DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS **CSG 15**

Research and Development

Final Project Report

(Not to be used for LINK projects)

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Project title	Joint probability: Dependence mapping and best practice
DEFRA project code	**FD2308**
Contractor organisation and location	HR Wallingford Ltd Howbery Park Wallingford Oxfordshire OX10 8BA
Total DEFRA project costs	£ 225191
Project start date	01/12/01
Project end date	28/02/05

Executive summary (maximum 2 sides A4)

Joint probability analysis addresses the probability of occurrence of events in which two or more partially dependent variables simultaneously take high or extreme values. Several different environmental variables are potentially important in design and assessment of flood and coastal defences, for example waves, tide, surge, river flow, rainfall, swell and wind. Joint probability methods could be used in most flood risk calculations, as flood risk is rarely a function of just one source variable, but more usually of two or three variables. Joint probability analysis gives the probability of the relevant source variables taking high values simultaneously and thus creating a situation where flooding may occur.

Defra has been funding research into joint probability methods for use in flood risk studies for many years. Take-up of joint probability methods has been patchy due to two main reasons: lack of information on dependence between the source variables, and perceived difficulty in usage and interpretation of the methods. This project analysed dependence between key pairs of variables around England, Wales and Scotland, producing results in a form suitable for use in simplified joint exceedence analysis methods. Confidence in the dependence estimates is indicated in a way that could be used in design calculations. The main strands of the work were to:

- involve and consult the wider industry on their joint probability requirements, intended to increase the chance of appropriate take-up of methods and results, and to identify any gaps in the research programme;
- bring together recent joint probability work at HR Wallingford, CEH Wallingford and the Proudman Oceanographic Laboratory;

- extend it where necessary to the whole of England, Scotland and Wales, analysing and mapping dependence for several variable-pairs relevant to flood and coastal defence, addressing the perceived problem of lack of appropriate data for use in joint probability work;
- produce and disseminate best practice guidance, including advice on use of analysis methods, use of dependence data, special considerations in complex areas and allowance for future climate change.

The results of the project are presented in three main reports, named at the end of this executive summary. A number of other related reports and papers, partially based on developments during FD2308, are listed in the scientific report.

The best practice guide (FD2308/TR2) is aimed at non-specialist users of joint probability methods, to encourage them to adopt and use joint probability methods without the need for specialist advice. It includes a high level overview, which could be extracted together with example dependence plots, to be published separately in the form of an Environment Agency introductory booklet. The main best practice guide contains enough information for routine use of the methods.

The guide includes a summary of the desk study and analytical approaches to joint probability analysis, and a software tool for application of the desk study approach. It includes advice on data preparation, parameter selection, application of the methods in complex areas, incorporation of climate change allowances, and interpretation of the results of the analysis. The variable-pairs presented in the guide, including enough information for calculations, are:

- wave height & sea level, relevant to most coastal flood defence studies
- river flow & surge, relevant to most river flood defence studies
- hourly rainfall & sea level, of potential use in drainage studies in coastal towns
- wind-sea & swell, of potential use in coastal engineering studies.

The guide includes outline case studies for each of the variable-pairs listed above, for each of the two main analysis methods. These include techniques for use in complex areas and for incorporation of climate change allowances.

The guide is supported by a separate longer technical report (FD2308/TR1) containing more detailed information and description for experienced users. The technical report includes the project glossary, descriptions of the source data sets, derivation and comparison of the dependence measures used, and descriptions of the desk study and analytical approaches to joint probability analysis. It also includes a record of the industry consultation and a full set of dependence results, with confidence limits, including some additional variable-pairs not reproduced in the guide, namely:

- wave height & surge
- tide & surge
- daily precipitation & surge.

A third report (FD2308/TR3) contains more detailed results from the river flow, surge and daily precipitation analysis, including some time-lagged and spatially separated dependence analyses, with interpretation relevant to hydrologists.

Project Reports

FD2308/TR1. Joint probability: Dependence mapping and best practice: Technical report on dependence mapping.
FD2308/TR2. Use of joint probability methods in flood management: A guide to best practice.
FD2308/TR3. Dependence between extreme sea surge, river flow and precipitation: a study in south and west Britain.

Scientific report (maximum 20 sides A4)

The results of the project are presented in three main reports, listed in bold type below. Non-specialists will probably do best to start with 'TR2', the best practice guide, which serves as the overall scientific report on the project. Three Defra Conference papers and two hydrological papers based on the project are also listed in bold type below. Some other closely related reports and papers, partially based on developments during FD2308 and produced during the time of FD2308, are also listed.

In addition to reports and papers, two open meetings were held: an industry consultation meeting on 30 May 2002 near the start of the project, and an industry dissemination meeting on 28 February 2005 at the end of the project. No training in the use of the best practice guide and analysis methods was carried out, but a CD containing reports, computer programs and presentations was prepared during the closing stages of the project, for future use in the training of potential users of joint probability methods.

List of Reports and Papers

Defra / Environment Agency (2003). Extreme water levels in estuaries and rivers: The combined influence of tides, river flows and waves. Defra / Environment Agency R&D Technical Report FD0206/TR1 (also referenced as HR Wallingford Report SR 645).

Defra / Environment Agency (2005a). Joint probability: Dependence mapping and best practice: Technical report on dependence mapping. Defra / Environment Agency R&D Technical Report FD2308/TR1 (also referenced as HR Wallingford Report SR 623).

Defra / Environment Agency (2005b). Use of joint probability methods in flood management: A guide to best practice. Defra / Environment Agency R&D Technical Report FD2308/TR2 (also referenced as HR Wallingford Report SR 653).

Defra / Environment Agency (2005c). Dependence between extreme sea surge, river flow and precipitation: a study in south and west Britain. Defra / Environment Agency R&D Technical Report FD2308/TR3 (also referenced as C Svensson and D A Jones (2005), Dependence between extreme sea surge, river flow and precipitation: a study in south and west Britain, CEH Wallingford Report).

P J Hawkes, B P Gouldby, J A Tawn and M W Owen (2002). The joint probability of waves and water levels in coastal defence design. Journal of Hydraulic Research, Vol 40, No 3, pp241-251.

P J Hawkes, B P Gouldby, W Sun, J A Tawn, D Hames, D Reeve, D Blackman, R Sproson and K Mavronasos (2004). A comparison of marginal and joint extremes predicted from synthesised wave and water level data. First International Conference on Flood Risk Assessment, University of Bath, published by the Institute of Mathematics and its Applications.

P J Hawkes, C Svensson and S Surendran (2005). The joint probability of pairs of variables relevant to flood risk: Dependence mapping and best practice. Defra Flood and Coastal Management Conference, University of York.

HR Wallingford (2004). Joint probability issues within estuaries: A numerical case study for the tidal Thames. HR Wallingford Report TR 143, August 2004.

I C Meadowcroft, P J Hawkes and S Surendran (2004). Joint probability best practice guide: Practical approaches for assessing combined sources of risk for flood and coastal risk managers. Defra Flood and Coastal Management Conference, University of York.

C Svensson D A Jones (2005). Climate change impacts on dependence between sea surge, precipitation and river flow around Britain. Defra Flood and Coastal Management Conference, University of York.

C Svensson and D A Jones (2004a). Dependence between sea surge, river flow and precipitation in south and west Britain. Hydrology and Earth System Sciences, 8(5), 973-992.

C Svensson and D A Jones (2004b). Sensitivity to storm track of the dependence between extreme sea surges and river flows around Britain. In Hydrology: Science and practice for the 21st Century, Vol. I. Proc. From the British Hydrological Society's international conference, 12-16, July 2004, London, UK, pp. 239a-245a (addendum).