Guidelines for Reducing Flood Losses

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A contribution to the International Strategy for Disaster Reduction

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Foreword

Throughout the history of mankind, floods have brought untold wealth and prosperity to civilizations, and yet at the same time, they have caused tremendous losses and resulted in untold suffering for millions of people. Even today, floods lead all natural disasters in the number of people affected and in resultant economic losses, with these numbers rising at alarming rates.

In response to the devastation arising from water-related natural disaster, particularly flooding, a series of three workshops and symposia were held, sponsored by the United States National Oceanic and Atmospheric Administration (NOAA) and the United Nations Department of Economic and Social Affairs. One objective of these events was to create comprehensive guidelines that could be used by governments, international organizations, non-governmental organizations and civil society to help avert losses from flooding.

The first session was the Flood Forecasting and Disaster Response Workshop. It was held in Tegucigalpa, Honduras, from 6-8 April 1999, following the devastation in the region stemming from Hurricane Mitch. This workshop was followed by an international Symposium on Flood Forecasting for the Americas, held in Brasilia, from 15-19 November 1999, and it was hosted by the National Institute of Meteorology of Brazil. A rough draft of these guidelines was prepared following this meeting. From 27-31 August 2001, an International Symposium on Water-related Disaster Reduction and Response was held in Bangkok, Thailand, wherein the draft guidelines were reviewed and new materials were gathered. Materials and ideas from these three meetings have been incorporated into this publication. It is hoped that these guidelines can be further improved and that additional experiences and concepts can be shared globally in an updated version.

This publication is based on the findings of those three sessions and is a contribution to the overall efforts that are required to help society cope with the forces of nature. Focused efforts are required to reduce the risk of flooding on society. Flood forecasting and warning systems, data collection systems, flood plain management practices and land-use planning, as well as economic and social measures can be adopted within an integrated framework to lead to sustainable solutions. Concerted efforts are required to achieve these solutions, and such efforts are necessary to stem the rising losses from water-related disasters. It is truly hoped that these guidelines will assist in the planning and implementation of actions leading to more healthy and resilient societies.

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Executive Summary

Floods have the greatest damage potential of all natural disasters worldwide and affect the greatest number of people. On a global basis, there is evidence that the number of people affected and economic damages resulting from flooding are on the rise at an alarming rate. Society must move from the current paradigm of post-disaster response. Plans and efforts must be undertaken to break the current event-disaster cycle. More than ever, there is the need for decision makers to adopt holistic approaches for flood disaster management.

Extreme flooding events are not relegated to the least developed nations, but can also devastate and ravage the most economically advanced and industrialized nations. In the last decade there has been catastrophic flooding in Bangladesh, China, India, Germany, Mozambique, Poland, the United States and elsewhere. When floods occur in less developed nations, they can effectively wipe out decades of investments in infrastructure, seriously cripple economic prosperity, and result in thousands of deaths and epidemics. The majority of the deaths associated with such disasters can be found within the most vulnerable members of society, namely women and children. The greatest tragedy is that most of these deaths, associated post traumatic stresses, and social and economic hardships can be either avoided or dramatically reduced through pre-, during, and post-disaster investments in preparedness activities and associated infrastructure, flood plain policy development, effective watershed land use planning, flood forecasting and warning systems, and response mechanisms.

It is recognized that comprehensive assessments of risks from natural hazards such as flooding, mud/land slides, and extreme wind and rain are necessary for society to better understand the risks which they face daily. Assessment of risk and the involvement of the community in the decision making, planning and implementation process can help lead to sustainable solutions. Solutions must reflect the human dimension and must also consider the impacts of changing land use on flooding, erosion, and landslides. Integrated water management practices must be embraced. Societies have much to learn from new approaches such as better forecasting techniques and applying experience gained from flood events and mitigation efforts employed elsewhere. Implementation will only be sustainable if solutions are suitable for the community at risk over the long term. As storms will continue to occur, risk assessment and planning followed by actions are needed to help reduce the overall risk to society, the economy and the environment.

These guidelines are oriented to the needs of the decision-maker and provide a description of the range of mitigation options that need to be considered when making efforts to reduce losses from flooding. The guidelines are designed to provide an introduction to the general area and to introduce the reader to various measures to mitigate the impacts associated with floods. A bibliography is provided that cites detailed material available for the planning and implementation stages. These guidelines are not meant to address floods resulting from storm surge, ice or debris jams, or the failure of human-made structures.

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Introduction

There is an increasing trend worldwide in the number of disasters and their total economic impacts. This is very evident in the analysis by Munich Re, a major reinsurance company, of what it terms Great Natural Catastrophes[1] (see Figures 1 and 2). Flooding causes over one-third of the total estimated costs and is responsible for two-thirds of people affected by natural disasters. Over 90% of people affected by natural disasters worldwide live in Asia, as the countries in Asia with large populations are particularly prone to recurrent flooding.

The number of disasters attributed to flooding is on the rise (see Figure 3), while the number of people killed[2] due to flooding remains steady (see Figure 4). However, the overall number of deaths due to all natural disasters is decreasing, and this has been attributed to investing in early warning and preparedness programmes. There is an alarming increasing trend in the number of people affected by natural disasters with an average of 147 million affected per year (1981-1990) rising to 211 million per year (1991-2000), with flooding alone accounting for over two-thirds of those affected. This might well be a result of the increasing growth of urban populations, some portions of which may be in flood-prone areas.

Figure 5 shows the number of people that have been affected by natural disasters from 1975 to 2000 by income and disaster type. More than 95% of all deaths as a result of natural disasters are in the least developed nations, and these same nations have the greatest number of people affected by natural disasters. Typically, disasters impact the elderly, women and children the most. This is a trend that will continue unless concerted actions are taken to mitigate the impacts from natural hazards.

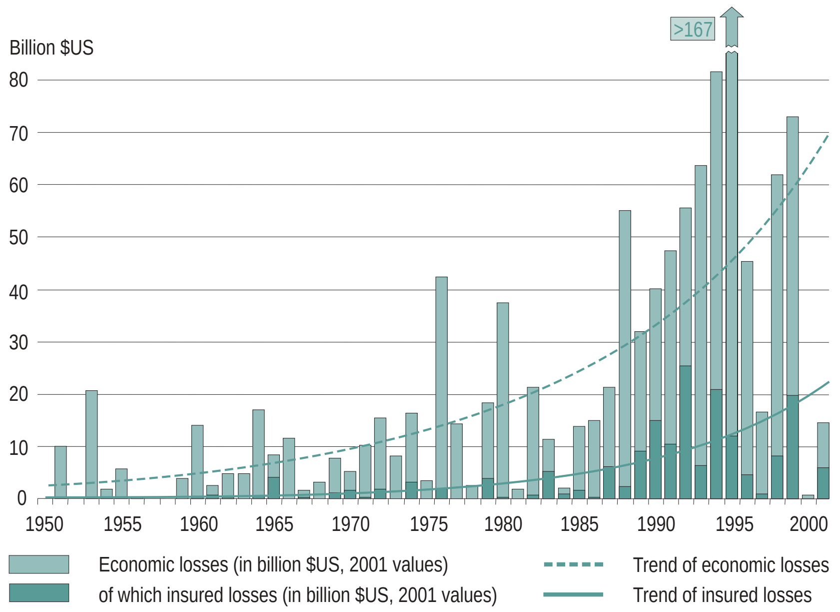
Flooding is the single most destructive type of natural disaster that strikes humans and their livelihoods around the world. In the last decade, there has been catastrophic flooding experienced in China, India, Bangladesh, Germany, Poland, Mozambique, the USA, and elsewhere. Flooding is not restricted to the least developed nations, but also occurs in devastating fashion in the most developed and industrialized countries of the world. However, it is the citizens of the least developed nations that suffer the highest toll from the occurrence of flooding. If we look at Hurricane Mitch as one specific example, it caused massive destruction and loss of life in Central America, affecting the peoples of Honduras, Nicaragua, El Salvador, and Guatemala. Honduras was hardest hit with economic losses estimated as being approximately US$ 3.64 billion (UNDP/ECLAC, 1998) or about 69% of their annual gross domestic product (GDP) in 1998 (IMF, 2002). In comparison, Hurricane Andrew resulted in estimated damages of US$ 30 billion (see http://www.aoml.noaa.gov/hrd/Landsea/Usdmg). These damages represented less than 0.5% of the GDP of the USA (IMF, 2002). When natural disasters such as flooding occur in developing nations, they can effectively wipe out decades of investments in infrastructure and the personal wealth of many of its people, not to mention the countless loss of lives, physical injuries, sickness and psychological trauma that result from the disasters.

[1] Munich Re in their 2001 annual review of natural catastrophes defines these as follows: "Natural catastrophes are classed as great if the ability of the region to help itself is distinctly overtaxed, making interregional or international assistance necessary. This is usually the case when thousands of people are killed, hundreds of thousands are made homeless or when a country suffers substantial economic losses, depending on the economic circumstances generally prevailing in that country."

[2] It should be noted that deaths from storm surge caused by cyclones are not included in these figures on floods, but are classified as resulting from wind storms. For example, in Bangladesh over 300,000 people were killed in tropical cyclones in 1970 and over 138,000 people in 1991.

Figure 1

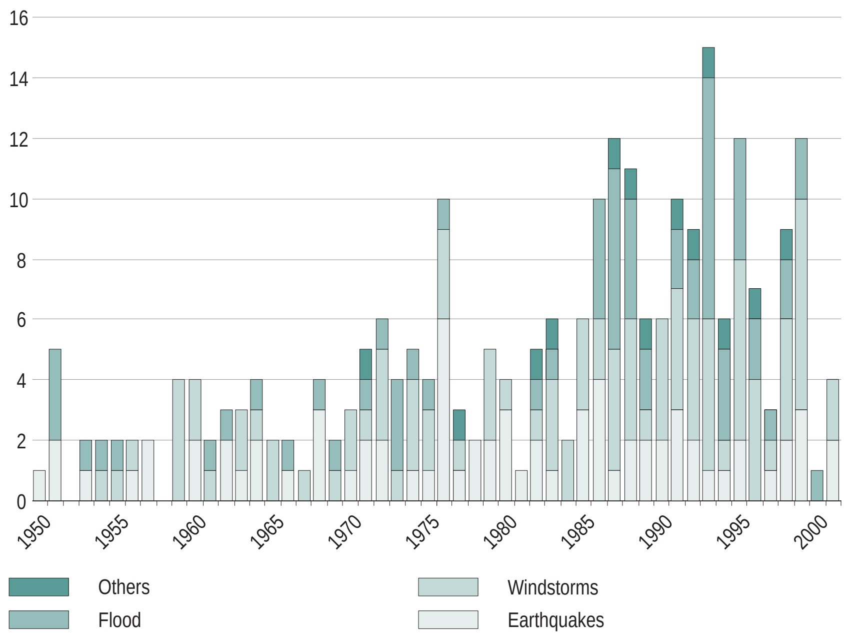
World economic losses from 1950-2002 for great natural catastrophes*



Source: Munich Re, 2002
*Note: Far exeeding 100 deaths and/or $US 100 million in claims

Figure 2

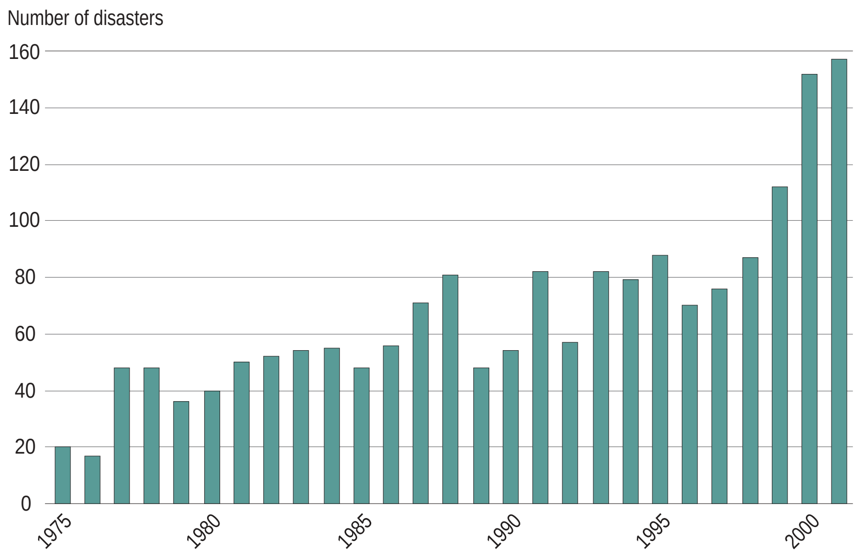
Number of great natural catastrophes from 1950-2001



Source: Munich Re, 2002

Figure 3

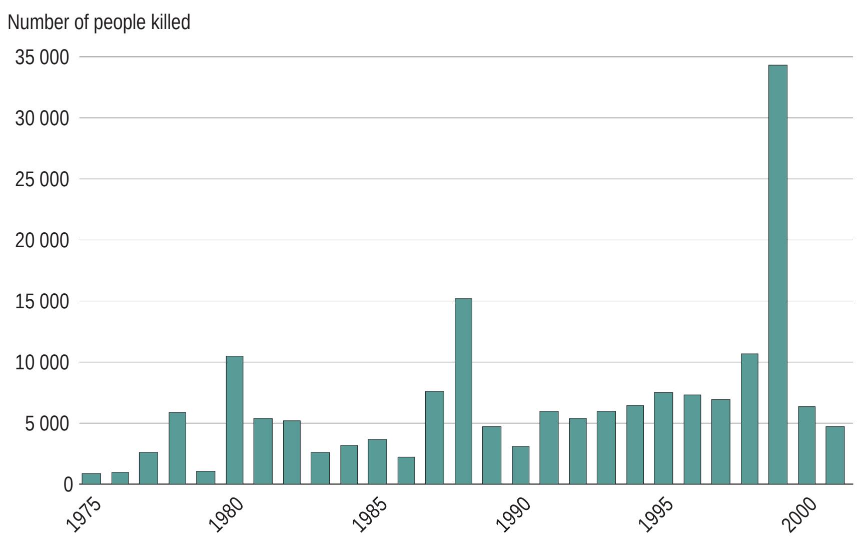
Number of disasters attributed to floods, 1975-2001



Source: EM-DAT, CRED, University of Louvain, Belgium

Figure 4

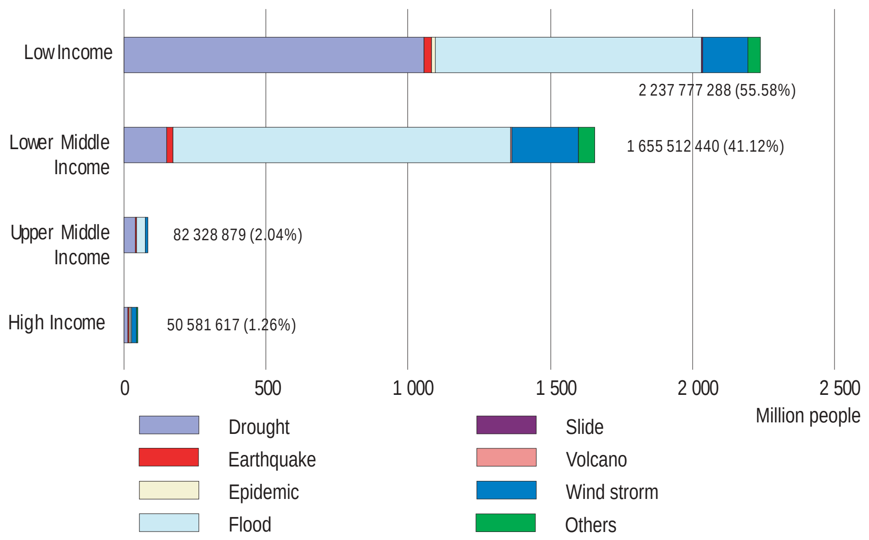
Number of people killed in floods, 1975-2001



Source: EM-DAT, CRED, University of Louvain, Belgium

Figure 5

World overview from 1975-2000 of number of people affected categorized by income class and disaster type



Source: ADRC, EM-DAT, CRED, University of Louvain, Belgium

In recent years, water topics have received great attention on the international agenda. The challenge for disaster and water managers is to bring their communities together and have them raise their combined profile at world and national policy events so as to allow for a greater ability to influence practices. The implementation of integrated water resources management (IWRM) has not been fully achieved in either developing or developed countries; and water continues to be managed in a compartmentalized fashion. The challenge is to recognize the importance of the impacts of natural water-related hazards within the framework of sustainable development.

Communities, nations, and regions can no longer afford to simply respond to and recover from these disasters. An integrated approach to flood disaster management will reduce the losses and break the cycle of event-disaster. A paradigm shift is required in perceptions, attitudes and practices in order to move from the current model of post disaster response and recovery to one of investing in the holistic disaster management process. The long tried approach of providing aid after a disaster needs to be altered to increasing investments in disaster mitigation management approaches before the occurrence of the next extreme event.

Flood disaster management is an end-to-end process for recognizing and effectively combating the risk associated with floods through a suite of planned actions. The process involves a number of activities that occur throughout the cycle:

- Pre-disaster - preventative measures and preparedness;
- During the flood - disaster relief, response and mitigative actions; and
- Post disaster - rehabilitation, reconstruction, economic recovery, and efforts to assess and fine-tune preventative measures.

Effective planning measures require an understanding of the factors that contribute to losses due to flooding. Typically, multiple actions must be taken to proactively manage the risk. A multiple mitigation approach would consider measures such as: preventing or restricting new or inappropriate development or activities in the flood plain; removal of certain structures from the floodway; flood proofing of structures in the flood plain; introduction of structural measures such as levees, dams and constructed channels; controlling land use practices within the basin; and applying flood forecasting and warning systems linked with response mechanisms. There is seldom a single approach to reduce and manage risk, but rather an array of measures that run from the development and enforcement of policies to the construction of works to the development of the forecasts, warnings, and response programme. Emphasis should be placed on arriving at solutions that are practical, appropriate and sustainable for the community at risk.

Establishing a flood forecasting programme enhances all other flood mitigation measures. Forecasts provide the necessary lead-time for a wide variety of

Hurricane Mitch Devastation

Hurricane Mitch, a category five hurricane, devastated Central America in 1998, causing widespread flood, storm surge, landslide and mudslide damages. Hurricane Mitch had wind speeds in excess of 240 kilometres per hour (150 miles per hour), and rainfall over a four-day period that exceeded 1,500 mm (59 inches) for several areas near the Pacific coast. Over 3.5 million people were affected, an estimated 9,214 were killed and 12,845 were injured. Damages have been reported to have exceeded $US 4.5 billion (UNDP/ECLAC, 1998) to $US 7 billion[3], primarily in Honduras, Costa Rica and Nicaragua. In Honduras the damages represented over 69% of GDP and about 73% of the total external debt. Major infrastructure such as bridges and roads were severely damaged and will take many years to be replaced.

Photo: J. Valdés

On 3 November, residents of Tegucigalapa, Honduras look at homes destroyed by a mudslide on Cerro El Berrinche. Triggered by torrential rains from the tropical depression that had been Hurricane Mitch, floods and earth slides devastated the region. Honduran officials put the death toll at 5,000 people, and climbing, with half a million left homeless.

[3]Source: Der Weltamanach, http://www.weltalmanach.de/archiv/00_338.html

actions to be taken by the community. Actions can reduce loss of life and economic losses by evacuating families, personal effects, produce, livestock and machinery, and by taking short-term efforts to increase the capacity of structural measures such as sandbagging operations and flood control operations at dams. Even in what are considered areas with low possibilities of flooding, complacency can set in and investments in forecasting and other mitigation efforts may be curtailed. Long-term investments and policies are needed so that the community will be prepared to respond to the relatively rare event when, not if, it happens.

Social and economic aspects are also very important and must be considered to effectively mitigate the impacts resulting from floods. Disasters in developing countries can literally wipe out the investments made in infrastructure of the previous 50 years, emphasizing the importance of sustainable practices in the design of the fabric of society and its economy. There is a need to build resilience to floods within the society. This is, in part, achieved through the recognition that the level of risk to society is highly linked to indifference and poverty, with this association being mutually reinforcing. Factors such as low income, inadequate housing, issues of land tenure, and lack of public services and social security force the poor to take actions that expose them to greater on-going risk. There is a need for governments to include the impacts of disasters in their financial planning scenarios and economic growth rate projections. This would trigger an awareness that inadequate measures lead to enormous economic and social shocks associated with disasters. Possibly through effective long-term fiscal planning, governments would better recognize the linkages between investments in flood disaster management and long-term social and economic stability.

There are many types of water-related disasters besides floods. Heavy rains can also produce mudslides, landslides, and releases of pollution. On the other extreme, there is also the possibility of drought. The negative impacts of drought in some countries can equal or even exceed the socio-economic damages of floods. Drought also reinforces the persistence of poverty, especially in rural areas that have a low adaptive capacity by the local population and weak institutions managing flood and drought-related disasters. The principles of integrated water resources management are being advocated to lead to sustainable practices for the benefit of society and the environment. There is a need for multi-hazard management systems within the framework of integrated water resources management. This report addresses only the flood aspects. From this holistic perspective, there is also a need to develop a similar approach for drought - the silent killer of the rural poor. The treatment of drought is different from flood, due to its slow onset and the absence of precise or standardized definitions.

This document is intended for the political decision maker, such as a mayor or minister, who wants to take positive steps to reduce flood losses but does not know how to proceed. The information outlined in this report provides guidance on a variety of measures. Some of these include identifying and mapping of areas prone to land/mud slide and flooding, preventing development in such hazard prone areas, enforcing controls on land use, and in implementing flood forecasting and warnings and emergency response programmes. These actions can significantly reduce the loss of life, socio-economic damages and disruptions to the communities. Additional benefits are also realizable in that a flood forecasting and warning programme can also provide much needed information on water availability for integrated water management leading to reduced water conflict and optimal water usage. This report stresses that one of the biggest challenges facing the decision-maker is to develop the appropriate linkages between the agencies involved at all levels and overcoming the rigidity of operational mandates.

The report is divided into seven major sections. The first section is the introduction to the report, while the second introduces social and economic aspects within flood disaster management, and highlights response strategies at various governmental levels. This section also addresses aspects of public awareness and communications within flood disaster management. The third major section provides an overview of various mitigation measures and technical aspects pertaining to flood management. These concepts span a brief introduction to risk management concepts, flood plain delineation, and watershed management practices. The need for development of policies, plans, and programmes is also addressed, as are climate variability and change and how these might impact upon flood hazards. The fourth major section provides an in-depth description of the components for consideration within a flood forecasting, warning and response system. This section provides the reader with an overview of what constitutes an integrated system, its individual components, and how these should be brought together to provide timely and reliable forecasts and warnings during critical periods. The fifth major section provides an overview of how to develop an integrated flood forecast, warning and response system. A bibliography is provided to facilitate the interested reader in obtaining a host of related material for more detailed study. The Annex contains four case studies outlining pragmatic examples of implementing concepts that are advocated within this document.

Integrated Water Resources Management

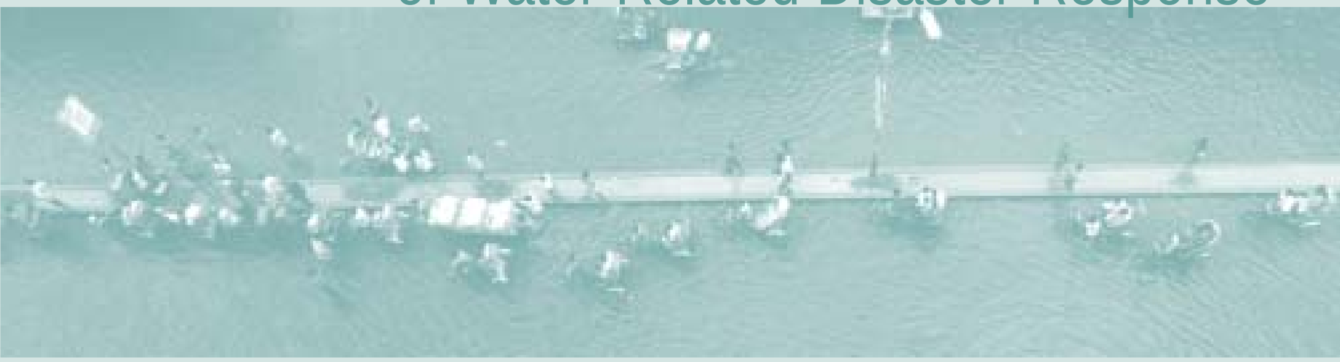
Integrated water resources management (IWRM) is an alternative to the dominant sector-by-sector, top-down management style of the past. IWRM aims at: integrating management of water resources at the basin or watershed scale; integrating both supply-side and demand-side approaches; taking an intersectoral approach to decision making; improving and integrating policy, regulatory and institutional frameworks; and promoting equitable access to water resources through participatory and transparent governance.

IWRM looks outside the narrow "water sector" for policies and activities to achieve sustainable water resources development. Focus areas for IWRM are water resources assessments, socio-economic assessments, water resources planning, implementation of action plans, day-to-day water resources management (adjustments of the plans) and water resources protection and conservation. Flood and water-related disaster management is a cross cutting issue that touches upon all of these aspects. Given the holistic approach, IWRM takes into consideration several aspects besides water governance. These include:

- Water supply and health, e.g., sanitation systems and water-borne diseases
- Water and agriculture, e.g., water productivity and agricultural practices degrading water sources
- Water and biodiversity, e.g., wetland loss and the need of water for ecosystems
- Water and energy, e.g., hydropower potential
- Water-related disaster reduction and response, e.g., floods and droughts

Sources: USAID Water Team: Integrated Water Resources Management - A Framework for Action in Freshwater and Coastal Systems, April 2002 and Global Water Partnership, GWP: ToolBox Integrated Water Resources Management, Stockholm 2001.

Socio-Economic Aspects of Water-Related Disaster Response



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1.1 Social Aspects of Disaster Reduction and Response

Disaster managers must recognize that different social groups have different needs when a disaster occurs. Generally, marginalized groups have less social power and fewer economic resources and physical capacity to anticipate, survive and recover from the affects of massive floods. There is an intrinsic relationship between poverty and vulnerability. In addition, the elderly, the disabled and children are particularly vulnerable, and gender is especially important to flood risk reduction.

Poverty

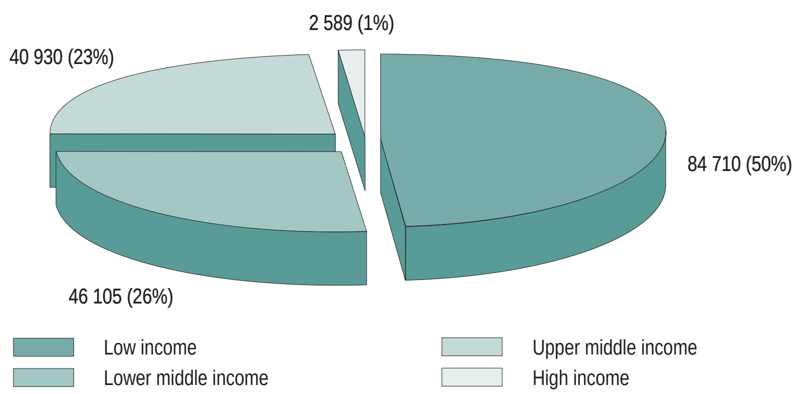
Poverty is a key dimension of any initiative in flood disaster risk management. Poverty affects people's capacity to protect themselves and their assets, as well as their ability to live in areas having less exposure to risk. Annually, floods cause great loss of life and severely affect large populations. The poor are the most severely affected by all natural disasters, as shown in Figure 5. From 1975 to 2000, people who belong to the low-income category accounted for about 50% of those killed in floods (see Figure 6), with over 90% of all deaths from natural disasters being attributed to water-related disasters.

Disaster vulnerability and poverty are mutually reinforcing. Factors such as low income, poor housing and public services, lack of social security and insurance coverage force the poor to behave in ways that expose them to greater risk. As the impacts of natural disasters tend to fall disproportionately on the poor, specific policies are required to tackle the link between poverty and disaster vulnerability. It is very important to link disaster management to poverty reduction. The failure to properly address livelihood issues hampers advancement on mitigating the impacts that result from natural disasters.

Creating diverse income-generating opportunities is an essential element of successful flood disaster risk management. While simple access to resources such as land is important, ignoring the full dynamics of a successful local economy can be disastrous. According to the World Disaster Report 2001, soft infrastructure, including training and work-and-life support services

Figure 6

Number of people killed in floods by income class, 1975-2001



Source: ADRC and EM-DAT, CRED, University of Louvain, Belgium (e.g., educational and health services, childcare for working mothers), acquires an equal if not greater importance than its hard equivalent of buildings, roads and bridges (IFRC, 2001).

Gender issues

The gender issue requires special attention in defining the community structures for disaster response. Women and children, being the most vulnerable groups of the society, tend to be most affected by natural disasters. There is a strong link between the well-being of children and that of women. Improving the situation of women is the best way to advance the survival and recovery of children.

Gender inequalities with respect to human rights, political and economic status, land ownership, housing conditions, exposure to violence, education and health, make women more vulnerable before, during and after disasters. Women often die disproportionately in disasters, if they do not receive timely warnings or other information about hazards and risks, or are prevented from acting on them. Their mobility in disasters may be restricted or otherwise affected due to cultural and social constraints. Gender-biased attitudes and stereotypes can complicate and extend the time for women's recovery, for example, if women do not seek or do not receive timely care for physical and mental trauma experienced in disasters (United Nations, 2001).

The need to stimulate community involvement and empowerment of women at all stages of disaster management programmes is an integral part of reducing community vulnerability to natural disasters.

However, women's abilities to mitigate hazards, to prevent disasters, and to cope with and recover from their effects have not sufficiently been taken into account nor developed (United Nations, 2001).

It is critical to understand the gender dimension in the development-disaster process in order to address root causes and take risk reduction measures that are equitable and efficient. At the most fundamental level, gender is a central organizing principle in the specific cultures and societies in which risk is constructed and disasters unfold. Gender patterns also manifestly shape development patterns and social vulnerability to natural disasters (United Nations, 2001).

Photo: C. Black and D. Revol, IFRC

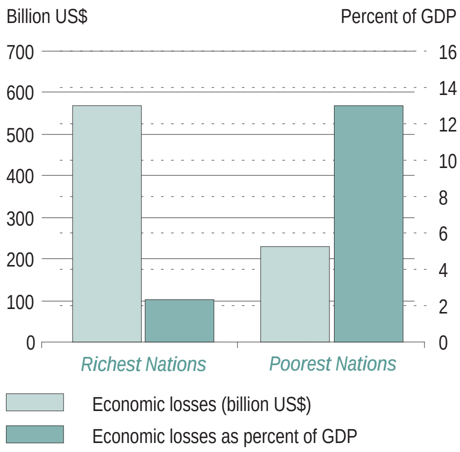
Mozambique Flood Catastrophe, 2000
With clean water in short supply, many people are forced to resort to using floodwater for cooking, and the risk of disease outbreak is high.

1.2 Economic Aspects of Disaster Reduction and Response

The number of major catastrophes and their total damages has greatly increased over the last decade (see Figures 1 and 2) - a trend that is likely to continue unless concerted action is taken to mitigate the impacts from natural hazards. The costs of weather-related disasters in 1998 reached a record high of more than $US 92 billion (Abramovitz, 1999). Moreover, natural disasters have a disproportionate impact on the GDP of developing as compared with developed countries (see Figure 7).

Figure 7

Disaster losses, total and as share of GDP, in the richest and poorest nations, 1985-1999



Source: Adapted from Munich Re, 1999

Lack of capital or wealth accumulation over the long run tends to undermine sustainable development. Recurrent floods and windstorms, for example, not only destroy national wealth, but also hinder efforts to accumulate physical and human capital.

Valuation of losses

It is important to assess disaster impacts to help governments adjust their financial planning scenarios and economic growth rate projections to offset or reflect the social, economic and environmental impacts of shocks caused by disasters. Such assessments also help to further our understanding of the importance of mitigation measures. It has recently been estimated that for every $US 1 spent for mitigation, there is an $US 8 reduction in losses (Abramovitz, 2001).

However, there seems to be a prevailing lack of support from governments to provide resources to vulnerable communities. There are several potential explanations for this. First, it is possible that economic decisions are sometimes made in a manner that stresses short-term benefits and costs. If, however, a long-term perspective is taken, the benefits of preventing, minimizing or responding to water-related hazards are clear. Second, it is usually difficult to include environmental and social impacts to economic calculations, even if the importance of those impacts is recognized.

There is still a need for standardization of the assessment of economic, social and environmental losses for comparative purposes, and for an approach that reflects the reality on the community level. When assessing the losses, it should be taken into consideration that calculating the losses in US dollars might not accurately reflect the different value and purchasing power of local currencies.

Insurance

Risk sharing and risk transfer at national, community and household levels can also help to reduce overall losses, improve resiliency and contribute to expeditious recovery (UN/ISDR, 2002). Insurance can be one tool to improve the situation of individuals by compensation. It helps spread the risk of disaster across society. For example, in Mozambique insurance companies and banks are active participants in the national disaster management system. Lending institutions can also play a different role by encouraging implementation of mitigation measures. Mitigation efforts are a form of protecting against future potential losses. Lowering risk can help lower the rates for insurance, thereby making it more affordable for the people. Rates should reflect the mitigation measures undertaken by the community and individuals (e.g., implementation of flood plain development policy and plans, flood proofing, forecasting and warning systems, and real-time monitoring).

The amount of catastrophe insurance purchased in the world insurance markets has increased enormously. For example, in 1997 catastrophic excess of loss coverage (the most common type of catastrophe reinsurance) purchased amounted to $US 52.9 billion. This indicates an increase of 34% in three years. Unfortunately, the benefits of this insurance were reaped almost entirely by the developed world. The United States, United Kingdom and Japan accounted for 55% of the total (MacKellar et al., 1999).

By contrast, developing Asia, which represented half of all the damages caused by natural catastrophes and two-thirds of all the casualties from catastrophic events in 1997, "owned" only 8% of the insurance coverage for catastrophes purchased in the world market. This coverage sufficed to absorb only 13% of the losses incurred. The remainder of these costs fell either to the government or victims, with some limited relief from international aid agencies (MacKellar et al., 1999).

The efficiency of risk-sharing and risk transfer depends upon the size of the risk pool and availability of financial instruments and services. In developed countries, governments, corporate entities and individuals engage in risk-sharing, which increases the size of risk pool, thus improving insurability of properties and assets. In developing countries, the size of the risk pool is smaller, resulting in inadequate insurance coverage and pay off. A related requirement is the commercial application of specific instruments and services for risk sharing at different levels (UN/ISDR, 2002).

Insurance schemes need to be complemented by other low-cost risk sharing mechanisms in poorer communities, such as kinship networks, microfinance and public works programmes to increase coping capacities. Additional tools and financial incentives are necessary to promote proactive disaster risk reduction investment. It is also important that all development projects include an assessment of vulnerabilities and risks from disasters (i.e., a risk management component). The policies and programmes meant for reducing risks from disasters should be incorporated into poverty reduction programmes (UN/ISDR, 2002).

Insurance can be used at the national, community and household levels, while microfinance services are only provided at the community and household levels. Public works programmes have their own specific context, and they can be undertaken to provide relief to households and communities struck by situations in which there are no income-earning opportunities. There can be a great deal of variation in their forms and applications. It is also likely that in a given situation a combination of these instruments may be required (UN/ISDR, 2002).

At the national level, improvements in the regulatory frameworks for disaster reduction and response, including disaster-related insurance, building codes and land use planning, will help ensure that infrastructure is properly sited and built to minimize damages as well as to reduce the costs of repair. This involves public insurance policy, market and regulatory incentives for risk and vulnerability reduction, protection against fluctuations in insurance/reinsurance prices, augmentation of insurance coverage at reasonable cost, and backstop financial mechanisms (UN/ISDR, 2002).

1.3 Response Strategies

Confronting global warming requires the enhancement of international cooperation, and the linkage between disaster reduction and poverty alleviation necessitates the involvement of all stakeholders at the local, national, regional and interregional levels. The present era of globalization has helped increase awareness that water-related disasters can happen in any society. There is an increasing recognition of a number of opportunities and approaches for building strategic alliances and partnerships among government institutions, private sector organizations, civil societies and other stakeholders to pursue the goal of sustainable economic development and IWRM.

There is a growing realization that various flood mitigation measures must be combined in ways that are appropriate to effectively address local situations. A balance between structural and non-structural measures to manage floods and reduce losses is required, where the emphasis is shifting from large structural solutions to innovative measures in flood proofing and improved building codes to non-structural flood measures such as land use regulation, flood plain management, compensation schemes, insurance schemes and the improved participation of local communities prone to flood hazards. The value of community-based forecasting systems is recognized in reducing loss of life and decreasing economic losses, as they make use of local empirical knowledge as well as increase local capacity for reducing communal vulnerability to floods.

The flood disaster management process should also be coordinated with efforts made in closely related fields. For example, the disaster mitigation process should consider human health impacts during flooding (e.g. cholera, e-coli, malaria), thereby more effectively addressing health issue that arise during flooding.

Community level

Community-based disaster management is essential for numerous reasons. First, communities are the ones who suffer the most. Second, community-based organizations act faster in responding to disaster before the arrival of external help. Third, local management leads to securing local support and ownership.

Community involvement is also needed in planning for disaster management, because in many cases there is a missing link between the disaster response actually needed and what is provided. In general, after the disaster has struck, responses are provided and managed at different levels in the form of relocation and zoning strategies, infrastructure rehabilitation, and restructuring of early warning systems. The problem is that most of the flood mitigation strategies are top-down in nature. Communities have no role in either the planning of disaster management, allocation of resources or implementation of the plan.

Community-level organization, management and empowerment are essential to mitigate the affects of disasters. Community structures need to be formalized, and their role and capacities in disaster management strengthened. The government and non-government institutions should work with community structures. In general, community organizations serve as an important bridge and instrument to link the ground-level response to a higher level of decision-making.

It is important to coordinate civil society action with government mitigation programmes. Reduction in future losses will depend on the ability of all levels to work together on preventative measures, to act jointly in the face of disasters, and to be able to draw on contingency plans.

An example of community level involvement is provided in Case Study 1 in the Annex. It describes approaches taken in the Philippines for preparing a community for disasters.

National level

Most countries are now recognizing the importance of dealing with floods in the context of IWRM and the need for a balanced approach to optimize the beneficial effects while minimizing the disastrous effects of floods. Two aspects have been identified as being necessary in flood management at the national level. The first is the need to introduce multi-hazard management systems, including coordination and response mechanisms. The second is the need for end-to-end disaster risk management of water-related disasters.

A major constraint to successfully being able to mitigate the effect of flooding is the fragmented institutional structures and lack of coordination and cooperation that can exist among national institutions. This can result in a general lack of planning and commitment to implement disaster mitigation activities.

Countries need to establish a clear national lead agency responsible for flood disaster management. Countries need to assess the level of additional inputs needed from governmental and non-governmental organizations as well as from organizations representing the civil society. There has been an encouraging trend of government commitments to establish early warning and flood forecasting systems and to expand flood forecasting and management to cover a larger portion of national populations. Countries that currently have little flood management capacity recognize the importance of improving effective systems to protect the lives and property of their populations. It is extremely important to integrate the flood disaster management process into social and economic development plans of the country.

Regional level

A special challenge is posed to flood management and disaster reduction and response in shared river basins. More regional cooperation is needed. Countries are encouraged to take full advantage of regional capacity. The exchange of relevant data and information related to hydrological data, hydrological forecasts, weather forecasts, reservoir operation as well as major changes in land use and water use management are important steps to improving flood disaster reduction and response of riparian countries in shared river basins. Consideration should also be given to regional training programmes and disaster assistance.

Regional collaboration is also a distinct possibility to foster data exchange, to develop common communication and forecast methodologies, and to exchange expertise. In this fashion the resources of a greater geographical area can be brought to bear as backup during extreme storm events.

Smaller countries may give consideration to bilateral arrangements with larger partners, or to develop joint activities with neighbouring countries. The latter is a distinct advantage when transboundary basins are involved or the goal is to increase joint scientific and technical abilities.

One good example of regional cooperation in Asia and the Pacific is the Typhoon Committee. It covers East and Southeast Asia and the North Pacific and has existed for 35 years. It was jointly established in 1968 under ESCAP and WMO auspices to coordinate efforts among countries of the region in predicting and monitoring typhoons and thus reducing losses. The Committee provides advice on improvements to forecasting and community preparedness and prevention activities, promotes research and training, and facilitates identification of funding sources.

Another example of regional cooperation is provided in Case Study 2, which is contained in the Annex, on the South African Development Community (SADC). The Case Study provides information on the recent developments on regional cooperation following the devastating flooding that occurred in the region in 2000 and 2001.

1.4 Public Awareness and Communication

Communities should not be passive recipients of information. There is a need to encourage people to help themselves, and communities must be provided with the mechanisms and tools to do so. Communities need to be active in the information dissemination system. They require technology adapted to local needs and conditions. Local communities should also be encouraged to document disasters and events at their level in any way possible for future research on flood mitigation and to increase local empirical knowledge of flooding.

There is a need to distinguish between information, education, and communication. For example, a forecast of water level by the technocrat may not be meaningful to the target groups. The forecaster and the people must be educated so that the message is understood by the various users, e.g. what to do when water level is classified as dangerous. Next comes the means to communicate to the target groups. Besides using the mass media, effective communication may include influential people such as local politicians and traditional leaders, whom the community respects.

Activities may also be targeted at children. Case Study 3 in the Annex describes a training project to introduce disaster awareness and preparedness to the elementary school system in Vietnam. This approach also helps to foster a greater awareness of natural disasters within families and their communities.

Flood warning systems and communication methods

The operation of a flood warning and response system is the most effective method for reducing the risk of loss of life and economic losses. This is particularly so where the unplanned occupation of flood-prone areas has taken place or where sectors of the community are vulnerable to flooding under extreme conditions. It is very important to link indigenous knowledge of basin response to forecasted or observed weather conditions. In some cases local communities may be unaware of weather events occurring upstream of their location that might well result in their destruction. People in communities need to understand what a prediction means: how exactly the predicted event would affect them personally. These predictions have to be applicable to people having varying economic status and reflect gender differences so that all elements of society can understand what response actions should be taken. Also, the flood warning and response system should be promoted in such a way that an "ownership" sense is created within the communities that operate the system to foster its sustainability. Special consideration should be given to language and cultural barriers to increase the effectiveness of the system.

A number of low-cost solutions could be used at the village level to enable local populations to foresee a coming flood. The African Centre of Meteorological Application for Development (ACMAD) takes advantage of the human resource capacity at the village level to reduce risk. Novel communication methods including wind-up radios and translation of forecast products to the village level have helped farmers reduce the impact of climate-related hazards. Local authorities are using a combination of high technology (data display and exchange using the Internet) and basic technology at the local level to inform communities about potential effects of drought or flood. Regional capacity building workshops help participants produce forecasts, enabling them to return to their home countries and update local forecasts. Small resources for small projects rely on large human resources at the community level, thereby effectively magnifying the effectiveness of the investment. Case Study 4 on Access to Information provides additional details on making information available to the community level.

Public education

An effective public awareness programme can contribute a great deal to reducing disaster-related losses. When developing such a programme, it is important that the seriousness of the risk is accurately perceived and that information be communicated with the appropriate level of urgency. Also risk communication should be viewed as a continuous process, where the contents of the message should be continuously reviewed and improved. Finally, the messages should be kept as simple as possible. There should be a designated lead agency for developing and issuing such messages.

Both formal and informal means of education should be used. Public education must be directed towards all levels - political leaders, bureaucrats, and the most vulnerable communities. For example, politicians and bureaucrats should consider shifting funding priorities from emergency aid to preventive measures. Currently, it is difficult to obtain funding for preventive measures.

Key Elements of Flood Disaster Management

2

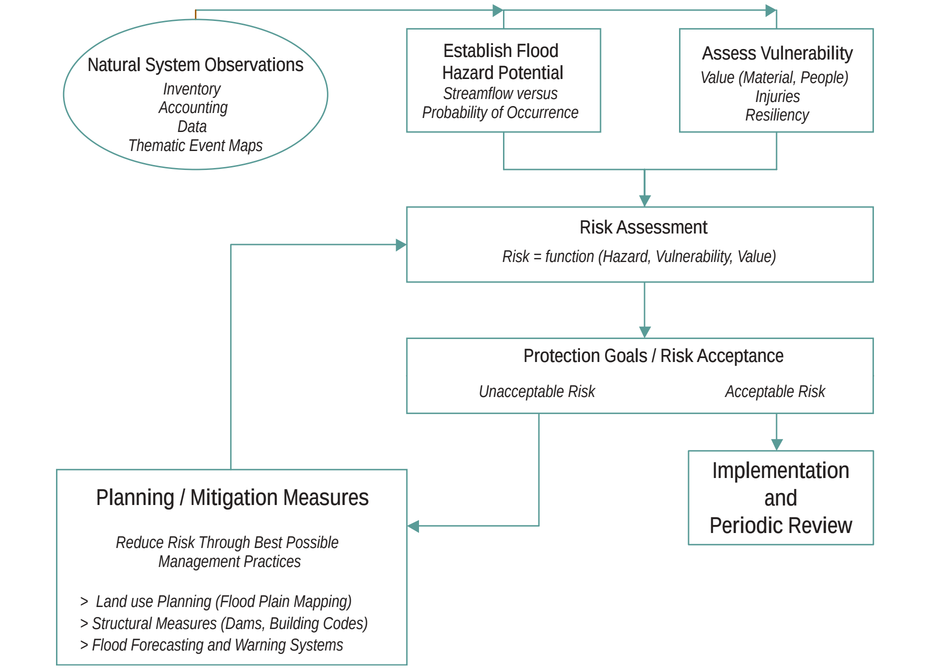
2.1 Risk Management and Flood Plain Delineation

A change to proactive management of natural disasters requires an identification of the risk, the development of strategies to reduce that risk, and the creation of policies and programmes to put these strategies into effect. Risk management is a fundamental activity geared to the evaluation of schemes for reducing but not necessarily eliminating the overall risk, as in may cases risk cannot be entirely eliminated. Figure 8 provides a schematic of the steps associated with risk assessment and management. It includes assessing the potential for a hazard to occur and a vulnerability analysis to provide an understanding of the consequences should an event of a certain magnitude and frequency occur. Based on this initial work, various mitigation measures can be evaluated to assess their ability for reducing risk exposure. Based on a thorough risk assessment, disaster management plans and specific mitigation measures can be identified. Efforts would then be undertaken to implement the selected mitigation measures.

For flooding events, there is a need to calculate the probability or likelihood that an extreme event will occur and to establish and estimate the social, economic and environmental implications should the event occur under existing conditions. Maps of the flood-prone areas should be prepared and detailed impacts outlined. A participatory process should be invoked, leading to the development of an acceptable level of risk. Measures can be evaluated and implemented to meet this level. This overall process assists the community in better understanding the various actions that can increase or decrease risk exposure, and can lead to greater community participation in the developed solutions to the flooding problem.

Figure 8

Framework for Flood Risk Assessment and Risk Management



Source: Adapted from WMO, 1999

Figure 9

Designation of floodplain and floodway components

Source: Environment Canada

There may be a necessity to define several zones within the flood-prone area, dependent on the velocity of the river and other physical factors. As an example, the flood-prone area may be broken down into floodway and flood plain components. Figure 9 shows a schematic of the designated floodway and flood plain for a hypothetical community.

Delineation of the flood-prone area

In order to map and delineate an area affected by floodwaters, there is the need to select a "design" event. Various approaches for estimating the design event exist, based in essence on "acceptable" risk, although at the time of their adoption, the concept of acceptable risk was not explicitly recognized. These approaches include using a historical worst-case scenario that happened in the basin or could plausibly have happened, which is referred to as storm transposition. Another approach is to theoretically maximize the meteorological factors that could happen in an area leading to the worst possible storm producing the worst possible flood. These are termed the Probable Maximum Storm and Probable Maximum Flood, respectively. The third approach is to use a probability-based analysis wherein systematic records and historical information on past flooding are used to develop a relation of probability of occurrence versus magnitude. It is becoming popular to adopt the concept of acceptable risk rather than adopting preset levels of protection associated with a specific probability of occurrence (e.g., the 100-year flood). A community and its government may wish to move to more extreme design levels when faced with the reality of future loss-of-life and extreme economic hardships when the future event occurs.

The frequency based approach is the predominate method used in most flood plain delineation studies when the potential for loss of life is considered negligible in terms of historical floods. The peak flood discharge and corresponding water level are established for various frequencies of occurrence or return periods of events such as once in 25 years (1:25), 1:50, and 1:100. Associated estimated damages are established for each probability. Many jurisdictions have set their design level to the "100 year flood". Statistically it is quite possible to have more than one "100 year flood" within a 100-year period, and a more extreme event can also occur at any time. A reasonable length of streamflow record is required to ascertain with some accuracy the probability of an event occurring.

When using a known historical flood to define the flood-prone area, various efforts are required to delineate the flood plain. This approach can at times rely on survey information collected during or immediately after the historical flood event. These data can be used to verify hydraulic model information to ensure accurate delineation of the flood plain. In cases using historical floods, care should be taken to adjust streamflow and water levels to reflect the present levels and possibly projected levels of development in the basin or other physical changes in the waterway. When a historical storm is transposed, hydrological models are used to transform rainfall to streamflow, and hydraulic models are, in turn, used to delineate the flood plain.

A shortcoming of using a known extreme flood event is the difficulty of assigning a frequency of return for evaluation of risk. However in data-short areas or when the event can cause catastrophic results, it is probably the preferred approach. It is also useful in establishing acceptable levels of protection.

These approaches tend to assume that events in the future are predictable based on the experience of the past. If changes in land use are occurring, this may not be true, and the changes should be reflected in the analyses. Similarly, the impacts of climate change or variability are not typically being incorporated in the analysis. If possible, such factors should also be taken into account in the delineation of flood-prone areas.

Floodway and flood plain

The floodway is that portion of the flood-prone area that is required to pass the design flood event without a significant rise in water levels compared to undeveloped conditions. "Significant" is normally defined as a rise in the range of 25 to 40 cm. The floodway is delineated using the flood frequency or extreme event information combined with a hydraulic analysis. Normally the floodway can be characterized as that part of the flood-prone area having high velocities, high potential for erosion, and high exposure to significant flow of debris. Often the floodway encompasses the normal river channel and some expanded high water area. No structures, other than critical infrastructure such as bridges, should be allowed in the floodway. In simple terms, the floodway is reserved for the river, not for humans.

The flood plain is the residual area outside of the floodway where the water velocities are less and flood protection and flood-proofing measures can be considered. When both the floodway and flood plain are identified, this it termed a two-zone approach. A simplified or one-zone approach is, at times, used when there is no existing incompatible development in the floodway and no new incompatible development will be allowed in the future. In such cases, only one designation of zone is used, and the entire area is treated as a flood plain. Under such circumstances, care would be taken to ensure that no new incompatible development occurs in the zone.

Figure 10 shows a section of a map for a one-zone application where the flood plain is designated in its entirety. The map shows homes, businesses, and institutions at risk at a 1:2,000 scale. Land contour information at 1-metre resolution is provided. Implications on existing and future land use (e.g., residential, parkland, industrial) would be set through policy and would be reflected in local zoning.

Figure 10

Section of map showing designated flood plain area

Source: Environment Canada

Implications on existing investments would also be set by policy, which could consider options such as relocation of incompatible uses, adoption of flood-proofing measures, or changes in designation of vacant or unused lands.

Areas beyond the defined flood plain may be subject to flooding by even rarer events, which are events that exceed the design event. Efforts should be made to ensure that "critical facilities" are flood proofed against these rarer events. Critical facilities include hazardous materials production, storage and waste facilities; essential utilities such as water and wastewater facilities and power plants; essential services such as hospitals, schools and airports; and emergency services such as fire stations or major computer centres. For example, if the 100-year flood is used to define the flood plain for zoning purposes, then critical facilities could be flood proofed to higher standards as if they were in the 500-year flood plain.

Vulnerability analysis

A vulnerability analysis considers the population and structures at risk within the flood-prone area. The analysis evaluates the potential costs of flooding in terms of damages to buildings, crops, roads, bridges and critical infrastructure, such as utilities. Normally the analysis is carried out for various probabilities of floods, and an elevation-damage curve is developed.

A vulnerability analysis, because it identifies the population at greatest risk, can also be used to identify the emergency responses that may be required, including the need for temporary shelters and evacuation requirements.

The analysis is also valuable for making a decision on the level of flood protection. The decision is based on knowledge of the degree of cost effectiveness of various options. However it should be a public process that establishes the "acceptable level of risk" that leads to the return period appropriate for the delineation of flood-prone areas. The analysis may also generate information useful in determining the benefits of flow forecasting.

Photo: International Association for Christian Action, Italy

Flood risk mapping

Mapping defines the area at risk and should be the basis for all flood damage reduction programmes and subsequent actions. The maps often have a legal connotation in terms of zoning and other structural and non-structural measures undertaken, so they need to be accurate and credible.

The mapping is normally based on a frequency of flood event determined by public consultation and reflected in policy, which may be based on a vulnerability analysis that is site specific. If regional or national flood reduction programmes are in place, there are advantages to a common mapping standard. If the historical flood is used, then some attempt should be made to assign a return period to the event for communication and design purposes.

Maps become the common element in terms of identification of flood-prone areas, identifying the risk to individuals and lending institutions, preparation of emergency response plans, and design of flood protection and flood proofing measures. Perhaps their greatest value is as an educational and communications tool, and they should be readily available to the public as well as to emergency response agencies at all levels of government.

Through modern computational systems, inundation maps can be generated in real-time and be part of the hydrological forecast system. These can greatly assist in communication to residents in areas of potential risk, and in planning response actions and assistance.

Protecting flood-prone lands

Policies and programmes to keep future flood damages from rising are based on the delineation and mapping of flood-prone areas. Generally the resulting programmes will mean some form of control over new development in the flood-prone area combined with measures to reduce damages to existing development. Such programmes are needed to curb the rising social and economic losses that results from floods.

Alternate use of flood-prone land should be considered where possible. It is better to have the land zoned and used for purposes such as parks, nature areas or ecological reserves than to try and ensure that future development is flood proofed. Zoning and flood proofing measures can be used to control development and reduce future flood damages, but the effectiveness of such measures is highly reliant on enforcement and maintenance. Local authorities are subject to developmental pressures and standards have a tendency to "slip" as the memory of a flood event fades.

Climatological forecasting

Climatological or seasonal forecasting has now advanced to the point of being a useful tool in reducing the risk of flooding. Extreme events are correlated to major changes in atmospheric and ocean circulation patterns, and once such patterns have been identified, the potential for a lesser or greater degree of storm activity can be forecast. This information can then be used to increase the degree of readiness of emergency response and forecasting agencies.

In certain cases the climatic forecasts can also be used to increase the availability of storage in reservoirs, to influence water management decisions and to create an awareness of the potential for flooding. All of these measures can reduce the severity of flooding, if it occurs.

When the probability of the extreme flooding event is greater than normal, then activities such as the stockpiling of sandbags, emergency food and water supplies, and the evacuation of high value stored crops or goods from flood-prone areas can be undertaken. It is a good time to create awareness in the public as to the potential for flooding, highlight the actions that the public and others should take, and to carry out emergency response exercises to test the degree of readiness. In some cases emergency measures such as temporary raising of flood protection works may be warranted.

China, Yangtze River, 1998

Photo: Xinhua News Agency

The photograph depicts Chinese soldiers and civilians struggling to maintain weakened levees during the summer floods of 1998.

It has become almost an annual occurrence: China's mighty Yangtze River swells under torrential rains, then surges downstream, flooding dozens of communities and leaving thousands homeless. During the summer of 1998, more than 2,000 people were killed, and the floods, which began in early June when seasonal rains arrived earlier and were heavier than usual, left 14 million homeless. For the fifth time that summer, the Yangtze hurled a massive flood crest toward the tens of millions of people who make their homes along its central and lower stretches. Earlier that week, a fourth flood crest was thwarted by millions of weary soldiers and civilians drafted into the flood-fighting campaign. More importantly, weakened levees that have withstood an early constant assault by the river remained largely intact.

2.2 Supportive Technologies

A number of tools are available to array and display information for the use of technical experts, to explain programmes of flood damage reduction to the decision-makers, and to communicate real time forecasts and warnings to the public. In general the tools should be interactive in the sense that the information can be easily updated, and flexible enough to develop scenarios, and to provide visual and quantitative information regarding the state of conditions during the forecasted event.

Geographic information systems

Geographic Information Systems (GIS) provide a computer-based information and manipulation system useful in support of flow forecasting and emergency response. Information from a variety of sources and scales can be combined as a series of layers, provided that the information can be identified in terms of the common denominator of location. For example, information on vegetative cover can be combined with soils and land slope information to estimate infiltration rates for forecasting purposes. Similarly layers of utility, land use, flood plain delineation, and structures information can help in the development and updating of emergency response plans.

A good representation of the basin topography is an important asset in flood forecasting, emergency action and mitigation. A digital elevation model (DEM) or digital terrain model (DTM) for the basin should be developed as part of any GIS. Technologies exist that enable the construction of a "seamless best available" DEM. In other words the DEM is constructed from whatever topographic information is available. Parts of the basin or certain features may be very accurate while others may be quite basic. The DEM can be improved with time.

The development of inexpensive global position indicators has made GIS information easier to obtain. For example, data network sites, buildings or physical features can now be easily located with precision and at low cost. Land use, vegetative cover or soils information is also easier to assemble.

Mapping

Maps of areas at risk from natural disasters are valuable information and communication tools. They can be used for a wide variety of purposes ranging from flood plain delineation, zoning and land use planning to presentation of information at public meetings.

Zoning maps, however, are static and may require updating with time as changes occur. For static information, such as the delineation of the flood-prone area, frequent updating is not required, and maps are a useful reference tool for a wide variety of users.

Visualization techniques

GIS and other computer-based information systems allow for a wide range of presentational material to be easily generated and tailored to the target audience. Three-dimensional displays, zoom and scan, and rotational techniques can be combined with other informational material such as pictures, overheads or slides. As an example, a GIS flood inundation map can be generated based on hydraulic model derived information. The map can be conveyed to residents in the flood plain and is useful for depicting the probable impact of the approaching flood.

This tailoring of technical information into displays that are more readily understood is valuable for explaining programmes to decision-makers, informed experts, and the public at large. Highly visual information is particularly valuable for public meetings or open houses, but must be tailored carefully for the audience. In particular, the information must be credible and easily understood.

The above techniques, combined with the flood forecast, provide a very effective means of delineating areas at risk and for communicating this to the decision-makers, emergency response teams, and the public.

2.3 Flood Plain Management

Management of activities within the flood-prone area can significantly reduce flood damages to existing development and prevent the amount of damages from rising in the future. The most desirable approach is to prohibit new development in the flood plain and to flood proof existing structures, or to replace the existing development by alternative usage of the land. However, where the amount of present development is substantial or the flood plain is essential for the production of food or other key economic activities, alternate strategies such as flood proofing and protection can be considered.

A. Structural Measures

Construction of dams/diversions/ storm channels/levees

Construction of protective works such as flood storage reservoirs, diversion of water to side channel storage or other watersheds, construction of storm channels to carry water around the area to be protected, and levees along the floodway provide tools to reduce flood damages. Such works can be constructed to various levels of protection, usually based on: 1) minimum standards for flood protection; 2) the optimum level of costs and benefits based on an economic analysis; or 3) to meet established levels of acceptable risk.

Protective works should be considered when major infrastructure has already been developed and costs to protect existing investments are far less than those related to reconstruction, lost economic activity, disaster assistance, or relocation of existing structures and activities. For example, flood protection measures for the city of Winnipeg, Canada, were completed in the late 1960s at a cost of $US 92 million. A rough estimate of damages prevented in five large floods since then is approximately $US 2.0 billion.

Protective works have a tendency to increase the level of development in flood-prone areas, as the assumption is made that it is now safe to build and invest in areas that are protected. However, it must be recognized that at some point in the future the design event will likely be exceeded and catastrophic damages will result. Levees and storage dams are particularly dangerous when design thresholds are exceeded in that unexpected failure can result in a rapid rise in water level and make evacuation and emergency protection extremely difficult. Diversions or storm channels are less prone to catastrophic failure and the level of protection can temporarily be increased by emergency measures if the lead-time of the flood warning is sufficient.

Flood control storage may be one component of a multi-purpose reservoir development. Over time the operation of the reservoir could be altered to enhance other beneficial uses of storage to the detriment of flood control. A commitment to "designated flood storage" and to reservoir operation procedures to achieve that storage is needed.

Inspection, rehabilitation and maintenance

Structural works require a periodic and systematic inspection, rehabilitation and maintenance programme to ensure that the design capabilities are maintained. For example, levees may be subject to weakening due to erosion during a past flood event, by the actions of burrowing animals, or the construction of utility lines through the levee. Of particular importance is an inspection programme and responsibility assigned for rehabilitation and maintenance.

Structures such as dams should be subject to a dam safety programme, usually at the national level, to ensure that the specialized expertise required is available for the inspection of all structures. Dam safety programmes are carried out in many countries and standards or guidelines are readily available.

Flood proofing of new and existing structures

Any new construction permitted in the flood plain should be flood proofed to reduce future damages. Building codes can be developed that minimize flood damages by ensuring that beneficial uses of buildings are located above the design flood elevation. For example, buildings can be raised above the design flood level by placement of fill; stilts or piles used to elevate the structure; and building utilities can be located above the flood level (see Figure 11). Ground floors can be designed in a way that little flood damage occurs through use of masonry materials and specifying that contents must be removable.

If any new development is allowed within the flood-prone area, then the impact of that development must be taken into account to ensure that flood levels do not rise significantly due to the additional constriction to flow. Hydraulic analyses can be undertaken to ascertain the impacts of potential activities and to keep the rise to within acceptable limits.

Flood proofing of existing structures is difficult and expensive. One successful strategy is to link flood disaster assistance available after a flood event to methods of reconstruction that minimize future flood damages. This approach often requires additional funding over and above a payment for damages, but can be cost-shared between various levels of government and the owner. This strategy is particularly useful when flooding is frequent and future disaster assistance can be expected as part of disaster policies.

Flood proofing of existing structures can include raising of structures to prevent damage, relocation of utilities, changed building use, installation of protective walls and waterproof closures, and use of materials that are not damaged by water and can be easily cleaned after the flood event. Relocation of existing buildings and structures to an area that is not flood-prone is also an option.

Buyout and relocation programmes for a particularly vulnerable development should form a component of flood proofing initiatives. In many cases it may be more economical to buy out and relocate the existing use than to protect it.

Figure 11

Flood proofed dwelling

Photo: Environment Canada

A number of critical services such as water lines, power pylons and telephone services often cross the flood plain. These utilities can be protected against the ravages of flooding at relatively low cost through additional depth of burial, a higher design standard for exposed components, and raising of components above design flood levels.

Water supply and treatment plants are particularly vulnerable. They are often located on the flood plain yet are critical for the protection of human health during and after a flood event. Such structures need to be protected against extreme events and designed to prevent cross-contamination from floodwaters or sewers.

Bridges and roads

Bridges generally constrict the flow of water, and they can act as artificial dams if debris jams on the structure. In all cases, their hydraulic characteristics must be considered at the design stage to prevent an unacceptable rise of water levels upstream of the structure.

Bridges are important in terms of maintaining access for evacuation and delivery of medical and other emergency services. Key transportation corridors should have high design standards that will withstand extreme flooding events. However not all bridges require a high level of protection, and the design criteria can be to a lesser standard that takes into consideration the possibility of overtopping.

Bridges are expensive, and difficult to replace quickly after a flood event. An alternative strategy is to design the approach roads to be the weak link in the chain so that extreme events wash out the road but do not damage the bridge. Approaches can be quickly repaired after a flood event and transportation corridors restored.

Photo: D. Rayner, GeoResources

In the days and weeks following Hurricane Mitch, people struggled to find even the basic needs such as clean, safe water.

Road design, either parallel to the river or leading to bridges, must be given careful consideration. There is a temptation to raise roads that have been overtopped by flood events without giving adequate consideration to the number and size of openings necessary to pass local drainage or tributary inflow. In such cases the road can artificially raise water levels upstream and cause additional flood damage. Roads can also act as levees when they are parallel to the river. This is a two-edged sword: while flood protection is provided, the water level upstream can increase, resulting in additional flood damages there. Hydraulic studies must be undertaken before roads are raised to fully establish the impacts of these activities.

Enforcement of standards and codes

The enforcement of standards and codes for flood-prone areas is as important as their initial development. There is a tendency to bend the rules as the memory of a flood event and its catastrophic consequences gradually fade away with time.

Enforcement procedures and penalties need to be built into the process, and emergency response drills undertaken to ensure that flood prevention measures such as waterproof closures still work. An audit procedure should be performed by higher orders of government with participation of all interested parties to ensure broad national standards are being met and that codes and rules are being suitably followed and enforced.

Governments should consider introducing requirements such as surveyor certificates to verify that design elevations have been met, or inspector reports that flood-proofing measures have been implemented. Lending and insurance institutions could usefully be involved in this process, as they have a vested interest in ensuring that their investments are protected.

B. Non-structural Measures

Non-structural measures are particularly applicable to flood-prone areas that are not yet developed. As such, they are a complement to structural approaches in areas where additional development may occur, and they also represent an independent approach where some control over flood plain development can be exercised at low cost. Non-structural approaches do not mean "no use", but rather "wise use".

Land-use planning

Land-use planning at the local or municipal level can be a useful tool in reducing future flood damages. Consideration should be given to ensuring that there are conforming uses in flood-prone areas as part of master plans. The land along a river is highly desirable for parks and recreational uses, as well as for ecological reserves. Supportive infrastructure such as washrooms, picnic facilities and changing rooms can be flood proofed. Private development of conforming uses such as golf courses can also be considered. The important point here is to integrate the land-use planning for flood-prone lands into the broader plans for the urban and surrounding area.

Zoning of flood-prone lands

The best way to reduce future flood damages is to prevent development from occurring on flood-prone lands. Zoning of such lands is an effective approach, but generally should be coupled with the broader land-use planning mentioned above so that the land has a defined use.

Zoning can be used to reduce damages from flooding and be flexible enough to recognize that other forms of land use are compatible. An example is agricultural use of lands in flood-prone areas where water velocities are low enough not to cause serious erosion. Flood-prone lands can continue to be used for agricultural purposes, particularly in countries where the amount of agricultural land is limited and self-sufficiency in food supply is a national goal. It is important, however, to ensure that the supporting infrastructure such as buildings and houses are located away from the flood-prone area or are flood proofed. It is also important that livestock, machinery or stored crops can be evacuated quickly from the area in the event of a flood. This underscores the importance of a flood forecast, warning and response system.

Zoning of flood-prone lands as ecological reserves or protected wetlands can often help to meet broader environmental or biodiversity goals. In addition, such lands often play an important role in sustaining the fishery, and they can also act as temporary storage and infiltration areas. Riparian buffer strips also reduce the movement of agricultural chemicals and nutrients into the aquatic system.

Redevelopment of flood-prone areas

A major flood disaster is sometimes an opportunity to correct the planning errors of the past. Removal of flood-prone development and conversion of the land to a conforming use is an option to consider. It may be less expensive in the long run to physically relocate flood-prone development, buy it out as part of a disaster assistance programme, or include its purchase in long term planning. The success of the latter approach can be enhanced by measures such as prohibiting improvements not required for health and safety, placing caveats on the land title, and by obtaining rights of first refusal on resale.

Photo: Ming Press

Compensation and incentives

Compensation as part of disaster assistance should always have as a goal the reduction of future flood damages. Rather than simply paying for damages, the funds should be focused on flood proofing, buyout, relocation and public education on the risks and consequences of living on flood-prone lands.

In a similar manner, incentives can be developed that encourage flood proofing or relocation, and these can be financed through cost-shared programmes. Here the cost of flood proofing can be shared in proportion to the benefits to the various levels of government of not having to compensate for future flood damages. Property owners should also be expected to pay a reasonable share in view of the enhanced value of a flood-proofed structure and the reduced inconvenience after a flood.

Land exchange programmes can be used as an incentive to relocate from flood-prone lands. In such cases a public entity makes alternate land available and disaster assistance is generally used to pay for relocation or replacement of structures, depending on the costs and benefits.

Incentives can also take the form of penalties. For example, if an individual is aware of the risk of flooding through such programmes as flood plain delineation, or caveats on land titles, and still decides to build on flood-prone land, then that person should bear the consequences of his/her actions and not be eligible for disaster assistance. However this is difficult to enforce and is reliant on strong political will at the time of announcing disaster assistance.

Insurance

Flood disaster insurance forms part of the suite of responses to reducing flood losses in the United States of America. When a prospective homebuyer seeks to purchase a property in a designated flood-prone area with funds obtained through a federally-insured or regulated institution, the lender is required to notify the borrower of the need for flood insurance. The losses covered by flood insurance are paid from the accumulated premiums of policyholders rather than disaster assistance funds. There are some weaknesses in this approach, as not all homeowners in flood-prone areas purchase insurance, and there is the necessity for public funding if losses exceed the accumulated premiums. Flood insurance schemes have been utilized in other countries, including parts of Germany, with varying degrees of success.

For insurance schemes to be successful, there needs to be a clear definition of the risk, as premiums should reflect the degree of risk at a given location. It is also desirable for governments to promote or, when possible, mandate universal insurance coverage and guarantee funding when payouts exceed premiums. Such schemes should be designed to be self-sustaining over the long term. An additional problem concerns the information base, which is seldom sufficient to define the degree of risk adequately. It is also difficult to effectively make insurance mandatory. Often those most at risk due to flooding are the least able to pay, or they refuse to pay because of high premiums.

The United States has an advantage from an insurance perspective in that 20,000 communities are at risk from flooding; with such a large number of flood-prone communities, the financial risk can be spread more easily than in smaller countries. Insurance is an option that needs to be considered, but is probably not feasible in many developing countries at this time.

2.4 Watershed Management

The water storage effect of vegetation, soil, shallow groundwater, wetlands and drainage has a direct impact on the flood level in downstream areas. Each of these storage media retain certain quantities of water for various periods of time and can influence the timing of tributary flows and hence their contribution to a flood event. The storage effect can be likened to a sponge and is dependent on the antecedent conditions and the magnitude of the flood.

Impacts of land-use changes

The impacts of land-use changes on flood events can be both positive and negative, so predictions are hard to make for a specific watershed. Generally the removal of forest and other natural cover, and the conversion of land to agricultural uses, compacts the soil and reduces infiltration rates, leading to higher flood peaks. Deforestation is believed to have been a significant cause of the catastrophic flooding in the Yangtze River basin in China and in Central America from Hurricane Mitch, both in 1998. Deforestation and other land-use practices can also lead to greater incidences of landslides and mud flows.

Natural water storage is also generally reduced due to the gradual loss of organic material and soil erosion, once an area is converted to agriculture. Additionally, natural vegetation may transpire moisture to the atmosphere at a greater rate than replacement crops, thereby affecting both the amount of storage available in the soil and the amount of local rainfall.

Drainage of wetlands and marshes contributes directly to changes in the timing of runoff, the amount of natural storage in the basin, and the vulnerability of the channel to the erosive forces of water. Even road construction can contribute directly to increased runoff rates through improved drainage as well as the effect of reduced infiltration through the road surface.

By far the greatest impact of land-use change is associated with urbanization itself. The paving of surfaces significantly reduces infiltration, natural storage is reduced by improved drainage, and streams are often constricted by development or crossings. A city will frequently have significant flooding problems that are local in nature, but will also be impacted upon by major flood events on larger streams or lakes that are not within the urban zone.

A general rule is that the impacts of land-use change will be greater for smaller basins than for larger ones. Increases in flood peak and runoff volume in the range of 15-25% for medium-sized basins (>5000 square kilometers) have been estimated in temperate climates. However, more detailed studies are required before making predictions for specific basins and their conditions. Scaling small basin results up to larger basins and vice versa remains a major scientific challenge.

2.5 Climate Variability and Change

There is growing concern about the impact of changing concentrations of greenhouse gases on our current climate system and the ramifications these changes might have on water availability. It is believed that further alterations of atmospheric chemistry could lead to increased abnormalities in climatic parameters such as temperature, precipitation and evapotranspiration and might well lead to more dramatic impacts on streamflow patterns and extreme conditions. Some analyses of streamflow over the last 30 to 60 years have shown evidence of increasing and decreasing trends in the low flows, with marked geographic patterns to these trends. Thus far, there has been less evidence of trends in annual flood data for natural pristine basins. However, based on scenarios of projected future atmospheric conditions, it is anticipated that there might be more pronounced alterations to the streamflow regimes in various regions of the world. If these projections are correct, more severe or extreme conditions may prevail.

Climate impacts on extreme events

A number of studies on the potential impacts of climate change on flooding have been carried out as part of the work of the Intergovernmental Panel on Climate Change (IPCC). These studies indicate potential future increases in flood peaks of approximately 15% in temperate zones due to increased storm activity and overall increases in depth of precipitation.

At this point in time, it is not possible to predict potential increases in flood peaks due to climate change for specific basins with the degree of certainty necessary for their incorporation into the design and planning process. However, the freeboard on levees and other works can probably accommodate the potential modifications in extremes due to climate change through modified operating procedures of control structures.

Sea level rise and storm surge

Coastal communities must also deal with the implications of sea level rise, tsunamis, and ocean storm surge in preparing for flooding events.

Sea level rise due to climate change will result in decreased river slopes in reaches above where the river enters the ocean, thereby reducing the capacity of the channel to pass flood flows. This increases the elevation of floods in coastal cities. While the rate of sea-level rise is slow, most protective works or flood plain delineation exercises are sufficiently long term in scope to warrant consideration of the predicted rise.

Some studies have indicated that there is potential for increased frequency of storm surges, which result from high winds and increased barometric pressure. Tsunamis can also be devastating natural disasters and must be considered in a manner similar to flooding. Forecasting and emergency responses to these events must be based on the same principles of acceptable risk and advance planning.

ENSO events

The El Niño Southern Oscillation (ENSO), related to changes in sea-surface temperatures in the Pacific Ocean, can profoundly change the weather patterns in Central and South America. The number of hurricanes that can be expected in a given season is also related. Climate predictions of above or below normal storm activity during El Niño and La Niña events can assist with the regulation of reservoirs and other water management activities that can reduce the magnitude of peak storm runoff. Flood forecasting and emergency response activities should also be periodically tested to ensure they meet appropriate levels of readiness.

2.6 Development of Policies, Strategies and Plans

The development of policies, strategies and plans to combat the risks associated with natural disasters should be based on a comprehensive risk assessment. This requires an integrated approach whereby a wide range of mitigation measures should be considered. For example, mitigation activities such as hazardous land mapping (i.e., flood plain mapping plus landslide- and mudslide-prone areas) should be designed so that considerations of other disaster types lead to sounder overall land-use plans. In essence, there would be very little purpose in moving people and goods from one risk zone to another, especially if the other hazard is equally or more apt to occur under the prevailing conditions such as torrential rain. Within this overall process, full consideration needs to be given to the social, environmental and economic impacts of policy and programme development. This chapter provides guidance on aspects of flood hazards that need to be considered within the overall planning process. The aspects contained herein are meant to complement other materials in this guide, such as the development of a flow forecasting and warning system, which are important tools within the range of options to be considered.

Basin wide planning

Reduction of flood losses must be considered, using the basin as the basic planning unit. It is absolutely essential to have knowledge of water uses, diversions, storage, and management practices in all parts of the basin, as well as the antecedent, present, and forecasted meteorological and hydrological conditions.

Transboundary basins represent a special challenge in that international collaboration is required. In such cases consideration should be given to expanding existing bilateral or regional arrangements for exchange of data and information and to the negotiation of treaties or agreements. Agreements can also include the option of projects of mutual advantage funded by all the countries involved, including construction of flood storage or other flood preventative measures at the most advantageous locations in the basin as a whole.

Multijurisdictional issues

Basin-wide planning for reduction of flood losses can involve government at the local, provincial/state and national levels. As such it is desirable to have the national government develop strategies and policies that ensure a consistent framework wherever they are applied. This can extend to matters such as installation and maintenance of data networks, design standards for protective works, flood proofing standards, cost sharing arrangements, and incentive and insurance programmes.

In general the national level of government should take the lead in bringing the parties together, but should delegate planning of the details and delivery of the emergency response programmes to the local level. Generally the national and provincial/state governments will play some direct role in operation of forecasting centres, and they will need to provide for emergency response that exceeds the capability of the local level. There should also be a role of higher orders of government in auditing enforcement of policy measures by local levels.

Inter-agency collaboration

Reduction of flood losses will involve a number of government agencies and often the private sector if, for example, reservoirs are operated by energy utilities. Development of common objectives and definition of a clear role for each of the players can be a major challenge. From a land-use planning perspective, land developers must also be directly involved in the solutions.

Normally some form of inter-agency body will need to be established, and the leadership role assigned to the agency with the greatest involvement or to a strong central agency. There is probably no ideal model for such a structure, as circumstances are quite different in every country.

An independent agency is an attractive option, but in general it is probably better to try and build on the strengths of existing agencies so that supportive resources can be marshalled quickly in case of extreme events. However, within this diverse model, it is imperative that one agency be given the overall lead, and that that agency be held accountable for the overall process.

International collaboration

There are a number of United Nations specialized agencies and programmes that can be of assistance to a country establishing a programme aimed at reducing the losses that result from flooding. Some of these are described herein and could be contacted by interested parties.

The UN Department of Economic and Social Affairs (UNDESA) has been actively involved in providing advice to governments on water resource management during extreme hydrological events in a wide range of environmental and climatic settings from the drought-prone upland plateaus of central Africa through large river basins and aquifer systems in Asia to vulnerable groundwater lenses on Pacific atolls. If one principal lesson is to be learnt, it is that managing water resources under conditions of climatic variability and extreme events involves no special approach; it is simply sound water resource management. To this extent, climate change should involve relatively few surprises, and should not be an excuse for poor management. It is only possible to undertake sound management practices, however, if the appropriate and accurate hydro-meteorological data are available to resource managers on a regular basis. One of the critical issues in this area is the breakdown in hydro-meteorological data collection systems and analysis. As funding for water resource organizations declines, monitoring networks and the capacity to collect, store and analyze data break down. Ironically, it is only in times of drought or severe flooding that the political will to fund these activities is revived, by which time it is often too late.

Water resources assessment is a core issue that the UN system is addressing through its technical cooperation activities and the World Water Assessment Programme. UNDESA's technical cooperation with developing countries and economies in transition uses state of the art technologies and software for the assessment of water resources availability as a basis for short-term and long-term planning horizons. National capacity has been developed to perform and continue these assessments in countries such as Bahrain, Burkina Faso, Cape Verde, China, Jordan, Madagascar, Mali, Mauritania, Niger, Senegal, and Yemen. This is of particular importance in water-scarce countries, where water has become a limiting factor for economic and social development.

UNDESA has been collaborating with governmental organizations to enhance national capacity to address the problems of water quality assessment and overall water management. Guidelines and recommendations concerning water quality protection and management are also prepared for national and regional organizations, dealing with monitoring and protection of environment.

The United Nations Development Programme (UNDP) has a programme for strengthening national capacities related to flood mitigation, prevention and preparedness in developing countries. UNDP works in flood reduction and recovery through practical application at the regional and country levels. UNDP has devoted special attention to reducing social and economic vulnerability and loss of lives, and to protecting livelihoods and broad-based development gains.

The World Meteorological Organization (WMO), a specialized agency of the UN, was established in 1950 to facilitate worldwide cooperation in meteorology, hydrology and climatology for the benefit of humanity. WMO promotes the following types of activities: the establishment of the networks of stations for acquiring meteorological, hydrological and related geophysical observations and the standardization of observational methodologies; establishment and maintenance of systems for processing and exchanging data and information; activities in operational hydrology, such as flood forecast and warning systems; multi-agency and interdisciplinary programmes on water resources, climate change, natural disasters, and other environmental issues; and research and training.

The International Strategy for Disaster Reduction (ISDR) was launched by the General Assembly of the United Nations in January 2000, to provide a global framework for action with the objective of reducing human, social, economic and environmental losses due to natural hazards and related technological and environmental phenomena. The ISDR aims at building disaster-resilient communities by promoting awareness of the importance of disaster reduction as an integral component of sustainable development. The General Assembly established two mechanisms for the implementation of the ISDR: the Inter-Agency Secretariat and the Inter-Agency Task Force on Disaster Reduction (IATF/DR).

The ISDR Secretariat serves as a focal point within the United Nations system for co-ordination of strategies and programmes for disaster reduction and to ensure synergy between disaster reduction activities and those in the socio-economic and humanitarian fields. The ISDR Secretariat also serves as an international clearinghouse for the management and the dissemination of information, in particular on current knowledge and status of disaster reduction through the publication of its *Global Review of Disaster Reduction Initiatives*. It develops activities such as advocacy campaigns to promote wider understanding of natural hazards, as well as risk assessment and management to motivate a worldwide commitment to disaster reduction. The ISDR Secretariat has a facilitating role, bringing agencies, organizations and different disciplines together, and providing a common platform and understanding of the scope of disaster risk reduction. In this regard, one main function of the Secretariat is to support the Inter-Agency Task Force for the development of policies on natural disaster.

In particular, the ISDR Secretariat supports activities, such as the development of guidelines, related to reducing the risk from water-related hazards. This requires, on the one hand, support for the development of capacities to monitor the magnitude, duration, timing and location of hazards, such as floods and droughts, as well as landslides, storms, earthquakes, and volcanic eruptions. All of these latter hazards also have impacts on freshwater resources and infrastructure. On the other hand, this also requires promoting the assessment and reduction of the vulnerability to such extremes. This requires decision-making on issues such as development and planning control, legislation and land-use, environmental management and financial tools (e.g., insurance).

The ISDR, with its focus on disaster and risk reduction, draws its relevance from previous practices in the disaster management fields, where traditionally the focus has been on preparedness for response. Political authorities, professionals from many different fields, commercial interests, public organizations, educational institutions and local community leaders are increasingly recognizing the essential public value of sustained efforts to reduce the social, economic and environmental costs of disasters. There is now increased emphasis placed on risk, and a growing acceptance that disaster, development and environmental problems are inextricably linked.

2.7 Emergency Preparedness and Response

The most critical element in the suite of activities associated with flood-loss reduction is emergency preparedness and response activity. The response to a natural disaster warning must be immediate, comprehensive, and demonstrate very clear lines of command. There must also be a mechanism in place to quickly draw upon external resources available at higher levels of government, or even internationally, when the local level of response will not be sufficient. Many countries have systems in place where a provincial/state wide or national disaster can be declared to bring in the resources needed. The keys to effective emergency response are advance planning, ability to mobilize sufficient resources quickly, and periodic exercises to identify weaknesses and problems.

Collaboration and coordination

Emergency planning and preparedness is first a local responsibility, but one that requires collaboration and coordination with others in a growing circle of like-minded and expert groups that can be drawn upon as events unfold. In particular, there must be strong and reliable communication linkages to storm warning and forecast centers so that the emergency response actions taken are appropriate to the magnitude of the probable event.

The network of linkages from the local level upward must be established in advance and, more importantly, key players must periodically meet to exchange information and become comfortable working together. Information sharing should be bi-directional, both upward and downward, between the levels of government. Practice drills are important.

Emergency response must include input from the community and political levels but cannot become a collective responsibility. There must be clear lines of authority, even if the lead agency changes dependent on the magnitude of the event.

The community and individuals must have a good understanding of what is expected of them. A good example would be evacuation. Information that defines evacuation routes, identifies emergency shelters, and specifies actions to be taken before leaving, such as removing mobile equipment and removing personal goods and furniture, must be available in advance.

Preparedness and response plans

Detailed response plans need to be prepared in advance and reviewed with all of the key agencies and players. There is no one "common" response plan as the linkages will be different in each case. The response to a toxic chemical spill is very different from the response to a major fire or flood.

Not only must the plan be in writing and available to those that will be responding, but also it must be continually reviewed and updated. Some of the key pieces of information are: which agency and individuals have the specific responsibility; whom to contact for expert advice; and where to go for information on backup communication systems. This information is constantly changing and needs to be verified periodically and tested in exercises. Multiple contact points need to be established as the emergency may occur on a weekend, holiday, or after regular business hours.

Mechanisms for coordination must be included in the plan, including the structure of response committees, where they will meet and sources of resource information available to them. Often this takes the form of something equivalent to a "war room" where maps, plans, other material and support staff are available immediately.

Inventory of resources

A key component of any emergency preparedness plan is an inventory of resources that can be accessed. In the case of flooding this could include items such as emergency vehicles, buses and trucks, earthmoving equipment, pumps, plastic, plywood, emergency generators, supplies of gravel and sand, sandbags, and mobile communications equipment. The inventory should also include access to expertise such as surveyors, levee or slope stability experts, forecasting specialists, the media and community leaders.

Emergency shelters should be designated in advance, their individual capacity defined and plans made for obtaining sufficient supplies of water, food, medicine and medical/social assistance.

If local resources are not sufficient, then the availability circle must be expanded to include adjacent communities, the provincial/state and national government levels.

Triggering emergency action

Advance warning is the key to effective response. It is possible to set up a series of warnings in advance of an actual extreme storm event that can be used as alerts. This could start with long-term climatologic forecasts or more immediate hurricane forecasts that identify potential danger. For specific basins an alert could be issued based on antecedent precipitation and rainfall intensity data in advance of an actual flood forecast. A more detailed forecast would then be issued when all of the data and information required to make a flood forecast became available.

The emergency response to such alerts is very site-specific and should be included in the plan. If, for example, emergency actions such as temporary levees are necessary, then the work could begin based on an alert rather than the specific forecast. The same may hold for emergency evacuation.

The response to an extreme flood forecast should be immediate, and with no uncertainty as to what actions and activities should be taken. The public expects governments to act quickly and in a professional manner under such circumstances. Community leaders should be visible, informed and active right from the start.

Training and response exercises

Emergency response teams need to be well trained in advance and their skills constantly upgraded. Once the disaster strikes, it is too late to train or try to find missing expertise. Trained staff should know their responsibilities, have immediate access to response plans and other critical information, and already have built a working relationship with colleagues in other organizations.

The only meaningful way to test response plans is to carry out periodic emergency exercises. These exercises are meant to simulate real emergency situations and test all aspects of the plan. Costs are significant, but have real payback in an actual emergency. Often critical gaps are identified and appropriate backup strategies developed as part of the exercise.

Advance preparation

Assuming that there is advance warning of a major storm event, a number of steps can be taken to increase readiness. Such steps include: construction of temporary flood protection works; placing emergency response teams on high alert; distribution of critical materials such as stockpiled sandbags to targeted locations; and preparation of emergency shelters and hospitals prepared for occupation.

The population at risk can be informed of what is expected of them in the actuality of an extreme event. As the event becomes more certain, actions such as evacuation of people, goods and machinery can begin. Even if the event is not as extreme as predicted, these preparations help test emergency response plans and inform the public as to the nature of natural hazards.

Media and public information sessions help set the stage as well. The media are key players in the link between public officials and the public. It helps if they are familiar with the terminology used in warnings and forecasts and know whom to contact for more detailed information during an actual flood event.

After the flood event

The emergency response does not end with the event, but continues through cleanup and resettlement stages. People will want to know what assistance will be made available, who is responsible, and how to go about seeking that assistance.

Senior levels of government should develop clearly defined response policies and programmes in advance. In the absence of such policies, the response is often ad hoc, politically and emotionally motivated, and sets precedents that are not wise in the longer run. Often the response is incomplete in that the obvious and immediate requirements are addressed, but fundamental changes in thinking and sustainable strategies are ignored.

After a major flood it is beneficial to conduct an assessment of the causes and effects of the flood and to make recommendations that would improve preparedness for the next event and reduce future flood losses. Such an assessment can also lead to improvements in flood plain management policies.

The long-term economic and social implications of flooding become evident in the post-disaster period. Governments need to demonstrate leadership and sometimes take bold steps to restore employment, address social issues and move the economy in a new direction. In that sense, natural disasters can be a positive motivator for change.

Integrated Flood Forecasting, Warning and Response System

3

3.1 Defining an Integrated System

Establishing a viable flood forecasting and warning system for communities at risk requires the combination of data, forecast tools, and trained forecasters. A flood-forecast system must provide sufficient lead time for communities to respond. Increasing lead time increases the potential to lower the level of damages and loss of life. Forecasts must be sufficiently accurate to promote confidence so that communities will respond when warned. If forecasts are inaccurate, then credibility of the programme will be questioned and no response actions will occur.

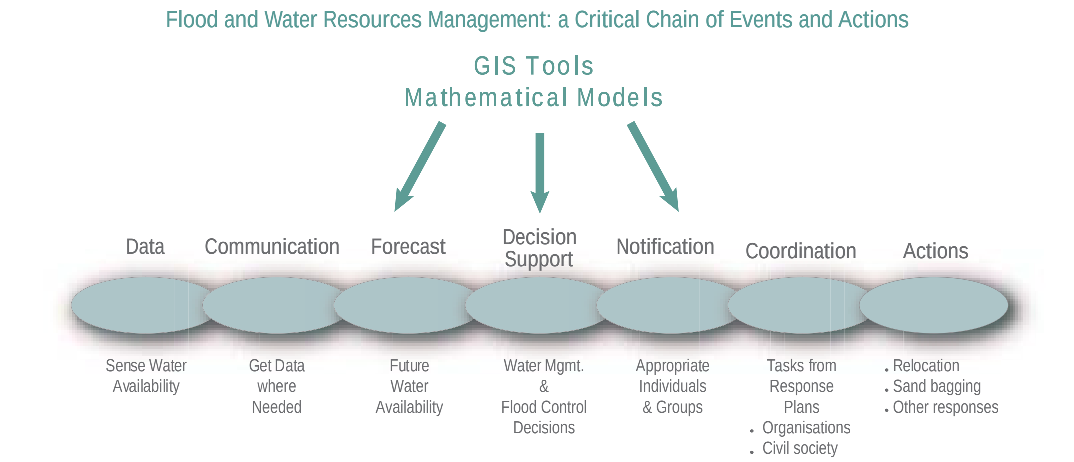
Flood-warning systems must be reliable and designed to operate during the most severe floods. The greatest benefits for an effective flood-warning programme occur when flooding is severe, widespread, and/or sudden, and when communities and organizations are prepared to mitigate impacts.

The implementation of an end-to-end flood forecast, warning and response system consists of many components. These components must be linked for successful operation. The interaction of components of the integrated flood forecast system or programme could be represented as a chain composed of many links. Each link must be present and functional if benefits are to be achieved. Figure 12 shows a schematic representation of the system as links in a chain.

The essential links or components of the integrated flood forecasting, warning and response system consist of a Data Source, Communications, Forecasts, Decision Support, Notification (often referred to as dissemination), Coordination, and Actions (or responses). A flood forecast and warning programme should be designed to mitigate floods, and, as such, it is an asset to overall water management. To achieve this, it is important that all of the components of the system be functional. If any component is dysfunctional, then this weak link could break the chain, resulting in an ineffective warning and response process. For example, if critical rainfall or streamflow data are unavailable or if the data are not relayed to a forecast centre for use in forecasting, then the critical lead time required to make decisions, coordinate activities, warn citizens, and take actions is not possible. If a perfect flood forecast is generated but does not reach the population at risk, then the warning system is useless. Equally, should the population at risk receive the warning

Figure 12

Integrated flood forecasting, warning and response system within IWRM



but not know what actions should be taken, then the system again would not have accomplished its purpose.

In the overall design of the integrated system, there are many factors that should be considered. The remainder of this chapter reviews some of these factors.

Basin characteristics

The physical characteristics of the basin, such as surface area, topography, geology, and land surface cover, will help to determine the nature of potential flooding and the basin's susceptibility to related hazards such as landslides and mudflows.

The hydrological response of the basin can be impacted upon by changes in land use associated with urbanization, forestry, agriculture, drainage, or channel modifications. A record of such changes over time is useful in establishing the dynamic relationship between rainfall and runoff. The following also contribute to an understanding of flood hazards: records of climate norms and trends for parameters, such as precipitation and evapotranspiration; and information on the usual effects of ENSO events and extreme events, from synoptic to mesoscale.

Population centres often are adjacent to rivers, and flood plains can be rich agricultural resources. Identification of populations and economic activities at risk should be carried out early in the process, as this will shape the eventual forecast output.

Flood history

Flood history, also known as paleohydrology, can be inferred from study of sediment deposits, tree ring analysis, and examination of a number of other biological indicators. Such analyses will not lead to a determination of flood volumes, but may help put a recent flood into context. Often, such records are of value in defining the flood history in a river basin, particularly when combined with stream gauge records that exist for contemporary periods. Other more recent historical information can be drawn from newspapers, journals and oral histories. Usually there is a perception level associated with flooding at a given location; large events are noted, smaller events are not.

The flood history will identify the portions of a basin subject to flooding, whether flooding is urban or rural or both, seasonal characteristics of flooding, and the feasible warning time. The type of flooding and associated hazards may be significantly different on tributaries compared to the main stem of the river. Knowledge of the factors contributing to or causing the flooding such as meteorological and antecedent conditions should be established for each flood event.

Lake flooding as well as flooding from ocean surge and tsunamis may pose problems quite different from river flooding. These guidelines are oriented to river flooding, but many principles contained herein are also applicable to varying degrees to other water-related disasters.

Environmental factors

Floods can induce major changes in river morphology, mobilize nutrients and contaminants in the soil, release other contaminants from storage depots, and discharge effluents to the river. Deforestation, fires and erosion of materials combined with saturated soils can lead to landslides, mudflows and other threats to human settlements. Sometimes floods are accompanied by strong winds that also can pose threats to human life and property. An analysis of potential environmental risks will help determine flood forecasting and warning needs. This can help to shape future approaches to flood plain management and regulation, and can assist in the design and establishment of response actions.

Economic factors

A flood forecasting, warning and response system comprises an important element of integrated water resources management. The benefits of river forecasts for power generation, navigation or irrigated agriculture make implementation of such a system more cost effective and sustainable. Even then, maintaining a system in a state of readiness between floods may be difficult.

An examination of past damages and the potential for future damages will help determine priority areas for flood forecasting, warning and response. Rigorous analysis would call for statistical analysis of flood peaks and the calculation of the present value of costs and benefits of flood forecasting and warning. In most cases, however, the benefits of flood forecasting, warning and response are virtually self-evident. The real questions are the affordability of various options and the desire of society to invoke a more pro-active stance to reducing flood losses.

Communities at risk

While flood losses in rural districts can be devastating to those areas, the most significant losses are usually in urban communities because of the concentration of people and related socio-economic investments. The basin characteristics and flood history of individual communities, combined with damage estimates from previous floods, will give some indication of the type of flood forecasting and warning system that may be most suitable for effective warnings. Once the system is defined, consideration should be given as to how it could benefit rural areas as well.

System identification

Depending on the nature of the basin and the type of event causing the flooding, potential warning times could vary from hours to several days to weeks. Communities subject to flash flooding require warnings of meteorological conditions that, when combined with antecedent basin conditions, could lead to flooding. This represents a special case of flood forecasting and warning. The challenge in such cases is rapid depiction of critical flood thresholds and their subsequent communication and emergency response. An analysis of historical rainfall records, including storm transposition and the resulting streamflow would help to identify areas of concern.

Photo: J. Laurie, Las Vegas Review Journal

Las Vegas, July 1999, flash flood meets desert

When warning times are longer than a few hours, full-fledged forecast systems should be contemplated. The degree of desired automation and sophistication must be considered in light of current needs and capabilities. Automation needs can be considered in sub-systems: data acquisition and transmission; data processing; forecast preparation; and forecast distribution. Different levels of automation may be required as the overall system develops and expands, and as financial resources become available. Systems may vary from those using largely manual observations, graphs and tables to highly automated multi-model systems running on computer workstations.

Benefit-Cost analysis

An analysis of the cost of floods and the potential benefits may help determine the type of forecast and warning system and response mechanisms that would be most cost effective. Costs resulting from flooding can be estimated for various magnitudes of events for various centres. Damage statistics from previous floods are also valuable in establishing the costs associated with such events. Judgement is needed to estimate the benefit of flood forecasting and warning in reducing damages and loss of life. Governments and financial institutions require such information on costs and benefits to help understand where expenditures will reap the largest rewards. Studies and analyses have shown that damage reduction due to forecast improvements can range from a few percentage points to as much as 35% of average annual flood damages.

A standard set of flood damage categories relevant to the basin should be developed. When loss of life is a threat, this too should be identified, even though it is difficult or impossible to quantify in economic terms. Other damage categories could include residential buildings; commercial, institutional and industrial buildings; agricultural lands; and infrastructure. Additional costs include temporary relocation and flood-fighting costs. Floods can have an effect on the population and economy of an entire country, and business losses should also be included in the analysis. Developing standard damage categories allows damages to be more accurately estimated for various levels of flooding.

A rigorous cost-benefit analysis would require determining a flood frequency distribution so that the present value of future benefits can be determined. In the absence of sufficient data or analysis, a more rudimentary presentation of costs and benefits may be sufficient to determine the size of the investment that is justified for flood forecasting, warning and response.

Evaluating existing capabilities

Most countries have basic networks of meteorological and hydrometric stations that are necessary for flood forecasting and warning. It is likely that the operators of the existing networks may be in many different agencies. In many cases, the networks may not have been designed to acquire data during extreme events, or they may not provide data in real-time or to common standards. Also, networks may not provide data for key urban centres where forecasts are required or for areas where the major inputs to the flooding are occurring. Identifying the existing network, its operators, and the existing approaches and capabilities are necessary steps in the evolution of a flood forecast system.

Another important element is an examination of existing communications capability. Given that important data are available at a remote site, how can these data be reliably transmitted to a flood-forecasting centre? Will telephone or radio links - manual or automated - function during a flood emergency?

Some agencies may have developed hydrological mathematical rainfall-runoff models and flow routing models for their own purposes. These models may be useful as flood forecasting models. An inventory of existing models will also help define current capability within individual agencies.

Identification of key users and collaborators

Establishment of a successful flood forecasting, warning and response system depends on a thorough analysis of existing capabilities, identification of key users for the system, and a good understanding of the interagency arrangements needed in an effective system. Considering these factors will lead to forecasts that meet user needs and that are more likely to be acted upon during an emergency. The ultimate goal of such a system is to ensure the safety and security of the public and to protect property and the environment. To achieve this result, however, means that the public must receive and understand forecasts, and the myriad of agencies having responsibility for emergency action and response also must receive the forecasts, have response strategies in place, and act upon the forecasts accordingly.

Key users typically include: civil agencies at the national, provincial/state, and local level; military organizations; corporations, especially those which operate structures; volunteer emergency response organizations; and the media. A user analysis, and close ties and interaction with these groups should be considered to help establish overall flood forecast needs and response measures. The role of the media in informing the public cannot be underestimated. It is critical that the media receive timely and authoritative forecasts and warnings. Media communications should encourage the appropriate public response and should not lead to counterproductive speculation.

Photo: V. Thanh, IFRC

Vietnam Mekong Delta floods, 2000
Roads and infrastructures were badly damaged by the floods in An Giang province, making relief distributions a challenge.

Many of the world's river basins have a transboundary component. In some cases transboundary basins are covered by treaty, international agreements, or other institutional arrangements. Such arrangements may or may not include river or flood forecasting. Shared basins imply a shared responsibility; an analysis of user needs should include users in other countries.

Often the mandate and capabilities of governmental organizations are not entirely clear. An institutional analysis of each agency's mandate, needs, capabilities and legal responsibility during a flood emergency will help shape an emergency preparedness and response plan. Overall, one agency should be assigned the lead responsibility (and accountability) for an end-to-end system, with the system itself potentially being operated by a number of organizations.

In the evaluation of the existing system, agencies that operate data collection networks or models, or that can contribute to a forecast system in other ways, will have been identified. In some cases the potential role of a specific agency in a flood forecast system may be relatively clear, while in other cases that role may have to be identified and negotiated.

A fundamental question is that of hydrological and meteorological coordination. In many countries one or more agencies operate meteorological forecast and climate networks, while hydrological networks may be the responsibility of entirely different agencies or departments. Coordination among these bodies is essential because development of a flood forecasting system may require the addition of new sensors or telemetry equipment funded by one agency being installed at a site operated by another one. A successful forecast system will depend upon cooperation among meteorological and hydrological agencies and could involve financial transactions among them.

Similarly there may be a number of agencies with responsibility for operation of structures for water management and flood control. These could include hydroelectric generation facilities, irrigation headworks, water supply reservoirs, and so forth. Individual structures may have an established operating plan, but an integrated plan for operations during extreme events is needed to provide optimal flood control benefits and to avoid structural failure. Interagency co-ordination and cooperation is required to ensure the integrity of the entire water management system during extreme events. A flood forecasting and warning system provides the information necessary to improve decision support for the operation of structures.

Some agencies may have arrangements for technical support or financial assistance with international organizations or with other countries. These may prove beneficial in developing or improving a forecast system through training and in general strengthening of much needed organizational infrastructure.

A logical agency to lead a country's flood forecasting and warning effort may emerge from this analysis. The identified agency will require technical support and leadership from several agencies. More importantly, there is a need for long-term political support for the endeavour. Flood forecasting and warning will have to compete with other national priorities, and resources and financial support can atrophy, particularly in the absence of flooding.

There is a need to establish a flood-forecasting centre having a legal mandate to issue authoritative forecasts and warnings on the river basin or at the provincial/state or national level. These forecasts must be understood by agencies having the responsibility for emergency response and by the general public. Such agencies, civil organizations and the general public must be aware of their roles, have response mechanisms in place, and know what actions to take under various circumstances.

Determination of specific forecast system requirements

Analysis of the basin characteristics, flood history, flood damages, and the existing databases will give some indication of the type of forecast system that is achievable and affordable. It is likely that the system will be based on enhancing existing networks and agency capabilities. Establishing a new system implies phased development from the existing system to the new one. Establishing a long-term plan with specific milestones is critical to future success.

3.2 The Hydrometeorological Network for Forecasting

The hydrometeorological network is the key requirement for most flood forecasting. In particular, precipitation and streamflow data are needed. If snowmelt is a factor in flooding, then measurements of snow water equivalent, extent of snow cover, and air temperature are also important. In many cases agencies other than the forecast agency have useful data. Rather than duplicate networks, it is preferable to develop cooperative arrangements. In some respects, it is preferable that the network serves many purposes as this may result in its broader financial support.

In most cases data network operational performance is the weakest link within the integrated system. Operational data networks must be examined. Are the rainfall and stream gauge (hydrometric) data networks satisfactory in sampling rainfall (intensity and spatial distribution) and streamflow response for the river basin? Are stream gauges operating properly, and are they providing accurate conditions of water level and streamflow? Are data communicated reliably between the gauge sites and the forecast centre? How often are observations taken, and how long does it take for observations to be transmitted to the forecast centre? Are data available to users who need the information for decision making? Are the data archived for future use? Are the data collected to known standards, is the equipment properly maintained and calibrated, and are the data quality controlled?

Network design

It is not possible to manage water or forecast floods without data. Various types and sources of data are needed to monitor the environment, conduct a water balance or provide input to hydrological models that estimate streamflow from rainfall. Operating a real-time hydrometeorological network is essential, as data provide the foundation for establishing the potential for flooding. In-situ observations of meteorological and hydrological parameters are required as inputs to the hydrological prediction system.

An analysis of the existing network should be undertaken. Tables and maps should be available providing details on monitoring locations, parameters, sensors, recorders, telemetry equipment and other related data. In addition, monitoring sites in adjacent basins should be inventoried. In low relief basins, data from those sites could be very useful. Analysis should be performed to identify sub-basins that are hydrologically or meteorologically similar.

Based on forecast needs, the adequacy of networks can be determined and required modifications can be noted. These could include new stream gauges, rain gauges and possibly other sensors in the headwaters, or additional telemetry equipment. In some cases, network sites may not be well suited for obtaining flow measurements or other data under extreme conditions. Costly structural alterations may be needed. Interagency agreements may be needed for maintenance and operation of the network.

A key variable to be established is the time step needed to adequately forecast a flood for a given location. If the time step is, say, six hours then data must be collected every three hours or even more frequently. In many cases, supplementing a manual observer network with some automated gauges may provide an adequate operational network.

Data acquisition

Generally the design and operation of data networks have a large influence on forecast system accuracy and in the ability of the system to provide the necessary lead-time to issue warnings so that response actions can be taken. It should be underscored that the design of reliable real-time operational observing networks is critical to the success of a forecast, warning and response programme. In order to be effective during extreme conditions, sensor installations may have to be "hardened" to withstand extremes in wind, rain or flood stage.

The advent of remotely sensed data has significantly improved the ability of operational hydrology to infer watershed conditions in data-sparse regions. The application of radar-derived precipitation estimates serves as the principle tool in forecasting floods and flash floods in many countries. The use of geostationary and polar orbiting satellites to derive large volumes of meteorological and hydrological products is rapidly advancing. Remotely sensed data can now be used to provide estimates of precipitation, snowpack extent, vegetation type, land use, evapotranspiration, soil moisture and flood inundation. This information is becoming increasingly useful in data-sparse regions of the world where water availability and flood forecasts are needed.

Many countries use the Global Telecommunications System (GTS) of the World Meteorological Organization (WMO) for the transfer of real-time meteorological data. More recently, some hydrological data from a number of projects were added to the system. Even with these advances in remotely sensed data and their use, inadequacy of data remains the biggest weakness in establishing a viable flood forecast programme for a river basin or for a country.

Data communications

For data to be useful to the forecast centre, point data observed at remote locations must be converted to digital formats. This may require changing the sensor itself or simply adding another component to an existing system. The format for the digital data must be specified. Remotely sensed images used in forecasts are usually already in a specified digital format. If the sensor output is film, arrangements must be made to make the conversion to a specified digital format within the required time.

Once data have been observed or collected at sites throughout the river basin or country, the data must be transmitted to locations where they can be stored, accessed, and used. The value of data increases with the speed of transmission and processing, from their initial observation to where they are used. Meteorological and hydrological data are needed almost instantaneously so that the hydrological forecast system can produce up-to-date and reliable forecasts. More importantly, this allows the system to provide the critical warning times needed for users to take actions. This is especially true for issuing warnings of flash flood events and of potentially hazardous mudslide conditions.

There are many types of communication technologies that can be applied to transmit data from sites in remote locations to the forecast centres. The most common form of data communication is by telephone. However, telephone lines frequently fail during severe flood events. More reliable but potentially more expensive forms of data communications are satellite, line of site radio, cellular radio and meteor bursts. These also have their strengths and weaknesses. An evaluation should be performed to establish the most suitable, reliable and cost-effective form of communication for the local situation.

Data may be transmitted by dedicated satellite links, radio links, by commercial telephone links or other shared services. In some cases the data link could simply be a voice telephone communication. The forecast centre may be required to poll sites individually, interrogate a third-party system, or use the Internet to obtain data. Data transmission links must be identified, and their reliability and speed should be determined. If image products are to play a role in the real time forecasts, bandwidth of the transmission system and speed of the processing system should be examined.

In many cases, national, provincial/state, local governments and the private sector operate real-time data networks to support their individual needs. In most cases, these data are not shared, and each organization is limited to its own data. Coordination and data sharing can significantly increase the amount of data available for all organizations. These additional data, possibly complemented with new sites, will help increase forecast accuracy at the least cost.

Network operation

Often times the current operator of a site will not have had a need for, or experience with, real time data acquisition. Intensive staff training may be required to ensure that data are available when needed and are of a suitable quality.

Long-term maintenance is a major requirement in operational forecasting. The forecast network may be in operation only seasonally or less frequently. Keeping the network in a state of readiness though necessitates major changes in operating philosophy. The development of water management operational forecasts by the forecast centre, as well as flood forecasts, enhances the usefulness of the data network and communications systems, as well as maintaining a state of readiness.

Funding of alterations to existing networks and for future maintenance presents a major challenge. Negotiations among operating or funding agencies may require abandoning entrenched positions if success is to be achieved.

3.3 Meteorological Support

Given the importance of meteorological data and forecasts to the production of flood forecasts, it is very important that there be close collaboration between national meteorological and hydrological services. This collaboration could take several forms and should focus on increasing the accuracy and utility of knowledge of existing conditions and forecasted states. Two important products are optimal quantitative precipitation estimates - where, when and how much precipitation has actually fallen - and quantitative precipitation forecasts - where, when, and how much precipitation will actually fall. Other parameters of interest include wind speed and direction, surface temperature, and relative humidity.

Quantitative Precipitation Estimation (QPE)

Optimal estimates of existing precipitation conditions provide the hydrologist with the most accurate estimates of what are termed "antecedent conditions". These are extremely important for hydrological process modelling. Much work has been done to increase the accuracy of the estimates through increasing the density of in-situ stations, implementing ground-based surface radar, in processing of satellite based data, and in merging various sources of data.

Quantitative Precipitation Forecasting (QPF)

The ultimate goal of flood forecasting is to provide accurate forecasts of hydrological conditions. Currently, deterministic quantitative precipitation forecasts and other forecasted meteorological parameters can be applied as input to hydrological models in order to derive hydrological forecasts using numerical modelling methods.

It is typical that the hydrological forecaster receives single "best effort" meteorological products such as QPF, wind speeds and direction, temperature, and pressure. These products are based on numerical weather prediction model output and are modified using expert forecaster judgement. Forecast models are typically run once or twice daily depending on the operational practices of the national meteorological service. The useful forecast horizon of such products is typically about five days, with accuracy decreasing rapidly towards that of long-term climatology. The usefulness of QPF products derived from such modelling is usually constrained to one to two days due to poor performance beyond these limits.

When very short forecast horizons on the order of six hours or less could prove beneficial, extrapolative and trend-based meteorological techniques are used. The use of these techniques is referred to as "nowcasting", resulting in short-range QPF. These shorter time horizons associated with nowcasting are particularly useful for flash-flood forecasting. Beyond this horizon, numerical weather prediction models combined with expert judgement provide more accurate estimates of future meteorological conditions such as QPF.

Work is currently proceeding on the coupling of mesoscale numerical weather prediction models with high-resolution hydrological process models. Questions still exist on how to best incorporate expert judgement into this process in order to provide a single "best effort" estimate of future hydrological conditions.

One forecast methodology that can be applied to both meteorological and hydrological forecasting is the "Ensemble Technique", wherein multiple forecast scenarios are generated by the execution of several model runs, each with slightly varied initial states. The magnitude and degree of the uncertainty associated with the forecast ensemble provide a probabilistic view of the potential future meteorological and hydrological states. Although more study and further development are needed before this becomes more broadly used in operational practice, the technique holds much promise.

Once a flood forecasting centre has been in operation for a period of time and close collaboration exists with meteorological counterparts, weaknesses in both meteorological and hydrological forecast products may become evident. Sometimes the weaknesses can be overcome by improving the database used for the forecast. In other cases, there will be a need to improve understanding of the underlying hydrological processes involved in the production of hydrological forecasts.

Other parameters of interest

Estimation of other parameters is important for flood forecasting and for assessing antecedent basin conditions. These include antecedent temperature, humidity, and evapotranspiration, all of which are very important in assessing soil moisture conditions and water deficits prior to the onset of precipitation.

3.4 The Forecast Centre

The flood forecast centre must be identifiable to agencies and to the public as the authoritative source of flood forecasts and warnings. The forecasts produced by the centre must be to the highest achievable technical standard and be released to the public unfiltered by agency or political interests. The long-term stability of the centre is dependent on the credibility and utility of its forecasts.

Administratively the centre can be part of one agency or it could be a new entity supported by several agencies. The forecast centre could be self-contained or, more likely, will depend on other agencies for support.

Establishment of the centre

Analysis of existing conditions and needs will determine whether a forecast centre will be established by strengthening an existing facility or by creating a completely new enterprise. The decision should be based on political, administrative and technical leadership of candidate agencies, as well as the ability of the selected agency to work with others.

A project initiation team drawn from several national agencies or consultants, with support from international organizations and working to agreed-upon terms of reference, could examine the issues identified in these Guidelines and make recommendations concerning the development of a Forecast Centre. Their report should identify technical issues, personnel needed, administrative issues, costs, and timelines.

Interagency agreements will be needed for provision of data, operation of structures, weather forecasts, technical and administrative support, and other tasks. Depending on the basin, it is possible that such agreements might already exist. They may include clearly articulated roles and responsibilities, clear specifications of work, performance measures, and provisions for financial arrangements. International agreements for provision of data, use of satellite technology, and other support activities may also be required.

The Centre needs financing over both the short and longer term. Short-term financing will be capital intensive as funding may be necessary for network improvements, construction, the acquisition of computers and software, and many other items. These could best be funded by special national appropriations or international support. There may also be a local market for specialized forecast products, which could be paid for by users.

Long-term financing will be needed to operate the Centre, pay staff, upgrade computer systems, and make improvements in the forecast methodologies. This operation will require on-going national support even where specific improvements are funded internationally. If the mandate of the Centre were expanded to include river forecasts for operational water management purposes, financial support could be made available from agencies using the river forecasts. The possibilities include revenue from sale of water licenses, other water use charges, or fees assessed to discourage development within the flood plain.

To operate effectively the Centre will need key personnel. Aside from technical skills, the Centre will need people capable of working collaboratively with other agencies and who can communicate effectively. A significant training programme will be needed at the onset of the Centre, and the costs of on-going training should be built into the budget. In the early stages, forecast procedures may have to be tailored to the ability of existing staff, and a training and development plan should be established to upgrade skills and techniques to improve the accuracy and utility of the forecast.

There will be an early need to gather basic data, calibrate and verify models, and establish working arrangements with other agencies. Visiting experts, or placing key staff in other Forecast Centres for training, could aid this process.

One approach in the early stages of development would be to concentrate efforts on a key basin or one of its sub-basins. Such a pilot project could help verify the suitability of models selected and the capabilities of staff. This would give funding agencies a level of comfort. In the very earliest stages of development, the Centre could simply analyze weather forecasts and provide warnings of potential high flow conditions.

Data processing

Although data may have been pre-processed elsewhere, the Forecast Centre will require in-house data processing capability. Although some work could be done manually, computer systems should have uninterruptible power supplies. At the very least, emergency power systems should be available.

If Geographic Information Systems and image products are expected to be used for real-time forecasts, computer memory and speed must be taken into account. Overall computing system architecture and design should be planned for as part of the future development of the Centre.

Data processing needs will also depend upon the selected forecast models and their data processing requirements. In the absence of other requirements, data should be digitally available and easily converted to formats used by commercially-available spreadsheet programmes.

Arrangements must also be made to electronically archive data so that they are available for use in subsequent years. Some data will have to be brought forward frequently for use, while other data will only be used on occasion.

Forecast Centre operation

It is necessary to establish basic operating procedures and assign staff responsibilities early in the operation of the Centre. Part of this is the assignment of responsibilities for on-going maintenance of systems.

Capable staff are the key to producing good forecasts and maintaining the Centre's credibility. Capable staff will also be attracted to positions elsewhere so some staff turnover can be expected. A systematic plan for staff training and development and the assignment of challenging work will help reduce turnover rates. Some contingency planning will be needed to ensure that the Centre will continue to operate when key staff members leave. Efforts should be made to develop an operations manual in order to reduce the Centre's vulnerability to loss of staff or other unanticipated events. The manual should cover all aspects of the Centre's operation and maintenance, and it should include lists of key contacts beyond the Centre.

Once the Centre has completed its first significant flood forecast season, an end-to-end review of all aspects of the forecast should be conducted to identify what went well and where improvement might be necessary. The review should include interviews with persons from other agencies and forecast users. The results of such a review should be used to modify procedures. Periodic audits of forecast procedures and Centre operations should be carried out, perhaps involving staff from other Forecast Centres.

Forecast models

There are a large number of public domain and proprietary models available for use in flood forecasting. Sometimes the model can be simply a statistical rainfall-runoff relation with a routing equation, while other models can be much more complex. Hydrological models can be classified as lumped, semi-distributed or distributed, and as being single event or continuous. Probabilistic models that take data uncertainties into account are also available. Model selection will depend on available data, basin characteristics, and the needs of the local user community.

A lumped model treats the watershed as a single unit for inputting data and calculating runoff. The calculations are statistically based and relate to the underlying hydrological processes as a spatially averaged process. Models based on scaling unit hydrographs would fall into this category. Some lumped models allow the watershed to be subdivided or for some parameters to be physically estimated and modelled. When subdivisions of a basin are combined to produce a forecast, this modelling approach is termed semi-distributed. Depending on forecast needs and the characteristics of the watershed, a lumped model may be all that is required.

A distributed model simulates the key hydrological processes that occur in a watershed using distributed data inputs and processes. For forecasting purposes these commonly include precipitation, interception, infiltration, interflow, and baseflow. Overland flow and channel routing may be incorporated into the model or calculated in a hydraulic model. Distributed models require much more data and knowledge of watershed processes than lumped models. When the model is first established, precipitation and land cover characteristics may be the only distributed features.

Hydraulic models used in channel routing calculate the travel time of the flood wave and its attenuation. These models use the standard equations of unsteady, non-uniform flow with various simplifications depending on the channel characteristics, available data and accuracy requirements. Storage-flow relations are often incorporated into hydrological models. One-dimensional unsteady flow hydraulic models can be used to route flows through multiple channels or in situations where overland flow is a serious concern.

Probabilistic forecasts are typically derived using hydrological process models wherein statistical distributions are used to describe the uncertainty of input data and basin conditions such as precipitation data, soil moisture and snow pack conditions. A large number of model projections are produced that can be statistically analyzed to allow for a better understanding of the uncertainty of the forecasted future water conditions. This approach is rapidly gaining popularity, as it provides the decision-maker with the probability of an extreme event to occur, not just that it might occur.

Simplified probabilistic methodologies that provide a range of possible forecasts have existed for some time. This is achieved by the forecaster making assumptions concerning future precipitation to determine runoff under normal, lower, or upper decile conditions. More modern approaches, which tend to be in the pilot testing stage, attempt to better quantify the uncertainty associated with the forecasted meteorological conditions and to directly link this uncertainty to the uncertainty of the flood estimate.

Sophistication of hydrological forecasting

Essentially, the prevailing geomorphological conditions of the river basin and the interaction of communities at risk with the river system dictate the level of sophistication of the modelling solution. The performance of existing models or forecast procedures should be evaluated. Whether the forecast process involves use of simple graphs or tables or a robust integrated modelling system, evaluation of forecast accuracy versus lead-time should be determined. Does the system perform well when adequate data are available? Are model parameters up-to-date? Do model parameters reflect land use changes that have occurred within the basin? Can the model or its parameters be easily modified to reflect pending land-use changes within the basin? Does the modelling system reflect flood control structures and their operations within the basin? Are there important hydrological processes occurring in the basin that are not reflected in the existing forecast model? Does the forecast system perform well for flooding but is inadequate to meet routine or low flow forecast requirements? Is there a need to convert hydrological forecasts to water level (stage) using a hydraulic model? In general, is the existing modelling system appropriate and sufficient to meet user requirements?

Hydrological forecasting knowledge

Highly trained hydrologists produce reliable hydrological forecasts. Forecasters use real-time data, knowledge of hydrology, knowledge of the hydrological modelling system and experience in producing forecasts and warnings. In determining the operational readiness or hydrological forecast capability of a forecast centre, the education, knowledge and skills of the forecasters are as important as the tools they use. Is the number of forecasters available sufficient to handle the flooding situation? Do the forecasters have sufficient education in hydrology and meteorology to appropriately apply the tools? Are they properly trained, and do they understand the limitations of the modelling system being used? Do the forecasters know the users, how to contact them, and what information they require for flood response actions? An assessment of the adequacy of the operational forecaster capability is important in determining how to improve flood forecast operations.

Forecasts

In order to produce a flood forecast for the communities and locations at risk, there must be a hydrological modelling capability that uses meteorological and hydrological data. Hydrological models use real-time precipitation and streamflow data. The models translate observed conditions into future stream conditions. Hydrological models or procedures vary in complexity, accuracy and ease of use. Simple hydrological models consist of tables, graphs or empirically derived relationships. More sophisticated hydrological modelling systems use in-situ data, remotely sensed data, and multiple hydrological models that are integrated to produce very accurate hydrological forecasts. Due to advances in Geographic Information Systems and the availability of geo-referenced data, parameters of some hydrological models can now be estimated without having to rely exclusively on historical hydrological data for model calibration. The evolution of personal computer technology has paved the way for quite complex modelling systems to be run on them. These systems are easier to use, are easier to maintain, and are more affordable.

Current hydrological forecast systems are quite affordable and powerful. The degree of success associated with these systems is dependent on the amount of training received by the hydrologists using them. These systems are capable of producing a broad range of forecasts of stream conditions that will occur in a few hours to seasonal probabilistic outlooks targeted to months in advance for larger rivers. Model system selection depends on the amount of data available, complexity of hydrological processes to be modelled, accuracy and reliability required, lead-time required, type and frequency of floods that occur, and user requirements.

Hydraulic models are often used to translate hydrological model-derived streamflow to water-level conditions. Hydraulic models are also valuable in forecasting the streamflow conditions of large rivers where sufficient lead-time is accorded through translation of upstream water levels to downstream communities at risk. Such models can be interfaced with geographical information systems to provide dynamic water level conditions on maps of communities. These types of forecast products can be invaluable to communities and emergency organizations, as they provide very precise information about areas that will be inundated and when.

Decision support

Hydrometeorological data and accurate forecasts are of no value if the forecasts do not reach users and if decisions are not made as to the appropriate actions required. Hydrological forecasts and hydraulic conditions must be disseminated so that decisions can be made and actions taken to reduce the impact of the pending event. Decision support refers to everything from forecasts reaching decision makers such as a mayor of a flood-prone community to the operator of a flood-control structure. For decision support to be effective, advanced planning must define prescribed actions linked to forecasted values.

Decision support systems vary from rules or procedures that must be followed under prescribed conditions to mathematical optimization programmes. Such approaches define actions to be taken based on tradeoffs among various options for water allocation.

Forecast output

Typically, calculations used in preparing a forecast are based on units of discharge, although some simplified systems correlate upstream with downstream water levels.

However, decision makers and the public are most often concerned with water levels and velocities at specific points, usually urban centres. Forecasted flows can be converted to water levels and velocities using stage-discharge and stage-velocity relations, hydraulic models, or other techniques. Decision makers and emergency workers should be consulted on their specific forecast requirements.

In many cases, forecast water levels are given according to a local vertical datum. This may be convenient for some purposes but may introduce potential for confusion. With the advent of global positioning systems, it is possible to provide a geodetic datum at any location and this should be done.

The forecast water levels released to the public could be in several formats: tabular, hydrographs, or inundation maps. It is very useful to provide comparisons with the previous year or with previous major floods. Inundation maps linked to databases can provide information on individual properties and can be most useful for public awareness and emergency services.

The forecast should be formally released and made available to key agencies as well as the media. The forecast should also be placed on Internet websites for easy access.

The points for which the forecast applies should be communicated very clearly. For example, the name of a city in the basin should be identified, or in the case of very large cities, well-known points within the city should be specified.

Uncertainty in the forecast should be represented accurately, but in non-technical language. Phrases such as "if present conditions continue…" are useful as are those that require simple statistical knowledge such as "there is an 80% chance that…"

Dissemination of forecasts and warnings

Forecast and warning dissemination is extremely important. Frequently, the lack of ability to disseminate warnings to the population at risk is the weakest link in the integrated system. Forecasts and warnings must reach users without delay and with sufficient lead-time to permit response actions to take place. Dissemination of forecasts and warnings can be achieved through a variety of communication methods. An inventory of the various communications media used by the forecast system will reveal the competency of the dissemination process. How are warnings transmitted to the public, to the flood control agencies, to the emergency services and civil protection organizations? Are communication systems reliable? What types of communication modes are used (such as satellite, radio, meteor bursts, telephone or internet)? How are communications lines maintained? Are there backup modes of communication? In what format are warnings transmitted? Do users understand the content of the warnings? These are a few of the questions that need to be answered in assessing the performance of dissemination systems.

Users

Who are the users? Understanding the needs of users is fundamental to achieving a successful flood forecast, warning and response programme. What kinds of data and information do they need? Where are they? How do you reach them during the day or late at night or during a national holiday? How do they make decisions?

Establishing a user group association or an inventory of users is important for a well functioning and effective forecasting system. The sophistication and needs of users can vary considerably. For example, the hydropower industry needs high-resolution data, detailed hydrological forecasts for short-term as well as for longer time horizons. Emergency services groups and media organizations need clearly stated warning information that defines the hazard and spells out what steps the public must take to minimize their risk.

Notification and action

The entire process of establishing a flood forecast is of no value unless data and forecasts reach users. An effective fail-safe forecast dissemination system must be established to allow forecasts and warnings to reach users, wherever they are. Notifying users is often problematic because many countries do not have communication systems that reach rural villages and other communities at risk. Internet is an effective worldwide communication system, but the user must have access and be vigilant in order to receive the warning. There are many examples of effective dissemination systems based on high-speed telecommunications that use satellite, microwave, radio, or meteor burst technology.

An effective flood-warning programme must also be linked to the media to reach populations inhabiting the areas at risk. In many cases, the media can provide an effective means of re-broadcasting warnings and assist in response-oriented communications.

The payoff from a successful end-to-end flood forecast and response programme is when actions are taken to reduce the impact of the impending flood. Actions can be as simple as moving contents from the first floor of a person's house to the second floor, evacuating the flood plain, blocking roads that will be flooded, or closing floodgates of a levee system that protects a city. If no mitigation actions result from flood forecasts and warnings, society is simply paying money for ineffective results.

Establishing an Integrated System

4

There are a number of steps that should be followed in establishing an integrated flood forecast, warning and response system. These steps are very important and have been introduced in greater detail earlier in these Guidelines. The intent of this section is to provide a brief overview of these steps. In doing so, there will be some reiteration of previously introduced concepts and material.

The first step for a community, country or region is to conduct an assessment of the existing flood forecast programme. Each of the links or components of the forecast system should be evaluated as to its effectiveness.

After the existing system has been assessed, a new and improved system can be designed. The new system design should strengthen the weak links of the existing forecast system, meet the needs of the users, and provide sufficient accuracy and lead time to reduce flood losses to the maximum possible extent. Like any other project, the new forecast system will be subject to cost constraints and must therefore concentrate on those improvements that will yield the greatest benefits in terms of reducing human and economic losses.

Frequently financial institutions supporting flood forecast modernization projects will require an economic analysis or feasibility study to determine the benefits versus the costs of the project and subsequent programmes. Usually there are significant economic gains that can be realized by investing in an integrated flood forecast system. For example the U.S. National Oceanic and Atmospheric Administration National Weather Service (NOAA/NWS) is proposing investing $US 60 million in the Advanced Hydrologic Prediction Services (AHPS) project. The economic analysis demonstrated benefits of $US 360 million per year from reducing flood losses and from providing forecasts to the water management sector of the economy.

The following are steps required for establishing an improved integrated system. Each of these components should be considered in the overall design with emphasis on strengthening the weakest links within the existing system.

- Design improved meteorological observing network
- Design improved hydrological network (precipitation and stream gauges)
- Automate the meteorological and hydrological networks
- Establish real-time communication system to move data reliably from field to the forecast office
- Establish operational network maintenance plan
- Determine feasibility of existing and new ground-based radar for estimating quantitative precipitation products
- Determine feasibility of using geostationary and polar orbiting satellite products
- Integrate in-situ precipitation data with satellite and radar precipitation estimates
- Establish hydrometeorological database and management system
- Select hydrological and hydraulic models appropriate for river basin conditions and needs of the users
- Establish real-time linkages between databases and modelling system

- Link numerical weather prediction model products to the hydrological forecast system (Quantitative Precipitation Forecasts and Climate Forecasts)

- Determine the training needs for new hydrological forecast methods versus current forecaster knowledge

- Establish training programmes and materials

- Design real-time communications system to disseminate routine forecasts and warnings to target audiences (e.g., communities, media, mayors, government officials)

- Establish user group networks and protocols to interact with forecasters and system outputs to ensure forecast products are appropriately designed for the users

- Establish an "Operations Concept" that defines how the hydrological forecast centre will operate in routine operations as well as during major flood episodes in the improved system

- Establish response strategies with communities, emergency services, and civil protectorate organizations

Once the design of the improved integrated system has been completed, this design must then be incorporated into a project proposal with associated costs and time lines for approval by the various governmental entities involved, as well as by donor and financial institutions. Once approved, a detailed implementation plan must be developed. It should show how the various components of the new system would be completed and integrated into a sustainable forecast programme.

The science and technology required to produce a fully integrated flood forecast and response system are available today. There are many systems now operating that have achieved a high degree of integration and sustainability. Cooperation amongst levels of government, ministries, civil society and private industry is absolutely necessary to achieve an integrated programme. Interaction between meteorological and hydrological organizations is essential for establishing a viable flood forecasting, warning and response programme.

Bibliography

General

Abramovitz, J. (1999), "Unnatural Disasters", World Watch, 1999 July/August. Worldwatch Institute, Washington, D.C.

Abramovitz, J. (2001), "Averting Natural Disasters" in: Brown, L., Flavin, C., and French, Hillary (eds.), State of the World 2001, Worldwatch Institute 2001, W.W. Norton & Company, pp. 123-142.

Affeltranger, B. (2001), "Public Participation in the design of local strategies for flood mitigation and control", IHP, Technical Documents in Hydrology No. 48, UNESCO, Paris.

Andjelkovic, Ivan (2001), "Guidelines on non-structural measures in urban flood management", IHP, Technical Documents in Hydrology No. 50, UNESCO, Paris.

Arnold, Margaret and Kreimer, Alcira (eds.) (2000), "Managing Disaster Risk in Emerging Economies", Disaster Risk Management Series No. 2, World Bank, Washington, D.C.

Barrett, Curtis (1999), "Development of Global Integrated Water Management Systems", Journal of Management in Engineering, American Society of Civil Engineers, Vol. 15,No. 4, July/August.

Centre for Research on the Epidemiology of Disasters (CRED) (2002), "EM-DAT: The OFDA/CRED International Disaster Database - www.cred.be/emdat", Université Catholique de Louvain, Brussels.

Economic Commission for Europe (ECE) (ed.) (2000),"Guidelines on Sustainable Flood Prevention", September 2000, Geneva, submitted at the Meeting of the Parties to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, Second meeting, The Hague, Netherlands, 23-25 March, 2000.

Enarson, Elaine and Morrow, Betty Hearn (eds.) (1998), The Gendered Terrain of Disaster: Through Women's Eyes, Greenwood Publishing (forthcoming).

Enarson, Elaine (2000),"Gender and Natural Disasters", Working Paper I, International Labour Organization (ILO)/Recovery and Reconstruction Department, Geneva, September.

Enarson, Elaine (2001), "Gender Equality, Environmental Management, and Natural Disaster Mitigation", Report from the On-Line Conference conducted by the United Nations, Department for Economic and Social Affairs, Division for the Advancement of Women, New York, November.

Freeman, Paul K.; Martin, Leslie A.; Mechler, Reinhard and Warner, Koko (eds.) (2002), "Catastrophes and Development. Integrating Natural Catastrophes into Development Planning", Disaster Risk Management Working Paper Series No. 4, World Bank, Washington, D.C., April.

Gilbert, Roy and Kreimer, Alcira (1999), "Learning from World Bank's Experience of Natural Disasters Related Assistance", World Bank Paper Series No. 2, Disaster Management Facility, World Bank, Washington, D.C.

Hydrology Subcommittee of the Federal Interagency Advisory Committee (1985), "Guidelines on Community Flood Warning and Response Systems", USA, United States Geological Survey, Office of Water Data Coordination, Reston, Virginia.

Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR) (2002), “Living with Risk - A global review of disaster reduction initiatives”, UN/ISDR, Geneva.

International Commission for the Protection of the Rhine (2002), "Non Structural Flood Plain Management Measures and their effectiveness".

International Federation of Red Cross and Red Crescent Societies (1999), "Vulnerability and capacity assessment: International Federation Guide", IFRC Geneva, (English, French, Spanish, Arabic).

International Federation of the Red Cross and Red Crescent Societies (2001), "World Disasters Report 2001", IFRC Geneva.

International Federation of the Red Cross and Red Crescent Societies (2002), "World Disasters Report 2002", IFRC Geneva.

International Monetary Fund (IMF) (2002), "The World Economic Outlook (WEO) Database", IMF, Washington D.C.

McKellar, L., Freeman, P.K. and Ermolieva, T. (1999), "Estimating Natural Catastrophic Risk Exposure and the Benefits of Risk Transfer in Developing Countries", In: Proceedings of the EuroConference on Global Change and Catastrophic Risk Management: Flood Risks in Europe. IIASA, Laxenburg, Austria, 6-9 June.

Munich Re (2001), "Topics, Annual Review: Natural Catastrophes 2000", Munich Re, Munich.

Parker, D.J. (ed.) (2000), "Floods Vol. I & Vol. II ", Routledge Hazards and Disasters Series, Routledge, London.

United Nations Development Programme and United Nations Economic Commission for Latin America and the Caribbean (UNDP/ECLAC) (1998), "A Preliminary Assessment of Damages Caused by Hurricane Mitch".

United Nations Economic and Social Commission for Asia and the Pacific (1999), "Regional Cooperation in the Twenty-First Century on Flood Control and Management in Asia and the Pacific", United Nations: New York.

United Nations Department of Economic and Social Affairs (2002), "Natural Disasters and Sustainable Development: Understanding the links between Development, Environment and Natural Disasters", Background Paper No. 5, submitted by the United Nations International Strategy for Disaster Reduction, for the Commission on Sustainable Development, Second Preparatory Session, 28 January - 8 February 2002, New York.

United Nations, Department of Economic and Social Affairs, Division for the Advancement of Women (DAW) and Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR) (2001), " Environmental Management and the Mitigation of Natural Disasters: a Gender Perspective", Report of the Expert Group Meeting, Ankara, Turkey, 6 - 9 November 2001.

U.S. Department of Commerce (2002), "Hurricane Reconstruction Program-Central America and the Dominican Republic, FINAL REPORT", Washington, D.C.

World Bank (2001), "Managing Economic Crisis and Natural Disasters", in World Development Report 2000/2001, (Chap. 9), World Bank, Washington, D.C.

World Meteorological Organization (WMO) (1999), "Comprehensive Risk Assessment for Natural Hazards", WMO/TD No. 955, Geneva.

Regional and country experiences

Asian Disaster Preparedness Center (ed.) (2002), Asian Disaster Management News, Drought Management, Vol. 8, No. 3, July-September.

Asian Disaster Preparedness Center (ed.) (2002), Asian Disaster Management News, Flood Preparedness, Vol. 8, No. 2, April-June.

Asian Disaster Preparedness Center (ed.) (2002), Asian Disaster Management News, Information Sharing and Networking in Disaster Management, Vol. 8, No. 1, January-March.

Asian Disaster Preparedness Center (ed.) (2001), Asian Disaster Management News, Linking Local Governance and Community-Based Disaster Management, Vol. 7 No. 4, October-December.

Asian Disaster Preparedness Center (ed.) (2001), Asian Disaster Management News, Reducing the Impact of Disasters on Tourism, Vol. 7, No. 2-3, April-September.

Asian Disaster Preparedness Center (ed.) (2000), Asian Disaster Management News, Networking in Disaster Management, Vol. 6, No. 3-4, July-December.

Asian Disaster Preparedness Center (ed.) (2000), Asian Disaster Management News, Public Health in Disasters, Vol. 6, No. 2, April-June.

Asian Disaster Preparedness Center (ed.) (2000), Asian Disaster Management News, Reconstruction after Disaster Vol. 6, No. 1, January-March.

Asian Disaster Preparedness Center (ed.) (1999), Asian Disaster Management News, Role of Local Government in Disaster Management Vol. 5, No. 1, February.

Asian Disaster Preparedness Center (ed.) (1998), Asian Disaster Management News, Extreme Climate Events Vol. 4, No. 1, October.

Asian Disaster Preparedness Center (ed.) (1997), Asian Disaster Management News, Gender and Disasters, Vol. 3, No. 3, November.

Asian Disaster Preparedness Center (ed.) (1997), Asian Disaster Management News, Community Based Approaches in Disaster Management, Vol. 3, No. 2, June.

Asian Disaster Preparedness Center (ed.) (1997), Asian Disaster Management News, Networking, Vol. 3, No. 1, February.

Asian Disaster Reduction Center (ADRC) (2001), "Information Technology For Disaster Management", International Paper No.1, August.

Asian Disaster Reduction Center (ADRC) (2002), "Report of Regional Workshop on Networking and Collaboration among Non-Governmental Organizations of Asian Countries in Disaster Reduction and Response", 20-22 February, 2002, Kobe, Japan.

Asian Disaster Reduction Center (ADRC) (2001), Annual Report No. 4.

Asian Disaster Reduction Center (ADRC) (2001), "Survey Report of Disaster Prevention and Management Frameworks in Northeast Asian Regional Government" (China, Japan, Russia, Republic of Korea, Mongolia), February.

Asian Disaster Reduction Center (ADRC) (2001), "Community-Based Flood Mitigation Project: The Case of Bandung City/Indonesia", Project Report, No. 1.

Bureau of Transport and Regional Economics, Commonwealth of Australia (2002), "Benefits of Flood Mitigation in Australia", Report 106, Canberra.

Department of Land and Water Conservation, Government of New South Wales/Australia (2001), "The NSW Floodplain Management Manual: the management of flood liable land", Sydney.

International Commission for the Protection of the Rhine (2002), "Non Structural Flood Plain Management: Measures and their Effectiveness", Koblenz.

Mekong River Commission Secretariat (2001), "Mekong River Commission Strategy on Flood Management and Mitigation", Phnom Penh, November.

Neto, Frederico (2001), "Alternative approaches to flood mitigation: a case study of Bangladesh", in: Natural Resources Forum 25, No. 4, November, pp.285-297, United Nations.

On-line libraries on natural disasters

Asian Disaster Preparedness Center, Bangkok/Thailand
http://www.adpc.ait.ac.th/infores/doc.html
The Center also publishes a quarterly newsletter, **Asian Disaster Management News**. This newsletter, designed to serve as a communication channel for the disaster management community in the Asian and Pacific regions, is disseminated in print to more than 2,000 people. The newsletter can be accessed through the Center's Website.

Asian Disaster Reduction Center, Japan
http://www.adrc.or.jp/adrc_events.asp

Disaster & Social Crisis Research Network
http://www.apu.ac.uk/geography/d&scrn/

Gender and Disasters Network
http://www.anglia.ac.uk/geography/gdn/resources/bibliographies.html

International Federation of Red Cross and Red Crescent Societies
http://www.ifrc.org/publicat/

Natural Hazards Research and Applications Information Center, University of Colorado, Boulder/USA
http://www.colorado.edu/hazards/litbase/litindex.htm

Pacific Disaster Centre, Hawaii
http://www.pdc.org/pdc/pub/frmain07.html

Pan American Health Organization/ Regional Office of the World Health Organization
http://www.paho.org/english/PED/catalog.htm
http://www.paho.org/english/ped/about-vdl.htm

Reliefweb
http://www.reliefweb.int/w/rwb.nsf/vLND

South Pacific Regional Environment Programme (SPREP)
http://www.sidsnet.org/pacific/sprep/publicat_.htm

United Nations International Strategy for Disaster Reduction
http://www.unisdr.org/unisdr/isdrpub.htm

World Bank, Disaster Management Unit
http://www.worldbank.org/dmf/

World Bank, ProVentionConsortium
http://www.proventionconsortium.org/publications.htm

Periodical publications (journals, newsletters)

The Australian Journal of Emergency Management, The Australian Emergency Management Institute (Rob Fleming), rfleming@ema.gov.au

Disasters: Preparedness and Mitigation in the Americas, Publication of the Pan American Health Organization (PAHO), Washington, D.C.
disaster-newsletter@paho.org; http://www.paho.org/english/ped/pedhome.htm

Hazards International: Newsletter for Safety, Health & Environment Worldwide, Coventry, UK; hazards@writer.demon.co.uk

International Civil Defense Journal, Geneva, Switzerland; icdo@icdo.org

International Journal of Mass Emergencies and Disaster, Articles index: http://www.usc.edu/sppd/ijmed/; http://www.usc.edu/schools/sppd/ijmed/articles.html

ISDR Highlights, Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR), Geneva, http://www.unisdr.org, isdr@un.org

ISDR Informs, Asia/Africa/LAC, Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR), Geneva, http://www.unisdr.org, http://www.unisdrafrica.org, http://www.eird.org

Journal of Contingencies and Crisis Management, Leiden University, The Netherlands
JCCM@RULFSW.LEIDENUNIV.NL

Natural Hazards: Journal of the International Society for the Prevention and Mitigation of Natural Hazards, Kluwer Academic Publishers

Annex

Case Study 1: Community Education

Practical experiences in preparing a community for a disaster in the Philippines

As a hazard strikes a community, the degree of preparedness of the local population and the local authorities sometimes spells the difference between the occurrence of a disastrous event or one that the community can cope with. In areas where a hazard regularly "visits", the population build methods for coping with it, even though it may be in an unorganized way. The demand for survival forces people to "invent" ways to withstand a disaster. On the other hand, local authorities who already know the cycle of disaster management often lack the skills and/or resources to undertake activities to operationalize the measures for risk reduction. Such is the case in the Philippines, which has comprehensive legislation to address disaster events. The provisions of this law mandate the national, regional, provincial, city/municipal, and village officials to organize "Disaster Coordinating Councils/Committees" (DCCs) with delineated functions and to conduct a series of activities to operationalize these functions.

Lack of or limited resources at all governmental levels are cited as the usual reason for the lack of support to the formation of these village structures. However, this situation can be improved if the local authorities encourage the participation of the local population. The quality of participation that seems to be most suited to the formation of an involved community is one that is not forced or coerced.

The village of Talba, in Central Luzon, Philippines, with a population of 779 families or 4,674 people, was situated along a river through which lava from Mt. Pinatubo had flowed. The possibility of an overflow of the river in the near future was a real danger. A non-governmental organization (NGO) focusing on disaster management was requested by a health-service NGO working in Talba to assist in the training and setting-up of a disaster management group in the community. The NGO established a community-based group, known as Barangay Disaster Response Organization. The participation of a Barangay councilman in this affair facilitated the interface between the Barangay Disaster Coordinating Committee and the people's organization, by making the members of the latter group also members of the committees of the former group. The Barangay Disaster Response Organization, however, maintained its identity by holding regular meetings with other organizations and stakeholders in the village.

Among the first activities of the community's disaster mitigation plan were the sandbagging of the area along the river's route and the construction of an "uplifted" walking path for the residents, which was also made of sandbags. The sandbags along the shoreline were intended to slowdown the flooding of the area in case a rampaging lava flow was to strike the village. In 1995, a lava overflow destroyed the village of Talba. In that event, the government communication system was disrupted and failed to give the proper warning to the residents. It was the parallel warning system developed by the community people that warned them on time to evacuate the area and avoid any loss of life. Resources of the community, such as privately owned small boats, jeeps and a truck, were used to move the village's population to safety.

In the Talba experience, the local authorities were "open" to the engagement of the people's organization and agreed to a cooperative approach. The involvement of a Barangay councilman in the people's organization enhanced this cooperation. This also points to the willingness of some local authorities to share their responsibilities with the local populace. This kind of cooperation enhances their relationship. Allowing the people's organization to maintain its identity, instead of co-opting it or forcing its integration with the government structure increased the "goodwill" and facilitated mutual support between the two sectors. A trained and organized village community can undertake lifesaving measures that complement the goals of the local authorities. They can initiate activities that can be sustained even after the occurrence of disasters. Therefore, in areas where active civil organizations or groups can be engaged to complement a local government's limitations, their participation has been proven to ensure the community's welfare in the face of disaster.

Case Study 2: Regional Cooperation in Southern Africa

Policy commitment to flood risk reduction

The Southern African Development Community (SADC) is comprised of 14 member states with a population of approximately 200 million: Angola, Botswana, Democratic Republic of the Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

Since the devastating floods that affected much of the region in 2000-2001, particularly in Mozambique, a process of intense regional cooperation has been started at the highest political level. This process is focusing mainly on improved technical collaboration including anticipating, mitigating and responding to sudden-onset natural hazards, such as cyclone-triggered trans-boundary floods, and allocating more resources to risk reduction. For a long time, the water sector has focused on the development of cooperative agreements on shared river basins, but the floods of 2000 and 2001 underlined the need for paying greater attention to regional flood risk, in addition to recurrent drought. The need for inter-state cooperation associated with water-related hazards in Southern Africa is particularly acute, as there are more than ten shared watercourses in the region.

Photo: C.Black and D.Revol, IFRC

Rain and flooding in February 2000 have left much of central Mozambique under water

As a starting point, an Extraordinary Summit for SADC Heads of State and Government was convened in Maputo, Mozambique in March 2000 to review the impacts caused by the floods across the region. In May 2000, the SADC Sub-Sectoral Committee on Meteorology Meeting was convened and the Directors of National Meteorological and Hydrological Services (NMHS) in the SADC countries recommended a regional project to be formulated to address and strengthen the local capacities of national meteorological and hydrological services for early warning and disaster preparedness. In addition, the SADC Committee of Ministers for Water asked for a strategic and coordinated approach to be developed to manage floods and droughts within the region. By August 2000, the SADC Council of Ministers approved an overarching SADC Disaster Management Framework for an integrated regional approach to disaster management and established a full Technical Steering Committee on Disaster Management. By the end of 2001, SADC had developed and set in place a multi-sectoral disaster management strategy for the region.

The successful implementation of this disaster reduction strategy rests on interaction among different technical and administrative networks across Southern Africa. The SADC Water Sector Coordination Unit formulated an integrated Strategy for Floods and Drought

Management in the SADC Region that will be implemented over a four-year period. The strategy focuses on preparedness and contingency planning, early warning and vulnerability information systems, mitigation measures, response activities and recovery strategies. The process involves regular consultations through which the heads of disaster management, early warning, and meteorological units and water authorities from individual countries in Southern Africa will meet with SADC technical counterparts in order to monitor progress and address impediments to reduce drought and flood-related disasters. Fifty real-time and coordinated data collection stations are currently being installed in eleven Southern African countries under the EU funded SADC Hydrological Cycle Observing System (SADC-HYCOS). These stations are expected to make major improvements in the timely availability of data and to provide more real-time data transmission and the dissemination of essential transboundary hydrological information for flood forecasting. The project is being implemented by the SADC Water Sector Resources in association with the national hydrological services of the participating countries.

Case Study 3: An Instructional Programme for the Local Level

A disaster awareness and response instructional programme for people at the local level in Vietnam

Vietnam is one of the most disaster-prone countries in the world. The 1996 flood season was particularly devastating: typhoons, tropical storms, whirlwinds, landslides and floods affected almost every province in the country, causing $US 655 million in damages and taking more than 1,000 lives. In 1997, Typhoon Linda alone caused almost $US 600 million in damages to the southern provinces. More significantly, 2,900 people were either killed or reported missing. In 1998, Vietnam faced not only typhoons and floods, but also severe drought that spread nationwide and lasted until May 1999. Forest fires were also widespread. In response to such threats, the United Nations Development Programme (UNDP), the Ministry of Agriculture and Rural Development, and the Central Committee for Flood and Storm Control (CCFSC) are working together to establish strategies for disaster preparedness, prevention, and mitigation. Strengthening national capacities to plan for and respond to natural disasters is a further target.

The new Disaster Management project builds on the success of a previous UNDP project that established a nationwide water disaster information and monitoring system focused at the provincial level that extends training in disaster awareness and response right down to the district and commune levels. The new project is extending this water disaster management capability to other disasters, including drought, seawater intrusion, and forest fires.

Photo: ECHO

Training of school children, Vietnam

The major purpose of this EU-UNDP funded pilot training project was to introduce disaster awareness and preparedness to the elementary school system in Vietnam. School children in selected communes are being taught how to mitigate disaster damage in their households and families. In addition to educating school children, this "grassroots" approach is also aimed at developing synergetic effects, such as fostering a greater awareness of natural disasters within families and their communities. Three provinces in Vietnam (Thanh Hoa, Quang Tri, and Long An Provinces) were selected. The three main objectives being pursued were: (1) to develop a community-based disaster awareness and preparedness training programme that, if successful, could be replicated nationwide; (2) to establish a nucleus of Master Trainers; and (3) to strengthen the institutions that deal with disaster management in Vietnam. Implementation steps of this training programme included: setting up a Steering Committee and a Working Group; drafting and signing a contract with the local Vietnam Red Cross Society; creation, design, and constant revision of training material; training of Master Trainers; and training of teachers and children in selected provinces.

Based on the review of books and student knowledge at the grade 4 and 5 levels, a children's book and a teacher's book were prepared and distributed to schools. "Disaster bags" were described and explained in the training materials: they are to be used by the pupils' families to store, and thus preserve, important documents. In addition, a videotape for educational purposes was produced by a television station in Hanoi, dealing specifically with disasters in Vietnam and incorporating many of the lessons contained in the training materials.

The Vietnamese Red Cross was responsible for organizing and conducting the training of schoolteachers. A total of 288 schoolteachers in all three provinces received the training. Following the training of teachers, the provincial Red Cross worked with the districts and schools to organize the teaching of fourth and fifth graders from selected schools. A total of 18,755 pupils were taught. The teaching was spread over a four-week period. The training programmes were not integrated into the existing curriculum; rather they were presented as extra courses added to the regular curriculum. These courses were taught over a weekend, when the pupils would not ordinarily be in school.

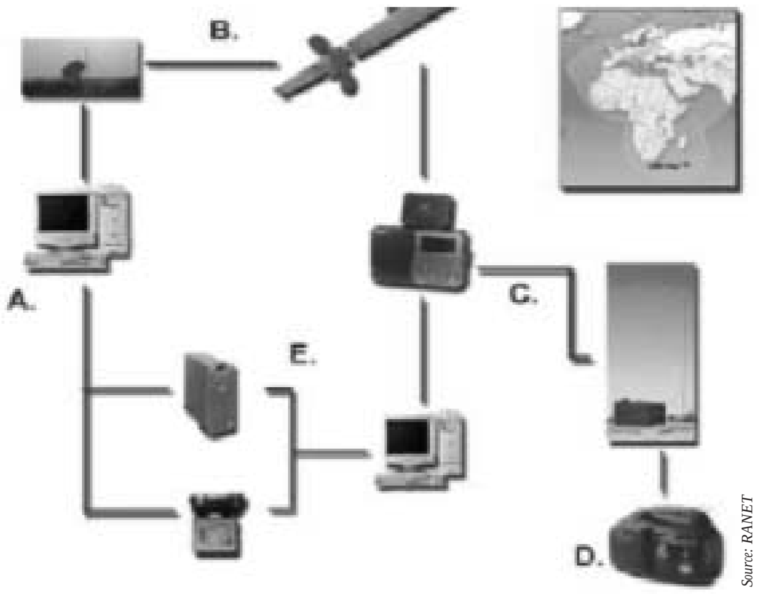
Case Study 4: Access to Information - The RANET Project

RANET is a project of several partners aimed at making climate and weather related information more accessible to rural populations and communities in Africa. RANET provides a radio-internet pathway between scientific results and individuals in remote locations for whom "early warning" information might matter greatly. The programme currently operates in Africa and is exploring appropriate roles in Asia and the Pacific. The goal is to improve access to climate and weather related material through a variety of activities, while also developing a system through which meteorological services can disseminate their own information to rural communities.

RANET endeavours to make available to national, regional, and local levels the tools and information required for decision-making. All activities of RANET are based on a participatory approach and are done in conjunction with, and with the approval of, the communities themselves and the national meteorological and associated services.

Technological and scientific advances in recent decades have provided not only a good understanding of climate and weather conditions, but also a wide variety of observations and forecasts that can be used in efforts to manage systems sensitive to meteorological events. At present, many rural populations most in need of hydro-meteorological and environmental information are not able to access the information already produced by national, regional, and various international organizations. The RANET Programme was created and designed specifically to address the problem of information access and interpretation at the level of rural communities.

RANET identifies and trains partners in the use of various technologies that are most appropriate for their information needs and are serviceable in their area. Aside from identifying a variety of techniques, RANET works to gain access for rural populations to "common networks"- large systems likely inaccessible by any one group, but usable by RANET and its partners when used together. Additionally, RANET focuses on integrating



RANET information cycle: Global, regional, national and local information is gathered from various technologies through different methods and then blended in a single broadcasting via Radio existing networks thereby reinforcing local, existing capabilities rather than developing new, resource intensive and unsustainable networks.

Many development projects with a component of telecommunications technology are vulnerable unless appropriate and sustainable solutions are identified and deployed. In Africa one of the more successful systems has been an integration of new and existing analogue (FM/AM) radio stations with new digital radio satellite technologies, as provided through the World Space Foundation. Taken together, these technologies allow for both local knowledge and new information to be used in support of rural populations. Radio is one of the most pervasive technologies in use throughout the globe, and RANET's inclusion of radio in its network design helps to ensure the programme builds upon existing capabilities, is community owned and operated, locally relevant, and therefore more sustainable.

The lessons learned by RANET underscore the need for a period of consistent follow-up and technical support until the introduced systems, or newly integrated networks, can be fully supported locally (or within a region), and therefore considered sustainable. Such a transition period means identifying serviceable technologies, identifying existing networks and capabilities, training, and the development of a support community. For this reason RANET is embarking on new education and training programmes, which allow participants to solve problems that arose during implementation (including revenue generation and sustainability), learn from each other's experiences, and build upon the basic knowledge gained in the initial training sessions and project development.

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Acronyms

ACMAD	African Centre of Meteorological Application for Development
ADRC	Asian Disaster Reduction Center
AHPS	Advanced Hydrologic Prediction Services project of the U.S. National Oceanic and Atmospheric Administration National Weather Service
CCFSC	Central Committee for Flood and Storm Control in Vietnam
CRASH	Comprehensive Risk Assessment for Natural Hazards
CRED	Centre for Research on the Epidemiology of Disasters
DCCs	Disaster Coordinating Councils/Committees
DEM	Digital Elevation Model
DTM	Digital Terrain Model
ENSO	El Niño Southern Oscillation
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EM-DAT	Emergency Events Database administrated by CRED, University of Louvain, Belgium
EU	European Union
GDP	Gross Domestic Product
GIS	Geographical Information Systems
GTS	Global Telecommunication System
HYCOS	Hydrological Cycle Observing System
IATF/DR	Inter-Agency Task Force on Disaster Reduction
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
IWRM	Integrated Water Resources Management
NGO	Non-governmental Organization
NMHS	National Meteorological and Hydrological Services
OFDA	Office of U.S. Foreign Disaster Assistance
QPE	Quantitative Precipitation Estimation
QPF	Quantitative Precipitation Forecasting
SADC	Southern African Development Community
UNDESA	United Nations Department of Economic and Social Affairs
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNDP	United Nations Development Programme
UN/ISDR	Inter-Agency Secretariat of the International Strategy for Disaster Reduction
USAID	United States Agency for International Development
WEO	World Economic Outlook
WMO	World Meteorological Organization

UN Department of Economic and Social Affairs (DESA)
Division for Sustainable Development
www.un.org/esa/sustdev

UN Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR)
www.unisdr.org

National Oceanic and Atmosphere Administration (USA NOAA)
www.noaa.gov