Flood risk management: A strategic approach

Paul Sayers
Sayers and Partners, United Kingdom

Dr Gerry Galloway
University of Maryland,USA

Dr Edmund Penning-Rowsell

Flood Hazard Research Centre, Middlesex and Oxford University, UK

Prof. Yuan Yuan, Prof Shen and Dr Yiwei Chen
General Institute of Water Resources and Hydropower Planning and Design, China

Prof Wang
Nanjing Hydraulic Research Institute

Dr Tom Le Quense, Lei Wang, Yuhui Guan

WWF, UK and China

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ABSTRACT: Remarkable progress in cultivating the concepts of flood risk management has taken place over the past decade, across many countries as diverse as India, China, Australia, the United Kingdom and the United States, and in many instances this progress has been transferred into decision-making practice. This change in practice highlights a risk management paradigm as potentially more complex than a more traditional standard-based approach as it involves 'whole systems' and 'whole life' thinking; yet this is also its main strength – paving the way for more integrated and informed decision making that utilizes a portfolio of responses across a full range of flood risk management activities whilst recognising their inter-relationship and contribution to integrated basin planning.

This paper is the result of an international collaborative effort to review and distill approaches to water management in challenging large scale and inter-related environments, providing new insights into good strategic planning and risk management of water resources and floods. The paper provides an overview of the common process and frameworks of flood risk management and provides guidance on the specific techniques available and to describe how and when these techniques might be used, illustrated with case studies from around the world. It is not intended, however, to provide guidance on the detailed technical tools and means of analysis that form part of the flood risk management analytical process, for example detailed hydrological, hydraulic, ecological or economic assessment methodologies, as these are easily found elsewhere. Instead, it is intended to provide an overview of the emerging good practice in strategic risk-based flood risk management, the process of developing plans and policies, and the appropriate times and places at which these more specific techniques can be used.

In particular the paper is focused on strategic flood risk management policy and practice and provides an overview of:

- The historical developments and emerging trends
- The purpose and characteristics of modern flood risk management.
- The goals, objectives and outcomes sought
- The on-going challenges in developing and implementing flood risk management in practice together with some of the common pitfalls and misconceptions

Summary taken from: Sayers et al, 2012. Flood risk management: A Strategic approach. Published by UNESCO/WWF/GIWP

1 INTRODUCTION

Remarkable progress in embracing and cultivating the concepts of flood risk management has taken place over the past decade across the globe. In many instances this conceptual progress has resulted in changes to decision-making practice. These changes in practice highlight a risk management paradigm as potentially more complex than a more traditional engineering standards-based approach. Strategic flood risk management takes a longer term , catchment-wide perspective, and includes an explicit trade-off between the risks reduced, opportunities promoted and the resources required to achieve these outcomes. Such an approach paves the way for a more informed decision making process that recognises the advantages of adopting a portfolio of responses (including structural and non-structural measures as well as policy instruments) and their inter-relationship with, and contribution to, integrated multi-sector basin planning.

1.1.1 *Brief history of flood risk management*

The earliest civilisations recognised the need to live alongside floods; locating critical infrastructure on the highest land (as seen through the Churches and Cathedrals of England); providing flood warnings to those that may be flooded (common practice in ancient Egypt); making flood sensitive land use planning choices (as practiced by The Romans). Increasingly through the early part of the 20th century the concepts of flood risk management continued to emerge and continued to be recognised not only as an engineering pursuit but also as a social endeavour.

The requirement for "protection" and a belief in "our ability to control floods" started to increasingly dominate attempts to "deal with flooding". Throughout the 1960s to 1980s, the principal means of mitigating the impacts of floods was *flood* control, via the construction of levees, dykes, diversion channels, dams and related structures. As populations and development grew, flood losses continued to increase, and the need to do things differently became more apparent. A new approach was needed, one that could not only identify the hazards and the consequences faced by society, but was also assess the relative significance of the risks faced – a progression of thinking reflected in Figure 1.

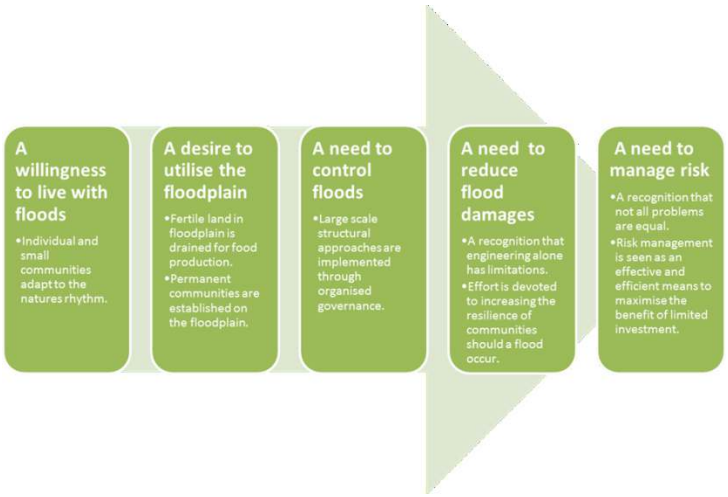

Figure 1. The evolution development of flood risk management

A strategic approach to flood risk management is now widely accepted as central to good practice. Acceptance of the concept however is not enough. Traditional flood control approaches continue to persist in many policies and, perhaps most importantly, in the decisions taken; decisions that ultimately we may come to regret.

The challenge now is to turn accepted theory into common practice. Although there is no single roadmap to aid this transition, and few comprehensive examples, many elements of good practice are starting to emerge as well as some clear failures of the traditional approaches to learn from (see Table 1).

Table 1. The influence of past flood events in shaping policy and practice

Flood event	Impact on thinking, policy and/or practice
1917 Mississippi River and the Sacramento River basins, USA and **1927** lower Mississippi, USA	Promoted the need for basin scale infrastructure and co-ordination.
1931 and the following decades, across three major rivers: the Yellow, Yangtze, and Huai, China	Promoted the need for basin scale infrastructure and co-ordination.
Major floods across the United States in **1936** (and to a lesser extent 1937 and 1951)	A need for national responsibility.
In March **1947**, river floods occurred across much of Europe, Shortly after Europe experienced devastating coastal floods in **1953**	Issues of food security, the need for clear roles and responsibilities and the performance of warning systems.
1991 and **1998** China	A rethinking of flood issues: how to carry out disaster mitigation approaches more efficiently and effectively.
1993 and **1997** Mississippi, USA	The 1993 Mississippi River flood was the US flood of the century in economic terms. Following this event, new regulations were issued (1996) that established the need to include uncertainty in assessment and justification for new flood control projects.
1993, **1995, 1997** on the Rhine and **1998** in the UK	Led to a demand for a new basin wide and strategic approach to flood management using a combination of structural and non-structural approaches.
2004, Asia Tsunami (Boxing Day)	A recognition of the vulnerability of coastal communities and need for better warning, emergency planning and spatial planning to reduce risk.
2005, New Orleans, US	A wider recognition that levees fail. A need to better understand levee performance and the wide acceptance of the need for a risk management approach and the communication of residual risks.
2007 in Hull, UK	A need to consider all sources of flooding and spatial extent of events, as pluvial, fluvial and tidal sources combine.
2010, Pakistan, **2011**, Japan, **2011**, Mississippi	A need to revaluate the use of floodplains, limitations of structural systems and the need for improved resilience of critical infrastructure and prevent secondary and tertiary risks developing.

2 THE DIMENSIONS OF RISK

A number of important concepts underlie our understanding of risk and bridge the gap from assessing the risk towards making risk informed decisions. One of the most important of these concepts is the multiple, and sometimes subtle, dimensions of risk (Figure 2). All of these dimensions are subject to change – either through autonomous pressures or purposeful intervention. Traditionally the focus has been on reducing the probability of flooding through extensive structural defence systems such as those in the Rotterdam, Netherlands, New Orleans, USA, Huai River, China – but increasingly there is the recognition that non-structural actions to reduce exposure such as effective planning control in flood prone areas,(as is done in the City of Cape Town) or the vulnerability of those exposed to flooding through use of safe havens, better warning and evacuation planning, modern flash flood forecasts through to flood specific building codes and insurance arrangements all offer a vital contribution to risk management. Recent actions in Bangladesh, alpines regions of Europe and China bear out the effectiveness of such approaches.

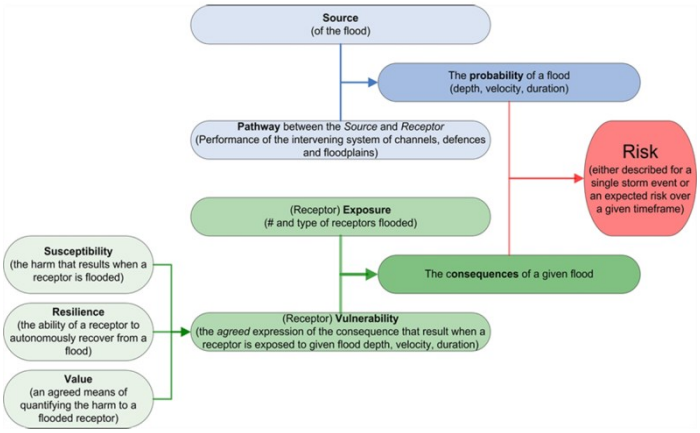

Figure 2. The components of risk – to understand risk, the individual components of the risk must also be understood

3 STRATEGIC FLOOD RISK MANAGEMENT

Flood risk management has multiple goals (Figure 3). Achieving these relies upon the development and implementation of appropriate portfolios (where the advantages of one compensates for the disadvantages of another); a process that is complicated by changing nature of the flooding system (through climate, geomorphologic and socio-economic influences -population growth, increasing development). Accepting that the future as unknown impacts the way in which plans are made and decision implemented. Flood risk management therefore embeds a continuous process of adaptation that is distinct from the 'implement and maintain' philosophy of a traditional flood defence approach – an approach central to the decision to delay the construction of the new major defences within the Thames Estuary.

Taking a longer term, whole system view, places a much higher demand upon those affected by flooding and those responsible for its mitigation. It involves collaborative action across governments, public, businesses, voluntary organisations and individuals. This places an increasing emphasis upon effective communication of the residual risks and actions to be taken.

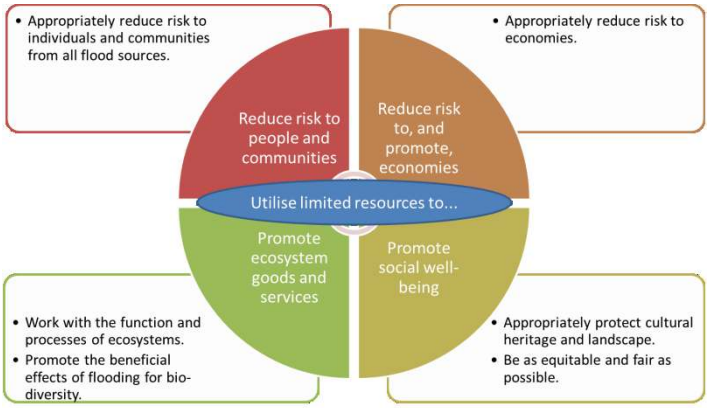

Figure 3. The primary goals of strategic flood risk management

These characteristics form the building blocks of good flood risk management (Figure 4) – an approach that concurrently seeks to make space for water and provide room for the river whilst supporting appropriate economic use of the floodplain.

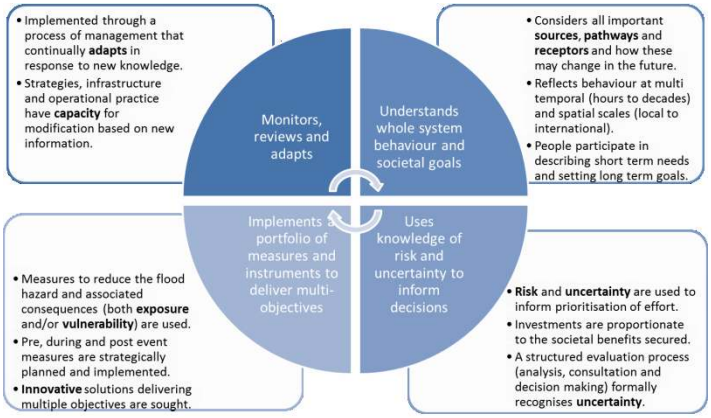

Figure 4. The characteristics of good flood risk management

3.1.1 *Supporting sustainability*

Supporting sustainability is much more than simply maintaining the long-term integrity of flood control structures. It also includes promoting the long-term health of the associated eco-systems, societies and economics. The manner in which these higher level goals are translated into specific objectives shapes the nature of the flood risk management that is delivered. For example:

Delivering efficiency and fairness - Flooding is not fair *per se:* the inherent natural spatial inequality in the frequency and extent of flooding, plus the legacy of differential interventions, being the cause. Every intervention in flood risk management tends to prioritise one group or location over another, creating further inequality and 'unfairness'. Maximising the utility of an investment, whilst ensuring that it is distributed through an equitable process that also protects the most vulnerable members of society, raises a number of practical problems. Providing protection to one community but not another, is *unfair*; providing a higher level of protection to one compared to another is *unfair*. However providing a common level of protection to all is impossible, and even if achievable would be inefficient. The desire to manage flood risk more *fairly* promotes the use of nationally consistent non-structural strategies that are available to all (for example better forecasting, improved building codes and grant or compensation schemes). Such an approach offers a greater contribution to equality and vulnerability-based social justice principles than the status quo of providing engineered solutions to the few (Table 3).

Table 3 Socio—Cultural justice - Influence on flood risk management decisions

Justice principle (type)	Rule / Criteria	Meaning for flood risk management	Potential implications for flood risk management
Equality (procedural)	All citizens to be treated equally	Every citizen should have the equal opportunity to have their flood risk managed	A greater focus on vulnerability reduction and state sponsored self-help adaptations that can be provided for all - avoiding the inherent unfairness in providing structural solutions that benefit the few.
Maximin rule (distributive)	Options chosen to be those that favour the worst-off best	Resources should be targeted to the most vulnerable	Need to identify, and target assistance at the most vulnerable members of society, even when greater economy returns can be found elsewhere.
Maximise utility (distributive)	Options chosen to be those that secure the greatest risk reduction per unit of resource input	Assistance provided to those members of society to which the benefits offer the greatest gain to society.	Need to identify a set of measures that deliver the greatest risk reduction for minimum resource - likely to be associated with a broad range of measures. The greatest risk reduction, for the most vulnerable, most likely to be provided in the form of non-structural responses, for example state-assisted self-help homeowner adaptations and improved preparedness etc with more capitally intensive structural solutions provided to areas of high economic activity.

Building resilience and adaptive capacity - Delivering resilience is much more than simply reducing the chance of damage through the provision of "strong" structures, and adaptive management is much more than simply "wait and see". Both are purposeful approaches that actively manage uncertainty – minimising damage when storm events exceed notional design values and enabling strategies to change with minimum regret as the future reality unfolds (Table 4).

Table 4. The recognition of uncertainty has a profound impact on strategy development (adapted from Hutter and McFadden, 2009)

Stages of strategy development	Traditional (certain) model of strategy development and decision making	Adaptive (uncertain) model of strategy development and decision making
Deciding what to do	Pre-defined system of goals, objectives and desired outcomes. Defined set of activities and resource demands.	Emerging pattern of goals, objectives and desired outcomes. Flexible configuration of resources and priorities.
Deciding how to do it	Sequential process of planning, programming and implementation. Top-down strategy development.	Continuous alignment of plans , programmes and implementation activities with the changing world. Continuous reconciliation of the bottom-up initiatives and top-down strategies.
Understanding the external and internal influences	Stable system of decision making. Predictable (deterministic) future change – climate, demographics, deterioration, preferences etc.	Changing decision processes and priorities. Unknown future change - climate, demographics, deterioration, preferences etc.

Safeguarding and promoting ecosystem services - If implemented well flood risk management can have a positive influence on eco-systems and the provisioning, regulating and cultural services they provide. Many flood detention areas in China and the US provide occasional flood storage and enhance habitat development. If little consideration is given to eco-systems, the impact may be devastating (for example the historical defences along the Danube caused severe environmental disruption and led to significant restoration needs). "Soft path" measures (such as land use changes, wetland storage, and floodplain reconnection etc) and selective "hard path" measures (such as bypass channels, controlled storage etc) both offer opportunities to simultaneously deliver effective and efficient flood risk reduction and promote eco-system services (Figure 5); a synergy all too often over looked.

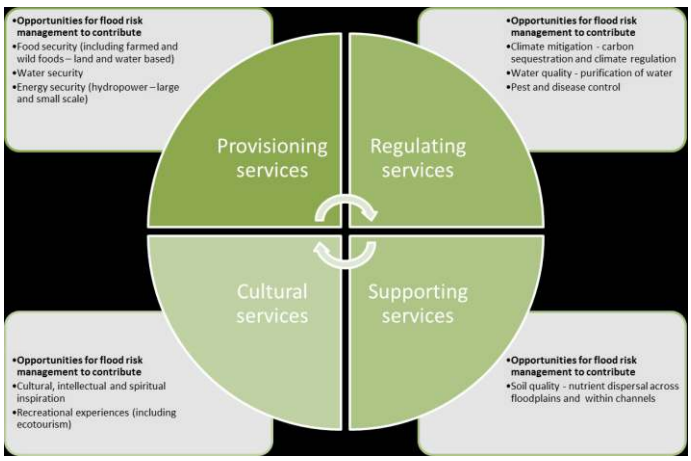

Figure 5. Four characteristics of a healthy ecosystem and mutual opportunities with flood risk management

4 FRAMEWORK OF POLICIES AND PLANS

Flood risk management is a key component of rational water management planning and execution. It involves the development of policies and strategies as well as plans for implementation and associated means of review.

In moving from national to local decision making, the nature of the information and data available varies considerably. Similarly the parameters of analysis, the required temporal and spatial resolution, the granularity of decisions to be supported (and hence the nature of the uncertainty that is acceptable) reflect the specific challenges faced at each level. Good strategy planning, at an appropriately large spatial and temporal scale, is crucial to this process. Around the world, poor flood risk management is typically a result of constrained thinking and a lack of innovation within the strategy plan and inability of the strategy plan to influence local choices; an outcome clearly seen in the uncoordinated development of myriad local protection works in the Upper Mississippi River Basin in the US has led to ineffective flood damage reduction and repetitive losses.

5 FRAMEWORK OF POLICES AND PLANS

Flood risk management is a key component of rational water management planning and execution and involves the development of policies and strategies as well as plans for implementation and associated means of review. These activities are carried out at the national, regional (basin), provincial (sub-basin), and local (sub-basin) levels and form an iterative and, sometimes, complex process. A simplified view of this process is shown in Figure 6.

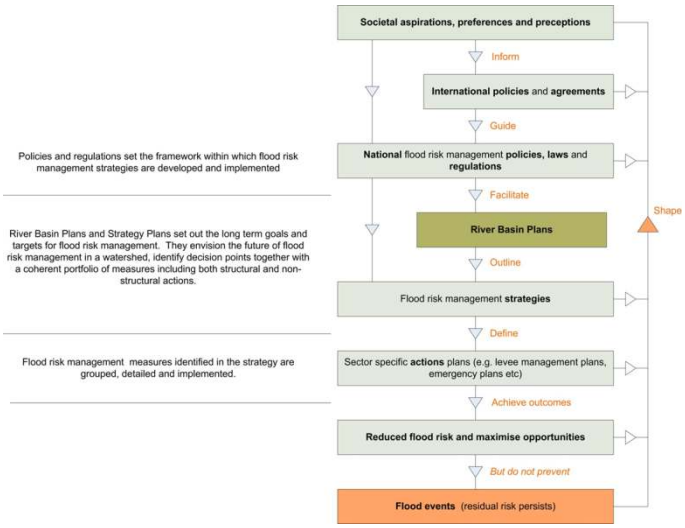

Figure 6 The relationship between policy, strategy plans, actions plans and on-the-ground outcomes

In moving from national to local decision making, the nature of the information and data available varies considerably. Similarly the parameters of analysis, the required temporal and spatial resolution, the granularity of decisions to be supported (and hence the nature of the uncertainty that is acceptable) reflect the specific challenges faced at each level. Table 5 provides an overview of the types of decisions made, data required, and methods of analysis that might be used at each level. As highlighted in the table, strategy planning at a basin level is perhaps the most critical component. Around the world, poor flood risk management is typically a result of constrained thinking and a lack of innovation in the mitigation options considered at the regional level. Strategy planning that takes a long term\system scale view, whilst actively addressing short term risks, provides the vehicle by which constraints can be removed and robust risk-informed goals and a coherent portfolio of measures developed and implemented.

Table 4. Typical decision levels – content, supporting methods and data (adapted from Sayers et al, 2002)

Decision level	Decisions made	Supporting data	Methods of analysis	Example applications
National				
based on societal goals and aspirations				
Basin				
based on national policy and regional realities				
Regional				
sub-basin - based on basin strategy, national policies and local realities				

6 IMPLEMENTING FLOOD RISK MANAGEMENT AS A CONTINUOUS AND ADAPTIVE PROCESS

In contrast to the linear model, based upon a more certain view of the future that is characteristic of traditional flood control decisions, engineers now seek to embed resilience and adaptive capacity within the choices made. Recognition that future conditions may change (perhaps significantly) from those that exist today or that existed when a structure was first designed, underlines the need for a continuous process of monitoring and intervention. The classical engineering control loop of data acquisition, decision making, intervention and monitoring reappears in contemporary thinking about adaptive management. Adaptive flood risk management is recognised as a continuous process of identifying issues, defining objectives, assessing risks, appraising options, implementation, monitoring and review. Conditions of uncertainty and change imply a commitment to on-going study of and intervention in the system in question, in the context of constantly evolving objectives.

All Flood Risk Management Plans (FRMPs) differ in detail and the specific actions they include, but the same cyclic process (Willows and Connell, 2003, Sayers *et al*, 2012), as summarized in Figure 7, are relevant to all.

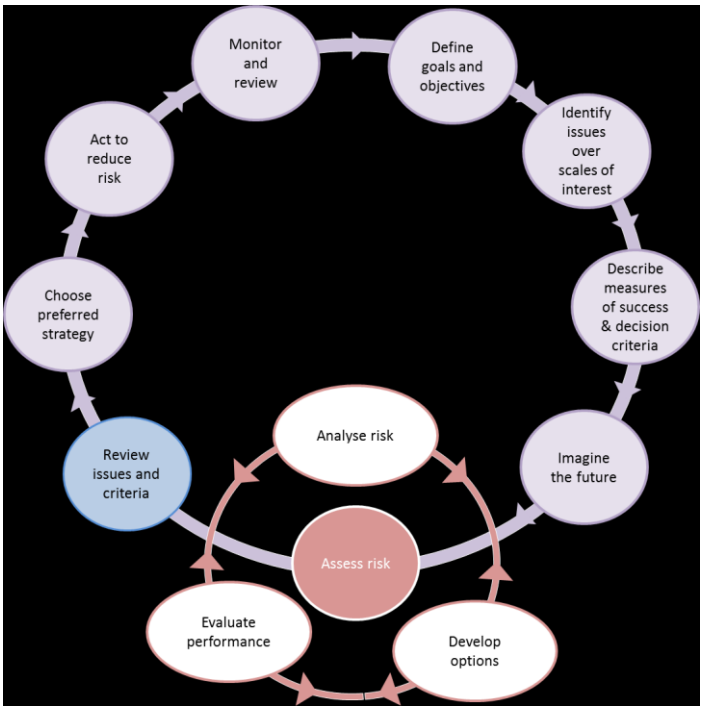

Figure 7 Flood risk management takes place as a continuous cycle of planning, acting, monitoring, reviewing and adapting

7 BARRIERS TO IMPLEMENTATION

The best strategy is of little utility if it cannot be implemented. The barriers that prevent the delivery of good flood risk management and the enablers that promote its implementation are summarized in Figure 8. Many good plans have failed duty to the lack of clear roles and responsibilities for policy, planning and implementation. Attempts to provide flood management in the Iguassu River basin in Brazil, for example, has been hampered by a lack of agreement

among national, regional, and local authorities. Identifying the specific issues as early as possible and providing solutions before they become 'roadblocks' to successful implementation is a vital step – easily said but surprisingly often not done.

Figure 8. Enablers and barriers to implementing good flood risk management

8 PRINCIPAL SUPPORTING TECHNIQUES AND TOOLS

The delivery of good flood risk management relies on many specific techniques and tools, including:

- **Risk and uncertainty analysis** - which provide the basis for decision-making over both individual risk management measures, and also over a whole, *integrated*, programme of measures and instruments. They enable the following key questions to be addressed when determining policy, strategic planning, design or construction decisions (i) What might happen in the future? (ii) What are the possible consequences and impacts? (iii) How possible or likely are different consequences and impacts? (iv) How can the risks be managed?
- **Spatial planning** - Spatial planning is perhaps the most effective approach to preventing the increase in flood risk, through active controls on (re)development of land and property.
- **Infrastructure management** - Ensuring acceptable performance of flood defence assets and asset systems is a considerable challenge. The wide variety in asset types and forms and the interaction between each asset and its physical surrounding further complicates the task. Within this context, the concepts of risk and performance provide the asset manager with a consistent framework to integrate short to longer term actions to maintain, repair, improve or replace assets appropriately alongside non-structural measures, whilst avoiding unnecessary expenditure.
- **Emergency planning and management** - Loss of life and injury can be significant in major flood events. The number of injures will depend on the execution of effective emergency plans. The Hyogo Framework for Action 2005–2015: Building the resilience of nations and communities to disasters (*Framework for Action*, ISDR, 2005) highlights the central role for emergency planning to ensure a flood event does not become a flood disaster.
- **Flood hazard and risk mapping** - A prerequisite for effective and efficient flood risk management is an appropriate level of knowledge of the prevailing hazards and risks. In recent years "flood maps" have increasingly been used by flood risk management professionals as a vehicle to support a wide range of stakeholders.. Various techniques exist, and understanding the advantages and limitations of each is vital if communication is to be meaningful and useful.
- **Flash flood management** – Managing flash flood risks represents a unique subset in the range of flood hazards**.** Flash floods rise quickly, frequently with limited or no warning, and giving rise to fast-moving and rapidly rising waters with a force to destroy property and take lives. Flash floods are the most deadly of floods world-wide – and a key focus in many parts of the world including China. Although mitigation of flash floods risks is difficult, it is not impossible and local building design, detailed emergency planning and local radar networks all have a role.
- **Insurance and flood risk** - Flood insurance is a major and legitimate activity in managing flood risk. For those insured, flood insurance provides a mechanism for them to transfer part of their risk and reduce their vulnerability to flooding.. Flood insurance has four main roles (i) **Reimbursing** those who suffer damage, (ii) **Spreading** the costs of flooding across communities; and for individuals through time (iii) **Reducing** the costs to the government of post-event recovery since the insured will receive insurance funds and (iv) Promoting **a change of behaviour** with regard to exposure to flood risk, by giving a signal of the hazard that people face and providing incentives for "good behaviour". Only the fourth of the roles seeks to reduce risk, the first two simply transfer the risk from the insured to the insurer and the third reduces government expenditures.

9 GOLDEN RULES OF STRATEGIC FLOOD RISK MANAGEMENT

Flood risk management approaches have developed across the world, and continue to evolve, in response to flood events, shifting priorities, increasing complexity in society and the demands placed upon flood management. A small number of principles have emerged as central to achieving good flood risk management in practice. These are summarised in Figure 9 and discussed further below.

Figure 9. The Golden Rules of Strategic Flood Risk Management

1. **Accept that absolute protection is not possible and plan for exceedence.** There will always be a bigger flood. Engineering design standards, however high they are set, will be exceeded. Engineered structures may also fail (breach, fail to close, etc). Non-structural measures such as early warning systems or evacuation plans taken to mitigate flood consequences also are susceptible to failure. Through an acceptance that some degree of failure is almost inevitable, a focus is placed upon building resilience into all aspects of the planning process (urban development planning, flood control structures, warning systems, building codes, etc.).

2. **Promote some flooding as desirable.** Floodplains provide a fertile area for agriculture and a variety of ecosystem goods and services to society, including natural flood storage. Making room for the river and the sea, utilising the natural ability of this space to accommodate flood waters and dissipate energy, maintains vital ecosystems and reduces the chance of flooding elsewhere.

3. **Base decisions on an understanding of risk and uncertainty.** The search for perfect knowledge (data, information and models with which to conduct analyses) should not be a reason to delay moving to the development of options and implementation of initial flood risk management activities. The flood risk management process is iterative and adaptive, taking in to account better information as it is developed and not waiting for conceivably unattainable information before proceeding to the next step. The uncertainty in the information should be explicit and choices made that are robust to that uncertainty.

4. **Recognise that the future will be different from the past.** The world is changing. Climate change, demographic change, changes in the condition of structure, and other societal changes means that planning processes that focus on a future that resembles the present are no longer acceptable.

5. **Do not rely on a single measure, but implement a portfolio of responses.** Integrated management of flood risk involves consideration of the widest possible set of management actions. This includes measures to reduce the probability and measures to reduce consequences (exposure and vulnerability). These are implemented in such a way to assist in promoting social justice, and socio-economic and environmental gain.

6. **Utilise limited resources efficiently and fairly to reduce risk.** The level of effort used in managing floods and their consequences must be related to the nature of risks and not universal or generalised engineering standards of protection. Management strategies are developed following consideration of the efficiency of mitigation measures, not only in terms of the risk reduction achieved and resources required, but also their fairness and ability to maximise ecosystem opportunities.

7. **Be clear on responsibilities for governance and action.** The role of governments, businesses, and other organisations including the affected communities and individuals must be clearly defined. Each level of government, from national through provincial and local, has a specific role to play in risk management. Sharing of both responsibility for and fiscal support of flood risk management activities ensures the full participation of leadership at all levels in the development of a common understanding of the processes being followed in the floodplain management activity. Effective flood risk management also requires that flood risk management activities be carried out on a watershed basis so that upstream-downstream, cross-river conflicts may be avoided and/or mitigated. Procedures must be developed to provide continuous collaboration among agencies with parallel or interlocking responsibilities.

8. **Communicate risk and uncertainty effectively and**

widely. Decision-makers and the public alike must understand the risks that they face; frequently they do not. Too often, after a flood, those affected claim that no one had told them of the risk they faced. Tools, such as risk maps, social networking, and educational processes are utilised to facilitate an appropriate understanding. Effective communication of risk enables both communities and individuals to understand the mitigation measures for which they will be responsible and why such measures are necessary. Communicating the risk after a catastrophe is too late.

9. **Reflect local context and integrate with other planning processes.** The strategy for each location will be different, reflecting the specific risks that must be faced and not arbitrary levels of protection that should be achieved. While the development of strategies should be location specific, the framework of risk analysis and evaluation should be adaptable to all situations.

10 DEFININING STRATEGIC FLOOD RISK MANAGEMENT

As our understanding and experience develops, a common definition of good flood risk management is also emerging:

The process of data and information gathering, risk analysis and evaluation, appraisal of options, and making, implementing, and reviewing decisions to reduce, control, accept, or redistribute flood risks. It is a continuous process of analysis, adjustment and adaptation of policies and actions taken to reduce flood risk (including modifying the probability of flooding and its severity as well as the vulnerability and resilience of the receptors threatened). FRM is based on the recognition that risks cannot be removed entirely but only partially and often at the expense of other societal goals.

11 ACKNOWLEDGEMENTS

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