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ABSTRACT: The future management of flood risk will not come from a single technical solution or policy but from a range of responses which are tuned to the specific circumstances at a local or regional scale, taking account of national governance structures and public attitudes towards flood risks. This diversity of approach is recognised by the embodiment of the subsidiarity principle in the European Directive on the assessment and management of flood risks. This paper covers some of the main areas of innovation achieved within the European funded research project FLOODsite. These innovations will facilitate the implementation of the European Directive actions of flood risk assessments, risk mapping and the preparation of flood risk management plans. FLOODsite does not propose a single integrated methodology for flood risk management; rather it provides a set of linked methods which support integrated flood risk management. We also compare FLOODsite against the ambitions set for the EC Sixth Framework Programme Integrated Projects.

1 INTRODUCTION

1.1 *The FLOODsite Integrated Project*

FLOODsite is the largest ever EC research project on flood risk management, with an EC grant to the budget of nearly €10 Million complemented by supporting national funds. The project, which started in 2004 and will be completed in February 2009, has involved over 200 researchers from 13 countries including many of Europe's leading institutes and universities. The project is interdisciplinary integrating expertise from across the environmental and social sciences, as well as technology, spatial planning and management. FLOODsite is an ambitious project to maintain the world-leading position of Europe in knowledge and practice for flood risk management. Pilot studies have drawn together the project knowledge and provided feedback from flood risk managers of rivers, estuaries and coasts as well as from local stakeholders. The use of pilot sites and collaboration with executive

agencies in several countries ensure that FLOODsite results are of real value, practicable and usable.

Externally, all professionals involved in flood risk management now need to consider the question of what actually constitutes "integrated" flood risk management and to prepare society at large for the change in policy from one of flood defence to flood risks being managed, but not eliminated. The circumstances in which the research will be implemented are changing with firstly the entry into force of the European Union Directive on the assessment and management of flood risks (EC, 2007) and secondly the concern of the potential for increased flood hazards arising from climate change as set out in the IPCC (2007) Fourth Assessment Report.

The scope of flood risk management is broad with FLOODsite providing several incremental contributions. FLOODsite has examined many aspects of flood risk management from risk analysis and assessment methods, appropriate policy and instruments, event

management and decision support. The research has concentrated on specific topics identified in response to the original call for research as it is set in a much broader context of national and international research projects. During the research the project team has identified links to over 80 other research projects and programmes.

1.2 The structure of the research

The research tasks in FLOODsite were undertaken in four of the project “Themes” and covered

1. Flood risk analysis methods
2. Sustainable Flood Risk Management—Innovative Mitigation and Flood Risk Management
3. Frameworks for technological integration
4. Pilot studies

The scientific advances described below principally arise for these four thematic areas. The remaining three project themes covered knowledge transfer, communication, dissemination, training, networking, and coordination activities.

Here we outline some of the results delivered in the first four years of the project and provide reference to the relevant reports which are available on the FLOODsite website. Other papers at this conference present more detail on research areas than is possible in this overview. For more information on FLOODsite visit www.floodsite.net.

1.3 Tasks under the EU floods directive

The European Directive on the assessment and management of flood risks (the “*floods directive*”) entered into force on 26th November 2007. The EU floods directive requires all EU Member States to prepare:

- preliminary flood risk assessments
- flood risk maps in areas of significant risk, and
- flood risk management plans.

These maps and plans should be coordinated at a basin scale for international river basins, should cover all sources of flooding and should take account of climate change. These maps and plans need to be coordinated where possible with actions under the complementary Water Framework Directive (WFD) and have a six-yearly review cycle synchronised with the WFD.

FLOODsite is one of the European actions cited in the background documentation to the floods directive. The wording of the directive allows for considerable flexibility in its implementation in national law, respecting the national and regional context in which flood risk management occurs through the Subsidiarity Principle. FLOODsite provides a set of methods for use in flood risk management practice, not one

single methodology, thus respecting the diversity of practice in each Member State.

2 FLOOD RISK ANALYSIS

2.1 Rationale

Flood risk analysis provides underpinning information for policies and plans to manage flood risk. The FLOODsite research on flood risk analysis was centred on the Source-Pathway-Receptor-Consequence (SPRC) model—see Figure 1 (Gouldby *et al*, 2005). In essence risk analysis provides a static evaluation of the risk (measured through an integration of flood probability and valuation of the consequences) either for current hydrometeorological and socio-economic conditions or for some future scenario. Within FLOODsite the research has concentrated on some specific aspects of flood risk analysis in terms of physical processes, performance of flood defences and the impacts of flooding. The research outputs will be of relevance to all three activities of the floods directive.

2.2 Flash flood generation

FLOODsite contained a set of linked research and development activities on the management of risks from flash floods (Tasks 1, 15, 16 and 23). The underlying assumption is that for flash floods the primary risk mitigation will be through improved emergency

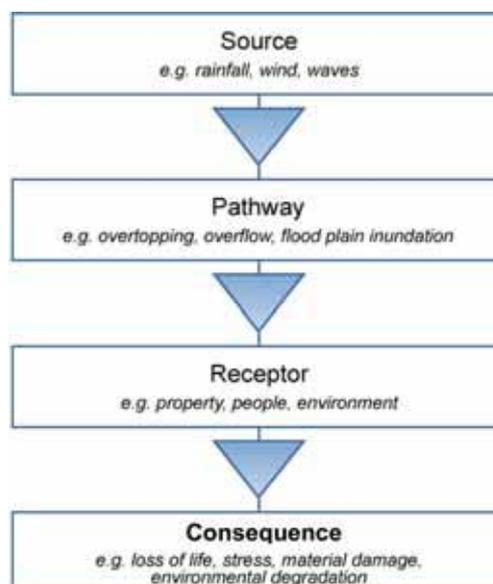


Figure 1. The SPRC model of risk analysis.

management rather than through physical defences. Flash floods are locally rare events and consequently good data are sparse. The research in Task 1 aimed to clarify open questions in flood prediction in ungauged basins and fed into the related Tasks. Improved understanding of flash flood mechanisms was sought, focussing on catchments under about 2,000 km² with significant topographic relief. Two factors were studied: a detailed analysis of storm events and of hydrological responses.

Meteorological analyses were based on both observations (radar, raingauge data) and on simulated rain fields. In total, four storms producing flash floods were analysed: three in Southeastern France and one in the Italian Alps (Anquetin, 2007). These analyses highlighted some common features and explained the steadiness of the storms that lead to locally intense precipitation: the rôle of the orography and synoptic weather conditions (low level convergence; slow evolving convective system). This work also highlighted the need to improve and extend radar observation for flash-flood understanding and the performance of the meteorological model to reproduce such intense precipitation events.

Several catchments (in Italy, Netherlands and Spain) were investigated to study hydrological processes associated with flash floods. The rôle of initial soil moisture and the link between the characteristics of the hillslopes and the dynamics of the flood have been identified. This work was based on simulation with the hill-slope Boussinesq model for which Berne (2006) provides an analytical solution.

2.3 *Statistics of extremes*

The study of hydro-meteorological extremes is an essential component of flood risk analysis as it takes data on past events to estimate the probability of future loading on flood defences. The FLOODsite research in Task 2 has examined a variety of methods for estimating extreme events from data principally on water levels at river, estuary and coastal sites. Many statistical methods have been considered for choice of distribution, assignment of parameters from data, temporal and spatial dependence, separation of cycles and trends and the influence of seasonal changes in system response. The investigation of the long-memory phenomenon in coastal processes at different timescales indicated that, with the increase of timescale, the intensity of long-memory decreases.

The main point in the analysis of spatial extremes was to investigate the joint distribution of extreme values at different locations. Strong spatial dependence can lead to flooding occurring simultaneously along entire stretches of coastline or in adjacent catchments and the hazard assessment therefore depends on the degree of spatial correlation of each process. In many

applications, the observations are scattered in space, either on a regular grid or at irregularly spaced locations. At some locations there are only few years of observations and so the exploitation of the degree of spatial dependence to other sites can be beneficial for engineering purposes. Spatial analysis has the potential to extrapolate the distributions to locations where observations are unavailable; it may also improve the knowledge of the underlying stochastic process, since it helps to understand the dynamic structure of a typical storm event. The joint spatial risk of the occurrence of extreme events, which are potentially the most dangerous ones, and the results of such a spatial dependence analysis may improve the spatial prediction or the design for a better reallocation of the monitoring sites. Another reason for such an analysis is the desire to use spatial knowledge to reduce uncertainty in the estimation of marginal (site-specific) extremal characteristics and to improve the efficiency of marginal extreme value estimates.

From the work in Task 2 a set of methods for trend analysis, stationarity tests, seasonality analysis and long-memory studies have been presented and critically reviewed (Sanchez-Arcilla, 2007). The methods have been applied to a number of datasets and compared. The Generalized Pareto Distribution appears to provide an optimal regional fit for a variety of environmental (coastal, riverine, estuarine) variables regionally for the North Sea and the NW Mediterranean. Task 2 has also developed a method to assess the uncertainty of the distribution from Bayesian analysis. Consistent selection and application of statistical techniques, both for the estimators and the underlying probabilistic distributions, should provide a competitive tool for the assessment of extremes resulting in more accurate and “certain” values than those currently used, including explicitly the corresponding error intervals. The research has also shown that alternative statistical techniques such neural networks or canonical correlation analysis or singular spectrum analysis may offer a number of advantages over physical (process-based) models.

2.4 *Failure modes and reliability of flood defences*

In Europe, there are many thousands of kilometres of raised linear flood defences—embankments, dikes, dunes, walls etc—which protect land from riverine, estuarine and coastal flooding. Should these defences fail (either through structural collapse or by being overwhelmed by the intensity of the hydrometeorological loading) a pathway is formed for the source of flooding to reach the “receptors” of flood risks. The move in philosophy for flood defence to flood risk management has highlighted the importance of understanding the likelihood and modes of failure of flood defence infrastructure (or “assets”), thus

enabling expenditure to be directed more effectively at reducing the overall chance of inundation.

Task 4 of the FLOODsite research has integrated knowledge on the potential failure modes of defences from several sources, combining in particular knowledge from Denmark, Germany, the Netherlands, the UK and the USA. The review report (Allsop, 2007) on failure modes provides an analysis of flood defence asset failure modes, structured according to asset and loading type. Failure mode information for each asset is presented in a common format and structured for use within reliability analysis models. The document forms for the first time a central compilation of agreed failure mechanisms for flood defence assets. During the review some new failure modes were identified. In addition to the review work Task 4 (together with Task 6) has carried out new experimental tests on failure processes of embankments and non-intrusive technologies for assessing embankment condition.

The failure modes identified in Task 4 were further considered and incorporated into reliability analysis in Task 7 of FLOODsite. The defence reliability analysis has been developed to support a range of decisions and adopt different levels of complexity (feasibility, preliminary and detailed design). Each tier in the analysis of the reliability of the defence and defence system demands different levels of data on the condition and form of the defence and its exposure to load, but also different types of models from simple to complex. As a result each level is capable of resolving increasingly complex limit state functions.

During the project, these levels have been considered and the complexity of models and amount of data adjusted accordingly. Task 7 has focused on the development of fault trees of different flood defence types and used as input the results of the Task 4 failure mode report. The fault trees contain components which consist of complex numerical models such as geotechnical finite element models.

The research in Task 7 included producing a software tool incorporating calculation routines which take into account differences between explicit limit state equations and implicit numerical models. A user interface has been developed in order to run the calculation routines as user friendly as possible. The resulting reliability tool was applied to the German Bight Coast case study site (FLOODsite Task 27) and compared to the results obtained with the preliminary reliability analysis.

2.5 Flood damage estimation and modelling

When flooding does occur it can cause a wide variety of economic and social impacts, this is the receptor and consequence part of the SPRC risk analysis model. In FLOODsite Tasks 9, 10 and 11 advances

have been made in understanding the damage caused by flooding and its effects on the public.

Task 9 has produced (Messner *et al*, 2007) a guideline document, directly dedicated to practitioners in government, local authorities and executing bodies dealing with ex-ante flood damage evaluation which are necessary under the requirements of the new EU floods directive. This document gives guidance both to countries that are just starting with flood damage evaluation studies and also addresses practitioners in countries which already possess some experience in this field. It describes the development of appropriate damage evaluation studies for situations where little exists; the guideline also contains a checklist to inspire experienced practitioners to improve their evaluation methodology, e.g., by including methods for damage types which have been neglected hitherto in their work, like social and environmental consequences of flooding.

To sit alongside this guidance, Task 10 has worked on four areas. The research has produced a new approach to assessing Risk to Life from flooding in Europe through combining the hazard and exposure thresholds and the mitigating factors at different scales. Although only a broad assessment, this approach can be applied at a range of scales. The purpose of the model is to allow flood managers to make a general and comparative assessment of risk to life and also where to target resources before, during and after flooding. An advantage of this scaled approach is that although it is still necessary to zone areas according to the hazard characteristics and vulnerability, it is not necessary to zone them homogeneously for both features.

Task 10 has produced a Flood Warning Response Benefit Model (FWRBP) to estimate the expected savings that may be expected from a flood warning service. The research compiled evidence on flood warning response and protective actions from a wide range of sources, including Task 11 case studies. Empirical research evidence related to different types of floods, including rapid response, medium speed response and slow response floods and showed a degree of similarity about how people currently respond to flood warnings across Europe. The research concluded that the factors affecting warning response and protective behaviours (including preparedness for floods) are complex and complexly inter-related. Nevertheless, the FWRBP model is directly relevant for the practice of flood risk management, and should be moved into practical application as soon as possible in European member states. It has the potential to enhance flood management benefits and to advance portfolio flood risk management. Other areas of research in Task 10 covered the transport and fate of pollutants in floods and the development of multi-criteria decision methods. The results of Task 10 are described more fully by Tapsell (2008).

The purpose of the sociological and geographical research of Task 11 was to better understand the impact of floods on communities, the rôle of subjective perceptions and situational interpretations, pre- and post-disaster preparedness as well as the capability and capacity of individuals and communities to recover from a disaster. Task 11 has the title of “risk perception” but the research itself revealed that this has some conceptual shortcomings. One of the main critiques is the impossibility of perceiving a mental construct like “risk” and the decision was made to replace it with risk “constructions”, a broader term which also comprises risk awareness and subjective perceptions of risk-related issues. These influence both the application of mitigation measures and the assessment of public flood protection and management by residents at risk. The research has led to a set of recommendations for flood risk management with communities at risk (Steinführer, 2008). These recommendations come from research focused on a bottom-up perspective, i.e. from the residents of flood-prone and, in most cases, recently flood-affected areas. Their points of view differ in many respects from so-called experts’ evaluations with regard to the way flood risk management should work on several scales. The significance of these findings and recommendations is enhanced by the requirements of the EU floods directive for “active involvement of interested parties in the production, review and updating of the flood risk management plans”, (Article 10 of EC, 2007).

3 FLOOD RISK MANAGEMENT

3.1 Rationale

In our research we have considered flood risk management as a process of “holistic and continuous societal analysis, assessment and reduction of flood risk” (Gouldby *et al.*, 2005, Schanze, 2006). Flood risk management involves many actors each with their own perspectives, objectives and priorities; hence the process of flood risk management depends upon the governance structures in place. The process is continuous so that it can adapt to changes in the economic, social and environmental contexts within which it is set.

The practice of flood risk management can be viewed as a cycle with three distinct phases: pre-flood measures, flood event measures and post flood measures (Kundzewicz & Samuels, 1997); see Figure 2. The research in Theme 2 of FLOODsite provides underpinning knowledge for making decisions on the management of flood risks both through long-term preventative planning and through forecasting, warning and emergency action during flood events. Although the research plan for FLOODsite did not formally

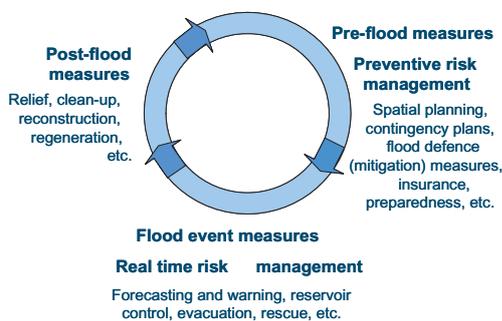


Figure 2. The risk management cycle.

include any research tasks on post-flood measures, the insights from the fieldwork on flood victims in Task 11 has also yielded information on the importance of post-flood activities.

3.2 Assessment of strategic alternatives

Preventative flood risk management requires policy making for the long term; this means policy making for a relatively far and largely unknown future. It implies the need to consider many uncertainties and many possible futures and it also means that different policy alternatives must be examined. Task 14 of FLOODsite (De Bruijn *et al.*, 2008) has set out how to undertake an assessment of the performance of strategic alternatives against scenarios for future environmental and societal conditions.

To assess the functioning of the strategic alternatives in different possible future scenarios a set of criteria has been defined. Together they show the contribution of the strategic alternatives on the sustainability aspects ‘people’, ‘profit’ and ‘planet’ and ‘sensitivity to uncertainties’ in different future scenarios. The assessment follows a Multi-Criteria Analysis approach in which both quantitative and qualitative criteria are incorporated. The qualitative criteria are assessed with a Delphi approach. The use of MCA and Delphi approach together enables to show the effect of strategic alternatives on all relevant aspects of sustainability, also on those aspects which are very relevant, but difficult to quantify.

Robustness and flexibility are both very important criteria since they reveal the sensitivity of strategic alternatives to uncertain events and changes. Robust strategic alternatives are less sensitive to uncertain events such as very extreme water levels, malfunctioning of structures, malfunctioning communication systems, unforeseen behaviour amongst the inhabitants etc. Flexible strategic alternatives can be easily adapted if future developments differ from the ones anticipated.

One interpretation of sustainable development is searching out development pathways which minimise the “regret” of succeeding generations for decisions made by the current generation. Future regret is thus less likely when such strategic alternatives are being adopted. In the case studies in Task 14, both robustness and flexibility were incorporated in the full assessment, scored for all strategic alternatives and evaluated. Important progress has been made on the robustness and flexibility criteria, but their definitions are not sufficiently clear and operational yet.

3.3 Radar estimation of rainfall

Lead-time is a critical issue in delivering an effective flood warning service and for flash flood prone catchments the science of radar hydrology has led to significant improvements in operational forecasting since the 1970's. However, substantial operational and research effort is still required to optimise the observation strategies and data processing techniques. This effort is justified by the potentially higher utility of weather radar systems in mountainous regions compared to flatland 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 (QPE) in order to mitigate flood and flash-flood hazards.

In Task 15 of FLOODsite a set of improved methods has been developed and piloted for QPE from radar imagery, building on earlier intensive observational campaigns (Delrieu, 2008). Improvements in the interpretation of the radar imagery have been made on several fronts including:

- a technique to identify “ground clutter”
- adaptation of two rain-type separation algorithms
- estimation, conditional on the rain type, of the vertical profile of radar reflectivity
- rainfall estimation at ground level from corrected reflectivities above
- a stochastic model of range profiles of raindrop size distributions to test the sensitivity of attenuation correction schemes to the variability in drop-size.

3.4 Flash flood guidance

FLOODsite Task 16 has included the evaluation of the Flash Flood Guidance (FFG) method (Georgakakos *et al.*, 1997) by considering a wide range of climatic and physiographic European conditions, and by focusing on ungauged basins. The FFG is the depth of rain of a given duration, taken as uniform in space and time on a certain basin, necessary to cause some flooding at the outlet of the basin concerned. This rainfall depth, which is computed based on a lumped

hydrological model, is compared to either real-time observed or forecast rainfall of the same duration and on the same basin. If the predicted rainfall depth is greater than the FFG (i.e., the Flash Flood Threat—FFT—is greater than a given threshold), then flooding in the basin is likely (see Figure 3). Thus direct flood alerts can be triggered from rainfall measurement or prediction.

The research in Task 16 has evaluated the FFG approach in terms of probability of detection and false alarm rate (Borga, 2008). The results show improvement over a static rainfall threshold alone to trigger an alarm. The FFG approach has been implemented into operational system for flood forecasting in the Adige River Flood Forecasting System in Italy. It has been shown that the concept of flash flood guidance can help considerably in the communication between hydrologists, meteorologists and decision makers.

3.5 Emergency evacuation

When flooding of populated areas occurs or is likely, a management system for the road network in and around the flood prone areas would be useful to identify the routes for the safe evacuation of people; to facilitate the access of emergency services to the flood prone areas; and to prevent traffic using roads that have a high probability of becoming inundated. Thus, Task 17 has focused on evacuation modelling and traffic management for flood events through case applications in France, the Netherlands and the UK.

A review of evacuation models used worldwide for a range of hazards was carried out that showed three main scales at which evacuation models are employed for event management—micro, meso and macro, according to the level of detail of modelling of the receptors and representation of the road network. The type of evacuation model that is appropriate for a particular flood risk area will depend on the level of risk and the

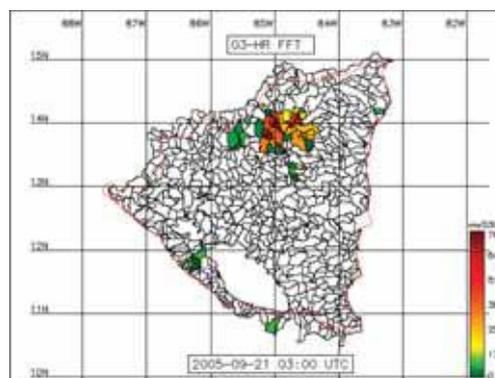


Figure 3. Graphical output of FFT in Adige Basin.

processes which the evacuation modelling is seeking to inform. Densely populated urban areas where the scale of potential evacuation is large may require a detailed simulation model where the traffic and flood hazard is modelled in a truly dynamic way. An understanding of the level of congestion delay that is inevitable under even the most effective traffic management schemes, and also the level of spontaneous evacuation that may occur in advance of an official evacuation warning are other issues that need addressing.

There has been little work undertaken in Europe, or the rest of the world, related to evacuation modelling and traffic management for flood event management. Previous work carried out in Europe has been generally limited in scope and carried out at a macro- and meso- scale. Task 17 (Lumbroso *et al*, 2008) developed for the first time a micro-level evacuation model for flood event management that dynamically links the movement of receptors (e.g. people and vehicles) with the flood wave. This has been applied to tens of thousands of receptors in a European situation. From the work carried out it would appear that micro-scale models, although more time consuming to set up, 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 buildings that collapse, loss of life and inundation of escape routes). However, to be effective such models should be applied to the whole area at risk.

In addition to the evacuation planning trials described above and in Section 4.2, Task 17 has worked in the flash flood pilot study Gard area on emergency management. This has involved the development and trial of linked flood forecast and traffic routing models, building on work under the FP5 ORCHESTRA project. This shows in a dynamic way the temporary closure from flooding of roads where they cross the river network and advises emergency services on the optimal rerouting of vehicles around the road closures.

4 SUPPORTING DECISION MAKING

4.1 Rationale

All of the research in FLOODsite is intended for use in improving decisions made in planning and implementation of flood risk management measures and instruments. There are three research tasks in FLOODsite Theme 3 which provide a degree of integration of the project knowledge and advances, in particular in the domains of long-term planning (Task 18), flood event management (Task 19) and the influence of uncertainty (Task 20). These tasks will complete in the final year of FLOODsite.

In Task 18 a general framework for a decision support framework has been designed with modules

organising information and decisions on the key aspects of long-term planning covering: sources, pathway, receptors, consequences, risk, external drivers, management response and finally, decision support. The use of this generic framework is being trialled in the context of the pilot studies on the Elbe, Thames and Schelde (Tasks 21, 24 and 25).

4.2 Flood event management

The decision support framework for flood event management has concentrated on evacuation issues since much research and operational experience is already available on forecasting and warning applications. Two prototype pre-operational systems have been developed ESS and FLINTOF. Both systems provide relevant information to the end user, who needs to make a decision on either operational management or evacuation strategies. Decision support frameworks have been trialled in the context of three pilot areas in the Netherlands (ESS), the UK (FLINTOF) and as bespoke use of models in France.

FLINTOF (Flood Incident Tactical and Operational Framework) was developed and applied on the Thamesmead embayment. It was not designed to identify 'optimal' solutions with respect to flood event management, but rather to provide information on selected options for use in the emergency management planning and decision-making process. FLINTOF does not contain hydrological or hydraulic simulation engines nor does it require the use of specific hydraulic modelling software. However, FLINTOF does require two dimensional hydrodynamic modelling results at a suitable temporal interval. FLINTOF provides:

- Calculation of the flood risk to people in terms of number of injuries and fatalities;
- Assessment of the road network with respect to emergency access;
- Use of information from external evacuation models to display typical evacuation times at a census enumeration level;
- Estimates of the probability of building collapse;
- information for the appraisal of different emergency management interventions

An alternative prototype support system for evacuation planning (Evacuation Support System, ESS) was developed and applied on the Schelde flood prone area of Walcheren and Zuid-Beveland. Its objective is to support decision makers in making evacuation plans, by providing relevant information on the area at risk. The ESS is a tool that links different breach locations to a database with simulation results of flood events. In the background spatial information is present, for example topographical data, location of hospitals and postal code zones containing the

number of inhabitants. Once the breach location has been selected, topographical data is shown with on top the flood time for each location indicated with a colour. From this information the end user can estimate the available time before the water reaches the highway and as such develop an evacuation plan for this situation. New flood event scenarios can be added in ESS, forming a library of all simulations done in one area.

In reviewing the operation of the decision support from the end-user consultations, the hazard-consequence-risk procedure is seen as an effective way to structure the data, but very much expert-based. The end-user is interested in the most relevant information being shown right away, preferably in the form of maps and tables, clicking as little as possible. For example, for a certain flood event scenario, the end user needs to know directly how many people are at risk, which roads are available and how much time is required to evacuate or to find shelters. This is a combination of hazard, exposure, risk and management. The task report (Mens *et al*, 2008) provides a fuller description of the development of these preoperational decision support systems and a demonstration of them will be available through the project website at the completion of the project.

5 PILOT STUDIES

5.1 Rationale

The seven pilot studies within FLOODsite cover a range of geographically different flooding situations, i.e. from a series of small river basins prone to flash floods, through a medium sized river basin, a large river basin, two estuary situations, and to two very different coastal situations. The pilot applications had a dual rôle in FLOODsite as both contributing knowledge to the research tasks as well as testing methods developed in the project (van Gelder, 2008). The overall integration of the pilot results from Tasks 21 to 27 will be presented as a book describing the lessons learnt. This will show that all relevant FLOODsite science is tested in one or more of these pilots. We can describe below only a few aspects of the pilots.

5.2 Impact of climate change

5.2.1 Example from the Elbe pilot

In the Elbe pilot (Task 21) two meteorological drivers of the flood risk systems were investigated based on regionalised climate change projections according to the IPCC scenarios: Pre-event moisture and heavy rainfall events. Research encompassed analyses of the daily climate scenario data (transient run) and the effects of climate change on design precipitation and return periods. Data are derived from the

ECHAM5 general circulation model (GCM) for the A2 and B1 SRES scenarios and the dynamic statistical downscaling using weather patterns. Three transient realisations (dry, mean, wet) for each station and decade between 2001–2100 were considered with mean realisation of 2041–2050 and 2091–2100.

Results indicate temperature and precipitation changes in the Mulde River catchment with higher precipitation changes in the lowlands in summer. Extreme precipitation (>50 mm, as in 2002) is not covered by climate projections which may change the probability density functions. However, based on the calculations historical 100 year return period event will probably be 65 years (1 day), 85 years (2 day), 97 years (3 day) by the end of the 21 st century. Changes in pre-event moisture and snow melt floods are possible and need further investigation.

5.2.2 Example from the Thames Pilot

Work on long-term planning in the Thames Estuary pilot integrates activities of Tasks 14, 18 and 24 through planned collaboration with other applied research within UK national RTD programmes. The Environment Agency of England and Wales, through the Thames Estuary 2100 (TE2100) project, is developing a strategy for the Thames Estuary to take account of increasing flood risk which could occur over the next century. Climate change, rising sea levels, ageing of defence infrastructure and new development in the tidal flood plain can all increase flood risk. Initial estimates suggest that the next generation of the Thames Estuary flood defences could cost over €5 Billion, with this protecting assets of value in excess of €100 Billion.

A sophisticated system model of the Thames Estuary has been developed that includes joint probability calculations, defence reliability, through a Monte-Carlo sampling approach—this has been allied to inundation estimates and economic damage model to create a sophisticated modelling tool. This model has been extended under the FLOODsite project to produce a ‘Rapid’ system model. This enables the fast exploration of potential strategies in the context of different socio-economic and climatic futures, at multiple epochs. It also provides the means for a more robust ‘variance-based’ uncertainty analysis, building confidence in the underlying methods and enabling prioritisation of data collection and quality. A further innovation is the development of methods for building long-term coherent storylines and assessing these in terms of their sustainability, robustness and flexibility. The model has been run for a number of different management scenarios. These include a “do nothing” and maintain existing defence standards under a variety of climate change scenarios on the Thames Estuary. Figure 4 illustrates the economic damage estimates for two policies for current conditions and the medium high climate scenario.

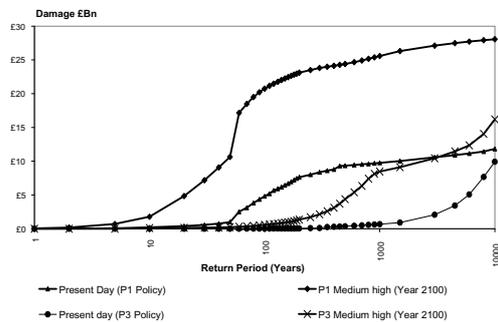


Figure 4. Damage-frequency relation in Thames pilot.

5.3 Stakeholder involvement

There is an increasing understanding that a valid flood risk assessment requires the involvement of the local public living in the area liable to flooding. Indeed, the new EU Floods Directive stipulates that all stakeholders must be given the opportunity to participate actively in the development and updating of the flood risk management plans. How to reach a satisfactory level of public participation, however, often leads to much discussion and confusion. Examples of good practice in participatory flood risk management are still scarce and theoretical guidance is only developing slowly. One of the key problems concerns the use of different types of knowledge and perspectives in discussions on flood risks between stakeholders, scientists and policy makers. Several of the pilot studies have included structured dialogue with stakeholders—both professional and the public—on flood risk management in the area. Examples of stakeholder engagement are in the Elbe, the Thames, the Schelde and the German Bight pilots, and all the pilots have worked in close collaboration with the flood risk management authorities.

6 DISSEMINATION

FLOODsite Theme 5 draws together our communication and dissemination activities, through text, the web and face to face activities. The FLOODsite website (www.floodsite.net) offers a focal point for accessing all information from the project and will be maintained for the long term. Outputs include overall (and specific) guidance documents, technical reports, tools and models, interactive demonstrations of tools and technology and masters level educational and training material. A high level assessment of the research and our main outputs may be made by viewing the task fact sheets and executive summaries, also available through the website.

The FLOODsite consortium is committed to open publication of its results so that they become public knowledge and available to all to use. This paper is part of that process. The EC reporting requirements stipulates that the consortium should prepare a “*Plan for Using and Disseminating the Knowledge*” (Samuels, 2008). In addition to the obligatory information, this also contains a consolidated list of publications. In total these amounted to 436 at the end of the 4th project year:

- 136 Journal papers
- 11 Contributions to books
- 228 Conference papers and 28 posters
- 33 Institutional reports and theses

7 ACHIEVING AN INTEGRATED PROJECT

FLOODsite was commissioned as an “Integrated Project” (IP), one of the new instruments of FP6. At the outset of the project we considered how best to achieve the ambition set out by the EC for an IP. This influenced the design of the project by clustering work into themes and the engagement of external advice, building on the success of the INTERREG III project IRMA-SPONGE. In particular FLOODsite has benefitted from the advice of our Scientific and Technical Advisory Board (STAB), our Applications and Implementation Advisory Board (AIB) and our Project Board. The members of the STAB are senior scientists who have reviewed the quality of the science undertaken in FLOODsite. Whereas the STAB membership has come from the project institutes, the AIB membership has been drawn from external organisations and agencies responsible for flood risk management in seven EU Member States. The AIB thus has delivered advice on the applicability of the results from the standpoint of end-users.

FLOODsite includes all the characteristics of an IP described in the EC (2003) FP6 Task Force report. FLOODsite is addressing a major need in society—that of managing flood risks; our research tasks are delivering knowledge which is openly published and may be applied for the public good. Section 1.2 of the Task Force report describes five aspects of integration—*vertical, horizontal, activity, sectoral and financial*. FLOODsite by its design and execution addresses each of these aspects; the first three are achieved through the execution of the research and discussed below whereas the sectoral and financial integration come from the project’s structure and financing.

In our research the requirement for horizontal integration is met by the comprehensiveness of the scope of our project in covering the flood risk system with its internal interactions. Focussing on the flood risk “system”, we understand this to comprise

- the natural hazard itself,
- the impact and consequences of that hazard on people, property and the environment and
- the societal processes and actions on management measures and instruments.

This led to a rich but complex understanding of the flood risk system and its behaviour with interactions between the physical and social scientific content of our work. Horizontal integration also has taken place within the project with the chain of flow on information between tasks.

The vertical integration was designed into the project from the outset through the testing of the project science from Themes 1, 2 and 3 in the pilot studies of Theme 4 which include interaction with external stakeholders, end-users and the public. The annual project review through our AIB has also assisted in ensuring end-user impact from our research. Activity integration has been assured by passing knowledge from the more basic research Tasks through to the more applied research Tasks to the pilot Tasks, working in partnership with flood management authorities and then into Theme 5 for knowledge transfer in written, web-based and face-to-face form.

One aspect of project integration is taking an overview of the character of results that come from the Pilot sites. This may be classed as “emergent knowledge” where certain issues are observed in common across several cases and may raise issues outside the boundaries of the original area of investigation. Our final project reporting will seek out such emergent knowledge.

8 CONCLUDING DISCUSSION

In this paper it has only been possible to give an outline of a few of the results from some of the tasks in the FLOODsite Integrated Project. Some of these have already found application in practice.

We have not discussed results on flood hazard mapping (Task 3), morphological response (Task 5), embankment breaching (Task 6), inundation model comparisons (Task 8), ex-post assessment of management measures and policy instruments (Task 12), strategy development (Task 13), uncertainty (Task 20), nor several of the pilots or much on the project’s activities on communication and dissemination. Details can be found on the project website.

The management of flood risks is a matter of ensuring public safety and provides benefits for the health and well-being of society; from the outset of the contract negotiations, the European Commission encouraged the FLOODsite Consortium to put its results in the public domain through publication in the open literature. Real public benefit from the expenditure on the research comes from others using

the project results in their broadest form; however, the implementation and uptake of the research outcomes lie outside the scope of the EC project.

ACKNOWLEDGEMENTS AND DISCLAIMER

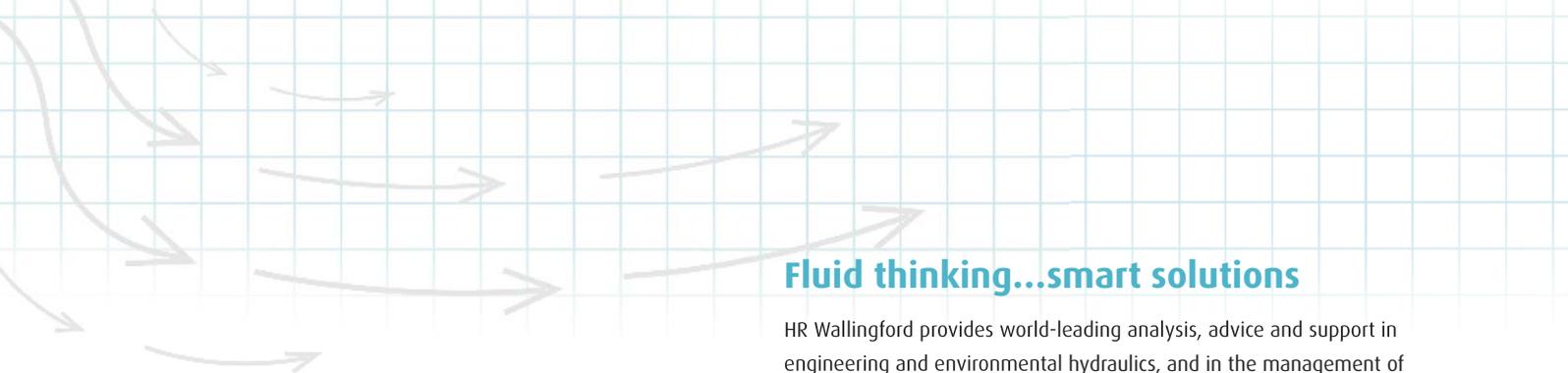
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