

# Integrated River Management and Flood Risk

**Dr P G Samuels**

HR Wallingford, Howbery Park, Wallingford, OX10 8BA, UK

e-mail [p.samuels@hrwallingford.co.uk](mailto:p.samuels@hrwallingford.co.uk)

## Summary

Flooding is one of the major natural hazards to human society and an important influence on social and economic development. Several major floods in different parts of Europe in the early 1990's were the catalyst for a review of the state of the art and research needs on river basin modelling, management and flood mitigation (RIBAMOD). This paper is drawn from the final report of the RIBAMOD Concerted Action, which formed part of the Hydrological Risks component of the EC Fourth Framework Programme.

Although the RIBAMOD expert meetings and workshops covered different topics the discussion often turned on similar key issues these included:

- the need for a catchment view of flood defence activities, integrated with environmental effects rather than a collection of unconnected, individual measures
- the need to use risk assessment to support decisions in flood mitigation and management
- the need for a holistic approach to flood management (pre-flood planning, operational flood management and post-flood response)
- the recognition that flood mitigation requires cross-disciplinary working from several professional groups
- that flooding problems have considerable social dimensions and engineering solutions are not always appropriate or possible
- the uncertainty which climate and other environmental change is bringing into flood management

These conclusions of the Concerted Action formed the starting point for the discussion of Integrated River Management and Flood Risk at the recent EuroConference.

## 1 Introduction

This paper is drawn from the final report of the RIBAMOD Concerted Action which formed part of the Hydrological Risks component of the EC Fourth Framework Programme. Internationally in the 1990's, severe flooding has devastated the Mississippi basin, and thousands of lives have been lost directly or indirectly from flooding in many countries including Bangladesh, China, Guatemala, Honduras, Somalia and South Africa. World-wide, floods pose the most one of the most widely distributed natural risks to life, whereas other natural hazards such as avalanche, landslide, earthquake and vulcanism are more regional in their distribution.

Most nations have institutional and physical infrastructure to combat floods and their effects, and in many cases these have a long history. For example, in the middle Loire valley some major flood embankments are over 200 years old and the courses of the Rivers Rhine and Danube were substantially straightened before 1900 providing improved navigation and flood control. In Hungary, there is documentary evidence of flood defence works as early as the 13<sup>th</sup> Century and in the UK flood defence legislation can be traced back to 1531. However, with increasing social and economic development bringing pressure on land use within the flood plains of rivers, the potential for flood damage is increasing on many rivers. Added to this is a popular conception that flooding is increasing in frequency and severity, possibly induced by changes in the Earth's climate. It is against this background that the RIBAMOD Concerted Action took place.

There are several different types of flooding and it is important to take account of their characteristics in developing mitigation and alleviation measures. Flooding may be:

- localised or distributed
- fast response or slowly developing
- generated by precipitation (both rainfall and snowmelt),
- caused by the failure of a structure (dam, embankment, control gate etc) or
- flooding from marine conditions.

The RIBAMOD Concerted Action considered flooding in the first three of the above categories (although in some cases high river flows will bring about the failure of structures and exceptionally high floods can overflow river embankments). In addition, severe meteorological conditions may trigger instabilities in the land surface generating debris flows, particularly in mountainous areas. The catastrophe in Sarno (Italy) in May 1998 is a recent and tragic example of the power of mudflows. Other EC research initiatives cover land instabilities and RIBAMOD did not consider these in detail.

In the 1990's, much attention in the national and European media has been given to floods. Some prominent examples have been:

- in France when 42 people died in 1992 during the flash flooding in Vaison-la-Romaine,
- the basin wide floods which caused widespread disruption and losses in the Rhine and Meuse basins in 1992, 1993 and 1995,
- the exceptional flooding which struck the Po in 1994.
- flash flooding in Athens in mid January 1997
- in July 1997 when exceptional rainfall in the Czech Republic and Poland causing catastrophic flooding on the Oder river, killing over 100 people and laying waste to vast areas of the countryside.
- in early November 1997, flash floods occurred, this time in Spain and Portugal with over 20 people losing their lives.

Following concern expressed by several EU member states, the Directorate General of Science, Research and Development of the European Commission (DG XII) organised an expert workshop in May 1995 to discuss the state-of-the-art and research needs in the area of river flood management. As a consequence, DG XII funded the RIBAMOD Concerted Action as a part of the Fourth Framework Research programme, co-ordinated by HR Wallingford with a steering group drawn from six countries. RIBAMOD is an acronym for River Basin Modelling, Management and Flood Mitigation. The Concerted Action focused on flooding within the framework of integrated river management. Participants in the Concerted Action have come from most member states of the EU as well as the USA, Paraguay, Switzerland, Poland and the Czech republic.

At the close of the Second RIBAMOD Workshop, Professor Jim Dooge, reminded the participants of the purpose and importance of the Concerted Action (Dooge & Samuels, 1998)

*“In the midst of all the exciting technical and scientific issues raised during the workshop, it is important for us not to lose sight of why the European Commission has funded the RIBAMOD Concerted Action. These workshops and expert meetings have been sponsored because we, in the scientific community, have been set the task of responding to a real social problem which affects the quality of life of many European citizens. Indeed flooding from all causes is the most significant natural disaster world-wide with over 200,000 human lives being lost in floods in the decade between 1986 and 1995 (Munch Re, 1997) and over 10,000 in 1997 (Munich Re, 1998). Each one of these deaths has been a tragedy for the family involved. More than this, those who survive the flood may suffer prolonged health problems or face financial ruin through the loss of home, possessions and livelihood.”*

### ***The RIBAMOD Objectives***

The Concerted Action had five main functions:-

- to identify difficulties arising from past management practices,
- to identify the state-of-the-art in its area,
- to identify best practice,
- to take an overview of current EU research projects in the area, and
- to identify research needs.

It was also expected that other benefits would ensue from the RIBAMOD Concerted Action including:

- establishing an informal network of researchers and practitioners, and
- transfer of information, results and experience between existing research programmes and practitioners.

It was intended that RIBAMOD would

- facilitate understanding of technical and policy issues in flood management,
- examine how advanced modelling should support planning, design, operation and maintenance of flood defence systems and
- identify methods and procedures for sustainable development, management and use of the river and its catchment.

These objectives were met through experts from many disciplines, from researchers to flood managers, meeting and sharing knowledge and experience during the RIBAMOD events.

## **2 The Conclusions of RIBAMOD**

Important themes which emerged from RIBAMOD are:

- the need for holistic approaches to flood management over whole river catchments
- the need for interdisciplinary communication and co-operation to achieve practical advances and benefits
- the substantial challenge of achieving sustainable development within river basins and
- the use of integrated catchment models to examine issues of long-term environmental change.

More specifically, the conclusions in the main areas of the Concerted Action may be summarised as follows.

### ***2.1 River Basin Modelling***

- There is (and will be) no universal model, especially of hydrological response, applicable in all circumstances.
- There is need to develop integrated catchment modelling, based on an “open system” philosophy to combine existing process models, tailored to the local needs and preferences.
- There is some development needed of process models, particularly for climate change impact assessment
- Better communication is needed between professional communities so that full benefit can be derived from their individual scientific advances.

### ***2.2 River Basin Management***

- The involvement is essential of the public as well as politicians and professionals in working out the sustainable development and management of river basins.
- There is need for a catchment view of flood defence activities, integrated with environmental effects rather than a collection of unconnected, individual measures
- The need is increasing to understand the effects of environmental change on flood risk (both land

use and climate)

- The special status of trans-border rivers must be recognised so that their management is undertaken as a whole rather than within administrative boundaries (either regional or international).

### **2.3 Flood mitigation**

- There is a need for a holistic approach to flood management (pre-flood planning, operational flood management and post-flood response).
- There is a need for multidisciplinary working between meteorologists and hydrologists to improve flood forecasting and between engineers, planners and ecologists for the design of flood defences.
- The prominence of non-structural measures for flood defence will increase as part of the sustainable management of rivers.
- The restoration of flood plains to their natural function should be encouraged (where socially and politically acceptable)
- There is a need to broaden economic evaluations to include “intangible” costs and benefits to assess the non-engineering aspects of flood defence activities within a common methodology for the assessment of flood damages
- Risk should form the framework for managing and communicating the effects of flooding.
- It is necessary to incorporate the “human” factors in flood defence planning – how information is presented to achieve the desired effects of action.

Of these conclusions probably the most important for integrated river basin management is the first on holistic flood management which in the Final Report (Samuels, 1999) is expanded as the following sequence.

#### Pre-flood activities which include:

- flood risk management for all causes of flooding and disaster contingency planning,
- construction of physical flood defence infrastructure and implementation of forecasting and warning systems,
- land-use planning and management within the whole catchment,
- discouragement of inappropriate development within the flood plains, and
- public communication and education of flood risk and actions to take in a flood emergency.

#### Operational flood management which can be considered as a sequence of four activities:

- *detection* of the likelihood of a flood forming (hydro-meteorology),
- *forecasting* of future river flow conditions from the hydro-meteorological observations,
- *warning* issued to the appropriate authorities and the public on the extent, severity and timing of the flood, and
- *response* by the public and the authorities.

#### Depending upon the severity of the event, the post-flood activities may include:

- *relief* for the immediate needs of those affected by the disaster,
- *reconstruction* of damaged buildings, infrastructure and flood defences,
- *recovery and regeneration* of the environment and the economic activities in the flooded area, and
- *review* of the flood management activities to improve the process and planning for future events in the area affected and more generally, elsewhere.

## **2 Research Needs**

Many issues remain to be addressed in the area of flood risk reduction and alleviation. Two of the objectives of RIBAMOD were to take an overview of current EU research in its area and to identify research needs. To meet these objectives, the Co-ordinators of relevant projects (in progress and recently completed) presented their research findings during the Concerted Action events and also a

review of Fourth Framework Programme projects was undertaken by members of the RIBAMOD Steering Group, see Casale & Samuels (1998). This review was cast somewhat more broadly than the specific topics of the five RIBAMOD events and the challenges and the research priorities laid out below are taken from that review, with additional points added from the RIBAMOD events.

Key areas for future research and development include

- the need to continue to improve the coupling of meteorological and hydrological forecasting for improved flood warning,
- the need for monitoring river and catchment conditions
- the need for improved estimation of flood discharge conditions over a variety of catchment sizes,
- the need for integrated approaches to flood management over whole river catchments and
- the need for integrated catchment models to examine issues of long-term environmental change.

These areas are further elaborated below using the headings of the review by Casale & Samuels (1998) rather than of the project brochure. However, all the issues in the brochure are included here.

### ***Meteorological and hydrological forecasting***

Advanced radar systems can differentiate rain from clutter, hail, and bright-band echoes, and can detect significant attenuation. They thus clearly provide better qualitative rainfall monitoring, but a full description of their quantitative capability has yet to be obtained. Forecasting of rainfall from current radar analysis needs further research taking account of atmospheric physics and the immediate past storm conditions. For example, can wind information from Doppler radar measurements improve the advection of convective storms and thus provide improved rainfall forecasting in severe storms?

Further research should improve the precipitation forecasts in the context of flood forecasting

- from limited area meteorological models using information from the radar and of the conventional precipitation gauge network.
- from the use of satellite imagery to produce quantitative precipitation forecasts.

Research is needed to determine whether it is the hydrostatic assumption or the parameterisations which limit the quality of hydrostatic meteorological forecast models at high (< 10 km) grid resolutions. The performance of non-hydrostatic meso-scale models should be investigated. Study of precipitation patterns and internal structures is required for use in filtering forecast precipitation fields.

Improved understanding is needed of how errors in radar rainfall measurement affect the prediction of river flows and further research is needed on the optimisation of hydro-meteorological networks for the explicit purpose of flood forecasting. This is coupled to the need to improve the understanding of the rôle of soil moisture in runoff forecasting, its integration into hydrological modelling and the associated effects of scale.

### ***Monitoring river and catchment conditions***

Unfortunately, in some countries the extent and availability of hydro-meteorological data for research is affected by the commercialisation of the agencies involved and the focussing of effort on monitoring to ensure compliance with water related directives. There is need to identify the true value of long term monitoring of climate and streamflow for assessing potential environmental change and to identify the best means of access to this data to the research community and institutions involved in long-term planning.

Research is needed on the optimisation of measurement networks for flood forecasting and warning purposes, linked with other hydro-meteorological measurement networks. A particular issue is to maintain security and adequacy of information during the extreme meteorological conditions which

can lead to severe flooding.

In the context of debris flow prediction, the monitoring of catchment and streambeds is clearly inadequate and insufficient. The installation of meteorological stations and various devices aimed at monitoring initiation areas and recording debris flow events is needed. Increased financial support by operating agencies as well as research funders is necessary and would be essential for practical applications.

### ***Improved estimation of flood discharge***

For the planning and design of flood defences it is necessary to assess the “design” river flow conditions according to the level of residual risk that is acceptable to the community. Hydrological models, in general, tend to be focussed on water resources investigations where the overall water balance is of primary concern and calibrations tend to produce models which compromise in accuracy between the low and the high flows. Flood risk research needs to concentrate on the appropriate modelling approach in cases where accurate estimation of the flood peak is paramount both in the planning and design context and also for flood forecasting when good forecasts are available of precipitation.

It is important to take account of non-stationarity of past data series and the possibility of future environmental change. The most appropriate estimation methods need to be established for different basin scales, climatic type and severity of event. In particular, the relative merits and applicability of continuous simulation, flow-duration-frequency (Qdf) and unit hydrograph approaches need research. For the investigation of the effects of climate change on flood risk, a key research issue is the generation of precipitation fields at the appropriate spatial and temporal scale from the results of GCM simulations of future climate scenarios.

### ***Integrated approaches to flood management***

The overall objective of flood management is to minimise losses within a river basin over time subject to constraints, such as society's attitude to risk, level of expenditure, etc. Thus a holistic view should be taken of flood management with distinct activities of:

- Pre-flood preparedness
- Operational flood management
- Post-flood response

The key actions in this area lie mainly in the development and dissemination of best operational practice (as begun in the RIBAMOD Concerted Action). In all flood defence activities it is essential to consider the impact of interventions on the flood risk in the river system as a whole and not just at the location of a particular project. This should be facilitated by the implementation of integrated catchment modelling and management information systems as these become available.

### ***Integrated catchment models***

There are many models available which are used in the overall assessment and management of flood risk. However, these mostly only tackle specific issues and there is a need to combine or couple models together to provide decision makers with tools which address the practical management of river systems. A particular challenge is the linking of models of water movement and riverine ecology. It is important that any framework produced should be built as an "open system" which will not be tied to specific proprietary software packages for particular tasks.

In addition to the integration of existing process models, research is needed on the interactions between different natural processes (e.g. sediment, vegetation, flow resistance, discharge time series, climate and water quality) and the complexity and level of integration of these interactions in an overall catchment simulation. Integrated catchment simulations may also address issues of other

areas of the water sector apart from flood risk. Transformations between different scales of resolution can present difficulties, requiring aggregation or disaggregation of data, model parameters and model results. The appropriate representation of the hydro-meteorological system may itself change with the scale of the river catchment.

In some areas, improvements in process modelling are needed to meet the needs of the potential user. These include:

- the parameterisation of land cover and vegetation in hydrological models and its relation to climate,
- sediment transport in “real” river cases,
- cohesive sediment transport,
- long term river morphology (plan form and section shape),
- processes triggering debris flows,
- interaction of pollutant with sediments, and
- flow simulation in steep and mountainous rivers.

In addition to these improvements in process modelling it is necessary to understand further the uncertainties inherent in the modelling and how the uncertainty should be expressed to the users of the model and its results.

The use of integrated catchment models also raises issues on the management of complex modelling tools, their data and results to deliver information for non-specialists. This leads to the need for decision support and expert advice to be available within the modelling systems. Other advances in Telematics (e.g. integration of remotely sensed data into models, Genetic Algorithms, Artificial Neural Networks and Expert Systems) may find application in river basin modelling, river management and flood mitigation.

## **5 Acknowledgements**

The RIBAMOD Concerted Action was funded by the European Commission (EC) Directorate General for Science, Research and Development under the Hydrological Risks component of the Environment and Climate Programme in the European Union Fourth Framework Programme. The EC Contract Number was ENV4-CT-96-0263. In addition the Environment Agency of England and Wales supported the activities of HR Wallingford as project coordinator from the National R&D programme on flood defence, project number W5A (96) 08.

The successful completion of the activities of RIBAMOD would not have been possible without the hard work and co-operation of the members of the Steering Committee who helped by organising the events, suggested speakers, reviewed papers and compiled the Proceedings. In addition, I am grateful to Ms A L Vetere-Arrelano who made the oral presentation of this material at short notice at the EuroConference

## **6 RIBAMOD Publications**

Six newsletters were issued in the course of RIBAMOD to disseminate the outline of the results of the Concerted Action widely, these were distributed by mail and through the project Internet site on the Co-ordinator’s server with the URL <http://www.hrwallingford.co.uk/projects/RIBAMOD>

The Proceedings of each of the events are being published by the EC together with the brochure on EC research and the RIBAMOD final report. The references are as follows>

1. Bronstert A, Ghazi A, Hladny J, Kundzewicz Z & Menzel L, (1999), The Odra / Oder Flood in Summer 1997, *Proceedings of the RIBAMOD European Expert Meeting in Potsdam, 18 May 1998*, Report 48, Potsdam Institute for Climate Impact Research, (also to be published by the EC, DG XII)
2. Casale R, Havnø K & Samuels P (Eds), (1997), RIBAMOD River basin modelling management and flood mitigation Concerted Action, *Proceedings of the first expert meeting on Model Structure and Decision Support*, EUR 17456 EN, ISBN 92-827-9562-4
3. Casale R, Pedroli G B & Samuels P (Eds), (1998), RIBAMOD River basin modelling management and flood mitigation Concerted Action, *Proceedings of the first workshop on Current Policy and Practice*, EUR 18019 EN, ISBN 92-828-2002-5
4. Casale R & Samuels P (1998), *Hydrological Risks - analysis of recent results from EC research and technological development actions*, European Commission, Directorate General of Science, Research and Development, BRUSSELS
5. Casale R, Borga M, Baltas E & Samuels P (Eds), (1999), RIBAMOD River basin modelling management and flood mitigation Concerted Action, *Proceedings of the Workshop and Second Expert Meeting on Integrated Systems for Real Time Flood forecasting and Warning*, (to appear)
6. Casale R, Samuels P & Bronstert A (Eds), (1999), RIBAMOD River basin modelling management and flood mitigation Concerted Action, *Proceedings of the Second Workshop on Impact of Climate Change on flooding and Sustainable River Management*, (to appear).
7. Samuels P G (1999), *RIBAMOD - River Basin Modelling, Management and Flood Mitigation - Final Report*, European Commission, Directorate General of Science, Research and Development, BRUSSELS (to appear)