BEST PRACTICE IN COASTAL FLOOD FORECASTING

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INTRODUCTION

A series of R&D projects was commissioned within the Flood Forecasting and Warning theme of the UK Government joint Defra / Environment Agency Research Programme for Flood Management. Unlike other more general forms of weather or ocean forecasting, *flood* forecasting focuses specifically on the probability of flooding, which depends on weather, ocean and defence conditions.

Defra commissioned HR Wallingford, Posford Haskoning and WS Atkins, under R&D Project FD2206, to produce best practice guidelines for coastal flood forecasting (CFF) services in England and Wales. The purpose of the project was to investigate ways of improving CFF and to provide best practice guidelines for the future development of CFF services. The objectives were to:

- identify present and future flood forecast needs and aspirations
- categorise available methods (for coastal flood forecasting) and identify advantages, disadvantages and inconsistencies
- short-list a range of suitable (coastal flood forecasting) options and appraise their performance with regard to meeting present and future needs
- outline the way forward for coastal flood forecasting including necessary R&D to fill any identified deficiencies in present practice
- review existing initiatives and develop a common understanding of requirements and an associated best practice framework for coastal flood forecasting

In risk assessment, one should consider all potential threats and all potential failure modes. In benefit / cost assessment, one should consider all costs throughout the life of the scheme and attempt to place values on intangible benefits. This paper attempts to introduce the same 'overall' approach to CFF. The aim is to maintain or enhance lead-time (i.e. the time between forecasting / warning and arrival of the impending floods) whilst meeting the requirements of the at-risk population in terms of the accuracy and reliability of forecasts. The paper will be of interest to anyone involved in flood forecasting, actions to mitigate forecast damage, or assessment of losses due to coastal flooding.

REVIEW AND RECOMMENDATIONS

The overall report (Defra / Environment Agency, 2003a) on Project FD2206 reviews current practice and aspirations for CFF within different Environment Agency regions of England and Wales. This provides a background against which to categorise and prioritise practices, models, data sources etc, and to recommend improvements.

CFF is developed by integrating the systemic risk management model (*Source, Pathway, Receptor, Consequence*) with the systemic flood forecasting and warning model (*Detection, Forecasting, Warning, Dissemination, Response*), but the particular interest here is in the *Source / Pathway* and *Detection / Forecasting* elements.

The project recommends managing the diversity of available models through an approach akin to 'horses for courses' (Khatibi *et al*, 2003). The physical extent of CFF is categorised, see Figure 1, into four zones, *Offshore* and *Nearshore* comprising the *Sources*, and *Shoreline* and *Flood* comprising the *Pathways*. The *Source* model types are categorised as *Offshore* wave forecasts, *Offshore* tide/surge forecasts, *Nearshore* wave transformation and *Nearshore* tide/surge transformation. The *Pathway* model types are categorised as *Shoreline* overtopping, *Shoreline* breaching and *Flood* inundation.

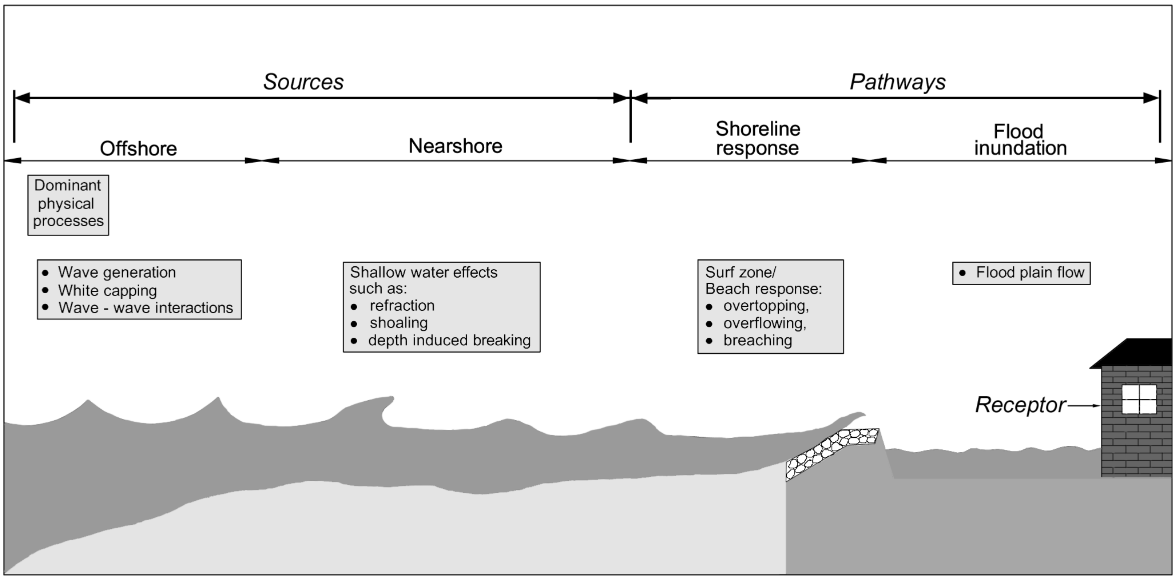

Figure 1: Characterisation of the flood system

The range of models within each physical category is further categorised by model complexity, see Figure 2, as *Judgment*, *Empirical*, *1st Generation*, *2nd Generation* or *3rd Generation*. Broadly speaking, higher complexity (i.e. greater model information content) implies greater accuracy and lower uncertainty, but possibly at the expense of increased cost and/or reduced lead time. The characteristics of each model type (defined in terms of physical type and model complexity) are considered in terms of the physical processes simulated, modelling methodologies used, inputs / outputs, and relative performance. The model types are compared, and those found suitable for use in CFF are short-listed, see model types highlighted in larger type in Figure 2.

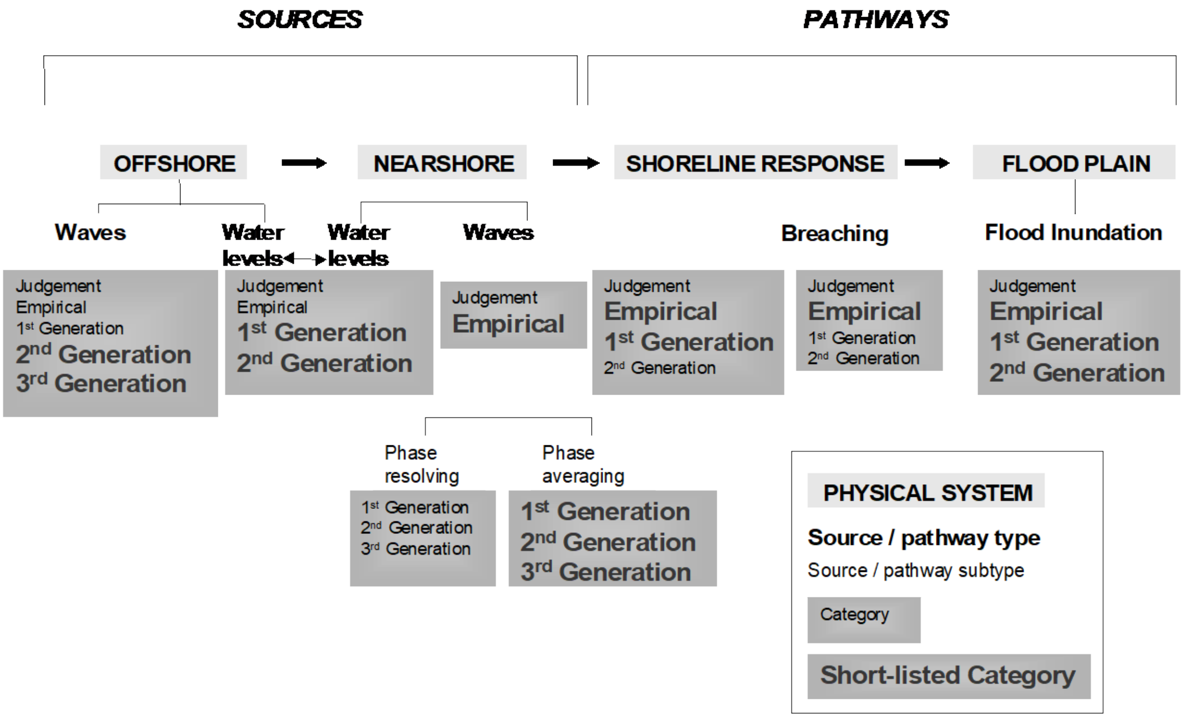

Figure 2 Categorisation of model types

It is recommended that the number of physical zones covered by CFF models be selected according to the risks inherent in a particular area, and the reduction in loss that might be achieved by mitigation measures prompted by CFF. The main difference between the four recommended levels of CFF, i.e. none, low, medium or high, lies in the extent of the physical system to be modelled, i.e. none, *Source* only, *Source / Pathway* or *Source / Pathway / Receptor / Consequence*. (At present, CFF is usually limited to the *Source* variables: waves, sea level and wind). Where alternative levels of model complexity are indicated in larger type in Figure 2, the choice from amongst the alternatives is recommended to be based on the complexity of the area and the number of physical processes to be modelled.

It is recommended that coastal flood forecasting not be looked at in isolation, but in the wider context of an overall CFF service, including the subsequent *Warning*, *Dissemination* and *Response* stages. Only in this way can the potential value and overall performance of the service be assessed.

The overall project report includes a section on future research requirements, concluding that basic science developments are not a priority. Instead it recommends continuing developments within existing forecasting models, continuing development and uptake of open architecture software systems and performance measures, and improvements in communication and sharing of existing data resources. The report includes a number of illustrative case studies.

BEST PRACTICE GUIDANCE

The shorter best practice guidance report (Defra / Environment Agency, 2003b) produced during this project is intended for actual use in design, implementation and evaluation of CFF services. The guide focuses on *Detection* and *Forecasting*, providing guidelines for appropriate selection of data sources, hydraulic process models and an overall modelling solution. It also describes the overall context of coastal flood forecasting, as an understanding of the subsequent *Warning*, *Dissemination* and *Response* stages is important to efficient design and implementation of the *Detection* and *Forecasting* stages. There is also a section on performance assessment and refinement.

The guide contains information boxes on:

- Sources, Pathways, Receptors and Consequences
- Types of model used in each physical zone
- Categories of model complexity
- Recommended levels of modelling for different levels of flood risk
- Selection of modelling solution from modelling options
- Typical minimum requirement for routinely monitored forecast variables
- Additional forecast information needed at times of potential flood incidents
- Potential interim improvements pending implementation of best practice

The guide contains checklists on

- Decisions to make during preliminary assessment
- Decisions and considerations for use during outline design
- Forecast data and real-time measured data
- Selection of hydraulic models
- Selection of an overall modelling solution
- Trigger levels and overall timeliness
- Intended operation of the CFF service
- Intended assessment of CFF service performance
- Suggested implementation topics to consider during design
- Criteria for assessing the likely performance of a CFF service

The example information box and checklist reproduced below relate to selection of an overall modelling solution for coastal flood forecasting.

The technical report and the best practice report are intended to be viewed together in electronic form, so that the many automatic links to greater detail in the technical report can be used as required. Launch of the two reports on 24 September 2003 at a workshop at HR Wallingford marked the end of the project, and the start of the Environment Agency's implementation stage. From October 2003, the guide (Defra / Environment Agency, 2003b) will be maintained and updated by the Agency.

ACKNOWLEDGEMENTS

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Example Information Box: Selection of modelling solution from modelling options

Offshore and Nearshore Zones

1. Determine the main physical processes and characteristics of the modelled area.
2. Assess each model by the number of dominant processes simulated and consider the potential damage reduction for each alternative.
3. Rule out the options not incorporating the dominant processes or meeting the required accuracy constraints.

Shoreline and Flood Inundation Zones

1. Establish the nature and scale of the potential damage due to flooding and how much time is needed to minimise the damage. There are two different measures of time to consider: (i) the timeliness that expresses the needs of the population at risk of flooding; and (ii) the lead time that expresses the capability of each category of model. For example, overtopping and inundation models might require 2 hours to run, whilst the addition of a 1st generation nearshore model might increase that time to 4 hours, and 2nd generation offshore, 2nd generation nearshore, plus overtopping and inundation might require 7 hours. Meanwhile, warnings may need to be issued 2 hours ahead of a potential flood incident to give enough time for planned actions in mitigation to be applied.
2. Make a note of these options and times, and consider the potential damage reduction for each alternative.
3. Rule out the options not meeting the required *timeliness* and *accuracy* constraints.
4. Identify requirements for and availability of data and specialist staff (and hence consider the *reliability* constraint, when properly defined).
5. Identify modelling options that meet the prescribed criteria.
6. Estimate the cost of developing models for each option.
7. Select the least costly while identifying the risks of not using the rejected solutions (i.e. compare the *benefit /cost* ratios for each option).
8. Review and repeat some of the steps above, as required to refine the option selection.

Example Checklist: Selection of an overall modelling solution

Topic	**Link to TR1**	☐
Short-list a number of overall linked modelling options, noting the passing of variables through them.	3.3.4	
Estimate the absolute timeliness, relative reliability, relative accuracy, relative availability and relative cost of the alternative options.		
Eliminate options not meeting the absolute timeliness requirement.	3.4.2	
Rank the remaining options according to the five criteria above, and select the optimum modelling solution.		
Check that source data, people and expertise would be available for the chosen option.	3.5	

REFERENCES

Defra / Environment Agency (2003a). Best practice in coastal flood forecasting: Technical report. Defra / Environment Agency R&D Technical Report FD2206/TR1. Issued for use by the Environment Agency as HR Wallingford Report TR 132.

Defra / Environment Agency (2003b). Guide to best practice in coastal flood forecasting. Issued for use by the Environment Agency as HR Wallingford Report SR 618, including CD version with many digital links to FD2206/TR1 (TR 132).

Khatibi, R., Gouldby, B., Sayers, P., McArthur, J., Roberts, I., Grime, A. and Akhondi-asl A (2003). Improving coastal flood forecasting services of the Environment Agency. Proceedings of the 1st International Conference on Coastal Management, Brighton, UK, (Ed. McInnes, R.G.), pp70-82.