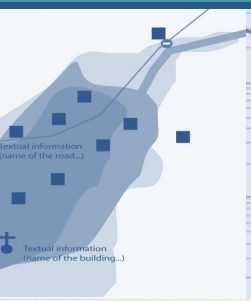
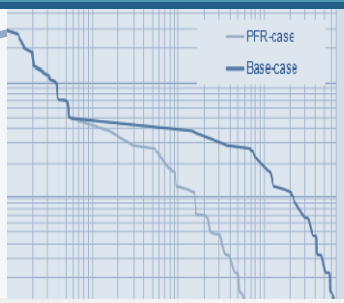
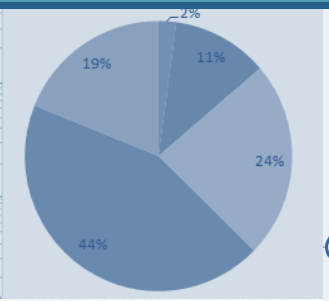
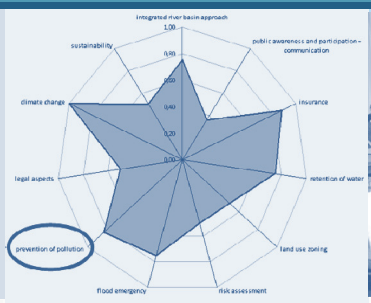
CRUE
FLOODING ERA-NET

Integrate, Consolidate and Disseminate
European Flood Risk Management Research









SYNTHESIS REPORT

Addressing the key findings of research related to

Flood resilient communities – managing the consequences of flooding

CRUE Flood Risk Management Research Monograph Series **2012**

CRUE Scientific Coordination Project: crue-scp@alps-gmbh.com
Project Website: www.crue-eranet.net

DISCLAIMER

Key findings of research related to: Flood resilient communities - managing the consequences of flooding

CRUE Synthesis Report No II-2012

The intent of the synthesis reports is to provide relevant information and to stimulate discussion among those having an interest in flood risk management. The results and conclusions of all reports produced under the **CRUE Flood Risk Management Research Monograph Series** are made available to governments at all levels, research funding bodies, universities, industries, practitioners, and the public by way of the CRUE website (http://www.crue-eranet.net).

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Published in March 2012

ERA-NET CRUE was funded by the ERA-NET Scheme under the 6th Framework Programme
General Directorate for Research in the European Commission
Contract number: ERAC-CT-2004-515742

CRUE Flood Risk Management Research Monograph Series, 2012

CRUE FLOODING ERA-NET

Key findings of research related to:

Flood resilient communities - managing the consequences of flooding

SYNTHESIS REPORT

March 2012

Written by: Susanne Beurton & Annegret Thieken in collaboration with the ERA-Net CRUE Steering Committee

2nd ERA-NET CRUE Funding Initiative

alpS (SCP)	BMBF	BMLFUW	EA	Defra
alp·S	Bundesministerium für Bildung und Forschung	lebensministerium.at	Environment Agency	defra

ISPRA	MEEDAT	MICINN	MinVenW
ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale	Liberté • Égalité • Fraternité RÉPUBLIQUE FRANÇAISE; Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire	MINISTERIO DE CIENCIA E INNOVACIÓN	Rijkswaterstaat Ministerie van Verkeer en Waterstaat

MMM	OPW	SQ-EQD	WL
mmm.fi	OPW The Office of Public Works Oifig na nOibreacha Poibli	The Scottish Government	waterbouwkundig LABORATORIUM

Preface

In recent years, Europe has suffered a number of severe coastal and river floods (in some cases in combination with surface water flooding) that have caused loss of life and widespread damage to homes and businesses. National governments have recognised the key role research can play in responding to these events and improving our resilience to floods in the future. It has also been recognised that improved coordination of flooding research across Europe is crucial to ensure partnership working on common research questions and more effective sharing of expertise and knowledge.

In late 2004, the CRUE network was established and funded as a European Research Area Network (ERA-Net) under the 6th EU Framework Programme. Its aim was to consolidate existing European flood research programmes and projects, promote best practice and identify gaps and opportunities for collaboration. The vision for the CRUE network was to provide a coordinated and comprehensive transnational evidence base on flood risk management. This evidence base would then be used to underpin the work of national and European policy-makers. It is not a coincidence that this occurred at the same time when EU Member States recognised the necessity to provide a legal European framework to assess and manage the risks that floods cause to human health, the environment, cultural heritage and economic activities. In parallel with the EU Water Framework Directive (2000/60/EC) – the cornerstone of EU water protection policy – the European Parliament and the Council of the European Union adopted the Floods Directive (2007/60/EC) in October 2007. Consequently the CRUE network decided to support the implementation of the Floods Directive by providing research-based knowledge, tools and governance strategies to the Member States. For this, CRUE identified five strategic research areas:

1. Developing resilience and adapting to increasing flood risks: climate change and new developments;
2. Risk assessment and mapping;
3. Implementing trans-national based strategies on flood event management and recovery;
4. Meeting the multifunctional demands on flood prevention and protection and their sustainable management; and
5. Addressing public knowledge of flood risk and enhancing awareness, perception and communications.

CRUE has implemented its research agenda in different ways. The two most important are the CRUISE (CRUe Information System Europe) database and joint calls for research funding. CRUISE allows access to flood-related research from across Europe and contains information on research programmes and individual research projects. This kind of information has already been used by CRUE to identify research gaps and needs in the field of flood risk management. On this basis, the CRUE partners designed two joint calls for research funding, where the universal applicability of strategies and methods as well as the trans-boundary relevance were central criteria for the selection of research bids.

The first CRUE funding initiative centred on risk assessment and risk management. In particular, it focused on the effectiveness and efficiency of non-structural flood risk management measures. Key research results and conclusions of the seven funded projects were summarized in a Synthesis Report that was published in 2009 and is available online on the ERA-Net CRUE website.

Given the success of the first funding initiative the CRUE partners decided to fund a second round of research. The CRUE research agenda and the requirements of the EU Floods Directive were important factors influencing the direction of the call. The second funding initiative focused on flood resilient communities and managing the consequences of flooding. It consists of seven research projects and a scientific coordination project. Details of all the projects, key findings and recommendations for policymakers, practitioners and researchers are summarised in this Synthesis Report. In addition, this report presents an overview of instruments developed and/or implemented by the researchers in order to meet the requirements of the EU Floods Directive (i.e. flood hazard and risk maps as well as flood risk management plans).

Readers are encouraged to refer to the final reports of the individual projects and other products (handbooks, guidelines, e-tools, etc.) provided by the seven research projects. Many deliverables are available online on the ERA-Net CRUE website and/or on the projects' websites and thoroughly document the results achieved in 35 case studies and the joint activities carried out between 2009 and 2011.

Formal funding from the European Union for the ERA-Net CRUE ended in October 2009. Nevertheless, since this time the CRUE partners have continued to cooperate and fund the second joint research initiative. There is a desire amongst the CRUE partners to continue working together, which is testament to the success of the CRUE network. At the time of writing, the Water Joint Programming Initiative (JPI) "*Water Challenges for a Changing World*" may be the most promising forum where flood risk management research can continue and be a core element of broader research needs.

Sean Longfield, Stefano Mariani, Wouter Vanneuville
(on behalf of the CRUE Steering Committee)

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Executive Summary

Enhancing resilience is a guiding principle of civil protection and flood risk management policies. It is a vital and sustainable response of a system to disturbances caused e.g. by natural hazards and it integrates three abilities: resistance, recovery and adaptive capacity. The damage to communities across Europe during recent flood events demonstrates the need for further development and implementation of adequate measures and strategies to enhance community flood resilience.

Against this backdrop, seven research projects were funded in 2009 within the 2nd ERA-Net CRUE Funding Initiative "flood resilient communities – managing the consequences of flooding". This funding initiative addressed the three aforementioned aspects of resilience with an emphasis on adaptive capacity, and in particular on learning processes. The seven funded projects are:

DIANE-CM Decentralised Integrated Analysis and Enhancement of Awareness through Collaborative Modelling and Management of Flood Risk

FIM FRAME Flood Incident Management – A FRAMEwork for improvement

FREEMAN Flood REsilience Enhancement and MANagement

IMRA Integrative flood risk governance approach for improvement of risk awareness and increased public participation

RISK MAP Improving Flood Risk Maps as a Means to Foster Public Participation and Raising Flood Risk Awareness: Towards Flood Resilient Communities

SUFRI Sustainable Strategies of Urban Flood Risk Management with non-structural measures to cope with the residual risk

URFlood Understanding Uncertainty and Risk in communicating about FLOODs.

These research projects have generated new knowledge, approaches and methods to enhance community resilience to flooding. The potential for practical application of these new methods has been tested via 35 case studies at sites across Europe. From the outset stakeholder participation was considered crucial to success. Consequently, local authorities, civil protection bodies and members of the general public have been involved in all research projects, through workshops, interviews and even as full members of project consortia.

This report aims to synthesise the results and recommendations of the seven research projects. It provides an overview of the methods and approaches that were developed and identifies key findings that may be helpful for implementation of the EU Floods Directive (2007/60/EC). Recommendations for practitioners and decision-makers are also summarised in this report. They can take this document as a starting point to effectively search for further relevant outcomes of the CRUE-funding initiative. More detailed information on findings and recommendations can be found in the individual project reports published on the CRUE website. The website also has links to many other deliverables produced by the seven research projects. Please see: www.crue-eranet.net.

1 Introduction and Context

Flooding is the most widespread natural hazard in Europe. Recent events in Austria and Switzerland (2005), the UK (2007), Ireland (2009), France, Italy and Poland (2010), and in Germany and Italy (2011) threatened millions of citizens and caused considerable loss of life and economic damage. Increasing river regulation and changing land uses have worsened the consequences in many regions. The potential increase in flood frequency and magnitude as a result of climate change is a further concern.

In the past, the European flood risk management research has been fragmented due to a lack of coordination of national programmes. To improve research synergy the ERA-Net CRUE was established in 2004. Its end-user focused coordinated programme was intended to respond to the challenges of flood risk management with innovative research approaches as well as to consolidate existing European flood research programmes. This has included the promotion of best practice and an identification of gaps and opportunities for collaboration on future research programmes.

At the same time, European policy was developing to reduce the adverse consequences of flooding on human health, the environment, cultural heritage and economic activities. It resulted in the European Directive on the Assessment and Management of Flood Risks (2007/60/EC) that came into force in November 2007. This directive has established a framework for a trans-boundary and coordinated assessment and management of flood risk throughout river basins. The Directive requires a preliminary assessment of flood risks by 2011; the production of flood hazard and risk maps by 2013 and flood risk management plans by 2015. This created a demand for evidence based methodologies and improved management and governance strategies are needed. In particular, CRUE responded to these demands for a scientifically robust evidence base through the outputs from the second funding initiative summarised in this report.

The following sections further outline the scientific challenges for the 2nd ERA-Net CRUE Funding Initiative as well as the background and the requirements for research on flood resilience. It ends with the objectives of the second CRUE common call.

1.1 Research agenda on flood resilience

The term resilience has introduced a new way of thinking about risk management. It emphasises the role of societies facing natural hazards based on the principle that floods (and other natural hazards) cannot always be fully prevented. As a result sound management of the consequences of flooding becomes a key component of flood risk management. The text box “Definitions of the term resilience” (see overleaf) further specifies the understanding of resilience by the CRUE network.

The overarching goal of the CRUE-funded research was to enhance community resilience to flooding. Five strategic research areas were identified by CRUE (CRUE Consortium, 2009):

- Developing resilience and adapting to increasing flood risks (e.g. climate change and new developments);
- Risk assessment and mapping;
- Implementing trans-national based strategies on flood event management and recovery;
- Meeting the multifunctional demands on flood prevention and protection and their sustainable management;
- Addressing public knowledge of flood risk and enhancing awareness, perception and communications.

Definitions of the term "resilience"

Enhanced resilience is a vital and complex aim for many strategies and policies of civil and environmental protection. In order to accompany the CRUE-funded projects, Schwindt & Thieken (2010) prepared a review on resilience, which is summarised here.

Although there is a multiplicity of definitions, resilience to natural hazards can be mainly characterised by three aspects (Fig. 1): resistance, recovery and adaptive capacity (also referred to as creativity).

Resistance is the ability of a system to resist a disturbance caused e.g. by a natural event and it is measured by the amount of disturbance the system can withstand or absorb before any changes occur. Resistance can be interpreted as a reactive approach to resilience that aims to strengthen the status quo in order to be able to withstand changes.

The recovery aspect of resilience refers to the ability of a system to recover from the impact caused, in this case, by a flood event and it is measured by the time a system needs to return to its original state after a disturbance has occurred. The quicker the pre-disaster growth-path is achieved, the more resilient a community is considered to be.

A third aspect of resilience is the adaptive capacity and it is understood as the ability of the system to learn from past events and to adapt in such a way that it develops beyond the pre-event-status. This proactive understanding of resilience accepts upcoming changes in the system and aims to develop a regime that is able to adjust to new conditions. It also includes the willingness and the ability of a society to learn from past disasters and adjust to changes. Social scientists (Lorenz, 2010) emphasise that besides adaptive capacity, also coping capacity and participative capacity are relevant for the enhancement of resilience. The former assures the continuity and identity of the system, whereas the latter measures the system's ability to self-organise.

The three aspects were addressed differently within the CRUE-funded projects. However, an emphasis on learning processes and the enhancement of the adaptive capacity are central. In addition, participation of stakeholders was a key principle in the research projects. An overall challenge especially for FREEMAN and URFlood was to translate resilience into measurable values. FREEMAN outlines, that optimal resilience of a system includes the return to higher levels of functioning as illustrated on the right hand side of Fig. 1. The project concludes by the statement that resilience is more than anything "knowledge" and the capacity to deploy it.

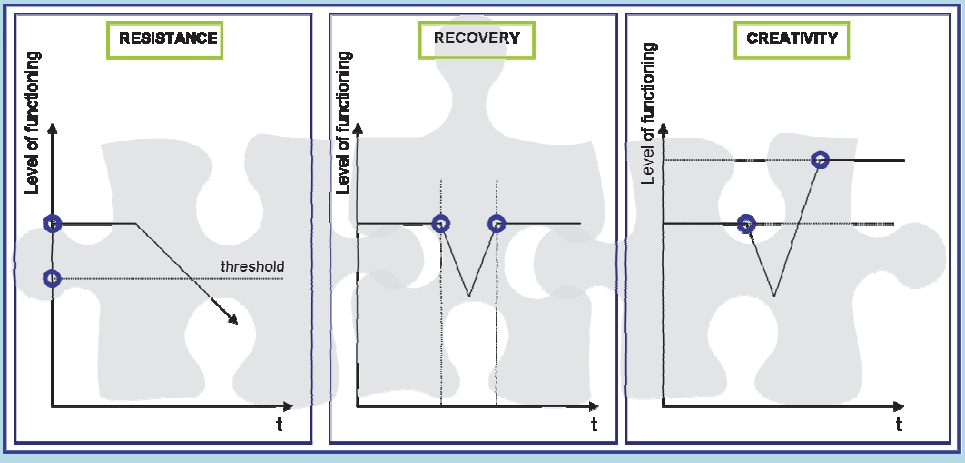


Fig. 1: The concepts of resilience illustrated (Source: FREEMAN).

1.2 The second CRUE Funding Initiative

The CRUE partners agreed to contribute to the five strategic research areas by launching a second common call for research funding in June 2008 entitled "Flood Resilient Communities – Managing the Consequences of Flooding".

Their vision was to support:

- transnational cooperation and learning to gain experience of research programmes and projects from across Europe;
- the integration of flood and water-related policies; and
- the implementation of the EU Floods Directive.

The successful research projects funded by the second common call were chosen by the CRUE partners based on experiences from the first common call (see Pichler et al., 2009), the perceived weaknesses in flood risk management research and the requirements that emerged from the EU Floods Directive. The second common call focused on two thematic areas of flood risk management:

1. Improving risk awareness and increasing public participation in flood risk management

The first theme centred around improving our understanding of risks and the ability of stakeholders to communicate risks across institutional frameworks. One of the main challenges was to formulate strategies which encourage members of the public to participate in the decision making process when developing new approaches to flood risk management were addressed. All of this work aimed to be of direct relevance to practitioners and policy makers.

2. Improving flood event management

The second theme focused on the way people behave, when a flood occurs. It aimed at understanding the interaction between people affected by flooding, rescue services, civil protection agencies and local and national authorities. It also examined optimisation of early warning systems and the development of coordinated flood risk management and recovery plans. Since these research areas have traditionally been driven by technical approaches and solutions, the inclusion of the ´human factor´ was highlighted as an explicit requirement of the scientific process.

The following partner institutions offered funding for research projects under the second funding initiative of the ERA-Net CRUE:

- Department for Environment, Food and Rural Affairs (Defra), United Kingdom
- Environment Agency (EA), England and Wales
- Flanders Hydraulics Research (WL), Belgium
- Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW), Austria
- Federal Ministry of Education and Research (BMBF), Germany
- Institute for Environmental Protection and Research (ISPRA), Italy
- Ministry of Agriculture and Forestry (MMM), Finland
- Ministry of Ecology, Energy, Sustainable Development and Land use planning (MEEDDAT), France
- Ministry of Infrastructure & Environment, formerly the Ministry of Transport and Public (MinVenW), The Netherlands
- Ministry of Science and Innovation (MICINN), Spain
- Office of Public Works (OPW), Ireland
- The Scottish Government, Environmental Quality Directorate (SG-EQD), Scotland

In addition, two projects of the funding initiative were co-funded by:

- Government of Styria (Govt. of Styria), Austria
- Wildbach- und Lawinenverbauung (WLV), Austria

2 Project overview

Seven research projects were funded within the 2nd Era-Net CRUE funding initiative between 2009 and 2011. The overall goal was to enhance the flood resilience of communities. Table 1 gives an overview of all projects including their objectives and websites.

In addition, a Scientific Coordination Project (SCP) was funded within such Funding Initiative to support both the CRUE Steering Committee and research projects. One of the main roles of the SCP was to facilitate scientific exchange within the network, and to disseminate its results.

Kick-off Meeting of the second CRUE funding initiative, Rome, Italy, October 2009.

2.1 The seven CRUE projects in brief

The aim of **DIANE-CM** was to enhance the capacity of stakeholders to better cope with flood risk by means of interaction with experts and with the assistance of computer tools. The main concept used by the project team was collaborative modelling. This is an interactive and iterative process in which stakeholder engagement and communication activities are constantly complemented by computer modelling and communication tools (such as a collaborative platform[(1)]). The project also investigated how data from flood hazard and vulnerability maps, and information on flood prediction could help with public dialogue.

The goal of the **FIM FRAME** project was to produce a method to assist emergency planners and other key stakeholders, such as water management organisations and emergency responders (i.e. the police and fire brigade), to assess, develop and improve emergency plans for flood events. The method developed comprised three transparent steps: (i) appraise in which areas of improvement in the plan are identified; (ii) tackle - in which potential resolving actions are identified; and (iii) implement - where actions are agreed to update the plan.

The **FREEMAN** project aimed to develop methodologies to quantify resilience and to provide an operational framework (including indicators and operational guidance) for professionals involved in flood risk management. Based on the design of three pillars of flood risk, namely policy and institutions, flood management tools as well as risk communication and perception, an innovative and complex instrument was developed. One of the key outputs from the project is the Resilience Checker which supports the analysis and visualisation of resilience and helps to translate basic assumptions about resilience into flood management practice.

The **IMRA** project considered procedural efficiency as a key approach for good risk governance. It aimed to improve decision making and communication processes and focused on authorities responsible for flood risk management. The project used tools and methods from education, social and media sciences to develop a 'toolbox' of methods and guidelines that can be used to aid decision making by flooding professionals.

(1) A web-based platform that can support stakeholder involvement processes in an interactive way

The **RISK MAP** project focused on improving the comprehensibility and content of flood maps. It actively involved end-users in the mapping process and explored ways to develop appropriate participation processes. The project findings are based on six case studies in four countries and illustrate the relevance of stakeholder participation in mapping. The main output from the project are a series of recommendations to improve flood mapping across Europe. The project also produced guidelines on appropriate stakeholder participation processes during risk assessment and the development of flood mapping.

"Crossing Wupper": Visualisation of 100 year flood level, Leichlingen, Germany, 2011 (IMRA).

The research topics of the **SUFRI** project range from advanced forecast models, flood warning and tools for flood risk estimation in urban areas to adequate strategies for risk communication on the basis of an opinion poll. The research work involves literature surveys on flood forecasting and flood warning, their advantages and disadvantages as well as experiences with their application. Tools have been analysed to develop a method for estimating the consequences of river and pluvial flooding on with specific reference to dam and levee safety. The project has recommended questionnaires and communication strategies to improve The actual state of the science of risk communication leads to the development of communication strategies and a questionnaire for improvement of the public awareness and participation.

Collaborative modelling exercise, London, UK, 2010 (DIANE-CM).

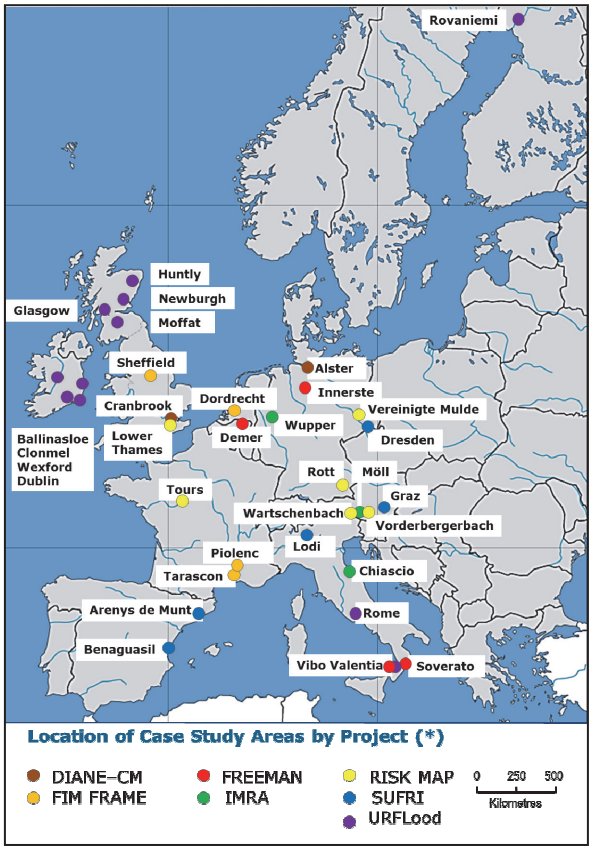
URFlood focused on flood risk communication. The project aimed at improving planning strategies and responses to flood warnings by the public at risk. The core element was investigation of knowledge systems and their impacts on risk perception and response. Eleven case studies in four countries were carried out and revealed the importance of trust and reliability as a precondition for successful flood communication among others. The findings were translated into a framework with eight guiding principles.

Table 1: Overview of the seven joint CRUE-funded research projects.

Project Titles, Main Objectives, Websites, Funders	Reference: Final Report
DIANE-CM: Decentralised Integrated Analysis and Enhancement of Awareness through Collaborative Modelling and Management of Flood Risk • Introduce innovative methods of risk quantification and participation in a public dialogue • Improve flood hazard and risk maps and near real time flood forecast • Increase preparedness of local communities in flood risk management due to collaborative modelling • Test the developments in two selected case studies for a feature of 'good governance' Website: www.leuphana.de/en/mariele-evers/forschung-projekte/diane-cm.html Funding: BMBF, EA, MinVenW	Evers et al. (2011)
FIM FRAME: Flood Incident Management – A FRAMEwork for improvement • Assess the effectiveness of flood incidence management plans in the UK, the Netherlands and France • Evaluate tools that are used for flood e management planning • Establish how these tools can be used to improve emergency management plans • Produce a method to assist stakeholders to develop and improve emergency plans for floods Website: www.fimframe.net/index.html Funding: Defra/EA FCERM Programme, MEEDDAT	Lumbroso et al. (2011)
FREEMAN: Flood REsilience Enhancement and MANagement: a pilot study in Flanders, Germany and Italy • Identify factors, strategies and measures that increase flood resilience • Provide guidance on the operational use of flood resilience into flood risk management • Provide practical policy recommendations to aid the implementation of the EU Floods Directive Website: www.feem-project.net/FREEMAN/index.php Funding: WL, ISPRA, BMBF	Uyttendaele et al. (2011)
IMRA: Integrative flood risk governance approach for improvement of risk awareness and increased public participation • Development of a methodology for an integrative concept for participatory flood risk management • Validate the concept by application to three case studies • Discuss the results with scientific experts and disseminate to policy and decision-makers, as well as to a wider public Website: www.imra.cnr.it/ Funding: BMLFUW, BMBF, ISPRA	Firus et al. (2011)
RISK MAP: Improving Flood Risk Maps as a Means to Foster Public Participation and Raising Flood Risk Awareness: Towards Flood Resilient Communities • Develop appropriate stakeholder participation processes • Improve the content of risk maps by considering social, economic and environmental risks • Improve the visualisation of flood risks in order to produce user-friendly risk maps • Provide quantitative information related to the content of risk maps Website: www.risk-map.org/ Funding: BMBF, Defra/EA, BMLFUW, MEEDDAT	Meyer et al. (2011)
SUFRI: Sustainable Strategies of Urban Flood Risk management with non-structural measures to cope with the residual risk • Compilation of advanced warning systems • Provide a questionnaire about people`s conduct and needs as a basis for adequate risk communication strategies • Development of a simple tool for supporting flood risk evaluation in urban areas • Help to improve crisis management planning by developing an interdisciplinary approach that combines societal and technical visions, as advanced warning, risk estimation and public participation Website: www.sufri.tugraz.at/ Funding: BMLFUW, Govt. of Styria, WLV, MICINN	Jöbstl et al. (2011)
URFLOOD: Understanding Uncertainty and Risk in communicating about FLOODs Main objectives: • Investigate and communicate how flood risk communications are incorporated into the knowledge systems of different actors • Evaluate current practice with regard to flood communications and uncertainty against existing good practice criteria to establish potential improvements Website: www.macaulay.ac.uk/urflood/index.php Funding: SG-EQD, ISPRA, MMM, OPW, EA	Waylen et al. (2011)

2.2 Case Studies

Many of the strategies and methods developed as part of this research programme have been tested and validated in case studies covering all countries that were involved in ERA-Net CRUE (Fig. 2).



(*) Cartographic background by Liuzzo (2006).

Fig. 2: Location map of case study areas by project.

Altogether, 35 case studies were undertaken. Some characteristics of the case study areas are provided in the Tables 2 to 4.

The data reveal that there was a focus on regions that are at risk of fluvial flooding or mixed flood types (Table 2), whilst a wide range of catchment areas were considered (Table 3). Table 4 shows that the majority of the case study locations were in areas that had recently (i.e. in the past ten years) been affected by flooding.

Each case study shown in Fig. 2 and Table 5 is described in a separate factsheet that can be downloaded from the CRUE website (http://crue-eranet.net → Calls for Research → Project List).

Table 2: Number of case studies per major type of flooding.

Flood Type	#	%
Fluvial	13	37%
Pluvial	3	9%
Coastal	1	3%
Mixed	18	51%
Sum	**35**	**100%**

Table 3: Number of case studies per size of catchment area.

Size of catchment area	#	%
< 10 km²	4	11%
> 10 – 100 km²	5	14%
> 100 – 1000 km²	10	29%
> 1000 – 10 000 km²	9	26%
> 10 000 km²	6	17%
Not applicable	1	3%
Sum	**35**	**100%**

Table 4: Period elapsed since the last (major) flood event (from the start of the projects in 2009).

Last flood event experienced in the case study areas	#	%
Up to 5 years ago	18	51%
> 5 to 10 years ago	11	31%
> 10 to 25 years ago	2	6%
More than 25 years ago	4	11%
Sum	**35**	**100%**

Table 5: Overview of the CRUE case studies.

Project	Country	Case Study Name
DIANE-CM	England and Wales, UK	Cranbrook Catchment (London Borough of Redbridge)
	Germany	River Alster
FIM FRAME	England and Wales, UK	City of Sheffield
	France	Piolenc
	France	Tarascon
	The Netherlands	City of Dordrecht
FREEMAN	Flanders, Belgium	Basin of River Demer
	Germany	Basin of the river Innerste
	Italy	Soverato, Calabria Region
	Italy	Vibo Valentia, Calabria Region
IMRA	Austria	River Möll
	Germany	River Wupper
	Italy	Chiascio River Basin
RISK MAP	Austria	Wartschenbach
	Austria	Vorderbergerbach
	England and Wales, UK	Lower Thames, Chertsey
	France	Tours
	Germany	Rott River
	Germany	Vereinigte Mulde River
SUFRI	Austria	Andritz, District of Graz
	Italy	Lodi
	Germany	River Weißeritz, City of Dresden
	Spain	Arenys de Mar / Munt, Catalonia
	Spain	Benaguasil, Valencia
URFlood	Finland	Saarenkylä of Rovaniemi
	Ireland	Ballinasloe, Co. Galway
	Ireland	Clonmel, Co. Tipperary
	Ireland	River Dodder, Dublin
	Ireland	Wexford Town, Co. Wexford
	Italy	Rome, Lazio Region
	Italy	Vibo Valentia, Calabria Region
	Scotland, UK	White Cart, Glasgow
	Scotland, UK	Huntly
	Scotland, UK	Moffat
	Scotland, UK	Newburgh

3 Key findings and conclusions

This chapter gives an overview of key project findings and conclusions. Each of the presented projects prepared a number of research products, e.g. reports, guidelines or tools. A list of all deliverables is provided in Table 6. The list with respective weblinks will be available at the CRUE website in April 2012. This chapter gives an overview of key project findings and developments.

3.1 Key research findings

The following section summarise the key findings of the research projects. Project conclusions are grouped under one of the headings below:

1. Risk analysis & reduction
2. Risk reduction & management
3. Risk management & communication

Topic 1: Risk analysis & reduction: collaborative modelling & mapping

Advanced methodologies to screen the resilience level of communities still need to be developed. Nevertheless, resilience enhancement starts with an inventory study of existing hazards, risks and reduction measures that promotes a dialogue between government institutions, private companies and citizens. During the CRUE funding initiative two approaches to these challenges were explored; first, scenario development in collaboration with stakeholders to support the decision making processes, and second, the improvement of existing or new hazard and risk maps. These approaches are based on the following key findings:

- Interactive collaborative modelling supports the development of a common understanding of current flood risk in locations under study. The general objective of a collaborative platform is to support the process of individual and social learning, through collaborative modelling, for participatory flood risk management (DIANE-CM).
- Collaborative modelling can support the assessment of alternative flood risk management options against different possible future scenarios. Alternatives for future implementation can also be selected and negotiated through collaborative modelling (DIANE-CM).
- In order to communicate risk information in an organized and efficient way, trained local champions could produce centralised information to share with other stakeholders (DIANE-CM).
- Different end-user groups have different requirements on the content of flood maps. These groups can be: strategic planning; emergency management; the (affected) public (RISK MAP).
- Multiple topics dedicated to different user groups should not be shown in the same map (RISK MAP).

Our research suggests that flood mapping and modelling strategies can be improved by:

- The use of collaborative modelling platforms which use a common framework to better integrate local knowledge (Fig. 3), (DIANE-CM);
- Using tools to analyse, compare and enhance resilience. The “resilience checker” developed by the FREEMAN project uses a three dimensional triangular approach to represent resilience (Fig. 4) (FREEMAN);
- Improving coordination of flood risk issues among professionals at different scales, e.g. local, regional and disciplines (DIANE-CM);
- Establishing data measurement networks for real time flood forecasting for selected areas (DIANE-CM);
- Implementing a methodology for pluvial and river flooding risk assessment in urban areas (Fig. 5, SUFRI).

Table 6: Overview of deliverables.

Project	Deliverable
DIANE-CM	Final Report
	Socio-technical framework for merging social and technical aspects of flood risk management
	Recommendations for novel risk quantification and communication management
	Manual for informatics support to awareness raising and resilience enhancement activities (for the usage of the Automatic Overland Flood Delineation tool – AOFD)
	DIANE-CM experiences in the Netherlands with stakeholder participation in flood management
	Conceptual design of the collaborative platform for flood risk management
	Results related to social aspects of flood risk management / Results of stakeholder consultation
	Web-based platforms (case studies)
	E-learning platform and short courses on flood risk management
	Project summary for policy makers
	Documentation of workshops and leaflets
FIM FRAME	Guidelines on the application of the FIM FRAME method
	Final report research reports
	'An assessment of flood emergency plans in England and Wales, France and the Netherlands': Peer reviewed paper published in Natural Hazards, July 2011
	Tools to improve the production of emergency plans for floods – are they being used by the people that need them?
FREEMAN	Guidelines on flood resilience and flood risk management
	Overarching framework for resilience task
	Strategies and measures, flood management plans and tools
	Set of "quick wins" to enhance resilience
	Brochure on guidelines and quick wins
IMRA	Reports on local case study results, including guidelines for implementation, report in local language: Wupper (German) / Möll (German) / Chiascio (Italian)
	Reports on local case study results, including guidelines for implementation, handbook in local language: Wupper (German) / Möll (German) / Chiascio (Italian)
	Handbook - Planning and implementing communication and public participation processes in flood risk management
	Report about the schools activities in the Chiascio river basin (in italian)
	Final report of the Italian case study (English, Chiascio river basin)
RISK MAP	Guidelines and recommendations for stakeholder participation in the risk mapping process
	Guidelines and recommendations for stakeholder-oriented compilation and design of risk maps
	Report on legal frameworks of flood risk mapping and participation
	Case study reports
	Methods
	Set of maps
	Multicriteria risk mapping tool and user manual
SUFRI	Final Report
	Methodology for investigation of risk awareness of the population concerned (German, English, Italian, Spanish)
	Methodology for pluvial and river flooding risk assessment in urban areas to inform decision-making
	Compilation of advanced warning systems
	Approach for crisis management planning
URFlood	Framework and methodology on flood risk communication
	Understanding uncertainty and risk in communicating about floods
	Report: New communication methods
	Case study reports
	Organograms of responsibilities

Fig. 3: Screenshot of a collaborative platform (DIANE-CM).

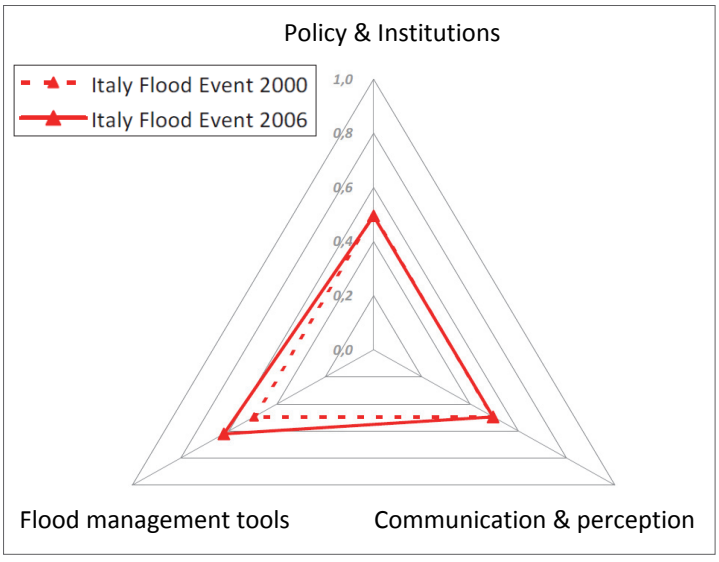


Fig. 4: Overall level of resilience, example for an Italian case study (FREEMAN).

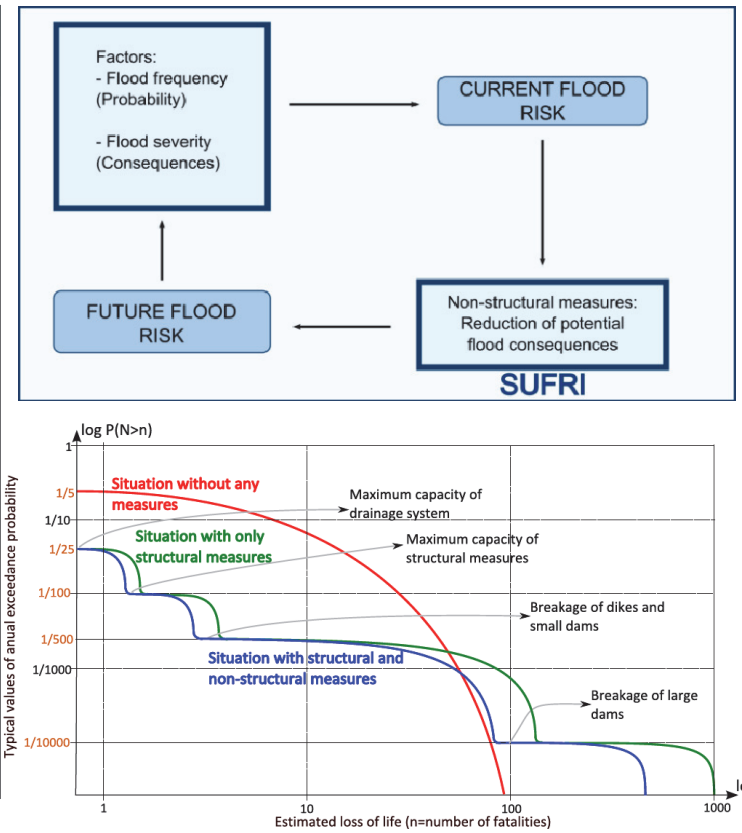


Fig. 5: above – Scheme of interaction between flood risk and non-structural measures; below– Effect of structural and non-structural measures in F-N curves[(2)] (SUFRI).

Several projects produced recommendations and guidelines on flood mapping and modelling, for example:

- The RISK MAP project makes recommendations on the visualisation and compilation of flood risk maps. These include suggestions for improved map content (with respect to the requirements of the EU Floods Directive) and target-oriented map design that is adjusted to the individual needs of different stakeholders (Fig. 6)RISK MAP also advocates the use of participation processes during risk assessment and mapping;
- RISK MAP and DIANE-CM have produced improved flood and hazard maps

(2) The F-N curve presents values in both axes (cumulative annual exceedance probability and estimated loss of life) and the area under this curve is the total societal risk.

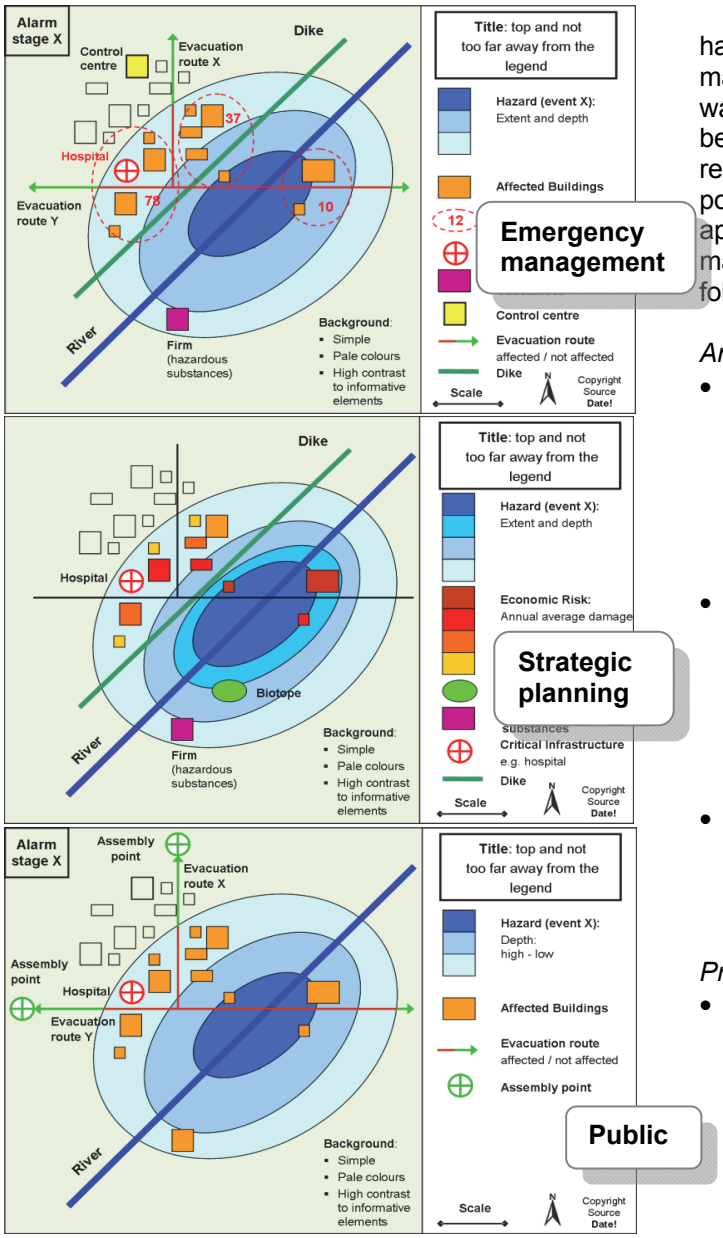


Fig. 6: Examples of idealized flood risk maps for different end-user groups (RISK MAP).

Topic 2: Risk reduction & management: Improving emergency management strategies

Flood risk reduction can be achieved by a variety of structural and non-structural measures. The first common call investigated the effectiveness of measures (see Pichler et al., 2009) whereas research in the second common call particularly focused on the improvement of warning and emergency management.
Emergency management comprises the direct response of societies to ongoing or future hazards. Different stages of emergency management (such as analysis, preparation and warning) can be distinguished. Effective interplay between stakeholders and their awareness of relevant technical tools are crucial for minimizing potential damages. Throughout CRUE, the approach towards improved emergency management plans has been based on the following key findings:

Analysis

- Emergency plans for floods often deal with a limited number of scenarios. They often do not deal with the concept of "possibilism" i.e. thinking in terms of "worst cases". Such "thinking outside of the box" could disrupt routine thought patterns and lead to more resilient systems (FIM FRAME).
- There is a discrepancy between the level of detail required by emergency planners and the actual level of detail that is available within emergency plans for a number of issues, in particular on risks to receptors – e.g. people, buildings, industrial facilities, critical infrastructure (FIM FRAME).
- Responsible authorities need to be better informed about existing emergency plans to make sure, that they are considered and used, when required (FIM FRAME).

Preparation

- The division of responsibility is not always clear. Some of the types of tools for improving emergency plans are perceived to fall outside the remit of all the stakeholders. A responsibility gap can result in the fact that tools are not used. An obstacle to the awareness of available tools is the lack of communication between flood risk managers and the stakeholders such as emergency services and local authorities responsible for writing emergency plans (FIM FRAME).
- There is a need for the training of stakeholders in tools that help to improve emergency plans, especially more "technical" tools (e.g. accessibility of inundated roads; optimisation of the location of shelters and safe havens) (FIM FRAME).
- The main challenge for emergency planners is to avoid filling plans with generic text and to provide an appropriate level of specific detail in the plan whilst ensuring the usability of the plan (FIM FRAME).

Warning

- Automatic warning message dissemination is not common in flood warning systems. The warning chain is often discontinuous. A linkage between forecast rainfall and flood induced damage remains a scientific challenge (SUFRI).
- Previous flood experience of persons at risk was found to have an effect on trust and reliability with regard to the authorities and agencies in charge. Depending on the sender, warning messages can produce different responses from members of the public (URFlood).
- Misunderstanding of terms associated with risk can reduce the effectiveness of communication (URFlood).

In order to overcome these weaknesses, a portfolio of applicable tools and techniques for producing, assessing and improving emergency plans are available as deliverables of the CRUE-funded projects. Stakeholders are invited to consider them for the following purposes:

- assessment, evaluation and improvement of the effectiveness and robustness of flood emergency plans.
  For example: A three-step framework for preparing or enhancing a flood emergency management plan (Fig. 7, FIM FRAME) is not restricted by scale or flood specific characteristics.
- development of new emergency plans (FIM FRAME);
- guidance on available tools (e.g. checklists, software) to help to improve emergency plans (FIM FRAME);
- compilation of advanced warning systems (SUFRI);
- an approach for crisis management planning (SUFRI);
- to understand the key factors of the perception of flood communication (URFlood);
- a survey on statements on risk, that are understandable to the public at risk (URFlood);
- instructions for proactive flood communication (URFlood).

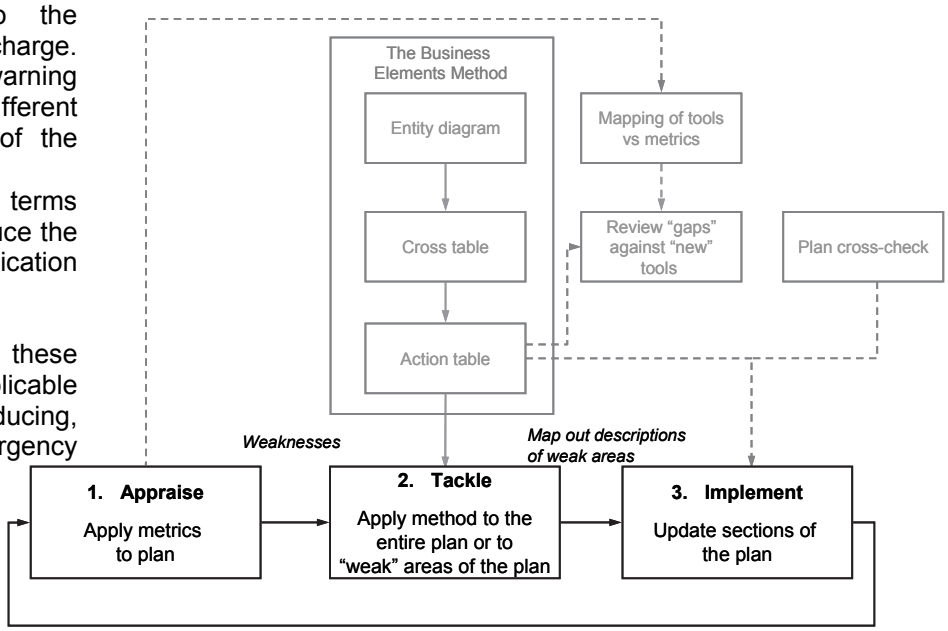


Fig. 7: Diagram of a proposed framework for improvement of emergency plans (FIM FRAME).

Topic 3: Risk management & communication: Enhancing awareness and perception

The EU Floods Directive (§ 2 of Article 10) outlines, that "*Member states shall encourage the active involvement of all interested parties into the production, review and updating of the flood risk management plans.*" Because active involvement is much more than just an information campaign, research on effective communication strategies and participatory approaches is central to meeting this requirement. Several CRUE-funded research projects addressed this overarching challenge.

Detailed research findings and technical reports can be found at specific project websites (see Table 1). A brief summary of the approaches is given in this section.

The main findings are:

- A strong, integrated model of communication which realizes a fusion among general and sectoral institutions in a clear and coherent model of partnership is missing (FREEMAN).
- Also in risk mapping, aspects of stakeholder involvement play an important role. The participation of end users in mapping processes can lead to more appropriate results and application. Quality and success of such processes depend largely on the purpose, which should be defined carefully. Rather substantive and a rather instrumental rational purposes can be distinguished and influence the final product (RISK MAP).
- Large differences exist between real flood risk and perceived risk by the public and the perception tends to be lower than the assessed risk (IMRA).
- Individual motivation can influence the involvement of institutional stakeholders by participating at flood risk reduction activities (i.e. workshops, meetings). Information activities might not be welcome on the political end, because of expected negative effects e.g. on tourism (IMRA).
- Media interest in flood management is related to the temporal proximity of flood events (i.e. the more recent the last flood, the more the media are interested). In times of their absence, the support of the media in enhancing public risk awareness tends to be low (IMRA).
- Terms to communicate flood risk with understandable and simple language are not sufficiently used. Furthermore, information is not tailored to different social or demographic backgrounds – e.g. on those who have no flood experience or with lower levels of the country's first language (URFlood).
- Pre-existing local experience and understanding are influential on the interpretation of risk communications and trust (URFlood).
- For disaster control management no common picture of the distribution of responsibilities (i.e. Who is responsible for medical service? Who informs the public?) can be found. The responsibility structure differs from case to case study (SUFRI).
- A high number of people felt uninformed during past flood events (SUFRI).

In order to tackle these challenges, practitioners can get support from:

- a 12-step process and methodological toolbox for the selection of appropriate communication and participation methods (Table 7, IMRA);
- Method for assessing risk awareness of the population (SUFRI);
- a framework of eight guidelines proposed to aid the design of effective flood communication systems in any European country (Fig. 8, URFlood);
- recommendations on the compilation of advanced warning systems and of risk communication strategies (SUFRI);

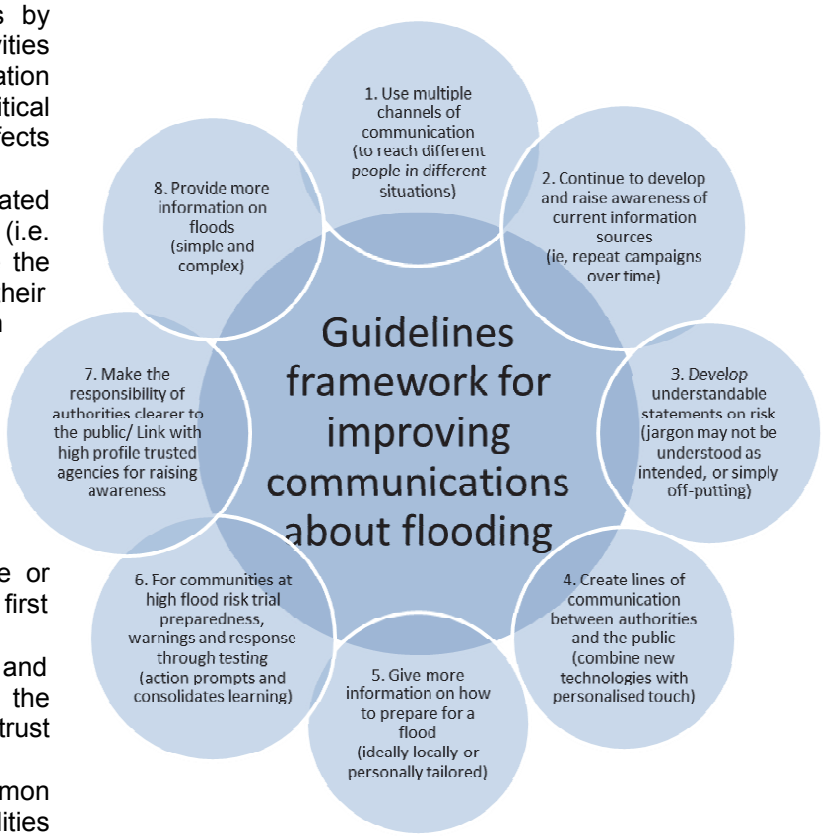


Fig. 8: Framework of eight guidelines proposed to aid the design of effective flood communication systems in any European country (URFlood).

Table 7: Example of a 12-step guideline for a communication and participation process, with indication of which method fits to each step (IMRA).

Steps:
1: Initial self-assessment of risk governance performance;
2: Define goals and scope of process;
3: Identify resources;
4: Identify relevant stakeholders;
5: Design and define scope of participation process;
6: Create a network of stakeholders;
7: Identify the public's view;
8: Agree on objectives;
9: Agree on targeted communication and participation measures;
10: Design an implementation plan for communication and participation measures;
11: Implement communication and participation measures;
12: Evaluate the process;

Abbreviations: asm.: assessment; com.: communication; Educ.: Educational; exb.: exhibition; gov.: governance; SKH: Stakeholder; WS: workshop

		Planning phase of governance process			**Information**						**Consultation**					**Common decision-making**	
Aim	Step	SKH analy-sis tool	Social milieu approach	Risk gov. asm. tool	On-line com.	Public stand with small exb.	Public exb.	Media coverage	Educ. infor-mation	School compe-tition	Online chat	Virtual social net-work	Survey: interviews or questio-nnaires	School project	World café	SKH WS	Public WS
Identify your own position	1			●												●	
	2			●												●	●
	3			●											●		
Identify your strategic partners	4	●		●												●	
	5	●	●												●	●	●
	6	●		●											●	●	
	7		●								●	●	●		●		●
Decide on measures	8			●												●	●
	9		●												●	●	●
	10			●													
Implementation	11				●	●	●	●	●	●	●	●	●	●	●	●	●
Evaluation	12			●									●			●	

3.2 General conclusions

According to the vision of CRUE (Section 1.2), projects should develop methods and tools which can be applied in other communities apart from the case study location and hence contribute to meet the requirements of the EU Floods Directive. The main successes and limitations of the research is described in the following section.

Communication and ways to account for interests of all potentially affected parties and their impacts

Adequate two-way communication of risks is a fundamental task for flood risk managers. The CRUE-funded research projects have tested and evaluated various communication tools and methods for stakeholder participation. The main conclusion is that a single solution to reach a maximum of recipients at once does not exist, but must be adapted to the target audience as well as to the context in which communication and participation takes place (e.g. mapping, scenario development, and warning). During the CRUE funding initiative, creative ways to account for the interests of all potentially affected parties were tested and evaluated (see, e.g., Table 7). These are summarised in Table 8.

The following successes and failures to strengthen public participation in the establishment of future flood risk management plans were identified.

The public needs and wants more information. Therefore, a careful analysis of the public view needs to become more common in the design of risk communication strategies. Good participation can be achieved through public opinion polls. The return rates can be increased by sending reminder letters or by delivering the opinion poll personally. On the other hand, by using public opinion polls, it is difficult to ensure equal representation of all sectors of the community. Contact with younger people can be significantly improved by working with schools.

Successes and failures to interact with stakeholders/public authorities were as follows.

In general, stakeholder involvement was judged positively by the researchers and the interaction with stakeholders as full project partners proved to be highly important. Research stays at public authorities or a "tandem" solution (i.e. a scientific partner and a stakeholder worked together in a particular case study) were successful for intensive exchange of experiences and knowledge. The main barrier to successful interaction were the limited resources for identifying and understanding local specifics as well as a potential lack of data. A continuous process needs further resources. However, strong stakeholder involvement ensures continuation of risk management and communication activities beyond the CRUE funding period.

Table 8: Ways to account for interests.

Surveys	• (expert) interview, semi-structured (*) • online survey (*) • public opinion poll (postal or telephone) (*)
Activities and events	• workshop, meeting or working group (*) • focus group discussion with randomly chosen citizens (*) • world café (*) • online chat (*) • public hearing • excursion • school lecture (*) • public stand • exhibition (*) • press conference
Media	• press, TV, radio • website • publication, flyer, brochure
Research-related cooperation and technologies	• (self-) assessment of existing management systems in place • (collaborative) modelling and testing exercise (*) • stakeholders as full partners in research projects • hosting a researcher at the agency/municipality • tandems of researchers and practitioners (e.g. in case studies) • training of 'local champions' • eye-tracking system to assess usability of maps • 'opt out' system • mobile communication (e.g. electronic alerts by SMS) • e-learning platform (*)

(*) To be presented in detail in CRUE method-factsheets scheduled for April 2012.

Impacts of the research projects on public risk awareness

The CRUE-funded projects improved public dialogue on flood risk and increased awareness, acceptance and understanding (e.g. of maps). Furthermore, methods and tools were successfully tested and verified with regard to their transferability.

Contributions to the implementation of the EU Floods Directive (2007/60/EC)

During the funding initiative, case studies, surveys, analyses of perception, analysis of stakeholder interaction, reviews of policies and flood risk management systems and literature reviews were undertaken by the projects. Table 9 provides an overview of the tools and methodologies developed and tested will facilitate the implementation of the EU Floods Directive. It clearly illustrates the strong linkage of the CRUE funding initiative to the requirements of the EU Floods Directive in the areas of mapping and risk management. The preliminary flood risk assessment was, however, barely addressed as implementation of this deliverable of the Directive ran concurrently with the second funding initiative.

Trade-offs between harmonisation of Flood Risk Management within the EU versus local Flood Risk Management optimisation

Countries and regions greatly differ in terms of the geographical, institutional and participatory landscape. Weaknesses, e.g. missing expertise and skills for risk communication in the administrations that are in charge, but also specific demands, e.g. flood maps for emergency response being different from maps for strategic planning, have been revealed by the systematic approaches in the CRUE-funded projects. Advocating a one-size-fits-all approach is not a recommended solution. The suitability of each approach needs to be verified for each member state and their specific regional requirements.

Restrictions for the generalization of the methods

The transferability of methods and tools at different scales is assumed for some of the developed approaches (e.g. FIM FRAME & URFlood). Others can be limited by several factors. When financial, personnel or data resources are missing, the implementation of flood risk management approaches is restricted by **economic factors**.

Cultural aspects such as local history and flood risk experiences, values, beliefs and social milieus may influence the applicability of a certain approach. As a minimum, **political aspects** like the complacency of institutions or the size of a community need to be considered before strategies are taken into action.

Moreover, flood research and risk management professionals have to deal with natural, social or personal **uncertainties**, such as climate change, multiple knowledge frames and personal motivation, or with conflicting ways of understanding a system. Further restrictions for the generalization of the results and the transferability of methods are due to characteristics of different flood types (pluvial, fluvial, coastal), e.g. with regard to differences in lead times, predictability, potential impacts.

Despite those restrictions, many opportunities for exchange and transfer of findings have been created during the 2nd Era-Net CRUE funding initiative. The international character of the projects resulted in multilingual questionnaires and websites. Their application in several case studies has already demonstrated their practicability. Still, enhancement of flood resilience remains a great challenge on the scientific, political and social level. Therefore, Chapter 4 summarises recommended actions for policy-makers and practitioners as well as requirements on future research.

Table 9: Contributions (selection) to the requirements of the EU Floods Directive.

Project	Flood hazard maps and flood risk maps	Flood risk management plans
DIANE-CM	• Modelling of dual drainage, surface runoff and river modelling (*) • Flood hazard mapping (*) • Collaborative Modelling (*)	• Stakeholder analysis & expert interviews (*) • Organi- and Sociogram (*) • Urban pluvial flood forecasting (*) • Collaborative web based platforms (see Fig. 3)
FIM FRAME		• Twenty two metrics for the assessment of current emergency plans for floods with regard to their fitness for purpose • Evaluation of tools for improving emergency plans for floods • Framework to enable stakeholders to improve emergency plans for floods (see Fig. 7) (*) • Insight into the similarities and differences in emergency planning for floods in four countries
FREEMAN		• The resilience checker (see Fig. 4) (*) • Health check tools for existing flood risk management systems • Recognition of quick wins • Uptake of European Flood Alert System forecasts • Elaboration of scientific procedures and protocols • Proposal of vision for integrated Flood Risk Management (vertical / horizontal)
IMRA		• Method toolbox • 12-step approach on participation, communication and flood risk management (see Table 7)(*) • Matrix for assessing existing flood risk management stakeholder analyses and governance (*) • Set-up and evaluation of communication tools, e.g. social network, exhibition, excursion, school, media (see Table 7) (*)
RISK MAP	• Creation and updating of flood maps • Recommendations on how to improve maps (see also Fig. 5) • Interactive elaboration of an idealised flood risk map	• Matrix about status of the implementation of the EU Floods Directive • Participation framework
SUFRI		• Compilation of advanced warning systems; risk communication strategies (*) • Methodology for pluvial and river flooding risk assessment in urban areas (see Fig. 5) (*) • Public opinion poll for rising risk awareness (*) • Approach for crisis management planning
URFlood		• Guidelines framework for improving communications about flooding (see Fig. 8) (*) • Organograms • List of key factors of perception of flood communication

(*) Presented in detail in the CRUE Final Report of each project (available) and in the CRUE method-factsheets (scheduled for April 2012).

4 Recommendations

This chapter provides a selection of recommendations, which were developed within the seven CRUE-funded research projects. Further descriptions can be found in each final project report and on each project website (cf. Table 1).

4.1 Recommendations for policy makers

Topic 1: Risk analysis & reduction: collaborative modelling & mapping

- Different map users (e.g. strategic planning, emergency management, the (affected) public) require **different maps** (RISK MAP).
- Priorities and policies related to urban pluvial flood management are still unclear. It is necessary to **define who is responsible** for modelling, forecasting, warning and managing urban pluvial or surface flooding (DIANE-CM).
- **Climate change** induced alteration of rainfall pattern is very likely to have significant effects on floods. The EU Water Framework Directive (2000/60/EC) provides guidance (document No. 24) on how Member States can respond to climate change in water policy. It is recommended to also consider the issue within the EU Floods Directive in the first implementation cycle. Water security, decline of ecosystem and hydro-geological risk should be framed in these terms (FREEMAN).
- **F-N and F-D curves** describe the quantitative results of the analysis of social and economic loss regarding probability in an understandable and easy way. They can assist in getting an overview of the social and economic flood risk and in evaluating the effects of several structural and non-structural measures (SUFRI).

Topic 2: Risk reduction & management: Improving emergency management strategies

- Stronger connection of national flood risk management policy to **regional policy** and increased capacity building through networks and programmes (IMRA).
- The division of responsibility (i.e. flood risk managers or emergency planners) should be reviewed in order to avoid **responsibility gaps** (FIM FRAME).
- Efforts to raise **awareness on existing tools** to support improving emergency plans (e.g. checklists and software) should be strengthened and local action plans need to be developed (FIM FRAME).
- A **compilation of advanced flood warning systems** can help optimizing disaster control management by giving an overview about flood characteristics in urban areas. It delivers a reference work for authorities and policy maker. It covers the state-of-the-art of flood warning and their advantages as well as disadvantages (SUFRI).
- Public awareness of urban pluvial flood risk should be enhanced. **Community members** should be encouraged to take an active role in the management of this type of flood (DIANE-CM).
- An **'opt out' system** of automated voice messages would greatly increase coverage of flood warning delivery. However, there could be legislative and/or data protection challenges to implementing an 'opt out' system of communication (URFlood).

Topic 3: Risk management & communication: Enhancing awareness and perception

- It is strongly recommended to support practitioners by **promoting communications** between all concerned groups and resourcing effective flood warnings (URFlood).

- **Social learning** processes help to enhance common understanding and build a broader picture of possible measures to be taken.
- Analysis of a **public opinion polls** can provide a clear picture as to the kind of measures, information or assistance needed in the population`s view. This kind of information can assist in the decision making process for setting tasks and flood management measures (SUFRI).
- Strategies on how to take care of a **continuous communication and participation process** without funding from research projects need to be developed (IMRA).

4.2 Recommendations for practitioners

Topic 1: Risk analysis & reduction: collaborative modelling & mapping

- Different map users (e.g. strategic planning, emergency management, the (affected) public) require **different maps** (RISK MAP).
- **Participation in mapping** enables a two-way learning process, network building and improved understanding of maps for both producers and users (RISK MAP).

Topic 2: Risk reduction & management: Improving emergency management strategies

- Emergency planners, spatial planners and flood risk managers need to **work more closely** in order to acquire an appropriate detail for a number of issues in emergency plans (FIM FRAME).
- Practitioners require more **training** in the types of tools that are available to help them improve their emergency plans and to enable them to make more informed decisions (FIM FRAME).
- Emergency plans for floods should be in the **public** domain (FIM FRAME).

Topic 3: Risk management & communication: Enhancing awareness and perception

- An **open platform for residents** with the possibility to speak out on their flooding problems is an opportunity to foster communication between administration and the public. These statements must be taken seriously by the authorities (DIANE-CM).
- **Public involvement and risk communication** can be optimized by stakeholder analysis; involvement of the media; alternative communication tools; addressing multipliers; tailored strategies towards the addressees (IMRA).
- Infrastructure linking centralised rainfall data, rainfall forecasting models and local urban pluvial flood models are strong tools for **central warning systems**. The extension of such platforms is therefore recommended (DIANE-CM).

4.3 Recommendations for further research

Topic 1: Risk analysis & reduction: collaborative modelling & mapping

- Research should bring **natural hazard risk prevention and climate adaptation** efforts together. The compound effects of individual threats and their cumulative and amplifying impacts should be taken into account (FREEMAN).
- Our understanding of economic losses caused by natural disasters is incomplete. More attention needs to be paid to social, indirect, induced and intangible **effects of future disasters** (FREEMAN).
- It should be explored how the **concept of resilience** refers to the other components of vulnerability. What is the most appropriate scale, level of (dis)integration, and functional relationship and trade-off between the various constituents of resilience? (FREEMAN).
- Further research is needed to provide a more complete tool for flood **risk evaluation and assessment** in order to achieve an integrated flood risk management, including all type of hazards such as seismic, hydrologic, and antropogenic threats (including impact of climate change) (SUFRI).

Topic 2: Risk reduction & management: Improving emergency management strategies

- Further studies are needed to develop **benchmarking tools** for measuring the efficiency of a flood risk management process (IMRA).
- A wider **assessment** of emergency plans is needed (FIM FRAME).
- Further simple **tools** need to be provided (e.g. checklist, guidance and software) via which emergency plans can be improved for flood risk managers (FIM FRAME).
- Automatic flood **warning systems** are currently subject to research in different disciplines. Here linking between forecast rainfall and flood induced damage is very complex (SUFRI).

Topic 3: Risk management & communication: Enhancing awareness and perception

- To understand **local knowledge** systems, data on community perceptions of past events and local agencies (reliability) needs to be collected and interpreted in a holistic way including social sciences and psychological approaches (URFlood).
- What kind of participation is successful to enhance resilience in the **long term** (URFlood)? Flood experiences was found to influence the level of risk awareness and preparedness. How can the broad public without experience with flooding be better involved in risk prevention activities (URFlood)?
- More comprehensive and quantitative research on risk awareness is needed. **Monitoring of perception** should be established (URFlood).
- The **relationship** between flood risk awareness, action capacity and implementation needs further research (DIANE-CM).
- Characterisation of system response should include all **critical infrastructure**, not only flood defence infrastructure. Research needs to focus on the over-lapping of Directive 2007/60/EC on the assessment and management of flood risks and Directive 2008/114/EC on the identification and designation of European critical infrastructures and their protection (SUFRI).

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