Integrated Flood Risk Analysis
and Management Methodologies

FLOODsite

FLOODsite Fact Sheets

A SUMMARY OF KEY PROJECT OUTPUTS – SECOND EDITION

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SUMMARY

FLOODsite was the largest ever EC research project on floods and included over 30 project tasks, producing valuable guidance and tools that are of benefit for researchers, practitioners, policy-makers, schools, universities and the public, in general. Two-page fact sheets have been produced highlighting these key outputs from the project tasks. These are available individually on the FLOOD*site* website, but have also been bound together in this document, providing a quick reference guide to these key project outputs.

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Flash flood hazards

Report on hydro-meteorological modelling

FLOODsite Task 1 has produced:

- A review of the meteorology of events that cause flash floods, the hydrology of the flooding and modelling approaches to flash flood events.

The document is intended for:

- Engineers and scientists involved with modelling flash flood events and flash flood risk management in general.

Where to find the document:

- FLOODsite report T01-07-01 'Hydrometeorological modelling for flash-flood areas' by Sandrine Anquetin et al. is available in the publications section of the website www.floodsite.net.

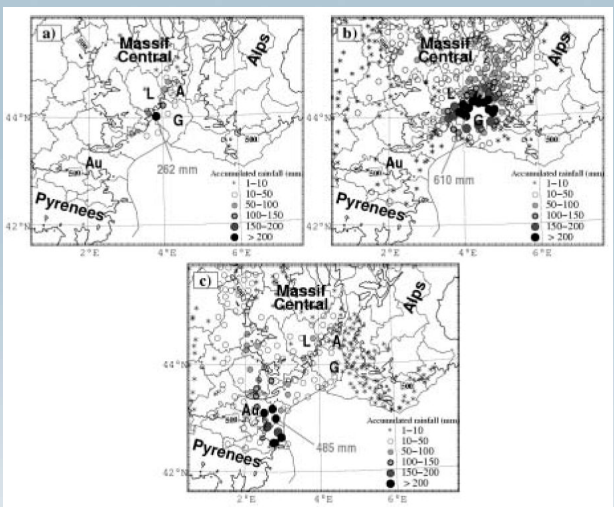

Fig.1. Surface rainfall in mm in flash floods studied in Task 1 (©Météo-France)

In Brief

The main purpose of the document is to give scientists and engineers a better understanding of the processes that lead to flash flood events.

The document examines each stage of the process:

- Meteorology of storms that have given rise to flash flood events, including the review of case studies to understand underlying patterns in meteorological behaviour;
- Hydrology of flash flood flows, involving the examination of the effects of antecedent soil moisture conditions on runoff and hill slope runoff processes; and
- Conceptualising and modelling the meteorological and hydrological processes involved in flash flooding with respect to ungauged catchments.

This work has led to a better understanding of the full process of flash flooding and is designed as an interdisciplinary report allowing the knowledge of meteorologists and hydrologists to be brought to bear on the modelling of this phenomenon. This work links closely with FLOODsite Task 16, which developed guidance for flash flood forecasting and Task 23, which undertook pilot studies in flash flood basins across Europe.

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Origins of flash floods

The report explores the meteorological origins of flash floods. Typically, flash floods occur as a result of Mesoscale Convective Systems (large ensembles of thunderstorms). The report outlines numerical modelling sensitivity studies that have been carried out in order to highlight factors that produce the particularly intense storms that result in flash flooding.

The storms that cause the most severe flash flooding possess an intense and very spatially variable rainfall coupled with a static position. This results in small catchments receiving extreme total rainfall depths and localised flash flooding. Fig. 2 shows the radar rainfall pattern recorded for one of the case study events in Italy. This shows a banded and highly localised distribution of the most severe rainfall.

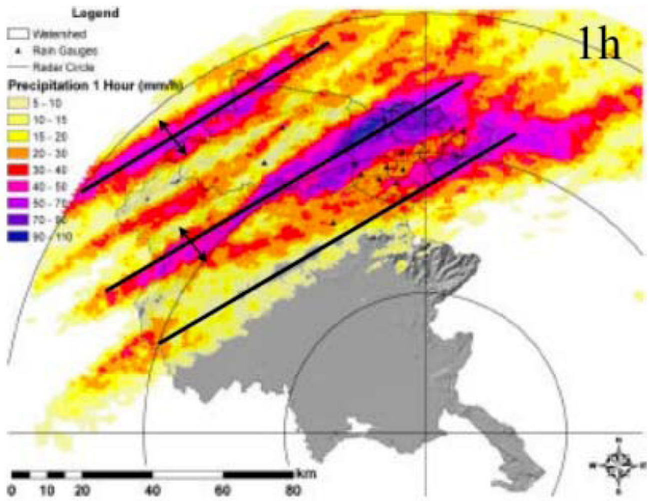

Fig. 2. Spatial patterns of rainfall over 1 hour 29th August 2003, Eastern Italian Alps (courtesy, Marco Borga)

Rainfall of this type is exacerbated by a number of factors identified in the report: low level convergence of air flow due to the Pyrenees and Alps, orographic uplift associated with the Massif Central (where an air mass is forced from a low elevation to a higher elevation as it moves over rising terrain) and the cold pool generated by the Mesoscale Convective System itself that maintains the storm in a static position.

The report also examines the behaviour of the rainfall once it arrives in the hydrological system and outlines the importance of antecedent conditions, which in turn may contain a high degree of spatial variability.

Another important consideration discussed is the generation of runoff and shallow subsurface flow on hill slopes, and modelling the movement of these components.

These hydrological considerations are then brought into some examples of modelling flash flood prone catchments in the Mediterranean region, such as the Besos catchment (see Fig. 3).

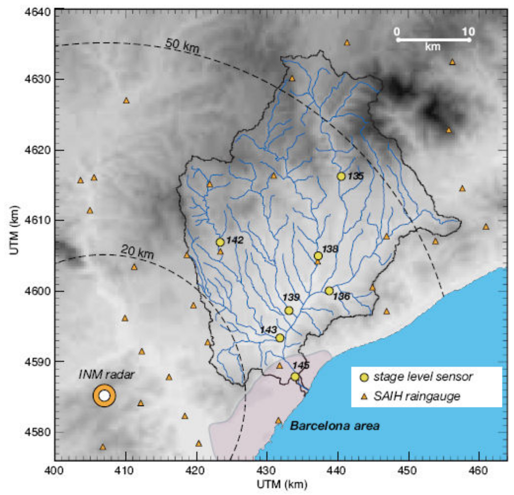

Fig. 3. Map of Besos catchment Northern Spain (1024km^2) (courtesy, Carles Corral)

The FLOODsite project

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FACTSHEET

Estimation of extremes
Guidance Document

FLOODsite Task 2 has produced:

- Guidance and examples for practitioners involved in extremes analysis of one or more environmental variables relevant to fluvial, coastal or estuarine flood risk.

The guidance document is intended for:

- Engineers and others involved in estimating or checking extreme values to be used in flood risk assessment.

Where to find the document:

- FLOODsite report T02-07-03 'Report on best suitable methods for a statistical analysis of joint probabilities of extreme event data' by Agustin Sanchez-Arcilla et al. is available in the publications section of the website www.floodsite.net.

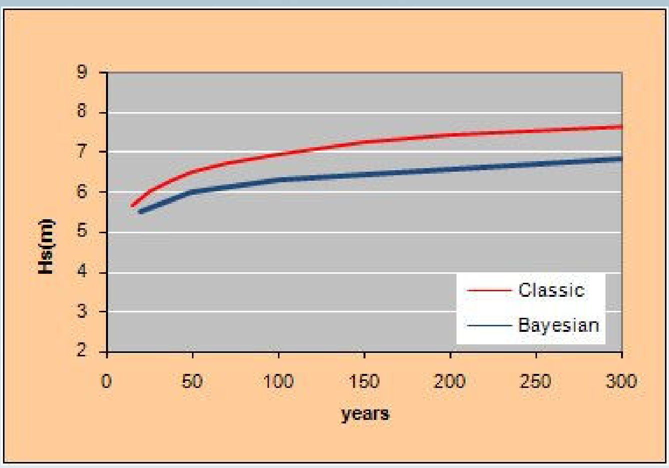

Fig. 1. Relationship between significant wave height (Hs) and return period (years) comparing Bayesian and Conventional/Classic extreme distributions (Ebro river delta, Spain)

In Brief

Two activities in FLOODsite Task 2 covered the analysis of single and joint probability extremes in river, coastal and estuarine environments, considering the sources of risk, such as: river flow and level, wave height, period and direction, and sea level.

Several statistical models and various fitting techniques are described in the document, all applied to single and multiple variables. Figure 1 illustrates the different results that can be obtained depending on the analysis method chosen.

Planning appropriate extremes analysis involves:

- Understanding the problem to be addressed,
- Selecting and preparing source data,
- Selecting the methods for analysis and parameter fitting, and
- Using the derived extremes to address the problem.

The situation is more complex when there is more than one variable, whether from multiple stations or multiple variables describing conditions at a single location.

Data gathering and preparation should consider the relevance, location, quality, length, parameters, separation into types, declustering, linking to other variables and capability to address the problem. Ideally, the data series used should be much longer than the return periods of interest. However, estimations of 100-year or even 1000-year design values are often made from recordings from only a few decades.

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Example Applications

The applications described in the guidance document illustrate some of the difficulties associated with extremes analysis, particularly for cases with more than one variable. Understanding the assumptions and interpreting the obtained results are important for extremes analysis. One example is presented here: Sea level and waves at Weymouth, UK.

Sea level recorded at each high tide during the period 1991 to 2001 was extracted from Weymouth tide gauge measurements. For each record, the concomitant wave height and period were taken from a wave hindcasting model. A long-term simulation method was used to synthesise 100,000 year samples of data for slightly different levels of dependence between sea level and wave height. The diagrams in Figure 2 illustrate the resolution of the high values available through Monte Carlo simulation. Small differences between the simulations can be seen, reflecting the range of uncertainty in the analysed dependence.

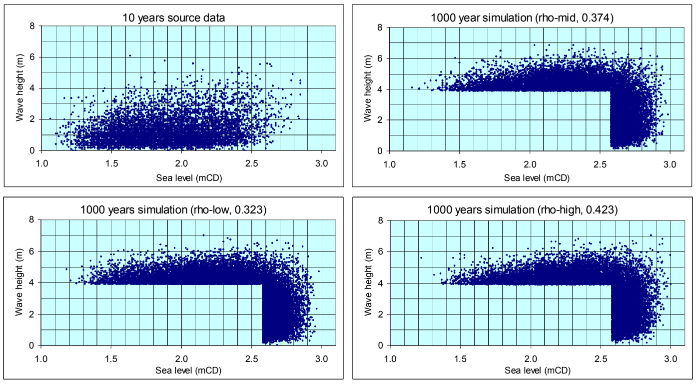

Fig 2. Comparison between source data, Weymouth sea level and significant wave height at high tide 1991-2001, and long-term simulations for three different levels of dependence

Joint exceedence curves for return periods of 1, 10 and 100 years, derived from each of the three simulations, are shown in Figure 3. The same source data set was used to produce joint exceedence curves using a simpler desk study method, and the results are given in Figure 3.

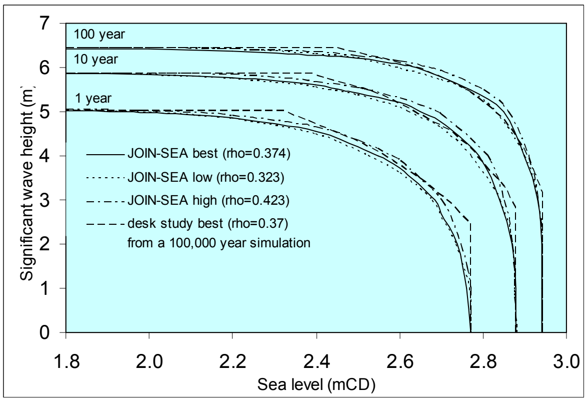

Fig 3. Joint exceedence extremes, based on Weymouth sea level and wave height at high tide 1991-2001, for different analysis methods and different levels of dependence

Other Outputs

One of the other developments in Task 2 was the incorporation of temporal sequencing into the existing JOIN-SEA joint probability analysis program code. Different methods were developed for different timescales of temporal dependence: long-term climate change; seasonal variability; and short term recurrence of individual storms.

Other reports that have been produced by member of the FLOODsite Task 2 team including T02-06-16 'Joint Probability: Dependence Mapping and Best Practice' by Peter Hawkes and Cecilia Svensson and T02-06-17 'Use of Joint Probability Methods in Flood Management: A guide to best practice' by Peter Hawkes can be found in the publications section of the website www.floodsite.net.

The FLOODsite project

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FACTSHEET

Hydraulic loading of flood defence structures

Guidance Document

FLOODsite Task 2 has produced:

- Guidance on how to select and estimate the most important hydraulic loadings for design and assessment of different types of flood defence structure.

The guidance document is intended for:

- Engineers and others involved in deriving hydraulic loading conditions for design of flood defence structures.

Where to find the document:

- FLOODsite report T02-07-04 ‘Hydraulic loading of flood defence structures’ by Andreas Kortenhaus et al. is available in the publications section of the website www.floodsite.net.

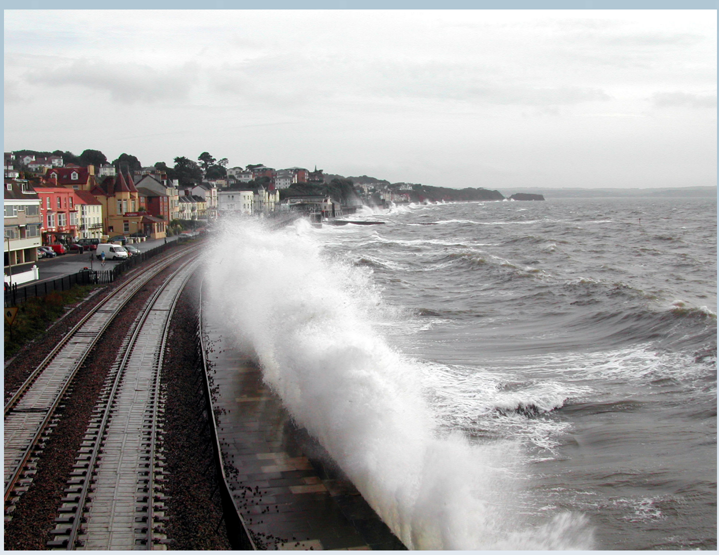

Fig. 1. Dawlish, UK

In Brief

FLOODsite Task 2 was split into three activities and one of these considered the hydraulic loading conditions for different types of flood defence structures such as sea dikes, dunes, beaches and seawalls. For each of these structures the physical processes involved are discussed in some detail and methods are given to derive relevant input parameters for failure modes of flood defences, and the behaviour of the flood defence system under actions from waves.

The report begins with a generic categorisation of the sources and relationships between flood risks. In simplified terms:

- ‘Coastal flooding’ is caused by high sea levels, large waves, and to a lesser extent wind and current, and combinations thereof.
- ‘River flooding’ is caused by an elevated water level in the river, in turn caused by high river flow and high downstream sea level.
- ‘Flash floods’ are caused by rainfall too intense to be removed by artificial or natural drainage.

The three types tend to be thought of separately in design and assessment and so are considered separately in the report. Examples in the report focus on coastal flooding.

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Risk sources and pathways

The relationship between the risk sources (large waves, high river flow, etc.) and the risk pathways, which determine the probability of flooding, is considered in the context of multiple source variables and multiple flood mechanisms.

For example, when would it be appropriate to:

- Estimate only the probability of the most likely flood mechanism at the location most likely to flood?
- Estimate the probabilities of all flood mechanisms at all locations and add them all together?
- Estimate the probabilities of all flood mechanisms at all locations, decide which would tend to occur at the same time, and then estimate an overall probability of flooding?
- Estimate which parts of the joint probability density of the source variables would cause flooding of one or more types at one or more locations?

Examples of methods for use at different coastal structures

The report provides methods to determine hydraulic loadings at different coastal structures as follows:

- Sea dikes – investigation of the wave transformation over shallow foreshores, flow parameters at seaward and landward sides of the dike and wave run-up and overtopping under 3D aspects.
- Beaches – investigation of the interaction of waves and morphodynamic changes at the coast.
- Dunes - a method is given on how to estimate the erosion of dunes due to wave attack.
- Seawalls - methods are reviewed to provide the loading details at the walls.

Wave transformation over shallow foreshores is relevant for most coastal structures. Depending on the situation, it may be combined with various complex processes such as percolation, detailed friction and turbulence parameterisations. The emphasis is on extreme wave evolution over very shallow depths. The hydrodynamic loading of natural and man-made flood defences is studied in more detail so that appropriate hydrodynamic parameters are available to describe the loading of flood defences at all points of interest.

Other Reports

The main report for FLOODsite Task 2 is T02-07-03 ‘Report on best suitable methods for a statistical analysis of joint probabilities of extreme event data’ by Agustin Sanchez-Arcilla et al. and this is also available in the publications section of the website www.floodsite.net.

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Fig. 2. Hartlepool, UK

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FACTSHEET

Coastal Flood Hazard Mapping

Guidance Document

FLOODsite Task 3 has produced:

- Guidelines for coastal flood hazard mapping.

The guidelines are intended for:

- Engineers and other practitioners undertaking flood hazard mapping.

Where to find the document:

- FLOODsite report T03-08-02 (Edition 3) 'Guidelines on Coastal Flood Hazard Mapping' by Jose Jimenez et al. is available in the publications section of the website www.floodsite.net.

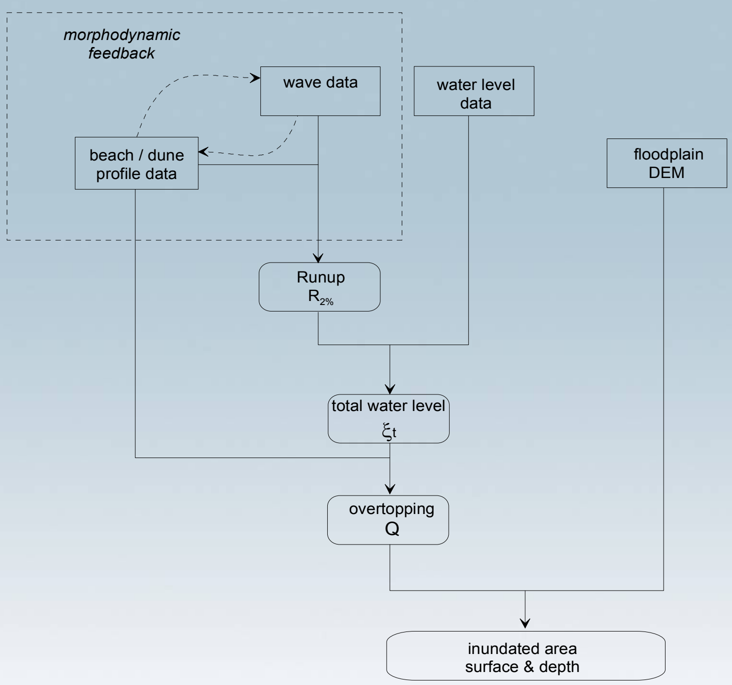

Fig. 1. Methodology to generate a coastal flood hazard map for sandy coasts

In Brief

Flood hazard mapping is a critical issue in coastal low-lying areas due to its intrinsic sensitivity to the impact of extreme storms.

FLOODsite Task 3 reviewed the main technical aspects of coastal flood hazard mapping and produced a document that recommends methods and techniques to evaluate the different variables required to characterise the (coastal) flood risk sources, pathways and receptors.

Within this context, the document provides general guidelines regarding:

- Data acquisition (requirements and techniques);
- Data analysis;
- Processes to be considered and how to evaluate them; and
- Types of flood hazard maps to be produced.

The main steps to producing a coastal flood hazard map for sandy coasts are illustrated in Figure 1.

The recommendations are particularly relevant for coastal sedimentary environments, where the impact of the storm can produce a significant morphodynamic response that will interact with the storm and can affect the scale of the flooding (enhancing or reducing its effect). The guidelines concentrate on coastal flood hazard mapping, because other EC Actions (see over) have dealt with fluvial flooding, and were implemented for a practical case in the Ebro delta, where the emphasis was on the impact of including the coastal morphodynamic response.

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Producing the maps

The main steps to producing a coastal flood hazard map for sandy coasts are:

- **Characterisation of the source.** This is primarily done by specifying wave and water level conditions associated with the required event probability to be used in the analysis. This links to work undertaken by FLOODsite Task 2 *Estimation of Extremes*.
- **Characterisation of the shoreline.** This is done by estimating the wave-induced run-up on a representative beach transect using representative beach profiles of the study area. If the area is morphodynamically active, it is necessary to estimate the coastal response to the impact of the event by using a morphodynamic model, which will update the estimated run-up and the beach/dune height during the event and, subsequently, the overtopping discharges can be calculated. This links to work undertaken by FLOODsite Task 5 *Predicting morphological changes*.
- **Characterisation of inundation.** The estimated overtopping discharges to the hinterland are "propagated" landwards over a Digital Elevation Model of the floodplain, from which the flood hazard areas are delineated in terms of extent and depth. This links to work undertaken by FLOODsite Task 8 *Flood inundation modelling/methods.*

For each of the steps above, specific recommendations are provided in the document regarding data acquisition, data analysis and modelling. These recommendations can be applied to most coastal environments, recognising that they need to be adapted to the specific conditions of the study area, including the selection of appropriate models and techniques.

Defining the coastline

Figure 2 shows the predicted flood extent for a single storm of return period of about 100 years for the North Ebro delta coast using different definitions of the coastline boundary. The red zone corresponds to the area flooded when the coast is defined by using the known (measured) highest beach profile. The yellow zone corresponds to the area flooded when the coast is defined by using the known (measured) lowest beach profile. The green zone corresponds to the area flooded when the coast is dynamically defined using the evolving (model estimated) beach profile during the storm. The flooded area ranges from 36 hectares to 155 hectares depending on approach.

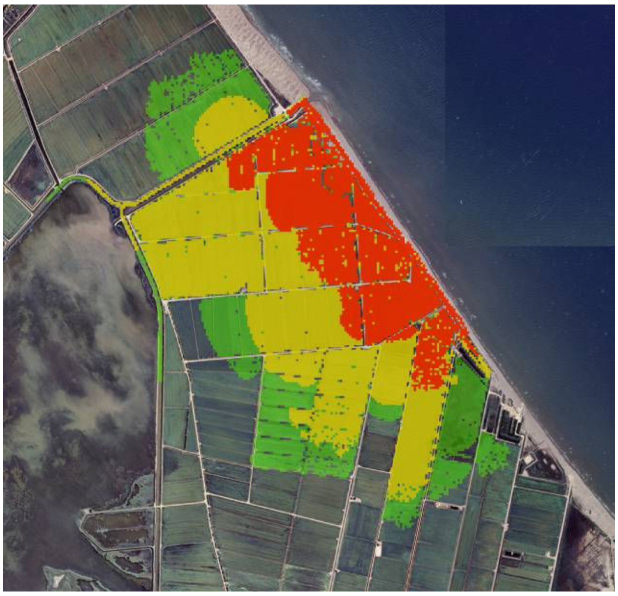

Fig. 2. Example of different flood extents generated based on different definitions of the coastline (North Ebro delta coast)

Relationship to Floods Directive

The Floods Directive requires flood hazard and flood risk mapping to be produced across the member states. The EXCIMAP group (European Exchange Circle on Flood Mapping) has produced the *Handbook on good practices for flood mapping in Europe* and *Atlas of Flood Maps*. These documents focus on river flooding, although some coastal examples are included.

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FACTSHEET

Failure Mechanisms for Flood Defence Structures

FLOODsite Task 4 has produced:

- A report collating and describing the failure mechanisms for a wide range of generic flood defence structures. It includes a definitive listing of reliability equations for the failure mechanisms for use in system modelling of flood risk.

This report is intended for:

- Engineers and others undertaking system modelling of flood risk.

Where to find the document:

- FLOODsite report T04-06-01 'Failure Mechanisms for Flood Defence Structures' is available in the publications section of the website www.floodsite.net.

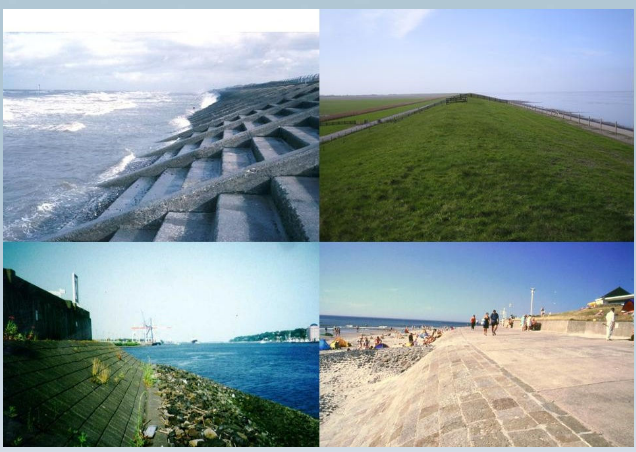

Fig. 1. Types of flood defences

In Brief

Every type of flood defence structure reacts differently under load. The factors that affect the structural performance are equally varied. In order to undertake an effective assessment of the overall reliability of a defence, it is essential to have a thorough knowledge and understanding of all key potential failure modes.

Over the past decade considerable effort has been devoted to improving our understanding of how defences fail. However, gaps in this knowledge still remain and different approaches and levels of detail can be found in different national approaches. Task 4 of the FLOODsite project *Understanding and predicting failure modes* gathered a substantial body of information and extended knowledge in a number of critical areas, to address some (but not all) of these gaps and to bring together different approaches. This resulted in the publication of a comprehensive report on 'Failure Mechanisms for Flood Defence Structures'.

It is anticipated that this store of knowledge will be updated and extended in the future as ongoing research refines and provides new knowledge on defence structure failure modes.

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Report Content

Three principal loading types are considered:

a) Water level difference across structures;

b) Wave loadings: and

c) Lateral flow velocity.

The actual hydraulic loading on any specific defence asset is likely to comprise one or more of these categories, hence multiple failure models (and methods of analysis) will be relevant to any given defence asset.

Flood defence assets are categorised into four main groups:

1. Foreshores, dunes and banks (e.g. Sand dunes, shingle beaches);
2. Embankments and revetments (e.g. homogenous and composite embankments)
3. Walls (e.g. mass concrete, sheet pile); and
4. Point structures (e.g. sluices, barriers, gates).

In practice, many defences are composite, so will include elements from more than one category (perhaps all categories).

How to use the report

The information presented in the report is intended to assist anyone working with flood defence assets in understanding potential failure modes. In particular, the limit state equations given for each failure mode may be used in system modelling of flood risk or in assessing the critical failure of a defence structure. A matrix listing the hydraulic loading and flood defence asset type directs the user to relevant summary templates where details of the particular structure failure mechanism are provided.

Other Research and Reports

Task 4 undertook other research to improve knowledge of defence structure failure modes.

Actions included investigation of

- The performance of grass under overtopping and overflowing conditions,
- The impact of air entrapment within heavily inundated embankments,
- The performance of shingle beaches under overtopping and
- Erosion processes of embankments under overtopping.
- Embankment integrity assessment using non intrusive geophysical techniques.

A review of embankment breach data from the earlier EC IMPACT project (www.impact-project.net) was also undertaken to better understand how soil parameters and soil state affects erodibility and hence breach initiation and formation.

Fig. 2. Investigating grass performance under overtopping

The research in Task 4 also links closely with work under FLOODsite Task 6 where a more detailed review of breaching processes and modelling capabilities for embankments was undertaken.

Detailed technical reports, including state of the art reviews, can be found via the project website.

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FACTSHEET

Predicting morphological changes in rivers, estuaries and coasts

FLOODsite Task 5 has produced:

- Guidance on how to predict the impact of morphological changes on flood risk

The guidance document is intended for:

- Practitioners who are involved in assessing flood risk in systems that may be subject to future morphological change

Where to find the document:

- FLOODsite report T05-07-02 'Predicting morphological change in rivers, estuaries and coasts' by Dominic Reeve et al is available in the publications section of the website www.floodsite.net.

Fig 1. Seawall at Teignmouth, beach levels lowered in front of seawall affecting flood risk (courtesy of Dominic Reeve, University of Plymouth)

In Brief

In the past it has often been assumed that the morphology of a system does not change and so flood risk is a stationary process. In many situations, however, future long-term or short-term morphological change may lead to changes in water levels or vulnerability and hence increases or reductions in the flood risk (see figures 1, 2 and 3). Flood risk managers need to take this into account when developing flood risk management strategies. The work undertaken by FLOODsite Task 5 enables future predictions of morphological changes to be made.

In the area of coastal morphology, there are new developments in four key areas, resulting in models that can be used to predict future coastal morphology changes that may affect coastal flood risk. (These models and methods are summarised on the reverse of this fact sheet.) The models were applied to selected European case studies.

Existing approaches to modelling morphological changes within fluvial and estuarine environments are also detailed in the report. For the fluvial system, a modelling framework was developed to show how morphological modelling can be implemented within a flood risk assessment to determine potential future changes in flood risk as the result of morphological change, both long-term and during a flood event. European case studies involving vertical and lateral movement and channel straightening are also described.

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Modelling coastal morphological change

The work undertaken as part of FLOODsite Task 5 resulted in the development of the following models and methods:

- The need to make long-term predictions over long coastal lengths motivated the development of a general rapid coastal evolution model that can simulate many kilometres of coastline over periods of decades or centuries to enable environmental analysis and management;
- A methodology was developed to assess the vulnerability of many kilometres of coastline to storm impacts in order to assess the potential for coastal flooding, taking into account the morphological response of the beach to the storm event;
- A beach is often a vital part of a flood defence (see figure 1) and a stochastic model was developed to predict plan shape variability for a bay; and
- A beach overwash and dune erosion model was developed to simulate the morphological changes induced when overwash occurs at a beach system during a storm (see figure 3).

These models and methods can be used to predict future coastal morphology changes that may affect coastal flood risk.

Fig 2. Trabucador Beach, breaching after November 2001 storm showing erosion of dune system by a storm

Fig 3. Erosion at toe of dune system affecting risk of failure of dunes

Related Work

Task 5 relied upon work carried out under Task 2: Estimation of extremes and Task 24: Thames Estuary Case Study. Results from Task 5 were subsequently incorporated into Task 4: Understanding and predicting failure modes. The work carried out under Task 5 also has application to the reliability analysis of flood defence structures and systems (Task 7). Details of all of these tasks can be found on the website www.floodsite.net.

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Breach initiation and growth

Predictive Models

FLOODsite Task 6 has produced:

- Models for predicting wave induced breach initiation processes, and
- Improved science in the established predictive breach models BRES and HR BREACH.

These models may be used to support:

- Inundation modelling, which underpins flood risk assessments;
- Performance assessment as part of asset management (e.g. acceptable overflow or overtopping and consequences);
- Design of emergency repairs to limit and seal a breach;
- Emergency planners seeking to identify timing, magnitude and impact of potential flooding or developing evacuation measures.

Where to find reports and models:

- Access to key reports, examples and animations is via Task 6 area of the project website www.floodsite.net. Key FLOODsite reports include T06-06-03 and T06-08-02.

Fig 1. Breach field test (IMPACT project)

In Brief

The accuracy of predicting breach initiation and breach growth through flood embankments, embankment dams and coastal dikes affects the accuracy of flood risk analysis and the degree to which flood risk management activities may be refined. Better prediction of breach initiation and breach growth allows for a more reliable flood risk assessment and greater confidence in any flood risk management plans. However, the current degree of uncertainty in the prediction of breach initiation and formation processes is high in comparison to, say, the accuracy of modelling flow in a river.

Task 6 of the FLOODsite project had the objective of improving the understanding of breach initiation and development and hence to improve the accuracy with which breaching processes could be predicted.

The focus of the research areas were:

- Analysis of wave induced breach initiation processes, including initiation through wave impacts (exposed face) and through overtopping (landward face), and

- Analysis of embankment soil state and associated processes leading to development of the next generation of the established predictive breach models BRES and HR BREACH.

Wave Induced Breach Initiation

Wave action and overtopping (rather than overflowing) flow can lead to breach initiation and ultimately failure of the embankment or dike from either the landward or seaward side. Understanding of this process was limited and no models existed to allow prediction of these failure processes. The effects of wave action and overtopping are made worse if the embankment has cracks or fissures that allow the water to ingress or allow the impact of wave forces to propagate into, and remove soil from, the cracks.

A programme of research to investigate wave induced breach initiation processes was undertaken, including detailed analysis of wave action on cracked soils and wave action in relation to soil state. Preliminary and detailed numerical models were produced to predict the wave induced initiation processes.

This research culminated with the testing to destruction of a large section of a reconstructed sea dike in the Grosse Wellen Kanal wave flume at Hannover during Spring 2008 (see Fig 2). This provided data on failure processes at near prototype scale that were then used to refine and validate the earlier predictive models.

Fig 2. Breach development caused by overtopping

HR BREACH and BRES Models

Programmes of research were also undertaken to extend and improve existing breach models. The BRES model was developed to address cohesive as well as non cohesive materials; the HR BREACH model was refined and extended to include multiple zoned structures (both cohesive and non cohesive, headcut and surface erosion).

As part of this work a detailed review of the earlier European IMPACT project breach field and laboratory data was undertaken and model development built upon this and other data. Development and testing of the HR BREACH model was also undertaken in conjunction with the CEATI (Canadian Electrical Association Technologies Incorporated) *Dam Safety Interest Group* breach modelling project team, and hence links wider international expertise and practice to the FLOODsite work.

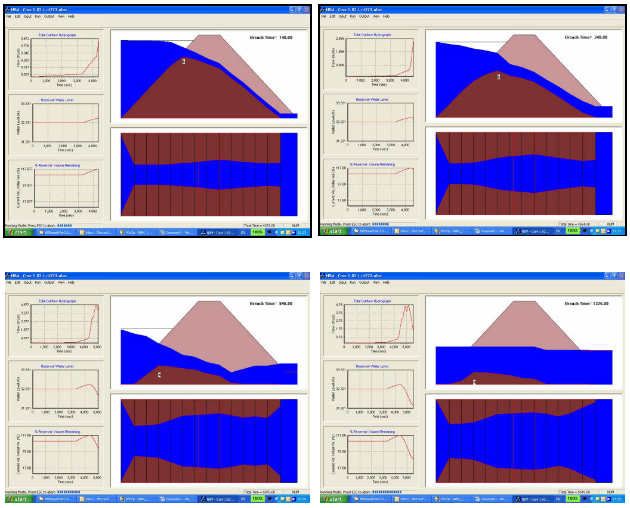

Fig 3. HR BREACH model predicting different stages of breach initiation and growth

Other Reports

More detailed information on the research into wave impact, wave overtopping and breach initiation and growth modelling can be found via the project website under FLOODsite Task 6. Example animations and guidance on how to obtain or access the different models are also available.

The FLOODsite project

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FACTSHEET

Reliability analysis of flood defence structures
Software Tool

FLOODsite Task 7 has developed:

- RELIABLE – A software tool that calculates the annual probability of defence failure and fragility curves for specific coastal and fluvial flood defence structures.

The tool is intended for:

- Engineers, scientists, researchers and specialist planners involved with the assessment and management of risks associated with flood defence structures.

Where to find the tool:

- The tool and user manual are available for download via the Task 7 area of the FLOODsite website under www.floodsite.net.

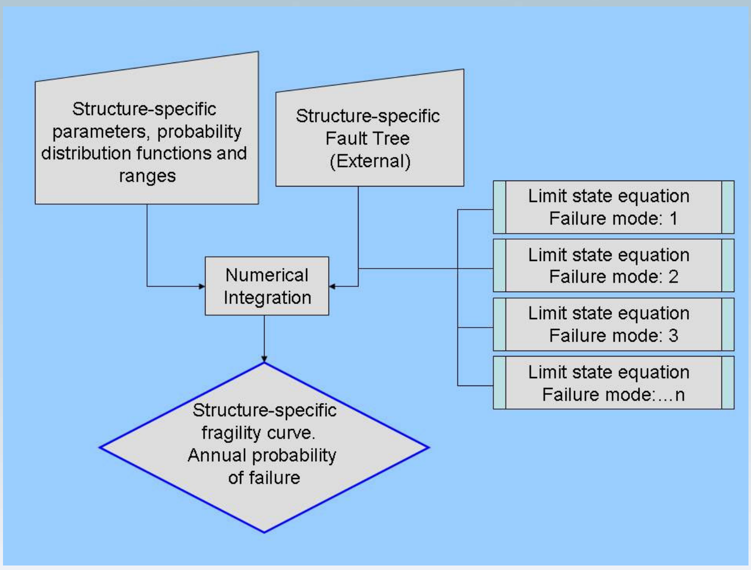

Fig 1. Components of the RELIABLE software

In Brief

Decision-making for flood risk management relies on an understanding of the likelihood of existing or proposed flood defences failing under given hydraulic loadings. This is often referred to as 'fragility'. For probabilistic risk assessment methods, a probabilistic measure of the structural performance is required. This is typically expressed as a *fragility curve* relating 'loading' to 'probability of failure' (Fig. 2). Combined with descriptors of decay or deterioration, fragility curves can be generated that enable the likely future performance of the structure to be described.

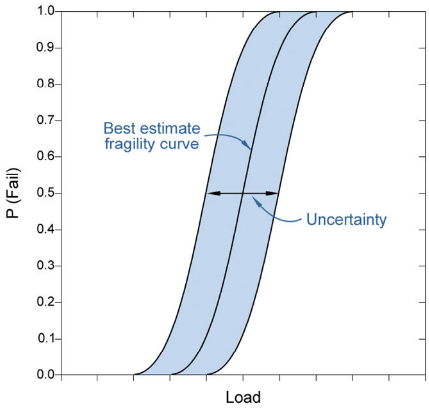

Fig 2. An example fragility curve

The RELIABLE software (Fig 1.) demands information on the flood defence relating to geometry, material properties, the potential failure mechanisms, fault tree and uncertainties, and calculates:

- The annual probability of failure of any flood defence structure;
- Fragility curves for specific coastal and flood defence structures.

SIXTH FRAMEWORK PROGRAMME

Fault Trees

Fault trees are a common method to analyse failure probabilities of complex systems. The fault tree is a tool for linking various failure mechanisms leading to an expression of the probability of system failure (e.g. breach of a sheet pile wall as shown in Fig. 3).

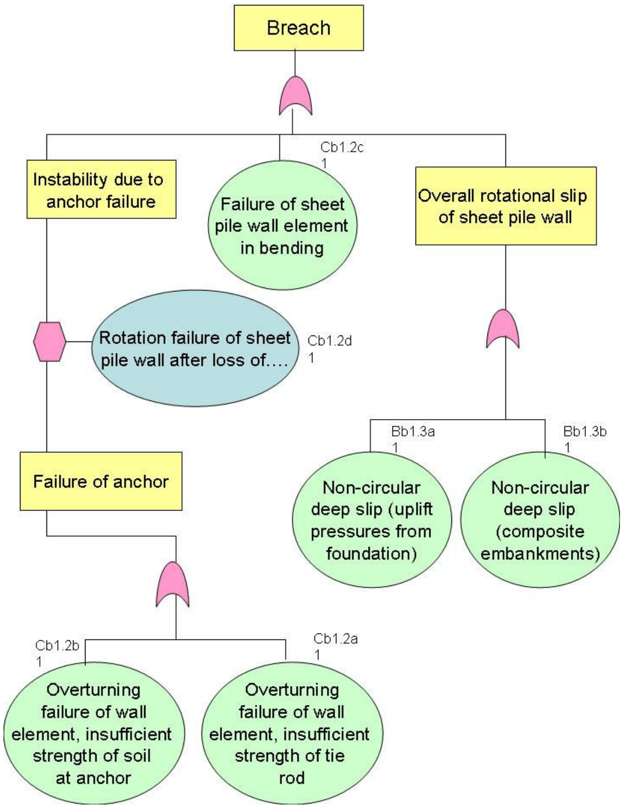

Fig 3. Example fault tree for sheet pile wall analysis

The fault trees included within the RELIABLE software contain components that consist of equations that describe the potential failure mechanisms of defences. It is also possible for users to link in external models that describe failure mechanisms that are not included within the RELIABLE suite. For example, these may include finite element geotechnical models.

The Software

The interface (Fig.4) enables the user to specify distributions and parameters for each failure mechanism in a straightforward manner. A large range of distribution types are available in the software tool (including extreme value distributions).

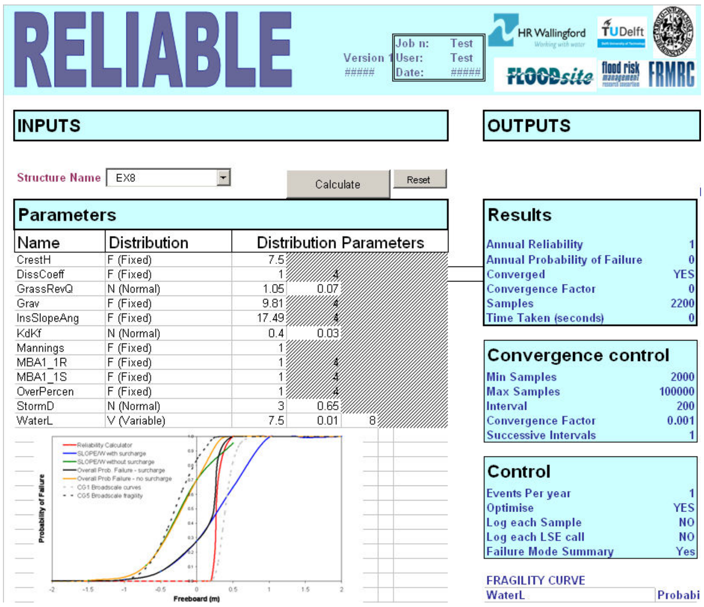

Fig 4. Screenshot of the RELIABLE interface

The outputs from the software can be used to help understand the performance of an entire flood defence system and its components.

Related Work

The development of RELIABLE has also been supported by the FRMRC research programme (www.floodrisk.org.uk).

FLOODsite Task 4 describes the failure mechanisms that underpin the equations used in the suite of RELIABLE subroutines. The software has been applied to pilot sites relating to the Thames (Task 24), Scheldt (Task 25) and German Bight (Task 27).

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FACTSHEET

Flood inundation modelling

Guidance Document

FLOODsite Task 8 has produced:

- Guidance for practitioners on selection and application of flood inundation models for flood mapping in the context of flood risk management and flood event management.

The guidance document is intended for:

- Engineers and others undertaking flood inundation modelling.

Where to find the document:

- FLOODsite report T08-09-03 'Task 8 – Flood Inundation Modelling: Model Choice and Proper Application' by Nathalie Asselman et al. is available in the publications section of the website www.floodsite.net.

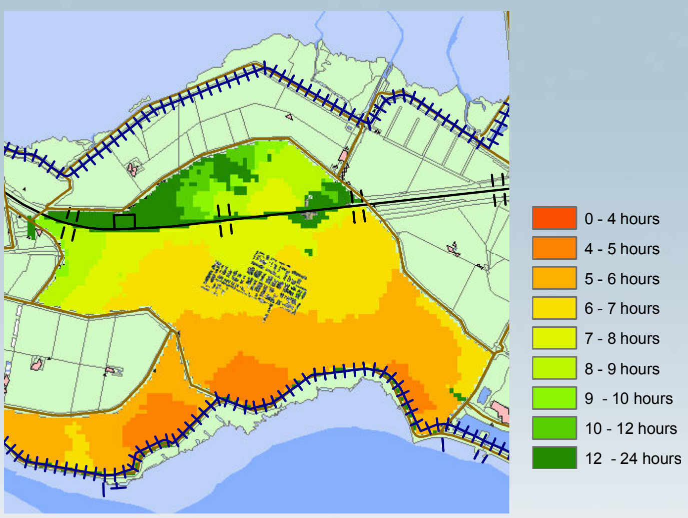

Fig. 1. Time of initial inundation after breaching of a dyke in a rural polder area

In Brief

The European Directive on the assessment and management of flood risks obliges the EU Member States to develop flood risk maps. In areas where data on floods are scarce, inundation models are indispensable. In order to obtain reliable flood risk maps it is important that a proper type of inundation model is selected and that the models are applied properly. FLOODsite Task 8 supports flood risk managers in the selection and application of inundation models.

The main purpose of the document is to give guidance to practitioners regarding the appropriate selection and correct application of 1D and 2D models for the purpose of flood inundation modelling.

The document outlines the suite of available model types, from 1D, through quasi-1D, 1D-2D linked and 2D models, providing guidance on the most relevant models for a variety of applications.

Guidance is also provided on the correct application of each model type in terms of data requirements and setting parameters such as 2D cell size.

The resulting knowledge platform allows practitioners to make informed choices on models and identify the most critical parameters for their model. This will in turn lead to improvements in the quality of flood mapping outputs for meeting the main obligations of the Floods Directive.

SIXTH FRAMEWORK PROGRAMME

Model selection

The guidance identifies four main inundation model types as shown in Fig. 2. The guidance is based on tests applying these different model types to pilot sites in order to understand the advantages and disadvantages present in each model type.

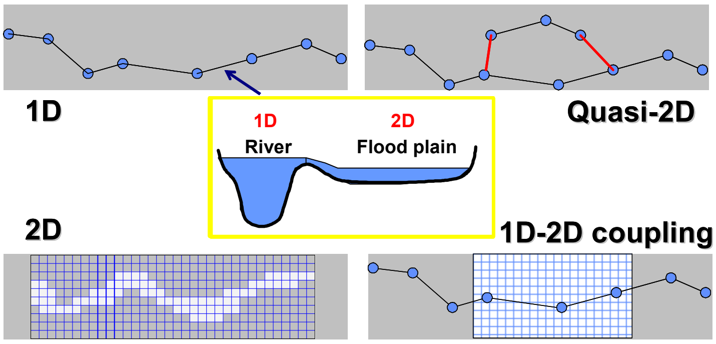

Fig 2. Four main model types appraised in Task 8.

Typically, 1D models are used to accurately represent linear features such as channels using detailed cross sections. 2D models are more commonly used to solve problems of flow over broad shallow areas such as flood plains. The guidance document gives the practitioner an understanding of the most appropriate model types for various applications and the way in which 1D and 2D can be linked together to solve channel and floodplain flow problems.

Sensitivity testing of the model types was also undertaken to gain an understanding of the impact of varying model parameters to represent data resolution or changing environmental variables.

Two examples of sensitivity tests undertaken are:

Changing cell size in 2D flow models: High resolution 2D models require high quality data and are more computer intensive. However, they will represent flow paths more accurately. This testing has lead to guidance on the appropriate data requirements and resolutions for 2D modelling problems.

Effect of wind speed and direction on 2D modelling: In some 2D modelling applications wind speed may have a significant effect on inundation patterns. The inclusion of this testing provided the guidance with novel aspects of flood modelling which may be often overlooked.

Fig.3 below shows schematically the significant effect on inundation pattern of the 1D and 2D modelling approach. A, B and C represent polders separated by dykes. Low sections of the dykes are given in red and green, green being lower than red. The 1D model will result in flow into C first since the green dyke is lower. However, in the 2D model, inflow near the red dyke causes flow into polder B first as the flood wave takes time to inundate A completely.

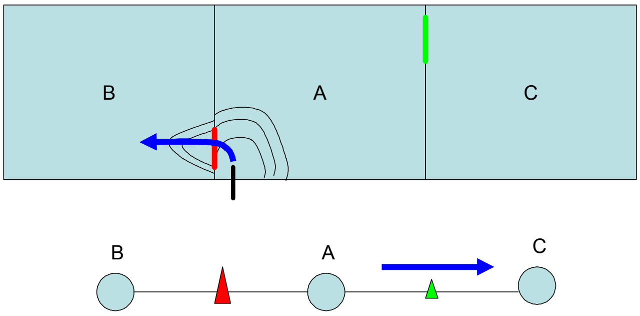

Fig 3. Schematic showing flood flow (blue arrow) between three polders in 2D (top) and 1D (bottom).

Other Reports

FLOODsite has produced a Best Practice Guide, which integrates the results from the whole of the project and translates them in practical terms and guidelines. This guide, which is also available on the FLOODsite website, is aimed at the experts and authorities that are directly involved in the flood management process.

The FLOODsite project

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FACTSHEET

Evaluating flood damages
Guidance Document

FLOODsite Task 9 has produced:

- Guidance for practitioners on how to undertake an appropriate appraisal of flood risk management strategies using flood damage evaluation techniques.

The guidance document is intended for:

- Practitioners within government authorities and executing bodies dealing with ex-ante (i.e. before the event) flood damage evaluation.

Where to find the document:

- FLOODsite report T09-06-01 'Evaluating flood damages: guidance and recommendations on principles and methods' by Frank Messner et al. is available in the publications section of the website www.floodsite.net.

Fig 1. St Ives, UK (courtesy of Ilan Kelman)

In Brief

The main purpose of the document is to give guidance to practitioners regarding the appropriate appraisal of public flood defence projects or strategies on different spatial scales.

The document gives guidance to countries just starting with flood damage evaluation studies, demonstrating how to proceed step by step in flood damage evaluations. However, it is also aimed at flood damage evaluators in countries that already possess some experience in this field, offering guidance in the form of a checklist and inspiring improvements in evaluation methods, for example, by including methods for damage types that have been hitherto neglected.

The document provides fundamental standard knowledge, specifies key principles for economic evaluation of damages and considers sources of uncertainty.

Rather than advocating specific practices, which may be superseded in time with improving science or technology, the document is intended to enable users to develop better practices. The guidelines provide a basis for recognising which innovations will be an advance upon current practice. Depending upon the current state-of-the-art, these guidelines either set out good practice or the principles of 'good enquiry'.

Such damage evaluation methods may be needed when preparing flood risk management plans required by the Floods Directive.

SIXTH FRAMEWORK PROGRAMME

Damage Types

The guidance addresses different types of flood damages. The current practice focuses very much on so called direct, tangible damages, such as damages to buildings and inventories. This document summarises different approaches for the evaluation of these damages (see figure 2) and gives guidance to build up damage databases.

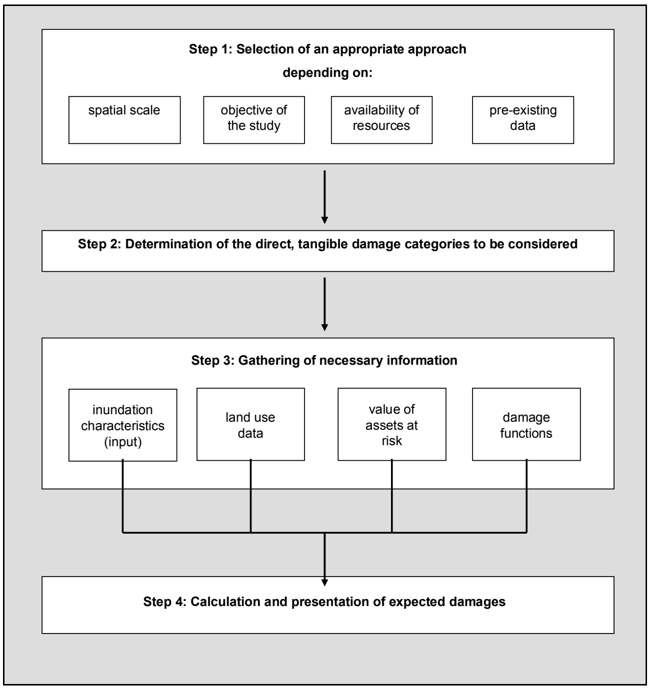

Fig 2. Basic steps of direct, tangible damage evaluation

However, the document also describes methods for the evaluation of damage categories that are currently rarely considered, like social effects (such as stress and health issues associated with the loss of irreplaceable items, evacuation from homes and general disruption to individuals and communities), environmental consequences as well as so called indirect economic damages, for example losses due to business interruption.

A final section of the document also deals with the evaluation of flood effects which were not in the focus of the research in Task 9 including loss of life and damage to agriculture. The estimation of loss of life is the most severe effect of flooding to people and has been looked in much greater detail in Task 10.

Fig 3. Contents from flooded properties, Lewes, UK (courtesy of Ilan Kelman)

Other Reports

Task 9 also produced a "country report" on damage evaluation methods applied in European practice. This report analysed approaches applied in England, the Netherlands, the Czech Republic and Germany. FLOODsite report T09-07-02 'National Flood Damage Evaluation Methods' by Volker Meyer et al. is available in the publications section of the website www.floodsite.net.

FLOODsite has produced a set of Best Practice Guides, which integrate the results from the whole of the project and translate them in practical terms and guidelines. These guides, which are also available on the FLOODsite website, are aimed at the experts and authorities that are directly involved in the flood management process.

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FLOODsite

Impacts of flooding on people

Methodology for modelling loss of life

FLOODsite Task 10 has produced:

- A methodology for modelling the impacts of flooding on people in terms of loss of life.

The methodology is intended for:

- Engineers, social scientists and government bodies involved in spatial planning and flood risk management.

Where to find further details:

- FLOODsite report T10-07-13 '*Socio-economic and ecological evaluation and modelling methodologies*' by Sue Tapsell et al. provides an overview of the methodology, whilst full details can be found in FLOODsite report T10-07-10 '*Building a model to estimate Risk to Life for European flood events*' by Sally Priest et al. Both reports are available in the publications section of the website www.floodsite.net.

Fig.1. Residents take refuge on car roof during Dresden flood of 2002, Germany (copyright IOER)

In Brief

FLOODsite Task 10 looked at innovative methods to understand, model and evaluate damages to people, property and the environment from flooding. There were four strands to this research; this fact sheet focuses on social impacts and damages, in particular human life and health.

A methodology has been developed for modelling loss of life, based on the UK Flood Risk to People project. This was applied to known flood events in Europe and refined based on an analysis of flood characteristics and the causes of fatalities at 25 locations across Europe in flood events between 1997 and 2005.

The methodology includes additional variables such as building collapse and mitigating actions. The new model is therefore more aligned with flood characteristics in the wider European context.

A GIS risk mapping system for the methodology was also included (Fig. 2). This involves the overlaying of hazard and vulnerability components to produce maps of risk of loss of life and exposure factors.

This methodology represents a significant step forward in terms of a Europe wide tool for modelling loss of life due to flooding.

SIXTH FRAMEWORK PROGRAMME

Loss of Life Modelling

The methodology for modelling loss of life due to flooding is rooted in the concept of risk as a function of hazard, vulnerability, exposure and mitigating actions.

Hazard is defined by the probability of flooding and the related depth and velocity of flood waters. This information is derived from hydraulic modelling.

Vulnerability is the susceptibility of the people, property or other receptors to suffering damage from the hazard. This is defined based on demographic data.

Exposure is a measure of the total number of receptors in a given area and the proportion of these that will be exposed to the flood water.

Mitigating actions such as issuing flood warnings will act to reduce the exposure to flooding.

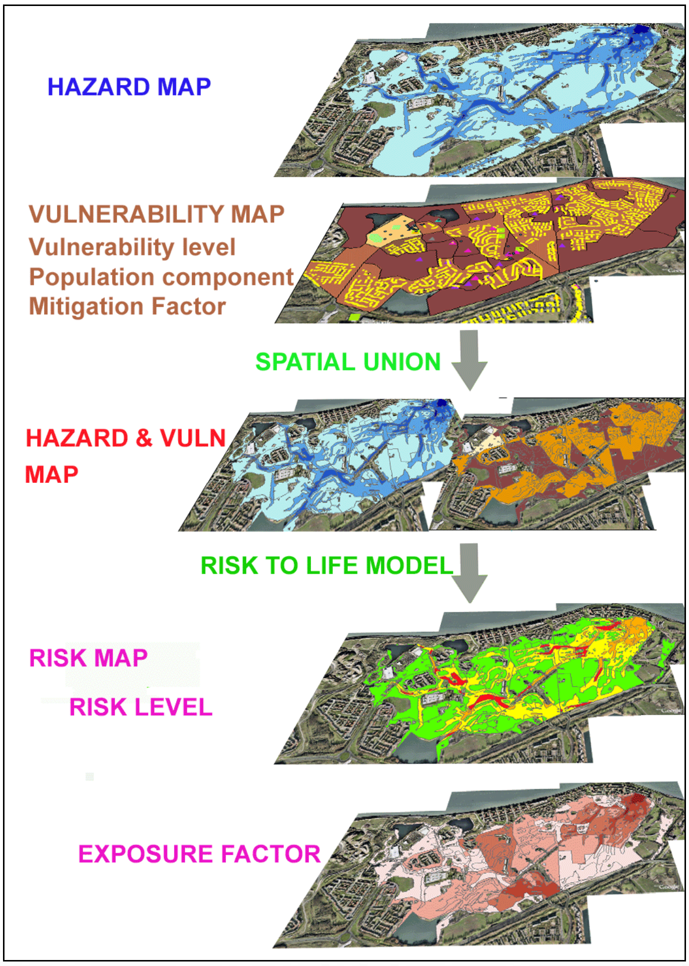

Fig 2. Schematic of loss to life GIS mapping procedure

Fig 3. Highly hazardous flooding, Dresden, Germany, 2002 (copyright IOER)

Related Work

FLOODsite Task 10 involved four separate activities. All of these activities are described in the FLOODsite report T10-07-13 '*Socio-economic and ecological evaluation and modelling methodologies*' by Sue Tapsell et al. available in the publications section of the website www.floodsite.net.

FLOODsite Task 9 also looked at the evaluation of economic damages associated with flood events and further information regarding this task can also be found on the website.

The FLOODsite project

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FACTSHEET

Effectiveness of flood warning

Methodologies for quantifying damages

FLOODsite Task 10 has produced:

- Methodologies for quantifying the effectiveness of flood warning systems for reducing the economic damage incurred through flooding.

The methodologies are intended for:

- Engineers, social scientists and government bodies involved in flood risk management.

Where to find further details:

- FLOODsite report T10-07-13 '*Socio-economic and ecological evaluation and modelling methodologies*' by Sue Tapsell et al. provides an overview, whilst full details can be found in FLOODsite report T10-07-12 '*Modelling the damage reducing effects of flood warning*' by Dennis Parker et al. Both reports are available in the publications section of the website www.floodsite.net.

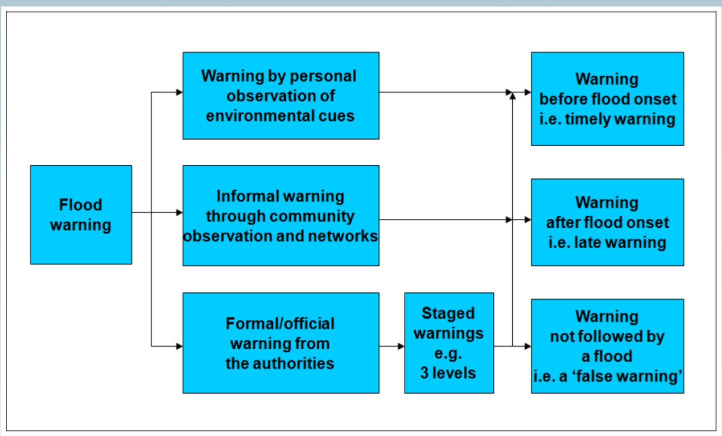

Fig.1. The different types of flood warning for which responses need to be considered

In Brief

FLOODsite Task 10 looked at innovative methods to understand, model and evaluate damages to people, property and the environment from flooding. There were four strands to this research; this fact sheet focuses on the effectiveness of flood warnings in reducing flood impacts.

Successful flood warning is not merely the forecasting of a flood event, it is the mitigating actions put in place in response to the forecast. The methodologies considered by this activity relate to the latter.

Two modelling methodologies are presented for quantifying the effects of different warning lead times and mitigating actions with the associated reduction in damage costs: the first is for use with the detailed calculation of domestic household damage savings, while the second is intended to provide a more flexible approach that incorporates a variety of mitigation strategies.

These methodologies are a significant step forward in European flood risk management, since they allow the justification of optimum flood warning systems on the basis of reduced flood damage costs. They also allow quantification of the effectiveness of mitigation strategies for reducing damage costs.

Guidance for improving flood warning response among receptors is also provided alongside the methodologies in the relevant FLOODsite reports (see T10-07-12 and T10-07-13). This is a frequently overlooked but vital component of a successful flood warning system.

SIXTH FRAMEWORK PROGRAMME

Response to flood warning

Adequate flood warning allows mitigating actions to be put in place, which may reduce the monetary damage costs due to flooding. This particular activity within the FLOODsite project has focused not on the generation of flood warnings but the potential to reduce damages by timely mitigating actions (such as activation of operational flood defences including closure of flood gates, construction of demountable defences, business contingency plans, contents moving and evacuation, flood proofing of residential properties).

Two modelling methodologies for the quantification of flood warning effects on monetary damages are presented:

- A 'Europeanised' version of the UK Flood Hazard Research Centre (FHRC) model. Refinements were made on the basis of new data since the model's inception and the addition of the effect of evacuation of people on flood damages which was previously excluded. This model is designed for the detailed calculation of flood warning effects on domestic household damages.

- The second, known as the Flood Warning Response and Benefit Pathways (FWRBP) model was developed with a much wider scope for the analysis of the impacts of flood warning under a variety of mitigating actions.

Fig. 2 illustrates one output of the FWBRP model on a case study of a European city. The chart shows that mitigating actions resulting from flood warnings (taking into account different levels of feasibility of implementing them for the city in question) can significantly reduce flood damage costs. Also, in this situation the flood warning lead time between 2 and 8 hours plays a small role in reducing damages. This is not necessarily the case in other scenarios that might have a different group of response pathways activated.

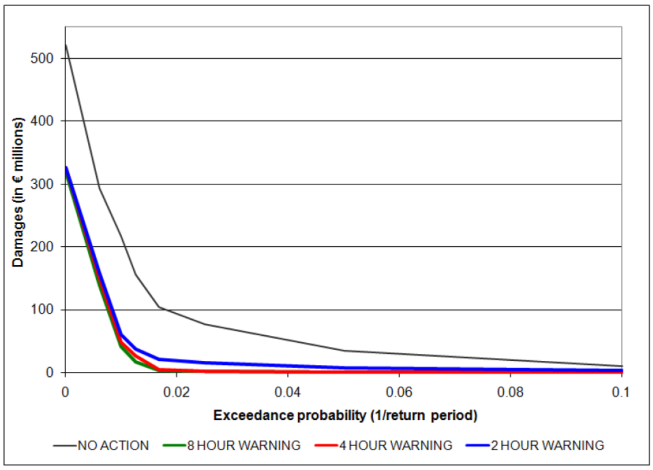

Fig 2. Damage versus flood event exceedance probability for no mitigation and mitigating actions requiring different warning lead times (FWRBP)

Related Work

FLOODsite Task 10 involved four separate activities. All of these activities are described in the FLOODsite report T10-07-13 '*Socio-economic and ecological evaluation and modelling methodologies*' by Sue Tapsell et al. available in the publications section of the website www.floodsite.net.

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FACTSHEET

FLOODsite

Flood induced pollution

Methodology for quantifying effects on ecosystems

FLOODsite Task 10 has produced:

- A methodology for quantifying the effects of flood induced pollution (multiple pollutants) on ecosystems.

The methodology is intended for:

- Engineers, scientists and government bodies involved in flood risk management and assessment.

Where to find further details:

- FLOODsite report T10-07-13 '*Socio-economic and ecological evaluation and modelling methodologies*' by Sue Tapsell et al. provides an overview of the methodology, whilst full details can be found in FLOODsite report T10-07-14 '*The effects of floods and flood-induced pollution on ecosystem health'* by Arjan Wijdeveld et al. Both reports are available in the publications section of the website www.floodsite.net.

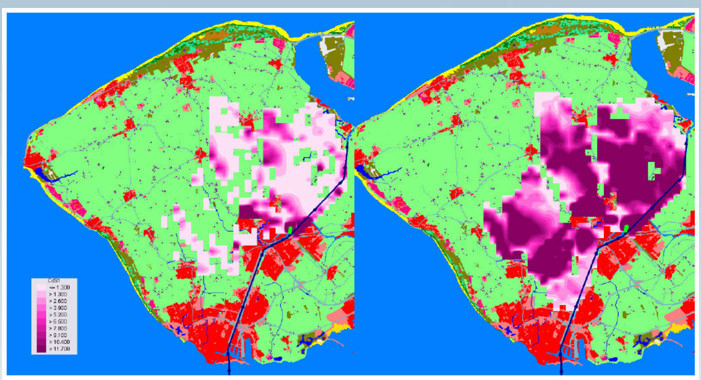

Fig.1. Maps of Cadmium deposition at two time slices after a flood event (Middelburg)

In Brief

FLOODsite Task 10 looked at innovative methods to understand, model and evaluate damages to people, property and the environment from flooding. There were four strands to this research; this fact sheet focuses on the effects of floods and flood-induced pollution on ecosystem health.

This research was based around the existing Optimal Modelling for Ecotoxicological Assessment (OMEGA) framework. The framework was enhanced and tested for use against multiple pollutants in aggregating pollutant effects.

The methodology allows the integration of water quality and sediment modelling with the ecotoxicological response of receptors. The highest level of output is given as a Potentially Affected Fraction (PAF) of the total population of interest. The methodology is therefore intended as a tool for identifying areas particularly susceptible to flood induced pollution.

Case studies of typical applications of the OMEGA framework are also presented alongside the methodology. The first case study (Western Scheldt) illustrates the application of the modelling framework to chronic estuarine pollution response over a year. The second case study (Middelburg) models the ecological impact of inundation of a low lying polder due to dyke failure (see Fig. 1).

SIXTH FRAMEWORK PROGRAMME

FACTSHEET

Effects of Flooding on Ecosystems

Fig.2 illustrates the hydraulic modelling components required by the OMEGA framework. The Sobek 1D/2D model is used to simulate the movement of water on tidal cycles. This is combined with a water quality model that allows simulation of pollutant concentration over time. Example maps are shown in Fig. 3 and Fig. 4.

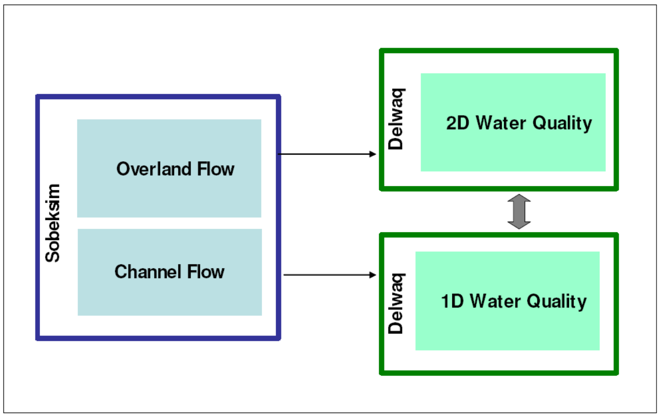

Fig 2. Combination of Sobek hydraulic modules with water quality models

Once the pollutant concentration has been modelled the OMEGA methodology may be implemented to calculate the PAF of different species groups for a combination of pollutants. This is extremely useful information as a component in considering the management of flood risk.

Related Work

FLOODsite Task 10 involved four separate activities. All of these activities are described in the FLOODsite report T10-07-13 '*Socio-economic and ecological evaluation and modelling methodologies*' by Sue Tapsell et al. available in the publications section of the website www.floodsite.net.

FLOODsite Task 8 looked at the inundation modelling tools and which models are best to use under which conditions. Further information regarding this task can also be found on the website.

The FLOODsite project

FLOODsite is an interdisciplinary project integrating expertise from physical, environmental and social sciences, as well as spatial planning and management. The project has over 30 research tasks across seven themes, including pilot applications in Belgium, the Czech Republic, France, Germany, Hungary, Italy, the Netherlands, Spain and the UK. The EC has identified FLOODsite as one of its contributions to the European Flood Action Programme. Further details can be obtained as follows:

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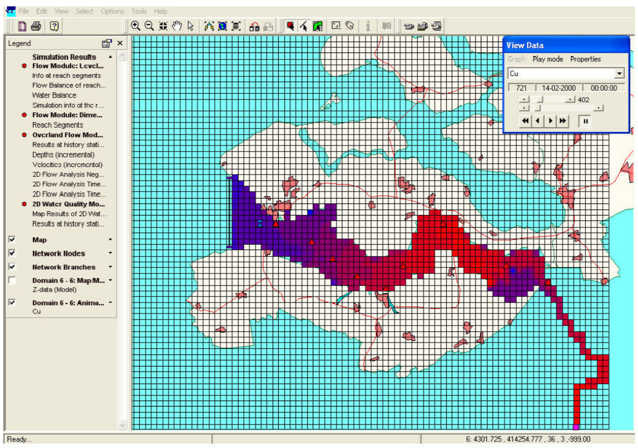

Fig. 3. Dissolved copper concentration in the Western Scheldt on 14-02-2000 (spring peak)

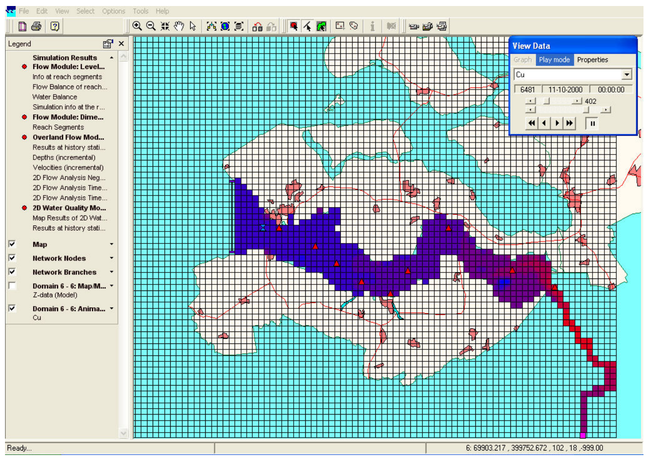

Fig. 4. Dissolved copper concentration in the Western Scheldt on 11-10-2000 (autumn low)

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FACTSHEET

FLOODsite

Multi-criteria analysis

Methodology for evaluating flood risk

FLOODsite Task 10 has produced:

- A methodology for evaluating flood risk based on a range of criteria, including social and environmental as well as economic factors.

The methodology is intended for:

- Engineers, social scientists and government bodies involved in flood risk management.

Where to find the document:

- FLOODsite report T10-07-13 '*Socio-economic and ecological evaluation and modelling methodologies*' by Sue Tapsell et al. provides an overview, whilst full details can be found in FLOODsite report T10-07-06 'GIS-based Multicriteria Analysis as Decision Support in Flood Risk Management' by Volker Meyer et al. Both reports are available in the publications section of the website www.floodsite.net.

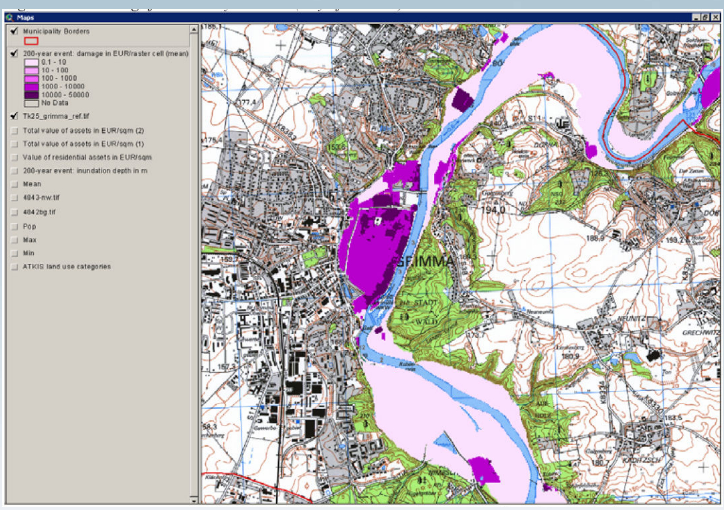

Fig.1. Map of expected economic damage for the 200 year flood in Grimma, Germany

In Brief

FLOODsite Task 10 looked at innovative methods to understand, model and evaluate damages to people, property and the environment from flooding. There were four strands to this research; this fact sheet focuses on the development of a Multi-Criteria Analysis (MCA) methodology for the decision-making process within flood risk management and a new methodological framework that attempts to address three shortcomings in existing decision-making techniques:

- Historically flood risk analysis concentrates on monetary damages (cost-benefit analysis). The MCA presented here also includes social and environmental consequences.
- The spatial distribution of the effects of flood risk management policies are often not included, potentially leading to disparities in benefits in different locations. This is considered by mapping risks and risk reducing effects respectively in a GIS environment.
- Uncertainty in flood risk assessment is often not communicated to the decision-maker. Therefore, some possibilities for integrating uncertainties in the results of risk analysis in this GIS-based MCA approach are also presented.

The methodology provides the possibility for evaluating monetary and non-monetary flood risk in an integrated way as well as showing their spatial distribution and the uncertainties included.

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Selecting Criteria for MCA

The MCA methodology focuses on economic, social and environmental measures of risk, which are aggregated together to form a single risk metric. Since they are measured in different units a means of standardisation is provided in the methodology.

The economic, social and environmental risks are calculated as a function of the hazard. In the figures presented here, risks have been calculated based on flood depth and the vulnerability of each type of receptor as follows:

- Economic damage has been based on the property value and its susceptibility (this links to the work undertaken by Task 9 on socio-economic damage evaluation);
- Social risk has been based on the population density in a given area and 'social hot spots' such as hospitals, schools, old people's homes, etc.; and
- Environmental risk is based on the potential for erosion, deposition and environmental damage.

The weighting of each criterion is undertaken and integrated into a single risk metric. Weightings are included to allow the representation of the relative importance of each risk type. This step allows for the incorporation of stakeholder preferences into the risk mapping process. Figs 2 and 3 illustrate two MCA risk maps produced for the city of Grimma on the river Mulde in Germany using different weightings for the economic, social and environmental risk components.

Related Work

FLOODsite Task 10 involved four separate activities. All of these activities are described in the FLOODsite report T10-07-13 '*Socio-economic and ecological evaluation and modelling methodologies*' by Sue Tapsell et al. available in the publications section of the website www.floodsite.net.

FLOODsite Task 9 also looked at the evaluation of economic damages associated with flood events and further information regarding this task can also be found on the website.

The FLOODsite project

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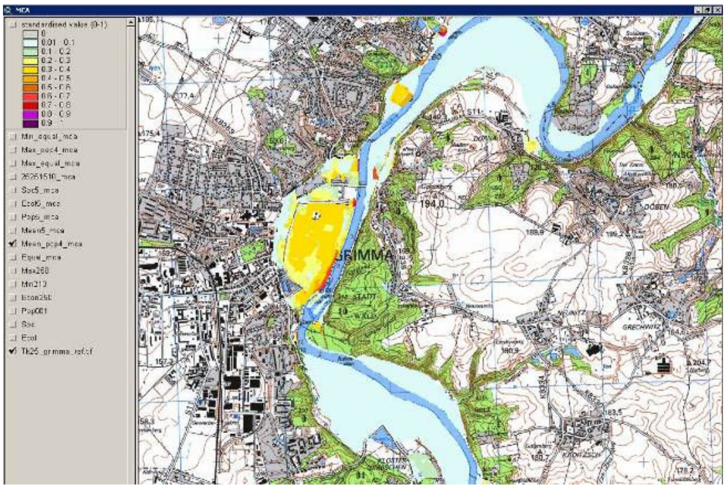

Fig 2. Multi-criteria risk values weighted towards economic (0.4) and social risk (0.4) (environmental and social hot spots both have weightings of 0.1)

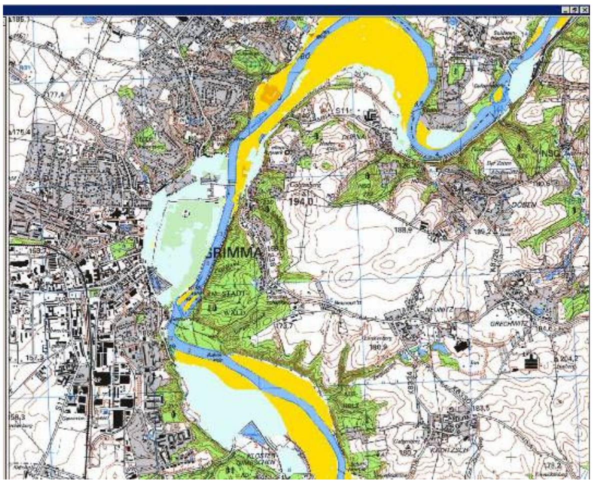

Fig 3. Multi-criteria risk values weighted towards environmental risk (0.625) (all other weightings 0.125)

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FACTSHEET

Communities at risk from flooding

Guidance Document

FLOODsite Task 11 has produced:

- Guidance on how to maximise the effectiveness of flood preparedness, mitigation and recovery strategies amongst affected communities.

The guidance document is intended for:

- Practitioners within government authorities and institutions involved with the impact of flooding on communities, before, during and after flood events.

Where to find the document:

- FLOODsite report T11-07-14 ‘Recommendations for flood risk management with communities at risk’ by Annett Steinführer et al. is available in the publications section of the website www.floodsite.net.

Fig 1. (above) The 2002 Elbe flood in Griesen (Copyright: André Künzelmann, Helmholtz Centre for Environmental Research)

Fig 2. (right) The post-flood monument in Mühlberg (Copyright: Annett Steinführer, Helmholtz Centre for Environmental Research)

In Brief

The main purpose of the document is to give guidance to practitioners on reducing the impact of flooding on affected communities. It concentrates on the following topics:

- Flood risk awareness
- Flood preparedness
- Flood risk communication
- Participation in flood risk management
- Social vulnerability

The guidance identifies problems flood risk managers face, gives recommendations regarding how to approach these problems and also provides background information. This approach adds value to the guidance by ensuring that readers understand the full context of the guidance. It furthermore gives a concise and understandable summary of the extensive research undertaken in Task 11.

The guidance is based on a ‘bottom up’ approach involving participation of all stakeholder groups in a process of triangulation, which refers to the analysis of a particular problem from a range of viewpoints. This has lead to particularly practical and evidence based recommendations that are informed by a well researched understanding of the interaction of communities and decision makers.

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Research themes

The research of Task 11 was undertaken on the basis that in order to understand the effects of a disastrous flood on a community, it is important to take into account the phases preceding and following the flood, as well as the actual event itself.

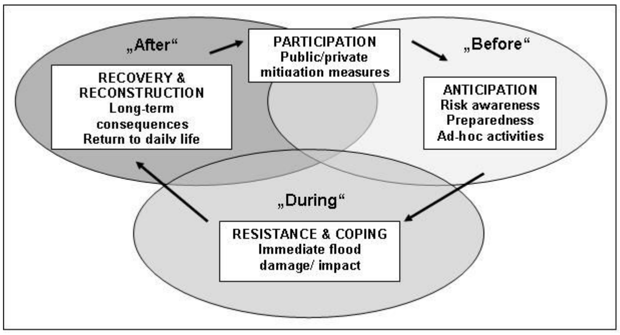

Fig 3. Conceptual hazard cycle for flooding

The core research was based on two main strands:

- Social vulnerability and its relation to resilience
- Social 'constructions' (e.g. values, belief systems, perceptions, etc.) of flood risk, focusing on their implications for flood risk management

It was found that social vulnerability was particularly difficult to quantify in the social-spatial contexts included in the research. Social vulnerability depends on several variables that change with the specific flood conditions experienced and through each phase of the flood process. The guidance does however distinguish certain groups within communities that under certain conditions have a higher overall vulnerability.

The guidance challenges the assumption that community flood preparedness is a direct result of risk awareness as there is no identifiable causal link. Instead, it points towards the importance of institutions involved in flood risk management and how much they should be aware of the responsibilities that affected communities attribute to them. A key task for flood risk managers is the correct recognition of the balance between community and institutional involvement in flood preparedness and resilience.

Communities and institutions

The guidance identifies a considerable gap between the views, behaviour and actions undertaken by residents and those perceived by flood risk professionals. While communities delegate responsibility for the handling of floods to flood risk managers, the latter are assuming that residents at risk are willing (and able) to participate in flood risk management. This gap is clearly described and guidance on how to tackle it is given.

The guidance also examines the conflict between the use of insurance as a swift and equitable tool for recovery against the disincentive this provides towards flood preparedness behaviour in the face of acknowledged flood risk.

Other Reports

Task 11 produced a vulnerability indicator report T11-07-01 and a series of "country reports" on community vulnerability in Germany (T11-07-08), Italy (T11-06-08) and England and Wales (T11-07-11). These reports are brought together in report T11-07-13 'Vulnerability, resilience and social constructions of flood risk in exposed communities. A cross-country comparison of case studies in Germany, Italy and the U.K.' All are available in the publications section of the website www.floodsite.net.

The FLOODsite project

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FACTSHEET

Evaluation of existing measures

Guidance Report

FLOODsite Task 12 has produced:

- Guidelines to evaluate effectiveness, efficiency, robustness and flexibility of measures and instruments that have been carried out as part of flood risk management in the past.

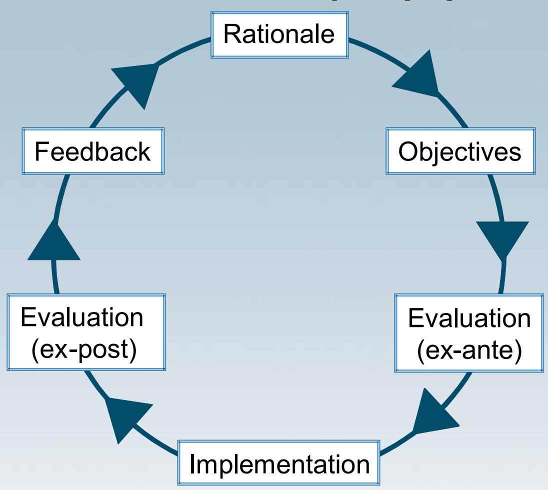
The guidance document is intended for:

- Practitioners who wish to understand more about the intended and unintended effects, effectiveness and efficiency of past flood risk management.

Where to find the document:

- FLOODsite report T12-07-03 'Guidelines for the ex-post evaluation of measures and instruments in flood risk management' by Alfred Olfert is available in the publications section of the website www.floodsite.net.

Evaluation in the policy cycle



Ex-post evaluation in the policy cycle of flood risk management

In Brief

The guidelines provide a framework for the ex-post (i.e. after implementation) evaluation of measures and instruments that have been carried out for flood risk reduction.

Criteria, indicators and evaluation methods are provided to help users to evaluate past experience in order to improve flood risk management in the future. The methodology addresses criteria effectiveness, efficiency, robustness and flexibility.

In order to carry out an evaluation of existing interventions, it is necessary to consider the type of intervention and the conditions under which it has performed. The methodology described contains two main elements:

- Indicators describing the effects of management actions, and
- Criteria and methods for the evaluation of these effects.

Application of the methodology should enable practitioners to learn about both the intended and unintended effects of past measures, and determine their effectiveness and efficiency. The methodology also takes account of the robustness of the measures that have been carried out. This is the ability of the measures to perform in a range of known and unknown conditions.

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FACTSHEET

FLOODsite

Classification of measures and instruments

The guidelines divide management actions into ‘Measures’ and ‘Instruments’. Measures are direct physical interventions while instruments are changes to the social, financial and institutional contexts of flood risk system. A range of different interventions are considered in the context of different types of water bodies, including rivers, lakes, estuaries and coastal waters.

A web based information tool has been developed that classifies almost one hundred known measures and instruments.

Indicators

Indicators are used to measure the intended and unintended effects of measures and instruments. Within the methodology an indicator set is suggested that includes social, economic and ecological indicators suitable for a wide range of potential measures and instruments. The precise set of indicators required for an evaluation is selected on a case by case basis, depending on the type of intervention studied and the individual set of conditions relevant to a particular case.

A web based tool has been developed that enables the user to select a case specific indicator set.

Criteria

Measures and instruments are assessed using specified criteria. These criteria consider:

- Effectiveness – extent to which objectives are achieved
- Economic Efficiency – cost/effect analysis
- Robustness – performance under different conditions
- Flexibility – operational and long-term flexibility

The guidelines provide methods for determining the values of these Criteria for a specific study.

Methodology

The methodology provides an operational and tested framework for the comprehensive ex-post evaluation of flood risk management measures and instruments. Its application will contribute to the further development of flood risk management and improve our ability to learn from flood risk management measures and instruments carried out in the past.

The FLOODsite project

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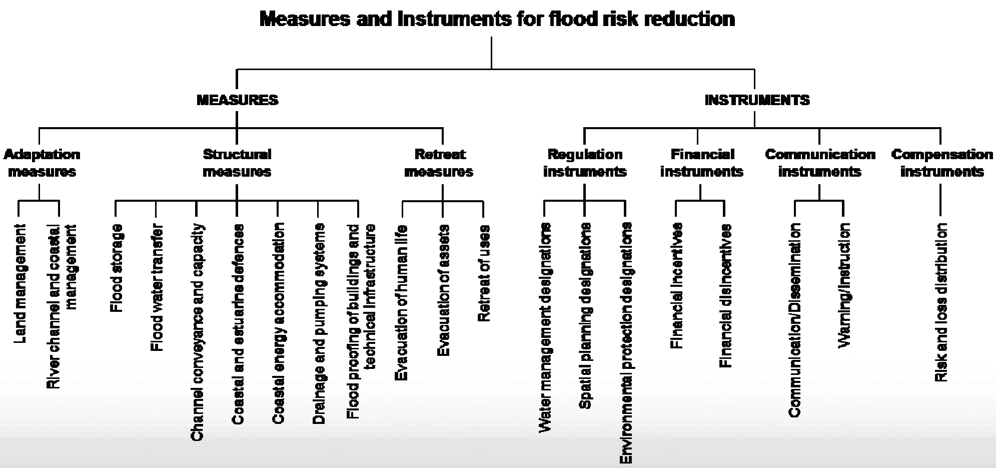
Classification of measures and instruments



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FACTSHEET

Strategic planning for flood risk management

Guidance Document

FLOODsite Task 13 has produced:

- Guidance on strategic planning for flood risk management.

The guidance document is intended for:

- Policy makers and practitioners within government authorities concerned with the development of flood risk management strategies.

Where to find the document:

- FLOODsite report T13-07-04 'Strategies for Pre-Flood Risk Management - Case Studies and Recommendations' by Gérard Hutter et al. is available in the publications section of the website www.floodsite.net.

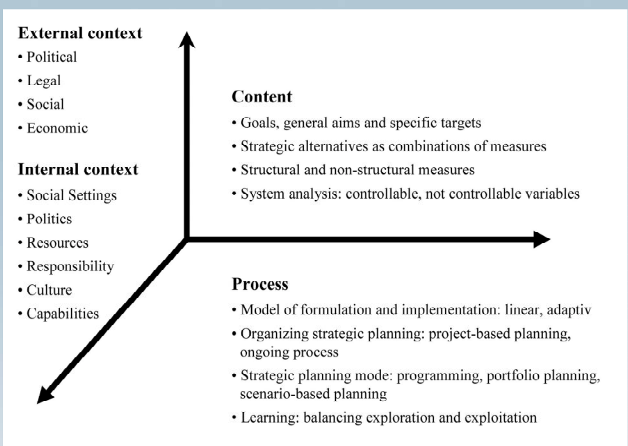

Fig. 1. The three dimensions of strategies for FRM (Hutter & Schanze, 2008)

In Brief

The main purpose of the document is to give guidance regarding the generation of successful flood risk management strategies. The guidance views the formulation of strategy as the key step between technical understanding, policy and practice.

The guidance is based on research into decision making processes and is informed by the historical development of flood risk management in the EU from flood protection to risk based approaches.

Strategies can be defined as multi-dimensional, as they encompass content, process and context (see Fig.1). Guidance on forming strategies is tailored around this concept, which is ideal for the highly uncertain processes involved in flood risk. Furthermore, the guidance discusses the merits of strategy-making as either an adaptive or a linear process, giving an understanding of the most valuable applications of both concepts.

This guidance document has been specifically developed for the field of flood risk management. This means that only strategy and decision making theory most relevant to flood risk management has been considered.

SIXTH FRAMEWORK PROGRAMME

Linear and Adaptive Strategy

The guidance identifies the changing paradigm of strategy formulation from linear to adaptive. Table 1 outlines the main characteristics of both. The hallmark of the linear strategy model is the notion of a well-ordered, step-by-step procedure to design, assessment and implementation of strategic alternatives. This model structure is predictable, but does lack the ability to cope with evolving political structures and technical understanding.

	Linear model of strategy	Adaptive model of strategy
Process	Sequential process of planning, programming, and implementation Top-down strategy making	Continuous alignment of content and process with context Combination of bottom-up initiatives and top-down strategic decisions
Content	Predefined system of goal, aims, targets, and measures Integrated set of strategic, operative and resource plans	Emerging pattern of measures, targets, aims, goals Flexible configuration of resources
Context	Stable Predictable	Unstable Limited predictability

Table 1. The linear and the adaptive model of strategy in different contexts (Hutter 2006)

Adaptive strategy is particularly suited to flood risk management since it allows for changing understanding of flood hazards and political decision making processes, although elements of linear strategy are still useful.

The guidance resulted in four principles for the development of flood risk management strategy:

- **Nurturing diversity in decision-making**

  This involves promoting the incorporation of a wide variety of scenarios and potential outcomes when building strategy. It is important in ensuring the most successful outcome is achieved in decision making.

- **Embracing uncertainty and change**

  The incorporation of risk based approaches to account for uncertainty in the science around flood risk management.

- **Combining the range of existing knowledge systems into the decision-making process**

  This involves creating strategies designed around the exploitation of existing knowledge to inform the decision making process.

- **Creating opportunity for self-organisation to generate new knowledge**

  This relates to adaptive strategy, which builds in capability to explore new options and gain new knowledge over time.

Other Reports

FLOODsite has produced a set of Best Practice Guides, which integrate the results from the whole of the project and translate them in practical terms and guidelines. These guides, which are also available on the FLOODsite website, are aimed at the experts and authorities that are directly involved in the flood management process.

The FLOODsite project

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FACTSHEET

Towards sustainable flood risk management

Guidance Document

FLOODsite Task 14 has produced:

- Guidance on how to undertake assessment of strategic flood risk management alternatives against an uncertain future.

The guidance document is intended for:

- Engineers, scientists and policy makers concerned with producing long term sustainable flood risk management strategies.

Where to find the document:

- FLOODsite report T14-08-01 'Long-term strategies for flood risk management: scenario definition and strategic alternative design' by Karin de Bruijn et al. is available in the publications section of the website www.floodsite.net.

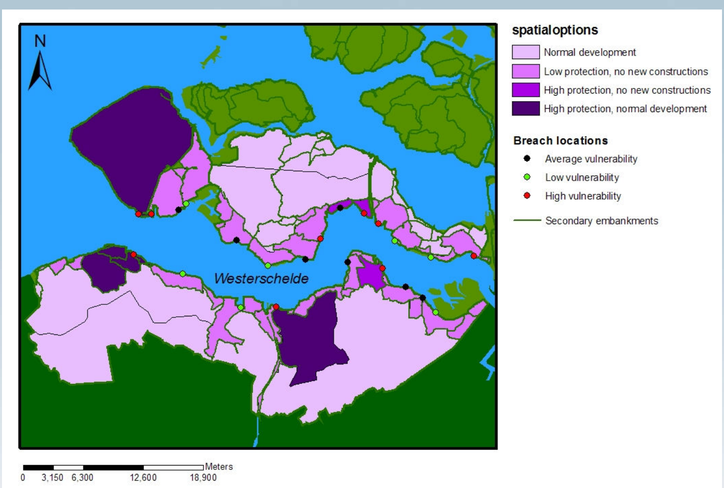

Fig.1 Risk based spatial planning zones. Development guided by flood risk.

In Brief

The main purpose of the document is to give guidance to practitioners on the most effective methods of carrying out analysis of the performance of flood risk management strategic alternatives into the future.

The document outlines a recommended methodology for carrying out the assessment and offers guidance at each of the three main stages:

- Development of future scenarios - These are concerned with providing potential future trajectories of demographics, economics and climate against which flood risk management alternatives are examined.
- Development of flood risk management strategic alternatives - These cover the range of approaches from 'do nothing' to 'full flood resistance' and also include spatial planning options.
- Assessment of alternative strategies - This is the analysis of every conceivable permutation of strategic alternative and future scenario. This involves multi-criteria assessment against economic, ecological and societal criteria.

The guidance details the most suitable approach to undertaking each of the three stages, complete with examples from the UK and the Netherlands. The guidance is not overly prescriptive, but does provide the foundations for logical and transparent strategy analysis, such as may be needed for flood risk management plans, required by the Floods Directive.

SIXTH FRAMEWORK PROGRAMME

Strategies and Scenarios

The guidance makes an important distinction between strategy and scenario in terms of strategy assessment. A strategy is a portfolio of measures for flood risk management, which can be physical or policy based. Strategies are determined as part of flood risk management. Scenarios on the other hand are potential future world trajectories that are uncertain and dependant on factors outside the influence of flood risk management decision making.

In this way scenarios allow the effectiveness of strategies to be assessed in a range of potential futures. This guidance document provides valuable information for adopting this powerful methodology correctly.

The guidance recommends the selection of preferably four or fewer future scenarios that encompass a full range of possibilities and are downscaled to the region of interest. Table 1 gives some examples of future scenarios from the UK Foresight project.

Table 1. Example qualitative future scenarios

	World Market	**National Enterprise**	**Global Sustainability**	**Local Stewardship**
Climate change	High	Medium/high	Medium/Low	Low
Economy	High growth	Average growth	Low growth	Very low growth
Demography	High increase	Average	Low increase	Low decrease

The guidance recommends selecting four or fewer alternative strategies that again encompass a full range of potentially adopted flood risk management approaches. Since the assessment is relatively broad scale, a wide range of strategies is appropriate to demonstrate the full range of their future implications.

The guidance recommends a methodology for the assessment of strategic alternatives against future scenarios. A multi-criteria approach is preferred using three themes:

- People (social outcomes),
- Planet (ecological outcomes) and
- Profit (economic costs and benefits).

The guidance also suggests rating each strategy according to its flexibility in the face of uncertainty and the requirements of the strategy to adapt. The method is acknowledged to have shortcomings as it is semi-quantative and the three criteria require relative scoring based on expert judgement. Table 2 gives an example output from such an assessment where the scores for each 'scenario-alternative' combination are integrated into a single simple measure.

Table 2. Example output from scenario assessment

		Future scenario		
		Scenario 1	Scenario 2	Scenario 3
Strategic alternative flood risk management	Alternative 1	+	+	+
	Alternative 2	+ +	-	- -
	Alternative 3	- -	- -	+ +

Other Reports

FLOODsite has produced a set of Best Practice Guides, which integrate the results from the whole of the project and translate them in practical terms and guidelines. These guides, which are also available on the FLOODsite website, are aimed at the experts and authorities that are directly involved in the flood management process.

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FACTSHEET

Satellite observation of rainfall

Structured algorithm system

FLOODsite Task 15 has produced:

- A tool to provide quantitative estimates of rainfall using satellite data to provide additional information for identifying rainfall events that might trigger flash floods.

The guidance document is intended for:

- Practitioners involved in flash flood prediction and analysis.

Where to find the document:

- FLOODsite report T15-07-08 'Observation of storm rainfall for flash-flood forecasting Volume 2: satellite structured algorithm system (SAS)' is available in the publications section of the website www.floodsite.net.

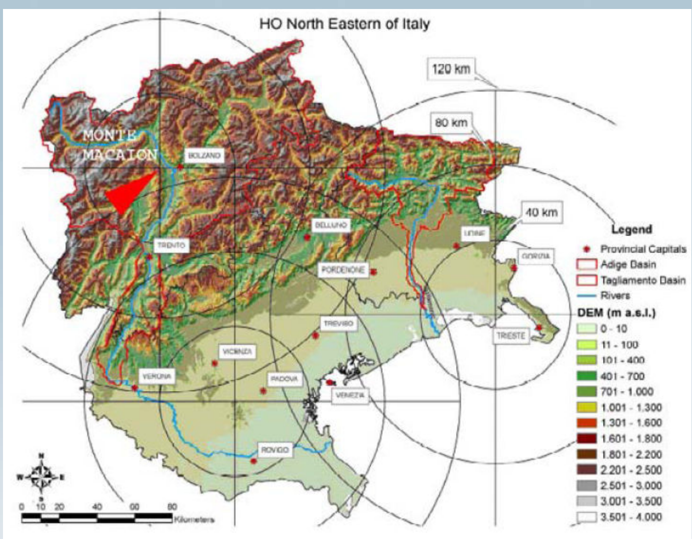

Fig. 1. Topography of north Italy including the Trentino-Alto Adige region showing radar stations of the North-eastern Italy Hydro-meteorological Observatory

In Brief

Flash flooding is caused by extreme rainfall events, which are normally small in extent, spatially variable and have a limited duration. Such events can rarely be described adequately by ground-based rain gauges.

Rainfall radar is the only ground based method that is able to observe extreme rainfall events at the spatial and temporal resolutions required, but these events commonly occur in mountainous areas where radar is prone to larger errors than in flatter areas. In these more mountainous areas, where there is low rain gauge and radar network coverage, satellite data can be used to improve rainfall estimations.

As part of FLOODsite Task 15, a Structured Algorithm System (SAS) has been developed to provide satellite based Quantitative Precipitation Estimation (QPE) at spatial and temporal scales required for flash flood prediction and analysis.

The work was based on the use of the high resolution geostationary satellite data provided by Meteosat-6 and Meteosat-8. The system was tested on selected rainfall events in the Italian Alps, the Cévennes-Vivarais region (France) and the Saxon Elbe river basin (Germany).

SIXTH FRAMEWORK PROGRAMME

Estimation of Rainfall

The tool includes existing methods of estimating rainfall from satellite data (such as the Auto-Estimator Technique and the Enhanced Convective Stratiform Technique – ECST) and a new ‘combined’ method in which the rainfall rate is estimated from the Infra-red cloud top temperature. These estimates of rainfall are then corrected to take account of topographic information, direction of wind, gradient of the local terrain in the direction of the wind, wind speed. A moisture correction factor and a cloud growth rate correction factor are also applied.

Comparison with Radar Data

Comparisons were made in the following areas: the Trentino-Alto Adige region of northern Italy (see Fig. 1 and Fig. 2), the Saxon Elbe river basin and the Cévennes-Vivarais region. One event was used for each basin. It was found that, in general, the rainfall rates estimated from the satellite data were less than those estimated from the radar. This was due in part to the following:

- Differences in location between the satellite and radar data, due to their different angles of view and scanning times, and
- Satellites scan only the top of the clouds and are unable to detect the processes within the cloud or the falling rain.

Related Work

Task 15 looked at developing SAS based on both radar and satellite data. Quantitative precipitation estimation algorithms for both systems were developed and assessed.

Details of the work undertaken developing the radar SAS can be found in FLOODsite report T15-08-02 ‘Observation of storm rainfall for flash-flood forecasting Volume 1: radar structured algorithm system (SAS)’ by Guy Delrieu *et al*. is available in the publications section of the FLOODsite website.

The FLOODsite project

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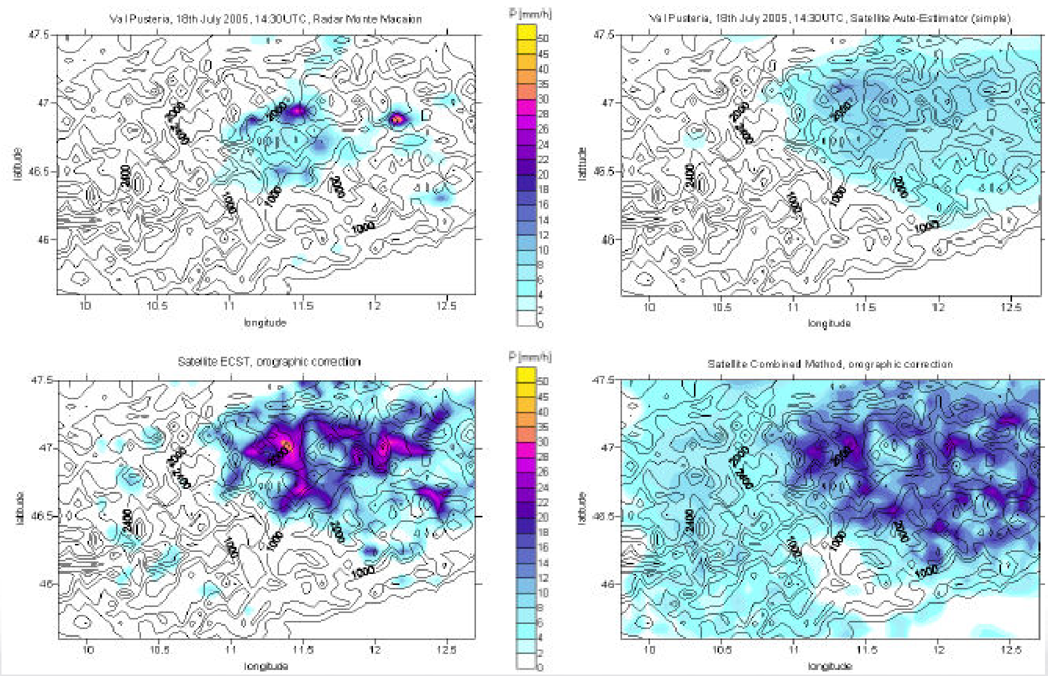

Fig. 2. Comparison between rainfall rates measured by radar and derived by Auto-Estimator, ECST and Combined Method (with orographic and wind correction)

The work described in this fact sheet was supported by the European Community’s Sixth Framework Programme through the grant to the budget of the Integrated Project **FLOODsite**, Contract GOCE-CT-2004-505420

Radar observation of rainfall

Structured algorithm system

FLOODsite Task 15 has developed:

- An improved set of methods for quantitative precipitation estimation (QPE) using radar imagery.

The guidance document is intended for:

- Practitioners involved in flash flood prediction and analysis.

Where to find the document:

- FLOODsite report T15-08-02 ‘Observation of storm rainfall for flash-flood forecasting Volume 1: radar structured algorithm system (SAS)’ by Guy Delrieu *et al*. is available in the publications section of the website www.floodsite.net.

Fig.1. Study area in southeastern France, showing the four S-Band weather radar systems (with 100-km range markers) deployed by Météo-France 1999-2004. The Bollène radar system is number 1.

In Brief

Lead-time is a critical issue in delivering an effective flood warning service. The science of radar hydrology has led to significant improvements in rainfall estimation and nowcasting (i.e. forecasting for the next three or six hours) since the 1970s. However, substantial operational and research effort is still required to optimise the observation strategies and data processing techniques especially in flash-flood prone regions. This effort is justified by the potentially higher utility of weather radar systems in mountainous regions compared to lowland regions. Mountains induce a wide range of meteorological phenomena at the mesoscale and their topography accentuates the generation of damaging floods. Both these factors emphasise the need for real-time quantitative precipitation estimation in order to mitigate flood and flash-flood hazards.

As part of FLOODsite Task 15, a set of improved methods for QPE from radar imagery were developed and piloted, using French and Italian sites and building on earlier intensive observational campaigns. Improvements in the interpretation of the radar imagery were made in several areas including:

- Dynamic identification of ground clutter
- Rain-type separation algorithms,
- Estimation of the vertical profile of radar reflectivity conditional on the rain type,
- Ground level rainfall estimation from corrected reflectivities above,
- A stochastic model to analyse the influence of the spatial variability of raindrop size distribution on rainfall estimation using weather radar.

SIXTH FRAMEWORK PROGRAMME

French Case Study

The radar and raingauge datasets collected during the Bollène-2002 Experiment for a series of five intense rainfall events were used for assessing the proposed methods. Results of this assessment included the following:

- The new ground clutter identification and correction algorithm worked satisfactorily.
- Good radar QPE is feasible within the 100-km radar range in mountainous regions by using well-sited, well-maintained radar systems and sophisticated physically-based radar data processing systems.
- The added value of the space-time adaptive processing is not very significant.

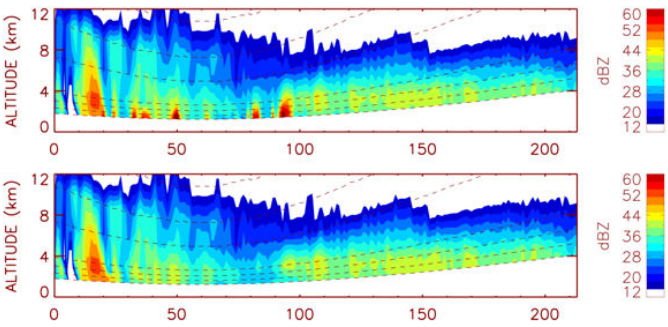

Fig. 2. Vertical cuts in volume radar data for an example mesoscale convective system. Top figure is raw mean reflectivity. Bottom figure is mean reflectivity after ground clutter identification and interpolation.

Italian Case Study

A methodology, based on the Generalised Likelihood Uncertainty Estimation (GLUE), was proposed to take into account and assess the uncertainty arising from errors in parameter selection for the radar structured algorithm system (SAS).

Data used in this study were collected by the C-band Doppler radar located on the Monte Grande Hill in northern Italy, close to Venice and Padua (Fig. 3).

Results of this assessment concluded that the uncertainty assessment approach is not only practical and relatively simple to implement, but can also provide useful information about the strength and limitations of the radar SAS.

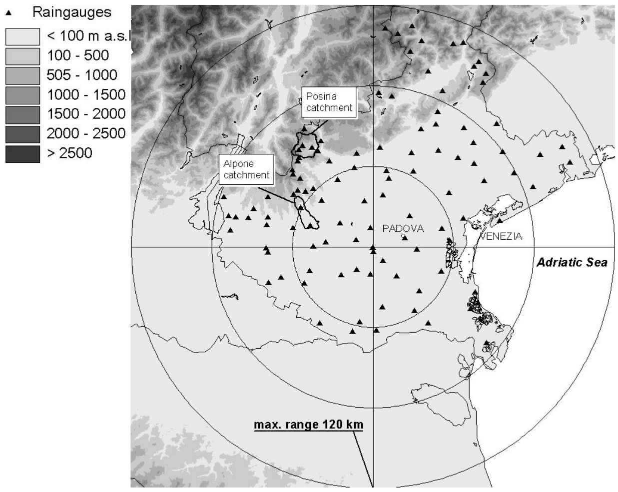

Fig.3. Italian study area showing location of the Monte Grande weather radar and the Posina and Alpone basins and raingauge network.

Related Work

Task 15 looked at developing structured algorithm systems based on both radar and satellite data. QPE algorithms for both systems were developed and assessed. Details of the work undertaken developing the satellite SAS can be found in FLOODsite report T15-07-08 ‘Observation of storm rainfall for flash-flood forecasting Volume 2: satellite structured algorithm system (SAS)’ is available in the publications section of the FLOODsite website

The FLOODsite project

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FACTSHEET

Flash flood forecasting

Guidance Document

FLOODsite Task 16 has produced:

- Guidance on the most appropriate methods for forecasting flash flood events.

The guidance document is intended for:

- Practitioners and other professionals dealing with flash flood areas.

Where to find the document:

- FLOODsite report T16-08-02 ‘Real time guidance for flash flood risk management’ by Marco Borga et al. is available in the publications section of the website www.floodsite.net.

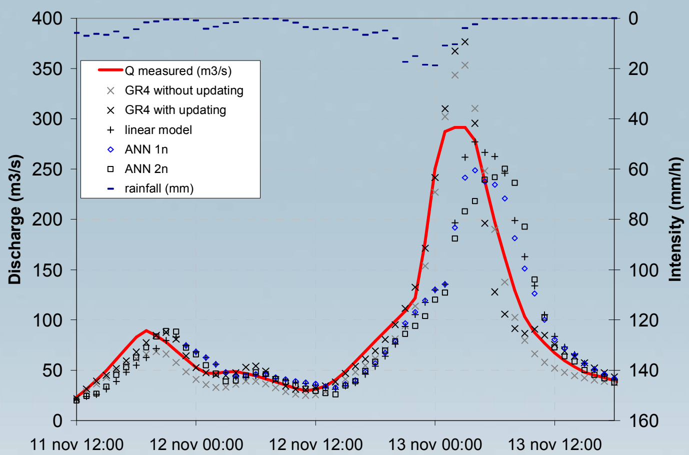

Fig. 1. Example of observed (red) and forecast flash flood discharge of a gauged catchment using various rainfall runoff models

In Brief

The main purpose of the document is to give guidance to practitioners on the most appropriate methods for forecasting flash flood events.

Flash flooding is a difficult hazard to mitigate since it typically affects small catchments, which are usually ungauged, and may occur as the result of highly localised rainfall events. The large number of catchments affected and low density of population and infrastructure often means that structural flood mitigation measures are not economically viable. Flood forecasting and warning are valuable tools in providing some level of mitigation against flash flood risk.

The guidance document is based around analysis of the performance of two methods for flash flood forecasting;

- Flash flood warning on ungauged basins with distributed and semi-distributed rainfall runoff models. This uses observed and forecast rainfall, distributed in space and coupled with catchment processes.
- Rainfall threshold levels based on Flash Flood Guidance (FFG), developed initially in the US. This assesses localised flash flood potential within a large area, incorporating the influence of initial soil moisture conditions.

The document discusses the data required for successful flash flood forecasting and illustrates the accuracy of each method using case study examples.

SIXTH FRAMEWORK PROGRAMME

Forecasting Methods

The research on distributed flash-flood modelling of ungauged basins aimed to make best use of model results, even when modelled flows are affected by a spatial bias. Distributed flood simulations are represented in terms of flood frequency, providing historical context for assessing the severity of an event. The two case studies showed that the method provides useful information for flash flood warning. The coupling of the hydrological models with rainfall forecasts allowed the forecast of peak, magnitude and spatiotemporal distribution of the event, with an absolute lead time in the order of 24 hours; sufficient time for authorities to take precautionary measures. Fig.2 shows the output of a probabilistic flash flood forecast.

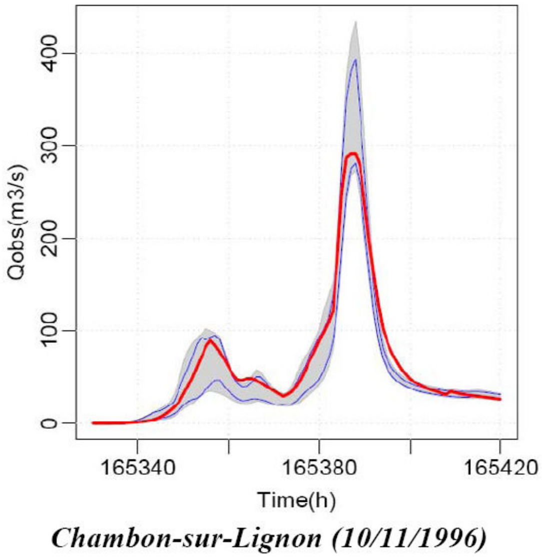

Fig. 2 Example of observed (red) and forecast 10 and 90 (grey) percentile flood flows

The research on the FFG rainfall threshold forecast method shows clearly that the performance of the FFG system depends on the accurate representation of the initial soil moisture conditions. Improvements can be expected from refining the model states in real-time. A natural choice is to adjust the basin soil moisture state by making use of runoff data in a real time model as runoff is usually an excellent indicator of the basin soil moisture state. Fig 3 shows a typical output from the rainfall threshold forecast approach. The forecast values are given in terms of a rainfall depth above a threshold known to cause flooding.

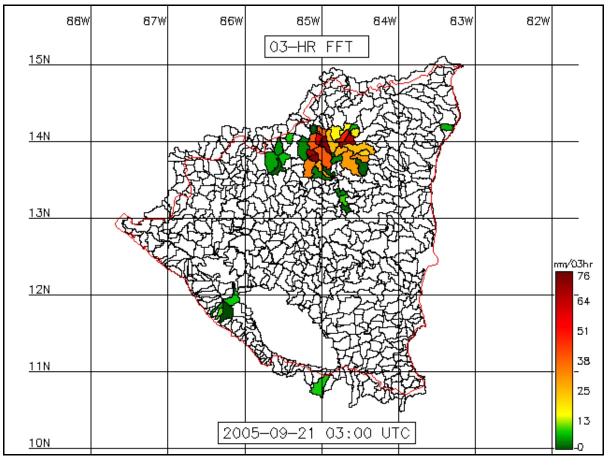

Fig. 3 Sample output of rainfall threshold type flash flood forecast

The most significant cause of uncertainty in both approaches is the rainfall event itself. The guidance recommends a move towards probabilistic flood forecasting rather than deterministic, single value forecasts.

Other Reports

Task 1 has produced a related report on hydro-meteorological modelling. FLOODsite report T01-07-01 'Hydrometeorological modelling for flash-flood areas' by Sandrine Anquetin et al. is also available in the publications section of the website www.floodsite.net.

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FACTSHEET

Evacuation and traffic management

Review of model use for emergency planning

FLOODsite Task 17 has produced:

- A review and assessment of evacuation and traffic management models for use in flood emergency planning.

The document is intended for:

- Engineers, scientists and planners involved with emergency planning for floods and flood event management.

Where to find the document:

- FLOODsite report T17-07-02 'Evacuation and traffic management' by Darren Lumbroso *et al.* is available in the publications section of the FLOODsite website www.floodsite.net.

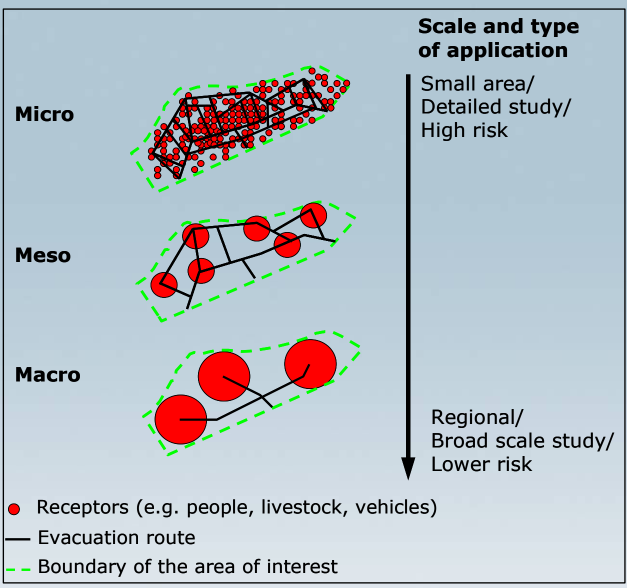

Fig. 1. Different scales of evacuation modelling

In Brief

Evacuation and traffic management are major issues for flood event managers. Evacuation, either out of the flood risk area or to safe shelters located within the area, is a possible response when flooding threatens life, health or well-being. Emergency plans allow the emergency responders to target the people most at risk, but also to evaluate the feasibility of an evacuation given the time available and to identify the most efficient and safest evacuation strategies.

In recent years, awareness has increased of the need for tools that facilitate evacuation and emergency planning. To develop emergency management plans, information is needed on the characteristics of potential floods, the current infrastructure, the capacity of the infrastructure and the vulnerability of the people at-risk.

FLOODsite Task 17 evaluated models to support evacuation planning and examined a number of aspects of evacuation and traffic management including:

- Flood event management practice in Europe;
- The requirements for evacuation planning based on end user consultation; and
- Evacuation modelling.

This led to the application and testing of evacuation and traffic management models relevant to flood event management in the Thames Estuary in the UK and the Schelde Estuary in the Netherlands.

SIXTH FRAMEWORK PROGRAMME

FACTSHEET

FLOODsite

Key Findings

Different evacuation models were evaluated. The key findings of the review can be summarised as follows:

- Evacuation modelling for flood events falls outside the remit of flood risk managers in most EU countries. Evacuation models are rarely used at present to inform flood emergency plans developed by emergency planners in Europe.
- There are potential benefits for flood risk managers to incorporate evacuation modelling into their flood event management work. Figure 2 shows an evacuation model used to reconstruct the events in 1953 when the flood defences of Canvey Island in the UK were breached due to an extreme storm surge.

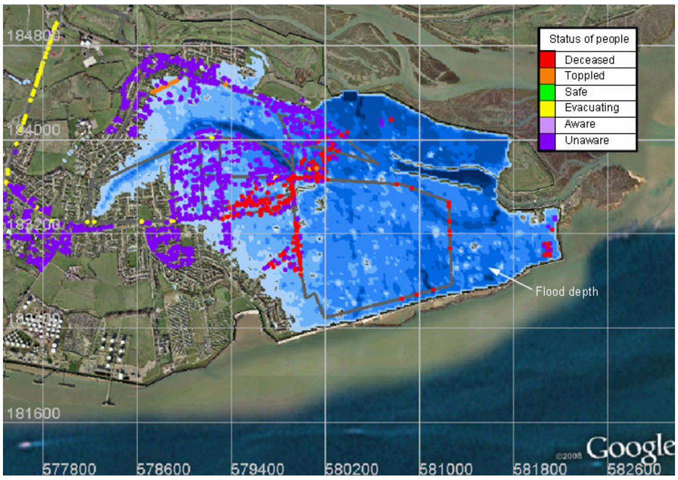

Fig. 2. Map showing evacuation modelling for the 1953 Canvey Island flood

- The split of responsibilities between flood management organisations and authorities responsible for emergency planning means that in some cases neither organisation wishes to be responsible for carrying out evacuation modelling.
- Flood risk managers and emergency planners have the potential to improve understanding and effectiveness by working more closely together.
- There are various scales at which evacuation modelling can be carried out. Macro-scale evacuation models are useful for obtaining first order estimates of evacuation times for relatively large areas. Meso- and micro-scale models are needed for detailed evacuation planning (Fig. 1).
- In some cases, for results to be useful there is a need for individual receptors (e.g. people, houses, vehicles) to be modelled and for additional information to be provided (e.g. loss of life and injury estimates, effects of different management plans) not just evacuation times.
- Micro-scale models, although more time consuming to set up than macro models, provide emergency planners and other end users with more insight into the areas at greatest risk and also provide decision makers with other risk metrics (e.g. number of collapsed buildings, loss of life, inundation of escape routes). However, to be effective such models should be applied to the whole area at risk.
- Further development of appropriate user interfaces will help encourage wider adoption and usage of evacuation models.

Related Work

Demonstrations of model application to Thames Estuary (UK) and the Schelde Estuary (The Netherlands) are available on the FLOODsite website, as part of Tasks 24 and 25 respectively.

Task 17 also produced a model to assess the risk of road inundation by flash floods. A separate fact sheet is available on the FLOODsite website describing this work.

The work carried out under Task 17 is closely related to that of Task 19. Again, further details can be found on the FLOODsite website.

The FLOODsite project

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FACTSHEET

FLOODsite

Evacuation and traffic management

A road network monitoring tool

FLOODsite Task 17 has produced:

- A prototype modelling tool to assess the probability of road inundation by flash floods that can be used to route emergency services.

The tool is intended for:

- Engineers, scientists and planners involved with emergency planning for floods and flood event management.

Where to find further information:

- Further details of this prototype model and examples of model results for the pilot area can be found via the Task 17 area of the project website www.floodsite.net.

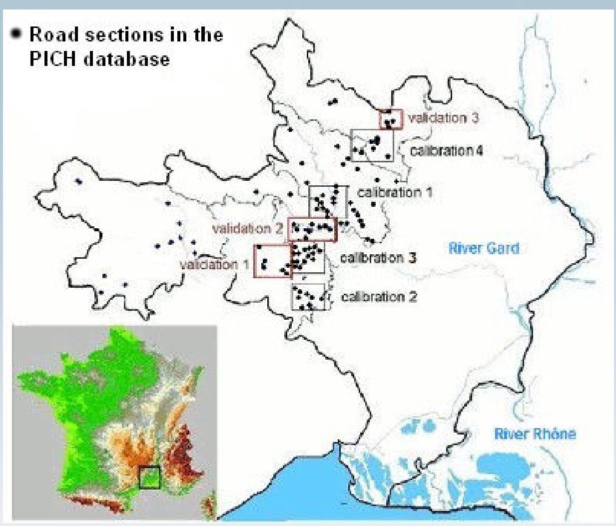

Fig. 1. The Gard region, showing areas used for calibration and validation of the prototype tool and the points included in the road inventory

In Brief

Road network and traffic monitoring are major issues for flood event managers. Real-time monitoring of the state of the road network during floods would be helpful to stop the traffic on roads that are likely to flood and identify the safest access routes for the rescue services. This is particularly true in areas prone to flash flooding where many victims are trapped in their cars due to the rapid rise of water over roads.

FLOODsite Task 17 developed a prototype tool that uses a distributed hydrological model to provide inundation risk warnings on a road network within areas prone to flash flooding.

The prototype tool was tested in the Gard Region of France (Fig. 1), which is exposed to frequent and intense flash floods. In this area, 40% of victims of flash floods over the last fifty years have been vehicle drivers or passengers. Due to the severity of the flooding problem in this area, a large amount of hydrological data was available as well as an inventory of flooded roads for the last forty years.

SIXTH FRAMEWORK PROGRAMME

Tool Components

The prototype tool determines a road submersion probability index for each road section. This is based on the following:

- Predicted discharge and corresponding return period – A distributed hydrological model is used to estimate the discharge for every vulnerable section of the road network using the available distributed rainfall and land use data. The return period of the predicted discharge is then estimated. A distributed rainfall-runoff model was selected for the pilot study area and was calibrated and validated using 15-years of measured data from 12 gauges catchments.

- Vulnerability rating – Each pre-defined vulnerability class has its own distribution of “flooding return period”, which is the probability of inundation for the estimated return period for the predicted discharge (Fig. 2). The vulnerability classification method was adjusted using the inventory of flooded roads.

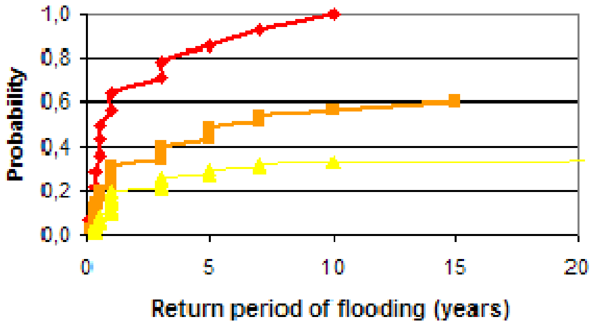

Fig. 2. Distribution of flooding return periods in each vulnerability class: High (red), medium (orange) and low (yellow)

Key Findings

The prototype tool was tested on five recent flash floods that occurred in the Gard region of France.

The results were promising: almost 100% of the submerged roads were detected as at risk in the test areas, while the number of false alarms (i.e. road predicted to flood but did not) was limited to between 20 and 30%.

This showed that despite their inaccuracy, results provided by the distributed hydrological models on ungauged basins may be useful for flood event management.

The effectiveness of the tool depends on:

- A reliable hydrological model and

- A good assessment of the vulnerability of the various road sections to flooding.

Distributed flood forecasts, as provided by this prototype tool, are a completely new service. Contact with the flood forecasting and road management services in the Gard Region has raised the question of who should take responsibility for running such a tool and publishing the forecasts.

Related Work

Task 17 also carried out a review and assessment of evacuation and traffic management models for use in flood emergency planning. A separate fact sheet is available on the FLOODsite website describing this work.

The work carried out under Task 17 is closely related to that of Task 19. Again, further details can be found on the FLOODsite website.

A web-based tool that can determine alternative traffic routes when there is a road closure, developed as part of the FP6 ORCHESTRA project, was also applied to the Gard region. This collaborative work was able to demonstrate that the two tools could be successfully linked to provide more valuable output for end users.

The FLOODsite project

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FACTSHEET

Long-term planning
Decision Support Tools

FLOODsite Task 18 has developed:

- Prototype decision support tools and a suite of integrated decision support frameworks for the long-term planning of flood risk management.

The tools are intended for:

- A range of end-users including policy makers within government authorities, decision-makers within executing bodies, specialist practitioners, and members of the general public interested in flood risk.

Where to find the tools:

- Demonstrations of the Thames and Schelde prototype tools are available via the FLOODsite website www.floodsite.net. The Elbe prototype tool is web-based and will become publicly available once further testing on behalf of the regional authority is complete. Further details can be found on the FLOODsite website.

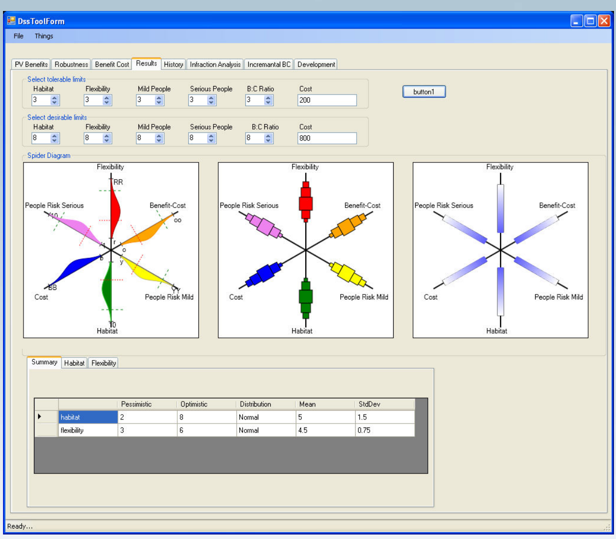

Fig.1. Thames Prototype DSS

In Brief

FLOODsite has developed integrated decision support frameworks to provide a more structured approach to the long-term planning for river, estuary and coastal flood risks, enabling decision-makers to integrate multiple and complex flood risk components and decision-making criteria.

Prototype decision support tools have been developed on the basis of these frameworks in different contexts, these being the Thames Estuary, the Schelde (or Scheldt) Estuary, and the River Elbe Catchment pilot study sites. Each location has different legal conditions and natural and societal systems and the tools have been developed on a range of platforms, suiting the needs of the relevant end-users.

In all instances, the prototype tools include:

- A simple graphical user interface;
- Direct access to background data (outlining the various frameworks and other background material);
- A series of underpinning models and data established for each pilot site necessary to support long-term management planning;
- A ‘mock up’ of each pilot site capable of being used as a useful training and educational tool – enabling key inputs to be changed and basic management scenarios to be explored.

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FACTSHEET

Tool Development

An important element of the framework is that, although the generic concepts are similar, precise methods and models are not prescribed as the preference will differ from country to country. Therefore, each prototype decision support tool has been developed based on the framework but with different capabilities and functionality to suit the circumstances.

In the UK, the tool is aimed at consultants and it is enacted in a standard SQL environment. The focus is on new science (e.g. robustness and sustainability performance measures through time) rather than the user interface. The UK tool has many more on-line calculations and the database of previously generated results only includes hydraulic model outputs. This provides the users with more flexibility in the range of what-if scenarios they can explore with the tool (Fig. 1).

In the Netherlands, the users are typically high-level such as members of parliament or planners, and they require a clear user interface that draws on a database of previously generated results. There are few on-line calculations and the emphasis of the development is on the user interface (Fig. 2.), the ease of use and the presentation of outputs.

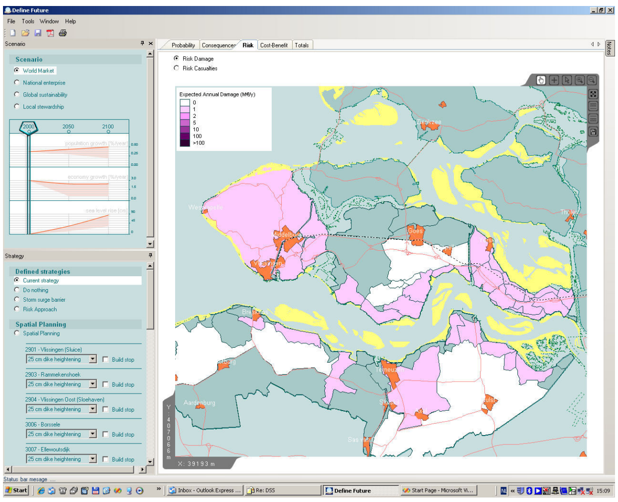

Fig.2. Schelde Prototype DSS

In Germany, the tool is aimed at high-level users (e.g. ministries) as well as the general public. It is developed on a web platform (Fig. 3), which provides a front-end to a series of pre-cooked results, enabling users to explore questions and view results in the form of maps and text.

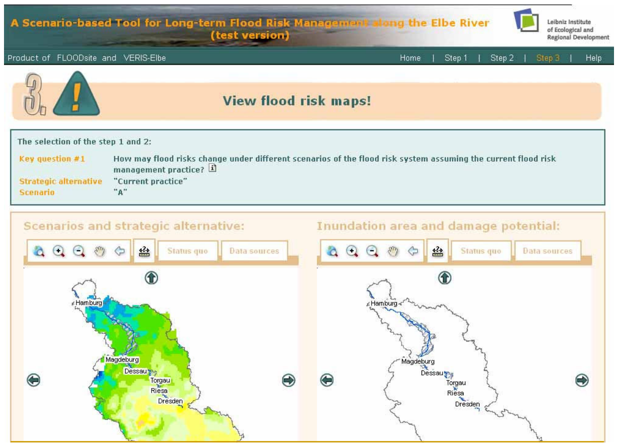

Fig.3. Elbe web-based Prototype DSS

These different tools and technologies are seen as a strength in the approach, as they demonstrate how the same generic framework supports the development of different levels of decision support tool according to the country's methods and end user requirements.

Reports

FLOODsite report T18-09-02 'Methodology for a DSS to support long-term Flood Risk Management Planning' by Caroline McGahey et al. is available in the publications section of the FLOODsite website.

Task 18 also produced a series of reports reviewing existing tools in the UK, the Netherlands and Germany. These are also available on the website.

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FACTSHEET

Framework for flood event management

Prototype Decision Support Systems

FLOODsite Task 19 has produced:

- A document detailing the development of a framework for flood event management.
- Two prototype Decision Support Systems for flood event management planning that were piloted in the UK and the Netherlands.
- A two-dimensional modelling approach for preparing flood event management plans and for selecting building locations and access routes, tested in France.

The outputs are intended for:

- Engineers and scientists involved with emergency planning for floods, flood event management and spatial planning.

Where to find the document:

- FLOODsite report T19-07-03 ‘Frameworks for flood event management’ by Marjolein Mens et al. is available in the publications section of the website www.floodsite.net.

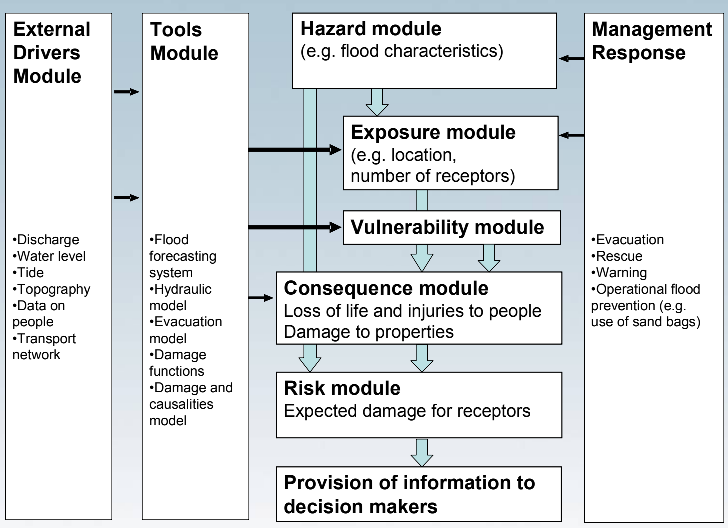

Fig. 1. Framework for flood event management

In Brief

During a flood emergency, the responsible authorities need to make key decisions relating to flood event management and evacuation and rescue strategies. Flood event management focuses on the short-term actions during, or just before, a flood incident. There is a clear need for flood event managers to be able to improve the coordination of their response to a flood event.

A review of existing Decision Support Systems (DSS) indicated that there are few that have been specifically developed for flood event management. Based on user requirements, a new methodological framework for flood event management DSS was developed, as shown in Figure 1.

The framework was used as a basis for developing proto-type DSS for areas of the Thames Estuary in the UK and the Schelde Estuary in the Netherlands. These were tested among end users.

Detailed two-dimensional hydraulic models were developed for two urban areas in France, providing a direct contribution to emergency management plans in these areas and for selecting building locations and access routes.

SIXTH FRAMEWORK PROGRAMME

FACTSHEET

FLOODsite

Prototype Decision Support Systems

FLOODsite Task 19 has provided prototype tools that can assist organisations to produce flood event management plans, which in turn contribute to the effective implementation of the EC Floods Directive.

A prototype support system for evacuation planning called the Evacuation Support System (ESS), was developed based on the new methodological framework and applied to the flood prone areas of Walcheren and Zuid-Beveland on the Schelde. The objectives of the ESS were to:

- Support policymakers in making evacuation plans; and
- Support decision-makers during a flood event.

The ESS utilises a Geographical Information System (GIS) that shows possible breach locations (see Fig. 2). The user can choose a breach location and see the resulting impact on the flood-prone area. For each breach scenario forecast water levels; maximum water depths and velocities; time of inundation; probabilities of building collapse are available.

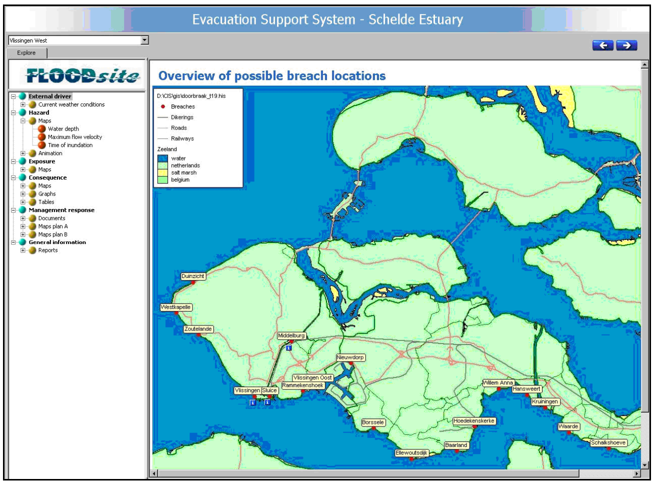

Fig. 2. Typical ESS screen showing the Schelde pilot area and possible breach locations

A prototype DSS known as the Flood INcident Tactical and Operational Framework (FLINTOF) was piloted in the Thamesmead embayment of the Thames Estuary in the UK. The key functionality of FLINTOF is assessment of: flood hazard; risks to people; evacuation times; probability of buildings collapsing; and comparison of different flood event management scenarios (see Fig. 3).

In the French pilots it was found that the use of a detailed two-dimensional model provides useful information for the preparation of flood event management plans, allowing decisions to be taken regarding evacuation routes at a detailed scale required for flash floods in urban areas.

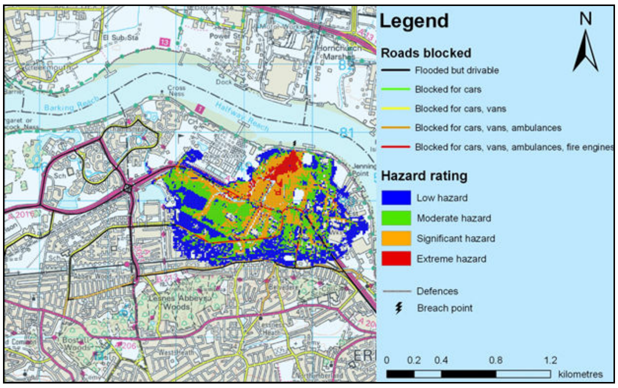

Fig. 3. Typical screen from the prototype Decision Support System FLINTOF

Related Work

Task 19 has links to a number of other FLOODsite tasks: 8, 10, 14, 17, 18, 24 and 25, details of which can be found in the main Task 19 report (T19-07-03). Task 19 has also produced report T19-07-01 ‘Review of flood event management Decision Support Systems’ by Rob Maaten et al. Both reports are available in the publications section of the website.

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FACTSHEET

Development of framework for the influence and impact of uncertainty

FLOODsite Task 20 has produced:

- A conceptual framework for the process of conducting uncertainty analysis and communicating to stakeholders;
- Reframe – a software framework for flood risk calculation and computational decision support;
- UNEEC – an innovative methodology for modelling errors in forecasting situations;
- Info-gap analysis – new methods for robust decision-making under severe uncertainty.

These tools are intended to be used by:

- Managers required to make robust risk-based decisions in both policy and emergency situations;
- Flood risk modellers requiring guidance on choice of model components and how they should be brought together to analyse uncertainty.

Where to find reports and models:

- Access to reports, examples and animations is via Task 20 area of the project website www.floodsite.net.

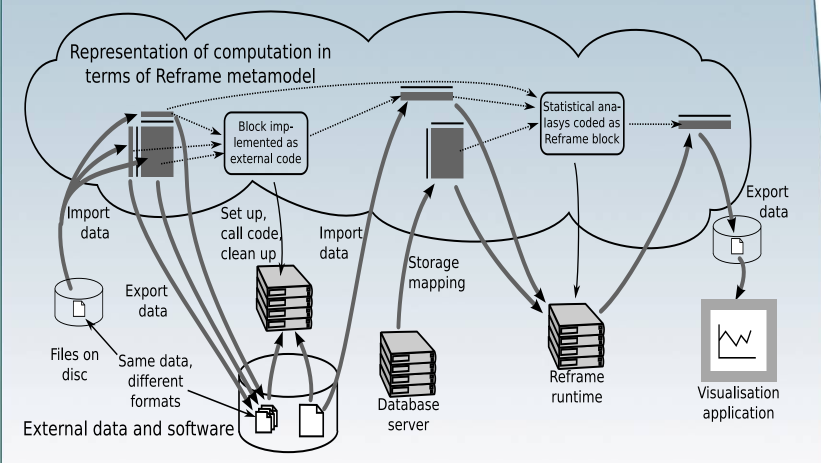

Fig. 1. Reframe metamodel

In Brief

Flood risk managers are required to make evidence-based decisions, but the data available to them are usually uncertain. It is important to quantify and consider the potential impacts of this uncertainty on the rational decisions made.

While methods for estimating uncertainty may differ, the logical structure of the conceptual framework developed through Task 20 of the FLOODsite project is intended to be applicable to risk-based planning, strategy and design decisions. Uncertainties are propagated through to key decision outputs in order to demonstrate the implications of uncertainty for decision-makers. Sensitivity analysis is used to understand the contribution that different factors make to the total uncertainty.

The conceptual framework is supported by the Reframe software framework, which enables:

- Coupling of software components,
- Propagation of uncertainty through coupled models, and
- Collaboration, including remotely and across organisational boundaries.

The UNEEC (Uncertainty Estimation based on local Errors and Clustering) methodology uses advanced machine learning techniques to propagate uncertainty through complex models.

SIXTH FRAMEWORK PROGRAMME

Conceptual Framework

A flow chart is available in FLOODsite report T20-08-04 that can be used as a guide through the process of uncertainty analysis. The process should be tiered and scalable, in much the same way as risk-based decision making. In this way, it can be an iterative process progressively refining uncertainty estimates with regard to the most significant factors.

Reframe

Reframe is built around a new metamodel (Fig. 1). It is designed to help people conceptualise and structure the complex multi-dimensional analyses which increasingly form the basis of support for flood risk management decision making; it facilitates communication about these kinds of analyses and encoding of them for manipulation by computer.

This work under FLOODsite took the conceptual developments made in earlier projects and built a prototype software system. However, considerable additional work will be needed to convert this into a robust tool ready for use by end users.

UNEEC

The UNEEC (Uncertainty Estimation based on local Errors and Clustering) methodology uses information regarding uncertainty extracted from residual errors between model predictions and observations. Patterns are identified in these errors, which can be applied to flood forecasting problems to predict uncertainties.

The methodology consists of three main parts:

- Clustering - partitioning the data into several natural groups that can be interpreted (Fig. 2).
- Estimation of the error probability distribution for the clusters.
- Building the overall model of the error probability distribution - in order to predict the uncertainty in flood forecasts. A machine-learning model is used with predictive power after being trained using the calibration data.

Info-gap Analysis

Information-gap theory, or info-gap for short, has been developed to enable robust decision-making under uncertainty. We have shown that even in situations of severe uncertainty it is possible to make well-justified decisions by exploring the implications of a wide range of future possibilities.

Info-gap theory has been applied to an example of strategic investment decision-making in the Thames Estuary. The FLOODsite analysis went on to demonstrate the possibility of exploring the value of waiting until improved knowledge becomes available by constructing options that explicitly model this possibility.

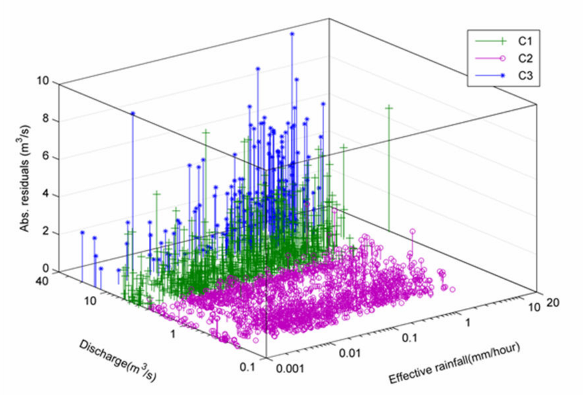

Fig. 2. Visualisation of UNEEC clustering of input data

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Elbe River Basin Pilot Study

Large catchment flood risk management issues

FLOODsite Task 21 carried out:

- A pilot study in the Elbe River Basin to test various methodologies developed by other FLOODsite tasks, principally looking at long-term flood risk management for a large transnational river basin.

The pilot study findings will benefit:

- Flood risk managers within the pilot study areas, within the Elbe River Basin as a whole and those dealing with other major European river basins.

Where to find further information:

- FLOODsite reports for Task 21 are available in the publications section of the website www.floodsite.net.

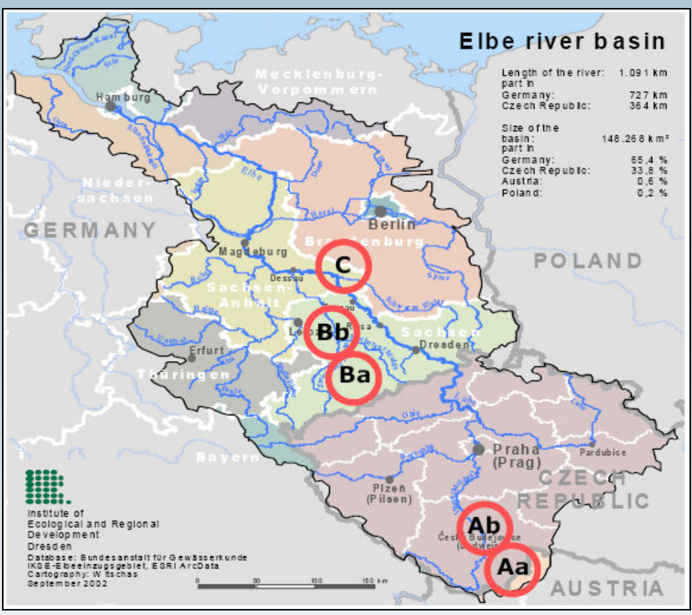

Fig. 1 Map of the Elbe river basin showing pilot site locations

In Brief

The transnational Elbe river catchment experienced the most serious damage ever caused by river flooding in Europe in August 2002. It suffers from a wide range of flooding issues that are typical for Europe, including flash-flooding in the mountainous regions and large inundation volumes in the lowlands. This made it an excellent case study to develop and test FLOODsite methodologies within the context of a large catchment and also an opportunity to identify lessons learnt from the 2002 flood and other events.

Data was provided by a large number of public authorities in Germany and the Czech Republic, through which the Elbe and its tributaries run and five pilot sites were selected (Fig. 1) for identifying sources, pathways, receptors and consequences of flood risk within the larger catchment.

The pilot sites were selected for detailed risk analysis, including social, economic and ecological impacts, and to understand the interrelation between different sites. Risk perception, risk assessment and risk reduction measures and instruments were also investigated as part of integrated flood risk management strategies being developed within the river basin. Examples of specific research topics included:

- The effects of regional climate change;
- The influence of land-use change on runoff generation;
- Multi-criteria risk evaluation; and
- Hydraulic investigations of flood polders.

SIXTH FRAMEWORK PROGRAMME

FLOODsite

Principal Results from Pilot Sites

Horni Stropnice (Aa) and Trebon Basin (Ab)

Existing dams in this rural region perform well during frequent flood events (5 year return period), but not during rare events (50-100 year return periods) such as the 2002 flood. While flood detention has been increasing since 1990 due to land-use change from arable land to forestry, flood conveyance has been reduced due to low bridges and congestion by sediment, garden waste and trees.

The downstream *Trebon Basin* pond system of about 500 km² originally had a detention function. Change of land-use and the detention capacity was analysed based on historical, hydrological and hydrogeological data and satellite imagery. An ecological vulnerability analysis also allowed for an assessment of the current ecological risk. Flood hazard, ecological vulnerability and risk were presented in a GIS project. A set of recommendations to improve the flood risk management was derived and discussed with local authorities and the public.

Upper Mulde River Catchment (Ba)

Meteorological investigations of pre-event moisture and heavy rainfall derived from the Intergovernmental Panel on Climate Change (IPCC) climate change scenarios suggested future reductions in return periods for extreme rainfall events as well as temperature and precipitation changes in the Mulde River catchment.

Macro-scale modelling of the influence of land-use and climate change on the rainfall-runoff process showed that land-use measures could be efficient for flood detention providing additional storage and transferring runoff into slower pathways. However, these effects were found to be site-specific and became less effective for the larger floods.

Meso-scale hydrologic modelling indicated a decrease in discharge for future climate projections, meaning the associated flood risk could be controlled by currently planned protection structures.

Lower Mulde River Catchment (Bb)

Hydrodynamic modelling showed that by employing polders there was an increased inundation area, but water levels were lower, compared to the pre-2002 event scenario.

Surveys and interviews with residents on risk awareness and preparedness highlighted the fact that there are no direct, immediate or unambiguous links between perceptions, opinions and attitudes and actual behaviour of people affected by flooding.

Lower Mulde River Catchment (C)

Modelling showed again that polders could be effective in reducing flooding. However, there were concerns regarding potentially negative environmental impacts. Additional management strategies need to be put in place to minimise these impacts.

Related Work

The Elbe River Basin is one of the two large river basins being used to test methodologies developed by the FLOODsite project, the other being the River Tisza (Task 22). This pilot drew on the following FLOODsite Tasks for the aspects noted: 1 (hazard sources), 9, 10, and 11 (vulnerability), 12, 13 and 14 (Pre-flood measures), 18 (frameworks for integrating technology).

Although funding did not allow consideration of the whole Elbe basin, the outputs are proving useful to the VERIS-Elbe project, www.veris-elbe.ioer.de. Major links between these projects include:

- Development and testing of a specific scenario planning approach;
- Design of a scenario-based strategic planning support tool; and
- Investigations of the decision-making and development process.

The FLOODsite project

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FACTSHEET

Tisza River Basin Pilot Study

Sustainable flood management strategies

FLOODsite Task 22 carried out:

- A pilot study in the Tisza River Basin to test various methodologies developed by other FLOODsite tasks in order to develop sustainable flood management strategies for the pilot study area.

The pilot study findings will benefit:

- Local communities along the river by improving the accuracy of flood forecasting and increasing the amount of time available for flood warning, evacuation, construction of temporary defences, etc.
- Flood risk managers in various regions of the Tisza basin by providing a better understanding of how floods happen and when they are likely to be most damaging.

Where to find the main reports:

- FLOODsite reports, including project deliverables T22-07-03 by Balázs Gauzer and T22-08-03 by Sándor Tóth, are available in the publications section of the website www.floodsite.net

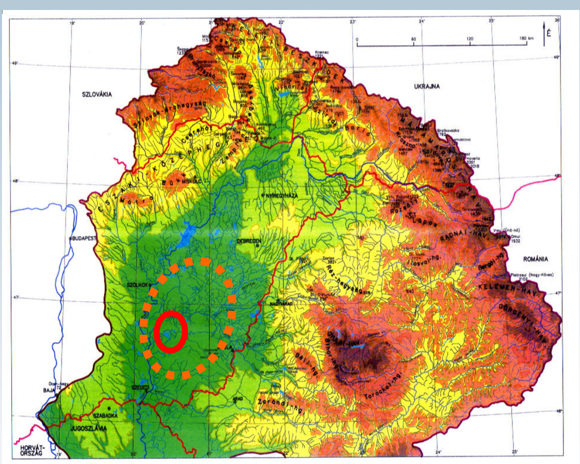

Fig. 1. Location of the Middle Tisza Region and pilot site in larger Tisza catchment (courtesy of Dr Károly Stelczer)

In Brief

The River Tisza is the largest tributary of the Danube and stretches across five countries (Slovakia, Ukraine, Romania, Hungary and Serbia). The river basin covers 157,000 km^2 (Fig. 1) and has a total length of 966 km.

The communities along the River Tisza are at significant risk from flooding. In Hungary alone there are over 400 communities housing 1.2 million people on a floodplain of approximately 16,000 km^2, which is protected by nearly 3,000 km of flood defences. The upper parts of the river suffer from flash flooding, while the middle and lower parts suffer from very high and long lasting flooding caused by the combined effects of upstream flows.

The pilot study focused on the following issues:

- Development of precautionary and sustainable flood management strategies for the river basin, based on the investigation and analysis of previous floods;
- Fostering international co-operation especially in the fields of monitoring, data exchange and methods of flood forecasting and warning; and
- Application of general vulnerability analysis techniques (using flood hazard mapping) developed by other FLOODsite tasks, to identify the effectiveness of flood management strategies.

SIXTH FRAMEWORK PROGRAMME

Principal Results

Inventory of pollution sources, fate of pollutants

- The contamination level of the sediments has decreased since the spills in the River Szamos (a tributary of the Tisza).
- High potential mobility of toxic elements was found.
- Repeated contamination threatens the use of the floodplain creating a risk to agriculture.

Scenario analysis of intervention options to increase flood conveyance capacity

The creation and maintenance of a hydraulic corridor (by relocation of levees and the removal of obstacles) would have a positive effect and could achieve a 1 to 1.5 m decrease in extreme flood levels (if combined with partial floodplain reactivation and flood detention).

Analysis of the impact of extreme precipitation patterns on the flood peaks along the Tisza River

- Antecedent precipitation and the water content of the snow cover are both more important than previously accepted.
- The amount of run-off generated is very sensitive to the path of the frontal zones; minor deviations in geographical location of the precipitation field can produce extreme floods.

Fig. 2. Dike failure at Tarpa, Upper-Tisza, Hungary, March 2001(photograph courtesy of Iván Kántor)

- The most dangerous situations for the lower Hungarian Tisza reach are precipitation events on the Upper-Tisza followed 8-10 days later by precipitation on the Körös-Maros catchment.

Scenario analysis of partial floodplain reactivation with controlled inundation

- Partial floodplain reactivation and flood detention would have a positive effect and could achieve a 1 to 1.5 m decrease in extreme flood levels (if combined with modifications to the hydraulic corridor).

Report on the development of the basin wide integrated system of monitoring, flood forecasting and warning

- Although there are many automated hydro-meteorological stations in the Tisza Basin, communication between the data collection centres (whether locally or across state borders) could still be improved to enable information to be transferred in time for use in forecasts. Therefore, a web-based database is proposed and a draft version has been prepared.

Related Work

The Tisza river basin is one of the two large river basins being used to test methodologies developed by the FLOODsite project, the other being the River Elbe (Task 21). This pilot drew on a wide range of FLOODsite Task outcomes: Task 1 (hazard sources), Tasks 9, 10 and 11 (vulnerability), Tasks 12, 13 and 14 (Pre-flood measures), Task 18 (frameworks for integrating technology).

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FACTSHEET

FLOODsite

Flash Flood Basins Pilot Studies

Evaluation of management strategies

FLOODsite Task 23 carried out:

- An evaluation of flash flood risk management strategies, in close collaboration with operational organisations, stakeholders and local communities in four pilot areas.

The pilot study findings will benefit:

- Local people in the flash flood affected areas by improving the effectiveness and efficiency of forecasting, warning, response and preparedness actions.
- Researchers and operational services throughout Europe looking to standardise methods of post-event data collection to enhance understanding of physical and social processes during extreme events.

Where to find the main reports:

- FLOODsite reports T23-06-01 by Guy Delrieu and T23-06-02 by Eric Gaume are available in the publications section of the website www.floodsite.net

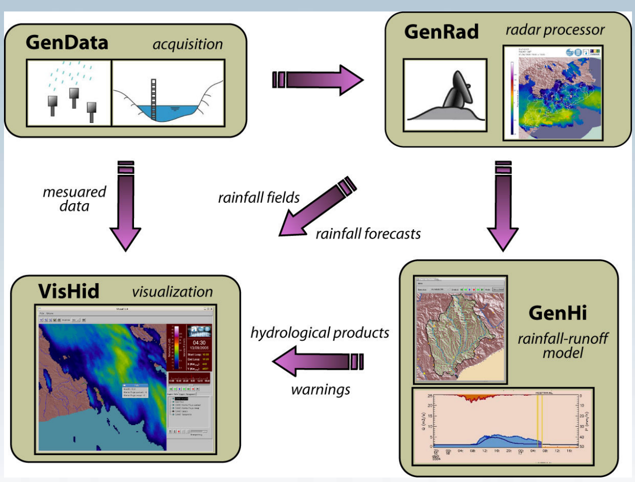

Fig. 1. Schematic of the flash flood forecasting process

In Brief

Lack of observation data has hampered advances in understanding the hydrological processes at work during flash floods, and consequently, in forecasting stream responses to extreme precipitations.

Observational limitations mainly stem from the fact that flash floods develop at spatial and temporal scales that conventional observation systems of rain and river discharges are not able to monitor. As these events are locally rare, they are also difficult to capture during traditional field-based experimentation, designed to last a few months over a limited area.

Four pilot areas were chosen in which to study these issues:

- Cévennes-Vivarais Region (France)
- Adige River (Italy)
- Besos River and Barcelona Area (Spain)
- Ardennes Region (transnational).

Specific objectives of this pilot study were:

- Development of a data-collection strategy for flash flood events and the systematic archiving of physical and socio-economic data concerning major flash floods.
- Testing the flash flood forecasting system developed in Task 15 and 16.
- Investigating the warning programme for communicating and alerting general public about flash floods (in close collaboration with Task 11).

SIXTH FRAMEWORK PROGRAMME

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Principal Results

Requirements for flash flood hydro-meteorological monitoring

Hydrological modelling of flash flood response in rural catchments of between 20 km^2 and 500 km^2 were shown to require a temporal resolution of between 30 and 60 minutes. The required spatial resolution was shown to depend strongly on the correlation between the distribution of rainfall and patterns of air flow, which is particularly significant where there is orographic enhancement of precipitation (i.e. precipitation generated by the upward movement of air over mountains) in elongated river basins.

Systematic archiving of physical and socio-economic data concerning major flash floods

Post-event flash flood surveys, including use of radar rainfall estimates, eyewitnesses interviews, field observations, and hydrologic and hydraulic modelling, allows the generation of fundamental data about the dynamics of flash flood events. This information is vital for the understanding of hydrologic response to extreme convective storms, to advance and verify hydrometeorological forecasting systems and to improve flash flood risk management.

Testing flash flood forecasting systems

Developments have focused on three main aspects:

- New capabilities and processed information offered to decision-makers, synthesising spatially distributed warnings according to the Flash Flood Guidance system;
- Visualization tools, evolving to a more easy-to-use and easy-to-interpret platform; and
- Modularisation of the system, related to the optimisation of computations, improvements in real-time data acquisition and storage, and operational radar data management and processing.

The analysis carried out in Tasks 15 and 16 to identify appropriate procedures for flash flood forecasting and warning was extended and implemented in Catalunya (Spain) and North-eastern Italy. This showed that:

- Improvements in the Flash Flood Guidance methodology translate to a significant increase in the warning accuracy in ungauged basins;
- Accounting for uncertainty in radar rainfall estimates and nowcasts enables the use of probabilistic runoff forecasts, which enables improved decision making;
- The lead-time with which hydrographs are well simulated ranges from the response time of the catchment, to just a few minutes more than would be obtained using a deterministic forecast.

Flash flood risk communication and warning

Interviews and focus groups highlighted that the main problems with warning systems were related to the methods of providing flood warnings, the content of warnings and the differentiation of warnings according to audiences.

The case studies have shown that, at the scales and lead-times required for flash flood event management, the reliable and high-resolution description of the actual rainfall field becomes the main source of information for decision-making processes.

Related Work

The warning program for communicating and alerting the general public about flash floods was investigated in close collaboration with FLOODsite Task 11, which aimed to investigate public risk perception and how this relates to the vulnerability of communities. There were close links with the work on flash flooding of roads in the Gard region of France for Task 17 and this pilot study also tested the flash flood forecasting methods developed in Tasks 15 and 16.

The FLOODsite project

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FACTSHEET

Thames Estuary Pilot Study

Long-term flood risk management planning

FLOODsite Task 24 has produced:

- A model enabling the quantification of flood risk that can be used to investigate different flood risk management strategies for the Thames Estuary, UK.
- A method for uncertainty analysis.

The pilot study outcomes will benefit:

- Practitioners involved in long-term flood risk management planning and maximising the benefits of limited capital expenditure.

Where to find the main outputs:

The following are available in the publications section of the FLOODsite website www.floodsite.net:

- Floodsite report T24-08-01 "Uncertainty and sensitivity analysis method for flood risk analysis" by Ben Gouldby;
- Journal paper T24-08-05 by Ben Gouldby et al. published by the Institution of Civil Engineers (abstract only); and
- Conference paper T24-09-01 by Ben Gouldby et al. published by Wit Press (abstract only).

Fig. 1. Thames Barrier - part of the flood defence system in the Thames estuary

In Brief

Effective flood risk management requires the quantification of flood risk. FLOODsite Task 24 has produced a new flood risk analysis model that enables a rational quantification of flood risk. The model facilitates the production of maps of both probability of flooding and flood risk, expressed as Expected Annual Damage (EAD). The model has been applied to the Thames Estuary in the UK.

The modelling method utilises the *Source, Pathway, Receptor, Consequence* conceptual representation of the flood system. The primary scientific advances of the model are:

- Development of a new computationally efficient flood spreading model;
- Development of an efficient Monte-Carlo sampling procedure for simulating multiple flood defence failure scenarios; and
- Development of a method for attributing residual risk to flood defences.

The model quantifies flood risk at a specific point in time so the input databases can be modified to reflect future changes to the system associated with, for example, different:

- Climate change scenarios;
- Asset maintenance strategies;
- Strategic management strategies, associated with both flood defence assets and flood warning or resilience measures (so-called receptor responses); and
- Floodplain development scenarios.

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FLOODsite

Uncertainty and Sensitivity Method

It is important for decision-makers to be aware of the limitations associated with models. Risk modelling is an inexact science and uncertainties are present from numerous different sources. A staged method (see FLOODsite Report T24-08-01) was developed that quantifies the uncertainty associated with the flood risk model. The scientific advances within this piece of work were the efficiencies achieved by selecting appropriate staging points within the overall model structure, to make the propagation of uncertainties through the model without drastically increasing computation time.

Sensitivity analysis seeks to identify those input variables that contribute most to uncertainty on the output variable. An existing method for sensitivity analysis was adapted for use with the staged uncertainty method. The output of this analysis can be used to identify priorities in development of the model, for example, to target data gathering activities to the most important input variables.

Thames Estuary Case Study

The Thames Estuary flood system is complex; it is subject to flooding from different sources, comprises a range of fixed and active structures, including the Thames Barrier (Fig. 1), variable floodplain topography and assets with a wide range of value within the floodplain area. The primary source of flooding is from high sea levels propagating up the Thames Estuary, although extreme fluvial flows can overtop defences, particularly in west London.

A 1D hydrodynamic model was used to simulate the flows in the estuary. Different tidal and fluvial events were simulated using a sophisticated joint probability approach to determine the distribution of extreme water levels at each node within the estuary. Sets of extreme water levels occurring at different future points in time under different assumed climate change scenarios were then generated by modifying the tidal and fluvial events for each future point-in-time and climate change scenario.

The primary outputs for each model run were:

- Floodplain economic risk and annual probability of inundation within each impact cell,
- Defence contribution to residual risk, and
- Annual probability of defence failure.

The model can be used to determine the risk reduction (benefit) afforded by different intervention strategies over their life-cycle, which can then be compared with associated costs within a relative cost-benefit framework. Outputs of the system model related to specific defence sections can be used for asset management purposes, identifying where it is most cost effective to invest in defence maintenance and refurbishment.

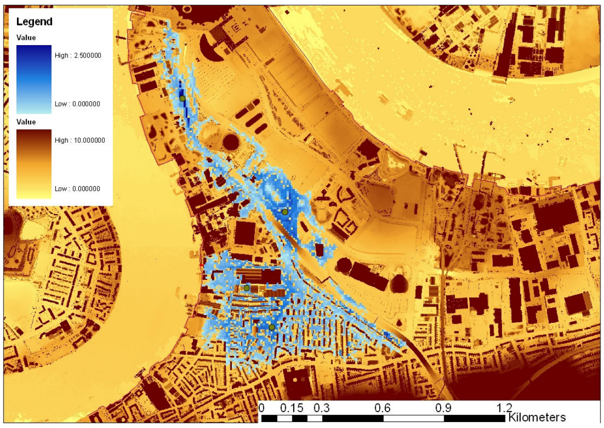

Fig. 2. Breach simulation at Thamesmead using the Rapid Flood Spreading Model

Related Work

The Environment Agency (for England and Wales) is applying this model methodology to their NaFRA, PAMS and Thames Estuary 2100 projects.

Task 24 also worked in collaboration with Tasks 14, 18 and 20. Further information regarding these tasks can be found on the FLOODsite website.

The FLOODsite project

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FACTSHEET

Schelde Estuary Pilot Study

Sustainable flood management strategies

FLOODsite Task 25 carried out:

- A pilot study of the Schelde Estuary, to implement and test FLOODsite methodologies and tools.

The pilot study outputs will benefit:

- People and property in the area by protecting them more effectively with improved flood warning and evacuation measures; and

- Improved relations and mutual understanding between professionals and the public in the area, which is vital to successful flood management.

Where to find the tools and documents:

- The Schelde prototype tools are available for download from the FLOODsite website www.floodsite.net.

- FLOODsite reports T25-06-01 and T25-08-03 by Marcel Marchand *et al*. are available in the publications section of the website.

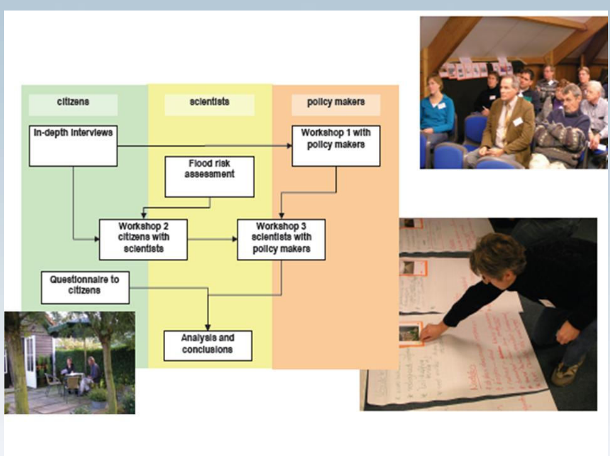

Fig. 1. Images from the stakeholder engagement process

In Brief

The Schelde Estuary pilot study area covers the tidally influenced part of the River Schelde (or Scheldt). The river flows from France through Belgium (Zeeschelde) until it reaches the Westerschelde in the Netherlands.

The crucial policy challenge for the estuary is how to accommodate present needs and future developments whilst:

- Minimising flood risk,
- Ensuring sufficient navigability, and
- Preserving the natural environment.

The pilot study activities included addressing the future vulnerability of the estuary to river flooding and coastal storms; evaluating sustainable flood management strategies in association with stakeholders; and providing guidelines on managing the transition towards their implementation.

The prototype tools developed for the estuary include:

- A simple graphical user interface;

- Direct access to background data (outlining the various frameworks and other background material);

- A series of underpinning models and data for the estuary;

- A 'mock up' of the estuary capable of being used as a useful training and educational tool – enabling key inputs to be changed and basic management scenarios to be explored.

SIXTH FRAMEWORK PROGRAMME

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Study Outputs

The following activities and outputs were undertaken as part of the pilot study, integrating knowledge from other FLOODsite tasks.

- The failure mechanisms of the flood protection system were evaluated (Task 7) providing new insight into the probability of estuarial flooding.
- A number of different inundation models were set up for the estuary, calibrated against the 1953 storm surge event that caused widespread flooding, and the results compared (Task 8).
- Trial modelling of the potential deposition of polluted sediments during a dyke break and flooding in the Walcheren area was undertaken using SOBEK 1D/2D (Task 10).
- A scenario analysis was performed to evaluate alternative future flood risk strategies using a 2D inundation model and damage and casualties model, taking into account climate and socio-economic change (Task 14).
- Three evacuation models were benchmarked on the Schelde estuary to test three different evacuation scenarios (Task 17). Key findings were that (a) model resolution often limited applicability for planning purposes and (b) evacuation of large areas was probably of less benefit than focussing on local refuges.
- The long-term planning decision support system (DSS) developed in Task 18 allowed visualisation and interrogation of Task 14 results for end-user applications.
- The methodological framework developed as part of Task 19 for flood event management was used to develop a prototype Evacuation Support System (ESS) for evacuation planning for the Schelde (see Fig. 2).
- Case study material was used to explore the perceptions and knowledge of flood risk and its management among scientists, local citizens and regional and local policy makers. Qualitative information was gathered through interviews, questionnaires and workshops and the barriers to effective communication processes were analysed.

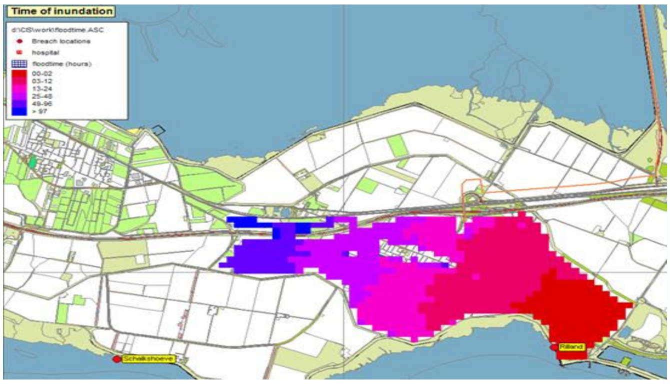

Fig. 2. ESS screen shot: time of inundation for breach scenario

Related Work

The FLOODsite science tested on the estuary comprised:

Task 7: Reliability analysis of flood defences
Task 8: Inundation modelling evaluation
Task 10: Toxic risk prediction of flooding
Task 14: Design and evaluation of innovative strategies for flood risk management
Task 17: Evacuation modelling
Task 18: Development of Framework for Long-term Planning DSS
Task 19: Flood event management DSS
Task 25: Stakeholder involvement and transition management

Reports for the tasks above are available in the publications section of the FLOODsite website.

The FLOODsite project

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FACTSHEET

River Ebro Delta Coast Pilot Study

Vulnerability, risk and defence needs

FLOODsite Task 26 carried out:

- An examination of the vulnerability, risk and defence needs for the River Ebro Delta Coast, Spain.

The results of the pilot study will benefit:

- People living and working on the delta by providing an objective assessment of vulnerability and flood risk
- Flood risk managers wishing to identify areas that need to be managed to reduce flood risk and assess the feasibility of buffer zone creation.

Where to find the report:

- FLOODsite report T26-06-02 by José Jiménez et al. is available in the publications section of the website www.floodsite.net.

Fig. 1. An aerial view of the Ebro Delta (photograph from the Institut Cartogràfic de Catalunya)

In Brief

The River Ebro Delta is located on the Spanish Mediterranean coast. It has an area of around 320 km^2 with 50% of its elevation between mean sea level and +0.5m. In total, there are 50 km of coastline, including the inner coast of the two main lagoons.

It is a very low-lying coastal area and, in consequence, it is extremely vulnerable to inundation, most commonly caused by a combination of eastern wave storms and storm surges.

The delta is an ecologically rich environment and includes a National Park of approximately 7,800 ha providing legal protection to the areas of highest environmental value, including freshwater and brackish habitats, saline lagoons, salt marshes and dunes.

Around 66% of the area is exploited for rice cultivation with a further 10-15% used to grow other crops. Approximately 50,000 people depend on the delta for their homes or directly for their livelihoods. Despite the potential for significant flood impacts associated with these factors, previous work has only focussed on coastal evolution rather than flood impacts.

This pilot study applied the science developed as part of Tasks 2, 3, 5 and 9 to evaluate the vulnerability, risk and defence needs associated with coastal erosion and flooding in the delta, identifying the areas most vulnerable and appropriate management strategies.

SIXTH FRAMEWORK PROGRAMME

Principal Results

Risk Sources

Coastal flooding and erosion result from the action of eastern storms in the Catalan Sea through the combination of high waves and storm surge. Typically, the wave-induced runup is significantly larger than the storm surge.

Risk Pathways

The Ebro Delta Coast is an unprotected sandy coast exposed to storms where the beach and dune row (if present) acts as a dynamic flood defence. Therefore, to estimate the flooding of the hinterland properly, the beach and dune evolution during the storm has to be included. To take into account these effects on the potential flood inundation, three different approaches were used to quantify the variability included in the analysis due to 'coastal dynamics'. These were:

a) No beach response (mean beach profile),
b) A known beach variability (maximum to minimum beach profile), and
c) A storm-induced beach profile response.

Figure 2 shows the estimated areas to be inundated in the Northern part of the Ebro delta as a result of a severe storm using the three presented scenarios for coast definition. It can be seen that the inclusion of the coastal response significantly increases the area to be flooded.

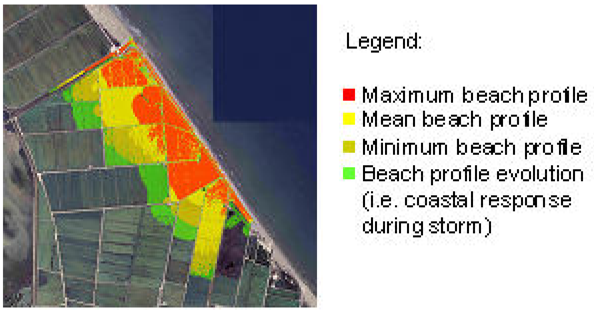

Fig. 2. Flood hazard areas in the N hemidelta for a 100-year return period storm for different scenarios of coastal response

Risk Receptors

These were defined at the physical, ecological and socio-economic levels. Areas affected by flooding were identified along with the events that caused the flooding. It was noted that many of the most harmful events had occurred in the period between 2001 and 2004, but that this may have been a result of the cumulative effects of erosion leading to continuously lower thresholds for inundation events to occur.

Vulnerability Analysis – Physical and ecological

Derivation of a vegetation-elevation model showed that sea level rise will have a strong impact on ecosystems. A sea-level rise of 0.5 m (based on a subsidence rate of 3 mm/year and the IPCC figures for eustatic sea level rise to 2050) will lead to the "drowning" of most low-elevation habitats (Fig. 3) and a further salinisation of freshwater and brackish habitats, resulting in a significant increase of unvegetated, shallowly flooded areas.

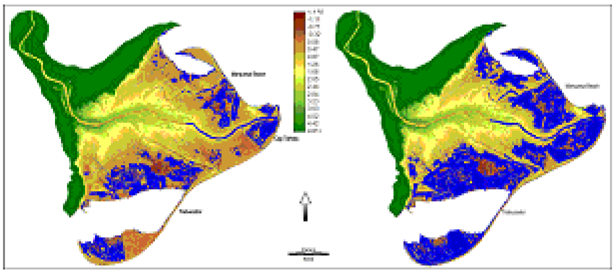

Fig. 3. Flood hazard areas (blue) for sea level rise scenarios (left: 0.25m, right: 0.5m)

Vulnerability Analysis – Socio-economic

The flood risk perception of the general public and stakeholders from the public authorities have been analysed, including awareness, preparedness and worry. The main difference identified was that private stakeholders are generally less worried than public stakeholders.

The FLOODsite project

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German Bight Coast Pilot Study

Micro-scale coastal flood risk analysis

FLOODsite Task 27 has developed:

- A micro-scale (i.e. at the scale of individual buildings) risk analysis tool based on the community of St. Peter Ording on the German Bight Coast.

The outcomes of this pilot will benefit:

- Coastal defence authorities intending to establish an integrated coastal defence management scheme.
- Researchers, modellers and engineers undertaking micro-scale flood risk analysis.

Where to find further information:

- Report T35-09-02 "FLOODsite Final Report, Volume 2" is available in the publications section of the website www.floodsite.net.
- A book will be published beyond the end of the FLOODsite project describing the development and testing of FLOODsite methodologies in the pilot studies.

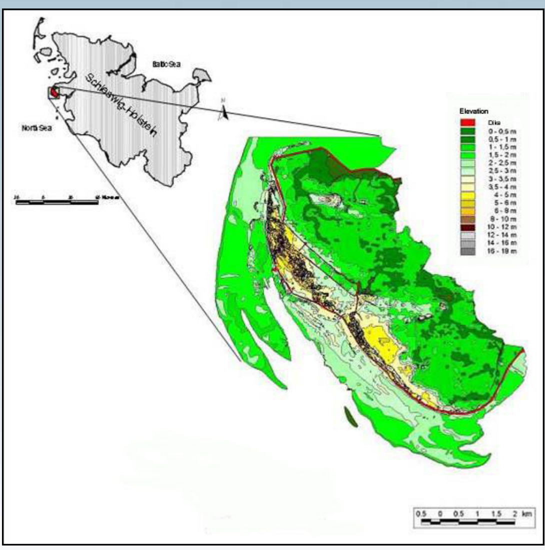

Fig. 1. Map of the St. Peter Ording pilot site

In Brief

The community of St. Peter Ording, on the German Bight Coast, is very exposed to the North Sea on the west coast of the Eiderstedt peninsula (Fig. 1). The size of the study area is approximately 6000 ha; of which 4000 ha are considered to be flood-prone due to their elevation. A flooding of the municipality could also potentially spread far into the hinterland of the Eiderstedt peninsula.

The flood defence system is complex, divided into a foreland, a major dike line (approximately 12 km in length), dune structures (more than 2.5 km long, and from 10 m to 18 m high) and a second dike line.

Detailed measurements were taken of the defence structures by laser scanning and analysis was undertaken to identify likely failure points, dimensions, and associated uncertainties and return periods. Probabilistic analysis was then performed and results were applied to a flood inundation model.

A micro-scale vulnerability analysis was undertaken following an integrated approach and combining economic, social and ecological criteria to estimate the overall damage for different flooding scenarios.

A spatial multi-criteria risk assessment was used to display overall results as risk maps.

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Principal Results

Hazard analysis

A source-pathway-receptor conceptual model was used, focussing on high sea levels and wave action (risk sources) and the area's dikes (risk pathways).

A fully probabilistic analytical approach was taken requiring mostly stochastic input parameters. Various failure modes and different sections of the defence line were investigated in detail using uncertainties of input parameters as obtained from previous investigations or literature. Results provided the failure probability due to wave overtopping of the sea dikes and breaching of the flood defences in specific sections. The defence section with the highest probability of breach failure was assumed to be where the flood inundation would start.

Definition of flood scenarios

The hazard analysis of likely defence failure locations and characteristics was input to a two-dimensional numerical inundation model to simulate flood spreading.

Vulnerability analysis

An integrated approach was chosen to assess economic, social and ecological vulnerability. It was found that micro-scale estimates of economic vulnerability could be simplified by reducing the key damage categories to those that make up 90% of the total damage potential. A high resolution database was used to derive a standardised methodology to estimate the economic value of buildings, private inventories, gross value added and fixed assets. Results were compared to a previous study to show that similar potentials for economic damage had been achieved with the simplified methodology.

Simple transfer of depth-damage relationships from fluvial studies was found to be problematic due to the differing hydrological and hydraulic conditions of coastal flooding. Expert interviews were carried out to develop a more appropriate damage evaluation model.

Community statistics including seasonal variations in tourist numbers were used to estimate social vulnerability. Vulnerable groups (particularly the young and elderly) were identified, allowing designation of social hotspots that would suffer most in a flood event.

A simplified approach was chosen for assessing ecological vulnerability. This mapped size and extent of coastal biotopes and weighted them according to their ecological relevance, for inclusion in the overall risk estimation.

Finally a multi-criteria risk assessment was conducted to produce risk zones and maps (Fig. 2). Based on this, a micro-scale risk analysis tool was developed that includes:

- A combined hazard probability, flood scenarios and micro-scale vulnerability assessment;
- An integrated approach for assessing economic, social and ecological risk, which is transferable to other coastal sites; and
- A multi-layer GIS output that can be used for the spatial analysis of flood risk.

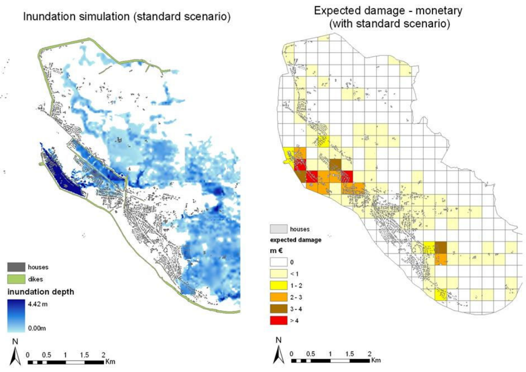

Fig.2. Flood simulation and damage estimation

Related Work

This pilot study enabled the integration of knowledge from the following FLOODsite Tasks: 2, 4, 6 and 7 for Hazard analysis methodology; Tasks 9 and 10 for Vulnerability analysis.

The FLOODsite project

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FLOODsite

Junior FLOODsite

A website for secondary schools

FLOODsite Task 29 has produced:

- A website designed to make scientific knowledge available to secondary school children. This is currently available in English and Dutch.

The website is intended for:

- Students in their final years at secondary school;
- Secondary school teachers; and
- Anyone interested in seeing information about flood risk presented in an accessible, simple and stimulating format.

Where to find the website:

- http://www.floodsite.net/juniorfloodsite/

Fig.1. Welcome page of website

In Brief

FLOODsite Task 29 was tasked with making scientific knowledge regarding flooding and flood risk available to secondary school children across the whole of Europe.

It was decided that a website would be the most effective medium for this knowledge and, after substantial consultation with students and teachers, the following features are included on the website:

- Things to know – information on: flood risk in Europe; climate change; hurricane Katrina; risk, probability, consequences and measures; flood types and hydrology.
- Quizzes – fun ways to test your knowledge of "the things to know".
- Games - downloadable games on evacuation and flood risk management and links to other sites for further games.
- Assignments – geography, water storage, make your own virtual tour, role-playing, debate, essay.
- Virtual tour around Europe taking you to significant places, giving information on types of flooding, flood events, their consequences and some protective measures.
- Lesson themes – to facilitate teachers the elements have been grouped around three themes: flood risks and management, flood types and hydrology, forming an opinion and debating about flood risks.

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FLOODsite

Example website features

The virtual tour is a tool for locating real-life flooding problems closer to home. There are ten locations across Europe to view that have experienced flash flooding (such as Boscastle, UK), urban flooding, river flooding or tidal/coastal storm surges.

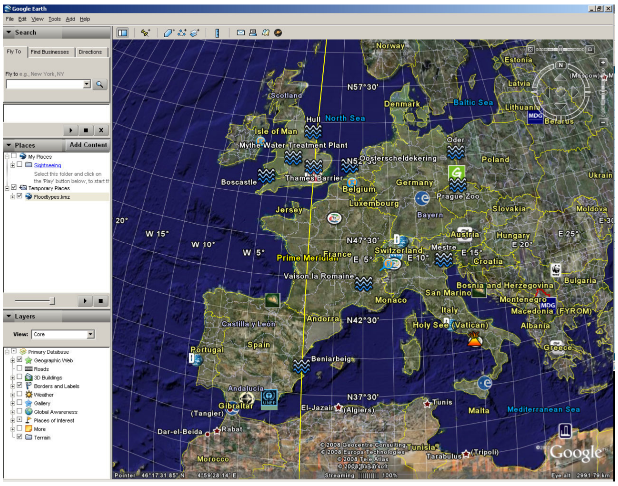
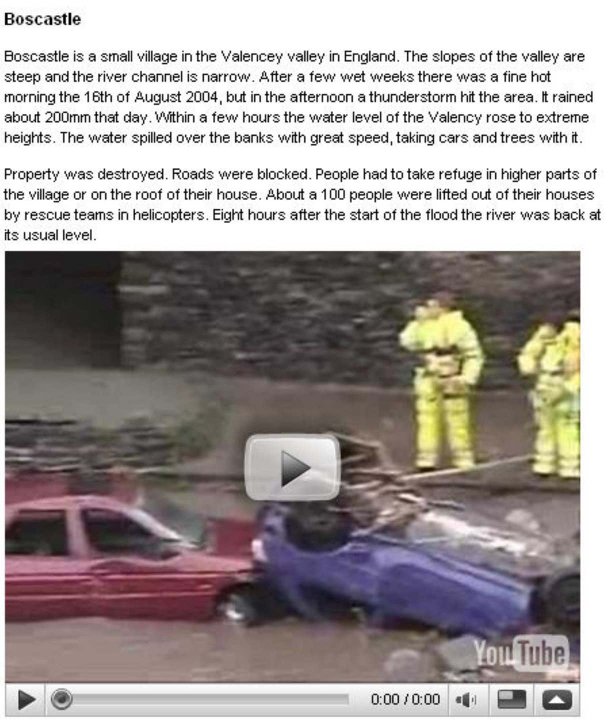


Fig 2. Virtual tour Europe-wide view


Boscastle

Boscastle is a small village in the Valencey valley in England. The slopes of the valley are steep and the river channel is narrow. After a few wet weeks there was a fine hot morning the 16th of August 2004, but in the afternoon a thunderstorm hit the area. It rained about 200mm that day. Within a few hours the water level of the Valency rose to extreme heights. The water spilled over the banks with great speed, taking cars and trees with it.

Property was destroyed. Roads were blocked. People had to take refuge in higher parts of the village or on the roof of their house. About a 100 people were lifted out of their houses by rescue teams in helicopters. Eight hours after the start of the flood the river was back at its usual level.

Fig 3. Example of information available at a flooding location – Boscastle

Fig. 2 and Fig. 4 are the copyright of Google Earth and their associated image providers (image specific).

Fig. 4. View of flooding location - Boscastle

The online quizzes are a fun way to check whether the information on the website regarding hydrology and flood types has been understood.

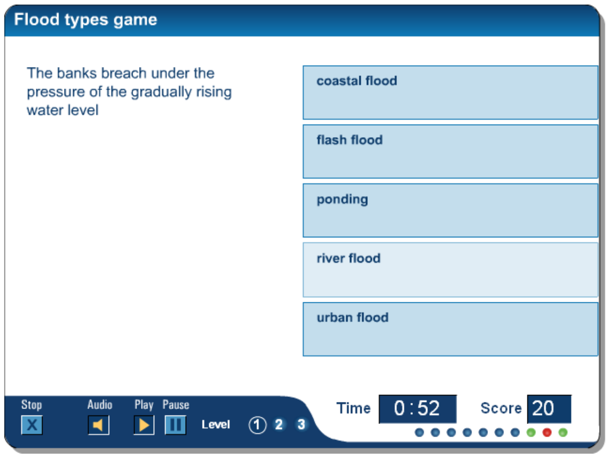


Fig. 5. Flood types quiz

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FACTSHEET

FLOODsite

FLOODsite Handbook

Text-based dissemination

FLOODsite Task 29 has produced

- An attractive handbook that serves as an introduction and guidance for flood risk assessment and flood risk management.

The handbook is intended for

- Educational purposes (students and teachers); and
- As an introduction to planners, policy-makers and the flood risk community in general across Europe.

Where to find the handbook

- The handbook is available for download from www.floodsite.net at both screen quality and print quality resolutions.

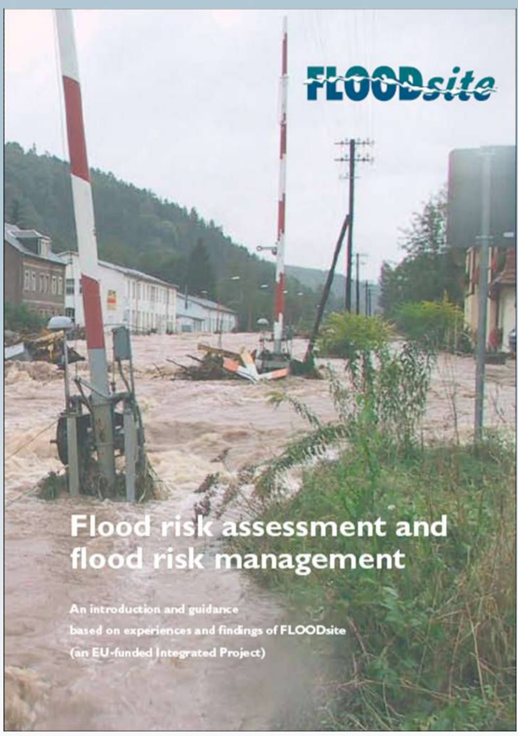

Fig.1. Cover page of the handbook

In Brief

FLOODsite Task 29 has produced a single volume handbook that gathers together the outcomes from the individual scientific tasks within the FLOODsite project.

The handbook covers both flood risk assessment and flood risk management and demonstrates the need for an integrated approach.

The handbook gives an overview of what flood risk management is about, and presents key findings from FLOODsite regarding the following:

- The science of undertaking flood risk analysis, including reference to state of the art approaches and models.
- Guidance to support policy-making for integrated flood risk management, with particular emphasis on flood risk management measures and policy instruments.
- The development of long-term strategic flood risk management plans in view of global change.
- Guidance to support flood event management planning.

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SIXTH FRAMEWORK PROGRAMME

Example handbook features

The handbook is divided into five chapters:

1. Flood risk management, what are we talking about?
2. On flood risk assessment: how big is the risk?
3. Management measures and policy instruments: how to reduce flood risk?
4. Flood risk management for the future: how should one decide what to do?
5. On remaining risks: what if flooding does occur?

In each chapter, questions and answers provide the story on the right-hand pages, whereas the opposite pages illustrate these with figures and photographs. Examples are shown in Figures 2 and 3.

References to individual research tasks are given to facilitate further reading.

FLOODsite's key research advances are summarized at the back of the handbook.

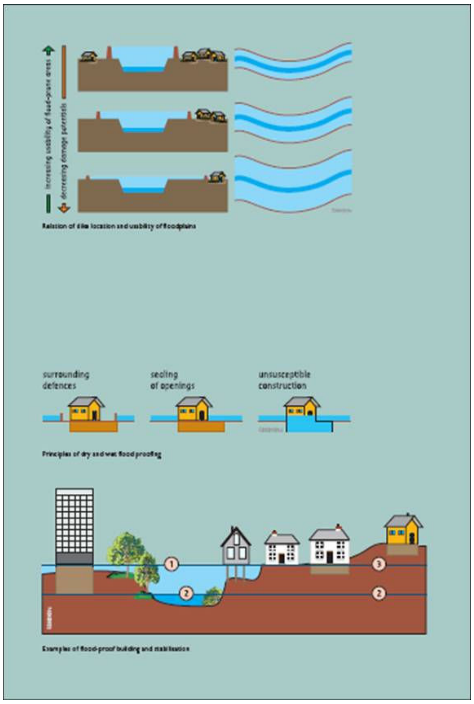

Fig. 2. Handbook illustrations showing the relation between dike location and usability of floodplains (top) flood proofing options (middle and bottom)

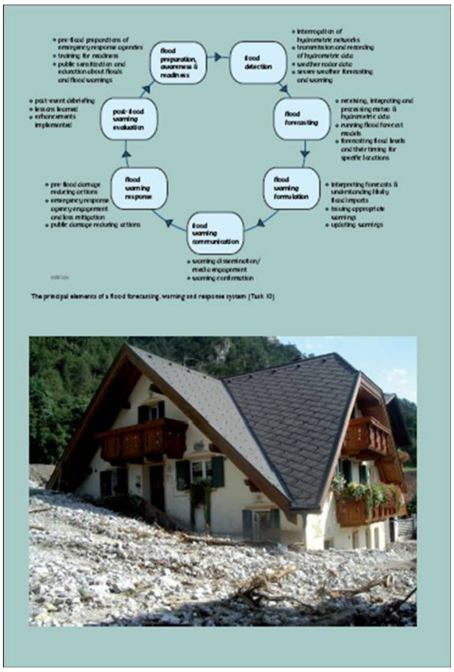

Fig. 3. Handbook page showing the principal elements of a flood forecasting, warning and response system

Related Publications

Task 29 has developed a website designed to make scientific knowledge from FLOODsite available to secondary school children. This is currently available in English and Dutch and can be accessed at www.floodsite.net/juniorfloodsite/.

There are also plans to use the handbook as educational material in undergraduate or postgraduate university courses. The development of this will be beyond the FLOODsite project.

The FLOODsite project

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FACTSHEET

Flood Risk Management: Research and Practice

Proceedings from FLOOD*risk* 2008

FLOODsite has produced

- The proceedings of the European Conference on Flood Risk Management Research into Practice (FLOODrisk 2008), Oxford, UK, 30 September – 2 October 2008, published by CRC Press, Taylor & Francis Group, London

The proceedings include

- A hardback book containing extended abstracts for all papers; and
- A CD-Rom containing the full papers.

The proceedings can be purchased via

- The publisher's website www.taylorandfrancis.com and entering the book title in the Product Search field.

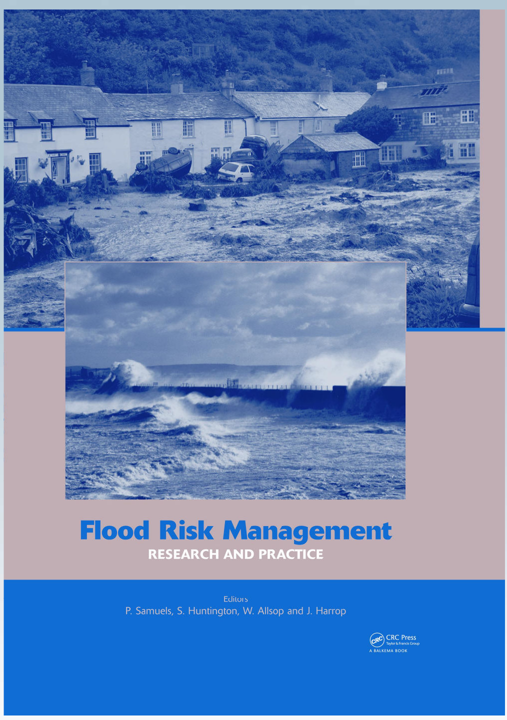

Fig.1. Cover page of the proceedings

In Brief

FLOODrisk 2008 was an initiative of the FLOODsite project, set up as an open forum for researchers, flood risk managers, policy-makers and practitioners from government, commercial and research organisations, designers, owners and national agencies to discuss advances, case studies and best practice in flood risk management.

The conference explored research advances in flood risk analysis and innovations in flood risk management practice. All aspects of flood risk were considered including:

- The causes of floods
- Impacts of floods on people, property and the environment, and
- Risk management measures and instruments.

There are 208 papers published in the proceedings, including 40 papers from the FLOODsite project. The proceedings include papers that did not have full length presentations at the conference.

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The Conference

FLOODrisk 2008 took place from 30th September to 2nd October 2008 at Keble College, Oxford (UK) with additional lecture facilities at the nearby University Natural History Museum. Approximately 350 participants registered for the event from 30 countries worldwide.

Fig. 2. Conference venue, Keble College, University of Oxford, UK

Young FLOODsite Prize

The conference closing session included the award of the Young FLOODsite Prize for the best of the 15 papers at the conference prepared and presented by a member of the Young FLOODsite network. The competition was assessed by members of the Project Board and Scientific and Technical Advisory Board.

Young FLOODsite was a multi-disciplinary group of early career researchers involved in the FLOODsite project, interested in sharing ideas, innovative research, knowledge and creativity within flood related issues.

International Networking

FLOOD*risk* 2008 was supported by the Flood Risk Management Research Consortium and sponsored by the CRUE ERA-NET action on flooding, Deltares (The Netherlands), the Environment Agency and Defra (England and Wales).

Conference Topics

The papers at the conference were grouped into the following topics:

- Flash floods
- Inundation modelling & mapping
- Forecasting and warning
- Vulnerability and resilience, human and social impacts
- Large programmes, funding, transnational issues
- Infrastructure and assets
- Environmental impacts, morphology and sediments
- Assessment of extremes
- Risk and economic assessment
- Civil contingency, emergency planning, flood event management
- Long-term planning, integrated portfolios, spatial planning
- Risk, sharing, equity, social justice
- Scenarios for social and environmental change
- System analysis
- Uncertainty
- Climate change

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Language of Risk

Terminology used in flood risk management

FLOODsite has produced

- A review of the terminology used in flood risk management to provide agreed definitions for use within the research.

The document is intended for

- The research team in their work, and
- Others with a professional interest in current approaches to flood risk management.

Where to find the document

- FLOODsite report T32-04-01 (Second Edition) "Language of Risk" can be found on the FLOODsite website at www.floodsite.net.

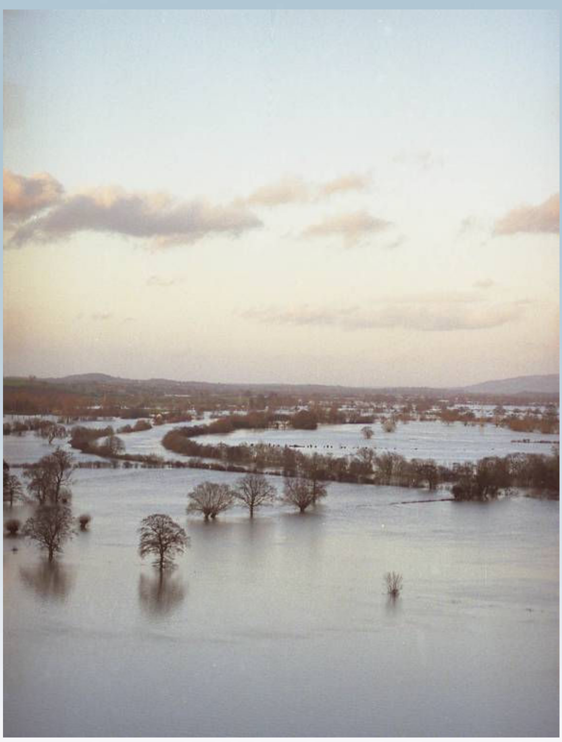

Fig.1. River flooding in the Severn Valley, UK

In Brief

The Language of Risk was one of the first deliverables of the FLOODsite project. It was intended originally to be a working document for the project partners to assist with communication throughout the project. However, the document attracted interest more broadly, as FLOODsite took place at a time of policy development and change with the international focus of activity moving from flood defence to flood risk management. This is most noticeably marked by the drafting, negotiation and entry into force of the European Directive on the assessment and management of flood risks (Directive 2007/60/EC; or the "Floods Directive").

The document contains:

- An overview of the concepts of risk and uncertainty;
- An extended discussion of 14 key definitions relevant to flood risk; and
- Definitions of approximately 150 terms used in flood risk management research and practice.

Some words are identified in the document as needing particular care in their use and interpretation, as there is scope for misunderstandings between different professional communities or national practices.

SIXTH FRAMEWORK PROGRAMME

Experience from FLOODsite

The Language of Risk was updated at the end of the FLOODsite project to reflect the experience of the project team and developments made in defining flood risk management concepts.

The document provides an overview of the concepts of flood risk management and uncertainty used in the project and includes definitions of various terms used in the project reporting.

The discussion provided builds upon a FLOODsite workshop in July 2004 and subsequent discussions within the project team. Experience and references from past international and national studies have been integrated into the text.

Fig. 2. Aerial view of a polder breach on the River Elbe (courtesy of Zebisch)

The Second Edition

The second edition contains some amendments from the first edition to provide continuity with the European Floods Directive. For example:

- The definition of a "flood" is now described as *"the temporary covering by water of land not normally covered by water.*"
- The phrase *"flood risk"* means *"the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event.*" The first edition did not specifically define this phrase.

In addition, the discussion and definition of sustainable flood risk management is now given as: *"Sustainable flood risk management provides the maximum possible social and economic resilience against flooding, by protecting and working with the environment, in a way which is fair and affordable both now and in the future."*

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Fig. 3. Sea defence at Blue Anchor Bay, UK

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