722
9	1.25	2.62	5.03572384	12085.73722
10	1.26	2.64096	5.157550649	12378.12156
11	1.26	2.64096	5.157550649	12378.12156

Table 2-1 Dimensions Tetrapod

In general two different sizes of tetrapods are present at the breakwater. For the small tetrapods an average length of one leg of 1.15 m (9.3 tons) is taken and for the large tetrapods a leg length of 1.24 m (11.9 tons) is used for the calculations. The reason why two different

sizes are used is because at the head of the breakwater larger wave attacks occur then at the trunk. Therefore larger tetrapods are needed at the head.
For this breakwater a design wave can be calculated using the following equations (CEM):

Van der Meer:

$$H_s = \left(3.75 * \left(\frac{N_{od}^{0.5}}{N_z^{0.25}}\right) + 0.85\right) * \Delta * D_N * s_{om}^{-0.2}$$

Where	H_s	Significant wave height in front of the breakwater.
	ρ_s	Mass density of concrete.
	ρ_w	Mass density of water.
	Δ	$(\rho_s / \rho_w) - 1$
	D_n	= 0.65*H (length of cube with the same volume as tetrapods).
	N_{od}	Number of units displaced out of the armour layer within a strip width of one cube length D_n.
	N_z	Number of waves
	s_{om}	Wave steepness, $s_{om} = H_s / L_{om}$

This leads to the following results:

Van der Meer

	N_{od}	N_z	Δ	D_{n50}	s_{om}	$N_{od}^{0,5} / N_z^{0,25}$	H_s
trunk	1	7000	1.37	1.559948	0.071	0.109327	4.570258
head	1	7000	1.37	1.693917	0.071	0.109327	4.962755

Table 2-2 Results Van der Meer

ρ_w = 1015 kg/m3
ρ_s = 2400 kg/m3
The value ξ = 2.5 has been chosen, because in this case (collapsing breaker) a large impact can be expected on the slope of the breakwater. With this value the wave steepness has been calculated.

Hudson:

$$H = \frac{M_{50} * K_D \left(\frac{\rho_s}{\rho_w} - 1\right)^3 \cot\alpha}{\rho_s} \text{ or } H = (K_d \cot\alpha)^{1/3} * D_N \ (D_N = 0.65 * H_{tetrapod})$$

in which K_D is the stability coefficient
This leads to the following results:

Hudson

	H_{gem}	K_d	cot α	D_{n50}	H
Trunk breaking	2.39992	7	1.5	1.559948	3.415911
Trunk non breaking	2.39992	8	1.5	1.559948	3.571389
Head breaking	2.606027	5	1.5	1.693917	3.315731
Head non breaking	2.606027	6	1.5	1.693917	3.52349

Table 2-3 Results Hudson

Hanzawa:

$$H_s = \left(2.32 * \left(\frac{N_{od}}{N_z^{0.5}} \right)^{0.2} + 1.33 \right) * \Delta * D_n$$

This leads to the following results:

	N_{od}	N_z	Δ	D_{n50}	s_{om}	$N_{od} / N_z^{0,5}$	H_s
trunk	1	7000	1.37	1.559948	0.071	0.412563	4.887925
head	1	7000	1.37	1.693917	0.071	0.412563	5.307704

Table 2-4 Results Hanzawa

The maximum depth-limited wave for this location:

The maximum depth limited wave can be determined with the simple rule: H = 0.5*h. The depth near the breakwater is approximately 8 meters, but some wave-setup can occur. This will be estimated to be about 0.5 meters, so the maximum depth limited wave will be about 4.25 meters. If we look at the coastline at this area it can be seen that no additional protection against wave impacts is present. So it is concluded that a maximum depth limited wave of 4.25 meters will be a good estimation.

The wave transmission according to CEM:

With the following figure from the Coastal Engineering Manual the wave transmission is calculated.

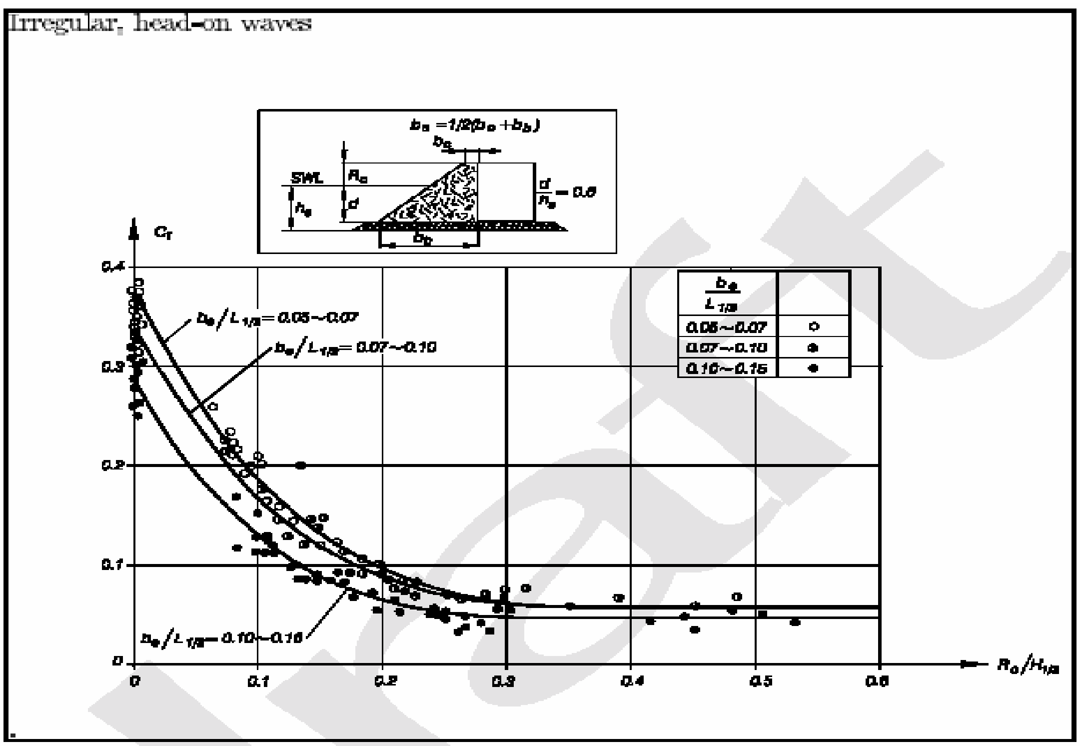


Figure 2-2 Wave transmission by overtopping of horizontal composite breakwaters armored with tetrapods (Tanimoto, Takashi, and Kimura 1987)

Additional information of the CEM:

(b) Wave transmission can be characterized by a transmission coefficient, C_t, defined either as the ratio of transmitted to incident characteristic wave heights (e.g., H_{st} and H_s) or as the square root of the ratio of transmitted to incident time-averaged wave energy (e.g., E_t and E_i) as given in Equation VI-5-51.

$$C_t = \frac{H_{st}}{H_s} = \left(\frac{E_t}{E_i}\right)^{1/2} \qquad \text{(VI-5-51)}$$

To determine the transmission coefficient C_t first $L_{1/3}$ is determined in the following way:

H_s = 4.25 m (maximum depth limited wave)
$T_{1/3}$= 7 s (estimated)

$$L_0 = \frac{gT^2}{2\pi} = \frac{9{,}81 \cdot 7^2}{2\pi} = 76.5m$$

$$\frac{h}{L_0} = \frac{8}{76.5} = 0.10$$

With the “short waves table, Annex X” this leads to h/L = 0.1410
So $L_{1/3}$ = 56.73 m
For the values in the formula the following estimations are made, first for the head of the breakwater:
R_c =4 m
b_c = 2.6 m (width of the largest tetrapod)
b_b = 20.6 m (with a slope of 1 : 1.5, a depth of 8 m and R_c = 4 m)

$$b_e = \frac{b_c + b_b}{2} = 11.6m$$

$$\frac{b_e}{L_{1/3}} = 0.20$$

$$\frac{R_c}{H_s} = 0.94$$

These values are outside of de range of the graph; the line for $\frac{b_e}{L_{1/3}} = 0.16$ is taken.

These values lead to a transmission coefficient of C_t = 0.05

Next, the trunk of the breakwater is looked at. The tetrapods in this section are smaller and lay lower so a higher C_t is expected.

R_c =2 m
b_c = 2.4 m (width of the largest tetrapod)
b_b = 17.4 m (with a slope of 1 : 1.5, a depth of 8 m and R_c = 2 m)

$$b_e = \frac{b_c + b_b}{2} = 9.9m$$

$$\frac{b_e}{L_{1/3}} = 0.17$$

$$\frac{R_c}{H_s} = 0.47$$

These values lead to a transmission coefficient of $C_t = 0.05$. This is the same value as has been calculated before. The values lay both on the horizontal part of the same curve in the graph.

Conclusion: The values of R_c are in this case large enough to prevent large wave transmission. If $\frac{R_c}{H_s} < 0.2$, the transmission is increasing. For this breakwater the transmission is minimal.

Next, the expected breakage according to CEM is calculated. The formula for this:

$$B = C_0 * M^{C1} * f_T^{C2} * H_s^{C3}$$

where B relative breaking
M Armor unit mass in ton
f_T Concrete static tensile strength in MPa, $2.5 \le M \le 50$
H_s Significant wave height in meters
C_0, C_1, C_2, C_3 Fitted parameters

	C_0	C_1	C_2	C_3	M	f_t	H_s	M^{C1}	Ft^{C2}	H_s^{C3}	B
trunk	0,00393	-0.79	-2.73	3.84	9.30	2	4.8879	0.17	0.1507	442.831	0.0450
head	0,00393	-0.79	-2.73	3.84	11.90	2	5.3077	0.14	0.1507	607.633	0.0509

Table 2-5 Expected breakage CEM calculation

On the breakwater, the number of broken tetrapods was counted by two groups. The results are:

number of broken tetrapods:		
Count 1	5 of 100	5%
Count 2	3 of 62	4.84%

Table 2-6 Number of broken Tetrapods

General analysis:
The core of the breakwater is made of caissons; on both sides tetrapods have been placed against the caissons in two layers. It was clearly visible that the concrete used for the tetrapods was of very low quality. Many tetrapods (about 5%) were broken. Largely this was because of the low quality concrete that had been used but it could also be seen that some tetrapods were made in two parts, one part one day and the rest the day after. Most of these tetrapods were cracked right where the new part was poured onto the older part. The reason why was because of the bad attachment between the older, hardened concrete and the new part in the tetrapod mould.

2.3 Conclusions and recommendations

Van der Meer, Hudson and Hanzawa each calculate the design wave for which the construction has been designed. The following values for H_s (in m) have been calculated:

	Head	Trunk
Van der Meer	4.96	4.57
Hudson	3.52	3.57
Hanzawa	5.31	4.89

Table 2-7 Design waves with different formulas

The formula by Hudson does not take into account the wave steepness, number of waves and amount of damage. Hanzawa compared to Van der Meer doesn't include the wave steepness, so is considered the best approximation of the wave height.

The breakage of the tetrapods according to CEM has been calculated to be 4.5% (trunk) and 5.1% (head). The percentage of broken tetrapods counted is about 5%, so it is concluded that even though the tetrapods on the breakwater look to be of low quality, they function as they are supposed to do.

Figure 2-3 Sunny day breakwater

2.4 Additional to this breakwater:

In the northern section of the breakwater a parapet structure is built, which consists of prefabricated elements. Over these elements a cap has been made with in-situ concrete. At some places, broken concrete is visible, see picture:

Figure 2-4 Tetrapods

It was also visible that the same had happened as the tetrapods as with the curved seawall behind the tetrapods, at the trunk of the breakwater. A part of the curve had been broken of by the waves. It could be seen that the curve was made in two stages and the place where the two parts were made together was the place where the curve had failed.

3 Beach Measurements

3.1 Preface

In some cases it is important to monitor the variation in the location of the beach.
The owner of a hotel just south of the Sirius wants to know what the changes of the beach profiles are during the years. Wednesday the 8th and Friday the 10th of October some profiles have been observed to get a clear view of the beach. This beach is partly artificial, because it has been expanded after the construction of the hotel.
It was the idea to start with these measurements in 2002, but because of a communication error not this beach, but one beach more south was measured. So therefore this year, 2003, is the first observation year.
In paragraph 3.2 a description is given of the way the baseline has been determined. When the baseline has been fixed, also a reproduction is given of the way of measuring in paragraph 3.3. After that the beach profiles are discussed and volume calculations are made. In paragraph 3.4 the results of the GPS en DGPS measurements of the shoreline and the differences in accuracy and recommendations are given. Finally the gradation of the beach sand is discussed in paragraph 3.5.

3.2 Description of the exercise

Some backgrounds about the way of measuring can be found in Annex I (beach measurements). Some conclusions can be made out of this appendix and have been taken into account while measuring.
At first it was very important to start measuring as soon as possible. During a short period the beach profile can already change a lot, for example caused by a storm. This should be avoided. Simple and cheap tools can also be used when sophisticated equipment is not available. The faster the start is, the better the reference.
At first the location of the baseline was determined, then some beach profiles perpendicular to this baseline were taken and finally the beach volume was calculated.
There have also been done some GPS and DGPS measurements and the accuracies have been compared and some conclusions have been taken out of that.
Finally some sand samples were taken and the sieve curve was calculated, which will be described in this chapter.

3.3 The measurements

Taking the appendix into account the following sequence of activities has been used.
The first step was to establish a baseline, which should never be changed during the years of measuring. Therefore it was very important to use reference points for the baselines, which could be used in the future (at least ten years). Perpendicular to the baseline several beach profiles have been measured. Further on in this paragraph more is told about the way the measurements have been done. It was preferred, that the line between the points (base line) was straight and on a dry beach. Further it was preferable, that the baseline was approximately parallel to the waterline. This took a lot of time, because it was difficult to find appropriate reference points for such a base line.
After discussing the appropriate points the location have been determined by taking some pictures and GPS information of these reference points. A good zero-point is the hotel.

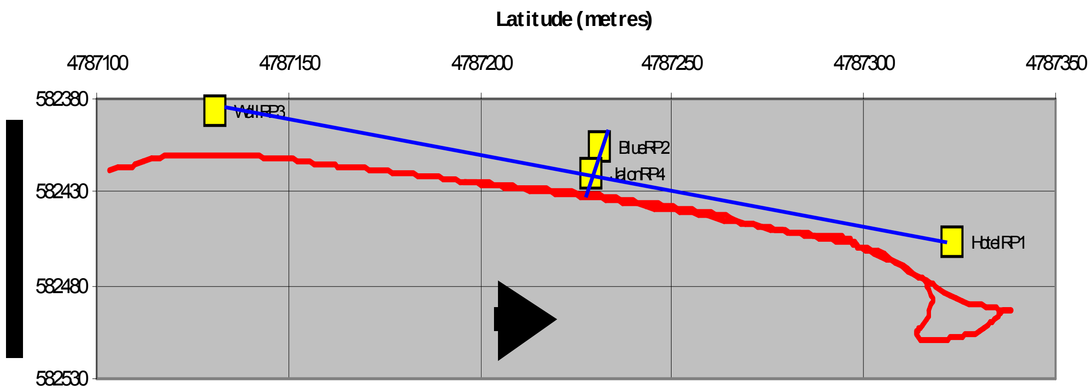


Figure 3-1 Beach south of Sirius

Figure 3-1 gives an idea of the points which were used for reference. The coordinates are translated from degrees to metres and defined by using the Universal Transverse Mercator (UTM) map system. The red line is the shoreline measured by DGPS. The tidal variation of the Black Sea was negligible and didn't cause shoreline differences. More information about the (D)GPS measurements and the way of measuring is found further in paragraph 3.4.
The coordinates of the four reference points have been measured by the GPS system. Every point was checked three times and the average values of the coordinates have been calculated. Table 3-1 shows the coordinates in degrees of the four reference points we used. These points agree with the points marked on the picture.

	Longitude from Greenwich	Latitude from equator
Hotel RP1	582456 m	4787323 m
Blue RP2	582405 m	4787231 m
Wall RP3	582386 m	4787131 m
Jalon RP4	582420 m	4787229 m

Table 3-1 Coordinates of the reference points

Reference point 1 is the main point, which has also been used for the reference height. In the pictures below this point is marked. This is a point at the hotel northeast to the beach.

Figure 3-2 Overview and detailed vision of RP 1: the hotel

In Figure 3-2 the hotel and the stairs of the hotel can be recognised. In front of another stairs to a different level there was a concrete plate. The corner of this plate was the reference in horizontal direction. In vertical direction the reference height was measured from the top of the plate.

Figure 3-3 Overview and detailed vision of RP 3: the wall

In Figure 3-3 reference point 3 is shown. This point functioned as the other corner of the baseline. On the south side of the beach, to the west of the little breakwater, there is a bending stairway leading up to the road. On the left side of these stairs there is a wall. From the stairs this wall has a bending shape. At the end of the bending part on the left side of this wall there is a perpendicular corner. This corner is defined as reference point three. On the right side picture a jalon is placed on this point.

Figure 3-4 Overview and detailed vision of RP 2: the blue building

Reference point 2 (Figure 3-4) is a point on the blue building on the beach (toilet) about in the middle. The beacon was placed at the upper left corner on the middle staircase. This point was used to fix the zero point about in the middle on the base line. With an angle mirror the angle between the baseline and the line between the baseline and reference point 2 was determined perpendicularly. After determining this point on the baseline the zero point of the baseline was defined. On this place a jalon was placed and the coordinates were determined. Yet the four reference points have been defined and described. All four points were marked during the measurements.

As stated before the beach profile was measured by using lines, which are perpendicular to the baseline and at fixed distances from the zero point. There are several ways to get a view on the beach profile. When sophisticated equipment is not available it is possible to use simple tools.
One way of measuring has been done by using the horizon as reference level. Every five metres the height of a point on a determined virtual beach line perpendicular to the baseline was defined. Using a theodolite for a clear and sharp view on the poles the relative height compared to the fixed pole and the horizon was measured. At the point on the fixed pole where the horizon met the pole, the value on the movable pole in a straight line to the horizon had to be estimated. Figure 3-5 gives an idea of this way of measuring the beach profile. Because of a lack of time these data are not collected and processed.

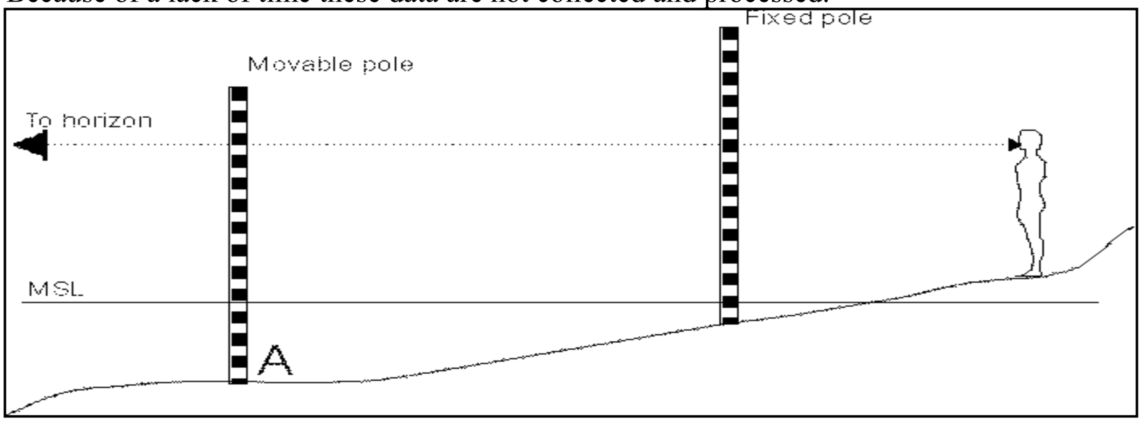


Figure 3-5 Measuring the beach profile with two poles.

When sophisticated equipment can be used there is a better way of measuring the profiles. As has been said before, by using a fixed baseline. On this baseline a fixed height is determined. For this fixed height we used the concrete plate at the hotel (Figure 3-2). At all other measured altitudes the height was read by using a theodolite. These points have been related to the height of the concrete plate. In this way it was possible to get a beach profile related to one reference point. As said before different profiles of rays perpendicular to the baseline have been measured. In Annex II the data of these measurements are given. The data of the different rays haven visualised in order to be able to compare the different altitude lines. In Figure 3-6 these lines are given.

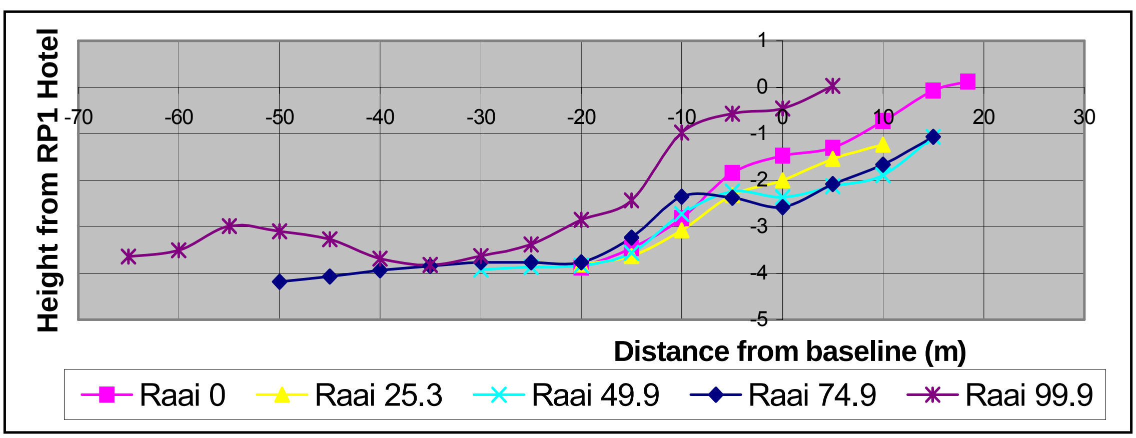


Figure 3-6 Length-altitude profile different rays

Because of the fact that the Bulgarian students did also some measurements, not all the rays are given in Figure 3-6. The Bulgarian group did also measurements on rays at a distance of –96.2m, -50m and –25.0m from the zero line.

The data have also been put in a 3D model (including the Bulgarian data) to get a clear view on the profile of the beach. In Figure 3-7 this beach profile is given. In order to monitor the variation of the beach during the years it is not only important to have a 3 dimensional view of the beach. A more important thing is to calculate the difference in beach volume. In Figure 3-7 the borders of the volume calculation are given.

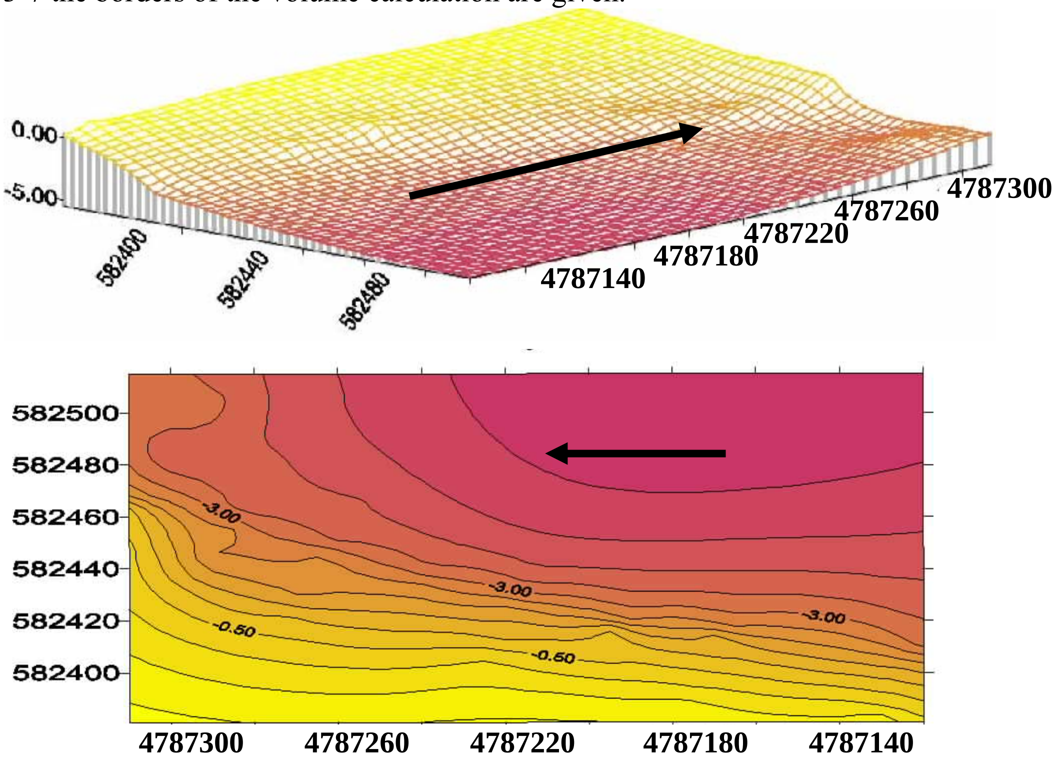


Figure 3-7 St. Constantine's beach profile

In this situation it is very important to use vertical borders as visualised above. When using horizontal borders, a horizontal zero level, the borders can change during the years. This is caused by variation of the beach profile. When the beach profile reaches the zero level, the borders lines change in horizontal level. This causes a variation of the measured part of the beach, which is not the purpose. Using these borders and data the beach volume is **1.71675E+006 m^3** (**Annex III**)

3.4 Measuring the beach line

The beach profile has been measured several times to create a separation line between the water and the beach on a map. The picture below gives an idea of the different routes.

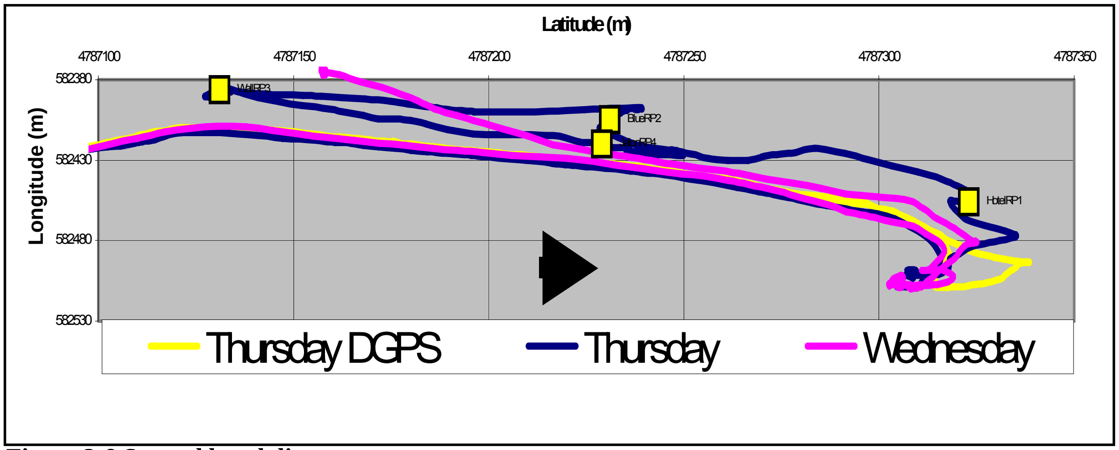


Figure 3-8 Several beach line measurements

Because of the negligible tidal difference we didn’t take these variations in time into account. We measured the beach line with two systems.

The first one is GPS. By using satellites you can determine your position. While doing this we used the European Geostationary Navigation Overlay system (EGNOS). Over the world there are many Wide Area Reference Stations. These stations send data to a Wide Area Master Station which in his turn send data to the handhold GPS. In this way you get a very exact result of your position using a reference station (comparable to DGPS). The accuracy of your location differs at most a few metres with your exact location. The EGNOS system is quite a new development. The GPS gave an EGNOS signal all the time, so we assume that all measurements have been done using this system. The GPS has been used on Thursday and Wednesday.

The second one is DGPS, differential GPS. With this system all kinds of errors caused by time difference, reflections and things are reduced. For this system you need more satellites and you need one satellite for a relative long period to calibrate the exact position. In this system you need two GPS units. One of them is fixed and sends data to the local (mobile) to reduce errors. The accuracy of determining a location can be enlarged to about 3 millimetres! The DGPS has been used on Thursday.

The data of the measured points have not been added to the appendices, because every few seconds a data-point was taken and during the measurements thousands of data points have been collected (including bathymetric survey).

We measured the beach two times with a handhold GPS (Global Positioning System) and ones with a DGPS.

Conclusions about the measurements can be found in paragraph 3.6.

3.5 Sieve analysis

In order to calculate sediment transport, some measurements have to be taken on the sediment. Within the sediment transport formulas D50 is the main characteristic, and therefore a sieve analysis is made of four samples taken from the beach in Varna, and the corresponding D50 can be obtained. The samples taken:

1. Sediment near the shoreline at the south side of the beach
2. Sediment from the sea bottom within the surf zone.
3. Sediment taken from the beach far from the shoreline
4. Sediment near the shoreline at the north side of the beach

At the hydraulic laboratory of Delft University the sieve analysis has been executed. Results are given in Table 3-2. Only one sieve measurement for each sample was executed. For our purposes, quantifying sediment transport, accuracy rates are of that small order of magnitude, only one sieve measurement satisfies. Calculations are given in Annex IV

Sample	D50(μm)
1	320
2	370
3	375
4	295

Table 3-2 D50 of different sand samples

Remarks:

Sample 1&4, Sediment near the shoreline at the south side of the beach and Sediment near the shoreline at the north side of the beach
Both the samples taken from the shoreline show a D50 of approximately 310 μm. This is much smaller than the other two samples. The dynamic character of the water movement near the shoreline can explain this. At the time when the samples where taken, the shoreline was progressing in direction of the beach, and was therefore taken sand from the beach. There actually was a visual receding shoreline. A sample taken from the beach on the shoreline shows a lower D50, as we can expect not all small particles to be in suspension at that time.

Sample 2 Sediment from the sea bottom within the surf zone
Latter in contrary to the sample taken from the sea bottom, which gives a much lower D50. This can be explained by the effect of the water orbital movements near the seabed. This causes the small particles to be in suspension all the time.

Sample 3 Sediment taken from the beach far from the shoreline
The sample taken from the onshore beach profile shows a much larger D50. Exact causes are hard to determine but some effects can be remarked. Probably there was a high dynamic beach profile, given the effect the shoreline receded at such a high speed. This can cause the sediment to be of a different characteristic as near shore. Maybe some aeolic processes may have occurred.

3.6 Conclusions:

Beach measurements
Two ways of measuring the beach profiles have been described. Only the last one, with theodolite and reference level, has been evaluated and conclusions are drawn from these data. The reason for this is that most profiles have been fixed in this way.
Taking into account the accuracy of the described ways, it can be supposed to use even the simplest model. The accuracy of the used method is too precise. It is no use to work out the data in decimals. This has to do with behaviour of sand. Taking only one step on the sand on the place where the height was measured can cause a difference in height of even many centimetres. Or putting the beacon in the water for a few seconds causes a decrease of many centimetres in height, because the sand around the beacon washes away. Taking the measures of the profile should be done very rough. A system of using two poles or using the horizon as reference will suitable enough.

Beach line measurements:
We can draw several conclusions from Figure 3-8 with respect to the accuracy and preferences.

- The GPS (range of few hundred euros) is much cheaper than the DGPS (many thousand euros).
- Using the DGPS system creates a lot of patience. To get the exact location you need much more satellites for a much longer period. Sometimes it takes many minutes, while GPS can be used immediately.
- Taking into account the error range the GPS score is worse than the DGPS. At the other hand it is very difficult to determine the beach line, because of wave action and things. The beach line also changes during short periods in the range of metres, because of tidal variation and wind. Keeping this in mind we come to the conclusion that the accuracy of DGPS is too big.
- If we finally look at the picture we see, that the GPS and DGPS line (profiles) do not differ significantly.

Taking these things and the present developments into account (EGNOS) we can conclude that for yearly morphological analysis the handhold GPS with the use of EGNOS is very suitable.

4 Wave Measurements

4.1 Preface

In this exercise visual wave measurements were taken with a theodolite. Several hundreds of wave data were obtained and analysed.
These wave measurements have also been obtained using a pressure meter. This data will be compared with the visual data and the differences will be discussed.
Using CRESS the shoaling and breaking will be analysed and the wave height in deep water will be calculated.
All these measurements were taken on the beach just north of the Delphin hotel.

4.2 Sample Descriptions

Visual measurements

To visual measure the waves a location had to be found where the beakon could be placed in such a way that waves can be measured where they are still "undisturbed". The theodolite must have a good, not too far away, position on shore to measure the waves. This place was found at the beach just north of the Delphin hotel where the beakon could be placed at the end of the jetty (Figure 4-4-2) and the theodolite on the other side in a straight line with the incoming waves (Figure 4-4-1).

Figure 4-4-1 Position theodolite

Figure 4-4-2 Position beakon (from theodolite position)

After positioning the theodolite one could start measuring every wave crest and every wave trough for a period of 100 waves. This was done several times and for both the Dutch and the Bulgarian students. These data can be found in Annex V to Annex VIII.

Pressure measurements

As an alternative on the visual measurements pressure measurements were taken with a pressure gauge. By measuring the water pressure, one can calculate back the wave height, using the linear wave relation.
The position of this pressure gauge is the same as were the beacon was situated, because that is the best place where the waves are still "undisturbed". Also the depth of the sea bottom and the depth of the pressure gauge itself must be obtained for the calculation of the wave height.
With a simple pc program the signal from the sensor was amplified by an analogue amplifier and these data can be found in Annex IX.

4.3 Results

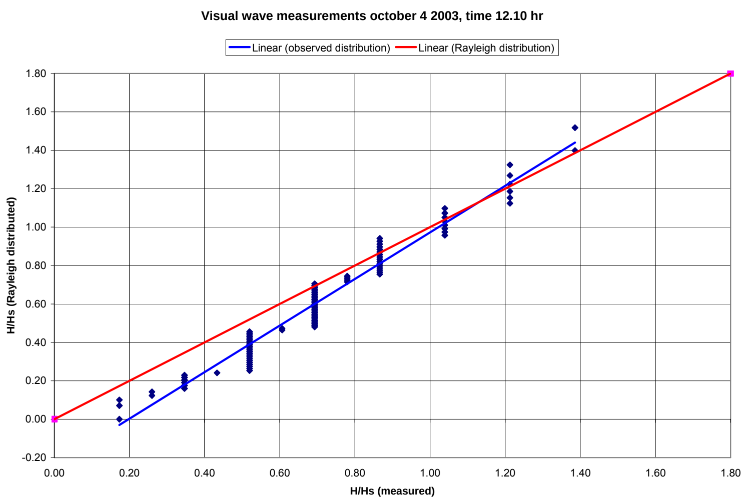
With the data achieved visually a few calculations have been made. First of all it was checked if the waves, which have been observed, are Rayleigh distributed. From all the measurements the H_s is determined by determining the 33 highest waves of each 100 measurements. The average of these 33 measurements is H_s. The measured waves are compared with the expected waves according to the occurrence chance using a Rayleigh distribution. To make this comparison possible the ratio H/H_s is used. The exceedence chance for Rayleigh distributed wave-heights is determined with the following formula.

$$P\{H_{visual} > H\} = \left[-2 \left(\frac{H}{H_s} \right)^2 \right]$$

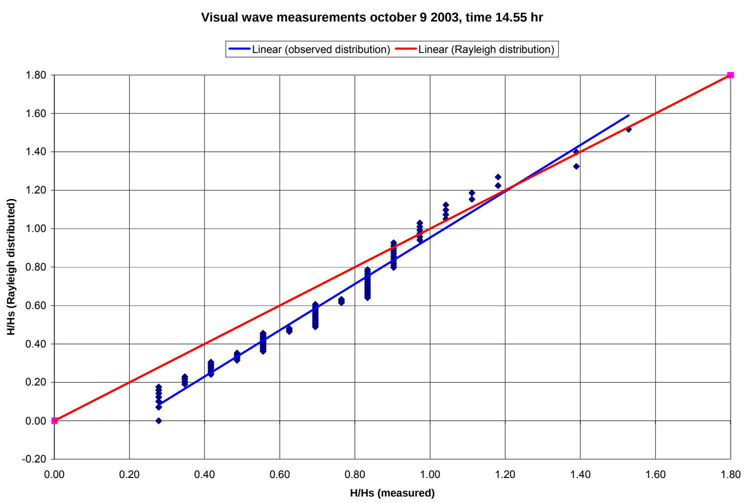
It is necessary to determine the exceedence chance of the waves so the ratio H/H_s can be calculated. The highest observed wave is never exceeded and the lowest wave is exceeded by 100% of the waves. Now the ratio H/H_s is determined as follows:

$$\frac{H}{H_s} = \sqrt{-\ln \frac{P\{H_{\text{visual}} > H\}}{2}}$$

The results are plotted in a graph with on the y-axis the Rayleigh distributed ratio and on the x-axis the measured ratio of H/H_s. A trend line is drawn through the obtained data. This line indicates how much the observed data obliges to the Rayleigh distribution of the waves. As one can see in Figure 4-3 the trendline is lower than the Rayleigh distributed line. In this figure two graphs are presented one for the Dutch data and one for the Bulgarian data, which was obtained on a different date. Especially for the lower waves the trendline lies much lower. This is as is expected because it is very hard to determine the height of the lower waves.



Dutch data



Bulgarian Data

Figure 4-3 Trendline and Rayleigh distribution

Waves, which are approaching a coast from deep water under an angle, will refract when propagating towards a coast. At the outermost point of the jetty the waves are already refracted but not yet perpendicular to the coast, the direction of the waves is measured to be 30° and at deep water they are estimated at 40°. Also at the outermost point of the jetty the waves became a little bit higher then they seemed to be on deep water. When propagating towards the coast the waves start breaking and become smaller afterwards.

These observations will be compared using calculations with Cress (IHE version).
In order to do this the deep water wave height must be determined. The following formula is used to calculate H_0: $H_1 = H_0 * K_s * K_r$.
$H_1 = 0.55$ m.
h/L = 2.85 m / 13 m = 0.22 → Annex X→ $K_s = 0.9231$

$$K_r = \sqrt{\frac{\cos\theta_0}{\cos\theta_1}} = \sqrt{\frac{\cos 40°}{\cos 30°}} = 0.9405$$

$H_0 = 0.55$ m * 0.9231 * 0.9405 = 0.48 m.
$T_m = 3.40$ s with $T_p = T_m / 0.8 = 3.40$ s / 0.8 = 4.25 s.

The depth profile near the jetty is shown in Figure 4-4.

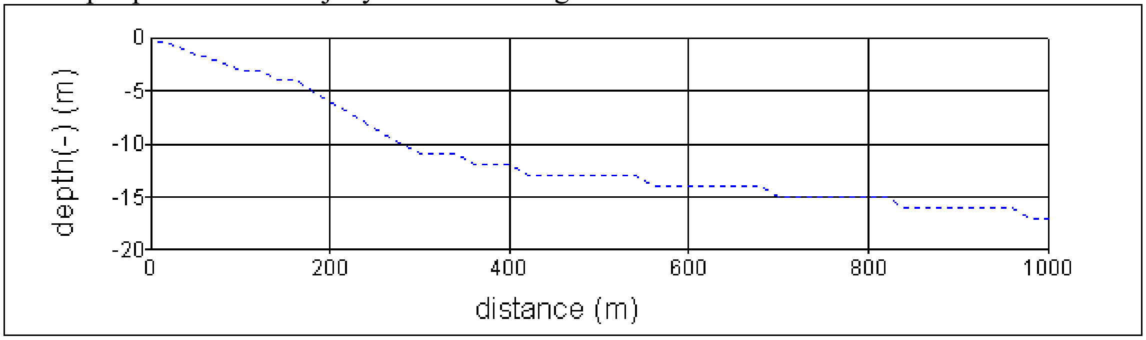


Figure 4-4 Depth profile

Using Cress, (Coastal Hydraulics, Changes of waves in shallow water, Energy decay of waves, including current; IHE-version) it is checked if the shoaling and breaking is as expected. The results calculated by Cress are illustrated in the next graph.

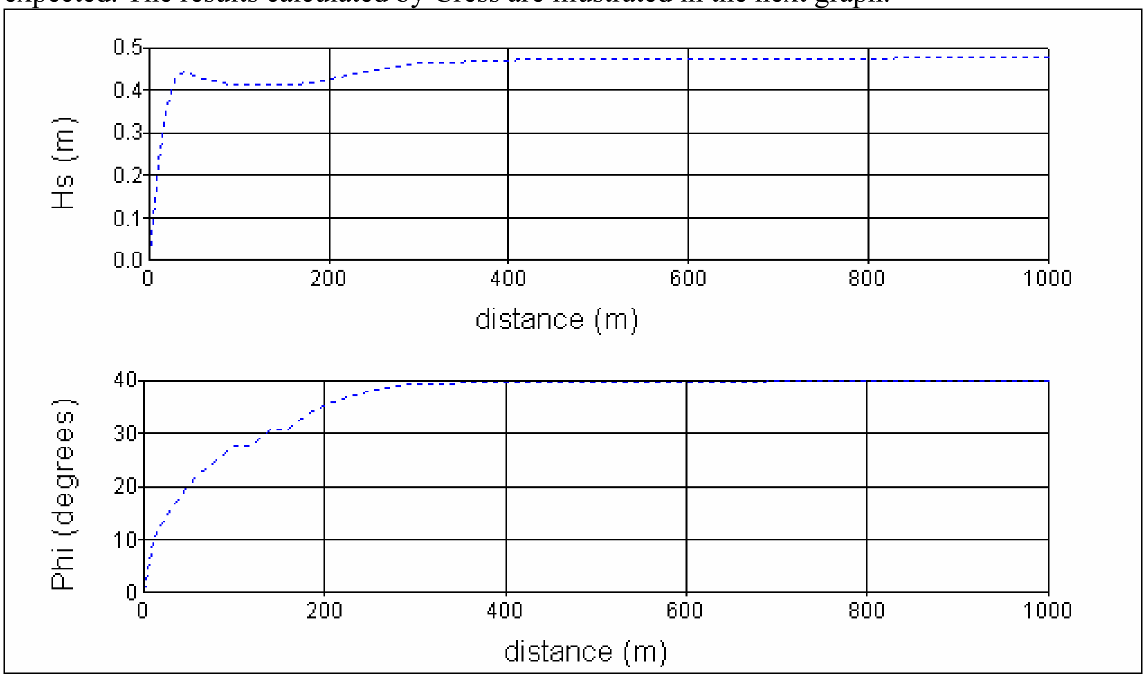


Figure 4-5 Hs and Phi calculated by CRESS

The graph clearly shows that the waves start growing just in front of the jetty and the waves start breaking very close to the coast at a distance of about 40 m, which is just as observed. Also the approach angle of the waves calculated by Cress is at a distance of 80 meters offshore (place of beacon) is about 25 degrees and the observed angle was 30 degrees. This is quite accurate for this type of calculation.

As an alternative the wave heights have also been determined with the use of a pressure gauge. The pressure gauge measures a pressure in [N/cm^2]. With this pressure the wave height can be determined using the linear wave theory.

$$p = \rho g a \frac{\cosh k(h+z)}{\cosh kh}$$

The formula above is simplified because the incident waves are assumed perpendicular to the pressure gauge so $\sin\theta = 1$.

In order to use this formula the wavelength must be determined because k is the wave number defined as $k = 2\pi/L$. The measured depth is h = 2.83 m and z is the depth of the pressure gauge in relation to the mean sea level (MSL) and is measured to be z = -0.75 m.
In Figure 4-6 the results of the measurements are illustrated.

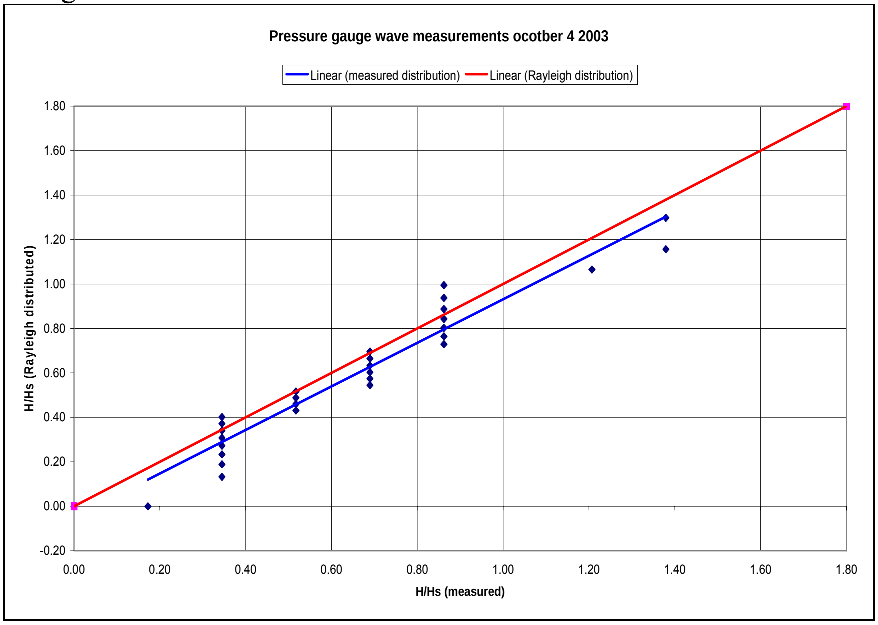


Figure 4-6 Results pressure gauge

Linear wave theory is used and this theory is valid. This is valid because the measured waves are Rayleigh distributed as can be seen in the graph. Only a small distortion can be seen $0.93 * (H/H_s)_{Rayleigh} = (H/H_s)_{measured}$

Visual observation is accurate for the bigger waves. If there are more visual observations, the accuracy becomes much better. So if there are many observations the accuracy of the visual observations is good.

Pressure reading is very accurate because it registers a Rayleigh distributed wave height. With the pressure gauge used there seems to be a constant error in the gauge resulting in a slightly lower H/H_s ratio. This is probably caused by a signal output error of the pressure gauge.

5 Groyne Measurements

5.1 Introduction

In this exercise the profile of a groyne will be measured. The same measurements were done in 2002 so if large changes have occurred they can be discovered. In 2002 a fixed point was chosen from which the groyne was mapped. This point was chosen in such a way that future measurements can take place from the same starting point leading to a series of measurements of this groyne spread out over several years. In such a way a good indication can be found about the stability of the groyne itself and the armour blocks in particular. To get a first impression about the change of the profile, the profiles are measured and then are plotted in order to be investigated visually. To get a better insight in the change of the amount of material a calculation of the total volume of the groyne is made.

5.2 Location of the starting point

At the end of the breakwater a fixed point was located that was easy to recognize and would not move or disappear in future. As can been seen the right side of the breakwater and outlet channel, seen from the shoreline on, was chosen to fix this point (Figure 5-1).

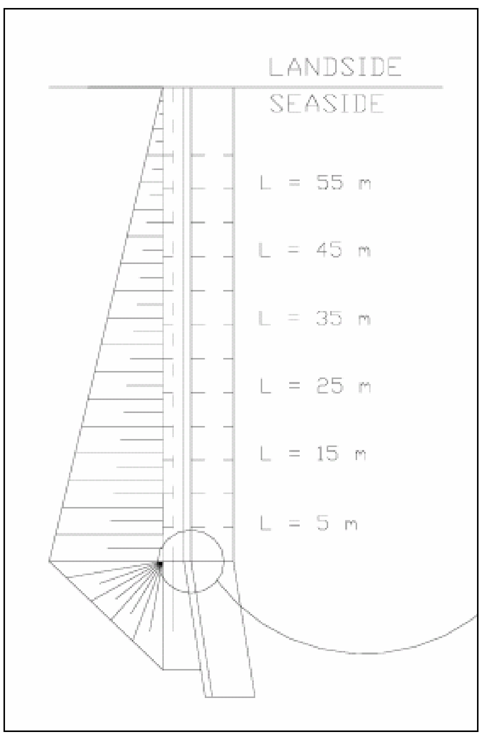


Figure 5-1 Groyne drawing

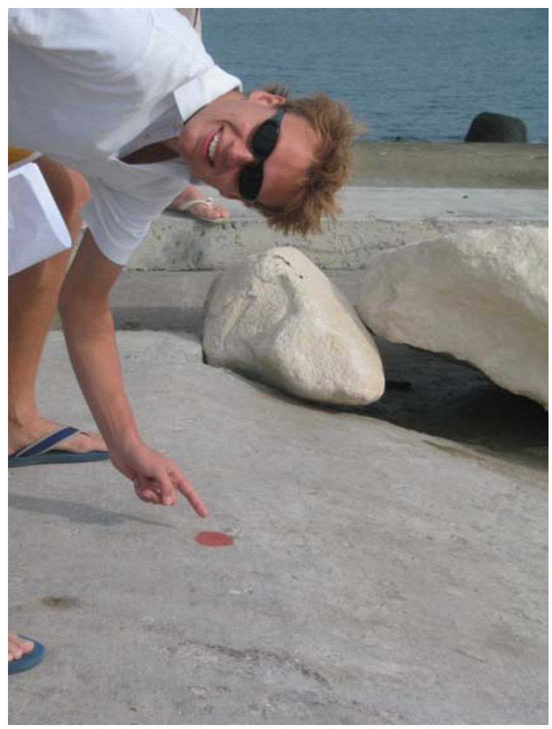


Figure 5-2 Starting point

As a starting point for the measurements the bended piece of the breakwater was ignored. Notice that at the last horizontal concrete plate (the one before the slope) a little corner was missing (Figure 5-2 and Figure 5-3). This corner was taken as the reference point of the line stipulated along the breakwater (x = 0, x-axis along the breakwater).
The starting point of the line is set 1.5 m perpendicular to this corner (Figure 5-3). Every 5 meters a point was marked, and every 10 meters a cross-profile was measure perpendicular to this line, starting at L = 5 m, ending at L = 35 m.

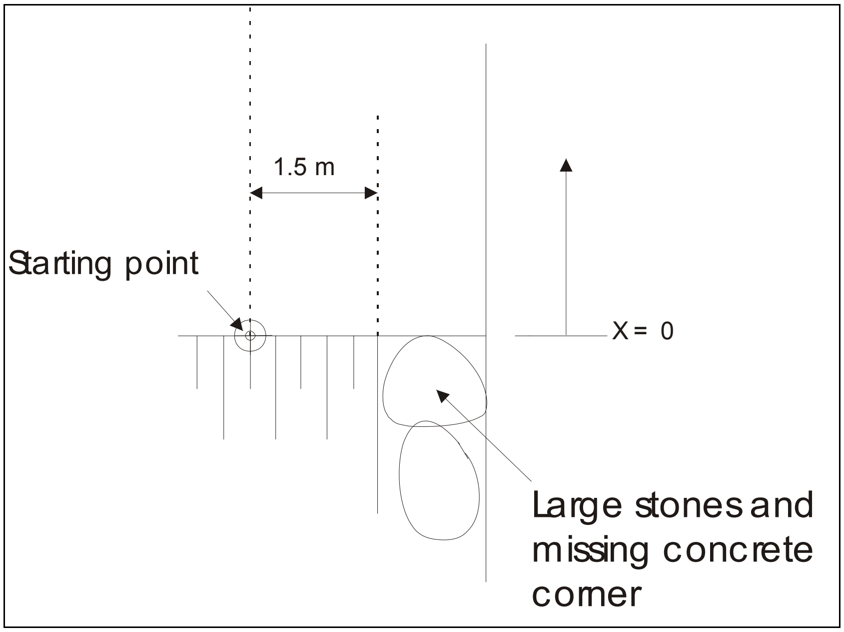


Figure 5-3 Detailed drawing starting point

5.3 Profile measurements of a groyne

The profile of the groyne was measured using the same reference points as last year. With a distance of 10 meter between each other 4 profile measurements were carried out using a hemisphere of 0.75 m attached to a rod. This hemisphere is used to level out the influence of an individual block on the measurement. The size of this hemisphere should be approximately ½* d50. In 2002 the same groyne was measured, using a hemisphere with a dimension of 0.25 m, and these measurements are used for comparison. The compare the different profiles the point at L= 5.0 m, Y = 0 is taken as the zero point in Z-direction and every point is calculated in reference to that. This leads to the profiles in Figure 5-4. All the data are collected in Annex XI. These profiles show some difference between the measurements in 2002 and 2003.

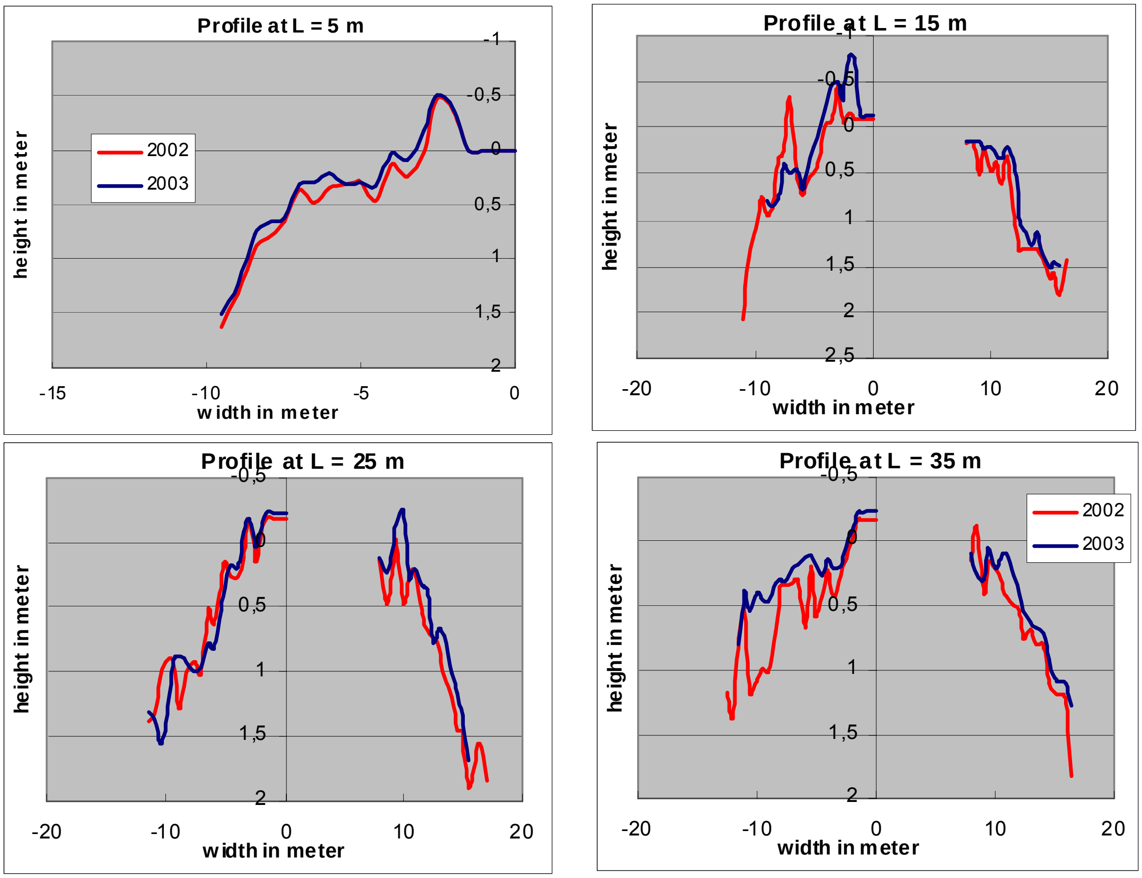


Figure 5-4 Profiles at different cross-sections

A part of the differences between the measurements can be attributed to the use of different hemispheres. As has been noted before two hemispheres were used. In 2002 only the small hemisphere, with a diameter of 0.25 meter, was used. In 2003 most of all the cross sections were measured with the large hemisphere, diameter 0.75 meters, but for a reference also measurements using the small hemisphere and no sphere at all were carried out. This was done for one profile, the profile at L = 15 meter. In Figure 5-5 the 3 different profiles from these 3 measurements are shown.

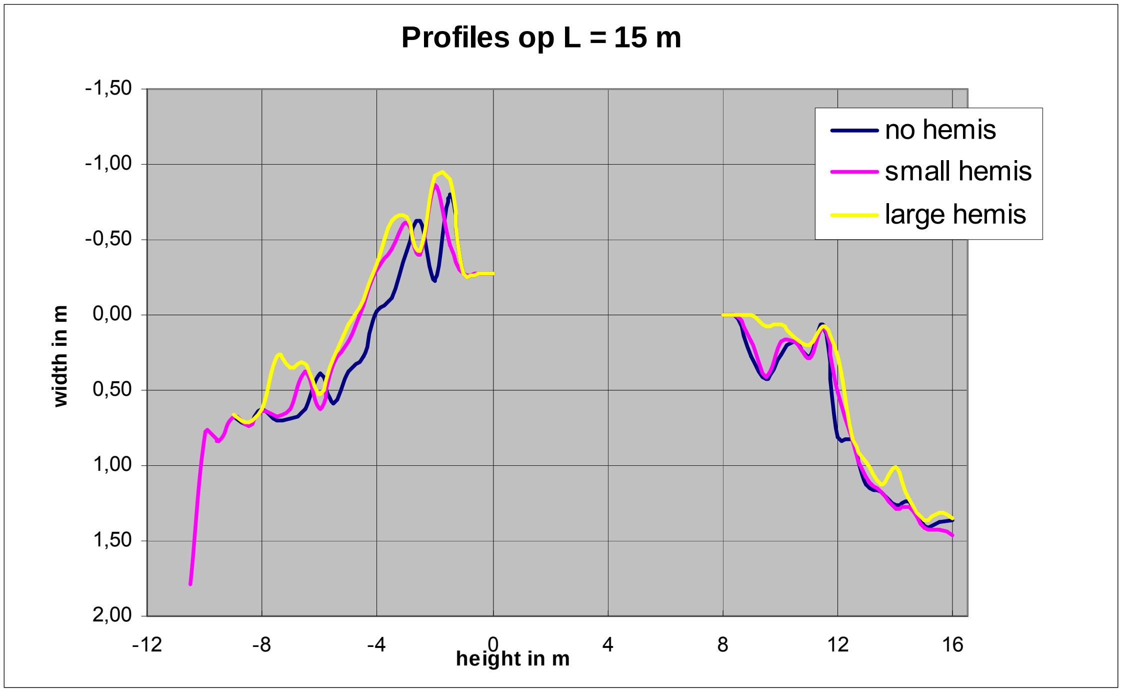


Figure 5-5 Profiles with different hemispheres

From this comparison it becomes apparent that the use of a different hemisphere has some effect on the profile that is measured. The large hemisphere flattens out small peaks in the profile where the small hemisphere, or just the rod without the use of a hemisphere, fits in the crevice between two stones. If the measurements for cross-section at L = 15 meter, done in 2002 with the small hemisphere are compared with the measurements from 2003 also made with the small hemisphere a better indication for the actual change in profile can be made visible. Also in this case differences occur between the measurements. Apparently material of the groyne has been moved throughout the year. Important to know in this case is whether the total amount of material of the groyne remains the same, is there change of volume?

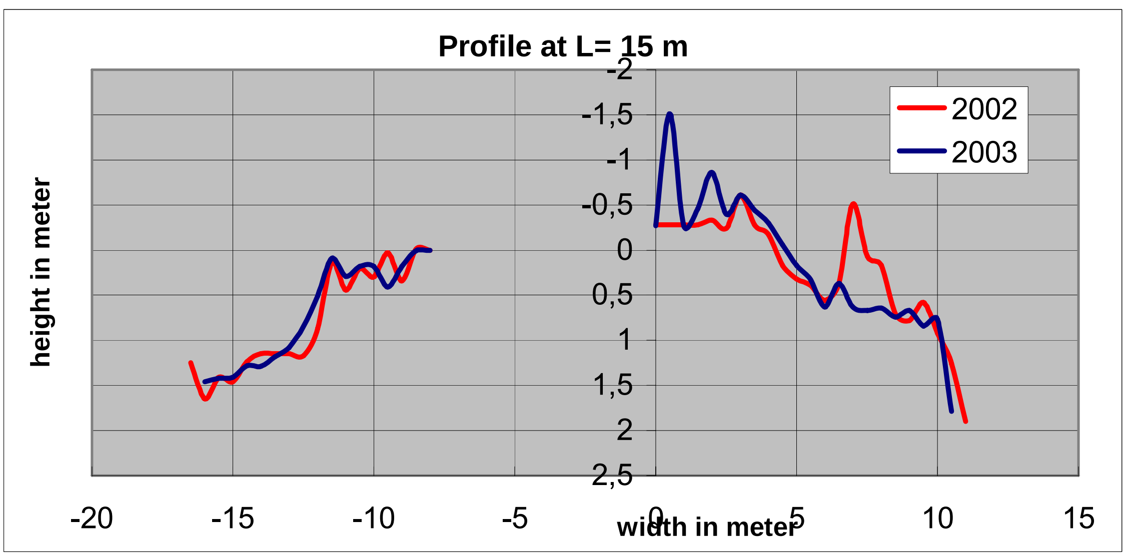


Figure 5-6 Profile at L=15 m, small hemisphere

The change of volume can be computed from the measurements. The cross-sections are known; the distance between the cross-sections is known, so also a rough estimate of the volume can be computed. Difficult in this case is the lower boundary, almost every cross-section measurement ends somewhere along the waterline. A fixed lower boundary is not to be found, so some value will be chosen. From looking at the data it becomes clear that no data exceeds more than 2 meter below the before chosen zero point. So 2 meter is chosen as the lower boundary. In Figure 5-7 this is shown for the profile at L = 5 meter. The surface of this profile is calculated between the lines Y = 0m, the blue line along the Y-axes, and Y = 9.5 m, the blue line at Y (width) is 9.5 meter. Above and below this area is bounded by Z= 0 m and the profile line, also given in blue.

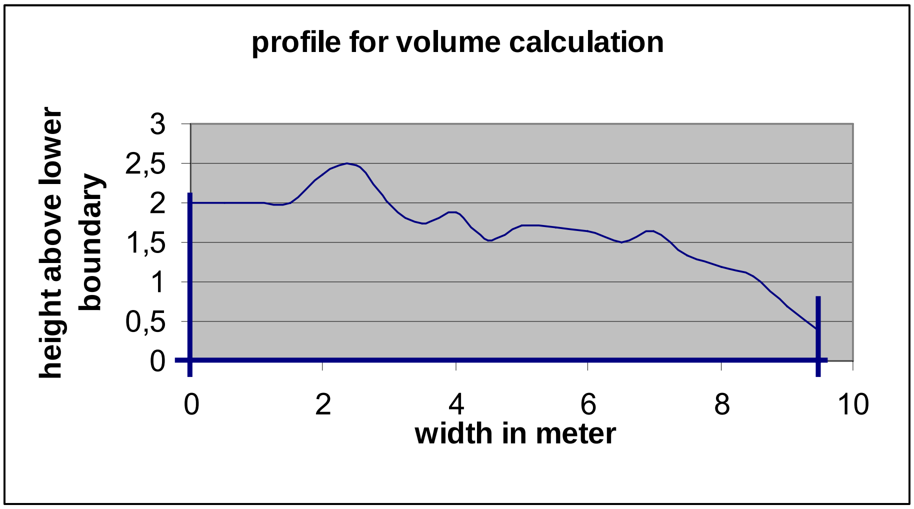


Figure 5-7 Profile volume calculation

In this particular case the surface is 15.9 m^2. Similar calculations were carried out for every cross-section for both the 2002 and the 2003 data. The results are shown in Table 5-1.

	Profile			
year	L = 5 m	L = 15 m	L = 25 m	L = 35 m
2002	15.9	25.9	27.4	30.3
2003	16.6	27.4	27.6	32.6

Table 5-1 Surface areas for profiles

Now the total volume of the groyne can be calculated. This leads for the data from 2002 to a total volume of 764 m^3 and for the data from 2003 to a volume of 796 m^3. The difference is rather small, just a few percent, and can be mainly attributed to the use of the different hemisphere. Also the volume in 2003 is a bit larger than it was in 2002. This means that the amount of rock in the groyne has increased while no suppletions have taken place. This can be explained by the fact that the measurements took place above the water level. Some material can be moved from below the water level and placed above, leading to an increase in the amount of rock. Although these mechanisms take place the differences are mainly due to the use of a different hemisphere.

5.4 Conclusion

Part of the differences between the measurements of this year and those of last year can be accounted to the use of a different hemisphere, but also some displacement of material has taken place.

6 Quarry

6.1 Introduction

Wednesday, the 7th of October, we have visited two quarries of Eskana S.A. At Marciana Quarry we identified a pile of rock. After having a good lunch at a beautiful reservoir for water storage, we paid a visit to Sini Vir Quarry.

Marciana Quarry

Figure 6-1 Marciana Quarry

This quarry produces crushed stone by fractions for road bottoming and asphalt coatings, limestone, mineral concrete and chalk. Marciana is an opencast working with application of borings. Although we took larger stones for our measurements, the produced fractions are 5/30 mm, 25/60 mm, 60/150 mm, 0/75 mm and some micronized products from 20 µm to 300µm. Too large stones will be crushed and then sorted in different fractions.

Sini Vir Quarry

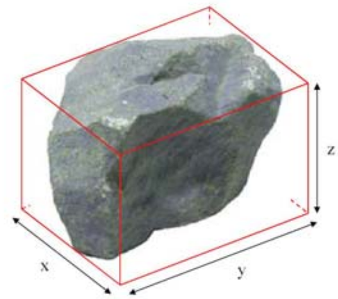
Figure 6-2 Sini Vir Quarry

This quarry is also an opencast working with application of borings. The quality of stones has a significant variation: soft 'yellow' stone and harder 'grey' stone. They try to keep them separated by well-thought blasting of the rock. The produced fractions are 5/15 mm, 5/25 mm, 25/60 mm and they are used for asphalt coverings, railway ballast and concrete.

6.2 Problem Description

At Marciana Quarry we selected a collection of 50 rocks. Our 'selection criterion' was: you shouldn't be able to carry the rocks with just one hand, but you should be able to carry them with both hands. In this way we created a set of stones with weights varying from 10 to 80 kilograms.
First we determined the weight of each of the stones with an accuracy of 0.05 kg. Then we measured the three axial lengths: x-axis longest length and z-axis shortest length.

According to CUR 154:



Elongation: $l/d = \dfrac{\text{longest\_axial\_length(x)}}{\text{shortest\_axial\_lenght(z)}}$

Blockiness:

$$BLc = \frac{\text{Volume\_of\_the\_rock\_block}}{x \cdot y \cdot z} \cdot 100\%$$

The volume of the blocks mentioned here, has to be determined in the laboratory in Delft by NEN 5186. The 'dry mass', 'mass under water' and the 'moist mass' will be determined to calculate the average density of the rocks, with the following formula:

$C = \dfrac{m_3 * \rho_w}{m_2 - m_1}$, with m_1 = mass under water; m_2 = 'moist' mass; m_3 = 'dry' mass.

By knowing the density, it is easy to calculate the volume of each of the stones and eventually the blockiness and the D_n. At this moment, it is possible to gain some information about the entire set of stones, like the mean elongation $(l/d)_m$, the mean blockiness (BLc_m), the standard deviation of the blockiness ($\sigma(BLc)$) and of course the D_{n50}.
Plotting the exceedance of a certain stone diameter against the stone diameter shows the typical S-curve. If the gradation is well chosen, a straight line should appear when plotted on a log-Gauss scale.

To come to the actual design of a hydraulic structure, the porosity n_v and the single layer thickness k_t have to be defined. Both can be calculated by substituting the values of the table underneath in the following formula:

$$\text{Parameter} = A + B \cdot BLc_m + C \cdot (l/d)_m + D \cdot \sigma(BLc)$$

Parameter	slope	A	B	C	D
Singe layer porosity nv	1:1.5	42.38	-0.2177	3.695	-0.4128
	1:2	42.90	-0.2204	3.740	-0.4179
	1:3	43.46	-0.2233	3.789	-0.4233
Layer thickness kt	1:1.5	1.1375	-0.0026	-0.1588	-0.0003
	1:2	1.0736	-0.0024	-0.1499	-0.0003
	1:3	1.1038	-0.0025	-0.1541	-0.0003
Double layer porosity nv	1:1.5	34.53	-0.2137	3.446	0.1852
	1:2	35.94	-0.2224	3.586	0.1928
	1:3	36.20	-0.2240	3.613	0.1942

Table 6-1 Calculations porosity and thickness

At last the groyne at St. Konstantin will be redesigned with use of the stones of Marciana Quarry. Therefore we need to reconstruct the design wave height and determine the corrections of the coefficients in the 'Van der Meer-equations', according to Stewart (2002).

$$\frac{H_s}{\Delta D_{n50}} = 6.2 P^{0.18} \left(\frac{S_d}{\sqrt{N}} \right)^{0.2} \xi^{-0.5} \quad \text{(Plunging breakers)}$$

$$\frac{H_s}{\Delta D_{n50}} = 1.0 P^{-0.13} \left(\frac{S_d}{\sqrt{N}} \right)^{0.2} \xi^P \sqrt{\cot \alpha} \quad \text{(surging breakers)}$$

BLc-range	l/d range	Armour Porosity (%)	Placement method	"6.2"	"1.0"
40%-50%	1.3 - 3.0	38.7	standard	7.09	-
40%-50%	1.3 - 3.0	36.1	dense	6.68	1.67
50%-60%	1.3 - 3.0	37.1	standard	6.44	1.51
50%-60%	1.3 - 3.0	35.2	dense	7.12	2.08
60%-70%	1.3 - 3.0	35.5	standard	7.71	2.63
60%-70%	1.3 - 3.0	34.4	dense	10.85	-
50%-60%	1.0 - 2.0	36.1	standard	8.50	1.45
50%-60%	1.0 - 2.0	34.6	dense	8.80	-

Table 6-2 Values for redesigning the groyne

6.3 Results

In Annex XII, all measurements done in Marciana Quarry are presented. It was very obvious that these stones were not suitable for hydraulic structures because of their poor quality. Picking up these stones resulted in ‘white hands’ and it was very easy to break them. The stones of Sini Vir clearly were denser and harder.

In the laboratory at TU Delft, while determining the densities of the stones from Sini Vir and Marciana Quarry, our suspicions were confirmed. The Marciana stones ‘dissolved’ in water and behaved like sponges: the mass under water kept running up. Following from the table, the average densities are:

ρ_s(Marciana) = 2349 kg/m^3

ρ_s(Sini Vir) = 2538 kg/m^3

	Dry Mass [g]	Mass under water [g]	Moist mass [g]	Density [kg/m^3]
Sample I	*Marciana Quarry*			
1	83.5823	49.9412	87.3512	2234.22
2	70.7973	42.5662	71.4462	2451.43
3	171.8067	104.1396	178.1409	2321.67
4	88.3710	52.8259	89.9583	2379.89
5	68.9881	40.7197	69.9823	2357.55
Sample II	*Sini Vir Quarry*			
1	217.2000	132.5500	218.0400	2540.65
2	169.0100	104.1900	169.0600	2605.36
3	175.4770	107.9500	175.7975	2586.34
4	60.4802	35.6671	60.6816	2417.81

Table 6-3 Laboratory measurements TU Delft

The differences in density are significant. By comparison, ‘normal’ rock in hydraulic engineering has an average density of about 2650 kg/m^3. One should realize that the determination of these densities isn’t very accurate, because of the large variation in the quality of the stones and the small amount of stones.

Now the D_n of each individual stone can be calculated: $D_n = \sqrt[3]{\frac{m}{\rho_s}}$, see also Annex XII.

The graphs of the exceedence, successively on log and log-Gauss scale show the well-known S-curve and straight line (see Figure 6-3 and Figure 6-4). It is remarkable, that our ‘random’ selection of stones approaches the straight line so well.

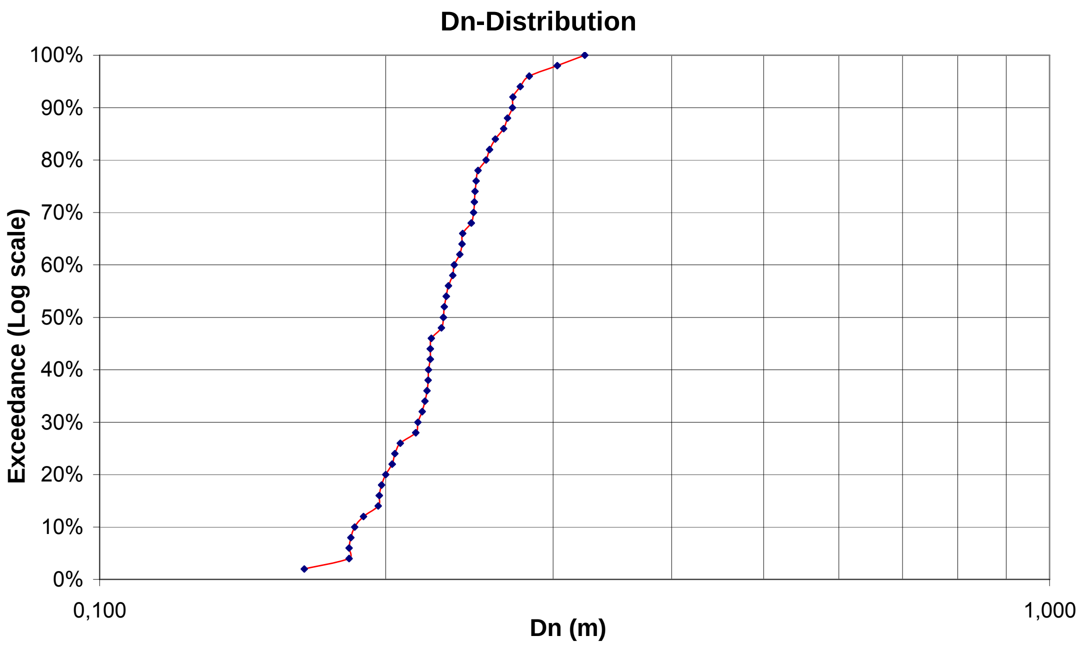


Figure 6-3 Exceedence (Log scale)

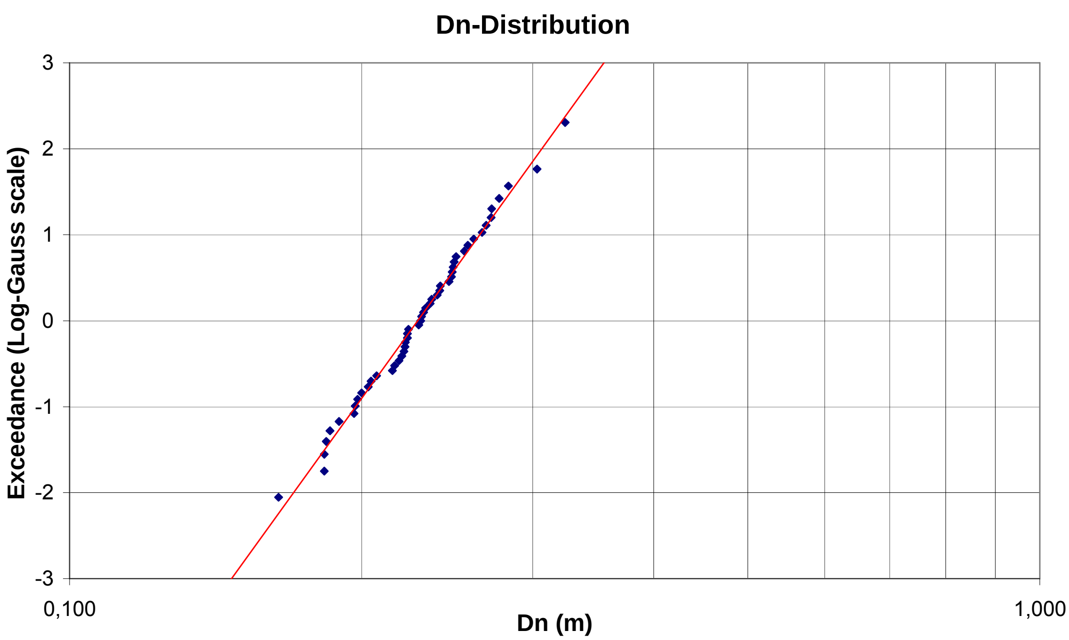


Figure 6-4 Exceedence (Log-Gaus scale)

Some statistical values of this distribution are needed to calculate the void ratio and the layer thickness (slope is 1:3), by substituting the values of A, B, C and D from Table 6-1. The coefficients in the Van der Meer equations become, according to Table 6-2, 7.09 (“6.2”) and 1.0 (“1.0”).

Nominal Diameter [m]	Dn50	0.230
Mean Elongation	l/dm	1.92
Mean Blockiness [%]	BLc_m	41.4
S.D. Blockiness [%]	sigma(BLc)	8.31
Single layer porosity [%]	nv	38.0
Layer thickness	kt	0.70
Double layer porosity [%]	nv	35.5

Table 6-4 Summary statistical data

At Marciana Quarry (MQ), there was also a heap of larger stones, which were too big to put on the scales. So we measured the axial lengths and estimated their weights by assuming that the blockiness of the larger stones was the same as that of the small stones. The D_{n50} was 0.91 m with a weight of approximately 1.8 ton.

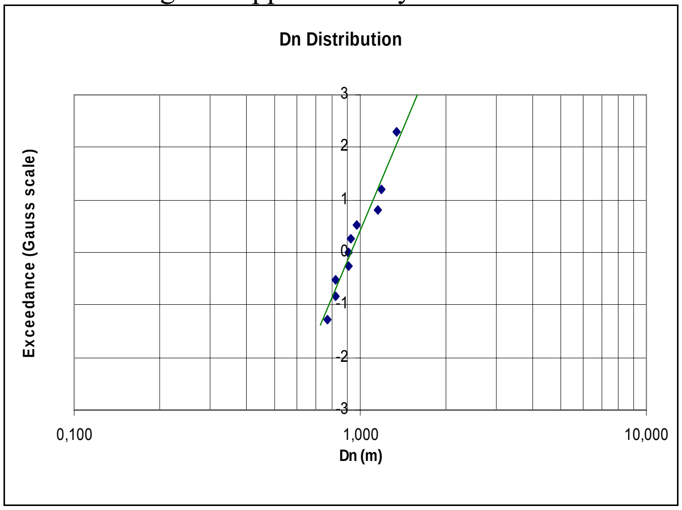


Figure 6-5 Dn distribution for larger stones at MQ

If we take the groyne at St. Konstantin as an example with estimated slope 1:3 (rough estimation; probably it was even less) and double armour layer, we can reconstruct the design wave height and period by calculating back with the Hudson formula.

For that purpose we estimated the D_n of 13 larger stones (the material was so widely graded, that taking the small stones into account would result in a very small value of the D_{n50}) and calculated a D_{n50} of 1.00m. In the laboratory the density was determined. Again this wasn't very accurate, because of the large variations in porosity of the stones and because of the fact we only brought one stone to Holland. This particular stone had a density of 2592 kg/m^3. The stones thus had a weight of about 2.6 tons.

Hudson-formula, rewritten:

$$H_S = \sqrt[3]{\frac{M \cdot K_D \cdot \Delta^3 \cdot \cot\alpha}{\rho_S}}, \text{ with } \Delta = \frac{\rho_S - \rho_W}{\rho_W} = \frac{2592 - 1000}{1000} = 1.59$$

K_D = 3.5 for rough angular quarry stone; 2 layers (SPM 1977; SPM 1984 probably too conservative!)

$$H_S = \sqrt[3]{\frac{2592 \cdot 3.5 \cdot (1.59)^3 \cdot 3}{2592}} = 3.48 \text{ m}$$

Now we will redesign this groyne with stones of Marciana Quarry while applying Van der Meer. A number of assumptions has to be made.

Permeability P = 0.1 (impermeable core; concrete)
Number of waves N =7500 (damage considered to have reached an equilibrium)
Damage level S = 10 (failure of the structure)

$$\xi_{transition} = [6.2 \cdot P^{0.31}\sqrt{\tan\alpha}]^{(\frac{1}{P+0.5})} = [6.2 \cdot 0.1^{0.31}\sqrt{1/3}]^{(\frac{1}{0.1+0.5})} = 2.55$$

For the calculation of ξ we need an assumption on the wave period: T_s = 8s, which leads to L_0 = $gT^2/2\pi$ = 102 m.

The wavelength in deep water becomes:

$$\xi = \frac{\tan\alpha}{\sqrt{H_S / L_0}} = 1.80 < \xi_{transition}(=2.55)$$, thus Van der Meer for plunging breakers.

$$\frac{H_S}{\Delta \cdot D_{n50}} = 7.09 \cdot P^{0.18}(\frac{S_d}{\sqrt{N}})^{0.2} \cdot \xi^{-0.5} = 7.09 \cdot 0.1^{0.18}(\frac{10}{\sqrt{7500}})^{0.2} \cdot 1.80^{-0.5} = 2.267$$

$$\Delta = \frac{\rho_S - \rho_W}{\rho_W} = \frac{2349 - 1000}{1000} = 1{,}35, \text{ so } D_{n50} = \frac{H_S}{2.267 \cdot \Delta} = 1.14m$$

Because of the lower density of these stones, the D_{n50} has to be slightly bigger; these stones have a mass of approximately 3.5 tons. Again it is stressed that the stones from Marciana Quarry aren't suitable for application in hydraulic engineering, not only because of their density, but mainly because of their poor quality (easily erodable).

6.4 Conclusion and Recommendations

The quarry exercise gave us a good insight in the operations carried out to produce rock, gravel and smaller fractions. Although these quarries do not serve the hydraulic engineering market, it is easy to imagine how it would be like to handle such stones. It has been remarkable that our selected heap of stones was so well graded.

Calculating back from an existing groyne to the design wave height, and then redesigning this groyne with an armour layer of a different stone quality, introduces a big inaccuracy into the equations. Also a few assumptions have been made, like the wave period of the design wave and the slope angle of the groyne.
Moreover, it is questionable whether the blockiness of the small stones will be the same as the blockiness of the large stones. Although the determination of the densities shows a big variety, the values are accurate enough for this type of calculations.

7 Bathymetry Survey

7.1 Introduction

At the Sirius beach of St. Konstantin and Eleena a new hotel has been build. The owner wants to improve the beach width, as he wants his guests to have more space to sunbathe. This survey is done in respect to the volume changes of the sediment in this coastal area and to investigate what possible measures the owner could take or shouldn't take to prevent severe erosion. This survey was the first in a row of more to come in following years. Attention has to be made to the fact that these groups are able to define the same reference levels.

Changing coastlines not only occur due to changes to be seen onshore but also due to changes offshore, beneath the water level. Visual observations of water depths are excluded so other methods have to be applied. One of these methods is the usage of an echo sounder for measuring depths in relation with a GPS, or a more precise DGPS, in order to determine the position of a certain water depth in the horizontal plane. In the fieldwork assistance of professional geodetics from the university of Bulgaria on DGPS and the echo sounder was at present.

This data can be used to determine the sediment volume in the coastal area at the moment of survey. Within time this can be repeated to analyse the loss or fill of sediment in the cross section.

7.2 Equipment

In order to get the equipment in the right place the use of a small vessel was necessary. Aboard was a DGPS system in contact with a shore based home station, and an echo sounder.

Echo sounding is based on the principle that water is an excellent medium for the transmission of sound waves and that a sound pulse will bounce off a reflecting layer, returning to its source as an echo. The time interval between the initiation of a sound pulse and echo returned from the bottom can be used to determine the depth of the bottom. An echo-sounding system consists of a transmitter, a receiver that picks up the reflected echo, electronic timing and amplification equipment, and an indicator or graphic recorder.

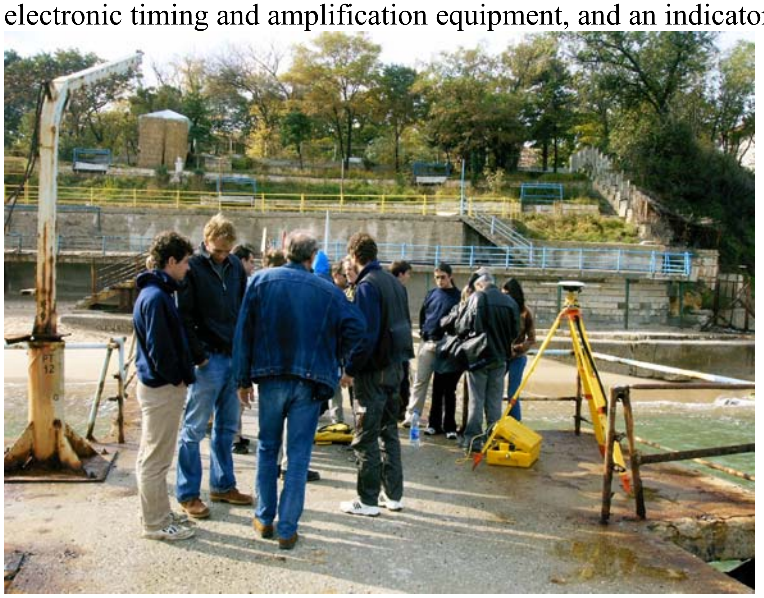


Figure 7-1 Home station in yellow

The DGPS was used to determine the exact position of the vessel at a certain time. This device is a much more sophisticated device in respect to the echo sounder. A much higher accuracy can be achieved using the DGPS in respect to a normal GPS, which is quite accurate for certain objectives it self. The precise position of the boat was determined using the relative distance to coordinates of a certain point onshore, which were determined with a very high precision last year. This point was then used to settle the home station (Figure 7-1) which could determine the distance to a handhold GPS onboard of the vessel. Accuracies in order of magnitude of 10^{-3}m can be achieved with such a system. Later on we discuss the value of such a high accuracy in comparison with the accuracy of the echo sounder.

7.3 Method

In order to get a reliable bathymetry along the whole beach, the vessel has to sail in straight lines somewhat perpendicular to the coastline. This can be done visually or what is done in this measurement on GPS. It's doubtful whether the highly precise GPS is more useful than a visual orientations method using two beacons onshore looking at the trajectories in last years report.
The position of the vessel is than linked to the measurement of the echo sounder. This is possible as the time of the both devices were adjusted to each other. Consequently the water depth at an exact position is known.
Afterwards the results can be linked to the beach measurements in a way that the total sediment volume in the coastal zone can be calculated.
The boundary definition of the area is based on the principle of looking at a sediment cell in the coastal zone. By setting the boundaries at two intersections between which you want to quantify sediment volume changes, you can investigate the sediment flux in/out the area of interest. As we are looking at the Sirius beach this area is given by a groyne in front of the hotel and by a jetty southwards. One usually takes the so called closure depth as the lower limit of the coastal profile. Depth changes seaward of these changes are not directly related to the shoreline dynamics. The closure depth is often the outer edge of the transport zone corresponding to the highest wave that may occur. The measured area in this case was up to a depth of more then MSL -11m and is in the upper bound of the range, usual regarded as sufficient of MSL –6m to MSL –12m.

7.4 Results

During a moderate wave climate the measurements were carried out. Purpose was to navigate along straight lines perpendicular to the coast (see Figure 7-2). In fact there were a number of trips, which can be clearly seen in the figure. It only increases the accuracy, and it has no meaning of splitting them from each other.

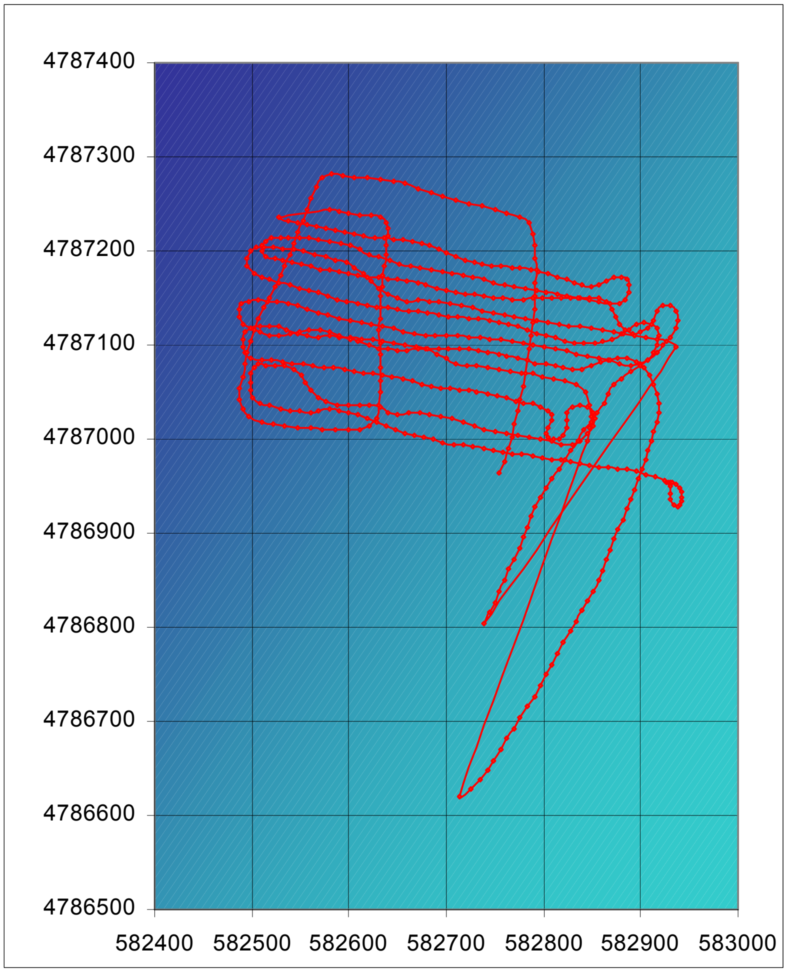


Figure 7-2 Trajectories of the vessel, the beach is in the upper left corner, stretching from the hotel in the top to the jetty more downwards

The results of these measurements are introduced into a profile-shaping computer program SURFER. It averages the single points of each data point to a line in between. This can be assumed realistic as the distance of these points to each other are relatively small compared to the morphologic timescale considered within this problem, which is plausible. The bathymetry is shown in Figure 7-3. Exact figures are not given in the report being waste of paper. This is added to the CDROM with the data.

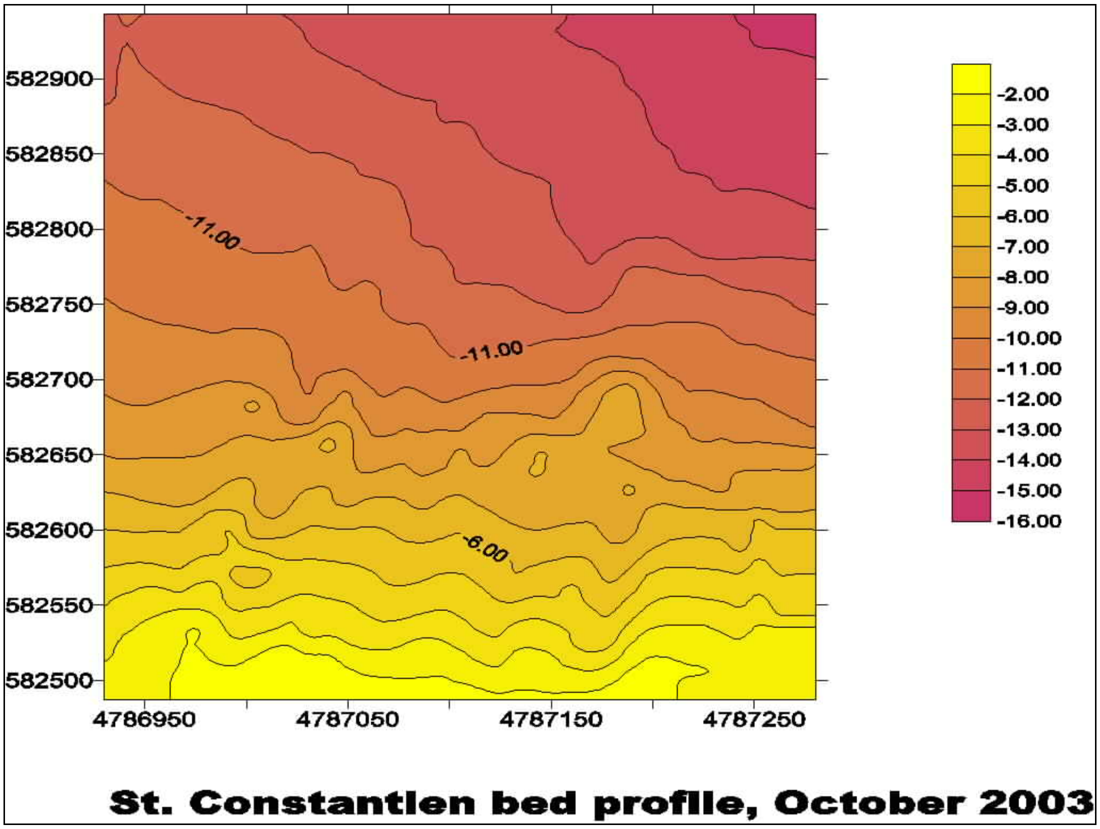


Figure 7-3 Bathymetry according to Delft students, the hotel is on the left and the jetty on the right

Another bathymetry, given in Figure 7-4, was plotted by the geodetic engineers.

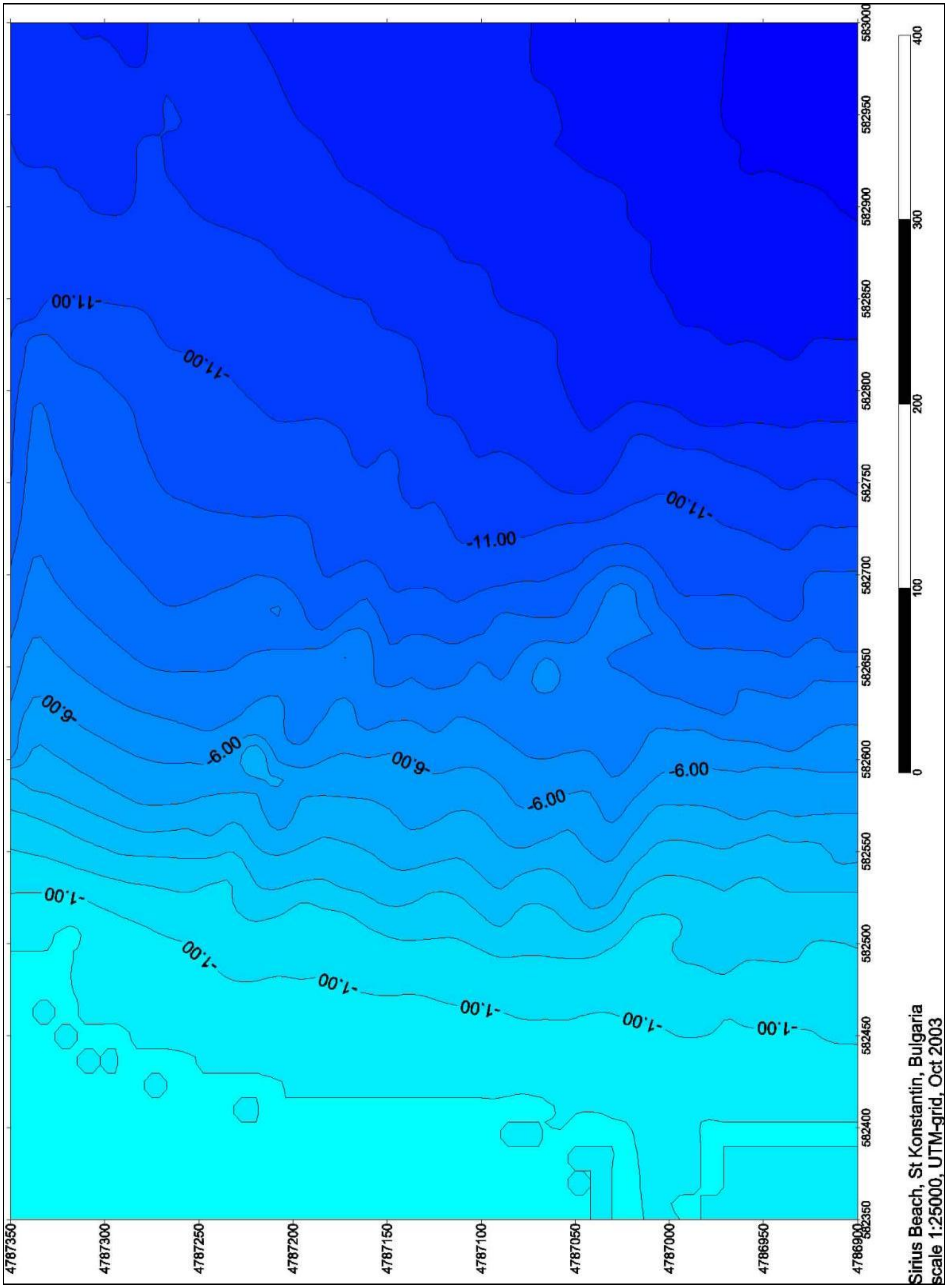


Figure 7-4 Bathymetry according to Bulgarian Geodetic engineers, hotel on the left hand jetty on the other hand

This is exactly the same profile, which was expected because of the same input data. It only underlines that the way of presentation is correct. From these results the total volume of sediment within the bounded area can be calculated. A reference level below sea level has to be chosen, which will never be exceeded by the bottom. In this case this was chosen at a reference level of MSL –20m. Results given by the program SURFER are given in Table 7-1 (see also Annex III)

Volume computations sea bed profile

```
UPPER SURFACE
      Grid File:  C:/BODEM02_MIRRORX.GRD
      Grid size as read:      39 cols by 50 rows
      Delta X:    9.21053
      Delta Y:    9.30612
      X-Range:    4.78693E+006 to 4.78728E+006
      Y-Range:    582487 to 582943
      Z-Range:    -15.3135 to -1.19955

LOWER SURFACE
      Level Surface defined by Z = -20 m

VOLUMES
      Approximated Volume by
      Trapezoidal Rule: 1.71673E+006
      Simpson's Rule:   1.71679E+006
      Simpson's 3/8 Rule:     1.71695E+006

CUT & FILL VOLUMES
      Positive Volume [Cut]:  1.71675E+006 m3
      Negative Volume [Fill]: 0
      Cut minus Fill:   1.71675E+006

AREAS
      Positive Planar Area
      (Upper above Lower):    159600
      Negative Planar Area
      (Lower above Upper):    0
      Blanked Planar Area:    0
      Total Planar Area:      159600

      Positive Surface Area
      (Upper above Lower):    159752
      Negative Surface Area
      (Lower above Upper):    0
```

Table 7-1 Calculations of volumes of the sea bed profile

This data will be of importance as a reference in following years when *exactly* the same reference levels have to be chosen to calculate sediment volume changes.

7.5 Discussion

After presentation of the results some discussion can be done on the results itself, and on the used methods. In other words, are the results realistic and are the applied methods of survey that accurate to draw conclusion from it?

Last year some deficiencies where presented in the calculated bathymetry. The echo sounder measured some peculiar sand ridges on the seabed. Comparing the results of the echo sounder with the trajectories of the vessel a possible explanation can be derived. It was obvious that the direction of the vessel was influencing the water depth. When the GPS system and the echo sounder were not on the same position on the ship in our case, i.e. the handhold GPS is handled in the fore and the echo sounder is attached to the vessels hull in the middle, introducing a distance between these devices, say ΔX.

The difference in height is then ΔX*i*, *i* being the slope, between the measured depth and the actual depth. This is then added or subtracted depending on the navigation direction of the vessel. The slope of profile is something of 1:20. The distance between the instruments was 1 to 2 meters. The difference between actual and measured water depth is then in the order of 10 centimetres. Depth at a certain position P, defined by GPS, is thus linked to a depth, defined by echo sounding, at the position P± ΔX . This results in sand ridges of two times the error, 20 cm. This is seen in the results. These ridges have no morphological meaning. This would be quite strange as we can expect there is no long shore current creating sand ripples.
Using more trajectories and thus measuring multiple depths near one point, we may assume these effects are cancelled out.

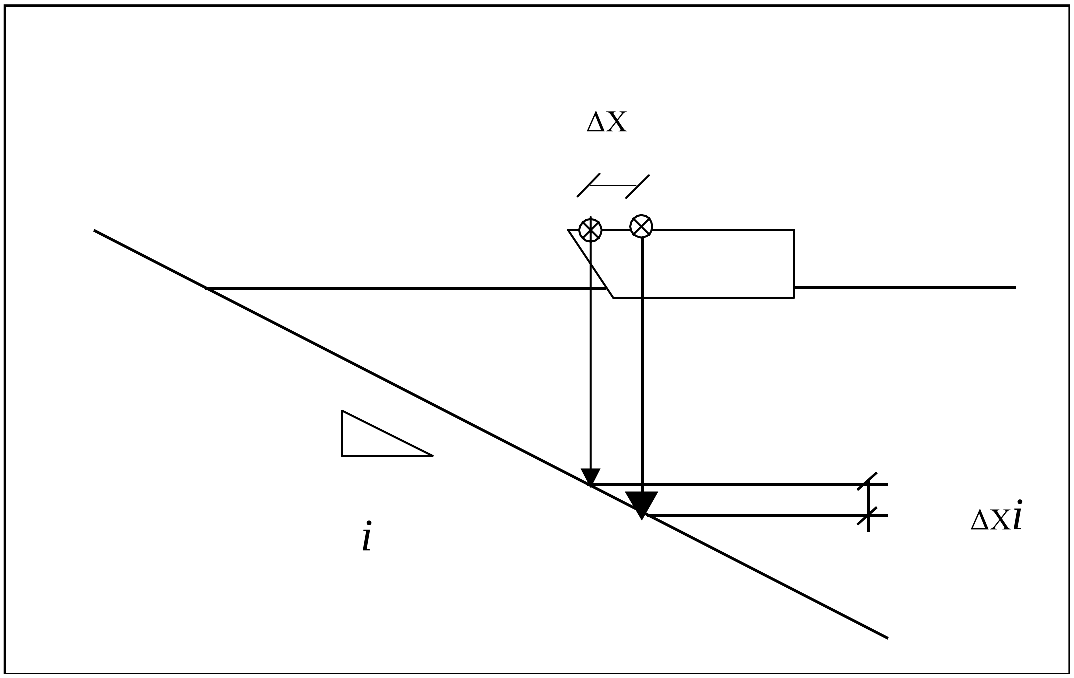


Figure 7-5Error due to distance between GPS and echo sounding

Besides that there is the influences of the elevation due to the waves. The DGPS also measures the exact elevation, which can be translated knowing the water level reference to the wave elevation. Difficulties occurred as the collected data of the echo sounder and the DGPS were unable to fit together. Besides that you can assume that with a dense data grid and good interpolation this effect can be neglected.

The influence of temperature and density on the travelling distance of an echo (and so on the calculated depth) is as a first approximation to be related as a function of the bulk modulus and the density. The relation is given as:

$$v = \sqrt{\frac{K}{\rho}}$$

$$\rho = density$$
$$K = bulkmodulus$$

$$\frac{\rho}{K} = \frac{d\rho}{dp}$$

$$K = 2.2*10^9\,Pa$$

The problem is that the density of water isn't constant with variable temperature and density. Temperature of the seawater was 21˚ C at the time of measuring. Salinity was not measured but is approximately 2 % given a density of water in the order of 1020kg/m^3. If we make the assumption that the echo sounder was calibrated to the situation at the side at that moment, thus taken the local water temperature and density into account, only gradients of temperature and salinity would be of interest. This is an empirical relation. This influence was calculated by the JavaScript calculator below of the UNESCO International Equation of State (IES 80)[1]. Changing both the salinity from 1020kg/m^3 to1030kg/m^3 increases the propagation velocity of a sound wave in water in the order of 1% and a difference of 5˚ C increases the velocity at the same rate. This is therefore neglected in the results.
The effect of the velocity of the vessel itself is not significant as the travelling speed of sound reaches approximately 1500 m/s. This being very large compared to the velocity of the vessel, the Doppler effects are then of no meaning.

7.6 Influence of used methods and instrument on accuracy

The accuracy is related to the method or instrument with the lowest accuracy like the strength of the chain is in the weakest link. We examine these influences by looking at the different methods and instruments used. In all cases, we have to be aware of the purpose of our survey, being morphological changes.

Navigating a small vessel with instruments
As stated earlier the position of the instruments on the vessel causes the measured figures to have a quite big error. This is in the order of 10-20cm. Adding up the elevation due to wave action this inaccuracy can slightly increase. There must be stated that this could be changed in an easy manner, putting the devices at the same spot on the vessel. Whether this is a problem can be disputed as we can expect the given effects to cancel out in some extent over the whole area and in a denser data grid.

Navigating in straight line on GPS
To get a nice profile navigating on straight lines perpendicular to the coastline is preferable. This was executed by using the direction given by a GPS instead of using beacons. This year it turned out to be better then last year. Results are satisfying as we expect the interpolation to be representative to the slope of the seabed. Changes in the slope are often quite smooth and small ridges are of too small importance of the morphologic scale.

[1] Fofonoff, JGR, Vol 90 No. C2, pp 3332-3342, March 20, 1985

DGPS
This instrument is very accurate *O(mm)* which doesn't make any sense compared to the other instruments. Next to that it takes a lot of time to install the instruments and calibrating them. Not taken into account the difficulty to use for a layman. It doesn't matter at all as you measure in trajectories of 10 meter if your exact point on the horizontal plane is of an order of magnitude of mm.

Echo sounder
The precise accuracy is unknown as the Bulgarian Geodetics used the echo sounder but will be in the order of centimeters looking at the output data accuracy of two decimals. The biggest problem would in fact not be an inaccuracy, which cancels out over a lot of measurements, in statistic terms high sigma but the mean at the right place, but a continuous error, like always adding a certain distance to the depth. This could occur when the instrument was poorly calibrated. Consequently this error would lead, when multiplied by the total area, to significant volume error. Unfortunately, there is no information on the calibration of the echo sounder. Details on the influence of the temperature and density are stated above.

Morphological changes
Severe erosion and accretion deals with a lot of sediment. As we look at the total volume of sediment in the area, you can expect significant changes to be of great magnitude as well. Small ridges are therefore of no importance to the big picture, but miscalculating depth over the whole area would introduce changes, much greater non-existing morphological changes.
Time effects are not taken into account at all. We only measured one day. It's really hard to tell if one measures structural erosion or incidental erosion due to a storm.

7.7 Conclusion

Looking at the plots of the profile we can be quit satisfied as it gives a realistic view compared to known depth profiles of that area. However, the purpose of the survey is not to quantify the volume of sediment in itself, but to analyze morphological changes, being the sediment volume changes, within the given area. When analyzing the accuracies of the different instruments, it's clearly that these are not adapted to each other. The DGPS is very accurate on one hand, but it turns out to be the vessel and the way it's navigated to be of much more influence on the results. Next to that the influence of the calibration of the echo sounder is relatively high. Nevertheless we can say that this method in order to quantify morphological changes is useful if it is done more times over and done in the same way.
Finally we must state that it is only a snapshot of the beach profile in its summer situation. Measuring a beach profile only one day a year is not sufficient to determine whether you are dealing with structural erosion or incidental erosions.

Annex I Beach Measurements

Start measuring today!

Beach measurements can be done with very advanced or with very simple tools. Using high quality tools is better, but certainly not a basic requirement. The most important point is that one has to start as soon as possible, also when no sophisticated tools are available. In the following section is described how a basic beach observation system can be set up without costly equipment. Only some manpower and very basic tools are needed. It is extremely important to have sufficient beach data. Therefore, start today with beach measuring. The method is simple, the tools cost nearly nothing., and you will collect extremely valuable data for all kind of decisions to be taken in future.

Measuring of beach lines; how to Set up a Coastline Measuring System

Generally it is not possible to start directly with a very detailed observation system. But at a certain time one has to begin with something. One of the major problems with existing old data is that they cannot be used in comparison with more recent measurements, because the measurements are usually from other locations.

It is therefore important to determine a general fixed baseline along the coast, which should never be changed. It is not that important where this line is today. It is advantageous to define this line as straight as possible, and it should be located on a dry beach, preferably for a number of years, and it should be approximately parallel to the water line.

This baseline has to be marked in the field with beacons. At fixed points along this line profiles have to taken.

In the first phase, one probably will not start with full profile measurements. As a good beginning the position of the LW-HW line and dune-foot should be measured. This has to be done once a year in the same month. The profile numbers should be indicated with the distance from the zero of the baseline.

One also has to define the vertical reference level. This can be the national datum (if available) or any other datum. The datum used for nautical charts (LLWS) is not advised, because this datum may vary significantly along the coastline. It is better to use a datum related to mean sea level.

Example of a Coastal Measuring System

In figure 1 a coastal section is drawn. It is clearly an island or peninsula with a resulting sediment transport from south to north. It is mainly a sandy beach; there are some groynes and some rock outcrops. One may expect some accretion at the northern tip of the island.

The baseline is defined in such a way that the number of "bends" in the line is minimal. Further it is drawn mainly on the dry beach.

A good zero-point is the lighthouse. However, the beach may accrete north of the lighthouse. So this point is not called 0, but 1,000. It is not expected that within a century the accretion is more than 1 kilometre. It is advisable to use the metric system, then it is not very important whether one uses kilometres or metres.

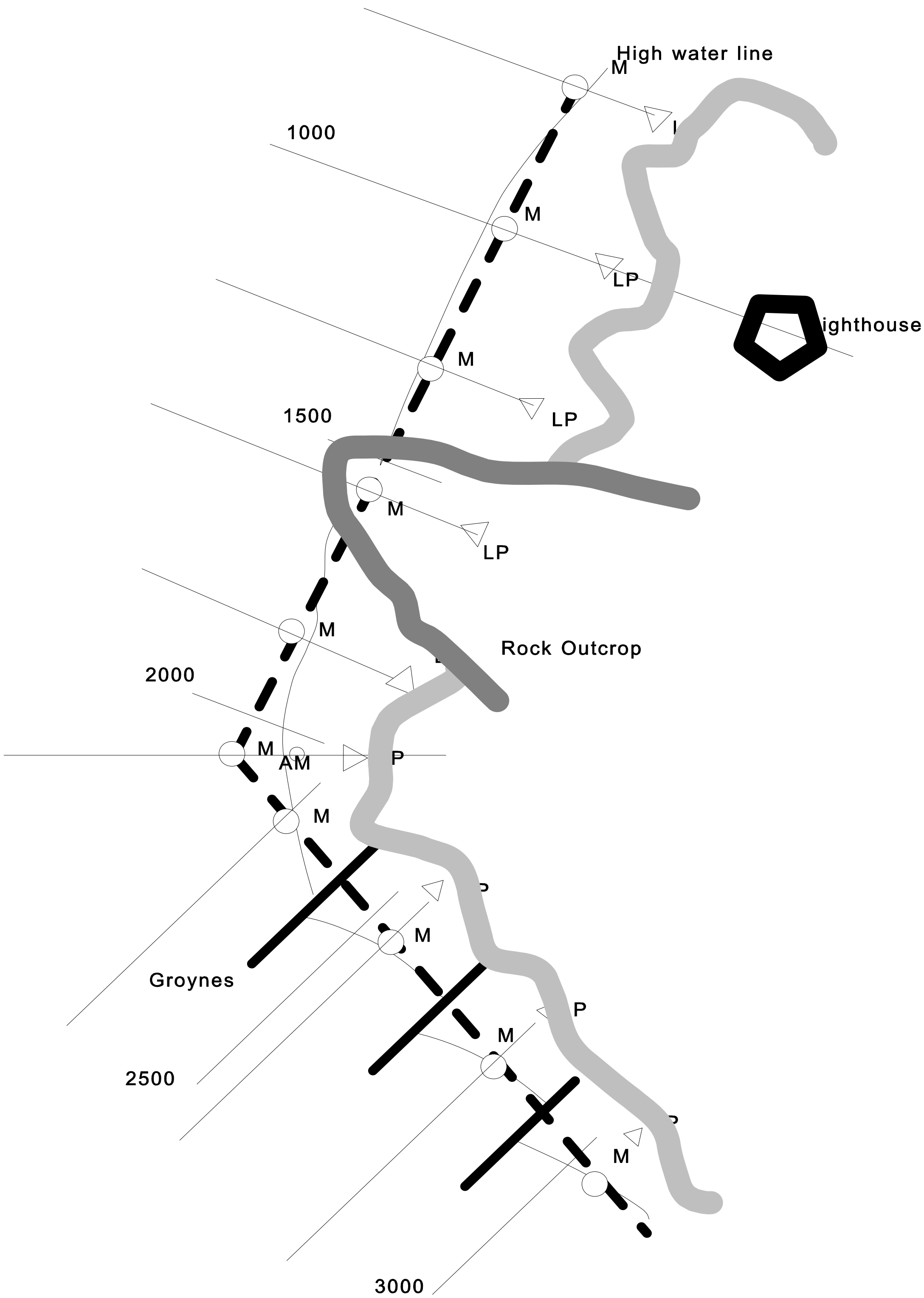


Figure 1: Example of a beach measurement set-up

Experience has shown that a system in kilometres is good for presentation. Computer storage can best be done in metres. Data retrieval in long-shore directions, which are more accurate than 1 metre are not useful.

Realise that in coastal measurement accuracy in long-shore direction can be very low, it has to be higher in cross-shore direction, and it should be very accurate in vertical direction.

On the map all distances can easily be read. One can also clearly define other elements like a rock-outcrop (km 1^{480} - 1^{640}) and the groynes (2^{440}, 2^{700}, 2^{940}). All coastal information can be presented in this co-ordinate system. In the cross-shore direction the baseline is zero. Seaward is positive, landward is negative.

At bends in the baseline it is wise to place monuments. (In this case on point 2^{150}.) At this position the monument stands between the high water line and low water line. If that is impossible because of the wave climate, one should place an additional monument a little further inland, as well as a leading point.
On the map, M = Main Monument, AM = Additional Monument, LP = Leading Point
In the field one can easily find the position of M by measuring 200 m seaward from AM, in line with the leading point L.P.

Profiles are always defined perpendicular to the baseline. There are two exceptions: in a bend of the baseline profiles are defined such that the angle to both parts of the baseline are equal. It is clear that these bends always give problems with the analysis of coastal data. Therefore one should define the baseline in such a way that the number of bends is as low as possible, and that the angle α is always as small as possible. These requirements are contradictory to each other so one should try to find an optimum.

The other exception is when a groyne is not perpendicular to the baseline. In that case it might be wise to make the profiles parallel to the groynes. However, one should try to avoid this situation. Groynes should be built perpendicular to the coastline (and thus perpendicular to the baseline).

After defining the baseline, one should define the positions of the profiles. Experience in The Netherlands has shown that for a straight, undisturbed coast profiles nearer to each other than 250 m are not useful. However near hard elements (rock outcrops, beach walls, groynes) this distance should be adapted. One should also always have profiles at bends in the baseline and at "important points". In this case, thus, at km 1^{000} and 2^{050}. In a groyne field one should always have a profile in the middle of two groynes. Thus, in the example profiles are required at km 2^{570}, 2^{820} and 3^{070}.

For the rest of the example area it is clear that the remaining section can be divided into more or less equal sections. Thus the profiles to be measured are 0^{750}, 1^{000}, 1^{190}, (1^{450}), 1^{795}, 2^{050}, 2^{245}, 2^{570}, 2^{890}, 3^{070}, 3^{350}, 3^{600}.

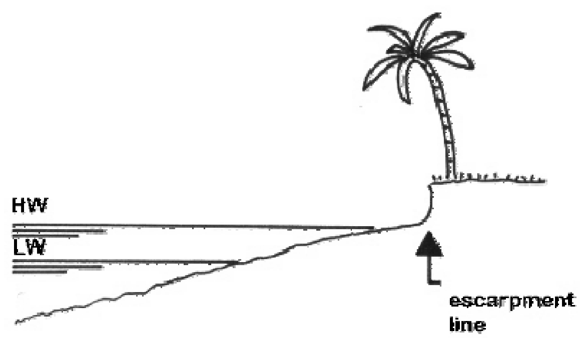
To start with only beach lines (HW and LW) and dune foot are measured at these points. Full profiles are measured at longer distances every year, for example only at 1^{000}, 2^{050}, 3^{070}, etc, in order to reduce costs in the beginning. But be sure that 3^{070} is measured and not 3^{000}!!! Otherwise one cannot compare data in future.

To make measurements easier, at the position of the profile one should place a marker beacon on the beach. On the beacon one should indicate the number of the profile (0^{750}, 1^{000}, 1^{190}, etc). For easy measuring a leading point can be placed in the dunes.
Beacons on the beach are also very useful for other purposes, for example lifeguards can use the system for indicating the point where assistance is needed.

Measuring near groynes
Near groynes one should make some additional measuring profiles. They are indicated in the figure. It is wise to place the standard profile in the middle between the groynes. An additional groyne profile is placed in the centre-line of the groyne. With data from this profile one can observe potential scouring holes in front of the groyne-head. These holes are formed by contraction of the tidal current.
Parallel to the groynes sometimes erosion-channels are formed because of rip-currents. One may observe them using lateral groyne profiles.

Simple measurements
The most simple type of measurement is the LW-HW-DF-measurement. This is executed as follows:

1. One determines the level of mean low water and mean high water, and the dune foot MLW and MHW can be read from any nautical almanac. For the dune foot no strict method is given. A practical way is to measure a number of dune profiles to determine the intersection between the beach slope and the dune slope. This intersection is the theoretical dune foot. One can calculate the height of the theoretical dune foot for a number of profiles. Then the mean height for that coastal section is determined. This gives the DF-level. In case one has no dunes, but a rather flat coast, one should use the escarpment line instead of the dune foot.



2. With simple water levelling equipment the position of LW, HW and DF can be determined in the field. In that case it is very handy if the reference height is indicated on the beacon. (Note: if the beacon height is used as a reference, the height of the beacon has to be calibrated regularly). In case no reference point is available, one can use the water level of sea, provided the water level of that moment is known from a reliable measuring station in the neighbourhood.

3. In case even no water-levelling instrument is available, one can still make the measurements, using the horizon as a horizontal reference. See figure above. Practical execution of this method is simple and reliable.

4. The position of HW, LW and DF with respect to base line can be measured with a measuring line or electronically.

5. It is advisable that the field crew enter the measured data as soon as possible in a (personal) computer themselves, and plot the preliminary data immediately on the screen. Erroneous data can be seen directly, and in most cases they can be related to reading errors of the fieldwork. When the field crew is doing this job themselves such errors can be corrected quickly and easily.

Data from these special groyne profiles are important to monitor the stability of the groyne. When these holes become too deep, the groyne is no longer stable, resulting in considerable damage.

Measuring of beach sand

For various morphological computations the type of beach sand need to be known. However, it is not relevant to know the sand characteristics in too much detail. One needs to know the D_{50}- value (=median grain size) of the beach sand, preferably at a number of locations. An exact value is not needed. Usually values rounded to 25 μm will be sufficient (i.e. 100, 125, 150, 175 … μm). One can obtain the value using a sieve analysis, but comparing the sand with a "sand-ruler" will be sufficient in many cases. It is more important to know the approximate grain size at many places, then to know the precise grain size at only one point.

In case of sieving, it is recommended to plot the data on a log-gauss scale. Basically this should result in a straight line.

Annex II Measured beach profiles

Raai (m)	-96,2		
Height reference point hotel (m)	0,69		
	Distance from baseline (m)	Original fieldwork data (m)	Data tov reference point (m)
land	7	-0,05	0,74
	6	-0,212	0,902
baseline	0	0,797	-0,107
	-5	1,165	-0,475
	-10	1,693	-1,003
	-15	2,098	-1,408
	-20	2,895	-2,205
sea	-25	3,848	-3,158

Raai (m)	-50		
Height reference point hotel (m)	0,69		
	Distance from baseline (m)	Original fieldwork data (m)	Data tov reference point (m)
land	15	0,08	0,61
	10	0,618	0,072
	5	0,983	-0,293
baseline	0	1,372	-0,682
	-5	1,85	-1,16
	-10	1,972	-1,282
	-12,3	2,02	-1,33
sea	-15	3,225	-2,535

Raai (m)	-25		
Height reference point hotel (m)	0,69		
	Distance from baseline (m)	Original fieldwork data (m)	Data tov reference point (m)
land	20	0,24	0,45
	15	0,63	0,06
	10	1,05	-0,36
	5	1,445	-0,755
baseline	0	1,502	-0,812
	-5	1,563	-0,873
	-10	3,365	-2,675
	-15	3,664	-2,974
sea	-18	4	-3,31

Raai (m)	0		
Height reference point hotel (m)	0,22		
	Distance from baseline (m)	Original fieldwork data (m)	Data tov reference point (m)
land	18,4	0,1	0,59
	15	0,29	0,4
	10	0,95	-0,26
	5	1,52	-0,83
baseline	0	1,7	-1,01
	-5	2,07	-1,38
	-10	3,04	-2,35
	-15	3,68	-2,99
sea	-20	4,1	-3,41

Raai (m)	25,3		
Height reference point hotel (m)	0,22		
	Distance from baseline (m)	Original fieldwork data (m)	Data tov reference point (m)
land	10	1,46	-0,77
	5	1,76	-1,07
baseline	0	2,22	-1,53
	-5	2,54	-1,85
	-10	3,3	-2,61
	-15	3,85	-3,16
sea	-20	4,03	-3,34

Raai (m)	48,4		
Height reference point hotel (m)	0,11		
Extra			
	Distance from baseline (m)	Original fieldwork data (m)	Data tov reference point (m)
land			
	15	1,18	-1,18
	10	2	-2
	5	2,24	-2,24
baseline	0	2,48	-2,48
	-5	2,35	-2,35
	-10	2,84	-2,84
	-15	3,68	-3,68
sea	-20	3,95	-3,95
	-25	3,98	-3,98
	-30	4,04	-4,04

Raai (m)	74,9		
Height reference point hotel (m)	0,11		
	Distance from baseline (m)	Original fieldwork data (m)	Data tov reference point (m)
land			
wall (15.25)	15	1,18	-0,49
	10	1,78	-1,09
	5	2,19	-1,5
baseline	0	2,69	-2
	-5	2,49	-1,8
ridge	-10	2,47	-1,78
	-15	3,35	-2,66
sea	-20	3,88	-3,19
	-25	3,88	-3,19
	-30	3,88	-3,19
	-35	3,96	-3,27
	-40	4,05	-3,36
	-45	4,18	-3,49
	-50	4,30	-3,61

Raai (m)	99,9		
Height reference point hotel (m)	0,11		
	Distance from baseline (m)	Original fieldwork data (m)	Data tov reference point (m)
land	5	0,08	-0,08
baseline	0	0,57	-0,57
	-5	0,68	-0,68
	-10	1,09	-1,09
	-15	2,55	-2,55
sea	-20	2,96	-2,96
	-25	3,49	-3,49
	-30	3,74	-3,74
	-35	3,94	-3,94
	-40	3,80	-3,8
	-45	3,38	-3,38
	-50	3,21	-3,21
	-55	3,1	-3,1
	-60	3,62	-3,62
	-65	3,75	-3,75

Annex III Volume computations

Volume computations sea bed profile

```
UPPER SURFACE
      Grid File:  C:/BODEM02_MIRRORX.GRD
      Grid size as read:     39 cols by 50 rows
      Delta X:    9.21053
      Delta Y:    9.30612
      X-Range:    4.78693E+006 to 4.78728E+006
      Y-Range:    582487 to 582943
      Z-Range:    -15.3135 to -1.19955

LOWER SURFACE
      Level Surface defined by Z = -20 m

VOLUMES
      Approximated Volume by
      Trapezoidal Rule: 1.71673E+006
      Simpson's Rule:   1.71679E+006
      Simpson's 3/8 Rule:     1.71695E+006

CUT & FILL VOLUMES
      Positive Volume [Cut]:  1.71675E+006 m3
      Negative Volume [Fill]: 0
      Cut minus Fill:   1.71675E+006

AREAS
      Positive Planar Area
      (Upper above Lower):    159600
      Negative Planar Area
      (Lower above Upper):    0
      Blanked Planar Area:    0
      Total Planar Area:      159600

      Positive Surface Area
      (Upper above Lower):    159752
      Negative Surface Area
      (Lower above Upper):    0
```

Volume computations beach profile

```
UPPER SURFACE
      Grid File:  C:/STRAND04_MIRRORX.GRD
      Grid size as read:      39 cols by 50 rows
      Delta X:    5
      Delta Y:    2.73469
      X-Range:    4.78713E+006 to 4.78732E+006
      Y-Range:    582381 to 582515
      Z-Range:    -5.48905 to 1.18267

LOWER SURFACE
      Level Surface defined by Z = -10 m

VOLUMES
      Approximated Volume by
      Trapezoidal Rule: 180118
      Simpson's Rule:   180108
      Simpson's 3/8 Rule:     180099

CUT & FILL VOLUMES
      Positive Volume [Cut]:  180120 m3
      Negative Volume [Fill]: 0
      Cut minus Fill:   180120

AREAS
      Positive Planar Area
      (Upper above Lower):    25460
      Negative Planar Area
      (Lower above Upper):    0
      Blanked Planar Area:    0
      Total Planar Area:      25460

      Positive Surface Area
      (Upper above Lower):    25509.1
      Negative Surface Area
      (Lower above Upper):    0
```

Volume computations integrated sea bed and beach profiles

```
UPPER SURFACE
      Grid File:  C:/GEHEEL02.GRD
      Grid size as read:     39 cols by 50 rows
      Delta X:    10.2632
      Delta Y:    11.4694
      X-Range:    4.78693E+006 to 4.78732E+006
      Y-Range:    582381 to 582943
      Z-Range:    -15.3135 to 4.23238

LOWER SURFACE
      Level Surface defined by Z = -20 m

VOLUMES
      Approximated Volume by
      Trapezoidal Rule: 2.77888E+006
      Simpson's Rule:   2.77852E+006
      Simpson's 3/8 Rule:    2.7787E+006

CUT & FILL VOLUMES
      Positive Volume [Cut]:  2.77888E+006 m3
      Negative Volume [Fill]: 0
      Cut minus Fill:   2.77888E+006

AREAS
      Positive Planar Area
      (Upper above Lower):    219180
      Negative Planar Area
      (Lower above Upper):    0
      Blanked Planar Area:    0
      Total Planar Area:      219180

      Positive Surface Area
      (Upper above Lower):    219396
      Negative Surface Area
      (Lower above Upper):    0
```

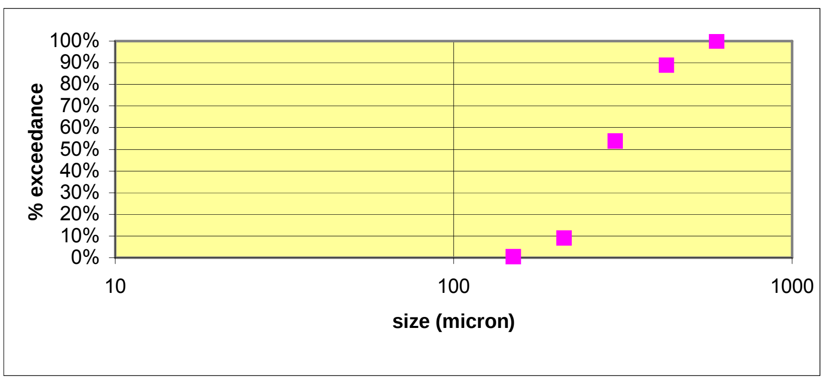
Annex IV Sieve Analysis

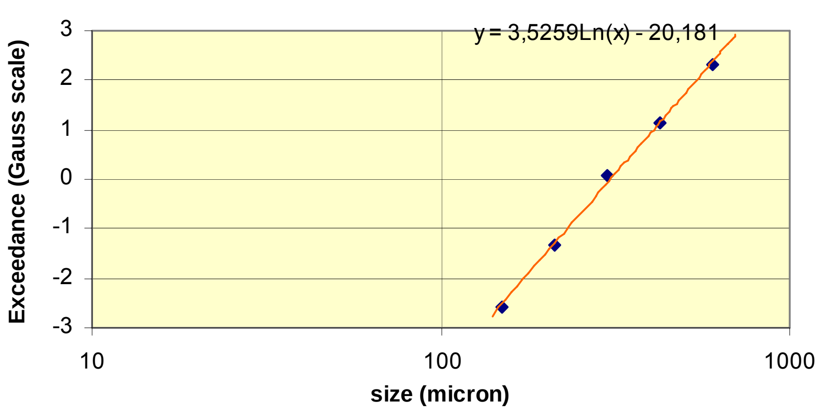
The sieve analysis was executed in the laboratory of hydraulic engineering, Delft University. For the first sample, at first, a different range of sieves was chosen. After the first sieving it was clear the small sieves were of no use looking at the amount of small particles. A second sieve range was used after that for the further analysis. In order to calculate D50 some values have to be introduced to be able to calculate within the Gaussian density function. T-value and p-value are therefore introduced, and the D50 is then easy to calculate. This method is a numerical method for calculating the cumulative density function of the Gaussian probability density function. The crossing of the line with the Scale-axis is now easy to be calculated.

Sample 1 Sediment near the shoreline at the south side of the beach

Sample 1 Sediment near the shoreline at the south side of the beach

Sieve size (microns)	Weight on sieve	cumulative weight	cumulative fraction	t-value	p-value
150	0.1	0.1	0.005171	3.24	-2.57
212	1.67	1.77	0.09152	2.19	-1.33
300	8.64	10.41	0.538263	1.11	0.09
425	6.79	17.2	0.889349	0.48	1.15
600	2.14	19.34	1	0.00	2.31

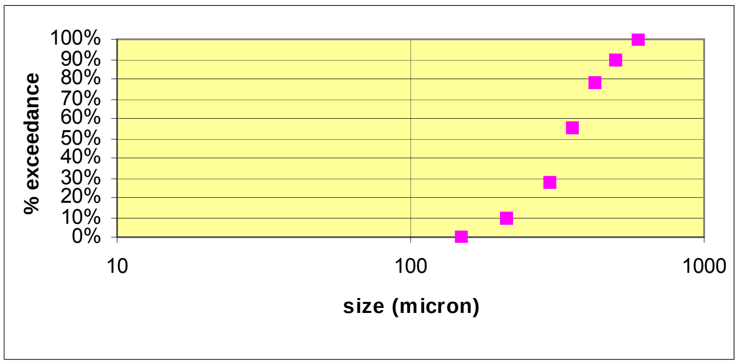


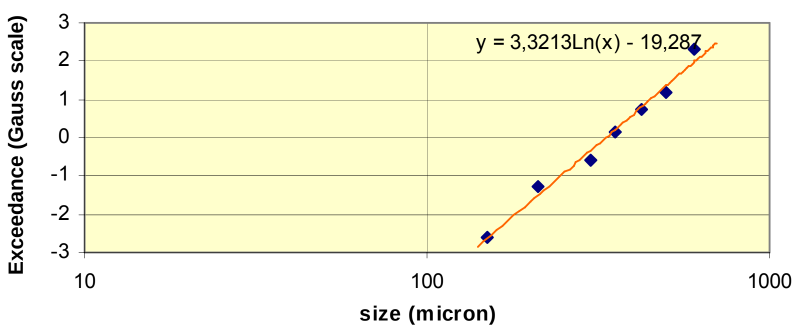


Sample 1 Sediment near the shoreline at the south side of the beach D50=306 μm

Sample 1 Sediment near the shoreline at the south side of the beach

Sieve size (microns)	Weight on sieve	cumulative weight	cumulative fraction	t-value	p-value
150	0.1	0.1	0.004726	3.27	-2.60
212	2	2.1	0.099253	2.15	-1.28
300	3.68	5.78	0.273183	1.61	-0.60
355	5.878	11.658	0.550997	1.09	0.13
425	4.78	16.438	0.776917	0.71	0.74
500	2.48	18.918	0.89413	0.47	1.17
600	2.24	21.158	1	0.00	2.31



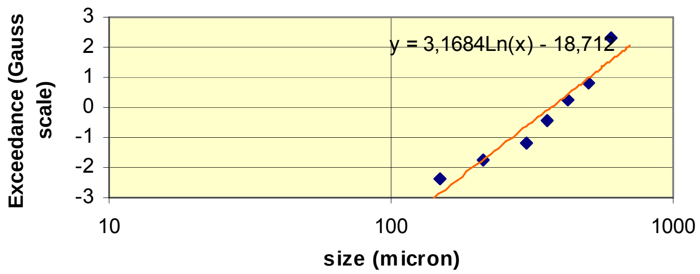


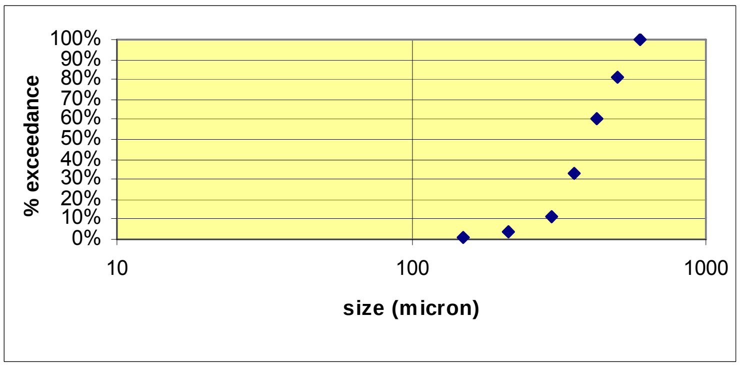
Sample 1 Sediment near the shoreline at the south side of the beach D50=332 μm
Now we can average these two sieves so D50 is approximately 319 sample 1 Sediment near the shoreline at the south side of the beach

Sample 2. Sediment from the sea bottom within the surf zone.

Sample 2. Sediment from the sea bottom within the surf zone.

Sieve size (microns)	Weight on sieve	cumulative weight	cumulative fraction	t-value	p-value
150	0.173	0.173	0.008962	3.07	-2.37
212	0.62	0.793	0.041082	2.53	-1.74
300	1.46	2.253	0.116718	2.07	-1.19
355	4.04	6.293	0.326012	1.50	-0.45
425	5.45	11.743	0.608351	1.00	0.27
500	3.86	15.603	0.80832	0.65	0.84
600	3.7	19.303	1	0.00	2.31



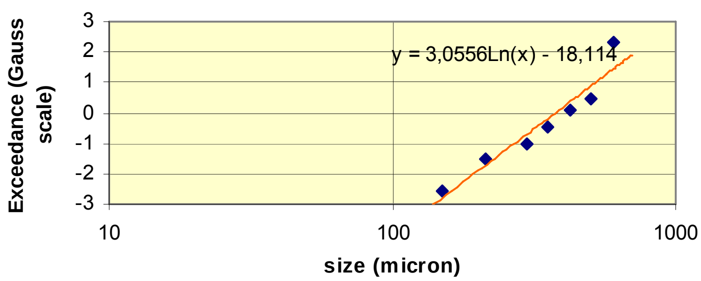


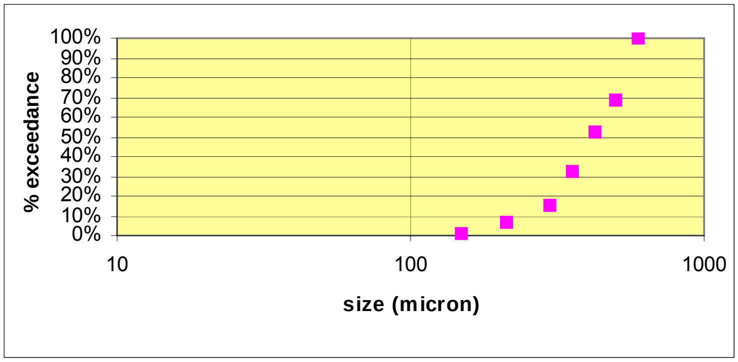
Sample 2. Sediment from the sea bottom within the surf zone D50=368 μm

Sample 3

Sample 3 Sediment taken from the beach far from the shoreline

Sieve size (microns)	Weight on sieve	cumulative weight	cumulative fraction	t-value	p-value
150	0.11	0.11	0.005405	3.23	-2.55
212	1.16	1.27	0.062408	2.36	-1.53
300	1.79	3.06	0.150369	1.95	-1.03
355	3.51	6.57	0.32285	1.50	-0.46
425	4.16	10.73	0.527273	1.13	0.07
500	3.3	14.03	0.689435	0.86	0.48
600	6.32	20.35	1	0.00	2.31

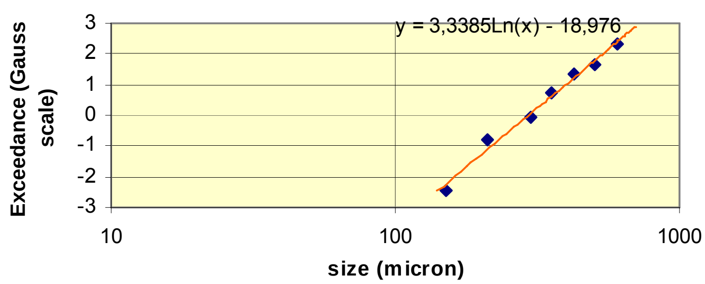


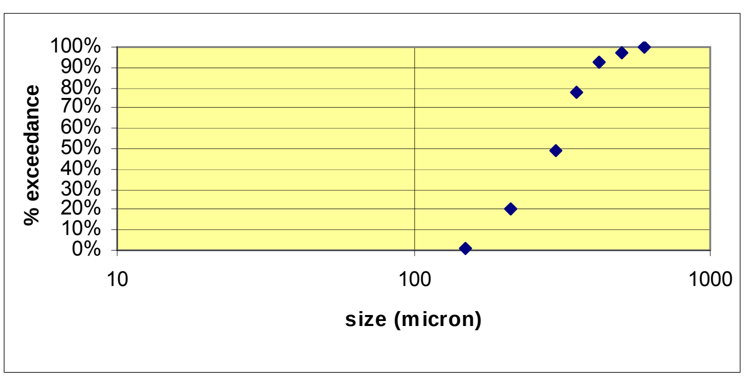


From the formula we can calculate the D50 of Sample 3 to be D50=375 μm

Sample 4. Sediment near the shoreline at the north side of the beach

Sieve size (microns)	Weight on sieve	cumulative weight	cumulative fraction	t-value	p-value
150	0.14	0.14	0.007021	3.15	-2.46
212	3.97	4.11	0.206118	1.78	-0.82
300	5.61	9.72	0.487462	1.20	-0.03
355	5.78	15.5	0.777332	0.71	0.74
425	2.93	18.43	0.924273	0.40	1.33
500	0.94	19.37	0.971414	0.24	1.67
600	0.57	19.94	1	0.00	2.31





Sample 4. Sediment near the shoreline at the north side of the beach D50=294 μm

Annex V Dutch Wave Data

Wave measurements 4 october 2003

Mesurment time	Hs [dm]	Hgem [Hgem]
12,10	5,8	4,1

No.	Highest point [dm]	Lower point [dm]	Wave height [dm]	H (High-Low) [dm]	H/Hs	exceedence %	Rayleigh Distribution H/Hs
1	9	6	3	8	1,39	0,01	1,52
2	10	5	5	8	1,39	0,02	1,40
3	10	5,5	4,5	7	1,21	0,03	1,32
4	10	6	4	7	1,21	0,04	1,27
5	10	5	5	7	1,21	0,05	1,22
6	10	4	6	7	1,21	0,06	1,19
7	12	4	8	7	1,21	0,07	1,15
8	11	4	7	7	1,21	0,08	1,12
9	12	5	7	6	1,04	0,09	1,10
10	10	7	3	6	1,04	0,10	1,07
11	9	5	4	6	1,04	0,11	1,05
12	9	5	4	6	1,04	0,12	1,03
13	9,5	5	4,5	6	1,04	0,13	1,01
14	10	5	5	6	1,04	0,14	0,99
15	11	5	6	6	1,04	0,15	0,97
16	8	6	2	6	1,04	0,16	0,96
17	9	5	4	5	0,87	0,17	0,94
18	8,5	7	1,5	5	0,87	0,18	0,93
19	10	5	5	5	0,87	0,19	0,91
20	9	6	3	5	0,87	0,20	0,90
21	10	6	4	5	0,87	0,21	0,88
22	10	5	5	5	0,87	0,22	0,87
23	11	5	6	5	0,87	0,23	0,86
24	10	5	5	5	0,87	0,24	0,84
25	9	5,5	3,5	5	0,87	0,25	0,83
26	8	6	2	5	0,87	0,26	0,82
27	10	5	5	5	0,87	0,27	0,81
28	11	4	7	5	0,87	0,28	0,80
29	12	5	7	5	0,87	0,29	0,79
30	10	5	5	5	0,87	0,30	0,78
31	10	6	4	5	0,87	0,31	0,77
32	8	5	3	5	0,87	0,32	0,75
33	10	6	4	4,5	0,78	0,33	0,74
34	9	5	4	4,5	0,78	0,34	0,73
35	8,5	4	4,5	4,5	0,78	0,35	0,72
36	10	6	4	4,5	0,78	0,36	0,71
37	10	6	4	4	0,69	0,37	0,71
38	9	8	1	4	0,69	0,38	0,70
39	9	7	2	4	0,69	0,39	0,69
40	9	6	3	4	0,69	0,40	0,68
41	9	6	3	4	0,69	0,41	0,67
42	9	6	3	4	0,69	0,42	0,66
43	9	5	4	4	0,69	0,43	0,65
44	9,5	6	3,5	4	0,69	0,44	0,64
45	9	6	3	4	0,69	0,45	0,63
46	9	6	3	4	0,69	0,46	0,62
47	8	6	2	4	0,69	0,47	0,61
48	10	6	4	4	0,69	0,48	0,61
49	10	4	6	4	0,69	0,49	0,60
50	12	4	8	4	0,69	0,50	0,59
51	11	5	6	4	0,69	0,51	0,58
52	9	5	4	4	0,69	0,52	0,57
53	10	5	5	4	0,69	0,53	0,56
54	10	5,5	4,5	4	0,69	0,54	0,56

55	11	4	7	4	0,69	0,55	0,55
56	10	6	4	4	0,69	0,56	0,54
57	9	6	3	4	0,69	0,57	0,53
58	9	6	3	4	0,69	0,58	0,52
59	9	5	4	4	0,69	0,59	0,51
60	9	5	4	4	0,69	0,60	0,51
61	12	6	6	4	0,69	0,61	0,50
62	9	6	3	4	0,69	0,62	0,49
63	8,5	6	2,5	4	0,69	0,63	0,48
64	10	5	5	3,5	0,61	0,64	0,47
65	9	6	3	3,5	0,61	0,65	0,46
66	9	5	4	3	0,52	0,66	0,46
67	12	5	7	3	0,52	0,67	0,45
68	10	6	4	3	0,52	0,68	0,44
69	8	5	3	3	0,52	0,69	0,43
70	7,5	6	1,5	3	0,52	0,70	0,42
71	9	6	3	3	0,52	0,71	0,41
72	9	6	3	3	0,52	0,72	0,41
73	9	6	3	3	0,52	0,73	0,40
74	9	5	4	3	0,52	0,74	0,39
75	10	6	4	3	0,52	0,75	0,38
76	8	7	1	3	0,52	0,76	0,37
77	9	6	3	3	0,52	0,77	0,36
78	9	5	4	3	0,52	0,78	0,35
79	10	6	4	3	0,52	0,79	0,34
80	11	5	6	3	0,52	0,80	0,33
81	10	5	5	3	0,52	0,81	0,32
82	8	6	2	3	0,52	0,82	0,32
83	9	6	3	3	0,52	0,83	0,31
84	7	6	1	3	0,52	0,84	0,30
85	10	6	4	3	0,52	0,85	0,29
86	9	6	3	3	0,52	0,86	0,27
87	10	4	6	3	0,52	0,87	0,26
88	10	5	5	3	0,52	0,88	0,25
89	10	5	5	2,5	0,43	0,89	0,24
90	11	6	5	2	0,35	0,90	0,23
91	9	7	2	2	0,35	0,91	0,22
92	8	5	3	2	0,35	0,92	0,20
93	9	6	3	2	0,35	0,93	0,19
94	8	4	4	2	0,35	0,94	0,18
95	10	6	4	2	0,35	0,95	0,16
96	10	5	5	1,5	0,26	0,96	0,14
97	9	5	4	1,5	0,26	0,97	0,12
98	10	6	4	1	0,17	0,98	0,10
99	10	7	3	1	0,17	0,99	0,07
100	11	6	5	1	0,17	1,00	0,00

Wave measurements 4 october 2003

Mesurment time	Hs [dm]	Hgem [Hgem]
13,14	6,5	4,5

No.	Highest point [dm]	Lower point [dm]	Wave height [dm]	H (High-Low) [dm]	H/Hs	exceedence %	Rayleigh Distribution H/Hs
1	12	3	9	10	1,55	0,01	1,52
2	13	3	10	9	1,39	0,02	1,40
3	10	4	6	8	1,24	0,03	1,32
4	10	4	6	8	1,24	0,04	1,27
5	9	5	4	8	1,24	0,05	1,22
6	8	6	2	8	1,24	0,06	1,19
7	10	6	4	7	1,08	0,07	1,15
8	8	6	2	7	1,08	0,08	1,12
9	10	4	6	7	1,08	0,09	1,10
10	12	6	6	6	0,93	0,10	1,07
11	10	4	6	6	0,93	0,11	1,05
12	12	4	8	6	0,93	0,12	1,03
13	10	4	6	6	0,93	0,13	1,01
14	12	6	6	6	0,93	0,14	0,99
15	10	6	4	6	0,93	0,15	0,97
16	8	4	4	6	0,93	0,16	0,96
17	8	6	2	6	0,93	0,17	0,94
18	10	6	4	6	0,93	0,18	0,93
19	8	4	4	6	0,93	0,19	0,91
20	9	6	3	6	0,93	0,20	0,90
21	11	5	6	6	0,93	0,21	0,88
22	8	5	3	6	0,93	0,22	0,87
23	10	6	4	6	0,93	0,23	0,86
24	10	4	6	6	0,93	0,24	0,84
25	10	4	6	6	0,93	0,25	0,83
26	11	6	5	6	0,93	0,26	0,82
27	10	4	6	6	0,93	0,27	0,81
28	11	3	8	6	0,93	0,28	0,80
29	13	6	7	6	0,93	0,29	0,79
30	10	5	5	6	0,93	0,30	0,78
31	10	4	6	5	0,77	0,31	0,77
32	10	4	6	5	0,77	0,32	0,75
33	12	4	8	5	0,77	0,33	0,74
34	10	5	5	5	0,77	0,34	0,73
35	10	6	4	5	0,77	0,35	0,72
36	10	4	6	5	0,77	0,36	0,71
37	10	4	6	5	0,77	0,37	0,71
38	12	4	8	5	0,77	0,38	0,70
39	10	6	4	5	0,77	0,39	0,69
40	10	6	4	5	0,77	0,40	0,68
41	8	5	3	5	0,77	0,41	0,67
42	8	6	2	5	0,77	0,42	0,66
43	9	5	4	5	0,77	0,43	0,65
44	10	4	6	5	0,77	0,44	0,64
45	8	5	3	5	0,77	0,45	0,63
46	8	6	2	5	0,77	0,46	0,62
47	10	5	5	5	0,77	0,47	0,61
48	10	5	5	5	0,77	0,48	0,61
49	10	6	4	4	0,62	0,49	0,60
50	8	6	2	4	0,62	0,50	0,59
51	11	6	5	4	0,62	0,51	0,58
52	9	7	2	4	0,62	0,52	0,57
53	9	7	2	4	0,62	0,53	0,56
54	9	5	4	4	0,62	0,54	0,56
55	9	6	3	4	0,62	0,55	0,55

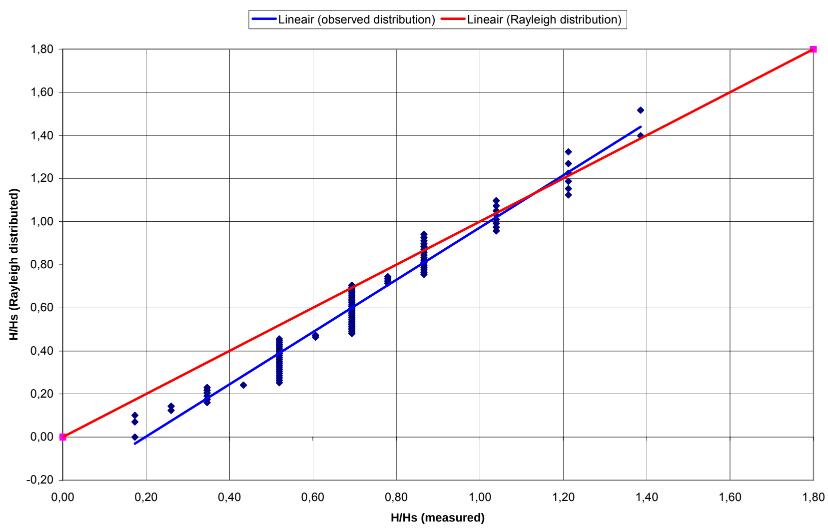
56	9	9	0	4	0,62	0,56	0,54
57	9	7	2	4	0,62	0,57	0,53
58	10	4	6	4	0,62	0,58	0,52
59	11	5	6	4	0,62	0,59	0,51
60	10	5	5	4	0,62	0,60	0,51
61	9	5	4	4	0,62	0,61	0,50
62	11	5	6	4	0,62	0,62	0,49
63	9	5	4	4	0,62	0,63	0,48
64	10	5	5	4	0,62	0,64	0,47
65	11	4	7	4	0,62	0,65	0,46
66	11	7	4	4	0,62	0,66	0,46
67	10	7	3	4	0,62	0,67	0,45
68	8	5	3	4	0,62	0,68	0,44
69	11	8	3	4	0,62	0,69	0,43
70	10	5	5	4	0,62	0,70	0,42
71	11	5	6	4	0,62	0,71	0,41
72	9	6	3	3	0,46	0,72	0,41
73	7	6	1	3	0,46	0,73	0,40
74	10	5	5	3	0,46	0,74	0,39
75	11	6	5	3	0,46	0,75	0,38
76	12	5	7	3	0,46	0,76	0,37
77	11	6	5	3	0,46	0,77	0,36
78	9	6	3	3	0,46	0,78	0,35
79	10	5	5	3	0,46	0,79	0,34
80	11	7	4	3	0,46	0,80	0,33
81	10	6	4	3	0,46	0,81	0,32
82	10	5	5	3	0,46	0,82	0,32
83	9	5	4	3	0,46	0,83	0,31
84	9	5	4	3	0,46	0,84	0,30
85	11	5	6	3	0,46	0,85	0,29
86	10	5	5	2	0,31	0,86	0,27
87	11	7	4	2	0,31	0,87	0,26
88	9	6	3	2	0,31	0,88	0,25
89	11	7	4	2	0,31	0,89	0,24
90	10	6	4	2	0,31	0,90	0,23
91	9	7	2	2	0,31	0,91	0,22
92	9	6	3	2	0,31	0,92	0,20
93	10	5	5	2	0,31	0,93	0,19
94	9	7	2	2	0,31	0,94	0,18
95	10	5	5	2	0,31	0,95	0,16
96	9	6	3	2	0,31	0,96	0,14
97	8	6	2	2	0,31	0,97	0,12
98	9	7	2	2	0,31	0,98	0,10
99	9	6	3	1	0,15	0,99	0,07
100	11	6	5	0	0,00	1,00	0,00

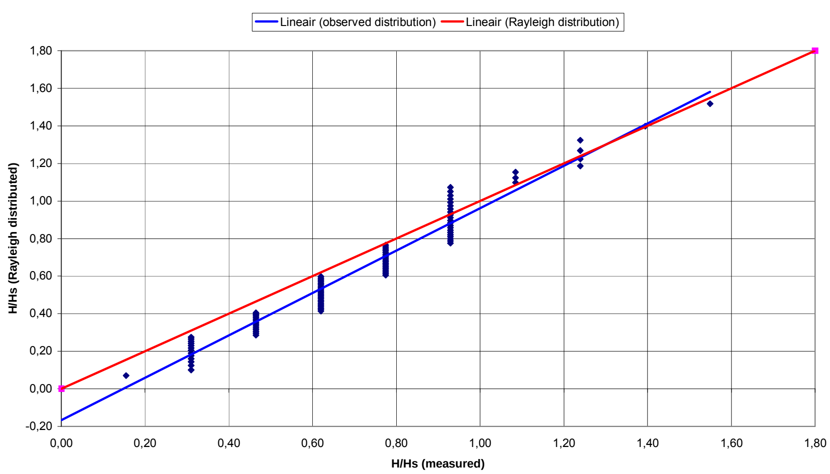
Wave measurements 4 october 2003

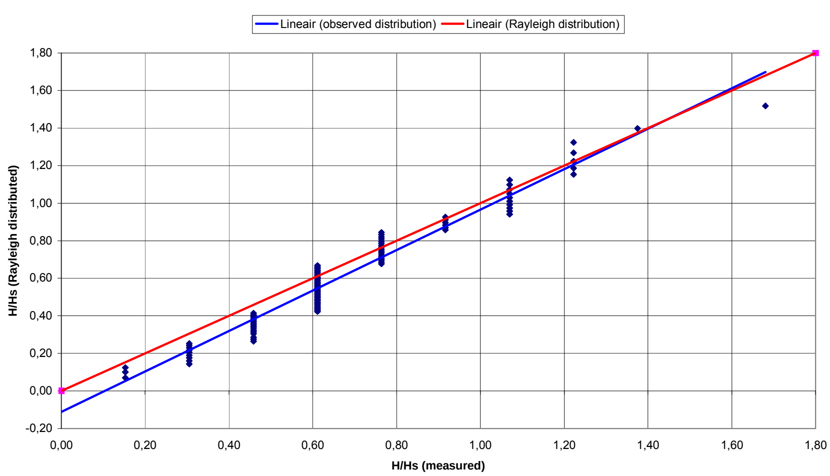
	Mesurment time				Hs [dm]	Hgem [Hgem]	
	14:55 - 15:00				6,5	4,4	
No.	Highest point	Lower point	Wave height	H (High-Low)		exceedence	Rayleigh Distribution
	[dm]	[dm]	[dm]	[dm]	H/Hs	%	H/Hs
1	12	4	8	11	1,68	0,01	1,52
2	9	7	2	9	1,38	0,02	1,40
3	12	6	6	8	1,22	0,03	1,32
4	12	5	7	8	1,22	0,04	1,27
5	13	4	9	8	1,22	0,05	1,22
6	10	6	4	8	1,22	0,06	1,19
7	11	6	5	8	1,22	0,07	1,15
8	11	5	6	7	1,07	0,08	1,12
9	10	5	5	7	1,07	0,09	1,10
10	10	7	3	7	1,07	0,10	1,07
11	10	6	4	7	1,07	0,11	1,05
12	10	6	4	7	1,07	0,12	1,03
13	12	4	8	7	1,07	0,13	1,01
14	9	5	4	7	1,07	0,14	0,99
15	9	7	2	7	1,07	0,15	0,97
16	9	6	3	7	1,07	0,16	0,96
17	10	6	4	7	1,07	0,17	0,94
18	10	6	4	6	0,92	0,18	0,93
19	9	9	0	6	0,92	0,19	0,91
20	10	5	5	6	0,92	0,20	0,90
21	10	7	3	6	0,92	0,21	0,88
22	12	4	8	6	0,92	0,22	0,87
23	11	7	4	6	0,92	0,23	0,86
24	9	6	3	5	0,76	0,24	0,84
25	9	5	4	5	0,76	0,25	0,83
26	10	4	6	5	0,76	0,26	0,82
27	12	4	8	5	0,76	0,27	0,81
28	10	5	5	5	0,76	0,28	0,80
29	9	6	3	5	0,76	0,29	0,79
30	10	5	5	5	0,76	0,30	0,78
31	9	4	5	5	0,76	0,31	0,77
32	10	6	4	5	0,76	0,32	0,75
33	10	6	4	5	0,76	0,33	0,74
34	9	6	3	5	0,76	0,34	0,73
35	12	5	7	5	0,76	0,35	0,72
36	12	5	7	5	0,76	0,36	0,71
37	11	4	7	5	0,76	0,37	0,71
38	10	6	4	5	0,76	0,38	0,70
39	10	4	6	5	0,76	0,39	0,69
40	14	3	11	5	0,76	0,40	0,68
41	12	4	8	4	0,61	0,41	0,67
42	10	6	4	4	0,61	0,42	0,66
43	10	5	5	4	0,61	0,43	0,65
44	10	6	4	4	0,61	0,44	0,64
45	10	5	5	4	0,61	0,45	0,63
46	10	6	4	4	0,61	0,46	0,62
47	9	6	3	4	0,61	0,47	0,61
48	9	6	3	4	0,61	0,48	0,61
49	10	3	7	4	0,61	0,49	0,60
50	10	5	5	4	0,61	0,50	0,59
51	9	5	4	4	0,61	0,51	0,58
52	10	8	2	4	0,61	0,52	0,57
53	10	5	5	4	0,61	0,53	0,56
54	10	7	3	4	0,61	0,54	0,56
55	10	6	4	4	0,61	0,55	0,55

56	10	6	4	4	0,61	0,56	0,54
57	10	7	3	4	0,61	0,57	0,53
58	9	7	2	4	0,61	0,58	0,52
59	10	5	5	4	0,61	0,59	0,51
60	9	6	3	4	0,61	0,60	0,51
61	11	6	5	4	0,61	0,61	0,50
62	10	7	3	4	0,61	0,62	0,49
63	10	6	4	4	0,61	0,63	0,48
64	8	7	1	4	0,61	0,64	0,47
65	9	5	4	4	0,61	0,65	0,46
66	10	6	4	4	0,61	0,66	0,46
67	8	7	1	4	0,61	0,67	0,45
68	11	4	7	4	0,61	0,68	0,44
69	11	4	7	4	0,61	0,69	0,43
70	10	5	5	4	0,61	0,70	0,42
71	11	4	7	3	0,46	0,71	0,41
72	12	6	6	3	0,46	0,72	0,41
73	10	5	5	3	0,46	0,73	0,40
74	8	7	1	3	0,46	0,74	0,39
75	8	6	2	3	0,46	0,75	0,38
76	10	6	4	3	0,46	0,76	0,37
77	10	6	4	3	0,46	0,77	0,36
78	9	6	3	3	0,46	0,78	0,35
79	9	6	3	3	0,46	0,79	0,34
80	10	6	4	3	0,46	0,80	0,33
81	10	6	4	3	0,46	0,81	0,32
82	11	7	4	3	0,46	0,82	0,32
83	11	4	7	3	0,46	0,83	0,31
84	11	4	7	3	0,46	0,84	0,30
85	10	5	5	3	0,46	0,85	0,29
86	9	6	3	3	0,46	0,86	0,27
87	10	6	4	3	0,46	0,87	0,26
88	8	6	2	2	0,31	0,88	0,25
89	10	6	4	2	0,31	0,89	0,24
90	10	6	4	2	0,31	0,90	0,23
91	9	7	2	2	0,31	0,91	0,22
92	9	7	2	2	0,31	0,92	0,20
93	10	7	3	2	0,31	0,93	0,19
94	10	6	4	2	0,31	0,94	0,18
95	10	5	5	2	0,31	0,95	0,16
96	8	6	2	2	0,31	0,96	0,14
97	10	5	5	1	0,15	0,97	0,12
98	10	4	6	1	0,15	0,98	0,10
99	10	6	4	1	0,15	0,99	0,07
100	10	7	3	0	0,00	1,00	0,00

Annex VI Graphs Dutch wave measurements







Annex VII Bulgarian Wave Data

Wave measurements 9 october 2003

Mesurment time	Hs [dm]	Hgem [Hgem]
14,55	7,2	5,2

No.	Highest point [dm]	Lower point [dm]	Wave height [dm]	H (High-Low) [dm]	H/Hs	exceedence %	Rayleigh Distribution H/Hs
1	12	4	8,0	11,0	1,53	0,01	1,52
2	16	6	10,0	10,0	1,39	0,02	1,40
3	13	5	7,5	10,0	1,39	0,03	1,32
4	14	7	7,0	8,5	1,18	0,04	1,27
5	11	6	5,0	8,5	1,18	0,05	1,22
6	11	5	6,0	8,0	1,11	0,06	1,19
7	12	6	6,5	8,0	1,11	0,07	1,15
8	10	8	2,0	7,5	1,04	0,08	1,12
9	11	6	5,0	7,5	1,04	0,09	1,10
10	12	6	6,5	7,5	1,04	0,10	1,07
11	11	5	6,0	7,5	1,04	0,11	1,05
12	14	7	7,0	7,0	0,97	0,12	1,03
13	12	6	6,0	7,0	0,97	0,13	1,01
14	11	6	5,5	7,0	0,97	0,14	0,99
15	11	7	4,0	7,0	0,97	0,15	0,97
16	12	6	6,0	7,0	0,97	0,16	0,96
17	10	7	3,5	7,0	0,97	0,17	0,94
18	11	8	2,5	6,5	0,90	0,18	0,93
19	12	8	4,0	6,5	0,90	0,19	0,91
20	12	6	6,0	6,5	0,90	0,20	0,90
21	11	7	4,0	6,5	0,90	0,21	0,88
22	12	6	6,5	6,5	0,90	0,22	0,87
23	12	7	5,5	6,5	0,90	0,23	0,86
24	11	7	4,0	6,5	0,90	0,24	0,84
25	11	6	5,0	6,5	0,90	0,25	0,83
26	11	7	4,0	6,5	0,90	0,26	0,82
27	12	6	6,0	6,5	0,90	0,27	0,81
28	10	7	3,0	6,5	0,90	0,28	0,80
29	10	8	2,5	6,0	0,83	0,29	0,79
30	12	7	5,0	6,0	0,83	0,30	0,78
31	12	6	6,5	6,0	0,83	0,31	0,77
32	13	6	7,0	6,0	0,83	0,32	0,75
33	14	4	10,0	6,0	0,83	0,33	0,74
34	13	5	7,5	6,0	0,83	0,34	0,73
35	13	6	7,0	6,0	0,83	0,35	0,72
36	12	6	6,5	6,0	0,83	0,36	0,71
37	13	6	7,5	6,0	0,83	0,37	0,71
38	12	7	5,5	6,0	0,83	0,38	0,70
39	10	7	3,0	6,0	0,83	0,39	0,69
40	10	7	3,5	6,0	0,83	0,40	0,68
41	10	8	2,0	6,0	0,83	0,41	0,67
42	11	8	3,5	6,0	0,83	0,42	0,66
43	11	6	5,0	6,0	0,83	0,43	0,65
44	10	5	5,0	6,0	0,83	0,44	0,64
45	14	6	8,5	5,5	0,76	0,45	0,63
46	11	6	5,0	5,5	0,76	0,46	0,62
47	12	7	5,0	5,5	0,76	0,47	0,61
48	11	6	4,5	5,0	0,69	0,48	0,61
49	12	6	6,0	5,0	0,69	0,49	0,60
50	10	6	4,0	5,0	0,69	0,50	0,59
51	10	8	2,5	5,0	0,69	0,51	0,58
52	10	8	2,0	5,0	0,69	0,52	0,57
53	11	6	5,0	5,0	0,69	0,53	0,56
54	14	6	8,5	5,0	0,69	0,54	0,56

55	12	6	6,5	5,0	0,69	0,55	0,55
56	11	7	4,0	5,0	0,69	0,56	0,54
57	12	6	6,5	5,0	0,69	0,57	0,53
58	10	6	4,5	5,0	0,69	0,58	0,52
59	11	8	3,0	5,0	0,69	0,59	0,51
60	10	8	2,0	5,0	0,69	0,60	0,51
61	11	8	3,0	5,0	0,69	0,61	0,50
62	11	7	4,0	5,0	0,69	0,62	0,49
63	12	6	6,0	4,5	0,63	0,63	0,48
64	12	6	6,0	4,5	0,63	0,64	0,47
65	11	7	4,0	4,5	0,63	0,65	0,46
66	10	8	2,0	4,0	0,56	0,66	0,46
67	12	6	6,0	4,0	0,56	0,67	0,45
68	12	7	5,0	4,0	0,56	0,68	0,44
69	12	7	5,0	4,0	0,56	0,69	0,43
70	12	8	4,0	4,0	0,56	0,70	0,42
71	12	6	6,5	4,0	0,56	0,71	0,41
72	13	5	8,0	4,0	0,56	0,72	0,41
73	12	6	6,5	4,0	0,56	0,73	0,40
74	13	7	6,0	4,0	0,56	0,74	0,39
75	11	6	4,5	4,0	0,56	0,75	0,38
76	12	5	7,0	4,0	0,56	0,76	0,37
77	12	6	6,5	4,0	0,56	0,77	0,36
78	11	6	5,0	3,5	0,49	0,78	0,35
79	10	7	3,0	3,5	0,49	0,79	0,34
80	10	8	2,5	3,5	0,49	0,80	0,33
81	12	5	7,0	3,5	0,49	0,81	0,32
82	11	7	4,0	3,5	0,49	0,82	0,32
83	11	6	5,0	3,0	0,42	0,83	0,31
84	12	6	6,0	3,0	0,42	0,84	0,30
85	13	7	6,0	3,0	0,42	0,85	0,29
86	13	6	7,5	3,0	0,42	0,86	0,27
87	16	5	11,0	3,0	0,42	0,87	0,26
88	10	8	2,0	3,0	0,42	0,88	0,25
89	11	8	3,5	3,0	0,42	0,89	0,24
90	11	7	4,0	2,5	0,35	0,90	0,23
91	11	8	3,5	2,5	0,35	0,91	0,22
92	10	8	2,0	2,5	0,35	0,92	0,20
93	11	8	3,0	2,5	0,35	0,93	0,19
94	13	7	6,0	2,0	0,28	0,94	0,18
95	11	5	6,0	2,0	0,28	0,95	0,16
96	13	7	6,0	2,0	0,28	0,96	0,14
97	12	6	6,5	2,0	0,28	0,97	0,12
98	12	7	5,0	2,0	0,28	0,98	0,10
99	11	8	3,0	2,0	0,28	0,99	0,07
100	11	6	5,0	2,0	0,28	1,00	0,00

Wave measurements 9 october 2003

	Mesurment time				Hs [dm]	Hgem [Hgem]	
	15,08				8,0	5,9	

No.	Highest point [dm]	Lower point [dm]	Wave height [dm]	H (High-Low) [dm]	H/Hs	exceedence %	Rayleigh Distribution H/Hs
1	11,0	7,0	4,0	10,5	1,31	0,01	1,52
2	12,0	5,0	7,0	10,5	1,31	0,02	1,40
3	12,0	7,0	5,0	10,5	1,31	0,03	1,32
4	13,0	6,0	7,0	10,0	1,24	0,04	1,27
5	10,0	5,0	5,0	9,0	1,12	0,05	1,22
6	12,5	5,0	7,5	8,5	1,06	0,06	1,19
7	13,0	5,0	8,0	8,5	1,06	0,07	1,15
8	14,0	6,0	8,0	8,5	1,06	0,08	1,12
9	10,0	8,0	2,0	8,5	1,06	0,09	1,10
10	11,5	7,0	4,5	8,0	0,99	0,10	1,07
11	12,0	5,0	7,0	8,0	0,99	0,11	1,05
12	11,0	7,0	4,0	8,0	0,99	0,12	1,03
13	11,0	8,0	3,0	8,0	0,99	0,13	1,01
14	10,0	6,0	4,0	8,0	0,99	0,14	0,99
15	10,0	7,0	3,0	8,0	0,99	0,15	0,97
16	13,0	4,5	8,5	8,0	0,99	0,16	0,96
17	13,5	5,0	8,5	8,0	0,99	0,17	0,94
18	10,0	7,0	3,0	8,0	0,99	0,18	0,93
19	10,0	6,0	4,0	8,0	0,99	0,19	0,91
20	11,0	7,0	4,0	7,5	0,93	0,20	0,90
21	12,0	5,0	7,0	7,5	0,93	0,21	0,88
22	14,0	5,0	9,0	7,5	0,93	0,22	0,87
23	10,0	7,0	3,0	7,5	0,93	0,23	0,86
24	11,5	5,5	6,0	7,5	0,93	0,24	0,84
25	10,0	5,0	5,0	7,5	0,93	0,25	0,83
26	11,0	8,0	3,0	7,0	0,87	0,26	0,82
27	13,0	5,0	8,0	7,0	0,87	0,27	0,81
28	13,5	7,5	6,0	7,0	0,87	0,28	0,80
29	10,0	7,0	3,0	7,0	0,87	0,29	0,79
30	11,0	7,0	4,0	7,0	0,87	0,30	0,78
31	11,0	5,5	5,5	7,0	0,87	0,31	0,77
32	12,5	4,5	8,0	7,0	0,87	0,32	0,75
33	10,5	5,5	5,0	7,0	0,87	0,33	0,74
34	16,5	8,5	8,0	7,0	0,87	0,34	0,73
35	12,0	4,5	7,5	7,0	0,87	0,35	0,72
36	11,0	7,0	4,0	6,5	0,81	0,36	0,71
37	12,0	7,0	5,0	6,5	0,81	0,37	0,71
38	13,0	4,5	8,5	6,0	0,75	0,38	0,70
39	11,0	5,0	6,0	6,0	0,75	0,39	0,69
40	14,0	6,0	8,0	6,0	0,75	0,40	0,68
41	11,0	5,0	6,0	6,0	0,75	0,41	0,67
42	12,0	4,0	8,0	6,0	0,75	0,42	0,66
43	11,0	6,0	5,0	6,0	0,75	0,43	0,65
44	11,0	6,0	5,0	6,0	0,75	0,44	0,64
45	10,5	7,0	3,5	6,0	0,75	0,45	0,63
46	11,5	7,0	4,5	6,0	0,75	0,46	0,62
47	10,0	6,0	4,0	6,0	0,75	0,47	0,61
48	12,0	6,0	6,0	6,0	0,75	0,48	0,61
49	13,0	5,5	7,5	6,0	0,75	0,49	0,60
50	12,0	6,0	6,0	6,0	0,75	0,50	0,59
51	12,0	6,5	5,5	6,0	0,75	0,51	0,58
52	11,5	5,5	6,0	6,0	0,75	0,52	0,57
53	13,0	6,0	7,0	6,0	0,75	0,53	0,56
54	14,0	5,5	8,5	6,0	0,75	0,54	0,56
55	11,0	5,5	5,5	5,5	0,68	0,55	0,55

56	11,5	7,0	4,5	5,5	0,68	0,56	0,54
57	12,0	6,5	5,5	5,5	0,68	0,57	0,53
58	12,0	5,5	6,5	5,5	0,68	0,58	0,52
59	14,0	6,0	8,0	5,5	0,68	0,59	0,51
60	14,5	4,0	10,5	5,0	0,62	0,60	0,51
61	13,0	5,5	7,5	5,0	0,62	0,61	0,50
62	12,5	5,5	7,0	5,0	0,62	0,62	0,49
63	14,0	6,5	7,5	5,0	0,62	0,63	0,48
64	12,0	6,0	6,0	5,0	0,62	0,64	0,47
65	12,5	5,5	7,0	5,0	0,62	0,65	0,46
66	13,0	5,0	8,0	5,0	0,62	0,66	0,46
67	13,0	5,5	7,5	5,0	0,62	0,67	0,45
68	11,5	5,5	6,0	5,0	0,62	0,68	0,44
69	16,0	5,5	10,5	5,0	0,62	0,69	0,43
70	15,0	4,5	10,5	5,0	0,62	0,70	0,42
71	11,0	5,0	6,0	5,0	0,62	0,71	0,41
72	10,5	7,5	3,0	4,5	0,56	0,72	0,41
73	12,0	6,0	6,0	4,5	0,56	0,73	0,40
74	15,0	5,0	10,0	4,5	0,56	0,74	0,39
75	12,0	7,0	5,0	4,5	0,56	0,75	0,38
76	12,0	6,0	6,0	4,0	0,50	0,76	0,37
77	11,0	7,5	3,5	4,0	0,50	0,77	0,36
78	11,0	5,0	6,0	4,0	0,50	0,78	0,35
79	13,0	6,0	7,0	4,0	0,50	0,79	0,34
80	12,0	5,5	6,5	4,0	0,50	0,80	0,33
81	13,0	6,0	7,0	4,0	0,50	0,81	0,32
82	11,0	6,0	5,0	4,0	0,50	0,82	0,32
83	11,0	5,0	6,0	4,0	0,50	0,83	0,31
84	10,0	6,0	4,0	4,0	0,50	0,84	0,30
85	12,0	7,5	4,5	4,0	0,50	0,85	0,29
86	11,0	5,0	6,0	4,0	0,50	0,86	0,27
87	11,0	6,0	5,0	4,0	0,50	0,87	0,26
88	10,0	6,0	4,0	4,0	0,50	0,88	0,25
89	10,0	7,0	3,0	4,0	0,50	0,89	0,24
90	11,0	7,0	4,0	3,5	0,44	0,90	0,23
91	12,0	6,0	6,0	3,5	0,44	0,91	0,22
92	11,0	6,0	5,0	3,0	0,37	0,92	0,20
93	13,0	6,0	7,0	3,0	0,37	0,93	0,19
94	11,0	7,0	4,0	3,0	0,37	0,94	0,18
95	11,0	6,0	5,0	3,0	0,37	0,95	0,16
96	11,0	5,5	5,5	3,0	0,37	0,96	0,14
97	11,0	7,0	4,0	3,0	0,37	0,97	0,12
98	12,0	6,0	6,0	3,0	0,37	0,98	0,10
99	11,0	7,0	4,0	3,0	0,37	0,99	0,07
100	13,0	5,0	8,0	2,0	0,25	1,00	0,00

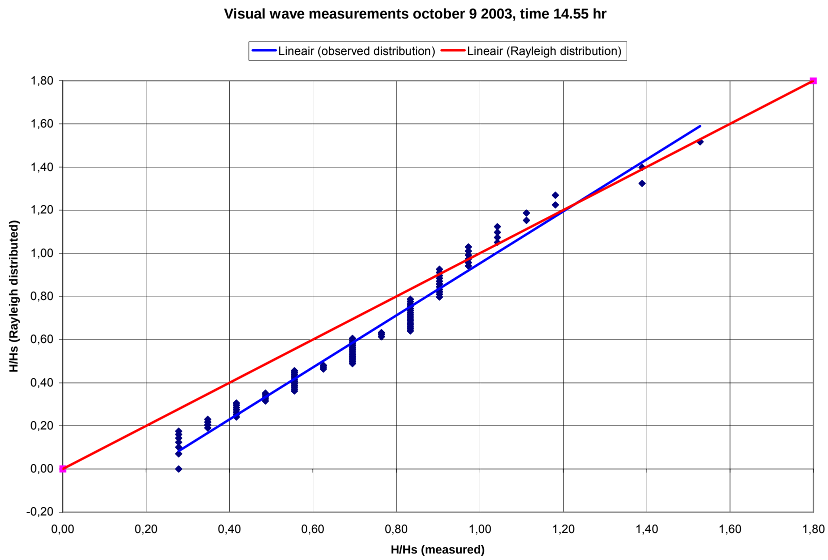
Wave measurements 9 october 2003

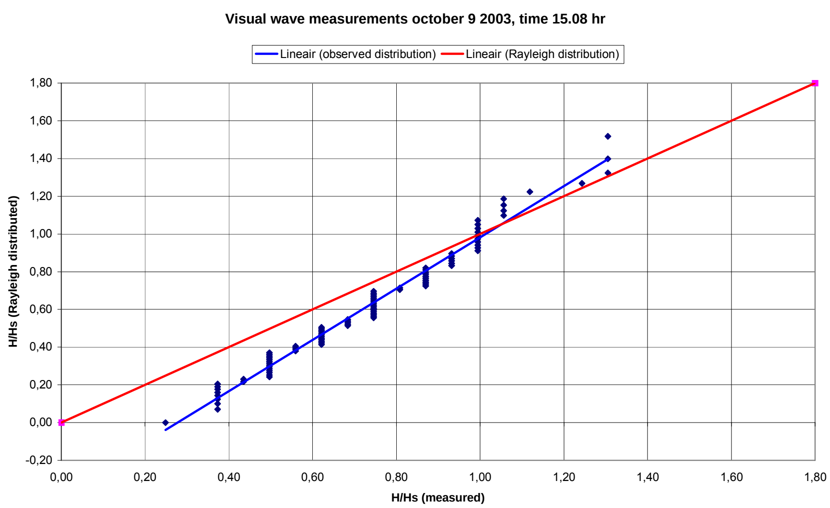
Mesurment time	Hs [dm]	Hgem [Hgem]
15,25	8,2	5,8

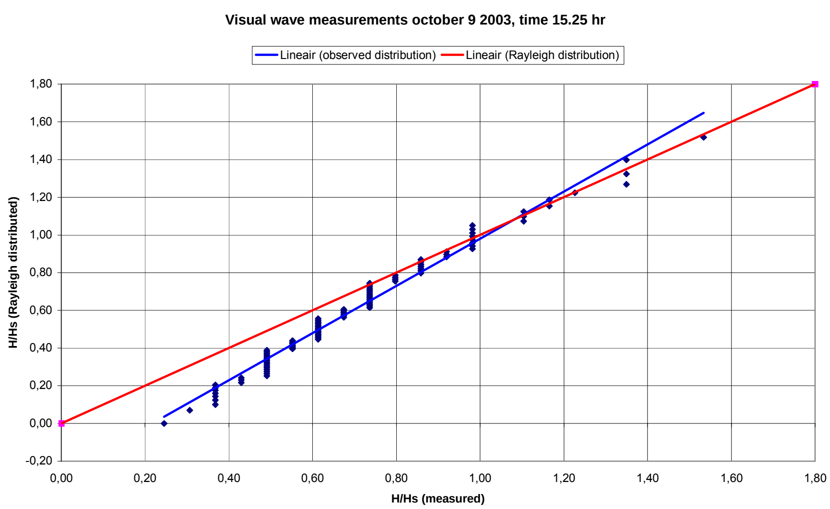
No.	Highest point [dm]	Lower point [dm]	Wave height [dm]	H (High-Low) [dm]	H/Hs	exceedence %	Rayleigh Distribution H/Hs
1	10,0	6,0	4,0	12,5	1,53	0,01	1,52
2	12,0	6,0	6,0	11,0	1,35	0,02	1,40
3	11,0	8,0	3,0	11,0	1,35	0,03	1,32
4	11,0	5,0	6,0	11,0	1,35	0,04	1,27
5	12,0	8,0	4,0	10,0	1,23	0,05	1,22
6	10,0	6,0	4,0	9,5	1,17	0,06	1,19
7	12,0	8,0	4,0	9,5	1,17	0,07	1,15
8	14,0	6,0	8,0	9,0	1,10	0,08	1,12
9	12,0	5,0	7,0	9,0	1,10	0,09	1,10
10	15,0	6,0	9,0	9,0	1,10	0,10	1,07
11	12,0	6,0	6,0	8,0	0,98	0,11	1,05
12	12,0	4,0	8,0	8,0	0,98	0,12	1,03
13	10,0	6,0	4,0	8,0	0,98	0,13	1,01
14	15,0	5,0	10,0	8,0	0,98	0,14	0,99
15	12,0	5,0	7,0	8,0	0,98	0,15	0,97
16	10,0	6,0	4,0	8,0	0,98	0,16	0,96
17	12,0	6,0	6,0	8,0	0,98	0,17	0,94
18	12,0	7,0	5,0	8,0	0,98	0,18	0,93
19	10,0	8,0	2,0	7,5	0,92	0,19	0,91
20	11,0	6,0	5,0	7,5	0,92	0,20	0,90
21	13,0	7,0	6,0	7,5	0,92	0,21	0,88
22	11,0	7,0	4,0	7,0	0,86	0,22	0,87
23	17,0	6,0	11,0	7,0	0,86	0,23	0,86
24	11,0	5,0	6,0	7,0	0,86	0,24	0,84
25	12,0	6,0	6,0	7,0	0,86	0,25	0,83
26	15,0	6,0	9,0	7,0	0,86	0,26	0,82
27	12,5	8,0	4,5	7,0	0,86	0,27	0,81
28	12,0	5,0	7,0	7,0	0,86	0,28	0,80
29	17,0	6,0	11,0	6,5	0,80	0,29	0,79
30	10,0	6,0	4,0	6,5	0,80	0,30	0,78
31	10,0	7,0	3,0	6,5	0,80	0,31	0,77
32	10,0	6,0	4,0	6,5	0,80	0,32	0,75
33	12,0	8,0	4,0	6,0	0,74	0,33	0,74
34	10,5	7,0	3,5	6,0	0,74	0,34	0,73
35	10,0	7,0	3,0	6,0	0,74	0,35	0,72
36	11,5	7,0	4,5	6,0	0,74	0,36	0,71
37	13,0	8,0	5,0	6,0	0,74	0,37	0,71
38	12,0	6,0	6,0	6,0	0,74	0,38	0,70
39	11,5	6,0	5,5	6,0	0,74	0,39	0,69
40	11,0	6,0	5,0	6,0	0,74	0,40	0,68
41	11,0	6,5	4,5	6,0	0,74	0,41	0,67
42	12,0	5,0	7,0	6,0	0,74	0,42	0,66
43	10,0	5,0	5,0	6,0	0,74	0,43	0,65
44	10,0	7,0	3,0	6,0	0,74	0,44	0,64
45	10,5	6,5	4,0	6,0	0,74	0,45	0,63
46	11,0	8,0	3,0	6,0	0,74	0,46	0,62
47	13,0	5,0	8,0	6,0	0,74	0,47	0,61
48	12,0	9,5	2,5	5,5	0,67	0,48	0,61
49	11,0	6,0	5,0	5,5	0,67	0,49	0,60
50	11,0	5,0	6,0	5,5	0,67	0,50	0,59
51	13,0	6,0	7,0	5,5	0,67	0,51	0,58
52	12,0	5,0	7,0	5,5	0,67	0,52	0,57
53	12,0	6,0	6,0	5,5	0,67	0,53	0,56
54	11,0	6,0	5,0	5,0	0,61	0,54	0,56
55	10,5	7,0	3,5	5,0	0,61	0,55	0,55

56	12,0	8,0	4,0	5,0	0,61	0,56	0,54
57	13,0	5,0	8,0	5,0	0,61	0,57	0,53
58	13,0	5,0	8,0	5,0	0,61	0,58	0,52
59	12,0	5,5	6,5	5,0	0,61	0,59	0,51
60	10,0	5,0	5,0	5,0	0,61	0,60	0,51
61	11,0	6,0	5,0	5,0	0,61	0,61	0,50
62	10,0	7,0	3,0	5,0	0,61	0,62	0,49
63	11,0	6,0	5,0	5,0	0,61	0,63	0,48
64	11,5	6,5	5,0	5,0	0,61	0,64	0,47
65	10,0	5,0	5,0	5,0	0,61	0,65	0,46
66	13,0	5,0	8,0	5,0	0,61	0,66	0,46
67	13,0	6,5	6,5	5,0	0,61	0,67	0,45
68	12,0	5,0	7,0	4,5	0,55	0,68	0,44
69	12,0	8,0	4,0	4,5	0,55	0,69	0,43
70	12,0	6,0	6,0	4,5	0,55	0,70	0,42
71	12,0	5,5	6,5	4,5	0,55	0,71	0,41
72	12,0	7,0	5,0	4,5	0,55	0,72	0,41
73	16,0	3,5	12,5	4,5	0,55	0,73	0,40
74	11,0	7,0	4,0	4,0	0,49	0,74	0,39
75	11,5	7,5	4,0	4,0	0,49	0,75	0,38
76	11,5	5,5	6,0	4,0	0,49	0,76	0,37
77	14,0	4,5	9,5	4,0	0,49	0,77	0,36
78	14,0	5,0	9,0	4,0	0,49	0,78	0,35
79	11,0	5,5	5,5	4,0	0,49	0,79	0,34
80	11,5	5,5	6,0	4,0	0,49	0,80	0,33
81	11,0	5,5	5,5	4,0	0,49	0,81	0,32
82	12,0	6,5	5,5	4,0	0,49	0,82	0,32
83	11,5	6,0	5,5	4,0	0,49	0,83	0,31
84	15,0	5,5	9,5	4,0	0,49	0,84	0,30
85	12,5	5,0	7,5	4,0	0,49	0,85	0,29
86	13,5	5,5	8,0	4,0	0,49	0,86	0,27
87	12,0	5,5	6,5	4,0	0,49	0,87	0,26
88	11,5	7,0	4,5	4,0	0,49	0,88	0,25
89	13,5	6,0	7,5	3,5	0,43	0,89	0,24
90	11,5	5,5	6,0	3,5	0,43	0,90	0,23
91	10,5	5,0	5,5	3,5	0,43	0,91	0,22
92	16,0	5,0	11,0	3,0	0,37	0,92	0,20
93	11,0	5,0	6,0	3,0	0,37	0,93	0,19
94	14,0	6,0	8,0	3,0	0,37	0,94	0,18
95	10,5	6,0	4,5	3,0	0,37	0,95	0,16
96	11,0	7,5	3,5	3,0	0,37	0,96	0,14
97	15,0	7,5	7,5	3,0	0,37	0,97	0,12
98	10,0	5,5	4,5	3,0	0,37	0,98	0,10
99	11,5	6,5	5,0	2,5	0,31	0,99	0,07
100	10,5	7,5	3,0	2,0	0,25	1,00	0,00

Annex VIII Graphs Bulgarian wave measurements





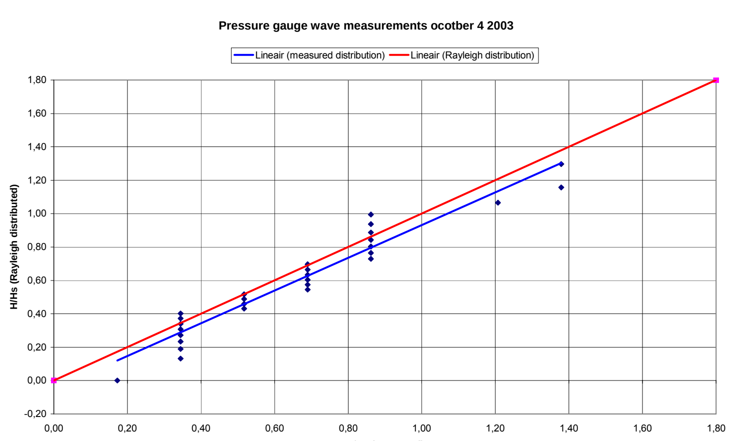


Annex IX Pressure Gauge

Wave measurements, pressure gauge 4 october 2003

Mesurment time	Hs [dm]	Hgem [Hgem]
14,55	0,54	0,36

No.	Highest point [m]	Lower point [m]	Wave height [m]	S (High-Low) [m]	H [m]	H/Hs	exceedence %	Rayleigh Distribution H/Hs
1	0,15	-0,06	0,21	0,55	0,74	1,38	0,03	1,30
2	0,15	-0,13	0,28	0,55	0,74	1,38	0,07	1,16
3	0,15	-0,13	0,28	0,48	0,65	1,21	0,10	1,07
4	0,08	0,01	0,07	0,34	0,47	0,86	0,14	1,00
5	0,08	-0,06	0,14	0,34	0,47	0,86	0,17	0,94
6	0,08	-0,06	0,14	0,34	0,47	0,86	0,21	0,89
7	0,08	-0,06	0,14	0,34	0,47	0,86	0,24	0,84
8	0,08	-0,13	0,21	0,34	0,47	0,86	0,28	0,80
9	0,15	-0,13	0,28	0,34	0,47	0,86	0,31	0,76
10	0,15	-0,20	0,34	0,34	0,47	0,86	0,34	0,73
11	0,15	-0,20	0,34	0,28	0,37	0,69	0,38	0,70
12	0,21	-0,13	0,34	0,28	0,37	0,69	0,41	0,66
13	0,15	-0,13	0,28	0,28	0,37	0,69	0,45	0,63
14	0,08	-0,06	0,14	0,28	0,37	0,69	0,48	0,60
15	0,08	-0,13	0,21	0,28	0,37	0,69	0,52	0,57
16	0,15	-0,13	0,28	0,28	0,37	0,69	0,55	0,55
17	0,08	-0,06	0,14	0,21	0,28	0,52	0,59	0,52
18	0,15	-0,20	0,34	0,21	0,28	0,52	0,62	0,49
19	0,28	-0,20	0,48	0,21	0,28	0,52	0,66	0,46
20	0,28	-0,27	0,55	0,21	0,28	0,52	0,69	0,43
21	0,21	-0,34	0,55	0,14	0,19	0,34	0,72	0,40
22	0,21	-0,13	0,34	0,14	0,19	0,34	0,76	0,37
23	0,08	-0,13	0,21	0,14	0,19	0,34	0,79	0,34
24	0,15	-0,20	0,34	0,14	0,19	0,34	0,83	0,31
25	0,15	-0,20	0,34	0,14	0,19	0,34	0,86	0,27
26	0,15	-0,13	0,28	0,14	0,19	0,34	0,90	0,23
27	0,08	-0,06	0,14	0,14	0,19	0,34	0,93	0,19
28	0,01	-0,13	0,14	0,14	0,19	0,34	0,97	0,13
29	0,08	-0,06	0,14	0,07	0,09	0,17	1,00	0,00



Annex X Short Waves Table

h/L_o	h/L	kh	tanh kh	sinh kh	cosh kh	K_s	n
0	0	0	0	0	1	∞	1
.005	.02836	.1782	.1764	.1791	1.0159	1.692	.9896
.010	.04032	.2533	.2480	.2560	1.0322	1.435	.9792
.015	.04964	.3119	.3022	.3170	1.0490	1.307	.9690
.020	.05763	.3621	.3470	.3701	1.0663	1.226	.9588
.025	.06478	.4070	.3860	.4184	1.0840	1.168	.9488
.030	.07135	.4483	.4205	.4634	1.1021	1.125	.9388
.035	.07748	.4868	.4517	.5064	1.1209	1.092	.9289
.040	.08329	.5233	.4802	.5475	1.1401	1.064	.9192
.045	.08883	.5581	.5066	.5876	1.1599	1.042	.9095
.050	.09416	.5916	.5310	.6267	1.1802	1.023	.8999
.055	.09930	.6239	.5538	.6652	1.2011	1.007	.8905
.060	.1043	.6553	.5753	.7033	1.2225	.9932	.8811
.065	.1092	.6860	.5954	.7411	1.2447	.9815	.8719
.070	.1139	.7157	.6144	.7783	1.2672	.9713	.8627
.075	.1186	.7453	.6324	.8162	1.2908	.9624	.8537
.080	.1232	.7741	.6493	.8538	1.3149	.9548	.8448
.085	.1277	.8026	.6655	.8915	1.3397	.9481	.8360
.090	.1322	.8306	.6808	.9295	1.3653	.9422	.8273
.095	.1366	.8583	.6953	.9677	1.3917	.9371	.8187
.100	.1410	.8858	.7093	1.006	1.4187	.9327	.8103
.110	.1496	.9400	.7352	1.085	1.4752	.9257	.7937
.120	.1581	.9936	.7589	1.165	1.5356	.9204	.7776
.130	.1665	1.046	.7804	1.248	1.5990	.9169	.7621
.140	.1749	1.099	.8002	1.334	1.667	.9146	.7471
.150	.1833	1.152	.8183	1.424	1.740	.9133	.7325
.160	.1917	1.204	.8349	1.517	1.817	.9130	.7184
.170	.2000	1.257	.8501	1.614	1.899	.9134	.7050
.180	.2083	1.309	.8640	1.716	1.986	.9145	.6920
.190	.2167	1.362	.8767	1.823	2.079	.9161	.6796
.200	.2251	1.414	.8884	1.935	2.178	.9181	.6677
.210	.2336	1.468	.8991	2.055	2.285	.9205	.6563
.220	.2421	1.521	.9088	2.178	2.397	.9231	.6456
.230	.2506	1.575	.9178	2.311	2.518	.9261	.6353
.240	.2592	1.629	.9259	2.450	2.647	.9291	.6256
.250	.2679	1.683	.9332	2.599	2.784	.9323	.6164
.260	.2766	1.738	.9400	2.755	2.931	.9356	.6076
.270	.2854	1.793	.9461	2.921	3.088	.9390	.5994
.280	.2942	1.849	.9516	3.097	3.254	.9423	.5917
.290	.3031	1.905	.9567	3.284	3.433	.9456	.5845
.300	.3121	1.961	.9611	3.483	3.624	.9490	.5777
.320	.3302	2.075	.9690	3.919	4.045	.9553	.5655
.340	.3468	2.190	.9753	4.413	4.525	.9613	.5548
.360	.3672	2.307	.9804	4.974	5.072	.9667	.5457
.380	.3860	2.425	.9845	5.609	5.697	.9717	.5380
.400	.4050	2.544	.9877	6.329	6.407	.9761	.5314
.420	.4241	2.665	.9904	7.146	7.215	.9798	.5258
.440	.4434	2.786	.9924	8.075	8.136	.9832	.5212
.460	.4628	2.908	.9941	9.132	9.186	.9860	.5173
.480	.4822	3.030	.9953	10.32	10.37	.9885	.5142
.500	.5018	3.153	.9964	11.68	11.72	.9905	.5115

Annex XI Data groyne measurements

In Bulgaria measurements with 3 different hemispheres were carried out. 4 cross- sections were measured with a large hemisphere, diameter of 0.75 m, and control measurements were done on one profile with a small hemisphere, diameter of 0.25 m, and without the use of a hemisphere. The outcome of these three measurements is given in this annex in table form. The level of the water level was 3.08 m. The numbers in these tables represent the vertical distance from the level of the measuring device, in this case a theodolite, and the top of the surface of the groyne given in meter. Y represents the width, X represents the length of the groyne, also given in meter.

positive to the north	X			
Y	5	15	25	35
				2,97
16,5				2,75
16		2,97		2,59
15,5		2,93	3,17	2,58
15		2,98	2,83	2,54
14,5		2,85	2,64	2,39
14		2,63	2,49	2,20
13,5		2,75	2,21	2,15
13		2,59	2,14	2,11
12,5		2,45	2,25	2,02
12		1,90	1,84	1,88
11,5		1,69	1,81	1,75
11		1,82	1,69	1,57
10,5		1,77	1,76	1,61
10		1,68	1,24	1,70
9,5		1,70	1,34	1,53
9		1,62	1,54	1,78
8,5		1,62	1,72	1,73
8		1,62	1,60	1,57
7,5				
7				
6,5				
6				
5,5				
5				
4,5				
4				
3,5				
3				
2,5				
2				
1,5				
1				
0,5				
0	1,48	1,35	1,26	1,24
-0,5		1,35		
-1	1,49	1,35	1,26	1,26
-1,5		0,72		
-2	1,11	0,70	1,40	1,40
-2,5	0,99	1,19	1,51	1,52
-3	1,30	0,97	1,30	1,68

-3,5	1,59	1,00	1,41	1,70
-4	1,50	1,28	1,68	1,61
-4,5	1,81	1,52	1,66	1,75
-5	1,78	1,68	1,83	1,65
-5,5	1,79	1,91	2,00	1,59
-6	1,69	2,14	2,31	1,60
-6,5	1,78	1,94	2,27	1,66
-7	1,80	1,97	2,44	1,69
-7,5	2,10	1,89	2,48	1,79
-8	2,15	2,25	2,44	1,78
-8,5	2,27	2,33	2,37	1,81
-9	2,72	2,28	2,36	1,95
-9,5	3,00		2,39	1,94
-10			2,93	1,87
-10,5			3,03	2,03
-11			2,85	1,86
-11,5			2,80	2,28
-12				
-12,5				
-13				

The measurements with the small hemisphere and without the hemisphere were performed on the cross-section at X = 15 m.

positive to the north	small hemisphere	no hemisphere
Y		
16,5		
16	2,97	2,98
15,5	2,93	2,99
15	2,92	3,02
14,5	2,79	2,86
14	2,80	2,88
13,5	2,69	2,79
13	2,59	2,75
12,5	2,35	2,45
12	2,02	2,43
11,5	1,60	1,70
11	1,80	1,90
10,5	1,69	1,79
10	1,69	1,88
9,5	1,92	2,04
9	1,69	1,89
8,5	1,52	1,65
8	1,51	1,62
7,5		
7		
6,5		
6		
5,5		
5		
4,5		
4		
3,5		
3		
2,5		
2		

1,5		
1		
0,5		
0	1,24	1,35
-0,5		1,35
-1	1,24	1,35
-1,5	1,05	0,82
-2	0,65	1,40
-2,5	1,11	1,00
-3	0,90	1,19
-3,5	1,07	1,51
-4	1,21	1,60
-4,5	1,45	1,89
-5	1,68	1,99
-5,5	1,84	2,21
-6	2,14	2,01
-6,5	1,88	2,24
-7	2,14	2,31
-7,5	2,18	2,32
-8	2,15	2,25
-8,5	2,25	2,34
-9	2,18	2,29
-9,5	2,35	
-10	2,28	
-10,5	3,30	
-11		
-11,5		
-12		
-12,5		
-13		

Annex XII Marciana Quarry measurements

No.	Mass [kg]	X [cm]	Y [cm]	Z [cm]	l/d	X*Y*Z [m^3]	Vol [m^3]	BLc [-]	Dn [m]
1	29,65	48	28	25	1,92	0,034	0,0126	37,6	0,233
2	19,70	37	26	19	1,95	0,018	0,0084	45,9	0,203
3	80,00	60	38	36	1,67	0,082	0,0341	41,5	0,324
4	25,65	35	32	21	1,67	0,024	0,0109	46,4	0,222
5	32,75	35	33	21	1,67	0,024	0,0139	57,5	0,241
6	18,80	37	26	22	1,68	0,021	0,0080	37,8	0,200
7	14,40	39	26	20	1,95	0,020	0,0061	30,2	0,183
8	16,00	38	30	17	2,24	0,019	0,0068	35,1	0,190
9	36,80	39	36	25	1,56	0,035	0,0157	44,6	0,250
10	29,20	54	24	22	2,45	0,029	0,0124	43,6	0,232
11	14,60	30	21	20	1,50	0,013	0,0062	49,3	0,184
12	24,50	44	28	25	1,76	0,031	0,0104	33,9	0,218
13	30,60	43	30	28	1,54	0,036	0,0130	36,1	0,235
14	26,00	32	29	27	1,19	0,025	0,0111	44,2	0,223
15	36,00	53	45	19	2,79	0,045	0,0153	33,8	0,248
16	35,80	46	29	21	2,19	0,028	0,0152	54,4	0,248
17	47,40	53	37	29	1,83	0,057	0,0202	35,5	0,272
18	20,90	36	24	22	1,64	0,019	0,0089	46,8	0,207
19	23,40	38	32	21	1,81	0,026	0,0100	39,0	0,215
20	50,00	49	41	29	1,69	0,058	0,0213	36,5	0,277
21	53,40	49	40	33	1,48	0,065	0,0227	35,1	0,283
22	28,60	47	30	26	1,81	0,037	0,0122	33,2	0,230
23	65,50	80	33	30	2,67	0,079	0,0279	35,2	0,303
24	10,40	28	19	18	1,56	0,010	0,0044	46,2	0,164
25	28,80	34	30	24	1,42	0,024	0,0123	50,1	0,231
26	35,60	53	29	27	1,96	0,041	0,0152	36,5	0,247
27	32,20	38	29	25	1,52	0,028	0,0137	49,8	0,239
28	15,00	38	28	20	1,90	0,021	0,0064	30,0	0,186
29	14,40	40	27	17	2,35	0,018	0,0061	33,4	0,183
30	18,25	36	28	19	1,89	0,019	0,0078	40,6	0,198
31	28,20	40	31	28	1,43	0,035	0,0120	34,6	0,229
32	32,90	53	36	26	2,04	0,050	0,0140	28,2	0,241
33	26,20	41	32	29	1,41	0,038	0,0112	29,3	0,223
34	45,60	54	42	24	2,25	0,054	0,0194	35,7	0,269
35	17,95	46	26	18	2,56	0,022	0,0076	35,5	0,197
36	40,00	54	31	31	1,74	0,052	0,0170	32,8	0,257
37	26,00	48	32	19	2,53	0,029	0,0111	37,9	0,223
38	25,40	48	28	20	2,40	0,027	0,0108	40,2	0,221
39	25,60	39	33	19	2,05	0,024	0,0109	44,6	0,222
40	17,80	30	20	20	1,50	0,012	0,0076	63,1	0,196
41	39,00	50	35	20	2,50	0,035	0,0166	47,4	0,255
42	41,70	45	40	25	1,80	0,045	0,0178	39,5	0,261
43	23,75	52	28	19	2,74	0,028	0,0101	36,5	0,216
44	20,10	47	22	20	2,35	0,021	0,0086	41,4	0,205
45	25,00	39	30	22	1,77	0,026	0,0106	41,3	0,220
46	47,25	35	31	30	1,17	0,033	0,0201	61,8	0,272
47	36,30	46	37	18	2,56	0,031	0,0155	50,4	0,249
48	44,30	54	35	22	2,45	0,042	0,0189	45,4	0,266
49	35,00	37	36	23	1,61	0,031	0,0149	48,6	0,246
50	30,95	37	30	21	1,76	0,023	0,0132	56,5	0,236