CONHAZ

Costs of Natural Hazards

Guidance for assessing flood losses
CONHAZ Report

Prof. Colin Green, Dr. Christophe Viavattene, Dr Paul Thompson

Flood Hazard Research Centre – Middlesex University

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Lead Author	Colin Green
Contributors	Colin Green , Christophe Viavattene, Paul Thompson
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Contact persons for WP6

Christophe Viavattene c.viavattene@mdx.ac.uk

Executive summary

We now have to take decisions that will move us on to the path of sustainable development and those decisions will be made by the diffuse group of stakeholders. This is the context for which these guidance notes are written. Delivering sustainable development means that we have to learn to do better, to do more with less, so it is about changing, and specifically learning, and we have to make those changes in the context of change, most obviously climate change. The past is therefore important in what we can learn from it; the future will be different and has to be different. Central to the concept of sustainable development is the recognition that we are dealing with dynamic systems and we have therefore to understand them as systems and to make changes which treat them as systems: to adopt integrated approaches. The implications for flood risk management have been discussed[1] in a number of other places and will not be detailed in these guidelines.

The relevant systems are the environment, people, and the economy; without a healthy environment, there is nothing. We take decisions in order to promote a better life for people as individuals, households, communities and societies. The economy is then the intermediary which draws resources from the environment with the intention of creating a better life for people.

Decisions are now being taken by the stakeholders where stakeholder engagement is by definition a social process where such concerns as the building of trust[2] are central to success. The basis for these guidelines is that the stakeholders will want the best available information as to the consequences of adopting different courses of action in terms of the effects upon the environment, people and the economy. This is the focus of these guidelines. The guidelines are set out in terms of rigorous, coherent frameworks of argument, leading to conclusions rather than as statements of economic theory. Framing them in this way is intended to make transparent, and thus open to challenge, the logic which leads to the conclusions.

The second area where the stakeholders can want help is with the process of actually making better choices: the process of inventing and selecting the best available option. Detailed guidance on this second area is outside of the scope of these guidelines[3]; it is assumed that an explorative form of Multi-Criteria Analysis[4] will be used by the stakeholders as part of the deliberative process. These guidelines leave it open to the stakeholders to decide when it is most helpful to include some consequences in economic terms and when to include those considerations in other ways into the Multi-Criteria Analysis.

[1] Technical Support Unit (2003) Integrated Flood Management: Concept Paper, The Associated Programme on Flood Management, Geneva: World Meteorological Organization/Global Water Partnership

[2] Lowry, W. R. (2003) Dam Politics, Washington DC: Georgetown University Press

[3] Green, C. and Penning-Rowsell, E. (2011) Stakeholder engagement in flood risk management in Pender G and Faulkner H (eds.) Flood Risk Science and Management, Chichester: Wiley-Blackwell

[4] Straton A, Jackson S, Mariononi O, Proctor W and Woodward E 2008 Evaluating scenarios for the Howard catchment: summary report for workshop participants and stakeholders, Winnellie NT: Tropical Ecosystems Research Centre, CSIRO

Contents

1. Introduction

These guidelines are for the purpose in assessing the losses from floods; those who have to make a decision in which the cost of some flood event or potential event is a determinant of what choice should be made. There are many such stakeholders and many potential decisions in which an assessment of the cost of flooding is relevant. It is these different needs that these guidelines seek to address.

It is an output of CONHAZ, an EC funded research project under the 7th Framework, to develop state of the art guidelines for loss assessment from the major natural hazards in Europe. The state of the art is a transitory point; a momentary point in the evolution from the past into the future. The faster the rate of progress in a field, the greater the rate of change, and the more transitory is the moment. Hence, to be useful, a discussion of the state of the art has not only to look backward, to reflect upon what has been learnt, but also to try to look forward to see what developments can be expected. To learn is to change. So, for these guidelines, the starting point taken is what is understood to be the future of natural hazard risk management: a focus on achieving sustainable development through stakeholder engagement, where sustainable development requires resilience in the face of such shocks as floods. A forthcoming CONHAZ paper will discuss in detail how loss assessment generally requires to be framed in order to fit within in this developing policy framework.

These guidelines are strategic in nature; they do not set out to be a 'cookbook' which would enable a detailed flood loss assessment to be undertaken in each one of the 27 countries of the European Union. Instead, they set out how each of those countries can best go about developing a practical methodology, and associated data, so that flood loss assessments for specific questions can be routinely undertaken.

Whilst three people are editorially responsible for putting these guidelines together, the guidelines are the product of a process. The guidelines distil the products of the series of in-depth reviews of the state of the art of loss assessment prepared by other members of the CONHAZ[5] consortium. Secondly, they are the product of discussions within the CONHAZ consortium and also with members of CIS Working Group F (floods). Thirdly, at the end of November a workshop was held in London with representatives of the principle stakeholders to shape the guidelines. The stakeholders were asked: "what do you want to know, and how do you want to know it?".

Finally, economics is one of those foods which some people (economists) love and other (most) people loathe. Therefore, as far as possible, these guidelines hide the economic detail in the background.

[5] http://conhaz.org/ Deliverable 1,2,3 and 4

2. Towards sustainable development

The current starting point for both assessing flood losses and the evaluation of mitigation options has now to be the adoption of the perspective of moving to sustainable development through processes of stakeholder engagement. Sustainable flood risk management different approach to traditional flood risk management but the principles of sustainable flood risk management have set out elsewhere and will not be elaborated in detail[6] here. Essentially, it requires managing flooding as part of the natural variability of the meteorological regime and seeking to maximise the overall performance of a catchment, a system, in terms of sustainable development. The task in delivering sustainable development requires that we make change but we have to do so in the face of change, notably climate change.

In doing both, economics, as the application of reason to choice, is potentially a valuable tool but traditionally conventional economics has addressed neither what is a better choice nor how people can go about making a better choice. In particular, conventional economics has arrogated to itself the power to make choices by seeking to determine what is the optimum choice rather than establishing a framework to help the stakeholders decide what is the best available course of action to adopt. Reason is this context is taken to be a transparent logical rigorous chain of argument[7], supported by evidence, which leads to a conclusion. Thus, it is open to questioning at each step and reaching a reasoned conclusion requires such questioning. Hence in this instance, economic analysis has a role in enabling the different stakeholders to express their differences and in seeking to resolve them. In that dialogue between stakeholders, the extent to which is helpful to express the consequences of alternative courses of action in economic terms is determined firstly by the degree to which the stakeholders find it useful to do so. It is unlikely to be useful to do about those consequences about which are there is disagreement as to their relative importance. Where there is agreement, then economic analysis can simplify and make routine the less important consequences so that attention can be focused upon the difficult questions.

There are, in addition, a number of outstanding but significant theoretical problems in economics which remain to be resolved. Those issues include the lack of any theories of capital[8] or of money[9]; the problem of pricing goods when the average cost of provision exceeds the marginal cost[10]; the limitations of markets as frameworks of analysis[11]; decision making under imperfect information[12] and the nature both of value[13] and of rationality[14]. These guidelines work around those problems.

[6] Technical Support Unit (2003) Integrated Flood Management: Concept Paper, The Associated Programme on Flood Management, Geneva: World Meteorological Organization/Global Water Partnership
[7] Toulmin, S.(1958) The Uses of Argument, Cambridge: Cambridge University Press
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[12] Frydman, R. and Goldberg, M. D. (2007) Imperfect Knowledge Economics, Princeton: Princeton University Press
[13] Boulding, K. E. and Lundstedt S. B. (1988) Value Concepts and Justifications in Peterson G L, Driver B L and Gregory R (eds.) Amenity Resource Evaluation: Integrating Economics with other Disciplines, State College: Venture
[14] Arrow, K. J. (1987) Rationality of Self and Others in an Economic System in Hogarth R M and Reder M W (eds) Rational Choice: The Contrast between Economics and Psychology, Chicago: Chicago University Press

2.1 Sustainable development

Sustainable development requires that we do more with less; climate change is only one symptom of our failure to date to achieve sustainable development. That we are using more worlds than exist[15] is the most obvious sign that the current trajectory of development is unsustainable. The requirement to do more with less raises three obvious questions:

- More 'what'?
- Less 'what'?
- How?

We draw resources from the environment and transform them into goods and services which are intended to provide a better life for people. One aspect of delivering sustainable development is therefore changing our abstraction of resources from the environment to a level and mix of resources which can be maintained over the long term.

For flood loss assessment, the critical issue is then: how well are we doing in delivering sustainable development, and will this possible course of action helping in delivering sustainable development? The two traditional performance measures were the benefit-cost ratio, as a measure of conversion efficiency, and Net Present Value, a global measure of the entire process. But both share the deficiencies of conventional economic indicators with regard to delivering sustainable development[16]. A number of different measures of the sustainability of resource use, our success in improving people's lives, and the efficiency of different forms of intervention have been proposed. **Figure 1** summarises the different measures that have been proposed[17].

In particular, the Stiglitz Commission adopted the term 'well-being' as the appropriate output measure, a more complex measure than the traditional economic measure of welfare:

"Current well-being has to do with both economic resources, such as income, and with non-economic aspects of peoples' life (what they do and what they can do, how they feel, and the natural environment they live in). Whether these levels of well-being can be sustained over time depends on whether stocks of capital that matter for our lives (natural, physical, human, social) are passed onto future generations;

- Material living standards (income, consumption and wealth);
- Health;
- Education;
- Personal activities including work

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[15] Kitzes, J,; Galli, A. Rizk, S.; Reed, A. and Wackernagel, M. (2008) Guidebook to the National Footprint Accounts, Oakland CA: Global Footprint Network

[16] Repetto, R.; Magrath, M.; Wells, M.; Beer, C. and Rossini, F.(1989) Wasting Assets: Natural Resources in the National Income and Product Accounts, Washington DC: World Resource Institute

[17] Best Foot Forward (2002) City Limits: A resource flow and ecological footprint analysis of Greater London, www.citylimitslondon.com; Chapagain, A. K. and Hoekstra, A. Y. (2004) Water Footprints of Nations, Delft: UNESCO-IHE; Commission of the European Communities (2009) GDP and beyond: Measuring progress in a changing world, COM(2009) 433 final, Brussels: Commission of the European Communities; Foran, B. Lenzen, M. and Dey C. (2005) Balancing Act: A triple bottom line analysis of the Australian Economy, Canberra: CSIRO; Jackson, T.; and Marks, N. (1994) Measuring Sustainable Economic Welfare: A pilot index, Stockholm: Stockholm Environment Institute; Linstead, C. and Ekins, P. (2001) Mass Balance UK, London: Forum for the Future; Matthews, E,; Amann, C,; Bringezu, S,; Fishcer-Kowalski, M,; Huttler, W,; Kleijn, R,; Origuchi, Y,; Ottke, C,; Rodenburg, E,; Rogich, D,; Schandl, H,; Schutz, H,; van der Voet, E. and Weisz, H.(2000) The Weight of Nations: Material outflows from Industrial Economies, Washington DC: World Resources Institute; Michaelson, J,; Abdallah, S.; Steuer, N.; Thompson, S. and Marks, N.(2009) National Accounts of Well-being, London: New Economics Foundation; Michaelson, J.; Abdallah, S.; Steuer, N.; Thompson, S. and Marks, N.(2009) The unhappy planet index 2.0, London: New Economics Foundation; Moll, S,; Brimezu, S. and Schutz, H. (2005) Resource Use in European Countries, Wuppertal: Wuppertal Institute for Climate, Environment and Energy

- Political voice and governance;
- Social connections and relationships;
- Environment (present and future conditions);
- Insecurity, of an economic as well as a physical nature."[18]

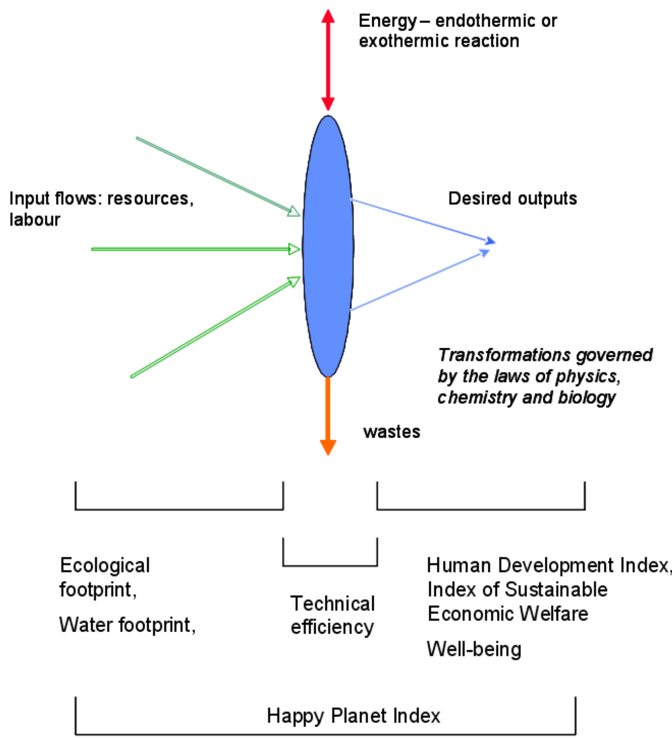

Figure 1: The lens model of development and measures of performance

In broad terms, the expectation in water management is that in order to do more with less it is necessary to adopt an integrated approach, Integrated Water Resource Management[19], a system approach. The Water Framework Directive can be regarded as an approach to implementing Integrated Water Resource Management. Thus, that the risk of flooding must be managed as part of the wider strategy of seeking to enhance the sustainable development of the catchment or coastal cell as a whole, including the variability in rainfall and consequent river flows. Thus, the benefits and costs of any form of intervention targeted reducing the risk of flooding must include the overall effects upon the catchment or coastal cell.

An obvious corollary of the need to more with less is the need to do better than we have in the past and thus to change and to learn. Hence, a prerequisite for the procedure for assessing the benefits and costs of flood risk management is that it must enable and promote learning.

[18] Stiglitz, J. E.; Sen, A. and Fitoussi, J-P.(2009) Report by the Commission on the Measurement of Economic Performance and Social Progress, Paris: Commission on the Measurement of Economic Performance and Social Progress www.stiglitz-sen-fitoussi.fr

[19] GWP (Global Water Partnership Technical Advisory Committee) 2000 Integrated Water Resources Management, TAC Background Paper 4, Stockholm: Global Water Partnership

SUSTAINABLE DEVELOPMENT

- Sustainable development requires us to do more with less, to do better than we have in the past: to learn.
- The economy withdraws resources from the environment in order to improve the well-being of people.
- Well-being is a pattern of relationships and not the state of each individual or the summation of the states of individuals.
- Doing better requires recognising that we are dealing with systems: the value of any part is thus derived from its contribution to maintaining the dynamic function of the whole in the face of the natural variability of the system environment.
- In case of flood risk management, a particular concern is the overall functioning of the catchment: Integrated Water Resource Management.

2.2 Stakeholder engagement

Decisions are now taken by the stakeholders. Stakeholders can be defined in various ways but there are two main groups of stakeholders: those who have the power to undertake either individually or collectively a particular course of action, and those who ought to have power to influence the decision. Increasingly, no single organisation has the power on its own to intervene to reduce the risk of flooding and so cooperation or collaboration is required. In particular, since spatial planning is commonly separated from water management, cooperation or collaboration between land and water planners is increasingly essential.

The second group is usually taken to include all those who have a legitimate interest that will be impacted by the decision made. In most countries, because a large proportion of the total costs of flood risk management are paid by the general taxpayer, the general taxpayer is a key stakeholder. Flood risk management should consequently reflect the concerns and priorities of the general taxpayer. A second important stakeholder in decisions about flood risk management in any single area are those at risk elsewhere in the catchment since actions in any one area may increase or decrease the risk elsewhere in the catchment. Finally, given limited resources, the use of resources to reduce the risk in one area means that risk reduction elsewhere in a country will be deferred. Hence, all those at risk of flooding are stakeholders in the decision to reduce the risk in one area.

Stakeholder engagement is by definition a social process and economics has a role in helping to support this social process; to help the stakeholders to make 'better' choices. Whilst the nature of this social process and the conditions for a successful outcome have been discussed elsewhere[20], there are a number of elements:

- The process must reflect the task: that of making a collective decision.

[20] Green, C. (2011) The practice of Power: Governance and Flood Risk Management in Pender G, Thorne C, Cluckie I and Faulkner H (eds.) Flood Risk Science and Management, Oxford: Blackwell

- The participants must individually have a sufficient incentive to participate in a collective decision process.
- The process must involve an informed deliberative process.
- Finally, all social processes are undertaken by people, and the people involved must have the necessary social skills.

Referring back to **Figure 1**, there are three components:

1. Defining what is the sustainable use of available resources;
2. Delivering a higher standard of well-being in the face both of shocks to the systems and systemic changes to the environments to those systems. That is, to enhance the resilience[21] of those systems where local optimisation to temporary conditions can degrade resilience.
3. Finally, we seek to improve the efficiency of this transformational process. This requires a combination of more efficient technologies and responding to the nature of the decision task itself where the preconditions for the existence of a choice are conflict plus uncertainty[22] and choice is therefore a process through which it is sought to resolve the conflicts and to become confident that one option should be preferred to all others. Since we have not only to make better choices than we have in the past but also discover how to make better choices in the future, a crucial characteristic of this process is that it is a social learning process[23].

Currently, the capacity of economics to help the stakeholders to make better choices is limited to providing a means of providing information as to some of the consequences of adopting different courses of action, and to do so in a way which responds to the nature of the task with which the stakeholders are faced.

[21] Holling, C. S. (1973) Resilience and stability of ecological systems, Annual Review of Ecology and Systematics 4, 1-23
[22] Green, C. H. (2003) Handbook of Water Economics, Chichester: John Wiley
[23] Goldstein, H. (1981) Social Learning and Change, London: Tavistock

STAKEHOLDER ENGAGEMENT

- Stakeholders are those who have power to induce or resist change, and those who ought to have power to influence the choice because they are significantly affected by the outcome of that choice.
- A key stakeholder is the general taxpayer as they pay a significant fraction of the costs.
- In turn, the different stakeholders have different interests and objectives.
- The different stakeholders are engaged in different decisions before, during and after a flood.
- It is the process through which decisions are made, procedural justice, that is crucial. The outcome is one indicator of the probable justice of the process.
- Stakeholder engagement is a social process in which the role of economic analysis is to help to inform that deliberative process.
- Evaluating each one of the consequences of alternative courses of action is useful to the extent to which all of the stakeholders agree on the usefulness of so doing. In particular, that they agree as to the rate at which one consequence can be traded-off against another. Where they disagree, then economic evaluation will not be appropriate.

2.3 Stakeholders' needs

Different decisions must be made by different stakeholders at different points in the flood risk management: decisions may be about what action to take against the risk of flood; how to respond in the event of a flood; or the best means of recovery from a flood. These decisions are clearly interlinked: deciding what action to take against the risk of a flood depending upon understanding what will be consequences of a flood and the best approach to recovering from a flood.

Table 1 sets out a possible pattern of relationships between the different stakeholders and the decisions that must be made to reduce the risk of flooding in the future, to respond when a flood is forecast or occurs, and to speed recovery from a flood.

Table 1: Relationships between stakeholders and the decision

Stakeholder	Before	During	After
Insurance industry	Appropriate insurance premium rates; catastrophic loss potential	Where will the claims be made? How many claims will be made? Where should staff be deployed?	Where are the claims? How much should the individual claim be?
Spatial planners	Where are the high risk areas? What forms of development should be discouraged in which areas? Where must space be left for flood defence structures? Where is runoff control or storage required?	How will service and utility provision be affected in other areas?	How to avoid planning blight
Emergency planners	Where will the risk to life lie? What are the evacuation routes? Where is evacuation required? What where are safe refuge areas? How will the flood develop? What is the rate of development of the flood? Where are the key flood defence structures? Where are the critical installations?	How will the flood develop over what time scale? Which areas may have to be sacrificed to protect others? Where should emergency works be undertaken?	What resources should be directed to which areas?
River basin managers	How will each flood risk management and flood affect the overall performance of the catchment? Are there any win-win options?	How will patterns of erosion and deposition be affected? What pollution will occur and where? What water and wastewater installations will be affected by the flood?	Is the geomorphological form of the river adversely affected?

Environmental interests	What trade-offs are involved between different environmental interests, and between environmental interests and flood risk management?		What damages has occurred to the environment?
Those at risk of flooding	What will be the effects of flooding on me? What is it possible, given the various limitations, for me to do to reduce the risk of flooding? Should I move out of the area?	What should I do?	What should I do?
Taxpayers	How much will intervention cost? How much am I being asked to pay? How will flooding in one area affect me? What will my money achieve? Is my money being well spent?	Was the response well-managed? How are my relatives and friends? Did everyone carry out their responsibilities? Is anyone to blame? How could the event have been avoided?	What will it cost me?

In turn, there are a number of different questions that might be asked about the consequences of flooding on different groups. These questions depend upon the interests and objectives of the different stakeholders. For example, just considering ecosystems, depending upon the ecosystems involved, both a flood and any form of intervention typically will have adverse consequences for some ecosystems and beneficial consequences for others since ecosystems are highly dependent upon the local flow regime.

In order to explore the needs of the different stakeholders, who have a concern with either deciding what to do prior to a flood, how to respond to an actual flood event or to promote the recovery from a flood, a workshop was organized in London with experts from key stakeholders. The workshop was split in two sessions. In the first session the participants were asked to describe their needs from their own perspective (policy, insurance, emergency, land use planning, and environment) within a 15 minutes PowerPoint presentation.

The key issue from a policy perspective is to accomplish the three steps of the Flood Directive implementation, i.e. preliminary flood risk assessment, flood hazard and flood risk maps, flood risk management plan. Economic issues are related to the risk assessment and to the preparation of flood risk management plan. In the last decade, progress has been made in the development of methodologies for loss and risk assessment in a number of States Members in particular regarding the assessment of the reduction of economic damages (i.e. assessing the benefits). However the variability of depth damages curves between countries used in the evaluation process can be questioned (**Figure 2**, example of residential buildings and content). The question is crucial when evaluating the risk on transboundary water catchment. Variability of flood damages curves could be explained in a certain proportion by the floods type and the assets type (national but also intra regional variability). But a key issue resides in the quality of the data collected and available. Thus efforts have to be made to express the uncertainty in the decision but also to reduce it by establishing a coherent framework for the data collection and evaluation.

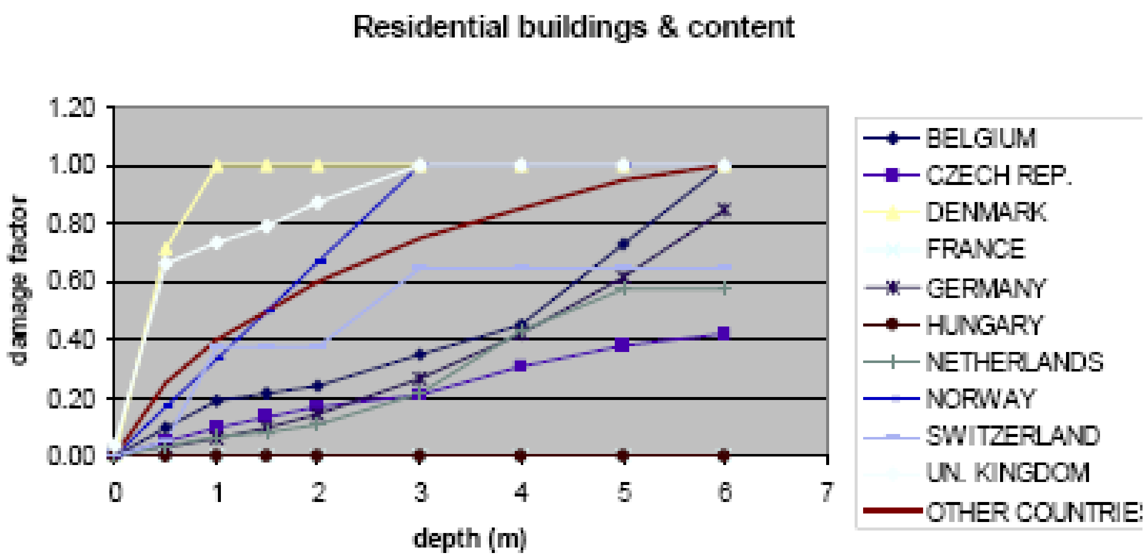

Figure 2: Damage factor for residential buildings including inventory (from Barredo[24])

The use of Cost-Benefits Analysis is largely questioned in regards to the monetizing and valuation of intangibles. The use of Multi Criteria Analysis tends to be preferred for assessing social, environmental and cultural heritage, although lacks of knowledge and methods exists in how and which indicators, scoring and weighting system should be used. The use of wellbeing indicator(s) could be a potential answer. It is probably too early to bring such new challenges in the policy agenda but the question should be investigated in the research agenda.
There is also a lack of consideration of indirect damages. Cost Benefits Analysis is mainly used for assessing the loss reduction in the flood hazard area for a particular event. The approach is too narrow (one flood scenario) and not systemic (focus on the flood plain only). In contrast the participants in the workshop have stated the new challenges posed by the switch from traditional flood defense management to flood risk management.

Different systems approaches at different scale were mentioned by the participants for different purposes. From an emergency perspective the system network and its potential failure in re-

[24] Jose I. Barredo (2010). Flood risk in Europe using Corine Land Cover Datasets. CONHAZ workshop Power Point Presentation.London

gards to the flooded area is important to evaluate in order to identify evacuation routes and isolated area and to coordinate appropriate actions. From a land use planning perspective a better understanding of the system in and outside the floodplain is critical to reduce the damages and potential disruption of various services and production but also to accelerate the recovery by a better adaptability. A coherent landscape management is essential to maintain the resilience and the use of natural processes for water management. For each system specific indicators are required such as population activity and traffic information for emergency services, number of employees and importance of companies for land use management, biodiversity richness and size of natural area for an environment perspective to take a decision. The different system may have different scales and different indicators; they are also interconnected due to common geographic areas and elements (for instance major chemical industries and the economic, heath and environment risk). Tension and conflicts may appear there as the state and resilience of each system may be affected at specific nodes and network. A multi-system approach is thus necessary to overlap in a harmonious way.

A second thing to consider for a better adaptation and recovery of the system is also that the various frequency and magnitude of floods may affect the system in different way. The question was particularly raised for developing multi-scenarios for emergency services, for adapting the type of in insurance scheme to be used and for considering appropriate ecosystems to be maintained.

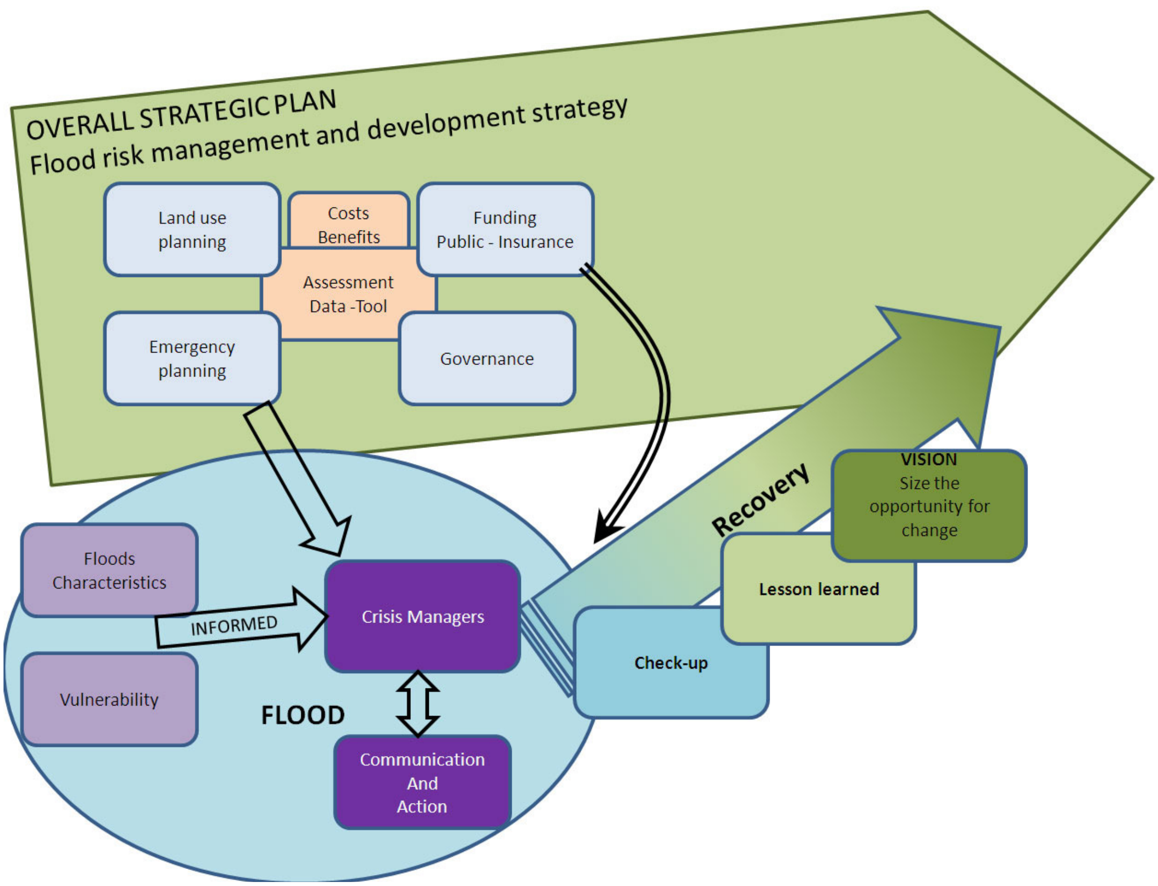

Figure 3"What do you need" outputs from the workshop

During the second session of the workshop the participants worked together in small groups and successively on flipcharts to express, categorize and prioritize their needs. They did this work for three different periods of a flood event: pre-flood, during the flood and the post-flood recovery period. Although the three phases were clearly separated in the exercise, the participants expressed various connections between the three phases (e.g. in terms of governance, funding, data collection…). Floods, therefore, should not be considered as a single isolated event but have to be included within the overall development strategy of the society. **Figure 3** regroups in a diagram the outcomes obtained by the groups working on the three phases (pre-flood, flood, and recovery phase). The pre-flood board was titled overall strategic plan by the participants. They stressed the fact here that the flood risk management plan should be included in the development strategy of the society. Four areas are fundamental for the development of the overall strategic plan:

- Governance: who is responsible? Who act and can act? Who will respond effectively?
- Land use planning: which land use development is appropriate when considering environmental, health, social and economic issues within the flood plain and outside? Adaptation to flood events is required within the plan for damages reduction but also to support a quicker recovery.
- Emergency planning: plans for crisis management, multi-scenarios for better flexibility.
- Funding scheme: Insurance and public. Floods insurance but also insurance should include the ripple effect outside the flood plain.

The existence of good data quality and appropriate tools are crucial to support the strategic plan. Cost benefit analysis plays a critical role for land use planning and the funding scheme.

The priority during the floods is to limit the damages and to increase the capacity for the recovery phase through an appropriate communication to the population and the team on the field and an appropriate use of the resources. The main problem with the flood event is that its characteristics are changeable leading to uncertainties on various factors (lead time, depth, velocity, flooded area, appropriate behaviour…). Emergency services need to cope with these uncertainties to take the “right” actions. However the decisions should not rely on the emergency services alone. The term ‘crisis managers’ has been employed to regroup various key deciders (policy, land use planner, emergency services, environmental services, health services…). Crisis managers have to be very active during the crisis deciding when to send the early warning and when to command specific actions. The decision should be based on scenarios prepared before the flood. It is thus recommended that the same persons are involved in the early phase. However they should adapt their decision to the actual flood event. For that they need to be informed in real time on the flood characteristics and on the main risks and potential failures of the system (vulnerability). The potential use of Information and Communication technology was mentioned as a support for better information.

The recovery was divided into three categories expressing very different phases: check-up, lessons learned and vision. During the recovery process in the immediate aftermath of the flood event it is critical to do a check-up and prioritize efforts for a quick recovery. The short-term recovery ensures that the system can return to “normal”. It was highlighted that the role of market forces and financial resources play a major role in this stage. In a second phase the process of data collection on direct damages but also on social impact and indirect impact is crucial. The data collection on small events tends to be severely neglected but may be useful; therefore, data collection should not be limited to major events. The lessons learned during the second phase can then be used to seize the opportunity to change and develop a new vision that can support new development in the strategic plan.

STAKEHOLDER'S NEEDS

- Stakeholders have their own needs and agenda. Tension and conflicts may appear. However their requests are related to the system (society) resilience and have to be considered as such. Only a coherent and common approach can ensure the maintenance of the system. Thus flood risk management should be part of an overall strategic plan.
- It is essential to investigate the various type, magnitude and frequency of floods.
- Loss damages assessment methods are available to answer the first requirements of the Flood Directive. Issues mainly remain in terms of data availability and data quality.
- In relation to the need, losses may not have to be expressed in monetary term. The value used has to fit the need.
- Cost-benefit Analysis does not represent all the flood losses likewise. Multi-Criteria approach seems more appropriate.
- During the flood event it is primordial for the crisis managers to receive adequate information to ensure appropriate decision and communication.
- Recovery phase should consist in three steps: check-up, lessons learned and vision. Each step is fundamental to learn and change.

3. The impacts of flooding

3.1 Effects of flood spread out in time and space

G.F. White[25] in his classic text "human flood adjustment to floods" (1945) famously asserted: "Floods are "acts of god", but flood losses are largely acts of man". Floods results from the transfer an unusual large quantity of water falling on a catchment to its outlet. Floods it has been argued are the consequence of meteorology times land form as modified by land use. This runoff may induce a surcharge conveyance or storage capacity of the water bodies (surface and groundwater) and wetlands leading to an expansion of water flow onto land that is not normally covered by water. A flood (e.g. this unusual large quantity of rainfall) is commonly expressed in terms of frequency or return period to figure the probability of such an event to happen. A flood can also be characterized at different points of a catchment by different variable, i.e. its depth, its velocity, its duration, its lag time, its extent and its loads. All these characteristics are the results from the "acts of gods" as they are the final product of a long and dynamic exchange between natural forces (climate, tectonic movement, erosion, and the evolution and development of ecosystems). The catchment characteristics (shape, slope, and runoff and infiltration coefficient for the different land use) and the hydraulic network influence the shape of its characteristic hydrograph. For example, a long shape watershed generates, for the same rainfall, a lower outlet flow, as the concentration time is higher. A watershed having a fan-shape presents a lower concentration time, and it generates higher flow. Floods plains with higher frequency of flooding exhibit a skew to shallow water with depth (less than 60 cm) (**Figure 4**). The distribution of depth tends to homogenize with lower frequency. The loads will also depend of the type of land use drained and flooded by the water.

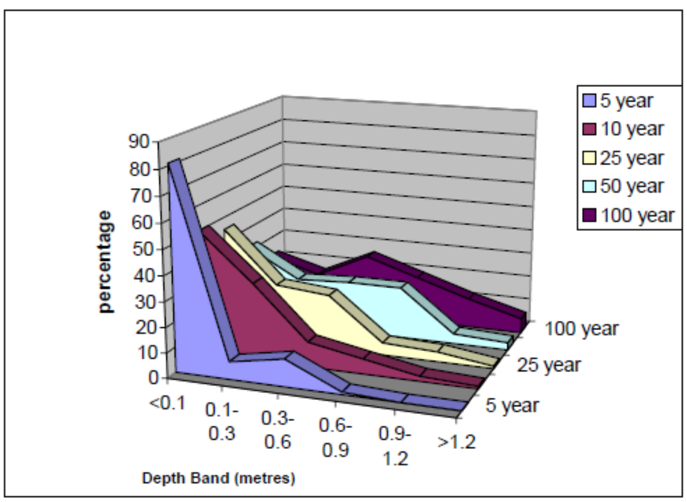

Figure 4: Property distribution per depth for different return periods (from Floodsite Deliverable[26])

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[25] White, G.F. (1945). Human Adjustment to Floods: a geographical project to the flood problem in the United States. Department of Geography Research Paper no. 29. The University of Chicago.

[26] Messner, F.; Penning-Rowsell, E.; Green, C.; Meyer, V.; Tunstall, S.; Van der Veen, A. (2007). Evaluating flood damages: guidance and recommendations on principles and methods.EU Floodsite project N. GOCE-CT-2004-505420.

Floods are no longer considered as Acts of gods, as the acts of man have played a major role in the last 40 years in Europe in changing the landscape, the type of land use and their properties (drainage, impermeable, use of chemicals), the water body capacity (channel, flood defense) as well as climate change. Some of the floods such as pluvial flooding at urban scale, dams break or tailing dams failure can even be entirely due to human acts.

Flood losses are largely acts of men as it refers to the development of society along river. The choice of the land use organization and the type of assets and contents in terms of floods vulnerability built on the flood risk area is a key factor in terms of flood losses as they refer to potential direct damages and in consequence to the indirect damages. This is reflected in the Source –Pathway –Receptor –Consequence approach which is commonly adopted to deal with the risk in flood damage assessment[27]. Receptor designs any entities (environment, habitat, and network) that may be harmed by a hazard (flood in our case). To evaluate the risk it is required to consider the nature and probability of the hazard, the degree of exposure of the receptors to the hazard, the susceptibility of the receptors and their value in order to measures their consequences. The receptors of a first order are located in the flood area as they would potentially be in contact with water. Their identification is simple and the measures of the consequences (e.g. direct losses) less complex as due a direct contact with the water than for receptors of the second order. Receptors of the second order may also suffer harm but indirectly as "close" to the flood area and, therefore, their activities may be altered and then measured as a consequence of the floods (disruption of production and services processes, e.g. traffic diversion). "Close" has to be used with caution as it points to the existence of a link rather than a distance. For instance if a minor road is flooded, it may induce indirect effect a few kilometres around. But if a railway is flooded, it may have consequence hundreds kilometres around. If an international airport is flooded it will affect other parts of the world. The third order also considered as an indirect consequence, relates to all consequences happening after the floods and related to the recovery phase. There is also a direct causal effect between the third order and the first order in terms of magnitude as for instance greater the number of properties is damaged longer it takes to repair them and longer the inhabitants have to pay for alternative accommodation. We have just mentioned that both second and third orders are highly dependent of the scale of first order. Thus it is important to focus first on the main receptors but it is also important to analyze their link with other receptors outside the flood plain area. In general current approaches limit their approach to the first order.

Either from the event characteristics, the catchment characteristics or the land use characteristics the effects of flood spread out in time and space is highly variable. Thus flood events can affect from 100 to millions of people[28]. Their consequences in terms of loss, of appropriate mitigation measures and of recovery are system dependant and changeable. The aim is to always have in mind ways an overview of the all potential effects and to distinguish between significant differences and to cut away the non-significant differences. Environment, people and economy are the key systems which support a society. The potential impacts of floods on these three systems are essential to understand the consequences on a society. A common definition of a system is that it is "a set of independent but interrelated elements comprising a unified whole", or

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[27] Gouldby, B..; Samuels, P.; Klijn, F.; Os, Ad Van; Sayers, P. and Schanze, J (2005). Language of Risk - Project definitions. EU Floodsite project

[28] Internet site: EM-DAT, The international Disaster Database.. http://www.emdat.be/ (Last visited December 2010)

simply that a system is more than the sum of its parts. As in the input – output model described in Section 2 (**Figure 1**), each element involves transforming some inputs into some outputs. The essential features of a system are thus a series of nodes at which some inputs are transformed into some outputs and the relations, the links, between those nodes. Mathematically, a system is a directed graph and can be summarized in the form of a matrix; in the case of the economy, this is often done in the form of an input-output table. This brings out one key feature of a system: its topology, the pattern of connections. But such a summary is only a description of the system and not an analysis, and it is difficult to predict the behaviour of a system from a simple description of that system. Systems are argued to have 'emergent' properties[29].

The patterns of interconnections between the components is the structure of the system and, together with the functional form of those interconnections, has a critical effect upon the performance of the system as a whole when it has to respond to external perturbations. Those interconnections have a direction, and a functional form. A particularly important form of interconnection is feedback: where the state of the dependent variable(y) then influences, after some lag, the state of the independent variable (x). That feedback can either be:

- Negative: the larger the y, the greater the negative feedback to the x
- Positive: the larger the y, the greater the positive feedback to the x.

But this simplification loses out a lot of crucial detail about the nature of the connections and how the system will respond to a change. Firstly, any system is spatially distributed and the way in which it is distributed can have significant effects. For example, a particular transformation, say the conversion of iron to steel, may be concentrated in a single location or take place at numerous small sites. Each of those transformations has a finite capacity in the short term and cannot therefore necessarily immediately adjust to changes as a result of effects elsewhere in the system. Changes also take time so there are lags in responding; stocks are sometimes available to buffer the effect of shocks but those stocks may themselves be highly concentrated (e.g. the distribution warehouses for supermarkets) and affected by the flood. Any change also incurs a cost; so, too do transfers along the links take time and these transfers also incur costs; the frictional costs of adjustment. In each case, an important question is: are the relationships linear, additive and reversible? If they all are then both the immediate shock and the recovery will be relatively straightforward. What makes life difficult is when they are non-linear or non-additive and particularly when they are irreversible.

Most systems also both draw on their environment and impact on their environment; a flood can be viewed as a perturbation in the environment. As a system, depending upon the initial point impacted by the perturbation, the perturbation will set off a series of adjustments which will ripple through the system. In the case of a flood, the hope is that after some period of time and some chain of adjustments, the system will return to its original state. How that shock will ripple though the system. From this systems perspective, vulnerability can be described as the chain of interrelationships between the initial points at which the perturbation impacts the system. Those relationships may either mitigate or amplify the magnitude of the initial impact. So, whilst the vul-

[29] Corning P A 2002 "The Re-Emergence of "Emergence": A Venerable Concept in Search of a Theory", Complexity 7(6), 18-30

nerability of B is simply the susceptibility of B to this particular form of impact, the vulnerability of A is defined by the chain BCA. A is also vulnerable to impacts that occur initially in other points in the system; for instance, the vulnerability of A to an impact at E is given by the chains EA; ECA, and ECBCA. In everyday terms, B might be A's child's nursery school, D A's home, and E their place of employment.

A significant issue then is what is the functional relationship between inputs and outputs at each node. If all these relationships are linear and reversible then the initial reduction in well-being is likely to be relatively small and easily recoverable. Therefore, the critical question is when will there be discontinuities in the output to inputs? More especially, when will an irreversible change take place?

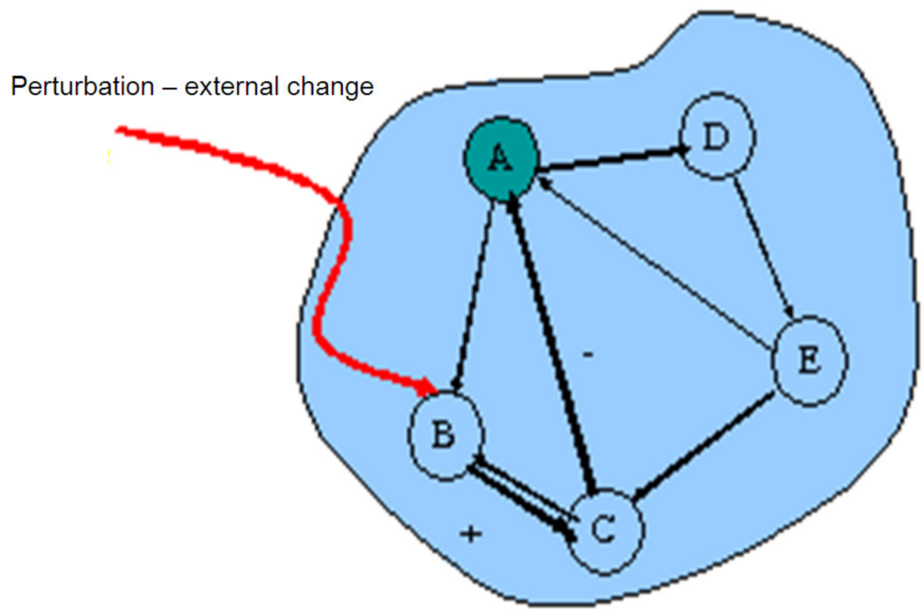

Figure 5: ***Vulnerability and resilience as response characteristics of a dynamic system***

In the same terms, resilience, the capacity of a system to remain in the same domain of states under external shocks, can be argued to depend upon the feedback to the initial element impacted. Thus that the resilience of B is determined by the chains BCB, BCAB, BCADEAB, BCADECB, and BCADEAB. Adjustments will be made throughout the system but those adjustments are not made automatically but as a result of people responding to changes in opportunities, constraints and incentives, and based upon the information available to them.

EFFECTS OF FLOOD SPREAD OUT IN TIME AND SPACE

- Floods reflect the catchment characteristics and the hydraulic network.
- Flood losses reflect human development choices, e.g. number and type of potential flood receptors, flood receptor vulnerability, importance and relationship with non flood receptors in the human society at different scale, mitigation measure.
- The dynamic response of a system to a flood perturbation depends on its structure and its functional interactions.
- Flood losses are variable and context dependant. It is important to distinguish between significant differences and to cut away the non-significant differences.
- Assessing the impacts on the environment, the people and the economy is essential

3.2 Impacts on the Environment

Ultimately everything else hangs on the environment and the relationships of both the economy and society to the environment are as the leaf to the tree. The environment is a mosaic of distinct biotopes, each of which is dependent upon the soil type; climate including specifically the water regime; and land form. Those biotopes are to a greater or lesser extent interconnected; for example, the health of forests on the west coast of the USA has been shown to be dependent upon the annual salmon run[30]. Each ecosystem is then organized into trophic levels – essentially what eats what – with carnivores at the top, each higher level therefore depending upon the lower levels.

A flood plain is then a variety of biotopes, the plants in the river channel specialized as either submerged or emergent vegetation. There is then a zone where the plants are adapted to saturated soils during the growing season – wetlands - and finally dryland ecosystems. The different biotopes are highly adapted to the prevailing water regime – the pattern of flows over the year. One consequence is that changing the pattern of flows as a result of increased or decreased flooding will usually involve trade-offs between different ecological impacts: an increase in wetlands requiring, for example, a loss of dryland ecosystems.

Plants are a form of mining, abstracting essential nutrients from the soil and carbon plus energy from the atmosphere, the plants trading water for carbon: photosynthesis being produced through the combination of carbon dioxide and water. In an undisturbed environment, the nutrients are returned to the soil when the plants die and decay; if part of the plants are harvested then the nutrients are removed and the soil fertility falls progressively[31]. Hence, the three primary determinants of the nature and health of a plant community are:

- The water regime
- The nutrient regime
- Plant management

[30] Reimchen, T.(2001) Salmon nutrients, nitrogen isotopes and coastal forests, Ecoforestry (Fall), 13-

[31] Loomis, R. S. and Connor, D. J. (1992) Crop Ecology, Cambridge: Cambridge Univesity Press

Dryland plants take in water through their roots but also require air in order to take up nutrients so it is the degree of water saturation in their root zone that determines their health. Thus, by the time surface water flooding occurs, the damage to the plant has often already been done. However, flooding outside of the growing season of dryland crops normally results in little harm to the plants but other consequences of the flood may do so. Wetland plants are specialized so that they can take up nutrients in saturated soils. Whilst some soft plants are adapted to saturated soils, trees are only more or less tolerant to saturated soils and flooding, different species being able to survive different durations of flooding. Root systems experience damage and, as flood tolerance depends upon the replacement of the root system, flooding retards growth[32]. Even most flood tolerant trees require no flooding during 50% of growing season.

Both the adaptation of wetland species to saturated soils and the tolerance of some tree species to occasional flooding come at some cost. Wetlands can be significant producers of methane and nitrous oxide[33], both very aggressive greenhouse gases and the tolerance of trees comes at the cost of some undesirable byproducts[34].

It is a myth that flooding is always beneficial to plants; floods may deposit silt, a flood moving good soil from one place to another, and in tropical climates, nitrogen fixing algae may grow in flood waters providing nitrogen, an essential nutrient. However, equally, a flood may deposit sand or gravel over both the bed of the channel or onto the flood plain with the resulting loss of fertility as the organic layer of the soil is buried under the sand or gravel. For example, in the 1993 Mississippi flood, some 455,000 acres, 60% of the cropland in the Missouri floodplain was buried under 1-5 feet of sand. The US Soil Conservation Service[35] estimated that it cost US$ 3200 per acre foot to remove the sand and a further US$ 190 per acre to restore the fertility of the soil. The same risk applies to natural ecosystems.

Whilst cropping plants necessarily removes nutrients, a natural ecosystem is largely a closed system and the species composition was determined by the natural levels of essential nutrients. Thus, if a flood increases the availability of a nutrient in an area where naturally the soil is nutrient poor, then the result may be to change the species composition. Mesotrophic (soils that are neither nutrient poor or nutrient rich) floodplain meadows are an important habitat in England and the summer floods of 2007 resulted in the deposition of up to 500 kg/ha, and up to 270 kg/ha[36] potassium. There was a significant loss of species richness in the Chimney Meadows National Nature Reserve[37] and also a loss of soil macro invertebrate populations: there was a 63% reduction in worm density over the Reserve.

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32 Parolin, P. and Wittman, F. (2010) Struggle in the flood: tree response to flooding stress in four tropical floodplain systems, AoB Plants Vol.2010 plq003, http://aobplants.oxfordjournals.org/

33 Mitsch, W. J. and Gosselink, J. G. (2000) Wetlands, Chichester: John Wiley

34 Parolin, P. and Wittman, F. (2010) Struggle in the flood: tree response to flooding stress in four tropical floodplain systems, AoB Plants Vol.2010 plq003, http://aobplants.oxfordjournals.org/

35 Soil Conservation Service. 1993. Impacts of the 1993 Flood on Missouri Agricultural Land. United States Department of Agriculture, Soil Conservation Service, Columbia, MO

36 Gowing (nd) Impact of summer flooding on floodplain biodiversity via nutrient deposition, Milton Keynes: Open University

37 Lock, K. (nd) The vulnerability of floodplain meadow communities to flood storage: a case study in the Upper Thames,

Flooding also can transport and deposit harmful materials for plants and other members of eco-systems. Both nutrients and pesticides may be washed off farmland – nitrogen concentrations in the 1993 Mississippi flood were the same as under normal conditions, the greater flow being counterbalanced by the greater load[38]- pollutants bound to sediment are remobilised and deposited downstream, and oil or chemicals can be released from storage tanks and deposited by the flood waters. So the question is to determine when and where a flood will have beneficial effects on the existing ecosystems and when it will have harmful effects. The ecosystems in the channel will also be affected by changes in the geomorphological form of the channel.

Ecosystems are naturally dynamic, developing through successive stages and Holling's[39] model of resilience argues that resilience requires the maintenance of these successive stages (**Figure 6**). Conversely, people often want to hold an ecosystem in a single stage rather than allowing natural progression; many ecosystems in Europe are artificially maintained in a particular state by, for example, grazing or water management. Many now important sites were created by anthropogenic action, included changing the water regime, and we now seek to keep them in this changed state. In England, many of what are now important areas for wading birds, such as the Somerset Levels[40], were created in the great period of land drainage in the Medieval period[41] when wetlands were drained to provide better grazing. Similarly, many of the now important water meadows were similarly the product of farming techniques[42].

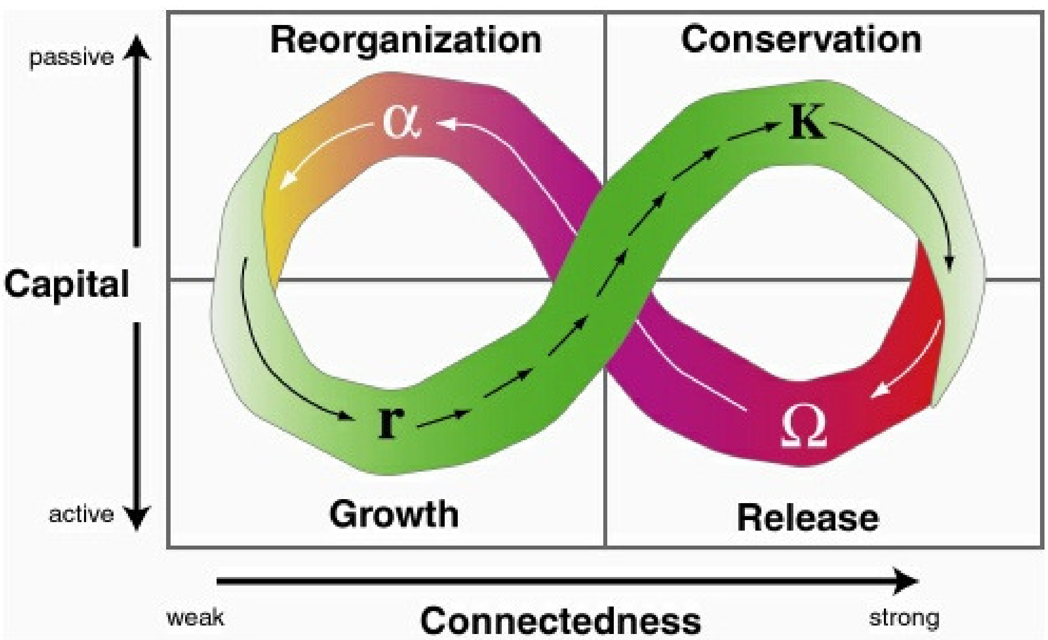

Figure 6: Holling Model

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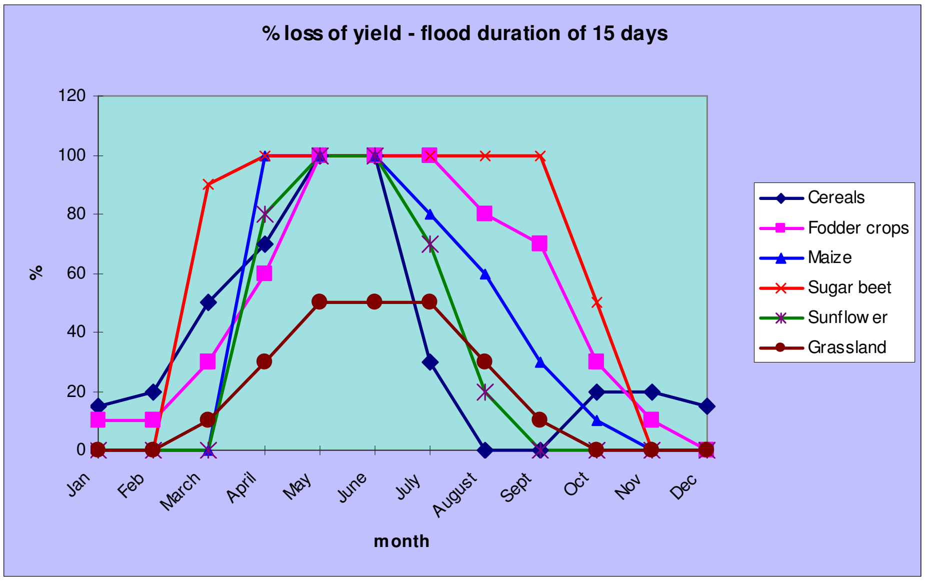
[38]Goolsby, D. A.; Battaglin, W. A. and Thurman, E. M. (1994) Occurrence and Transport of Agricultural Chemicals in the Mississippi River Basin July through August 1993, US Geological Survey Circular 1120-C, Washington DC: US Geological Survey
[39] Holling, C. S. (1973) Resilience and stability of ecological systems, Annual Review of Ecology and Systematics 4, 1-23
[40]Williams, R.(2003) The Somerset Levels, Bradford on Avon: Ex-Libris
[41]Hoskins, W. G. (1955) The Making of the English Landscape, Harmondsworth: Penguin
[42]Cook, H.; Stearne, K. and Williamson, T. (2003) The origins of water meadows in England, The Agricultural History Review 51(II), 155-162

Arable farming is effectively a highly simplified ecosystem; and the effect of flooding depends on when it occurs in relation to the growing season. Thus crop losses in the North hemisphere are most pronounced in the summer period (**Figure 7**). Except where multi-cropping, in the form of horticulture is practiced, flooding in winter generally has little or no effect.

Figure 7 **Hungary: agricultural losses**[43]



43 Green, C. H.(2003) Handbook of Water Economics, Chichester: John Wiley.

ENVIRONMENT

- The relationship of the economy and people to the environment is as the leaf to the tree: all the resources on which we depend are withdrawn from the environment..
- Those resources can be categorised into provisioning, regulating and cultural services but the availability of each is dependent upon the underlying supporting services of the environment. It is necessary to maintain these supporting service is if the other services are to be provided.
- The environment is an interconnected mosaic of interdependent ecosystems.
- Ecosystems are inherently dynamic and go through a series of successions: for ecosystem health, it is generally desirable to maintain the succession. However, people frequently want to hold ecosystems in a single state rather than permitting natural succession.
- Ecosystems develop around the prevailing water regime; any change to that regime for whatever reason is likely to have consequences for the ecosystems.
- For plants, the timing of the flood relative to the growing season is critical; floods outside of the growing season are relatively unimportant.
- It is a myth that floods are always good for ecosystems. Extreme floods, particularly those in upland catchments, can mobilize and then deposit sand and gravel both in the river channel and the flood plain; both are harmful to the existing ecosystems. Regular flooding of dryland ecosystems during the growing season is undesirable.
- Arable agriculture can be considered as a highly simplified ecosystem and so the effects of flooding can be analysed in the same way as those upon other ecosystems.
- Regulating and provisioning services can be comparatively readily evaluated in economic terms.
- Because the landscape is a mosaic of ecosystems, each of which is dependent upon the prevailing water regime, many decisions will involve environment to environment trade-offs e.g. the preservation of a dryland ecosystem or the enhancement of a wetland ecosystem.
- Recommendations as to what environment to environment trade-offs ought to be made from the perspective of environmental functioning should be made by ecologists; these are not decisions to which economic analyses can generally usefully contribute. In particular, what people would like and what is required to maintain the environment should not be confused.
- Environmental functioning is one area where economic evaluation is generally only useful to the extent to which all stakeholders agree on the extent to trade-offs can be made.

3.3 Impact on the Population

Beside the economic loss of their houses and their contents, the potential impact on health but also the risk of the degradation of the social connection and relationship within a population are essential to measure the changes in well-being as defined by the Stiglitz Commission. Potential physical impact on individual are[44]: mortality, injuries, disease (e.g. diarrhoeal, vector-borne) and infections, chemical pollution, nutrition and displaced population. Psychological or mental health impacts are also recognised and are related to various flood impacts such as the stress of the flood itself, the evacuation, the disruption to life and household and the loss of memorabilia and personal belongings[45].

From the perspective of resilience, the risk to life is clearly a special case as it is irreversible. Hence, the first effect that may come in mind to consider when assessing the impact of a disaster on the population is the risk to life. Loss of life due to floods exists. However this risk[46] is really low compare to other disasters such as earthquake, storm (cyclone), storms or tsunami in the last forty years. In the last ten years high loss of life due to floods mainly concern developing countries. In Europe the risk of dying directly by flood is pretty low especially for floodplain and pluvial flooding. The average event mortality is estimated at 4.9*10-3 for river flood and at 3.6*10-2 for flash floods stressing a higher risk of death in flash floods[47]. The worst cases of death are usually related to coastal flooding, flood defense failure and flash floods (e.g. North-See floods of 1953: Netherlands 2000 persons and UK 53 persons; Xinthia 2010 France: more than 50; flash floods in Maison la Romaine in France 1992 : 30 deaths). During the 2002 floods which cost 15 billions Euros damages in Europe, more than 100 persons died[48] but this number is small for such large scale event. At a local scale for an extreme event up to 50 persons can die. The difference between fluvial/pluvial flooding and other floods in terms of risk to life can be explained by the characteristics of the floods. Indeed high velocity and high depth associated with debris involve loss of stability in the water and risk of drowning. The lag of time is also crucial as it constraints the potential time of warning and evacuation. However it is not because there is a flash flood that there is death. Indeed other characteristics need also to be considered. The local circumstances play a strong role in the risk to life and involve multi-variable such as presence of shelter, type of building (risk of collapse, single floor), the time in the day, the seasonality (summer and campsite), flood warning. Injuries or death can also happen after the flood event when the household return in home (e.g. due to unstable building, electric danger)[49].

When considering the long term effects of the flood, the social, cultural but also geographical, climatic context can be determinant. Because of the scale of some events but also because of the living conditions and preexistent diseases, vectors and rodents long-term effects of flood are

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[44] Few, R.; Ahern, M.; Matthies, F. and Kovats, S. (2004) Floods, health and climate change: a strategic review. Tyndall Centre for Climate Change Research, Working Paper 63

[45] Tapsell, S. and Priest,S. (2009). Developing a conceptual model of flood impacts upon human health. Floodsite project.

[46] Internet site: EM-DAT, The international Disaster Database.. http://www.emdat.be/ (Last visited December 2010)

[47] Jonkman, S.N.and Vrijling, J.K. (2008) . Loss of life due to floods. Journal of flood risk management 1 43-58

[48] Risk Management Solution (2003)Central Europe Flooding, August 2002 – Event report

[49] Ahern, M.; Sari Kovets, R.; Wilkinson, P.; Few, R.and Matthies, F. (2005). Global Health Impacts of floods: epidemiologic evidence. Epidemiologic reviews vol.27

mainly related to low-income and medium-income countries[50]. European citizens will mainly suffer from headaches, colds coughs and flu. However Ahern et al. (2005) stress that mental health impact is mainly studied in high-income and middle-income studies. Mental health impact includes common mental disorder such as anxiety and depression, and post-traumatic disorder (PTSD). Mental health impact results from different causes happening at different time of the flood and after the flood event during the recovery phase. The experience of the flood itself is of course a main component but dealing and recovering from the floods' consequence is another one. A recent study[51] indicates that the immediate mental impacts also include the anxiety of being out of one's home, the discomfort of living in temporary accommodation and the time and effort in dealing with insurers and builders. A UK survey[52] stresses that health effect can be increased by socio-demographics factor (age, long-term illness, social grade, house type in terms of vulnerability), by floods characteristics (contamination, presence and extent of floods within the household) and by post-floods factors (problems with insurers and builders, evacuation).

In addition to the characteristics of the flood experienced, the vulnerability and resilience of a person might be influenced by:

1. The socio-economic (e.g. income) and demographic characteristics of the individuals impacted by the flood. For example, it seems reasonable to expect that the elderly will be more vulnerable or less resilient than the young with regard to health effects.
2. The personality characteristics and life experience of those impacted.
3. The social context in which those individuals are situated, notably social and other forms of capital[53]

Current approach tends to limit to the approach to individuals. However higher level may need to be considered. For instance households are spending their time, their energy and their money for recovering from the flood which leads to sacrifices. The tiredness and anxiety resulting from dealing with recovery may also affect the social relationships within the family and within their community. The time and effort to return to a normal life can then extend over the "physical" recovery phase[54].

The needs of stakeholder engagement and public participation supported by EU directive leads to the development of social capital, e.g. catchment community, flood action groups. The flood risk in this sense can be seen as a benefit for social capital (as fear and reaction create a group). Social capital by definition[55] focuses on networks, norms and trust which allow a group of individuals to achieve more effectively common objectives. But negative effects can also result from the floods such as social disorganization due to the loss of life, refugees, loss of trust on the authorities leading to the ruin of local economy, even to political instability and change. For

[50] Mike Ahern, R. Sari Kovets, P. Wilkinson, R. Few and F. Matthies (2005). Global Health Impacts of floods: epidemiologic evidence. Epidemiologic reviews vol.27

[51] Werritty, A.; Houston, D.;Ball, T.; Tavendale, A.and Black,A. (2007). Exploring the social impacts of flood risk and flooding in Scotland. Scottish Executive Social Research

[52] DEFRA/Environment Agency (2005). The appraisal of Human-related intangible impacts of flooding. R&D Technical report FD2005/TR

[53] Bourdieu; P. (1986). The forms of capital. In J. Richardson (Ed.) Handbook of Theory and Research for the Sociology of Education. New York, Greenwood,

[54] Tapsell, S.and Priest,S. (2009). Developing a conceptual model of flood impacts upon human health. Floodsite project.

[55] Bourdieu; P. (1986). The forms of capital. In J. Richardson (Ed.) Handbook of Theory and Research for the Sociology of Education. New York, Greenwood,

instance extreme events or frequent events may entail an impossibility to return to a normal life because of political decision not to rebuild or of an individual decision to move away. The extreme case of the environmental migrants/refugees is highlighted by the recent consideration of Climate Change[56].

People are obviously the core component in flood losses assessment and the effects of either on the economy or on the environment end up in affecting more or less the population. The population can be affected in different ways directly and indirectly. Thus even when assessing the impact on population by a simple approach, i.e. considering the number of persons affected, the approach is not so evident and is actually hiding various questions. Classic assessment will consider the number of flooded households and eventually applied a factor to adjust the number to a population number. Shall we also integrate in some way other aspects: loss of jobs (temporary), inconvenience due to loss of services such as traffic disruption?

PEOPLE

- The requirement is to measure changes in well-being as defined by the Stiglitz Commission.
- Do not place a value on a statistical life: think instead as to what you would say at the Disaster Inquiry. Decisions do not have to be right in retrospective but the reasons for having reached that decision do have to be defensible.
- Risk to life is low in Europe for fluvial and pluvial flooding. Higher risk exists for some floods. Hotspots can be identified based on hazard and vulnerability characteristics. Primarily those areas where water velocities can be expected to be high (e.g. alluvial fans, upland valleys), need to be defined. These hotspots require specific measures to reduce the risk to life. Personal behavior needs also to be considered as an important component in risk to life
- Injuries may also happen when rescuing or during the recovery phase when coming back home or cleaning
- In Europe common health impacts are headaches, colds, coughs and flu but also mental health impact such as anxiety, depression and post-traumatic disorder.
- Three components have to be considered: social and demographic characteristics/ personal behavior/ community response. Social and demographic characteristics are statistically available via census data but can be poorly flood related. Local surveys are necessary to better understand and apprehend potential impacts of flooding on people.
- Extreme events and frequents events can weaken social capital e.g. loss of trusts, loss of jobs, temporal or permanent flood refugees

[56] Few, R.; Ahern, M.; Matthies, F.and Kovats, S. (2004) Floods, health and climate change: a strategic review. Tyndall Centre for Climate Change Research, Working Paper 63

3.4 Impact on the Economy

The problem has two parts:

1. To estimate the shock to the system;
2. To predict the consequent change in the trajectory of the system.

The initial shock can be considered in terms of the transformational diagram shown in **Figure 1**. A flood can then destroy or damage some of the environmental resources, the transformations in the economy, or final consumption. Considered as a simple output/input model, a flood may destroy inputs, destroy outputs or reduce the rate or efficiency with which outputs can be created from inputs. Further, since sustainable development requires that we increase efficiency, do more with less; a further potential source of loss is of the capacity to increase that ratio over time.

Therefore, in estimating the shock to the system, initially it is necessary to calculate:

- loss of environmental resources
- loss of production durables
- loss of consumption
- loss of multipliers

In principle, each loss can be estimated as a change in the stock or a change in the flow: the value of a change in a stock being given by the discounted present value of the change in flow. The practice is to calculate whatever it is easier to estimate; what is critical is to avoid counting both the change in the stock value and the resulting change in the flow. Thus, labour is a flow and most readily therefore evaluated in terms of the value of the flow. A television, a consumption durable, could in theory be evaluated as the stream of consumption flowing from the use of that television over its lifetime but it is considerably easier to use the capital value of the television as derived from its market value. Again, the loss of agricultural productivity as a result of the deposition of sand could be estimated by as the change in value added as a result of reduced fertility but it is easier to estimate by the cost of restoring the fertility of that land to its pre-flood level.

Damage in floods to things occurs in one of three ways:

1. physical processes (e.g. mechanical damage as a result of impact)
2. chemical processes (e.g. corrosion)
3. biological processes (e.g. mould)

The prevalence of each depends upon the particular characteristics of the flood and the characteristics of the materials and assemblages of materials which are impacted by the flood. The characteristics of the flood and mechanism causing damage interact (**Table 2).** The relationships shown have not yet been examined in detail. Clearly, there should be expected to be some relationship, for example, between duration and damage because capillary action takes time. Similarly, there might be expected to be some relationship between some forms of load (e.g. ph) and damage. Instead, the available data is largely empirically derived with exception for that on the effects of velocity.

Depth

The best known and most commonly assessed mechanism by which floods cause losses is the depth of flooding.

Duration

Very long flood durations (over one week) are associated with increased physical damages compared to short duration floods[57].

Velocity

High velocity flows increase damage to buildings in a number of ways:

- High velocity flows entrain debris such as vehicles, trees and rocks; collision damage with buildings.
- Obstructions create standing waves and scour which can undermine foundations.
- High pressure differentials between inside and outside buildings.

The combination of depth and velocity can result in partial or complete structural failure of a building, the combination of depth and velocity required depending upon the structural form of the buildings[58]. Only the last causal mechanism can currently be modelled. For coastal flooding, the problem is significant only in consequence of breaches of defenses, natural or artificial, which create localized very high velocity flows.

Load

The extreme are mud flows, essentially the movement of liquefied soil; mud flows are capable of wiping entire urban areas of the face of the earth. However, such instances are usually the result either of volcanic eruptions causing instantaneous snow melt consequent soil erosion (e.g. Armero 1985) or on alluvial fans (e.g. Venezuela 1999). Some rivers carry a very high load of sediment but the sediment load varies greatly between rivers, as does the nature of that sediment (silt or sand). Sewage, oil and other petrochemicals are all commonly released in floods, along with agricultural chemicals such as fertilizers and pesticides. However, because of the very large volumes of water involved, dilution of pollutants will normally be such in coastal floods that the only load of significance is the salts of the waters. A number of materials are subject to quite aggressive attack by the combination of water and salts.

In turn, the different contexts of flooding are generally associated with particular characteristics (**Table 3**).

[57] Green, C.; Wilson, T.; Masterson, T.and Boothby, N. (2006). An assessment of the additional flood losses associated with groundwater flooding: a report to Hampshire County Council and Winchmester City Council. FHRC-Middlesex University.

[58] Dale K W, Edwards M R, Middelmann M H and Zoppou C (nd) Structural flood vulnerability and the Australianisation of Black's Curves, Canberra: CSIRO; Kelman, I. (2002). Physical flood vulnerability of residential properties in coastal, Eastern England.University of Cambridge

Table 2 ***flood characteristics and mode of damage***

	Physical	*Chemical*	*Biological*
Depth	●	●	●
Duration		●	●
Velocity	●		
Load	●	●	

Table 3 ***flood types and damage characteristics***

	Depth	*Duration*	*Velocity*	*Load*
Groundwater		●		
Pluvial			○[1]	
Flash	○[2]		●	●
Alluvial fan	●		●	●
Lowland river	●	●		○[3]
Coastal	●			

[1] *very dependent upon form of catchment, especially steepness*

[2] *very dependent upon shape of catchment and degree therefore to which flood flows are concentrated e.g. through constrictions*

[3] *dependent upon sediment load of river*

In looking to evaluate the shock, the logical starting point is the relative values of assets at risk. In Europe, the total current value of all assets varies in the range of 2:1 to 4:1 as a ratio to GDP per capita[59]; thus, the loss of assets can never exceed these ratios. For areas where multi-storey buildings predominate, the loss of assets cannot reach these values. Buildings constitute the largest proportion of the assets at risk. Generally, whilst dwellings constitute by far the larger proportion of the stock of buildings, non-domestic buildings have a higher value per unit floor area.

The damages of assets or the impossibility to use them due to an absence of accessibility (presence of water within or surrounding them for instance) leads to a disruption of production and services during the flooded and recovery period. Because it is a loss of flow, the time component and the production function are critical. But the existences of alternatives to replace this flow have also to be considered as reducing the loss.

The effect of the loss of assets is to change the supply of the goods or services produced by those assets. In turn, that reduction in the supply of goods and services may result in the reduction of other goods and services (e.g. the reduction in the supply of flour might limit the production of bread) and these reductions in supply may also change prices. Conversely, the increase in demand caused by the desire to replaced assets which have been damaged or destroyed in the flood may also result in increased prices or the shift of available goods and

[59] Green, C. H. (2010) **Coastal cities: assets at risk and depth-damage curves**; report prepared for the OECD, Middlesex University

services away from their pre-flood use. Thus, the loss of production and services can have a ripple effect on the economy at various different scales.

Figure 8 is the standard 'scissors', or Marshallian consumer surplus, diagram of microeconomics; demand is assumed to fall as price increases and the incremental or marginal cost of supply to increase as supply increases. An equilibrium is assumed to be achieved when the demand curve and incremental cost curves cross: at this point, economic theory predicts that the quantity supplied and the price at which is sold fall out of the market. The area above the cost line and below the demand curve is the “Consumer Surplus”, the difference between what the consumers would have been prepared to pay and how much they had to pay. The area above the incremental cost curve and below the price line is the “Producer Surplus” and represents both the fixed costs of production and also pure profit.

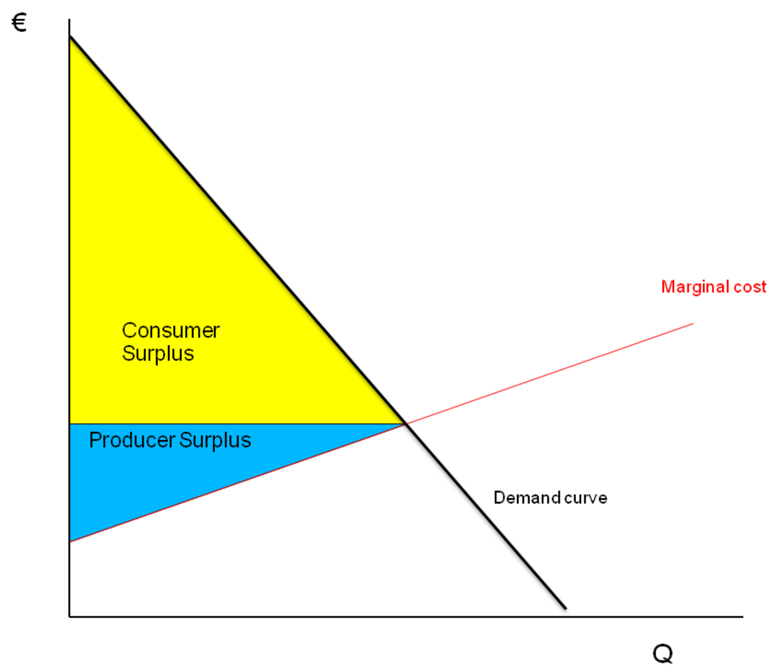


Figure 8: Marshallian consumer surplus diagram

There are some problems with this form of analysis, notably the necessary assumption that the market is perfect, which is a highly restrictive condition[60]. There are further assumptions: that the market is in equilibrium; incremental costs rise with the quantity supplied (which is not the case when there are economies of scale in production); and the way that the size of the producer surplus, necessary to cover the fixed costs of production (e.g. rents, the cost of loans), is determined by the slopes of the demand and incremental cost curves rather than by the size of the fixed costs of production. A critical assumption is that the response to any change in demand or supply as a result of a shock will be both instantaneous and costless. Nevertheless, the scissors diagram offers a simple starting point for explanation.

[60] Frank R F 2006 Microeconomics and Behavior, Boston: McGraw-Hill

After a flood, either supply or demand for different goods and services will be affected: damaged factories and shops will not be able to supply so supply is reduced whilst the demand for some goods, those lost or damaged in the flood, will increase. In turn, increased expenditure on these goods will force a reduction in expenditure on other goods and so demand for these goods will fall. The overall result will be to change prices. To take two cases; firstly, supply is reduced whilst demand remains constant (**Figure 9)**. For demand and supply to be in balance, the price increases and the net effect is to increase Producer Surplus at the cost of Consumer Surplus. The result is both redistributional, the producers gaining at the expense of the consumers, and inefficient – because the Producer Surplus is now greater than is required under normal conditions to produce a higher quantity of goods – the ratio of outputs to required inputs falls.

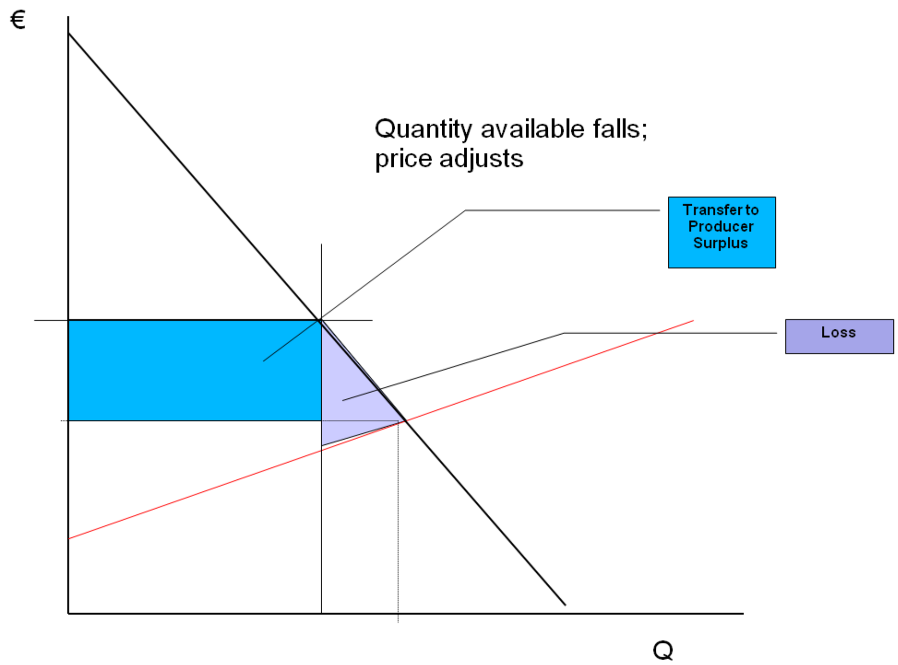


Figure 9: Change in price when the supply is reduced

Similarly, if demand increases (for example, for building repairs) whilst supply remains constant then again there is a transfer from Consumer Surplus to Producer Surplus (**Figure 10**). Again, the effects are both redistributive and result in a loss of efficiency.

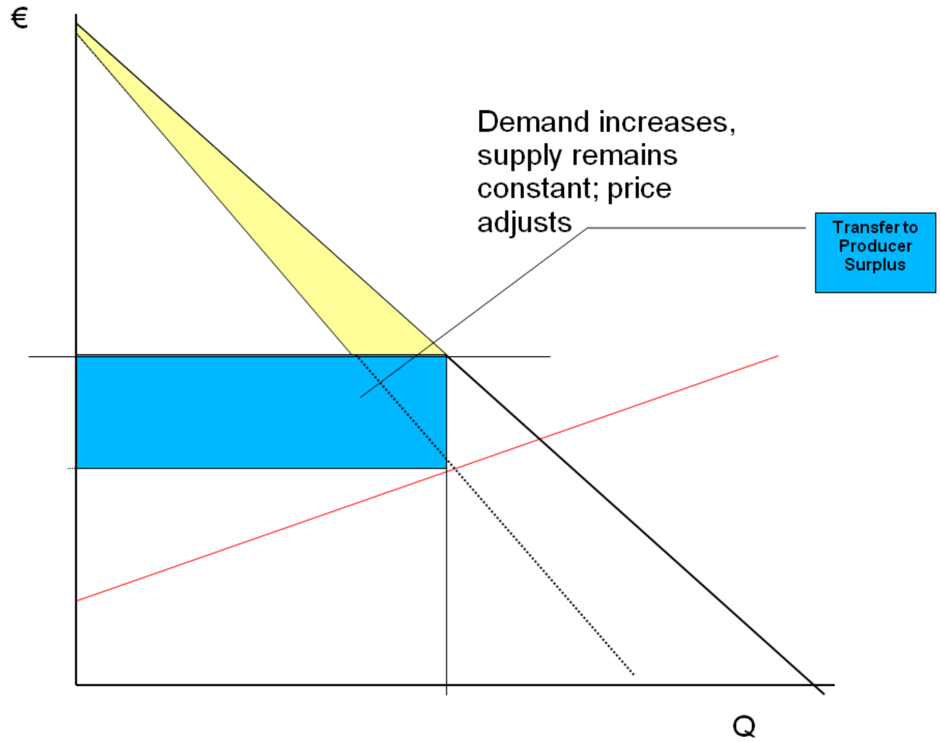


Figure 10: Change in price when the demand increases

Considering recovery from a flood, suppose a flood results in losses of assets equivalent to 10% of GDP; for simplicity, assume that GDP is 100 units. In a European economy, the ratio of net assets to GDP is approximately equivalent to 3:1 so 10 units of assets are lost from a stock of 300. Similarly, in a European economy, the ratio of gross annual investment in assets to the GDP is roughly 1:4[61]. The immediate effect of the loss of assets may be approximated as 3.3 of output of which 0.8 would have gone to investment and 2.2 is the reduction in consumption. Replacing the lost assets could either be undertaken by displacing other investment which would prevent the growth in the economy or by reducing current consumption. To replace the lost assets, consumption would have to be cut by a further 10.8 units in one year, a savage reduction in consumption, or the cut in consumption spread over more years. Here it is not savings but investment that is important: either those savings are already being used for investment or, if left as cash under the bed, are not producing any output whatsoever. Hence, any other form of saving when drawn down reduces current investment.

[61]Green C H 2010 **Coastal cities: assets at risk and depth-damage curves**; report prepared for the OECD, Middlesex University

ECONOMY

- The aim in flood risk management is not to minimise flood losses but to enhance the performance of the catchment.
- It is resilience which matters and not vulnerability: the latter is important to the extent to which it influences resilience.
- It is the proportional losses rather than absolute losses that are primarily of importance: a loss of £20 million when the total stock of that asset is £100 million likely to be more significant than a loss of £20 million from a stock of £2 billion.
- Scale is thus important because it affects the proportional loss.
- Recovery has two stages: returning to the level of well-being that existed prior to the flood and returning to the trajectory of well-being that existed prior to the flood.
- Generally, in order to recover, it is current consumption that should be reduced rather than investment.

4. Flood damages assessment: current costs methods and gaps

Evaluating the losses of productive (e.g. factories) and consumption assets (e.g. dwellings, televisions and cars) is relatively straightforward; those assets have a market price which can generally be used to calculate the appropriate 'shadow price'. To a greater or lesser extent, prices normally diverge away from the shadow price, the price that would have occurred in a perfectly competitive market in which supply and demand were in balance. Both various market imperfections (e.g. the existence of monopolies) and money transfers which are not offset by flows of goods and services in the opposite direction (e.g. indirect taxes) need to be taken out, as do subsidies. Only in a perfectly competitive market does a price equal the economic cost and also the economic value of the good or service.

The major problems arise when there is no market price to take as a starting point for deriving an estimate of the economic cost of an undesirable change (and, conversely, the economic value of a desirable change) in the availability of some good or service. Obviously instances where this problem arises is for the health impacts of flooding on households and impacts on the environment. Even more problematic are such impacts as the effect of the disruption of education on the future growth of the economy.

The other area where there are problems is in estimating the second and subsequent order impacts. For example, it is comparatively simple to estimate the cost of damage to a bread factory; much more difficult is to estimate the losses than result from that factory being out of production for some period of time. Here, the scale of analysis is important: the local effect of the temporary closure of a factory providing most the local bread production will be different than the effect on the national economy if that factory produces only 2% of national bread production. The difficulties of evaluating such impacts are compounded because they arise largely because the assumptions of perfectly competitive markets and equilibrium conditions are not met in practice.

4.1 Evaluating the shock (losses to the economy)

The first stage is to estimate the shock to the systems; the second stage, how the trajectories of the systems will consequently be affected. In assessing the shock, it is appropriate to differentiate between resources, production durables, productivity durables, and consumption durables. The loss of consumption durables (e.g. chair, car, dwelling) results in a loss of consumption until the durable is replaced and similarly the loss of a production durable (e.g. factory, machine tool) the loss of production until the durable is replaced. In both cases, the recovery will take time and be progressive; the building will, for example, usually needed to be cleaned and dried before any repairs can take place. The availability of resources may also be affected: stocks of raw materials, semi-finished and finished goods may all be damaged by the flood. But other resources, including labour and the availability of capital may also be affected: those who are flooded may have to look after their family and deal with the damage to their home, or may be unable to get to work because of the flooding. Similarly, the availability of capital may be affected because the flood has converted some existing loans into bad debt and so reduced the availability of credit, or because the disruption to financial services has simply made the process of capital availability more cumbersome and slow. Now that a large fraction of any economy is devoted to reducing the frictional, the transaction, costs of exchanges elsewhere in the economy[62], disruption induced by flooding in that fraction of the economy will increase costs elsewhere.

In the longer term, and almost impossible evaluate, is the effect of flooding on productivity enhancers such as future levels of education, skills and knowledge: technologies and the capacity to exploit those technologies.

Furthermore, whilst an economy can be represented in abstract by such means as an input-output model, a real economy is spatially distributed[63] and the connections (roads, utilities) between the individual productive and consumption facilities, simultaneously exist to support the supply of necessary inputs and incur costs in so doing. The connections can also be disrupted by flooding and their safe operation may require that they be closed even when they do not experience physical damage.

The various impacts of flooding on the environment, people and economy described in the previous sections may represent a change in their state. The state from an economic point of view can be associated with a value or utility usually represented by a monetary unit. Or the change induced by the flood can be associated with a new value (**Figure 11**). If the value decreases, a loss should be associated with the flood. If the value increases, then a benefit should be associated with the flood. Thus in order to assess the various losses due to a flood, it is necessary to define the elements at risk, their values in their initial state and their new values after the flood event (e.g. are they damaged, disturbed, destroyed or improved).

Before starting any valuation it is important to consider who is requesting the loss assessment. Is it for the public or is it for private purpose? Indeed economic loss (nation, public point of view) has to be distinguished from financial loss (private point of view) as they are not accounting for the same value. Financial losses will integrate all type of losses at current price including taxes. With economic losses valuation the taxes have to be excluded, any losses compensated by a gain should not be counted and only the depreciated value should be considered[64].

[62] Wallis, J. and North, D. C. (1986) Measuring the Transaction Sector in the American Economy in Engerman S and Gallman R (eds.) Long Term Factors in American Economic Growth, Chicago: Chicago University Press

[63] Rose, A. (2004) Economic Principles, Issues and Research Priorities in Hazard Loss Estimation in Okuyama Y and Chang S (eds.) Modeling Spatial and Economic Impacts of Disasters, Berlin: Springer

[64] Penning-Rowsell, E.; Johnson, C.;Tunstall, S.; Tapsell, S.;Morris,J.; Chatterton,J.;Coker, A.and Green,C. (2003). The benefits of flood and coastal defence: techniques and data for 2003. Middlesex University

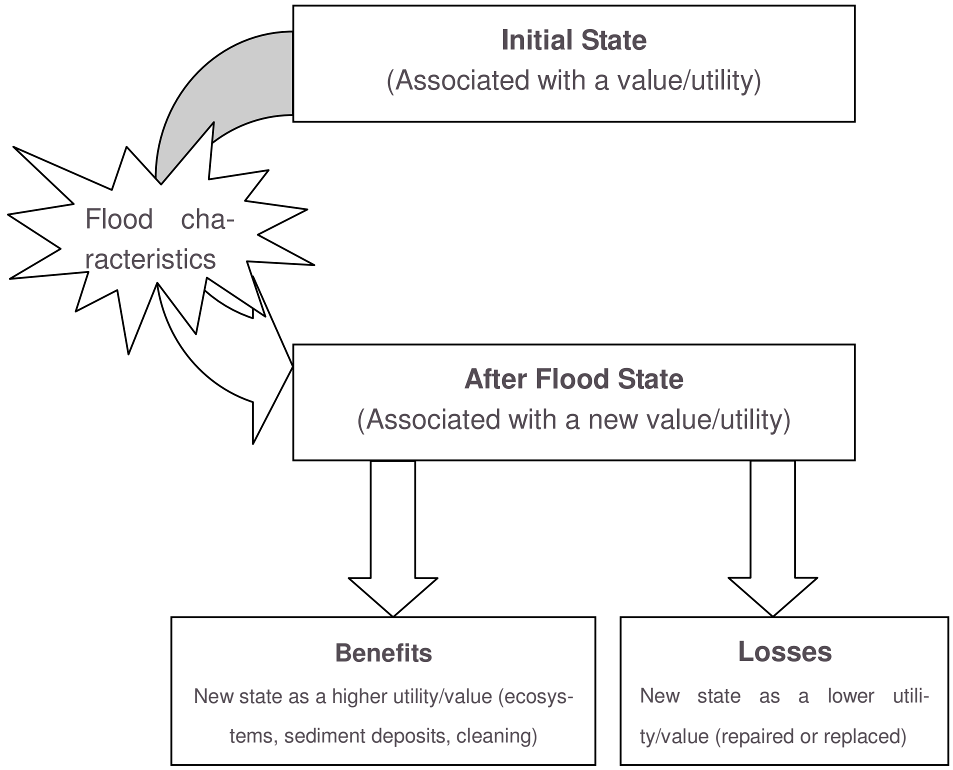


Figure 11: Change in the value induced by a flood

Although the terminology differs occasionally, flood damages are mostly categorized firstly in direct and indirect damages and secondly in tangible and intangible damages. Direct damages are the costs induced by a direct contact with the flood on humans, on assets or on the environment.

Indirect damages include all losses due to by its consequences (secondary effect) such as emergency services, inconvenience during the recovery phase, post traumatic effects…. The losses are thus simply defined by antithesis, i.e. directly in contact with water or- not due to time or spatial consideration (**Figure 12**). The losses due to disruption of production processes and services stand between these two categories. For some it is considered as a direct damage, for others as an indirect damage, or as a separate category. Within the CONHAZ consortium the third option was preferred to avoid any confusion and any risk of double counting. The sub classification of the losses in tangibles and intangibles is also done in the same principle: tangible if the damages can be valued monetarily or as intangible in the opposite case. Damages can not be valued monetarily for two reasons: there is no market value or there is no quantified impact.

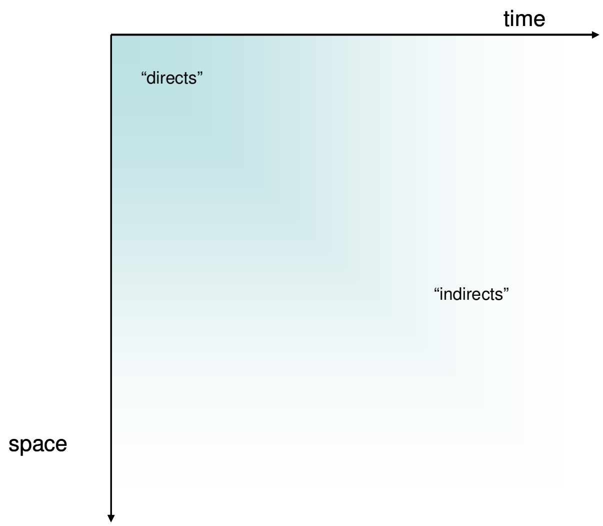


Figure 12: Direct and indirect damages

The most frequently used procedure for the assessment of direct monetary flood damage comprises three steps[65]:

(1) Classification of elements at risk

(2) Exposure analysis and asset assessment by describing the number and type of elements at risk and by estimating their asset value.

(3) Susceptibility analysis by relating the relative damage of the elements at risk to the flood impact.

Identification of receptors at risks

The direct receptors (on the flood plain) are easily identified by categories: economic sector approach /land use classification. The progress in Geographic Information System and on land use database in the last forty years have contributed largely in the spatial identification of receptors at risks from small scale unit providing statistics for territorial unit (e.g. NUTS[66]) to large scale providing individual building information (National Property Dataset)[67]. We can still make a difference here between intangibles and tangibles. Physical assets are well identified. The identification of ecosystem is on going with the millennium ecosystem assessment[68]. Population is more difficult to apprehend as the population and its characteristics are changing over time. Census data can support the identification of the most vulnerable. But census data are rarely update and are released at such scale due to individual information protection that they limit hotspots identification, which are usually revealed by specific land use such as nursery,

[65] Merz,B.;Kreibich,H.,Schwarze R. and Thieken,A. (2010).Assessment of economic flood damage. Natural Hazards and Earth System Sciences,10.1697-1754

[66] epp.**eurostat**.ec.europa.eu/portal/page/portal/**nuts**.../introduction

[67] Jose I. Barredo (2010). Flood risk in Europe using Corine Land Cover Datasets. CONHAZ workshop Power Point Presentation.London / NPD : http://www.geostore.com/environment-agency/WebStore?xml=environment-agency/xml/dataLayers_NRD.xml Last visit January 2011

[68] Alcama J. et al. (2003). Ecosystems and Human Well-being : a framework for assessment. IslandPress.

school, or hospital. These specific hotspots are easily identified and are supported with special protection and evacuation schemes. The identification of receptors of second or third order requires a good understanding and knowledge of the system and its potential failures in time and space. They entail of network, services and flow capacity.

The progresses in the accuracy of digital elevation model and in flood modelling have largely improved the identification of the risk too. The old classic maps show the extent of a flood event for a given return period. The use of 1D/2D models now a day provides depth, velocity, duration values but also uncertainty outputs at a meter or less square resolution. They allow the testing of different scenarios and the generation of probability maps. Nevertheless, the use of such models needs high expertise and requires a large amount of information and time and can be costly[69] Dynamic results are also now possible allowing the spatial pattern of the floods during a certain period.

Figure 13 represents the current practices and existing methods to address the identification of receptors at risks. Current practices represented by the blue line tend at focus at the neighbourhood scale (proportion of receptors in an area) and receptors scale (geographic position of the receptors) coupled with information relative to depth. It is now also possible to have much detailed approaches (red line) including a very detailed assessment of each receptor type and new parameters such as duration and velocity. However the efforts required are higher and can limit their application on large flood plain area in terms of data collection or at local scale due a lack of skills and budget.

[69] Messner, F.; Penning-Rowsell, E.; Green, C.; Meyer, V.; Tunstall, S.and Van der Veen, A.(2007).Evaluating flood damages: guidance and recommendations on principles and methods.EU Floodsite project N. GOCE-CT-2004-505420.

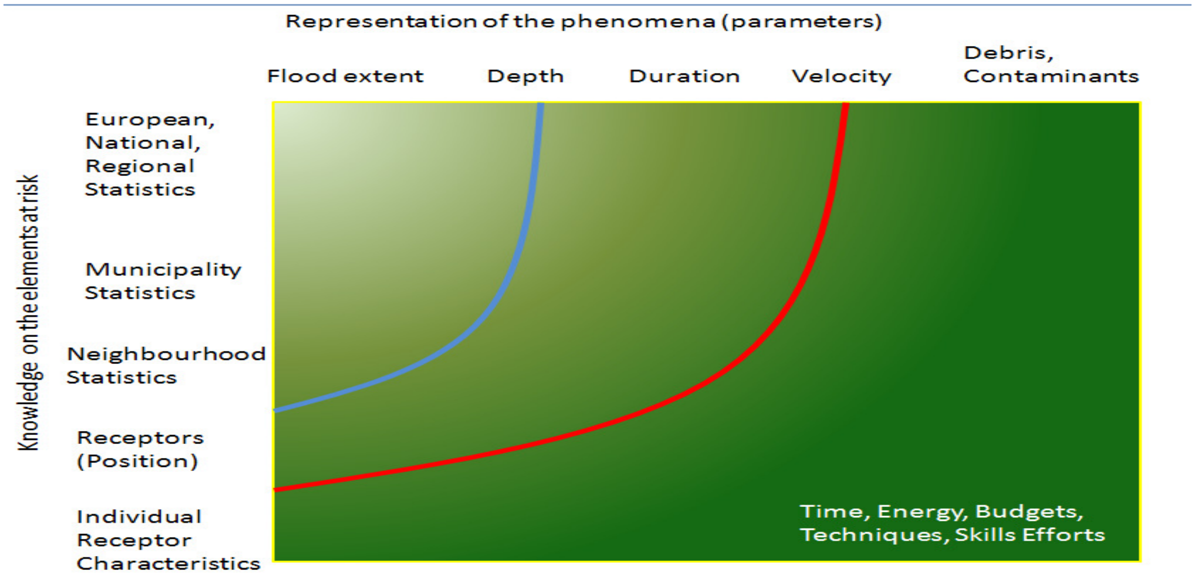


Figure 13: Identification of receptors at risk

Susceptibly and Value

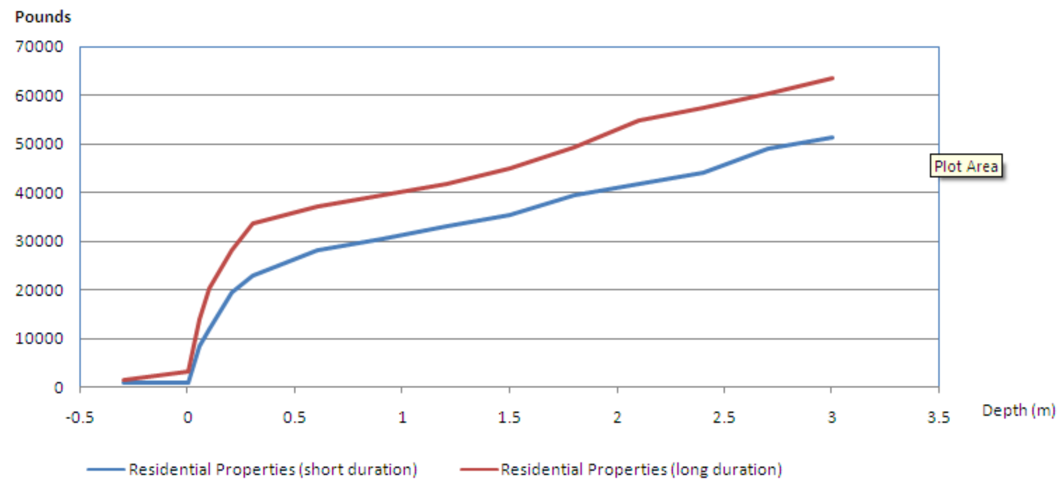
The methodologies used for assessment loss is very dependant of the nature of the damage. For each type, i.e. direct damages on assets, services disruption and intangible different approaches have been developed.

In order to evaluate the loss by direct contact with the water it is important to define the level of damage associated with the floods characteristics. For physical assets such as buildings (contents and structure) two functions are commonly used: the relative or the absolute function (**Figure 14**). The absolute function consists in establishing the damage function for a particular asset in monetary terms either in relation to the building or per unit area. The relative function provides the susceptibility expressed as a percentage of the total value of the assets. The total value of the asset has to be estimated from other data during the appraisal. In each case the function can be established with a synthetic and or an empirical approach. The empirical approach consists in using ex-post damages assessment values. The synthetic, an ex-ante method, involves the judgment expert (what if analysis). A listing of the approaches used in different countries is detailed in another CONHAZ Deliverable[70].

The synthetic approach (ex-ante approach - group of experts) is recommended as the only practical starting point. In the long term, empirical approach (based on damages data collection from events) can be used to complete and test the results. In using the synthetic approach, several experts should be used both to establish the reliability, the level of agreement between experts, and to aid in the identification of critical factors as these affect the susceptibility to damages.

[70] Kreibich, H.; Liu, M. (2011). Direct costs and losses due to the disruption of production processes. CONHAZ deliverable 1.

A Absolute Depth Damage function (UK)



B Relative depth damage function (Belgium)[71]

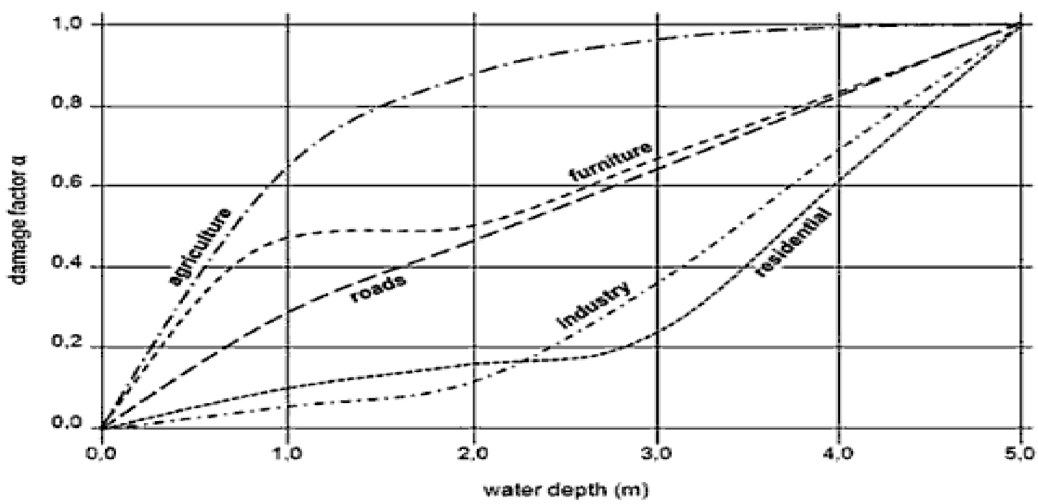


Figure 14: Example of absolute and relative depth damage functions

Assets are very different in shape, in structure, in nature, in lifetime, in numbers and in economic value and thus the variability in terms of response to a flood and of associated loss are very high. Different damage curves are used to reflect it. The first approach consists and often is limited in considering socio-economic or land use categories as it is driven by the standard classification and knowledge: residential, commercial, industrial, public, agriculture (**Figure 14 B**)…A more refined approach will consider the sub-type within these categories, e.g. flats, houses, local shop, supermarket, warehouse, and factory…However it is also necessary to consider the intrinsic variability within each subclass. For instance residential building may have different shapes and structure (surface of walls and flood in contact with the water, floor and ceiling), nature (timber frame, concrete). The damages can then vary for different house type (**Figure 15**). Same could be said for non residential building (**Figure 16**). But caution may be required when associ-

[71] Sholwater P.S., Lu Y. (2010). Geospatial techniques in urban hazard and disaster analysis. Springer.

ating a particular type of building with an activity for instance in central town as the building type is rarely activity specific. For that reason it may be pertinent in some cases to distinguish the type of building from the activity (contents) in the damages assessment.

Using a national average depth damage curve is not wrong. However it is important to question the existing variability of asset types within the flood plain to assess if an average curve can represent statistically the average type of building on the floodplain. Using an average depth damage curve from another country is very questionable and should generally be avoided.

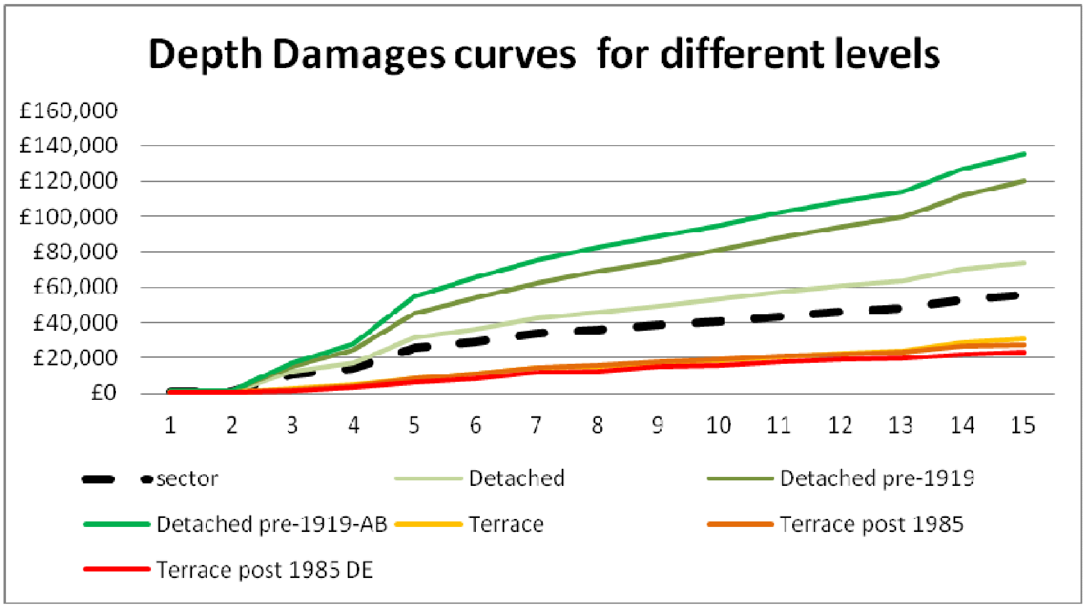


Figure 15: Variability of the damages for Residential Property type in UK

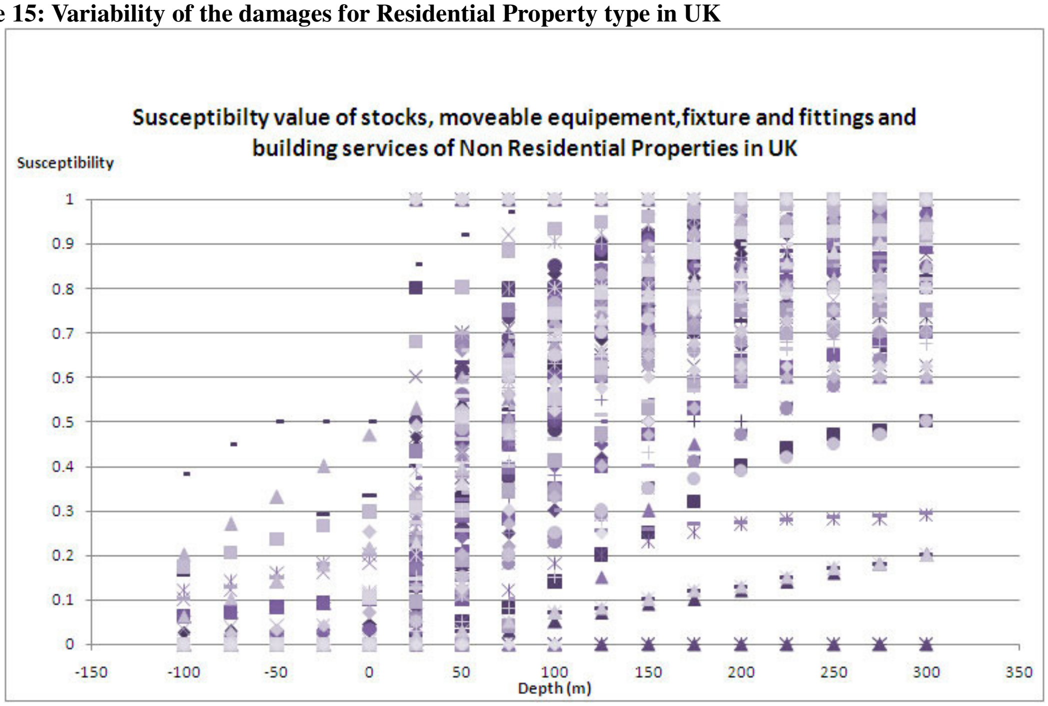


Figure 16: Variability of the susceptibility to the flood depth for Non Residential Properties (UK)

The use of the depth damages curves can be questioned when high velocity is expected, particularly in the case of dams or embankments failure. Without discrediting the impact of “natural” flood plain event, dams and embankments failures have a higher catastrophic characteristic when population lives behind the defence with feeling of safety. In such situation, the extreme condition of high velocity, high depth and rapid flood rise may lead to building collapse. Building collapse leads to a very different situation in terms of damages assessment. Direct costs are higher than the classic repair costs and thus the use of the latter is inappropriate for such situation. The structure of the building needs also to be carefully inspected after the flood and it may be required to raze the building afterwards. In such situation the building market value has to be used. Tangible and indirect costs are also expected to be higher (evacuation cost, alternative accommodation for a longer time, cost of the recovery phase if the area is classified as unsuitable for settling and therefore settlements have to be destroyed). Intangible direct and indirect costs are also higher (risk to life increase, psychological impact is higher). Current approach tends to represent the risk of building collapse by vulnerability matrices for depth velocity value[72].

For direct damage the methodology to assess the susceptibility have to be flood related. For losses caused by disruption the methodology does not have always to be flood specific as long as the duration of disruption due to the flood is known. Indeed the losses mainly relate to the interruption of production or services resulting from the impossibility to use an asset during the flooded and recovery period. Thus it is not necessary to develop or use hazard related methods. It is sometimes better to use approach developed in other disciplines related to the services in question.

In the previous **Figure 16**, the stocks are counted as existing stocks (before the floods) directly damages at a specific time (flood event). These stocks can also include the stocks for future production. However what could have been produced during the floods and after during the recovery phase due to a stop of production is not completely assessed (except the stocks for production). Because these losses are over the time they are easily measured as losses to flows. But if both stocks and flows values are used in the assessment it is essentially not to double count them. An essential rule is[73]: each individual component of a damage of any category should be monetized by stock values or by flow values; including both for one component would be double counting.

[72] Kelman, I. (2002). Physical flood vulnerability of residential properties in coastal, Eastern England. PhD Thesis University of Cambridge.
Roos, I.W. (2003). Damage to buildings. Delft Cluster.

[73] Messner, F.; Penning-Rowsell, E.; Green, C.; Meyer, V.; Tunstall, S.and Van der Veen, A.(2007).Evaluating flood damages: guidance and recommendations on principles and methods.EU Floodsite project N. GOCE-CT-2004-505420.

Table 4: Example of disruption losses

Damages	Example	Who?
Business disruption	Loss of income	Business
Business disruption	Loss of wages, of jobs	Employers
Business disruption	Increase of import/decrease of exports	Nation
Alternative accommodation	Extra renting costs (hotel, B&B, restaurant)	Households
Traffic disruption	Diversion roads (longer journey)	Drivers
Traffic disruption	Train delays, diversion	Users
Services disruption (network)	Loss of water, electricity, gas, telecom	Consumers
Emergency costs	Extra costs	City, police, fire, ambulance…

Three approaches are generally used to assess the losses caused by disruption:

- The use of a percentage of direct damages

This simple approach is for instance used in the Australian flood loss models Anuflood[74] and RAM[75]. The business interruption losses are defined as a fixed ratio of direct losses. The losses include costs of emergency response, the costs of non-provision of public services and the clean-up costs. In Anuflood a ratio of 55% is used. In RAM different ratio are recommended to highlight differences related to the leaving environment. Thus an average ratio of 33% is proposed but a ratio of 20% can be used for rural area and of 45% for densely populated areas.

- The use of a reference value. The value is then multiplied by the number of affected persons/business (e.g. national compensation figures, Yearly Income…)

During the 2007 summer floods in UK the Severn Trent's Mythe Water Treatment Works water treatment work was submerged by rising flood water and shut down, affecting water supplies to 350,000 people in Tewkesbury, Cheltenham and Gloucester[76]. With respect to loss of value to water users, using OFWAT (2008) guidance on the cost imposed on households when water is cut off, at £10/household/day, a cost burden of £23.5 millions has been calculated for the consumers[77].

In a similar way the US model Hazus-MH MR[78] estimates losses due to the disruption of production processes on the basis of relocation expenses, capital related income losses, wage losses and rental income losses. Cost per day and area factors are specified for various economic sectors in order to derive monetary losses and are then multiplied by the recovery time. For instance building recovery time is calculated by summing up the time needed for physical restoration of the building, as well as time for clean-up, time required for inspections, permits and the approval

[74] NR&M (2002). Guidance on the assessment of the tangible flood damages. Department of Natural resources and Mines Queensland.

[75] NRE (200). Rapid appraisal method (ram) for flood plain management. Victorian Department of Natural resources and Environment Victoria Melbourne,

[76] Pitt, M.(2007). Learning lessons from the 2007 floods. The Pitt Review

[77] Chatterton, J.;Viavattene, C.; Morris, J.; Penning-Rowsell, E.and Tapsell, S.(2010). The costs of summer 2007 floods in England. Environment Agency- DEFRA.

[78] FEMA(2011). HAzus-mh mr5. Flood model. Technical Manual.Federal Emergency Management Agency.

process, as well as delays due to contractor availability. All these components are estimated in function of the water depth and the considered activity.

- To model the activity under flooded and non flooded conditions

The Department for Transport data and methodology[79] can be used for estimating the services disruption of road traffic in UK[80]. The traffic disruption cost method is designed to be applied at local scale with local knowledge. The method consists of:

1– Assessing the traffic in normal condition (flow and speed on the main roads per vehicle type category)

2– Assessing the roads likely to be disrupted by flooding

3– Assessing the traffic in flooded conditions (flow and speed on the diverted roads)

4– Calculating the costs of traffic in both conditions (flooded and non flooded) using the costs of travel as a function of speed

The costs of travels include the Fuel VOC (fuel Vehicle Operating Costs), non-fuel VOC (other costs e.g. oils, tyres, engine maintenance) and the VoT (Value of Time, i.e. time loss in the transport) and is defined for different type of vehicles (Car, Light Good Vehicles, Other Goods Vehicle 1&2, Public Service Vehicle). The difference of costs (flooded versus not flooded condition) provides the value for extra costs due to traffic disruption.

Disruption of production and services can also be used to assess losses to the environment including the agro-environmental component. Arable farming is the more obvious example as their products are marketed as other economic activities. Hess and Morris[81] (1986) provide the following equation to estimate the losses caused by flooding to arable crops:

$$L = Y + (P_r{*}RC) - (P_h{*}HC) + REM$$

Where:

Y is the loss of output (reduction in yield times price)
P_r annual probability of the need to re-seed
RC the cost of reseeding
P_h annual probability of complete harvest loss
HC cost of harvest and inputs avoided because of flooding
REM post flood clean-up costs

For the flooding of grassland and other animal feedstuffs, Hess and Morris (1986) then give the following equation:

$$D = GMJ * RF + C$$

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[79] Department for Transport (2009). Transport analysis Guidance.

[80] Penning-Rowsell, E.; Viavattene, C.; Pardoe, J.;Chatterton, J.;Parker,D.and Morris,J.(2010). The benefits of flood and coastal risk management techniques 2010. FHRC

[81] Hess T M and Morris J 1986 The Estimation of Flood Damage Costs for Arable Crops, Silsoe: Silsoe College

Where:

GMJ, energy from grass lost due to flooding (MJ/ha);

RF, cost of replacement feed (£/MJ); and

C refers to the other costs incurred.

Conversely, the benefits of land drainage, of controlling the soil moisture levels during the growing season can be substantial (**Table 5**).

Table 5 Economic benefits of land drainage in the UK[82]

Economic net return (£/ha - 1997/98 prices)	***drainage status***	
land use type	***good***	***bad***
Extensive grass	-73	-81
Intensive grass	320	245
grass/arable rotation	283	215
all cereal rotation	280	217
cereal/oil seed rotation	329	263
cereal/ root crop rotation	280	217
horticulture	*1500*	*750*

The Millennium Ecological Assessment[83] defined the value of ecosystems in terms of four functions (**Figure 17**). Without the supporting function, none of the other three functions can exist and so it is necessary to maintain and preferably enhance the supporting functions but no direct means of evaluating this function is possible. Provisioning and Regulating functions are generally quite straightforward to evaluate in economic terms; most obviously this is the case for flood regulation. Much more problematic are the cultural functions, what used to be termed 'nonuse value'. There are three problems:

1– It is a system that provides the function but the problem is generally to decide what to do in one place. The value or cost of the change in that place is derived from the change in the performance of the system as a whole.

2– We do not have a good understanding of why people value the environment, although their behaviour demonstrates clearly that they do, or what it is about the en-

[82] Dunderdale, J. A. L. (1998) Evaluation of FDMM and Guidelines for the Justification of River Maintenance, unpublished MPhil thesis, Silsoe: Silsoe College, Cranfield University

[83] Alcamo J et al (eds) (2003) Ecosystems and Human Well-being: A Framework for Assessment, Washington DC: Island Press

vironment that they value. In the absence of such an understanding, any attempts to value local, partial changes will be speculative at best.

3– Often the condition is not satisfied that all stakeholders should agree what trade-offs they are prepared to make between different aspects of the environment and also with the consequences of some action in regard to people and the environment. What trade-offs should be made is often the heart of disagreement between stakeholders. Hence, some decisions are best left to the exploratory Multi-Criteria Analysis dialogue between stakeholders.

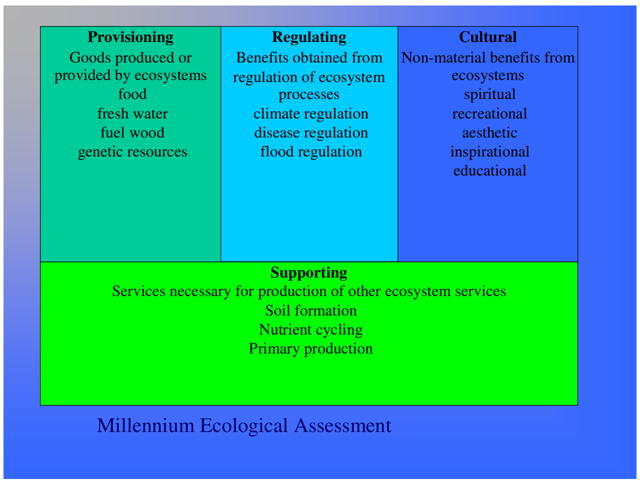

Figure 17: Millennium Ecological Assessment

If the stakeholders agree where deriving from market prices an economic value to the environment for quantifying the loss, environmental economists have provided various methods re-grouped in two typologies: revealed preference methods and stated preference methods.

Revealed preference methods look for related markets in which the environmental good is implicated traded. Hedonic prices method, travel cost method, cost of illness approach, replacement cost method, production function approach. Stated preference methods revealed the preference or willingness to pay directly from the people (Contingent Valuation method, Choice modelling method, life satisfaction method). **Table 6** describes broadly the existing methods which are also detailed with various examples in another CONHAZ deliverable[84] from which two have been extracted below as an example of replacement cost method and contingent valuation method.

The first example is how the economic value of services provided by a wetland can be compared to the costs of an engineering system. Leschine et al. (1997)[85] propose a case study where the replacement cost method has been applied to estimate the economic value of wetlands' flood protection capacity in Western Washington. Their approach is based on a case where the city has proposed to enhance flood flow reduction through projects that would enhance the ability of the existing wetland to lower flood flows. The enhancement is accomplished via construction of a channel, which works as an interconnection between the wetland and a detention pond. Cost

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[84] Markantonis, V.; Meyer, V.and Schwarze, R. (2011). Intangible effects. CONHAZ deliverable 3.

[85] Leschine, T.M.; Wellman,K. and Green,T.H. (1997). The economic value of wetlands –wetlands'role in flood protection in western Washington. Washington State Department of Ecology. Ecology publication.

estimates of the engineered system were used to establish an economic value of the flood protection currently provided by the wetland. The cost estimation was based on the assumption that each acre of the wetland has an equal effect in reducing flood flows. To establish a value of the flood protection service provided by the existing wetland the cost of enhancement per percent reduction effect was multiplied by the existing reduction effect per acres of existing wetland.

The second example is a contingent valuation method which was conducted in the USA[86], to estimate the willingness to pay for the maintenance of status quo flooding and/or corresponding ecological improvements for two watersheds. The survey showed a mean WTP of $83.56 per person and per year. The survey was conducted in November, 1999 – May, 2000 amongst the residents of two metropolitan Milwaukee watersheds: the Menomonee River and Oak Creek watersheds. During the implementation period, eight focus groups were conducted in order to explore residents' feelings and thoughts about local flooding and the ecological quality of the rivers. The final survey was constructed with three separate question paths:

- Path A: "Flood Path," Menomonee River residents only, asked about WTP for flood risk only
- Path B: "Environment Path," Menomonee River and Oak Creek residents, asked about WTP for improvements to the ecological health of the river only
- Path C: "Combined Path," Menomonee River residents only, asked about WTP for both flood risk and ecological improvements.

Pascual U. et al., (2010)[87] provide an extensive literature review regarding the use of these methods. They indicate that, for cultural and supporting services, revealed[88] and stated preference methods dominate and that, for provisioning and regulating services, cost and/or production based approach dominate. However the proportion of methods used varies depending on the type of ecosystems. For instance stated preference method and cost based method have the higher rate of use (40% and 25% respectively) for valuating wetlands service (see table 7 for more details) as for forests stated preference method and revealed preference method are mainly used (50% and 36% respectively).

Benefits transfer method may be considered as a cheaper, faster and easy way to value the different services. Depth damage curves are similarly a form of benefit-transfer. They consist in transferring to a similar ecosystem the value established in other studies. Different techniques exist: unit BT, adjusted unit, value function transfer and meta-analytic function transfer[52]. Cautions and rigours are yet required as differences in socio, economic and cultural context, and biophysical conditions or in scale for instance may induce errors which need at least to be considered, corrected and if not highlighted. Meta-analytic function transfer has the ability to consider these factors and therefore may represent a more reliable approach. Brander et al.

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[86] Daun, C.M. and Clark, D.(2000). Flood risk and contingent valuation willingness to pay studies: a methodological review and applied analysis. Institute for Urban Environment Risk Management , Marquette University, Milwaukee,WI.

[87] Pascual, U.;Muradain,R.;Brander,L.;Gomez-Baggethun, E.; Martin-Lopez, B. and Verma,M. (2010). The economics of valuing ecosystem services and biodiversity. In *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations* Pushpam Kumar Edidition.

[88] In their classification revealed preference methods include hedonic pricing and travel cost method. Production function, replacement cost function and cost of illness approach are in separate categories; production-based approach for the first one, cost-based approach for the two others one.

(2008)[89] have used this technique to up-scale the value of ecosystems services at national and regional scale and to estimate the effects of change in wetlands area. The method values the wetlands according to different parameters (e.g. location, size, type, abundance, GDP per capita and population density) and different environmental services (e.g. flood control, surface and groundwater supply, fishing, hunting, biodiversity etc…). Corine Land Cover data were used to measure the change in wetlands area and abundance in Netherlands. An average value of 5 400€/ha was estimated for the period 2000-2006. The approach was also applied in UK (Morris,J. Camino, M. (2011)[90]. They highlight that the benefits provided by a given wetland depends highly of the service rendered; services such as flood control, water quality improvement and biodiversity making the largest contribution. Thus they estimate a contribution of 608€/ha/year and 3 730€/ha/year from flood control. Therefore a key issue still lays in measuring these services and their potential reduction due to flooding conditions.

[89] Brander,L.;Brauer,I.;Gerdes, H.; Ghermandi, A.;Kuik,O.;Markandya,A.;Navrud,S.;Nunes,P.; Schaafsma,M.;Vos,H.;Wagtendonk,A.(2008). Scaling-up ecosystem service value:using GIS and Meta-analysis for value transfer.

[90] Morris,J. Camino,M. (2011). Economic assessment of Fresh water, wetland and flood plain ecosystem services. Working paper. UK national ecosystem assessment.

Table 6: Revealed and stated preference methods

	Methods	Description
Revealed Preference Methods	**Hedonic pricing methods**	Used to estimate the impact of environment on market values such as houses considering that the value of assets is function of some characteristics including the environment.
	Travel Costs method	Used to estimate use value associated with ecosystems or sites based on time and travel costs spend by people
	Cost of Illness Approach	Used the medical costs or wages/income lost as an estimate of health impact
	Replacement Cost Method	Use to estimate the services of the environment by considering the costs of technologic substitute
	Production Function Approach	Use to estimate the production value of the environment by considering its contribution in production of market product
Stated preferences Approach	**Contingent Valuation Method**	Questionnaires directly addressed to individuals assessing their willingness to pay (WTP) or to accept (WTA)
	The Choice Modelling Method	Individual have to chose between different alternatives scenarios based on an array of attributes
	The Life Satisfaction Method	Individuals have to evaluate well -being, life satisfaction or happiness rather than economic value. The economic value is then assessed based on their answer and their socio-economic indicators (utility function)
Benefit Transfer Method		Consist in transferring the results of pre-existing studies (Stated or revealed) based on statistical similarity with the case study

Table 7: Proportion of valuation methods applied for wetlands (From *Pascual et al.,* 2010)

	Cultural	Provisioning	Regulating	Supporting
Benefit Transfer	16	6	3	25
Cost based	9	24	**52**	25
Production based	0	**39**	10	0
Revealed preference	20	4	0	0

Stated preference	**56**	25	35	**50**

Similar approach can be used to measures the intangible related to health and risk to life. The first step is to define what proportion of the population is at risk. Three general steps have to be taken into account to measure the risk to life[91]:

1- Analysis of flood characteristics, such as water depth, rise rate and flow velocity
2- Estimation of the number of people exposed (including the effects of warning, evacuation and shelter)
3- Assessment of the mortality among those exposed to the flood

An economic value can then be used to monetize the costs. In UK for instance the value placed on a human life by the Treasury for the appraisal of public investments in health and safety is used is estimated at £1.15 million per fatality[92].

For health same techniques as used for the environment can be applied. Thus DEFRA[93] lead a WTP survey to value the mitigation of intangibles effects of flooding. Categories responders included persons at risk of flooding and not at risk. An order of £200 per year per household was found. Revealed preferences method can also be used such as the cost of illness approach evaluating working days lost due to illness and medical costs[94].

[91] Jonkman, S.N.;Vrijling,J.K. (2008). Loss of life due to floods. Journal of flood risk management 1. 43-56

[92] Chatterton, J.;Viavattene, C.; Morris, J.; Penning-Rowsell E. and Tapsell, S.(2010). The costs of summer 2007 floods in England. Environment Agency- DEFRA.

[93] Defra/EA, Flood and Coastal Erosion, Risk Management R&D Programme (2004): The Appraisal of Human related intangible impacts of flooding

[94] McDonald, T.M. (2001). Valuing environmental health risks: a comparison of stated preferences applied to groundwater contamination.

EVALUATING THE SHOCK

- The first stage is to estimate the shock to the systems; the second stage, how the trajectories of the systems will consequently be affected.
- It should not be assumed that losses are simply additive or the significance of any loss varies linearly with the magnitude of the loss. Thus, it is the proportion of assets that are damaged or destroyed that is often of significance. In turn, proportionality is related to the scale of the event.
- In theory, the value of a stock is the present value of the stream of income (or costs) it yields; therefore, it is never appropriate to measure both the value of some change in stock and the resulting change in income/costs. Usual practice is therefore to evaluate whichever is easiest to evaluate of the change in stock or flow. In looking to evaluate the shock, the logical starting point is the relative values of assets at risk. Buildings constitute the largest proportion of the assets at risk. It is also the loss per unit ground area that is generally important and hence the ratio of building footprint to ground surface has an important influence.
- Procedure usually follows three steps: classification of the element at risk, exposure analysis and value of the elements at risk, flood susceptibility assessment
- Direct damages on assets are flood related method mainly based on depth (flood depth damage curve). Other flood characteristics can be used to improve the assessment (duration, velocity, loads, and mitigation measures). The function can be relative (expressed as a percentage of the value) or absolute (currency). The synthetic approach (ex-ante approach - group of experts) is recommended as the only practical starting point. In the long term, empirical approach (based on damages data collection from events) can be used to complete and test the results. In using the synthetic approach, several experts should be used both to establish the reliability, the level of agreement between experts, and to aid in the identification of critical factors as these affect the susceptibility to damages.
- Disruption losses are mainly time-related, the duration extending well beyond the flood event itself. Current approaches are the use of a percentage of direct damages, the use of a reference value (national) applied to a number of affected persons/business, the use of a model to represent an activity under various scenarios.
- Revealed preference and stated preference methods have both been used to assess the value of intangibles.
- It is not currently possible, and for small events it is likely never to be possible, to reliably predict the flood losses; models will remain too coarse, too highly aggregated for adequate modelling, as will data. Instead, it is possible to estimate the comparative effect on different systems based upon the system features described in the main text.
- Whilst the shock in terms of loss of assets is relatively easy to evaluate, flood losses in terms of the difference in trajectories is more difficult to estimate. Critically, the immediate fall in the trajectory is a consequence of the shock and is not given by the estimate of the magnitude of the shock; that the change in the trajectory is determined by the response of the system after the shock losses have been absorbed.

4.2 Evaluating the loss of material well-being

As defined by the Stiglitz Commission, 'well-being' is an all encompassing and multi-dimensional conceptualisation of what a society seeks to achieve. One component is 'material living standards' and until now analyses have focused upon the effects of floods on National Income or Gross Domestic Product and associated indices. There are many well-known problems with this family of measures: the reason why they are now being replaced[95]. In addition, each member of this family is a form of double-entry book-keeping, expressed in flows of money, which means that a shock may change the distribution of the flows of money without necessarily reducing the total flow on either side of the equation (e.g. visits to restaurants may be replaced by buying new televisions to replace those destroyed in the flood). It also obviously includes only those goods and services for which there is a market price so changes in flows of non-priced goods and services are not considered.

In considering the effect of a flood on 'material living standards', some definition is consequently first required. For these purposes, the two following definitions are used:
Material welfare – the total usage by households of desired goods and services whether those goods and services are priced or non-priced.
Secondly, over the long term, we seek to do more with less: to create more well-being, such as material welfare, whilst using resources sustainable and more effectively. So, maintaining a given level of material welfare by simply using more resources than before or using resources less sustainably is not a satisfactory long term solution. Therefore:
Sustainable efficiency – the requirement is that over the long term that a given level of material welfare is provided by using resources both more effectively and sustainably.

Conventionally, the loss of or damage to assets in a flood are called the 'direct damages'. Their magnitude is relevant as a measure of the shock to the system. But there is no clear relationship between magnitude of this shock and the immediate reduction in well-being or the subsequent trajectory over time of the system. If the direct damages were instantaneously replaced then this distinction between physical losses and lost of well-being would be almost irrelevant, because the trajectory would be unchanged. But the resources to replace those losses would have to be diverted from other uses and so either current consumption or future consumption or growth in consumption would have to be sacrificed. Each response will have some effect upon the trajectory of the system. In general, it is likely to be preferable for the long term to sacrifice some current consumption, and thus to sacrifice current well-being, in order to enable the replacement of lost assets.

There are two issues which can affect the degree to which assumptions of linearity and additivity will give serious errors: proportionality and additivity. For additivity, it would require, for example, that a loss of €20 millions of housing, €20 million of televisions, or €20 million of schools all have

95 Commission of the European Communities 2009 GDP and beyond: Measuring progress in a changing world, COM(2009) 433 final, Brussels: Commission of the European Communities

exactly the same effect. But it would not be unreasonable to expect that the loss of €20 million of televisions would have a relatively minor and transitory effect whilst the loss of €20 million of homes would cause a loss of wellbeing for a substantial period of time; and the loss of €20 million of schools might result in the permanent reduction in educational attainment of the affected children. Again, suppose there were a loss of €20 million of flour and €20 million of bakeries; because the bakeries are out of action, the €20 million of flour could not be turned into bread.
The second example can be extended to illustrate the problem of proportionality: a loss of €20 million of bakeries from a total asset value of bakeries of €200 million is likely to have a more severe effect than a loss of €20 million of flour from annual production of €2 billion.

For the system as a whole, we want to promote a path of sustainable development. The effect of a flood on that path of sustainable development will then appear as shown in **Figure 18**. The trajectory is expressed in terms of the measure of success in achieving outputs, such as 'well-being', so the effect of the flood is shown as an immediate reduction in well-being followed by a subsequent recovery. The loss resulting from a flood is thus the difference in the areas under the trajectories of sustainable development without a flood as compared to that with a flood.

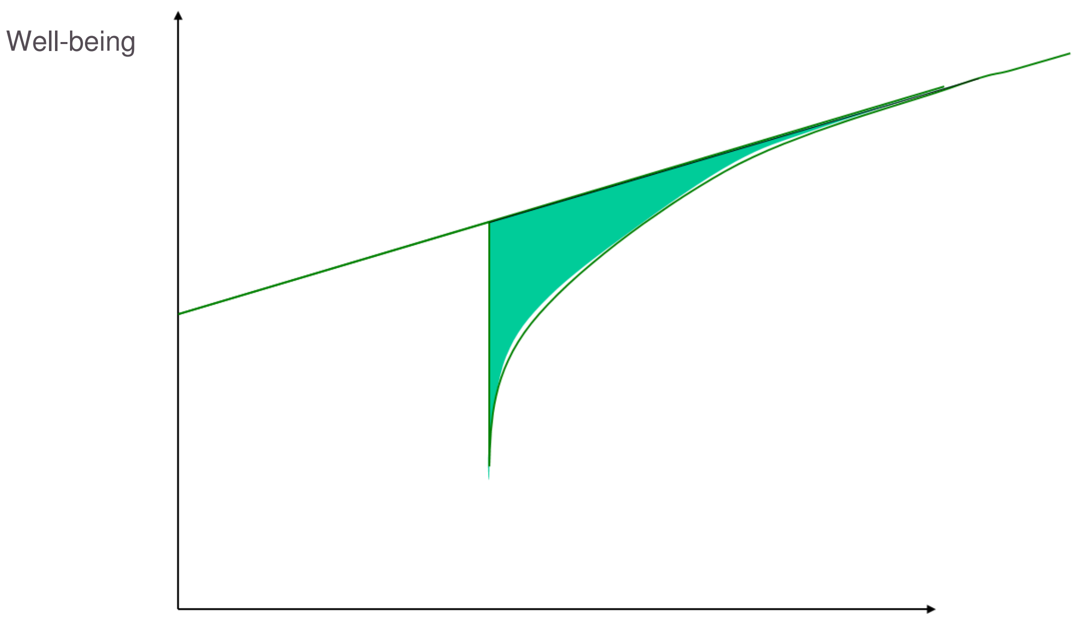

Figure 18

In managing water to make the best use of land, the aim in flood risk management is not to minimise floods losses but to maximise the efficiency of the use of land. In turn, increasing the efficiency with a catchment is used can result in an increase in flood losses[96]. Therefore, the choice can be formalised as being between:

- Developing the flood plain without taking any action to reduce the flood risk.
- Developing the flood plain but taking action to reduce the risk of flooding.
- Developing some other area outside of the flood plain.

[96] Green C H, Parker D J and Penning-Rowsell E C 1993 “Designing for Failure” in Merriman P A and Browitt C W A (eds.) Natural Disasters: Protecting Vulnerable Communities, London: Thomas Telford

The logic for developing on a flood plain as opposed to some other area is that either or both the returns from development on the flood plain exceed those from other areas, or the costs of development are lower. For example, if an oil refinery is developed in a port area, the costs of moving raw oil from the jetties and shipping the final products out for loading will be lower than if it is located inland. In addition, coastal flood plains offer flat sites which will require lower development costs than sites on slopes or uneven ground. Flood plains and other areas at high risk of landslides, earthquakes and other hazards are often the sites of informal settlement because of their proximity to income earning opportunities and lower transport costs. The costs of providing utilities, infrastructure and services are now a high proportion of the costs of developing a site and those costs are borne by a wider community to the residents through taxes, utility charges and other transfers.

Which of the three options is then the best option in the particular instance then depends upon the growth paths of the three development possibilities (**Figure 19**). If the growth path for developing the flood plain is sufficiently faster than could be achieved by development off the flood plain then development should take place on the flood plain if the pattern of losses is such that the on flood plain development trajectory will remain above the off flood plain development path.

One of the corollaries of this conceptualization is that it is the frequency of flooding which is likely to determine which pattern prevails. If the frequency of flooding is greater than the average life expectancy of capital assets, then in terms of the economy, it is likely that development on the flood plain will be undesirable. From the narrow perspective of the economy, the relatively short effective life of most capital assets[97] implies that very high standards of flood protection will seldom be justified except if the local consequences have wider impacts on the economy as a whole.

[97] Omundsen B, Bentley A, Saunders B and Ware T-A 2009 Capital Stocks, Capital Consumption and Non-Financial Balance Sheets, London: Office for National Statistics

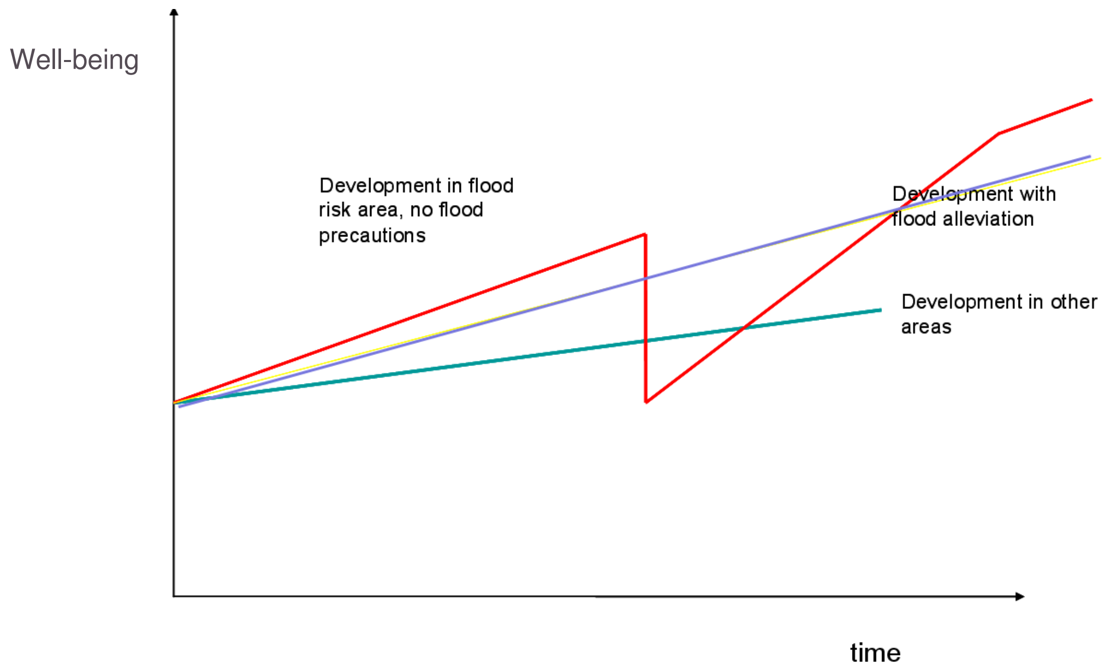

Figure 19: ***The economics of development on flood plains***

Current approaches for the identification and the measurements of indirect or higher-order losses are focused on the economic losses, i.e. the GDP is used as a key indicator instead of the well-being indicator shown in figure 18. In the absence of well-being data, GDP provides available data albeit or a very limited kind. Two types of approach dominate: econometric approaches and model-based approaches[98]. Econometric approaches aim at analysing statistically economic data in order to highlight correlation between changes in economic growth and existing events. The lesson learned can then be used to guess-estimate future floods impacts on the economy. The data availability and their quality are the weakest point of such approach. Model-based approaches[99] consist in input-output models, computable general equilibrium models and hybrid models (intermediate between CGE and IO). These models require high skills and are often considered as a black box by the practitioners. Their use is mainly limited to macro scale (at which scale sufficient information is available) and to disaster events in which case the effects are global and therefore not hidden or absorbed by the global economy.

Without discrediting the potential of these methods for other purposes, their potential use can be questioned in the decision process. Indeed in the context of this document we can consider that both approaches failed to answer the stakeholder's needs. For instance most of the stakeholders will be interested in assessing the indirect impact at micro (cities) or meso (catchment) scale for various types of events, small and large, with or without mitigation measures. But the methods discussed can only generally assess the impacts of disaster at the national scale. Their potential transfer to practitioners is also quite unrealistic considering the skills requirement, the complex mechanisms and the uncertainties associated with such models.

Thus it is important to recognize that currently, we do not have either the models of the socio-

[98] Please refer to Przyluski V., Hallegate S. (2011). Indirect costs of Natural Hazards. ConHaz Report WP2. For more detailed information.

[99] Please refer to Przyluski V., Hallegate S. (2011). Indirect costs of Natural Hazards. ConHaz Report WP2. For more detailed information.

economic system nor the data with which to calibrate the models to adequately evaluate the impact of a shock on the trajectory of welfare. Indeed, it is likely that it will never be feasible to do so at the community level. Therefore, the best approach is to look for the weak points in the system both at nodes and on linkages, notably:

- Concentration
- Specialisation
- Time critical production
- Critical facilities
- Lack of spare capacity
- Presents a secondary hazard (e.g. storage of dangerous chemicals)
- Clean production
- Frictional costs
- Proportional loss of capacity

Weak points for nodes are those where there is a high degree of specialisation and concentration, coupled to a lack of spare capacity. Critical facilities are typically those where there is a high degree of specialisation and concentration. Unfortunately, there is generally a lack of adequate data on the degree of concentration within an industry, that data being limited to firm data rather than plant data[100]. Equally, the sectors are highly aggregated; for example, suppose that there were only two plants in the country producing animal vaccines, that data would probably be lost in that for pharmaceuticals.

Secondly, it is production for which consumption is time critical, particularly where production cannot be stored, that is most likely to be important. Again, medical treatment is often time critical and so, for that matter, is news supply but the consequences of the loss of the latter generally have smaller consequences.

It is facilities satisfying these three conditions that are general termed 'critical facilities'[101]. With the increased focus upon the threat of terrorism, more data is now available on these issues although for obvious reasons, it is not publically available. The UK government[102] has designated the following infrastructure services as providing essential services:

- Communications
- Emergency Services
- Energy
- Finance
- Food
- Government
- Health
- Transport
- Water

When all resources are being used to maximum efficiency then the effects of reduction in some of those resources will necessarily be more severe than when there is spare capacity. For example, the loss of a power station will be more significant in winter than in spring. However, it is

[100] Mahajan, S. (2006) Concentration ratios for business by industry in 2004, Economic Trends 635, 25-47
[101] Cabinet Office (2010) Strategic Framework and Policy Statement on Improving the Resilience of Critical Infrastructure to Disruption from Natural Hazards, London: Cabinet Office
[102] Cabinet Office (2010) Strategic Framework and Policy Statement on Improving the Resilience of Critical Infrastructure to Disruption from Natural Hazards, London: Cabinet Office

usual for there to be mismatches between supply and demand either because of economies of scale – global oil refinery capacity was in surplus from the 1970s to 1990s[103] - because of a recession, or because of general inefficiencies. In addition, there is generally a degree of inefficiency in the use of resources: in the short term, more can be done with less.

Some industrial sites, those holding quantities of inflammable, toxic or radioactive materials either for production purposes or as waste materials, can pose a significant secondary hazard. Sites designated under the Seveso Directive[104] need to be identified and the threat, if any, created by the risk of flooding identified.

Whilst the traditional old ('metal bashing') industries involved dirty processes and hence took place in dirty environments, the newer technologies require clean, and in some cases, hyper-clean environments. Examples include microelectronics and pharmaceuticals. One consequence is that the deep cleaning required after a flood will delay the resumption of production irrespective of any damage to the production machinery itself.

Weak points for linkages depend upon the local topology of the network – the extent to which alternative routes exist – and the spare capacity in those links. The old landline telephone was a star shaped network, centred upon the primary telephone exchanges and hence a large area of the network and trunk connections could be lost if a primary telephone exchange were to be flooded[105]. River crossing are an obvious potential point of weakness for transport networks, bridges commonly failing either because of scour, local high velocity flows undermining the abutments or piers, or as a result of the bridge openings being blocked by debris[106].

Transport costs are a readily observable instance of frictional costs, flooding of parts of road networks displacing vehicles on to the remaining network and reducing the speed of movement of all the vehicles on those roads. The relationships both between the volume of traffic and the speed of flow and between speed and fuel consumption are non-linear[107] at low speeds, and this makes modelling the effect of flooding on transport costs difficult[108].

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[103]BP(2010) BP Statistical Review of World Energy, London: BP

[104]Seveso II Directive (2003/105/EC)

[105] D.J. Parker, C.H. Green and P.M. Thompson 1987, Urban Flood Protection Benefits: a project appraisal guide, Aldershot: Gower

[106] JBA Consulting (2005) Safe Management of Railway Structures: Flooding and Scour Risk, report to Rail Safety and Standards Board, Skipton: JBA Consulting

[107] Department for Transport 2009 Transport analysis Guidance, London: Department of Transport

[108] D.J. Parker, C.H. Green and P.M. Thompson 1987, Urban Flood Protection Benefits: a project appraisal guide, Aldershot: Gower

FLOOD AS A SHOCK TO THE SYSTEM

- The aim throughout is to determine when there are significant differences which must not be ignored from and distinguish these from those differences which are trivial. Simplification, by reducing the differences considered to those which are significant, is necessary so that decisions can be reduced to manageable proportions.
- In turn, the role of economic analysis is to routinise the trivial so that attention can be focused upon the important differences.
- A flood can be considered to be a perturbation in the environment of the different systems and the first problem is to determine the magnitude of that shock to each of the systems involved.
- The importance of estimating that shock is the extent to which it is then possible to estimate or predict how the trajectory of the relevant state of that system will change over time in consequence of that shock: how well-being will change over time.
- The object in flood risk management is to ensure firstly that well-being does not change to a less desirable domain space and secondly that within the domain space it recovers as quickly as possible to previous trajectory of well-being over time.
- Flood loss is the area between the trajectory of well-being over time with the flood event and trajectory that would have occurred in the absence of the flood.
- 'Vulnerability' can thus be thought of as the initial shock to the system and 'resilience' as the system's natural tendency to recover from that shock. If any system returned instantaneously to its prior state following a shock, its vulnerability would be irrelevant. Both are relationships rather than either characteristics or states.
- In consequence, vulnerability is only of interest in so far as it influences resilience.

5. Deciding

A decision is a task, a problem to be resolved satisfactorily. Thus, any economic tool must address the reasons that make the choice necessary in the first place. A choice only exists if there are at least two mutually exclusive alternatives with at least one good reason to prefer one option over all others, and at least one other reason to prefer a different option over all others. Hence, the two conditions for the existence of a choice are the existence of conflict, mutual exclusivity, and doubt, uncertainty as to which option should be preferred. The task is therefore to resolve the conflicts and achieve some confidence that one option should be preferred to all others. This means that the tools need to focus on the reasons why the conflicts exist and be framed in terms of the degree of confidence that can exist as to which option should be preferred. The potential reasons why there are likely to be conflicts have been outlined elsewhere[109] but typically include conflicts of interest between the different stakeholders. For this reason, it should not be expected that it will common to find a 'win-win' outcome in any single decision. Instead, it has been argued that a 'win-win' outcome is only likely to be possible over a series of decisions chained together[110].

Key points are that decisions are a process and since the aim is to move from a state of uncertainty to one of relative confidence, that process can be termed a learning process. What matters in this process is thus to determine what are the parameters whose values will reduce that initial uncertainty and the invention of options. Secondly, those decisions are ordinal: it is sufficient to become confident that one option should be preferred to all others; it is unnecessary to be able also to distinguish between the remaining courses of action. Thirdly, because decisions are ordinal, all choices are both relative and comparative; we have to choose between different courses of action and do so by comparing them. In turn, choices are usually between the incommensurate; the consequences of the different courses of action generally vary in terms of who is affected, how they are affected, and when those affects occur[111] . Making a choice involves either explicitly or implicitly making trade-offs across these three dimensions. The advantage of doing so explicitly, through such techniques as discounting in the case of different distributions over time, is that the procedure is transparent, and thus open to challenge, and that the adoption of an explicit approach imposes a consistent approach both within each decision and also between decisions. Fourthly, the stress is upon a deliberative process: essentially that we make a choice based firstly upon an understanding of what the choice involves, secondly an informed choice, and thirdly through discussion, negotiation, and argument. In this process, it is mutual understanding that is the key condition; numbers are useful to the extent to which they capture this mutual understanding and only to the extent to which they do so. In effect, the virtue of economic analysis is the degree to which it can routinise the trivial so that the stakeholders can focus their attention on the important issues; those about which they disagree. In particular, so that they can focus their attention on those areas where they disagree or are uncertain as to what trade-offs they are prepared to make between the different consequences. Thus, economic evaluation of a consequence is limited to those consequences where there is substantial agreement between stakeholders as to the relative importance of that consequence and the

[109] Green, C. H. (2003) Handbook of Water Economics, Chichester: John Wiley.
[110] Green, C.H. and Penning-Rowsell, E. (2011) Stakeholder engagement in flood risk management in Pender G and Faulkner H (eds.) Flood Risk Science and Management, Chichester: Wiley-Blackwell

[111] Green, C. H. (2003) Handbook of Water Economics, Chichester: John Wiley.

extent to which they are prepared to sacrifice either achievement or avoidance of that consequence for the sake of avoiding or gaining other consequences. The expectation in these guidelines is that exploratory Multi-Criteria Analysis[112] will be used by the stakeholders as the tool to support their debate and negotiation of the final decision.

5.1The assessment of alternative courses of action

The objective in flood risk management is not primarily to reduce flood losses but to ensure a well functioning catchment or coastal zone, in terms of the overall benefits from human use and ecosystem services and functions, after consideration of risks and uncertainties associated with flooding. In other words, the aim is to do better than would result from the uncoordinated actions of the many actors in the catchment-coastal-floodplain system. In assessing the available possible courses of action, it is therefore necessary to take account of all the possible consequences of each alternative course of action and not restrict the assessment solely to the effects upon flood losses. Thus, the assessment should include the wider effects, implications and costs upon the **environment, people and the economy.**

Sustainable flood risk management has also been argued[113] to require examining each intervention strategy against all floods and not just those up to some design standard of protection. It is important to consider what will happen when extreme events occur, how the intervention will respond or fail, what will be the short and longer term consequences of failure, and what will be the responses of floodplain users.

Previous sections have examined in depth the losses and impacts that arise from floods, and within the confines of an economic appraisal of alternative courses of action, these are the major component of potential benefits from flood risk management options. Hence this section focuses on other aspects of the assessment of alternatives, including the costs both narrowly and more broadly defined, of flood management options, and differences in the benefits associated with different flood mitigation measures.

For society as a whole the holistic aim of improving the overall returns or benefits from a floodplain, catchment or coastal zone are condition for delivering sustainable development. But different stakeholders will have more specific or partial interests in potential mitigation measures. For example, the insurance industry's interest will lie in those financial losses that it insures against, and would not take into account the environmental implications of mitigation options or social impacts of floods. Similarly if flood risk management is the responsibility of sub-national government authorities then implications of structural mitigation works up- and down-stream of their

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[112] Straton A, Jackson S, Mariononi O, Proctor W and Woodward E 2008 Evaluating scenarios for the Howard catchment: summary report for workshop participants and stakeholders, Winnellie NT: Tropical Ecosystems Research Centre, CSIRO

[113]Green C H 2010 "Towards sustainable flood risk management", International Journal of Disaster Risk Science 1(1), 33-43

part of the floodplain/catchment would not be of concern (and in assessing flood mitigation benefits a regional rather than national economic viewpoint would be taken).

Baseline for comparisons

Decisions inevitably are based on comparisons and are relative, but alternative interventions are not the only course of action. The baseline is the key reference point for comparison, and needs careful definition since it may not be so straightforward. The “do nothing” option is the one recommended in the UK, for example, in comparisons with mitigation options. Where there is an existing intervention in place, this because the ‘walk away’ option: cease to operate and maintain that option beyond making safe. Where the intervention in question is part of a wider intervention strategy, often covering a larger area, then the identification of the appropriate baseline is more difficult.

This raises the issue of constructing reasonable scenarios or predictions of the future, and comparing these. Traditionally appraisal of specific flood mitigation options has taken a static or partially dynamic view of the future, for example in the UK considering predicted relative sea level rises, but assuming existing patterns of settlement, land uses and infrastructure. The Foresight Future Flooding study in the UK[114] took a wider strategic view and used four general policy–economic-environment scenarios within which to consider alternative flood management strategies.

The different possible means of intervening to reduce the risk of flooding (i.e. to reduce the floods probability or to reduce the flood losses), and the alternative means of categorising those means, have been set out in many different places and so will not be repeated here[115].   Broadly those intervention strategies can be categorised as:

		Point of intervention	
		Generator	Receptor
Type of intervention	Physical world	E.g. runoff control, flood storage	E.g. flood embankments, bypass channel
	Behaviour of individuals	E.g. Cropping practices; source control	E.g. flood warnings, insurance

[114] Evans,E; Ashley,R.; Hall,J.; Penning-Rowsell, E.P.;Saul,A.;Sayers,P.;Thorne,C. and Watkinson,A. (2004). Future Flooding Scientific summary: volume 1 Future risks and their drivers. Office of Science and Technology

[115] Please refer to Bouwer, L.M.; Daniel, V.E.;Poussin,J.; Aerts, J.C.J.H; Pfurtscheller, C. and Thieken, A.H. (2011). Costing methodologies for mitigation of natural hazard risk. CONHAZ deliverable 4.

Criteria for assessing flood management options

In assessing and comparing mitigation strategies and measures, direct implementation costs and economic benefits are obviously important but not sufficient criteria. In other words a decision is ultimately a judgment that rests on a wider set of values and priorities than can be condensed into benefit-cost analysis. Some of the main criteria that are increasingly applied include:

1. Effectiveness – in terms of reducing flood losses or the magnitude of events.
2. Reliability of the measure – which depends in part on what operational actions are needed, and the frequency of problems.
3. Failure including the mechanism of failure and its consequences. Fig x illustrates, in terms of economic impacts, the characteristics of failure for some structural measures.
4. Adaptability for changing condition

Not all potential flood mitigation measures can be said to be effective with the same confidence. Measures that require little operation can be expected to be more reliable than those dependent on human responses to floods. A moveable flood barrier may be designed to just the same technical standard of protection as a permanent dyke, but its reliability will be less as it has to be in working condition and has to be moved in place based on local operators receiving a flood forecast. For example, in the case of the Thames Barrier, one of the largest such examples, there is a significant cost in terms of monthly operation to ensure that it is working and in terms of systems to receive flood and storm surge warnings. In general it has proved very difficult[116] to provide reliable flood warnings under the best conditions: where the potential lead time is long and the system is well-maintained. Moreover the reliability of many non-structural intervention strategies including household level flood proofing is essentially unknown.

Implications of failure

In **Figure 20**, compared with the red do-nothing option, the so called "residual" loss pattern and magnitude typically differ considerably between mitigation options. The key distinctions are physical interventions designed to keep water out, which in a flood more severe than some design standard or level will fail, then resulting in losses typically greater than would have occurred without mitigation in a flood of the same magnitude/return period (the vertical sections of the lines). This applies both for flood proofing of individual properties and for embankments and arises because sudden failure is associated with rapid flooding and higher velocities, and secondly the structures retain water and prolong flooding after having failed. By comparison flood storage or channel improvements, so long as these are designed not to structurally fail in over-design floods, continue to mitigate flood impacts even in extreme events, and effectively shift the loss-probability curve left. But to these implications would also be added impacts such as those on health and society – sudden structural failure is likely to be associated with risks of death and

[116] Von Lany, P.;Barnes,A.; Dawson,R.; and Parker,J. (2009). Reliability in Flood Incident Management Planning. SC060063/SR1. Bristol: Environment Agency.

injury, people trapped in houses, and in the case of embankments severe damages over large areas that cause social dislocation.

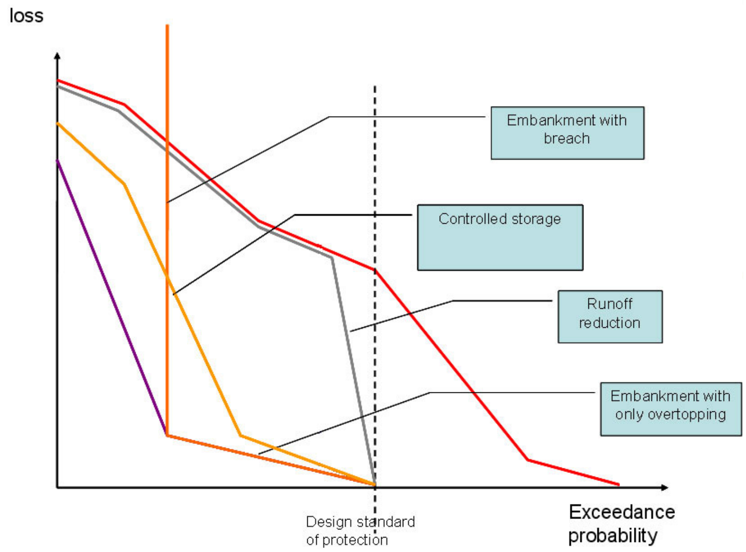

Figure 20: Hypothetical loss-probability relationships for a range of alternative flood mitigation options

Operation and Maintenance

The investment costs of flood management options, particularly those involving construction, receive considerable attention in project appraisal, and when decisions are based on cost-effectiveness may even be the main decision criteria. However, any decision based on forecasting effectiveness and implications of alternatives over a typical time horizon of say 50 years, should take into account operation and maintenance (O&M) costs. Yet in assessing all intervention strategies, the extent of O & M costs has tended to be neglected, often with simple percentages of construction costs assumed. All intervention strategies are more or less reliant upon adequate maintenance. In particular, 'non-structural' options are typically highly reliant upon adequate O & M expenditure and thus at risk during financial crises. For example, flood warnings depend on annual spending on not only maintaining a forecasting system, but also maintaining staff levels, training, rehearsals and information flows for the warning services and communities at risk.

The implications of choice between a high capital/low O & M strategy or a low capital/high O & M cost strategy therefore need careful consideration. Particularly as the former strategy may appear to have lower costs for future generations, but locks society into a sunk investment and development path that may have had high environmental costs in the first place. Coastal embankments are a good example, where these have encouraged urban development the option of managed retreat in the face of sea level rise and increasing flood risk is not an easy one as it involves abandoning houses and other infrastructure and raises questions over the social justice and costs of such measures and how affected people should be compensated. Whereas lower standard embankments that protected agricultural land leave a wider range of long term options more easily available – considering total value to society and even the biological productivity allowing protected fields to revert to saltmarsh and mudflats can be a viable land use of ecological and fisheries value.

Social relationships

Factors that can at least in part be readily incorporated into traditional benefit-cost analysis are not the only ones relevant to choices. Any flood mitigation strategy and associated measures will have implications for social relationships. Although these may be difficult to predict and quantify, this does not reduce their importance. Social implications can be strongly linked with strategies for the future of communities – measures that enable vulnerable communities to stay together and that encourage cohesion (for example re-development for existing communities that incorporates flood resilience) have different implications from leaving a floodway that includes flood-prone properties that suffer from blight and depending on investment by those, most likely poorer, owners in flood proofing. In general higher standards of protection are more likely to maintain existing social relations and communities, while extreme events that result in failure of mitigation measures such as dykes run the risk of social dislocation and loss of community identity.

Environmental costs and implications

In considering holistic implications of catchment and floodplain management options, the environmental externalities and service implications of measures are clearly relevant. At their most obvious these include changes in run-off and flood characteristics in each compartment or reach of the catchment associated with different structural mitigation options. More widely, the implications of land use patterns expected to arise over the foreseeable time horizon with these options are also of considerable significance – such as induced urbanisation and whether this will be controlled by planning regulations. But there are wider environmental implications to also consider such as the extent of carbon capture and emission of greenhouse gasses including methane associated with different options. For example, catchment management that seeks to enhance runoff absorption/retention in upper catchment peatlands by restoring peat habitats would have positive implications, whereas structural measures that require imported equipment and consume more energy would have negative implications. Estimating the lifetime carbon footprint of the options would be one way to summarise an aspect of environmental implications. But to this the implications of options for different aquatic and terrestrial habitats and their biodiversity should be added. In this regard “non-structural” options such as warnings and flood proofing on average are benign or neutral.

Scale

Holistic catchment level planning and assessment has the disadvantage of requiring information for larger areas and on more indicators, than does a choice between flood mitigation measures for a well defined “scheme” area. As noted earlier, decisions based on more information may be better informed, but there are costs in generating better or more locally relevant or more comprehensive data. On the other hand, planning for a wider area makes available options that could not have been considered at a local scale – there is even the possibility with a transnational catchment of planning mitigation options in one EU state that mainly benefit the citizens of another downstream state. Whether across nations, or parts of a nation, options that depend on catchment plans and land use controls over large areas may bring environmental benefits and economies of scale but they may also be less reliable as they depend on consistent coordination of decisions and plans over large areas for the long term, and temptations will always be there to break agreed rules for local gain (economic, social, political), especially when opportunities for economic growth arise.

THE ASSESSMENT OF ALTERNATIVE COURSES OF ACTION

- Deriving estimates of the loss probability curve is a sampling problem: deciding how many and which events for which to estimate the flood losses. Sensitivity analysis should be applied to the initial choice of return periods in order to determine whether additional events, and which ones, need to be included to improve the estimate of the loss-probability curve.
- In estimating the benefits of each of the do-something options, determining the appropriate baseline option is crucial: the benefits of each doing something option are the advantages of the do something option relative to the baseline option and the costs of the do something are the relative disadvantages.
- Since well-being is a multi-dimensional concept, no single measure, such as a benefit-cost ratio, is an adequate summary of the performance of each option. More generally, efficiency is the ratio of some output to some input and there as many measures of efficiency as their measures of output times the number of relevant measures of inputs. Stakeholders will consequently need to decide which ratios of which outputs to which inputs are relevant.
- The present value of the annual net benefits of each option should be plotted over time; the net present value of each option takes no account of preferences for the distribution of benefits and costs over time.
- Similarly, it is desirable to plot the distribution of each distinct stream of benefits and costs over time to see whether each of these distributions are desirable.
- A critical consideration for each intervention option is how likely is to fail, under what circumstances, and with what consequences. Rather than designing to meet some arbitrary design standard of protection, the principles are to manage all floods and not just some; hence it is necessary to design for failure.
- Arguments about non-structural versus structural interventions are misunderstood if they are considered only in terms of effectiveness: they are fundamentally about what should be the nature of social relationships: who has the responsibility to act and who has the responsibility to pay.
- Both 'nonstructural' and 'natural' intervention strategies can and should be evaluated in the same way as 'structural' options.

5.2 Less 'what'?

If one side of sustainable development is changing the targets and time horizon of decisions, developments and investments, the other is achieving this with less. Doing it with less in this instance is about avoiding a reduction in the resources and options that will be available in the future. Typically this involves shifting away from use of scarce natural resources particularly those that are non-renewable, towards greater use of abundant resources, and in particular to use of renewable resources. For example, expanding use of non-depletable resources such as solar energy, and those that may be depleted such as forests and fisheries, in which case the constraint become to ensure use at levels that do not deplete those resources beyond their capacity for self-renewal.

Finance is of course in itself a scarce resource, and incorporates claims on current resources generated by exploitation of non-renewable resources and use of processes that have compromised ecosystem functioning and reproduction and the options of future generations. Money both as income and as capital is an intermediary measure of values; its utility depends entirely upon the extent and nature of the opportunities for which it can be used. It retains this utility when considering greater long-term efficiency in use of scarce resources, but may not be on its own a sufficient indicator of value and sustainability. For example, market prices do not give the weight to greenhouse gas emissions that society may now wish to apply, in the absence of agreed adjustments to monetary values one approach is to quantify costs of alternative choices using one or more additional summary measures, such as changes in carbon emissions/absorption.

In considering the choices among flood mitigation strategies and measures the implications for annual operation and maintenance costs need to be considered as well as the nature of capital costs and resource use. Typically structural works are one of the least efficient uses of materials, but there are opportunities to make use of fill from excavation and other construction waste as part of flood and floodplain management (for example the use of spoil from excavating flood relief channels and re-excavating silted up channels to restore or help adapt nearby habitats or to flood proof settlements.

As a general strategy all forms of flood management should adopt principles of 'reducing, reusing, recycling' resources as far as possible. In planning flood management this means that in addition to traditional economic, environment and social indictors to inform decision making, other indicators should also be considered such as:

- What proportion of input materials are reused or recycled?
- What proportion of input materials end up as waste?
- What is the carbon footprint of the option?

In assessing the costs of options, a life-cycle costing approach needs to be taken that considers the lifetime of the system or option being considered and the most likely wider scenarios under which it will operate. This means considering not only construction or investment costs, but reliable estimates of operating and maintenance costs and implications, and estimating and planning for the closure of the option at its end of lifetime including the disposal of and reuse of the materials involved. This should be in the context of expected economic and social conditions, for example plausible projections of the sources of energy during the lifetime of the option.

It is not only material resources that are scarce, skills and attention are also scarce resources. For example, a flood warning strategy that requires more hydrologists and meteorologists than exist in the country is not currently sustainable. Similarly, a regulatory programme setting standards for buildings is not sustainable if it requires more building inspectors than can be expected to be available. Alternatively the costs of training and employing the staff needed to operate these systems need to be fully taken into account.

LESS WHAT?

- Usually O & M costs are not assessed in anything like the same detail as capital costs but at low discount rates, they can contribute the majority of the present value of the costs. Therefore, a detailed assessment of the O & M costs should be prepared.
- That O & M budget should differentiate between routine maintenance tasks (e.g. annual grass cutting), renewals (e.g. the replacement of electrical and mechanical equipment) and other costs as these vary between O & M cycles.
- Non-structural options in particular are highly dependent upon adequate O & M but O & M costs are often the first target in times of financial crisis.

5.3 Data available

There is almost always a difference between the data that is necessary to make a decision and that which is available. Decisions therefore have to be made both with available data and in the knowledge that it is inadequate; one definition of engineers is thus that they are people who have to take decisions using totally inadequate data.

The data availability and the potential in collecting the data are subject to their nature and to existing methodologies. But each country has also its own history, its own ethics, and its own rules. It influences in terms of data what has been collected in the past, what is available for different purposes and for whom, and what could be available in the future. These limits have to be defining in each case in order to efficiently target the efforts and improve the assessment. Indeed it may be possible to collect more or better data but doing so involves both cost and takes time so one decision is whether it is worth spending those costs and perhaps delaying taking a decision in order to get better data. Whether it is worth doing so depends upon whether it would make any difference to the final choice of the course of action to adopt. It also depends upon the cost of collecting further data and the consequences of the decision. As Peter Drucker remarked is not worth spending more than 99c to save $1. Hence, for small scale decisions it will not worth spending very much money and time to refine the data available. Conversely, for major decisions, the opposite will be the case.

So, normally, available will be more or less deficient along four dimensions:

- ➔ Precision: repeatability or reproducibility of the measurement. Precision reduce the variance of the distribution around a value. It is related to the methodology used to give the results.
- ➔ Accuracy: it indicates how the measure is close to the true value (more or less unknowable).
- ➔ Aggregation: it provides an indicative value from a group of values. Different function can be used (mean, median, mode, weighted average…) and provide a different result. The main issue is the problem of scale and the aggregation of different populations of distribution.
- ➔ Representativeness: it measures if the data can be used in certain context or not and stress the potential transferability of the data.

There are two approaches to obtain information: developing its own protocol and methods and then collecting the data or use second source of information. In flood losses assessment it is recommended to start with available information. Second source of information are useful as they are already available and usually less expensive and time consuming to obtain.
It is for example the case for instance for data on potential hazard and elements at risk which are essential to assess flood losses assessment as they provide information on the initial shock. The progress made since the 1960 and the launch of the first America's satellite surveillance (Corona Project, declassified only in 1995), in remote sensing techniques and new Information and Communication technologies have revolutionary changed our vision on the system Earth and on our societies. It has also changed our way to collect, treat and communicate the information.

Available data to model the hazard and to identify elements at risk has incredibly increased in precision and accuracy allowing better aggregation and representativeness of the data. For instance the resolution of data on land use has jumped from 79 meters (Landsat 1 in 1972) to 50 cm resolution (ex: 2009 worldview-2 46 cm panchromatic imagery) with higher quality information (from three bands to high spatial resolution with multi-spectral imagery). LIDAR (light detection and ranging) techniques can now also provide elevation measure at a cm resolution. Investments in radar and models development have also increased meteorological prediction. Stereo visualization technique is also supporting the mapping of 2D object into 3D objects. It is also now easy to access detailed land use information using the Internet (Google Maps and Street View).

One using second source information it has to be officially recognized. The methodology used needs to be coherent and known to better understand the limit in using them. Limits which need to be considered are:

- Inappropriate or different methodologies to obtain the raw data. Comparison, analysis and aggregation are then hazardous. (example flood damages database)

- Nature of information may not be relevant, inadequate or up-to-date to do the flood loss assessments (for instance: no data on the building type, 10 years-old census data).
- The data are not representative for the case and then not transferable (ex: using other countries depth damage curves).

In such cases, primary source of data have to be collected. In this case it could be very costly and time consuming to get this data. A key rule is to approach the gain in information by having a progressive refinement of critical parameters that need to be considered for further investigations. It is indeed important to first define how this data will improve the precision, the representativeness and the accuracy of the assessment. Accuracy can be gained from the entity point of you but it also needs to be considered from the over whole loss point of view. For instance is it worth to spend time and money to have an accurate value for a loss which represents less than 5 % of the potential total losses? The same question needs to be posed from a representativeness point of view: which entities are mainly represented in the system in terms of quantity and quality and need further attention? Improving the precision over a certain point may also not be cost-effective.

Choices and decisions are made according to the perspectives and responsibilities of those taking the decisions, and according to the information available. For example, strategic and catchment level decisions, and decisions early in the planning process of flood risk management are generally made on the basis of less detailed information and analysis than subsequent decisions on the detailed merits and standards of protection of flood mitigation measures. Generating detailed information and estimates of flood scenarios, probabilities, and land uses in the floodplain all have costs, so generalized assessments based on simplified methods and more easily available information form the inputs for decisions at early stages or landscape-catchment scale. In the foreword to Penning-Rowsell et al. (2005)[117], the UK Defra thus recommended "a greater understanding of the principle that for most cases appraisal effort should be proportional to the scale and scope of the decisions required".

[117] Penning-Rowsell, E.;Johnson,C.;Tunstall,S.;Tapsell,S.;Morris,J.; Chatterton,J.and Green,C.(2005). The benefits of flood and coastal risk management: a Handbook of assessment techniques. Middlesex University Press

DATA AVAILABLE

- Any practical methodology will rely heavily upon available data from existing sources. Therefore, both the form and the details will have to be compatible with this existing data. For example, the UK system of depth-damage curves reflects the fact that unlike many other countries there is no available local data on the values of assets at risk. Conversely, unlike Germany, census data provides a great deal of data at a small spatial resolution as to socio-demographic statistics. Land use classifications will normally have to be consistent with the classification used in existing data sources.
- All data is more or less inaccurate, coarse or imprecise; any attempt to improve any of the characteristics costs money and takes time so a key question is whether it is worth doing so.
- Sensitivity analysis should be undertaken at the start of the analysis in order to identify which are parameters whose values critically determine which option should be chosen. It is these critical parameters upon which efforts to improve the quality of the data should be focused.
- In cost-benefit analyses, most of the benefits are contributed by the losses from frequent floods so attention should be focused upon these events rather than on the extreme events.
- Secondary source of information can be used as long as the methodologies is known, the information is relevant for flood losses assessment, and the data are enough representative for their transfer
- Primary sources of information are better and can contribute to second source of information. But they are costly and time consuming. The collecting protocol need to be rigorous.
- In considering transferring depth-damage data from one country to another, it is first necessary to establish why losses are likely to be similar in the two countries.

5.4 Uncertainty

Flood risk management is about decision and, therefore, the existence of uncertainties that may affect the final choice needs to be considered as in any decision process. What has changed is that we have now a better understanding of the complexity in the context of flood risk but also that we need to consider this risk within more complex systems (integrated water management, climate change, carbon sequestration etc). Thus beyond the progress the society has done, our understanding on the uncertainties has also increased. And this increase does not mean that we know better; in fact it just highlights, when a problem is identified, that the domain of knowledge is bigger and emptier than we thought. Indeed there is never ‘complete knowledge’, and clearly, absence of information, or information that may be unobtainable, leads to uncertainty[118].

The uncertainty expresses the existence of different states or outcomes that may happen and therefore the inability to differentiate; however, what we are unable to differentiate between and the reasons why we are unable to differentiate often vary. Someone who says 'I don't know what

[118] Rowe, W.D. (1994). Understanding Uncertainty. Risk analysis 14(5).pp 743-750)

to do' can be described as being uncertain but question is then: why is it impossible to differentiate? This example illustrates two often linked forms of uncertainty: uncertainty as to what to do and uncertainty as to the consequences of taking some action. The practical question is: what should we do? And often the reason why we are uncertain what to do is a lack of knowledge about the future consequences of taking action. But perfect knowledge is not always enough to destroy the uncertainty about what to do: a couple planning a holiday together may have full knowledge about the possible destinations but if their preferences are very different, the process of resolving the uncertainty as to what to do may take a long time. Uncertainty lay in various dimensions and it is a complex task to identify which has been studied elsewhere[119].

J.P van der Sluijs (2007)[120] identified various styles of monster treatment for the monster of uncertainty:

- Monster-hiding: do not talk about the elephant in the room
- Monster-exorcists: Science can solve the problem and reduce the uncertainties. The question is which feasibility and at which costs?
- Monster adaptation: uncertainties have to be accepted, revealed and integrated in the decision. Uncertainties can be enclosed within delimited domain and then compared in a scientific approach.
- Monster embracement: uncertainties make any decision irrelevant.
- Monster assimilation: uncertainties have to be accepted, revealed and integrated in the decision but other approaches than science can be used.

Currently, the dominant view in economics and in engineering is that uncertainty can be expressed in terms of probabilities, through such approaches as Monte Carlo analysis as for example in the form of ensemble forecasts (Monster-exorcists and Monster adaptation). In both conceptualisations, given that decisions have to be made about action in the future and based upon predictions of the future, the virtue of the currently dominant view is that it offers a way of dealing with both problems. Whilst predictions of the future have almost invariably proved to be grossly erroneous[121], the probabilistic at least offers a way of dealing with the inability to differentiate to a greater or lesser degree.

The traditional view of economists was that probability and uncertainty are two quite different things[122]. This latter view has also been taken by a number of firms who have argued that whilst decisions have to be taken for the future, that future is inherently unknowable[123]. The first problem with the classic view of uncertainty is that it requires defining a boundary between probability and uncertainty; conversely, the current conventional view asserts that everything is probability. The classic view therefore requires a clear specification of when it is appropriate to take a prob-

[119] Walker W.E., Harremoes P., Rotmans J., Van der Luis J.P., Van Asselt M.B.A., Janssen P. and Krayer Von Krauss M.P. (2003). Defining uncertainty: a conceptual basis for uncertainty management in model-based decision support. Integrated assessment 2003 vol.4 No.1 pp5-17. Bammer, G.; Smithson,M.; (2008). Uncertainty and Risk: multidisciplinary approach.Earthscan

[120] J.P van der Sluijs (2007) Uncertainty and precaution in Environmental Management: insights from the UPEM conference, environmental modelling and software,22,(5),590-598)

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abilistic approach and when to take an approach of uncertainty. However, the critical practical problem with the classical view is that it does not appear to offer much in the way of guidance as what to do in the face of uncertainty. Early work did look at such criteria as 'Min-max'[124] but little in the way of practical advice resulted. More recent approaches have included:

- The use of maximally different scenarios to test the viability of particular intervention strategies rather optimizing on the basis of a single forecast[125].
- Adaptive management; treating each intervention as an experiment whose results will reveal more about the system concerned[126].
- Robustness analysis: first using sensitivity analysis to identify which are the variables whose values have significant implications for the selection of the intervention strategy and then testing how extreme those values have to be before the preferred choice is affected[127].
- Designing for resilience; a system which will stay within the desired region under a wide range of shocks and other changes[128].
- Designing for failure; an intervention strategy that does not fail catastrophically when the design conditions are exceeded[129].

Nevertheless, the dominant view of uncertainty does offer a way of expressing both the degree of uncertainty and a way of choosing between uncertain options. It requires defining the probability distributions for each of the key variables and then multiplying those distributions together, through Monte Carlo analysis, to get a composite probability distribution. There are a number of specialized software packages available to implement the approach; some of those packages however have problems with correlated variables.

The key problem in this approach is to define the probability distributions for each variable: the functional form of those distributions has a critical effect upon the final probability distribution[130], specifically whether the distributions are symmetrical and how flat are the distributions. For example (**Figure 21**), the potential damages to a house is calculated based on the probability of having a certain level of flood (hazard), the probability of having a certain house thresholds and the probability of potential damages. The red distribution represents the probability of flood depth in the house (flood depth distribution + thresholds distribution). The green distribution represents the probability of damages (flood depth in the house distribution * damages distribution).

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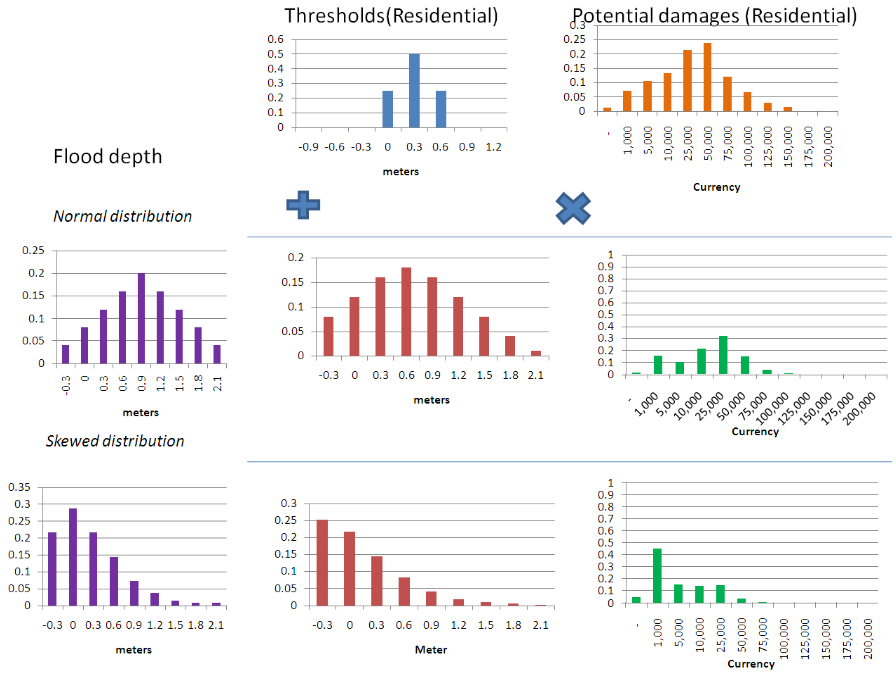

Figure 21: Effect of the variable distribution on loss assement

UNCERTAINTY?

- The benefit-cost ratio gives a clear indication of how confident it is possible to be that the do something option should be preferred to the baseline option. A benefit-cost ratio of 3 shows that the benefits can have been overestimated by a factor of three or the costs underestimated by a factor of three before the baseline option should be preferred to the do something option.
- Uncertainty as the likelihood of a flood or the performance of an intervention strategy can be managed by designing to manage all floods and not just some floods (those up to some design standard of protection) and designing for failure.
- What is important is how any intervention option will fail, what happens when it fails, and how likely it is to fail.
- Uncertainty can be handled in various way and integrated in the decision: hiding, embracement, exorcism, adaptation, assimilation.
- In any appraisal it is necessary in an early stage to identify their location of the uncertainties, their level and their nature to better identify how to handle them (methods, time, costs, consequence in the decision, consequence in terms of adaptive management plan).
- The uncertainty of individual elements needs to be considered but the combined effects of various uncertainty due to the relation between these elements need also to be considered

5.5 Supporting the process of choice

The 'best' choice might be defined as a process of choice which is successful at identifying the best of the available options in terms of the performance of each of those options in achieving the objectives of that society. Doing so may also be taken to involve a process of logical reasoning supported by the best available evidence. This is much easier said than done for at least five reasons:

1. What is the 'best' course of action to adopt can only be established in hindsight but decisions have to be about trying to select a future. We use reason to make best arguments about what option should therefore be adopted.
2. There is commonly disagreement about the relative importance which should be given to achieving each of the goals of that society in the particular case. Hence, choices essentially involve negotiation, debate and argument in order to try to resolve these conflicts.
3. As discussed earlier, the consequences of the different courses of action can differ widely in terms of who is affected, how they are affected, and when they are affected.
4. Knowledge about the world and particular about the world in the future is always incomplete and may be totally wrong. This uncertainty must be addressed in one way or another.
5. The complexity of decisions is often at the limit of or exceeds human cognitive capacities and so decisions have to be simplified to a level which we can handle. Tools and techniques are therefore required which simplify the choice to a level we can manage without losing sight of the critical issues. The requirement is to routinise the trivial in order to allow us to focus our attention upon the crucial issues.

Two quite different techniques are often used to help simplify the decision to a manageable level. Cost-benefit analysis (CBA) is ideally suited to a technocratic approach, one where experts or others make decisions on behalf of others, and the primary purpose of using CBA is to ensure that other people's money is used efficiently. It is a way of ensuring that the experts decide appropriately. Because it is based upon a rigorous framework of analysis, it ensures consistency in judgements both within and between choices, and that rigour also provides a clear audit trail and transparency. It requires determining the value of each stream of cost or benefit occurring in each year; discounting those values to a common, or present, value; adding these present values together; and comparing the sum of the benefits to the sum of the costs. It is, in principle, an almost entirely mechanical approach which can be used to determine what is the optimum choice to make. But that mechanical approach is bought at the cost of making many sweeping assumptions; the values of each stream of cost or benefit have to be known in advance so that the trade-offs made as to the desirability of every trade-off are automatically determined. That in turn assumes that everyone agrees as to these values and trade-offs so a CBA essentially treats a country or region as a single person who knows in advance what they want and simply has to find the best means of achieving those ends.

The primary alternative approach is Multi-Criteria Analysis (MCA). This comes in a number of different forms, some of which seek to mimic the rigour of CBA, but the exploratory form of MCA is intended to help the stakeholders to discover which option they should adopt. Rather than assuming that all values and trade-offs are known in advance, it seeks to help the stakeholders argue, discover, debate and negotiate those values and hence what trade-offs should be made. If CBA seeks an optimum outcome, MCA is centred on helping the stakeholders to choose by exploring the implications of making different choices and it does so by seeking to highlight the critical differences from the essential similarities. Rather than assuming that there is some optimal course of action, MCA is directed towards finding a course of action which the stakeholders can agree to adopt. If CBA is an approach designed to control experts, MCA is intended to help the stakeholders decide.

It requires establishing a set of criteria against which the performance of the different options can be compared; ordering those criteria in terms of their importance; and ordering the performance of each of the options against each of those criteria. Those criteria can cover a much wider range than those which can be included in a CBA. In particularly, several of the Stiglitz Commission criteria cannot be included in a CBA. Clearly, the stakeholders can disagree as to the relative importance of achieving each of the criteria, and the individual options are likely to differ in the order of their performance against each of the criteria. The stakeholders can then argue and debate with each other as what importance ought to be attached to each criteria and the strength of the evidence supporting the ranking of each of the options against each of the criteria. Thus, the argument between those who agree and disagree with the outcome of a CBA is limited to whether or not the analysis is technically right; in the case of the result of a MCA, the argument can be in terms of agreement or disagreement with the rationale of the decision.

6. A programme of implementation

6.1 First steps

The following is a strategy for introducing a methodology to assess flood losses. Again, this is presented as a learning process and focuses upon what to do in the first two years and then the process of learning through doing. The core issue is: what to do first? The answer is to start with estimating the initial perturbation caused by the flood. The central message is that there is no point in introducing differences unless those differences are significant; conversely, it is necessary to identify what are the significant differences and then to make those distinctions. The suggested actions in the first two years are:

1. Establish a user community of stakeholders, perhaps including an annual specialized conference.
2. Review the availability of data on building stock and other assets. Generally, the stock of dwellings represents about half of the value of built assets but the largest proportion of buildings. Thus, whilst the greater proportion of the buildings affected in a flood are usually dwellings. The damageability of buildings depends upon their constructional form whilst the damageability of the contents depends upon the nature of the activity undertaken within that building. Flood loss assessment typically depends upon the availability of existing data as to numbers, types and locations of buildings, and the activities undertaken in those buildings so any feasible flood loss assessment methodology will be determined by the nature and availability of existing data.
3. Decide upon a system of land use classification. It is recommended that initially the number of categories for urban properties should not exceed 10 to 12, further differentiations only be introduced at a later date where significant differences in loss potential are found. The categorization is likely to be based upon a combination of built form and the activity engaged in the building. For example, it is generally appropriate to distinguish in the case of dwellings between single storey, single family two storey dwellings, and apartments and between masonry/mass concrete construction and other constructional forms. Other possible classes are: shop/office conversions from dwellings; workshops; factories (dirty processes); factories (clean processes); warehouses; purpose built offices; large shops/supermarkets; and cars.
4. Identify 'critical installations': generally, standard data is unsuitable for use with such installations. At least three categories of critical Installations have to be considered: emergency services location, distribution and network centre delivering important services (e.g. train station, bus station, source of power, water, and telecommunication), vulnerable area (hospital, school, camping site in which appropriate evacuation or rules have to be applied).
5. Identify major network (traffic, gas, electricity, rail...), their topologies and associated flows.
6. Identify areas where depth-damage data will underestimate the damages done by floods to buildings and their contents. These areas are primarily those where high

velocity flows are expected resulting in the partial or complete structural failure of buildings.

7. Develop synthetic depth-damage curves for each of the land use classes. In the short run, it will only be possible to derive synthetic depth-damage curves because adequate, current data on experienced losses will not be available. It is suggested that a number of different experts be used so that inter-judge reliability can be assessed. If estimates of losses at a specific depth differ markedly between judges then this implies that there is an inadequate understanding of how flood damage is produced. Data collection and data availability is essential for the learning process and for assessing the uncertainty. It is essential to establish a coherent framework for data collection and assessment.
8. Flood loss assessment is centrally about probabilities. Fragility curves for the failure of different intervention options need to be developed or agreed. Equally, the present value of flood losses is derived as an estimate of the area under the loss-probability curve: a sampling strategy for the loss-probability curve must be agreed.

In the third year onwards, the goal is to learn how to do better and in particular which areas would result in the highest overall gains from further research and then to undertake that further research. The methodology should be applied to a variety of problems at a variety of scales by a number of organizations; these problems should include some small scale projects as the way to learn what simplifying assumptions are acceptable for use at the large scale is knowledge of the detail. It is important that this approach should be adopted in the framework of a user community which exchanges, and thus builds up, experience both in best practice and in the knowledge and limitations of the available methodology.

6.2 How to make better choices – outside the scope of this document

The problem for the stakeholders is how to make a better choice; what process of reasoning and discussion is most likely to result in the adoption of that course of action which will, in hindsight, prove to have been the best available one. This is the most challenging task and conventional economics is unable to provide guidance as to what are the best means of undertaking this task, how to structure the process of negotiation, debate and argument between the stakeholders or how to negotiate debate and argue most effectively.

The assumption in these guidelines is that exploratory Multi-Criteria Analysis will be used by the stakeholders to support the process of negotiation, debate and argument; in particular, to aid in the invention of new intervention options. One of the advantages of exploratory MCA is that it can be used to select out the worst performing options so that attention can be focused upon the competing advantages and disadvantages of the best performing options. MCA lacks the rigour of economic analysis but that is its strength: it can be used to explore what makes a difference to the decision as to which is the best option. In addition, in seeking to combine the best features of those options which are preferred to other options it may be possible to invent a better option than those originally considered.

It is important to integrate flood risk management within the overall strategic plan. The first step is to ensure that key partners are involved in the decision (e.g. land use planner, catchment planner, emergency services, insurance, authorities…) but also in the crisis management. Negotiation and decision are an on-going process. It is then crucial to learn and to change based on the flood experiences. For that reason a second important step is to set-up a system for supporting data collection, promoting the learning process and then facilitating change in future choices.

6.3 Future

Whilst stakeholders want to know what to do, and how can research help them to make better decisions, researchers are interested in what is not known or what is imperfectly understood as this defines the field for further research. For the researcher this is consequently a good time; a point of rupture between the past and present. In the past, the focus in flood loss assessment was on economic efficiency and the role of the loss assessor was understood to be to advise the decision maker as to what was the best, or optimum, course of action to adopt. Consequently, in economics, efficiency and optimality came to mean the same thing and economics sought means of determining what course of action would be optimal. In the search of a means of determining optimality, a great many simplifying assumptions had to be made.

But with the shift to decisions being made by the stakeholders, the problem is how to help the stakeholders to make what are, in a sense that they define, 'better' decisions. The relevance of economics is thus the extent to which the stakeholders, those who own the choice, find economics useful in helping them to make a better choice. Secondly, the shift to sustainable development, as exemplified in the report of the Stiglitz Commission[131], also requires thinking much more broadly than focusing solely upon economic efficiency as well as requiring considering what constitutes the sustainable use of resources. These guidelines seek to draw upon these two principles but what people mean by a 'better' choice, and the best means of supporting stakeholders in seeking to decide which is the best available option in a particular instance, both require considerable further work.

The concept of 'well-being', defined by the Stiglitz Commission as the multi-dimensional objective of collective decision making is considerably wider than the aggregate of flood impacts which have been considered in flood loss assessment. Those approaches have been essentially piecemeal rather than systemic and such a systemic approach is needed, perhaps drawing upon the concepts of Sustainable Livelihoods[132] and Household Economy[133] used in development studies. In developing countries, such studies have shown dramatic changes in the use of time [134]and the redeployment of monetary resources[135] following a flood. Current approaches also tend take either the individual household as the unit of analysis or the community as a

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whole. Recognising the duality of the individual household and community may generate new insights.

Defining the objective of collective decision making as being well-being has wider implications for economics. The instrumental value of any action is then the contribution of that action to achieving well-being. But since well-being is regarded as a multi-dimensional concept, any action will have multiple values. The concept of value which follows from a focus on well-being is also markedly different from that currently used in economics although closer to the everyday usage of 'value'[136].

These guidelines noted that there are two entirely different conceptualisations of 'uncertainty' in use, with each having quite different implications for decision making both in terms of the process of choice and the choice of the course of action to adopt. Considerable work is required to develop both how choices should be taken and what course of action should be adopted if uncertainty is taken to be quite distinct from probability.

Assessment of how the shock of a flood ripples through the economy over time requires a comprehensive and valid model of the economy. Although some very interesting work[137] has been done looking at such shocks, this has used models of the economy which are highly simplified both at the specific level and at the macro-level. Since the consequences of a shock on a system are dependent upon the structure of the system, we need models of the economy which are realistic, and have been validated, if decisions are to be based upon them. In particular, any activity in the economy can be considered as the transformation of some inputs to some, more desirable, outputs. The nature of that transformation function, the economists' production function, is crucial but we do not currently have a good understanding of the nature of those functions either in the general or in the specific[138]. In addition, rather than using models which assume some equilibrium state and rather simple modelling techniques, the use of agent based modelling[139] and general systems modelling[140] may given greater understanding of what are the critical issues in the effects of a shock on an economic system.

Finally, ultimately decisions are reflective of existing social relationships or claims as to what social relationships should exist. Things and actions then are important in that they articulate those social relationships, acting as an intermediary to express the relationship[141]. Social relationships are important both in functional terms, as means of doing more with less, but also normatively; what ought those relationships to be. Thus, the Stiglitz Commission identified 'social connec-

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tions and relationships' and 'political voice and governance' as two components of well-being. Both the functional and the normative aspects of social relationships deserve greater study: on one side, a key question being when cooperation is more efficient than competition[142]; on the other, what principles should apply to social relationships[143].

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