Surf and Swash Zone Hydrodynamics

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LONG-TERM GOAL

Improve understanding of the hydrodynamics of the near-shore motions on beaches, with particular reference to the zone where the incident waves break, form surf, and run-up on the beach to give a fluctuating shoreline. This includes the waves and currents that the breaking waves, surf and run-up generate together with necessary details of the motions beneath the waves. Particular attention is directed to improving theoretical models of these motions.

SCIENTIFIC OBJECTIVES

The main topics for study are:

(a) the turbulence generated by breaking waves and bores. A rational, non-empirical, approach to modelling unsteady spilling breakers and bores is a major target.
(b) the modelling of surf in the presence of co-existing long waves.
(c) improved, and perhaps simplified, modelling of the swash zone.
(d) understanding the currents, eddies and long waves generated by the incident waves, especially for irregular non-uniform waves over non-uniform bed topography.

APPROACH

This grant is to enhance cooperation between the P.I.s and their respective groups in working towards the above goals. The P.I.s meet each other each year and their more junior associates can make extended visits to each other's institution. In both groups the emphasis is on developing mathematical models through to practical numerical programs, including significant interaction with field and experimental results.

WORK COMPLETED

Svendsen and Veeramony have completed an experimental study of strong hydraulic jumps (Svendsen et al. 1998), which can provide useful input to Brocchini & Peregrine's theoretical development for strong turbulence at a free surface. This latter study has progressed to the point where the main outstanding questions concern the foot of a breaker where its turbulence is initiated, and a suitable direction of study has been identified. The study of the flow in surf zone waves using a Boussinesq approach with vorticity included uses the results from the hydraulic jump study and is able to accurately predict velocity field and velocity related wave properties (Veeramony and Svendsen, 1998).

The propagation of edge waves along nonuniform coasts has been studied at Bristol, with a variety of results, including strong indications that reflections of long waves from moderately remote coasts can be important (Santos & Peregrine, 1998). Analysis of the development of rip

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currents on a barred beach are progressing at Delaware and shows good agreement with laboratory measurements (Haas et al., 1998).

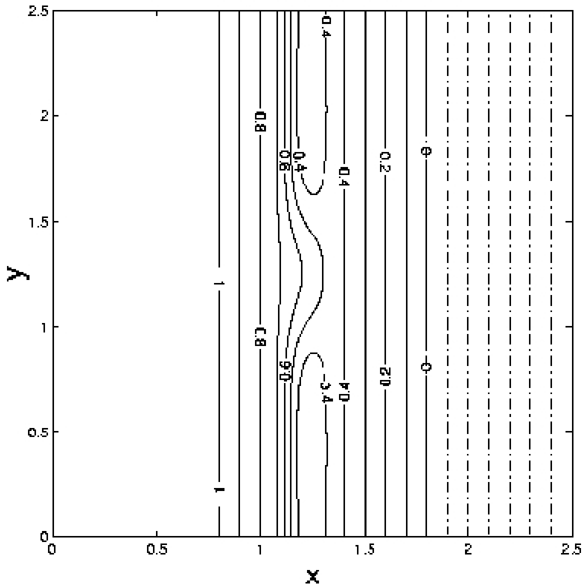

Figure 1: Contours of the bed. Solid contours denote wet areas and dashed ones the dry beach.

The studies of wave interaction before breaking have been somewhat disappointing; in part, because of the enormous range of relevant parameters. Some results have been presented, Bird & Peregrine (1998).

Personnel exchanges between Bristol and Delaware are summarized in Table 1 below. In 1997-98, Peregrine and Svendsen have met on two ocassions. The existence of the NICOP contract has led to excellent interactions between both groups with benefit to all sides. Both groups sent strong teams to the 26th International Coastal Engineering Conference and the interactions between the two teams deepened the collaboration.

Table 1: Personnel exchanges 1997-1998.

Name	Position/rank	Dates visit	Home institution	Place of visit
M. Brocchini	Professor	August 1997	School of Maths[1]	CACR
O. Bokhove	Dr.	Nov. 1997	School of Maths	CACR
J. Veeramony	Ph.D. student	May/June 1998	CACR[2]	School of Maths
C.C. Bird	Ph.D. student	July/Aug. 1998	School of Maths	CACR

WORK IN PROGRESS

Following Peregrine's (1998a) insight into large-scale vorticity generation in the surf zone, Bokhove has developed detailed computations of potential vorticity generation and convection due to a bore passing over non-uniform topography (Peregrine & Bokhove, 1998). A contour plot of the bed for a barred beach with gap in the middle of the bar is shown in Figure 1. An originally uniform, one-dimensional, irrotational wave approaches this barred beach from left to right. This shallow-water wave breaks before it meets the bar and generates potential

[1] Now at: Istituto di Idraulica, Universita di Genova.
[2] Center for Applied Coastal Research Delaware, Delaware.

vorticity in the form of two counter rotating eddies once its front runs across the bar. Here the longshore (y) variation in the bed, that is the gap through the bar, creates the non-uniformity in the wave. The evolution is shown in figure 2, where contours of potential vorticity are plotted at dimensionless times t = 0.4, 0.6, 0.8 and t = 1. In addition the basic ideas have been useful in indicating the type of currents generated by nonuinform waves (Peregrine, 1998b). The computations show that proper representation of the bores and the potential vorticity they generate is a severe test of numerical codes: this aspect is being developed.

Assisted by Veeramony's discussions at Bristol, progress has been made at Delaware in the modelling of surf zone waves using an extended Boussinesq-type model, especially with regards to the development of a description of wave breaking. The boundary conditions at the surface and at the toe of the roller was obtained from the measurements in hydraulic jumps. One journal article has been submitted for publication and another article is in preparation.

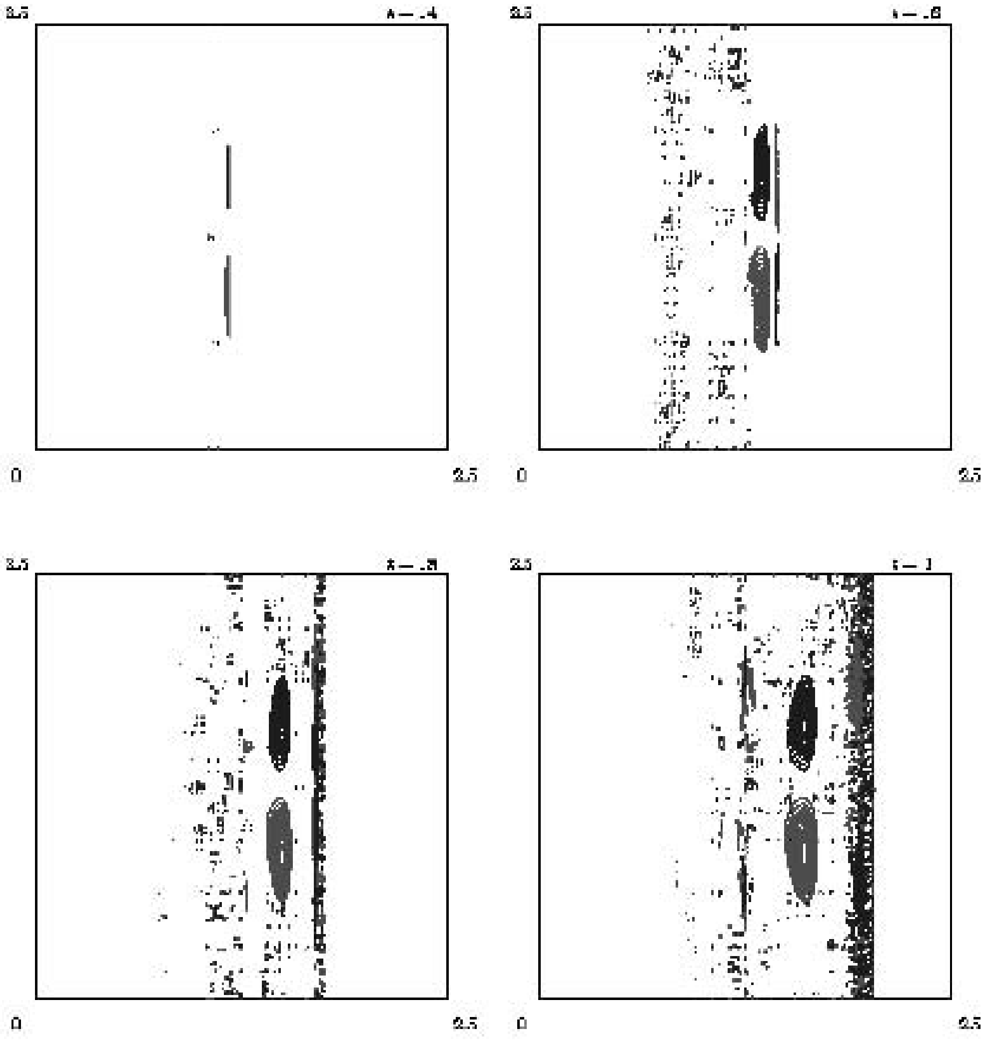

Figure 2: Contours of potential vorticity with 9 contours in [-0.3,-0.06] and [0.06, 0.3].

Innovative velocity profile measurements in the swash are taking place at University of Florence, Italy, under SASME, involving close collaboration with Peregrine and Brocchini. The visit to Delaware has also advanced preparation of a series of papers by Brocchini & Peregrine on the effects and modelling of strong turbulence at a free surface.

IMPACT/APPLICATION

In all areas mentioned under OBJECTIVES major improvements in modelling are sought.

(a) At present the best models for the surf zone include 'rollers' to model the breakers. The parameters describing these rollers are obtained from best fits to data. We aim to gain sufficient understanding of the hydrodynamic feedback between the foot and crest of a breaker such that a more deterministic model that includes breaker initiation, merging and decay can be created.

(b) It is well documented that the number of wave crests diminishes significantly through the surf zone. No available wave-averaged models include this feature, with its influence on the generation of long waves and currents. Experiments at Delaware (Veeramony & Svendsen, 1996) show this clearly. Bristol studies of slightly more complex incident waves show other effects (Bird & Peregrine, 1998) and need further development.

(c) Almost all wave averaged models ignore the swash zone, simplifying it to a point of zero mean water depth and no velocity. This has stimulated the present work since the swash zone forms the land/sea boundary and is a place where the most active sediment motion tends to occur. Work to date (Brocchini & Peregrine, 1998) is already leading the way to improved modelling of this vital zone. Detailed velocity measurements have been made very recently at Florence and full information should be available soon.

(d) Quantification of the changes of circulation and generation of vorticity by bores (Peregrine, 1998a) is giving a new and simpler way of assessing currents from observation of the wave field (Peregrine 1998b). In addition they promise new insights into horizontal mixing and transport properties of the surf zone currents.

RELATED PROJECTS

Several of the twelve other groups in the SASME project cooperate with Bristol. This includes contacts with experimental groups (e.g. at the Universities of Cantabria, Edinburgh, Florence, and Plymouth) which includes interaction on the best measurements for advancing theoretical studies and assistance in the interpretation of results. Similar interactions will occur with those running complex computer programs (e.g. Danish Hydraulic Institute [DHI], and Delft Hydraulics).

Interactions occur between Delaware and the groups conducting hydrodynamic field experiments at Duck, North Carolina (Scripps, Naval Postgraduate School, Oregon State University and others). Close interaction continues between Delaware and the researchers at NorthWest Research Associates (Putrevu, Oltman-Shay) and with DHI in Denmark.

At Bristol, in addition to the SASME project Peregrine also has:

1) A project funded by the U.K.'s Defence Evaluation and Research Agency (DERA), including Reading University, to study the effects of surface currents on the patterns and breaking of surface waves with reference to remote sensing (Donato, Peregrine & Stocker, 1998). This is closely related to experimental work DERA is participating in at the University of California Santa Barbara, Ocean Engineering Laboratory with radar and water waves. It helps this grant’s area of study by giving a different view on the modelling of breakers. Further, recent work has revealed interesting aspects and limitations of different ways of modelling wave propagation.
2) Another MAST 3 project: Probabalistic Design of Vertical Breakwaters (PROVERBS). Aspects of this project relating to porous berms and foundations provide valuable insights for studying porous beaches. A further project on impacts between waves and the base of

structures such as decks, funded by the U.K. Engineering and Physical Sciences Research Council started in early 1998 jointly with experimental work at Manchester University.

3) A research student funded by the U.K. Natural Environment Research Council (NERC) has commenced study of waves over porous beaches with emphasis on coarse sediment where the porous flow is at high Reynolds number.
4) A research student funded by Portugal's Research Funding Council is studying the effect on edge waves of strong changes in otherwise uniform coasts (Santos & Peregrine, 1998). This has greatly extended our understanding of the propagation of low frequency waves along coasts.

Related projects at Delaware include an ONR funded project for collecting additional field data (waves & currents) at Sandy Duck to enhance modelling capabilities, in particular with respect to nearshore circulation, and the generation and propagation of infragravity waves. Laboratory and numerical modelling of rip currents on barred beaches have been the subject of an ONR funded project with two graduate students involved. An extension of this project aiming at studying the 3D effects of rip currents with one graduate student is presently funded by Sea Grant, and funding for further research in this area will be sought soon. Funding is pending for planned work on modelling and analysis of the new Sandy Duck data and so is funding for work on developing an effective Boussinesq wave driver for nearshore circulation models. The latter of these two projects will be closely connected to the present NICOP project, and will also benefit from close contact with ICCH, and the remote sensing project at Delaware (Kirby, Dalrymple).

REFERENCES

Bird, C.C. & Peregrine, D.H. (1998) Wave crest interaction in water of intermediate depth. *Proc. 26th Internat. Conf. Coastal Engnrs. ASCE*, Copenhagen, to appear.

Brocchini, M. & Peregrine, D.H. (1998) The modelling of a spilling breaker: strong turbulence at a free surface. *Proc. 26th Internat. Conf. Coastal Eng. ASCE*, Copenhagen, to appear.

Donato, A.N., Peregrine, D.H. & Stocker, J. (1998) The focussing of surface waves by internal waves. *J. Fluid Mech.* Accepted for publication.

Haas, K. A., I. A. Svendsen & M. C. Haller (1998) Numerical modeling of nearshore circulation on a barred beach with rip channels. *Proc. 26th Internat. Conf. Coastal Engnrs. ASCE*, to appear.

Peregrine, D.H. (1998a) Surf zone currents. *Theor. & Comp. Fluid Dynamics* **10**, 295-309.

Peregrine, D.H. (1998b) Large-scale vorticity generation by breakers in shallow and deep water. Submitted for publication.

Peregrine, D.H. & Bokhove, O. (1998) Vorticity and surf zone currents. *Proc. 26th Internat. Conf. Coastal Engnrs. ASCE*, Copenhagen, to appear.

Santos, J.W. & Peregrine, D.H. (1998) Trapped and free-wave propagation in channels and harbours. *Proc. 26th Internat. Conf. Coastal Engnrs. ASCE*, Copenhagen, to appear.

Svendsen, I.A., Veeramony, J. & Yu, K. (1996). A Boussinesq breaking wave model with vorticity. *Proc. 25th Intl. Conf. Coastal Engrg.*, ASCE, Orlando 1192-1204.

Svendsen, I. A., J. Veeramony, J. Bakunin, & J. T. Kirby (1998) "The flow in weak turbulent hydraulic jumps". Submitted for publication in the Journal of Fluid Mechanics.

Veeramony, J. & I. A. Svendsen (1998), A Boussinesq model for breaking waves: comparison with experiments. *Proc. 26th Internat. Conf. Coastal Engnrs. ASCE*, Copenhagen, to appear.

WORLD WIDE WEB PAGES

http://www.maths.bris.ac.uk/~madhp	Peregrine's home page.
http://www.coastal.edu/~ias	Svendsen's home page (8 reprints available)
http://www.wldelft.nl/sasme/sasme.htm	The home page of the SASME project.