Cities and Flooding
A Summary for Policy Makers
Abhas K Jha | Robin Bloch | Jessica Lamond

THE WORLD BANK
Cities and Flooding
Cover photo: Wilaporn Hongjantuek walks through chest-high water in Amornchai on the outskirts of Bangkok, Thailand (2011). Source: Gideon Mendel

Back cover photos source: Gideon Mendel

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Background

Urban flooding is a serious and growing development challenge. Against the backdrop of demographic growth, urbanization trends and climate changes, the causes of floods are shifting and their impacts are accelerating. This large and evolving challenge means that far more needs to be done by policymakers to better understand and more effectively manage existing and future risks.

This summary accompanies Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century which provides forward-looking operational guidance on how to manage the risk of floods in a transforming urban environment and changeable climate. The Guide argues for a strategic approach to managing flood risk, in which appropriate measures are identified, assessed, selected and integrated in a process that both involves and informs the full range of stakeholders.

The Guide embodies the state-of-the art on integrated urban flood risk management. It is designed in a comprehensive and user-friendly way to serve as a primer for decision and policy makers, technical specialists, central, regional and local government officials, and concerned stakeholders in the community sector, civil society and non-governmental organizations, and the private sector.

It contains chapters which:

- Describe the causes, probabilities and impacts of floods
- Propose a strategic, innovative, integrated approach to managing flood risk accomplished by selecting and combining structural, hard-engineered measures and non-structural management measures
- Discuss the means by which these measures can be financed and implemented while engaging with and drawing on the capacities and resources of all involved stakeholders
- Specify the procedures by which progress with implementation can be monitored and evaluated.
Over fifty case studies on management measures and procedures from across the world illustrate the key policy messages. They demonstrate what has been implemented in a wide variety of urban contexts in order to meet the challenges of dealing with flood risk.

A series of “How To” sections covers the operational details of implementing a number of key flood risk management measures, and provides the reader with core technical information.

In conclusion, 12 guiding policy principles for integrated flood risk management are presented.

This overview summarizes the key areas that policy makers need to be knowledgeable about and to take action on as they create policy directions for urban flood risk management and develop the strategic frameworks to manage successfully the growing risk of urban flooding.

Urban flooding poses a serious challenge to development and the lives of people, particularly the residents of the rapidly expanding towns and cities in developing countries.
Ghulam Rasool Buriro walks through the flooded centre of the town of Khairpur Nathan Shah, 2010, Pakistan. Source: Gideon Mendel
The growing challenge of urban flooding

Flooding is a global phenomenon which causes widespread devastation, economic damages and loss of human lives.

Over the past eighteen months, destructive floods occurred along the Indus River basin in Pakistan in August 2010; in Queensland, Australia, South Africa, Sri Lanka and the Philippines in late 2010 and early 2011; along with mudslides, in the Serrana region of Brazil in January 2011; following the earthquake-induced tsunami on the north-east coast of Japan in March 2011; along the Mississippi River in mid-2011; as a consequence of Hurricane Irene on the US East Coast in August 2011; in Pakistan’s southern Sindh province in September 2011; and in large areas of Thailand, including Bangkok, in October and November 2011.

The occurrence of floods is the most frequent among all natural disasters. In the past twenty years in particular, the number of reported flood events has been increasing significantly. Figures 1 and 2 illustrate this trend. The numbers of people affected by floods and financial, economic and insured damages have all increased too. In 2010 alone, 178 million people were affected by floods. The total losses in exceptional years such as 1998 and 2010 exceeded $40 billion.

Figure 1: Number of reported flood events. Source: based on EM-DAT/CRED
Immediate loss of life from flooding is increasing more slowly or even decreasing over time, reflecting the successful implementation of flood risk management measures. While this is encouraging, fatalities still remain high in developing countries where flood events have a disproportionate impact on the poor and socially disadvantaged, particularly women and children.

Urban areas at risk from flooding have been hit particularly hard by the observed increase of flooding impact across the world. The current and projected levels of flood impacts give urgency to the need to make flood risk management in urban settlements a high priority on the political and policy agenda. Understanding the causes and effects of flood impacts and designing, investing in and implementing measures which minimize them must become part of mainstream development thinking and be embedded into wider development goals.

Floods affect urban settlements of all types, from small villages and mid-sized market towns and service centers, for example along the Indus River, to the major cities, megacities and metropolitan areas like Sendai, Brisbane, New York, Karachi and Bangkok, all of which were struck by recent floods.

Countries define “urban” settlements in very different ways, which makes urban flooding hard to define in a consistent manner. Damage statistics are not usually classified by urban or rural location, making it difficult to apportion losses between urban and rural populations.
However, there are real functional differences between urban and rural flooding. While rural flooding may affect much larger areas of land and hit poorer sections of the population, urban floods are more costly and difficult to manage.

The impacts of urban floods are also distinctive given the traditionally higher concentration of population and assets in the urban environment. This makes damage more intense and more costly. Urban settlements also contain the major economic and social attributes and asset bases of any national population, so that urban flooding, by causing damage and disruption beyond the scope of the actual floodwaters, often carries more serious consequences for societies.

![Economic Losses and Flood Deaths graph](https://example.com/graph)

**Figure 3: Reported economic losses and deaths. Source: based on EM-DAT/CRED**

Direct impacts from major events represent the biggest risk to life and property. Figure 3 shows the growth in direct monetary impacts resulting from flood events. Indirect and often long-term effects, such as disease, reduced nutrition and education opportunities, and loss of livelihoods, can also erode community resilience and other development goals, as does the need to constantly cope with regular, more minor, flooding. Such indirect impacts can be hard to identify immediately and harder still to quantify and value. However, the poor and disadvantaged usually suffer the most from flood risk.

Urbanization, as the defining feature of the world’s demographic growth, is implicated in and compounds flood risk. In 2008, for the first time in human history, half of the world’s population lived in urban areas, with two-thirds of this in low-income and middle-income nations. This is estimated to rise to 60 percent in 2030, and 70 percent in 2050 to a total of 6.2 billion, or double the projected rural population for that time. As the urban population comes to represent the
larger proportion of world population, urban floods will account for an increasing part of total flood impact.

Urban flooding is thus becoming more dangerous and more costly to manage because of the sheer size of the population exposed within urban settlements. This affects all settlement sizes: while in 2030 the forecast is for 75 agglomerations of over five million inhabitants, urban populations in all size classes are also expected to continue to grow, as Figures 4 and 5 demonstrate. By 2030 the majority of urban dwellers, in fact, will live in towns and cities with populations of less than one million where urban infrastructure and institutions are least able to cope. Management of urban flood risk is not an issue that is confined to the largest cities alone.

Poorly planned and managed urbanization also contributes to the growing flood hazard due to unsuitable land use change. As cities and towns swell and grow outwards to accommodate population increase, large-scale urban expansion often occurs in the form of unplanned development in floodplains, in coastal and inland areas alike, as well as in other flood-prone areas.

In the developing world, a very high proportion of urban population growth and spatial expansion takes place in the dense, lower-quality informal settlements that are often termed “slums.” These are located in both city-center and peripheral, suburban or peri-urban locations and are frequently at highest risk. The concentration of the poor within these areas, which typically lack adequate housing, infrastructure and service provision, increases the risk of flooding and ensures that flood impacts are worst for the disadvantaged.

The increased impacts of urban flooding which policy makers must address are further affected by development outside the protection of existing flood defenses; an increase in paving and other impermeable surfaces; overcrowding, increased densities and congestion; limited, ageing or poorly maintained drainage, sanitation and solid waste infrastructures; over-extraction of groundwater leading to subsidence; and a lack of flood risk management activities.
Climate change is the other large-scale global trend perceived to have a significant impact on flood risk. The alterations in meteorological patterns which are associated with a warmer climate are potentially drivers of increased flooding, with its associated direct and indirect impacts. Observed and projected patterns of climate change can have an amplifying effect on existing flood risk, for example by:

- Augmenting the rate of sea level rise which is one of the factors causing increased flood damage in coastal areas
- Changing local rainfall patterns that could lead to more frequent and higher level of floods from rivers and more intense flash flooding
- Changing the frequency and duration of drought events that lead to groundwater extraction and land subsidence which compounds the impact of sea level rise
- Increasing frequency of storms leading to more frequent sea surges.

In the opinion of climate scientists, as reflected by the Intergovernmental Panel on Climate Change (IPCC), the observed increase in extreme weather is consistent with a warming climate. Although individual extreme weather events cannot be attributed to climate change, climate change can increase the chance of some of those events happening. Sea level rise is also an acknowledged and observed phenomenon. While climate change has the potential to greatly increase flood hazard and the risk from flooding, it does not appear to be the main driver of the increased impacts seen at present.

Over shorter time scales the natural variability of the climate system and other non-climatic risks are in fact expected to have a higher impact on flood risk than longer term climate trends. Accelerating urbanization and urban development could also increase significantly the risk of flooding independent of climate change. As an illustration, in Jakarta, Indonesia, land subsidence due to groundwater extraction and compaction currently has effects on the relative ground and seawater levels ten times greater than the anticipated impact of sea level rise.
On longer time scales, climate change might play a more significant role. Both short-term and long-term prospects need to be considered in managing flood risk: "The basic issue is finding ways to build into near-term investments and choices an appropriate consideration of long-term trends and worst-case scenarios." Figure 6 illustrates trends in water-related disasters over a 30 year period.

In managing flood risk today, and in planning for the future, a balance must be struck between common sense approaches that minimize impacts through better urban management and the maintenance of existing flood mitigation infrastructure, and far-sighted approaches which anticipate and defend against future flood hazard by building new flood mitigation infrastructure or by radically reshaping the urban environment. The balance will be different for each city or town at risk. In reaching decisions on the appropriate prioritization of flood management effort, an understanding of both current and future flood risk is needed.

A resident tries to remove mud after flooding in Gonaïves, Haiti, 2008. Source: Gideon Mendel
Understanding the causes and risk of urban flooding

As a first step in urban flood risk management, policy makers need to understand the flood hazard that can affect the urban environment. Understanding hazard requires a better comprehension of the types and causes of flooding, their probabilities of occurrence, and their expression in terms of extent, duration, depth and velocity.

This understanding is essential in designing measures and solutions which can prevent or limit damage from specific types of flood. Equally important is to know where and how often flood events are likely to occur, what population and assets occupy the potentially affected areas, how vulnerable these people and their settlements are, and how these are planned and developed, and what they already do towards flood risk reduction. This is critical in grasping the necessity, urgency and priority for implementing flood risk management measures.

As flood risk evolves over time, policy makers also need to explore how decisions change in the light of changing climates. Information about the existing models used to account for climate change at different scales and an understanding of the uncertainties regarding those results need to be at the core of any decision-making process.

Urban areas can be flooded by rivers, coastal floods, pluvial and ground water floods, and artificial system failures. Urban floods typically stem from a complex combination of causes, resulting from a combination of meteorological and hydrological extremes, such as extreme precipitation and flows. However they also frequently occur as a result of human activities, including unplanned growth and development in floodplains, or from the breach of a dam or an embankment that has failed to protect planned developments.

It is important here to distinguish between the probability of occurrence of a weather event and the probability of occurrence of a flood event. Flooding is primarily driven by weather events which can be hard to predict. For this reason, flood hazard predictions are commonly available in terms of probabilities computed using historical data for the area of interest. The value of inference based on historic observations is naturally dependent on the availability and quality of data.

Understanding these probabilities is therefore critical to understanding risk. The language of probability can be confusing as people do not intuitively
understand an annual one percent (or one in 100) chance of flooding. The use of the alternative concept of the estimated return period, such as “a 100-year flood” is also misunderstood as a flood that is certain to occur over the next 100 years – or is sometimes even assumed to be a flood that can only occur once in 100 years. Similarly, two events reported with the same return period can have different magnitudes, and consequently affect the same people in different ways. When the uncertainties are far-reaching or poorly understood, for instance due to inadequate data, the communication of flood risk in terms of flood probabilities and their use in flood management decisions can be misleading.

The use of maps for communicating hazard and associated risk is therefore a valuable aid to decision-making. Flood hazard maps are visual tools for communicating the hazard situation in an area. Hazard maps are important for planning development activities, for emergency planning, and for policy development. Flood risk maps incorporate flood hazard information within the context of data on exposed assets and population, and their vulnerability to the hazard. They can often be articulated in terms of expected damage, and can be used as supplementary decision-making tools.

Flood forecasting is another essential tool which provides people still exposed to risk with advance notice of flooding in an effort to save lives and property. However, without an analysis of the physical causes of recorded floods, and of the geophysical, biophysical and anthropogenic, or human-made, context that determines the potential for flood formation, predictions have the potential to contribute to the damages caused by floods by either under-estimating or over-estimating the hazard. Modelling today’s hazard has many challenges.

For the projection of future flood risk, there are even greater sources of uncertainty. The assumption usually made is that future flood patterns will be a continuation of the past because they are generated from the same cyclical processes of climate, terrain, geology, and other factors. Where this assumption holds true, a system is said to be stationary, which makes the future predictable from the past. If this assumption is not true, the future becomes much more uncertain. Figure 7 illustrates the use of hazard maps to depict current and future hazard situations. For urban flooding, two potential major sources of what is consequently termed non-stationarity (i.e. past patterns and trends are poor predictors of the future), are the rapid development of flood-prone areas as urbanization proceeds, and the changes in weather patterns associated with climate change.
Urbanization is arguably an inevitable, unstoppable and positive trend which nevertheless has the potential to greatly increase flood risk. However, the projection of future urban population growth has associated uncertainties in the scale and spatial distribution of populations. Equally, the impact of future urban growth on flood risk is influenced by the policies and choices of urban dwellers as they may or may not occupy areas at risk of flooding, or adopt suitable urban planning and design.

There are also considerable uncertainties in climate projections. This owes to the difficulty of accurately predicting the future trajectory of socio-economic development, and as a consequence of incomplete knowledge of the climate system and the limitations of the computer models used to generate projections. The relative and absolute importance of different sources of uncertainty depends on the spatial scale, the lead time of the projection, and the variable under consideration.

The inevitable conclusion is that the accuracy or precision of long-term flood risk forecasts will be low, and that over-reliance on future probabilities is not appropriate. It is equally apparent that better planned and managed urban development can mitigate the expected growth in future flood risk.

The development of appropriate adaptations that will protect against an uncertain future risk is further complicated by a combination of the characteristics of the urban infrastructure to be protected and the long lead-in and lock-in periods
of urban flood protection infrastructures and projects. This can result in large
flood protection schemes facing new challenges even before they are completed
as for example in Ho Chi Minh City, Vietnam, where the 2001 Master Plan to
mitigate flooding via improved drainage had to contend with higher than expected
increases in peak rainfall.

Defending against future floods will therefore require more robust approaches
to flood management that can cope with larger uncertainty or be adaptive to
a wider range of futures. This could lead to a greater reliance on more flexible,
incremental approaches to flood risk management, the incorporation of greater
flexibility into the design of engineered measures, or acceptance of potential
over-specification for inflexible measures.

With a solid understanding of the causes and impacts of urban flooding, an
appreciation of the likely future flood probability and of the uncertainties surrounding
it, and knowledge of both the potentials and the limitations of various flood risk
management approaches, policy makers can adopt an integrated approach to
flood risk management.
People queue for food relief in the flooded city of Gonaïves in Haiti two weeks after the entire city had been engulfed during Hurricanes Ike and Hanna, 2008. Haiti. Source: Gideon Mendel
An integrated approach to urban flood risk management

An integrated flood risk management approach is a combination of flood risk management measures which, taken as a whole, can successfully reduce urban flood risk. The Guide helps policy makers in developing such an integrated, strategic approach to reducing flood risk which fits their specific conditions and needs.

Flood management measures are typically described as either structural or non-structural. Structural measures aim to reduce flood risk by controlling the flow of water both outside and within urban settlements. They are complementary to non-structural measures that intend to keep people safe from flooding through better planning and management of urban development. A comprehensive integrated strategy should be linked to existing urban planning and management policy and practices.

Structural and non-structural measures do not preclude each other, and most successful strategies will combine both types. It is also important to recognize the level and characteristics of existing risk and likely future changes in risk to achieve the balance between the required long and short term investments in flood risk management. But as both urbanization and climate change accelerate, there may well be the need to move away from what is often today an over-reliance on hard-engineered defenses towards more adaptable and incremental non-structural solutions.

Structural measures range from hard-engineered structures such as flood defenses and drainage channels to more natural and sustainable complementary or alternative measures such as wetlands and natural buffers. They can be highly effective when used appropriately, as the well-documented successes of the Thames Barrier, the Dutch sea defenses and the Japanese river systems attest. Structural measures can, however, be overtopped by events outside their design capacity. Many structural measures also transfer flood risk by reducing flood risk in one location only to increase it in another. The redirection of water flows also frequently has environmental impact. In some circumstances this is acceptable and appropriate, while in others it may not be. In all cases a residual flood risk remains. Structural solutions can also have a high upfront cost, can sometimes induce complacency by their presence, and can result in increased impacts if they fail or are overtopped, as was tragically illustrated in the tsunami in Japan in 2011.
These considerations, and the fact that there will always remain a residual flood risk, leads to the need to incorporate non-structural measures into any strategy. There is always a role for non-structural measures which manage risk by building the capacity of people to cope with flooding in their environments. Non-structural measures such as early warning systems can be seen as a first step in protecting people in the absence of more expensive structural measures – but they will also be needed to manage the residual risk remaining after implementation of structural measures. Non-structural measures do not usually require huge investments upfront, but they often rely on a good understanding of flood hazard and on adequate forecasting systems – as an example, an emergency evacuation plan cannot function without some advance warning.

Non-structural measures can be categorized under four main purposes:

- **Emergency planning and management including warning and evacuation as, for example, in local flood warning systems in the Philippines and in the Lai Nullah Basin, Pakistan.**

- **Increased preparedness via awareness campaigns as demonstrated in Mozambique and Afghanistan. Preparedness includes flood risk reducing urban management procedures such as keeping drains clear through better waste management.**

- **Flood avoidance via land use planning as seen in the German Flood Act and planning regulations in England and Wales. Land use planning contributes both to mitigation of and adaptation to urban floods.**

- **Speeding up recovery and using recovery to increase resilience by improving building design and construction – so-called “building back better.” Planning the resilient reconstruction of a damaged village has been seen, for example, in the tsunami-damaged village of Xaafuun, Somalia. Appropriate risk financing such as flood insurance, where it is available, or using donor and government sources of funding assists in quick recovery.**

The challenge with many non-structural measures lies in the need to engage the involvement and agreement of stakeholders and their institutions. This includes sometimes maintaining resources, awareness and preparedness over decades without a flood event, bearing in mind that the memory of disaster tends to weaken over time. This challenge is also made greater by the fact that most non-structural measures are designed to minimize but not prevent damage, and therefore most people would instinctively prefer a structural measure.
Generating the necessary attitudinal and behavioral change may take time and investment in wide communication and consultation. A good practice example of community engagement via didactic tools is seen in Mozambique where the River Game developed under a Cities Alliance project by UN-HABITAT and local partners (Figure 8) is used to educate, communicate with and engage multiple stakeholders.

Flood management may hugely benefit by the involvement of stakeholders. Indeed, if the communication and consultation challenge is successfully overcome, the gains in flood resilience are significant.

It is also important to take account of temporal and spatial issues when determining strategy. Integrated urban flood risk management takes place at a range of scales, including at the river basin and water catchment as a whole. This is due to the fact that the source of flooding may be at some distance from the city or town. Often the best option may be to tackle flooding before it reaches the urban setting.
There are multiple management techniques that can be identified in their appropriate catchment locations surrounding an urban environment, as illustrated in Figure 9. Structural measures such as flood defenses and conveyance systems can form a long-term response to flood risk. However, these require large investments which will not always be available. Non-structural measures such as flood warning systems and evacuation planning are necessary for the safeguarding of the population of cities and towns already at risk from flooding, whether protected by defenses or not. There are also urban design and management measures which can be implemented more quickly, such as better operations and maintenance of infrastructure; greening of urban areas; improved drainage and solid waste management; and better building design and retrofitted protection. These will enable occupation of flood risk areas while reducing the expected impacts from flooding.

Land use planning and the regulation of new development is a key aspect of integrated urban flood risk management. In developing countries in particular, the opportunity to better plan the formation of new urban areas is central to prevent the predicted increase in future flood impacts from being realized.
The need to integrate flood risk management into land use planning and management is therefore important in order to minimize risk and manage the impacts of flooding. In growing urban settlements in particular, flood risk may be seen to be of lesser importance than other social and economic concerns. It is hence likely that floodplain development will continue, due to pressure on land resources and other political and economic considerations. However, where new urban environments are better planned within areas at risk from flooding, flood-receptive design can be employed at a potentially lower cost and disruption during the build or reconstruction phase than to attempt to later retrofit. This allows the building in of resilient design – with potential payoff well into the future.

The potential for reduced costs and extended benefits from flood risk management measures also needs to be explored. For example, a highly effective utilization of the limited land available in densely populated cities and urban areas is the construction of multi-purpose retarding basins which store flood water for outflow control when necessary. At other times these basins are used for other purposes such as sport and leisure facilities or car parking. Rainwater harvesting can also be seen as an innovative measure to prevent urban flooding. It forms part of a sustainable drainage system and can simultaneously be used for non-drinking purposes, resulting in water conservation. Investment in better urban management, such as for solid waste, also reduces flood risk, can have health and environmental benefits, and can be used to create employment and relieve poverty.

Groundwater management can prevent land subsidence which mitigates flood risk in low-lying areas but also protects buildings and infrastructure from subsidence-induced failure, as for example has been attempted in Bangkok. Wetlands, bio-shields, environmental buffer zones and other “urban greening” measures that produce environmental and health benefits in urban areas can also reduce flood impacts. These greening measures will have many other benefits in addition to reducing flood risk in surrounding areas, including reducing the urban heat island effect and the level of CO₂ emissions, and thus creating a healthier urban environment. For example, buffer areas around the Primero River in the city of Cordoba, Argentina, improved the urban environment and removed residents at risk to safer locations.

Given the many urgent development goals and resource constraints faced by urban policy makers, it is not possible to be overly prescriptive in the application of flood risk management. The specific set of measures that might be suitable
in a particular location should only be adopted after serious consideration – and consultation with stakeholders. Action to create an integrated approach will involve identifying technically feasible sets of measures designed to reduce flood risk.

Integrated urban flood risk management strategies are naturally designed to fit in with water-related planning issues and can be part of a wider agenda such as urban regeneration or climate change adaptation. Action to reduce flood risk should be carried out through a participatory process involving all those stakeholders that have an interest in flood management, including those people at risk or directly impacted by flooding. The measures selected will need to be negotiated by stakeholders, and to be adaptable to natural, social and economic conditions which can be expected to change over time.
Villagers work together to build flood defenses to keep the floodwaters out of their community, 2010, Pakistan. Source: Gideon Mendel
Implementing integrated urban flood risk management

A Guide to Integrated Urban Flood Risk Management argues for an integrated approach to urban flood risk management, which combines structural and non-structural measures. Such integrated urban flood risk management is holistic in scope, strategic in content and collaborative in nature.

An integrated approach can be difficult to achieve where municipal managements suffer from a lack of technical capacity, funding or resources. The interests of stakeholders also vary, leading to different incentives and motives for action. Very often, for instance, residents are unwilling to move from already-developed locations in floodplain areas, which are vulnerable and contravene the land use regulations drafted by decision makers and planners. This situation can involve poorer residents, living on riverbanks close to economic opportunities, or wealthier people who have houses on seafronts.

Implementation requires wider participation and a change in traditional management methods to be successful. At political and institutional levels, actions to reduce flood risk need to employ tools and techniques to extrapolate current trends and drivers into the future, to assess alternative scenarios, and to build strategic, integrated approaches. Repeating past mistakes can have disastrous consequences for the present and the future.

It is a fundamental requirement to identify the information, experience and methods that different stakeholders, including practitioners and residents, can provide – and to design measures using such experience and knowledge. It is also important to be aware of the context within which urban flood risk management operates. It can fall between the dynamics of decision-making at national, regional, local/municipal and community levels.

Integrated flood risk management therefore requires greater coordination between city governments, national governments, ministries, public sector companies, including utilities, along with meteorological and planning institutions, civil society, non-government organizations, educational institutions and research centers, and the private sector. It is essential to understand the capacities and incentives of these actors, including how they choose or are able to use their own limited resources under high levels of uncertainty. Government decisions about the management of risk are balanced against competing, often more pressing, claims on scarce resources as well as other priorities in terms of land use and economic development.
Getting the balance right between structural and non-structural measures is also a challenge. Policy makers require a clear vision of the alternatives and methods and tools to assist them in making choices. Decisions regarding flood risk management are complex and require wide participation from technical specialists and non-specialists alike. Tools and techniques exist which allow policy makers and their technical specialists to decide between alternatives, and to assess their costs. There is clearly a role for tools which can predict the outcome of decisions, communicate risk and create linkages between stakeholders. Examples are risk and hazard maps or simulation and visualization techniques which can illustrate the impacts of decisions to multiple stakeholders, and cost-benefit analyses which can make the decision-making process more transparent and accountable.

The right metrics, realistic simulation games, good risk data and data visualization tools help. But underlying such tools there has to be a fundamental understanding, which is often lacking, of the physical processes involved in flooding and the expected outcome of the flood management measures which are undertaken.

While the implementation and outcomes of flood risk management measures can be defined in purely economic terms, the judgment made by policy makers, urban planners and technical specialists must also consider broader issues. They need to consider many aspects such as the impact of measures on environmental degradation, biodiversity, equity, social capital/capacity, and other potential trade-offs. It is important to recognize that the residual risk never reduces to zero, that the cost of reducing the risk may exceed the benefits of doing so, and that funds may not be available to invest in measures. In addition, policy making in the era of urbanization and climate change must deal with the large uncertainty associated with future predictions of flood patterns. Such uncertainty can lead to indecision.

Decision-making needs instead to be robust. Evaluation of the costs and benefits of each measure, or combination of measures, must be integral to a wider strategy which sets future targets for investment in measures and prioritizes spending on the most urgent and effective of these activities. Combining alternatives that perform well under different scenarios then becomes a preferred strategy rather than finding the optimal solution, as illustrated in Figure 10. This will lead to the preference for flexible and so-called no regret approaches that will include measures which will be cost effective regardless of changes in future flood risk.
Many non-structural measures tend to be inherently flexible, for example early warning systems or evacuation plans. Structural measures are seen as less flexible, but flexibility can sometimes be incorporated, such as in the installation of wider foundations for flood defenses so that they can be raised later without strengthening the base. The purchase of temporary flood defense barriers can also be seen as a flexible alternative as they can be deployed when and where necessary, as flood risks change. Such no regret measures yield benefits over and above their costs, independent of future changes in flood risk. Further examples here are forecasting and early warning systems which are not sensitive to future flood risk and are relatively low in cost to set up; improved solid waste management systems which have many benefits for environmental health regardless of flood risk; and environmental measures that have amenity value.
Identifying which institutional arrangements are most effective in the delivery of urban flood risk management measures is also fundamental to success. Countries – and cities – with well-performing institutions are better able to prevent disasters. Nevertheless, there is often lack of suitable institutional arrangements and lack of a suitable policy framework to encourage integrated and coordinated urban flood risk management. This mismatch between the governance of official disaster management mechanisms and what is actually needed for implementing integrated flood risk management is a major constraint to effect change. Where the role of institutions is not well established or clear, reforms are required so that institutions complement each other and complement existing systems to create efficiency in delivery of measures and faster uptake. Informal institutions and social networks also have a crucial role to play. Valuable lessons can be drawn from grassroots experiences of dealing with flooding at the household and community level.

Integrated urban flood risk management is a multi-disciplinary and multi-sectoral intervention that falls under the responsibility of diverse government and non-government bodies. Flood risk management measures need to be comprehensive, locally specific, integrated, and balanced across all involved sectors. Due to spatial proximity, local authorities are able to make well-informed decisions. Nevertheless, wider supportive political and organizational underpinnings are vital to ensure the success of integrated flood risk management.

Under the pressure of rapid urbanization, urban governance and decision-making often fall short of what is needed to adequately respond to the challenge of flooding. Enforcement of standards and regulations is often incomplete or even absent. Regulatory frameworks often demand unrealistic minimum standards while at the same time there is lack of adequate mechanisms for the enforcement of regulations. Funding is often limited too.

It is vital, then, to link urban flood risk management with poverty reduction and climate change adaptation initiatives, and with more specific issues of urban planning and management, such as housing provision, land tenure, urban infrastructure delivery and basic service provision. Robust solutions can contribute to flood risk reduction, while at the same time create opportunities to promote better and more sustainable and resilient urban development.
Figure 11 in the next page illustrates the process for Integrated Urban Flood Risk Management. It covers five steps from understanding flood hazard and identifying the most appropriate measures, to planning, implementing and finally evaluating the strategy and its measures.
1. Understand
...the flood hazard now and in the future. Understand who and what will be affected during a flood.

2. Identify $$
...which measures will be most effective at reducing risk to life and property.

3. Plan $$$
...flood risk management measures with urban planning, policy and management practices. Integrate measures to create solutions with other benefits, to the environment, health and economy.

Failure to enforce policy could cost lives and money and the need to start again

Figure 11: The five stages of integrated flood risk management.
Source GHK Consulting and Baca Architects
Stage 1: Understanding the hazard is essential in designing measures and solutions which can prevent or limit damage from specific types of flood.

Stage 2: An integrated flood risk management approach is a combination of flood risk management measures which, taken as a whole, can successfully reduce urban flood risk.

Stage 3: Urban flood risk management requires the development of a comprehensive long-term integrated strategy which can be linked to existing urban planning and management policy and practices.

Stage 4: Integrated urban flood risk management is a multi-disciplinary and multi-sectoral intervention that falls under the responsibility of diverse government and non-government bodies.

Stage 5: Evaluation is important in improving the design and implementation of flood risk management measures, both structural and non-structural.

4. Finance & Implement

...measures to reduce risk. Prioritize ‘no regrets’ measures and easy wins.

5. Evaluate

...how effectively the measures are working and what could be changed in the future.
Twelve key principles for integrated urban flood risk management

1. Every flood risk scenario is different: there is no flood management blueprint.

Understanding the type, source and probability of flooding, the exposed assets and their vulnerability are all essential if the appropriate urban flood risk management measures are to be identified. The suitability of measures to context and conditions is crucial: a flood barrier in the wrong place can make flooding worse by stopping rainfall from draining into the river or by pushing water to more vulnerable areas downstream, and early warning systems can have limited impact on reducing the risk from flash flooding.

2. Designs for flood management must be able to cope with a changing and uncertain future.

The impact of urbanization on flood management is currently and will continue to be significant. But it will not be wholly predictable into the future. In addition, in the present day and into the longer term, even the best flood models and climate predictions result in a large measure of uncertainty. This is because the future climate is dependent on the actions of unpredictable humans on the climate – and because the climate is approaching scenarios never before seen. Flood risk managers need therefore to consider measures that are robust to uncertainty and to different flooding scenarios under conditions of climate change.

3. Rapid urbanization requires the integration of flood risk management into regular urban planning and governance.

Urban planning and management which integrates flood risk management is a key requirement, incorporating land use, shelter, infrastructure and services. The rapid expansion of urban built up areas also provides an opportunity to develop new settlements that incorporate integrated flood management at the outset. Adequate operation and maintenance of flood management assets is also an urban management issue.
4. An integrated strategy requires the use of both structural and non-structural measures and good metrics for “getting the balance right”.

The two types of measure should not be thought of as distinct from each other. Rather, they are complementary. Each measure makes a contribution to flood risk reduction but the most effective strategies will usually combine several measures – which may be of both types. It is important to identify different ways to reduce risk in order to select those that best meet the desired objectives now – and in the future.

5. Heavily engineered structural measures can transfer risk upstream and downstream.

Well-designed structural measures can be highly effective when used appropriately. However, they characteristically reduce flood risk in one location while increasing it in another. Urban flood managers have to consider whether or not such measures are in the interests of the wider catchment area.

6. It is impossible to entirely eliminate the risk from flooding.

Hard-engineered measures are designed to defend to a pre-determined level. They may fail. Other non-structural measures are usually designed to minimize rather than prevent risk. There will always remain a residual risk which should be planned for. Measures should also be designed to fail gracefully rather than, if they do fail, causing more damage than would have occurred without the measure.

7. Many flood management measures have multiple co-benefits over and above their flood management role.

The linkages between flood management, urban design, planning and management, and climate change initiatives are beneficial. For example, the greening of urban spaces has amenity value, enhances biodiversity, protects against urban heat island and can provide fire breaks, urban food production and evacuation space. Improved waste management has health benefits as well as maintaining drainage system capacity and reducing flood risk.
8. It is important to consider the wider social and ecological consequences of flood management spending.

While costs and benefits can be defined in purely economic terms, decisions are rarely based on economics alone. Some social and ecological consequences such as loss of community cohesion and biodiversity are not readily measureable in economic terms. Qualitative judgments must therefore be made by city managers, communities at risk, urban planners and flood risk professionals on these broader issues.

9. Clarity of responsibility for constructing and running flood risk programs is critical.

Integrated urban flood risk management is often set within and can fall between the dynamics and differing incentives of decision-making at national, regional, municipal and community levels. Empowerment and mutual ownership of the flood problem by relevant bodies and individuals will lead to positive actions to reduce risk.

10. Implementing flood risk management measures requires multi-stakeholder cooperation.

Effective engagement with the people at risk at all stages is a key success factor. Engagement increases compliance, generates increased capacity and reduces conflict. This needs to be combined with strong, decisive leadership and commitment from national and local governments.
11. Continuous communication to raise awareness and reinforce preparedness is necessary.

Ongoing communication counters the tendency of people to forget about flood risk. Even a major disaster has a half-life of memory of less than two generations and other more immediate threats often seem more urgent. Less severe events can be forgotten in less than three years.

12. Plan to recover quickly after flooding and use the recovery to build capacity.

As flood events will continue to devastate communities despite the best flood risk management practices, it is important to plan for a speedy recovery. This includes planning for the right human and financial resources to be available. The best recovery plans use the opportunity of reconstruction to build safer and stronger communities which have the capacity to withstand flooding better in the future.
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### Abbreviations

### Glossary
Urban flooding is a serious and growing development challenge. It is a global phenomenon which causes widespread devastation, economic damages and loss of human lives. *Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century* provides forward-looking operational assistance to policy makers and technical specialists in the rapidly expanding cities and towns of the developing world on how best to manage the risk of floods. It takes a strategic approach, in which appropriate risk management measures are assessed, selected and integrated in a process that both informs and involves the full range of stakeholders.