NON-LINEAR WAVE PROPAGATION IN THE COASTAL ZONE: THE MAST G6-M PROJECT

by

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1. Introduction

The MAST Programme (Marine Science and Technology) launched by the EC really appears to be a step forward in European research on coastal processes.

It has brought together a large number of European research institutes, including universities and advisory institutes, which were working on the subject more or less independently until 1990.

The MAST programme provides for a total EC budget of 50 million ECU (about 70 million US$) out of which 40 million ECU will be spent in co-financing research projects in Europe on the basis of 50% of the total cost.

2. Overall view of the MAST-G6M projects

2.1 Brief historical review

In December 1987, the EC invited a number of experts to help in setting up the MAST Programme, for which credits had been voted. It soon became apparent that we live in a small world and a few leading institutes decided to combine efforts to propose major research themes in coastal engineering. At the beginning of 1988, the following themes were suggested:

- coastal morphodynamics,
- coastal structures,
- coastal ecosystems.

Other suggestions such as oceanography, numerical modelling and marine technology were also adopted by the EC.

This was followed in spring 1988 by a call for expressions of interest, which was a success, since more than 1000 were received by the EC. This also explains why it took nearly one year before the EC could send out a call for proposals in spring 1989. This again was a success, for the EC received over

200 proposals and the total amount of financing required was eight times the available EC budgets.

Hence, quite dramatic cuts in the projects were necessary and it again took about a year to reach a series of satisfactory projects.

Now, in September 1990, projects have just been started, contracts are signed and researchers are getting organised.

The so-called Group of Six (G6), which decided to combine their efforts from very beginning of 1988, includes the following institutes:

- Danish Hydraulic Institute (DK)
- Delft Hydraulics (NL)
- Hydraulics Research (GB)
- Laboratoire National d'Hydraulique (F)
- Leichtweiss Institute (D)
- SOGREAH (F).

The G6 was able to set up a vast collaboration scheme with about 20 other institutes all over Europe, who were called in as associates. The total financial support from the EC amounts to 3.0 million ECU for coastal morphodynamics and 1.0 million ECU for coastal structures.

2.2 G6 - Morphodynamics

The general objective is "an agreed, validated and balanced modelling concept for morphological problems in coastal areas, to be implemented and applied by the leading European advisory institutes in this field and made accessible to others, through their participation in the programme, through a reference handbook for coastal morphodynamical modelling and through presentation of the results in an open final workshop".

To achieve these goals, six interlinked projects are defined (figure 1):

- Project 0, concerning the overall coherence of the programme, the consolidation of results in the overall modelling concept and the exchange and diffusion of knowledge.
- Project 1 - 4, concerning the constituent physical processes (waves, currents, non-cohesive sediment transport, cohesive sediment transport). These shall provide knowledge of these processes and their modelling at the level required for incorporation in a consistent morphodynamic modelling concept.
- Project 5, concerning morphodynamics and its short-term and long-term modelling concept.

It is stressed here that the projects deal with "concepts" rather than with (numerical) "models". This follows from an EC requirement (DG XII for

Science Research and Development) which will provide financial support exclusively to "precompetitive research".

2.3 Project organisation

Each of the above-mentioned projects is led by a G6 member (figure 2):

- Project 0: Delft Hydraulics acting as overall leader,
- Project 1: SOGREAH,
- Project 2: Hydraulics Research,
- Project 3: Danish Hydraulic Institute,
- Project 4: Laboratoire National d'Hydraulique,
- Project 5: Delft Hydraulics.

Each project thus has a project leader from the above-mentioned institutes, which is in charge of interconnections with the other projects and with the associates.

A Technical Committee comprises five project leaders (the same person is leading projects 0 and 5 at Delft Hydraulics) and a representative from Leichtweiss Institute. The Technical Committee is chaired by the Overall Leader (= leader of projects 0 and 5 - Delft Hydraulics) and is in charge of day-to-day coordination, contacts with other programmes, preparation/ reporting of meetings and workshops, and of course scientific steering and evaluation.

A Management Board consists of one representative from each G6 member, and is in charge of contract formulation and monitoring of collaboration.

2.4 Project 1: Waves

The general aim of this project is to advance understanding and model concepts of the processes associated with the propagation of random surface waves in shallow waters, including the surf zone, as far as they are needed to understand and predict the morphological behaviour of the coast. The project has been divided into 12 tasks, including laboratory experiments, field measurements and modelling of physical processes.

Two different modelling techniques will be applied to simulate natural wave propagation outside and inside the surf zone, namely:

- time-domain modelling with Boussinesq-type models, including dissipation terms to reproduce breaking effects,
- non-linear spectral modelling, in order to incorporate non-linear effects relevant to sediment transport in the nearshore area, including breaking effects.

Three series of flume tests, two series of basin tests and field measurements from Sylt Island will be carried out during the project and be used to validate the modelling part of the work. The work planned will now be described in greater detail:

3. Description of planned work

3.1 Flume tests 1: University of Padua

These tests will be carried out in a wave flume (33 m long, 1 m wide and 1.2 m deep), equipped with a piston-type random wave generator (Liberatore and Petti, 1988) and 10 wave gauges.

The aim of the tests is to investigate the shoaling process and wave height decay of random waves for three bottom configurations.

The first consists of a flat bottom with a bar (see fig. 3), in order to analyse the development of sub- and superharmonics in front of and behind the bar. Frequency changes behind the bar are also expected (Dingemans and Battjes, 1988).

The two other configurations are plane beaches with very gentle slopes (1 in 50 and 1 in 100), in order to extend previous experimental works carried out by Battjes and Janssen (1978) and Stive (1984) (plane beaches with 5% and 2.5% slopes respectively).

3.2 Flume tests 2: University of Brunswick (LWI)

Full-scale experiments will be carried out in the large wave flume (GWK) over natural beach profiles with sand to extend the results obtained in previous experiments (Oelerich and Dette, 1988).

The flume is 324 m long, 5 m wide and 7 m deep. The free-surface elevation is measured with 10 wave gauges. Regular tests will be performed to analyse vortices generated in plunging breakers and individual wave height decays into the surf zone.

Random wave tests will demonstrate the evolution of the initial spectrum along the beach. Video recordings of the surf zone will make it possible to analyse the position and type of breakers.

3.3 Flume tests 3: University of Edinburgh

These measurements will be carried out in a small-scale flume (10 m long, 0.33 m wide and 0.9 m deep) equipped with a Particle Image Velocimetry system (PIV). The PIV system is a non-intrusive technique which allows the complete two-dimensional flow field in a wave tank to be captured at a single instant (Gray and Greated, 1988). It will be used for mapping velocities in breaking waves on a beach or over a bar.

This technique has been used to study waves breaking on offshore structures (Easson and Greated, 1984) and has been compared with time-stepping numerical simulations (Skyner et al., 1989).

3.4 Field measurements: LWI

These are taking place at Sylt Island in Germany (fig. 4) on a sandy beach which has suffered severe erosion for many years. This coast is monitored regularly (Dette and Fuhrboter, 1974) and two beach profiles have been equipped with 2-component electromagnetic currentmeters and pressure cells. Fig. 5 shows the equipment of the barred profile, including a directional wave buoy outside the surf zone, 1000 m offshore, four measuring points with a currentmeter and a pressure cell at each point. At one point a resistive wave gauge was installed temporarily in order to check the validity of the transfer function, enabling computation of the sea surface elevation from the pressure cells.

3.5 Effect of directional spreading of waves

The effect of short-crested waves in the breaking zone will be investigated during the second year of the project, both in wave basins and by numerical simulations.

Three-dimensional wave breaking processes on a flat bottom will be investigated at Edinburgh in a 3D basin 11 m long, 27 m wide and 1.2 m deep fitted with 80 absorbing wave-makers driven by computer. Wave fields can be generated with up to 1024 sinusoidal components from a method developed by Bryden and Greated (1984). By focussing the wave components, extreme breaking waves can be accurately and repeatedly created at a particular location.

3D basin tests on a beach configuration to be defined will also be carried out in a new wave basin 30 m long, 30 m wide and 1 m deep fitted with 60 wave-makers at SOGREAH/LHF.

Analysis of the influence of short-crested waves on sediment transport will be carried out by means of numerical simulations at DHI.

3.6 Time dependent domain modelling in the surf zone: the Boussinesq approach

The drawback of traditional Boussinesq models is that they cannot reproduce wave propagation and energy dissipation into the surf zone.

In this project, the concept of a surface roller (Deigaard, 1989) will be applied to include the effects of breaking waves. The surface roller can be described as a lump of water riding on the front of a breaking wave and thus advancing with the wave celerity (fig. 6). By defining the surface roller in a pure geometrical approach, it is thus possible to derive the conservation equations of mass and momentum by considering the flow beneath the surface roller and the surface roller itself.

In a first approach (Deigaard, 1989), very promising results have been obtained by including (essentially) only the pressure term in the momentum equation. Calibration and validation will be carried out by Snam-Projetti.

A second approach is now being derived slightly differently by DHI in order to allow full inclusion of surface roller effects in the complete set of equations.

3.7 Spectral modelling in the nearshore zone. A non-linear approach

The aim of this part of the project is to provide an engineering tool to be incorporated into a system of mathematical models for the simulation of morphological processes in the coastal zone.

This programme should incorporate the essential wave processes which are relevant to the sediment transport outside and inside the surf zone. These processes are:

- randomness and multidirectionality of natural waves,
- growth of sub- and super-harmonics generating dissymmetries of the sea-surface elevation and bottom orbital velocities,
- energy dissipation in the surf zone,
- refraction over depth and currents.

Additionally, the model must be as simple as possible in order to be suitable for use in an industrial morphological model, where periodic updating of the hydrodynamic velocity field is expected.

In this study, a spectral approach will be developed by assuming a linear superimposition of non-linear components. Low-frequency waves and wave-current interactions are excluded from the present study (Project 1) and will be studied in MAST G6-M Project 2.

An analysis program will be developed in order to extract non-linear components from wave records following the method originally derived by Swart (1982). In this method, the wave theory to be used for the analysis has to be chosen. In a first step, the Stokes third-order theory will be used in depths where the Ursell number is less than 0(1).

A bispectral analysis will also be used in order to check the results of the previous analysis.

A spectral model will then be developed and validated with the laboratory and field measurements. The energy dissipation term will be a special subject of analysis.

4. Conclusions

The EC MAST Programme may be considered as a major initiative to enhance concerted research in coastal engineering. It should, within this decade, lead to major breakthroughs in the understanding and modelling of the physical processes involved.

The organisation of large-scale research requires a great deal of effort and patience. It calls for a clear hierarchy which can best be led by a group of advisory institutes which stand in the middle between strategic management (governmental agencies) and fundamental research (universities), and which are faced with practical problems in their daily advisory work. Great attention must be paid to maintaining the coherence of the many research projects performed by each of the associates, since centrifugal forces tend to scatter efforts.

Project 1, devoted to the study and modelling of wave propagation in the nearshore area, is spurred mainly by morphological considerations. The project team should act as a forum of specialists, ready to suggest other projects in the field of wave problems, e.g. input of specialist knowledge into test applications, support of sensitivity analysis and validation tests, support of model simplifications.

5. Acknowledgements

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We should also like to take this opportunity to thank all those scientists involved in this project, who provided the technical information contained in this paper. A complete list is given in table 2.

6. Bibliography

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TABLE 1 - KEY PERSONNEL

Insitutes	Technical Committee	G6 Board
Delft Hydraulics (NL)	H.J. de Vriend	J. van der Weide
Hydraulics Research Ltd (GB)	R.L. Soulsby	M. Owen
Danish Hydraulic Institute	J. Fredsøe	A. Kej
SOGREAH (F)	L. Hamm	A. de Graauw
LNH/Electricité de France (F)	C. Teisson	B. Manoha
LWI/Techn. Univ. Braunschweig (D)	H.H. Dette	H.H. Dette

TABLE 2 - SCIENTISTS PRESENTLY INVOLVED IN PROJECT 1

Luc HAMM	SOGREAH
Patrick SAUVAGET	LHF
Jean-Pierre GERMAIN	LHF/IMG
Marteen DINGEMANS	DH
Hans DETTE	LWI
Johannes OELERICH	LWI
Luigi IOVENITTI	SP
M. BROCCHINI	SP
Clive GREATED	UEd
Gianfranco LIBERATORE	UPa
Rolf DEIGAARD	DHI
Hemming SCHÄFFER	DHI

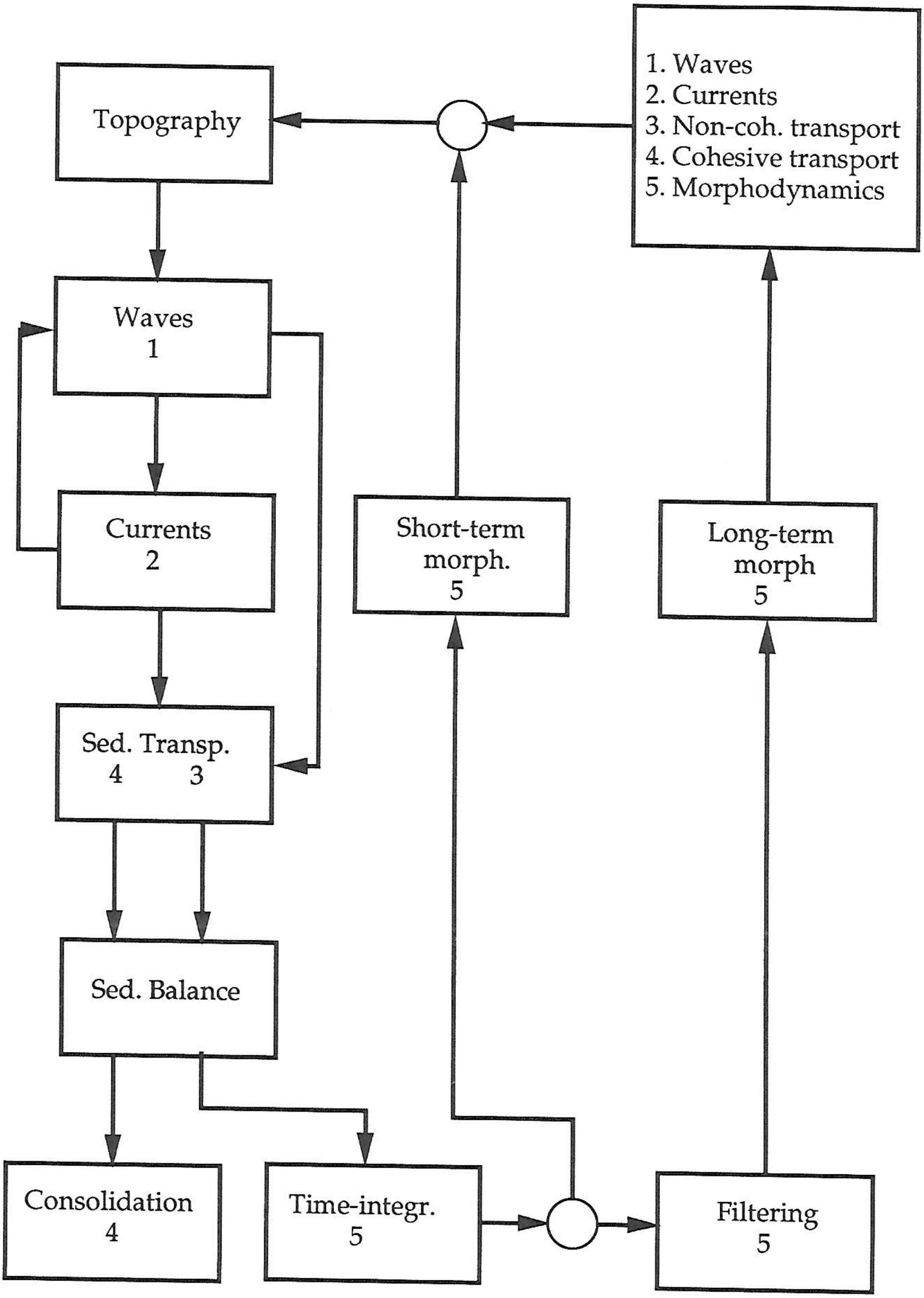
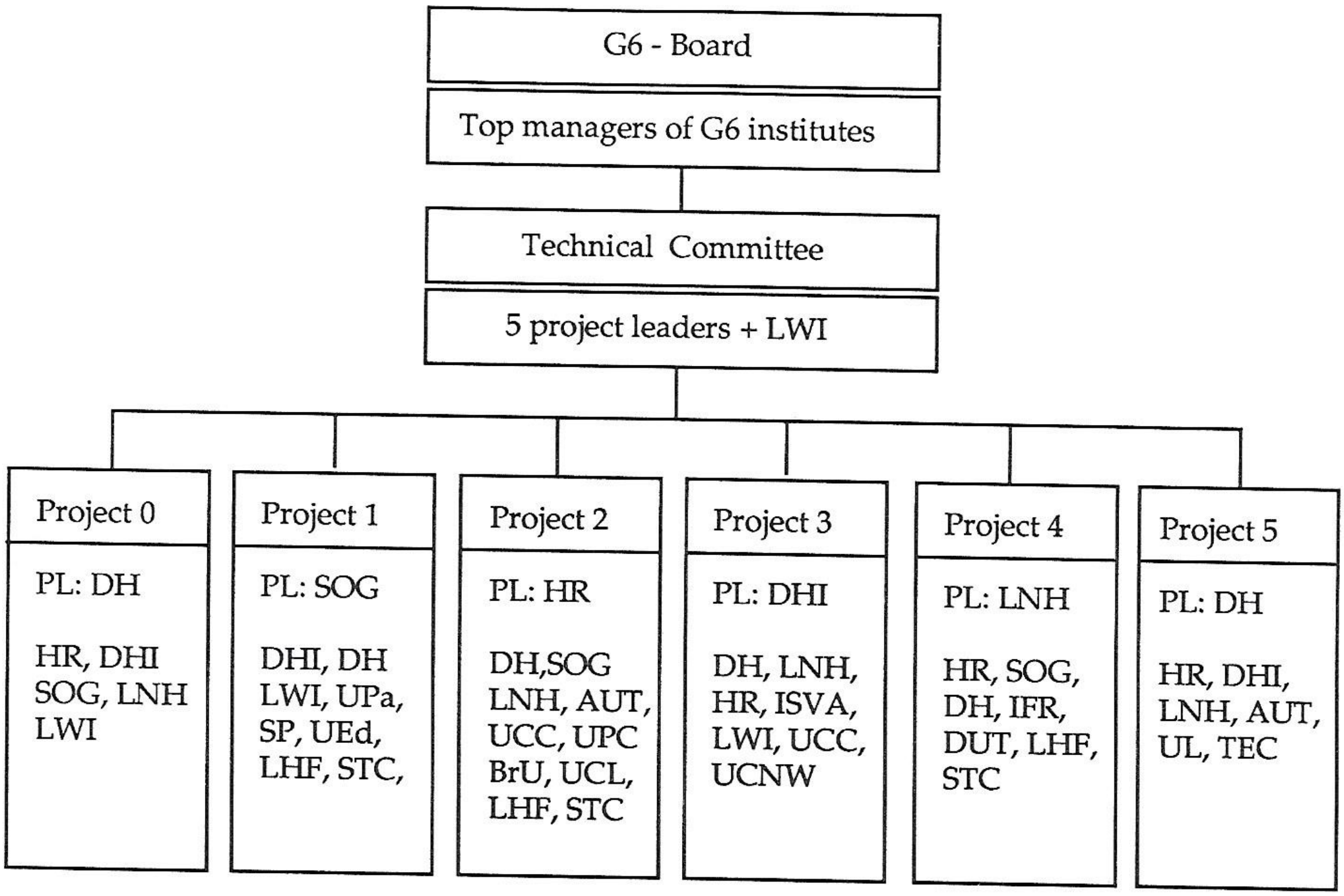


Figure 1: Interlinking of the project



DH: Delft Hydraulics
HR: Hydraulics Research Ltd.
DHI: Danish Hydraulic Inst.
SOG: SOGREAH
LNH: Lab. Nat. d'Hydraulique
LWI: Leichtweiss Inst.
UPa: Univ. of Padua
SP: Snamprogetti
UEd: Univ. of Edinburgh
AUT: Univ. of Thessaloniki
UCC: Univ. Coll. Cork

PL: Project leader

UPC: Univ. Catalunya
BrU: Bristol University
UCL: Univ. Coll. London
ISVA: Techn. Univ. Denmark
UCNW: Univ. Coll. North Wales
IFR: IFREMER
DUT: Delft Univ. of Techn.
UL: Univ. of Liverpool
TEC: Tecnomare
LHF: Lab. Hydr. de France
STC: Service Techn. Central
IMG: Institut de Mécanique de Grenoble

Figure 2 - Management structure of the project

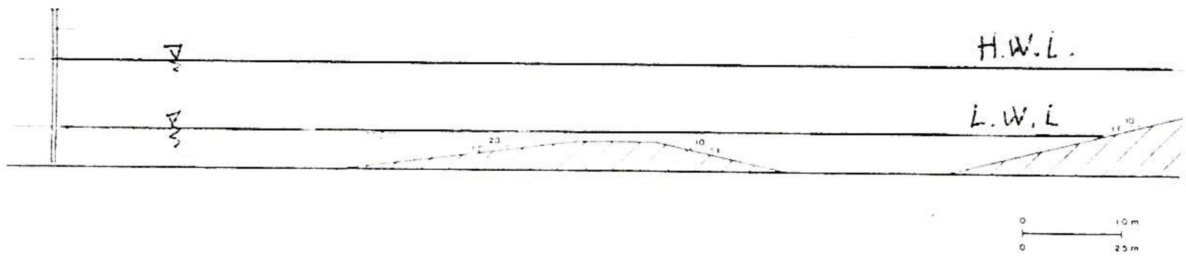


Figure 3 - Padua flume tests on a flat bottom with a bar: bottom profile

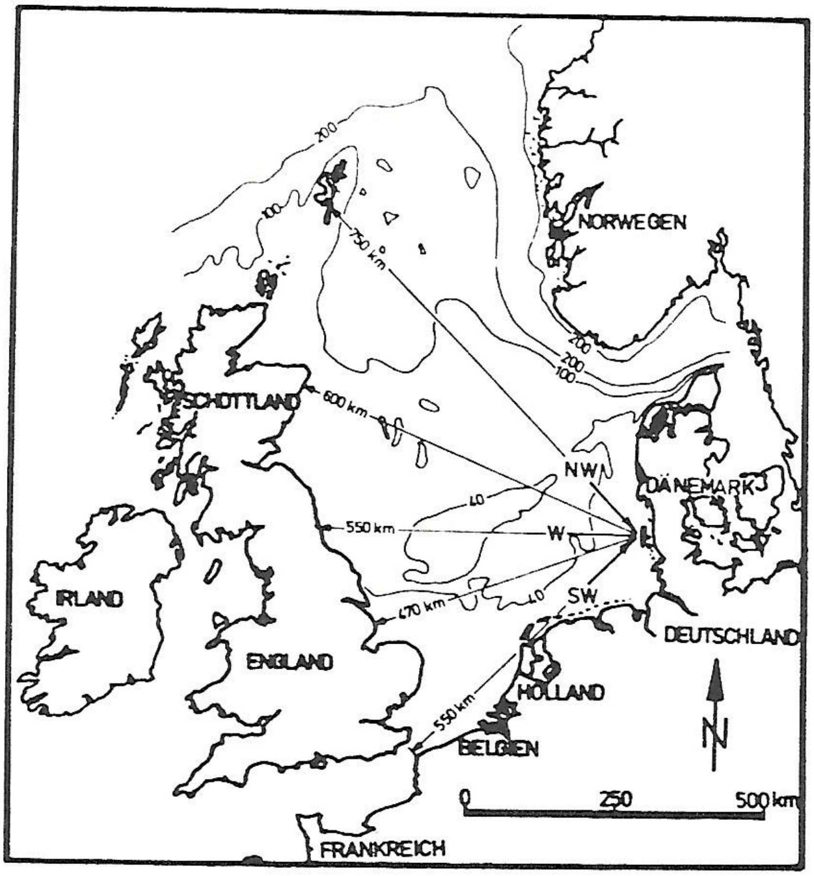
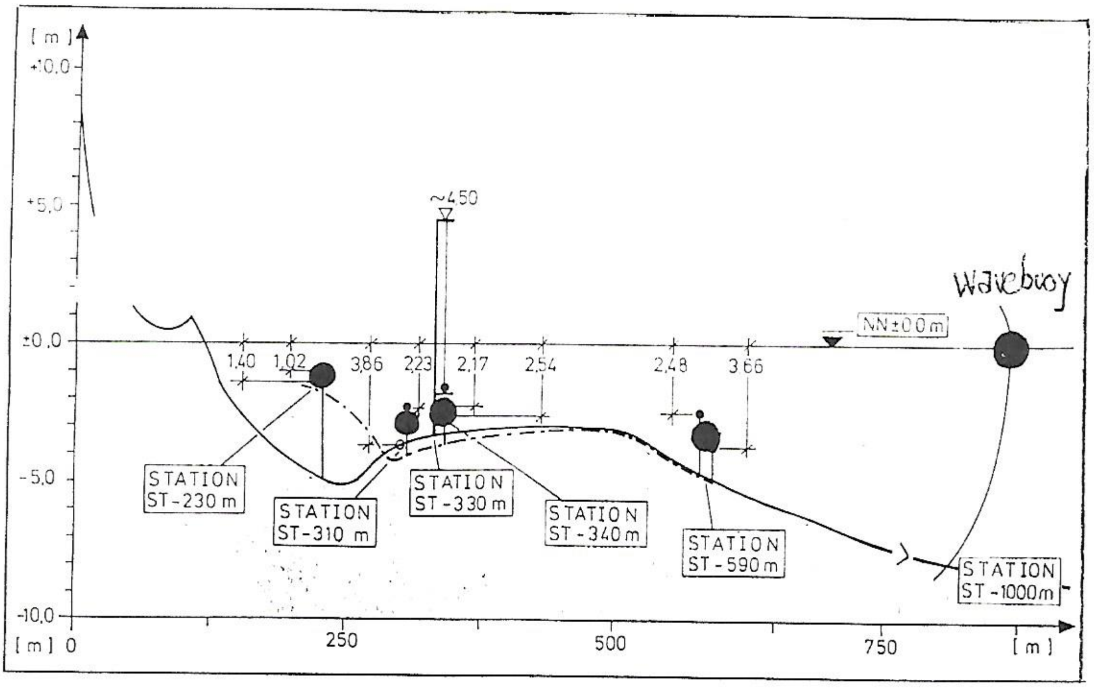
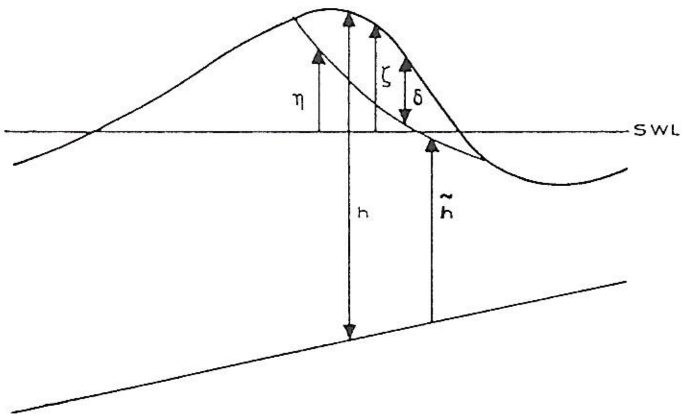


Figure 4 - Sylt location (from Dette et al., 1974)



<u>Figure 5</u> - Measurement profile at Sylt Island



<u>Figure 6</u> - Cross-section of a breaking wave with a surface roller (from Deigaard, 1989)