Chapter 5
Flash Flood Risk Management

Flash flood risk management can include structural and non-structural measures. A common strategy to cope with floods has been to construct civil works such as floodwalls, transversal protection works, embankments, conduits, and reservoirs to protect the environment up to an acceptable risk threshold. Structural measures tend to consider mainly the hydrological and hydraulic implications of flooding, which are generally solved by choosing the alternative that maximises the expected net benefit. In addition, such measures can have a substantial impact on the riverine environment and ecology. Furthermore, while structural solutions contribute to flood reduction and protection, they also have hidden 'piggy-back' liabilities associated with them, such as the issue of their long-term value, the false sense of security they may provide, their possible environmental impact, and costs related to their operation and maintenance.

In contrast, non-structural measures (see below) offer a variety of possibilities, ranging from land use planning and construction and structure management codes, through soil management and acquisition policies, insurance, and perception and awareness, to public information actions, emergency systems, and post-catastrophe recovery, all of which contribute towards the mitigation of flood-related problems. The advantage of non-structural measures is that, generally, they are sustainable and less expensive. Table 8 gives some examples of structural and non-structural measures. Non-structural measures are often the most effective in managing flash floods. However, they can only be efficient with the participation of a responsive population and an organised institutional network. A combination of structural and non-structural measures can be the best. This manual deals explicitly with the non-structural measures for flash flood risk management.

Table 8: **Structural and non-structural measures for flash flood risk management**

Structural measures			Catchment-wide interventions (agriculture and forestry actions and water control works)
			River training interventions
			Other flood control interventions (passive control, water retention basins and river corridor enhancement, rehabilitation and restoration)
Non-structural measures	Risk acceptance	Tolerence strategies	Toleration
			Emergency response system
			Insurance
	Risk reduction	Prevention strategies	Watershed management
			Delimitation of flood areas and securing flood plains
			Implementation of flood area regulations
			Application of financial measures
		Mitigation strategies	Reduction of discharge through natural retention
			Forecasting and early warning
			Emergency action based on monitoring, warning, and response systems (MWRS)
			Public information and education

Source: Colombo et al. (2002)

5.1 Non-structural Measures

The need for non-structural measures becomes very important when dealing with settled areas, as they allow control of the vulnerability component of flood risk (see Chapter 4).

Non-structural measures are particularly important for the HKH region for several reasons:

- the high cost and short lifetime of structural measures
- lack of capacity to build and operate structural measures
- low involvement of local community, lack of feeling of ownership
- other environmental impacts of structural measures

Non-structural measures tend to be more sustainable because they include the active involvement of the community. National and regional policy should favour non-structural alternatives due to their low cost and reduced number environmental side effects, and implement structural measures only as a last resort.

Non-structural measures can be grouped into two categories: risk acceptance and risk reduction measures.

Risk acceptance

Acceptable risk is the level of loss a society or community considers acceptable given existing social, economic, political, cultural, technical, and environmental conditions (UN/ISDER terminology[8]).

Risk acceptance implies that the government or community accepts a degree of human and material loss due to a flash flood that could impact the area in the short-, medium-, and long-term. There are mainly three types of risk acceptance strategies: toleration, emergency response system, and insurance.

Toleration

Toleration of risk implies that a competent authority (local, regional, or national) accepts that flash floods occur. Generally, proactive initiatives will not be carried out other than, perhaps, a risk analysis (see example in Annex 1). In this case, it is very likely that the competent authority will accept the results of the risk assessment and not promote any complementary activities. Although risk analysis is gradually gaining ground with competent authority routines, it still needs to become common practice.

Emergency response systems

The use of emergency response systems implies that the local, regional, or national competent authority is aware that their area of jurisdiction is prone to flash floods. Risk assessment and modelling, coupled with mapping, is probably carried out, but flash floods will mainly be dealt with via the elaboration of emergency plans and using already existing structures.

All emergency plans (regional, district, local) should be based on a national emergency plan in order to carry out the same doctrine of civil protection emergency operations within a particular country in a concerted manner. In general, the various public authorities taking part in the emergency plan will play roles related to their day-to-day responsibilities. They must prepare themselves according to the mission statement established in the emergency plan. To achieve this, each competent authority (regional, district, local) must have its own emergency plan, accompanied by an operations manual. Furthermore, each collaborative unit (police, fire brigade, hospital, and so on) should also have its own emergency plan and operations manual.

Insurance

Insurance against flash flood damage should be an integral part of risk acceptance. However, many countries in the HKH region still do not use flood insurance due to its high cost. Existing solutions to flood coverage are

[8] UN/ISDR terminology of disaster risk reduction (http://www.unisdr.org/eng/library/lib_terminology_eng%20home.htm; Accessed June 2007).

quite diverse, mainly due to the technical difficulties involved in providing insurance cover against flooding, differing views on the role of the state in managing flood risk, and last but not least, diverging perceptions of the dangers posed by flooding. The solutions in place range from unrestricted private insurance coverage to state aid for flood victims.

Insurance companies have various instruments available to cover the risk. Some examples are given below.

- **In combination with other natural perils:** Flood risk is usually covered in combination with other natural perils in order to appeal to as many customers as possible, achieve maximum market penetration, and minimise the risk of selection bias.
- **Grouping of several insurance portfolios in a pool:** Flood risk is spread among other insurance portfolios and is offered as a package. This also decreases the risk to the insurer.
- **Resilient reinstatement:** Flood insurance is made available only to floodplain residents who make an effort to make their houses more resistant to flooding (e.g., use of flood-resistant products and techniques when repairing a flood-damaged property, installing electrical sockets one metre above the floor instead of just above the skirting board).

Generally there is difficulty in dividing the risk fairly among the parties involved (i.e., the property owner, (re) insurer, and the state). This is mainly due to the very different hazard potentials in play and the differences in perception of these hazards. Furthermore, the system of insurance policies applied only on a local level is far too expensive both for insurance companies and for private and public entities. The following recommendations may help overcome these problems:

- A mandatory national or regional (e.g. South Asian Association for Regional Cooperation [SAARC], HKH) insurance fund against natural hazards should be established, so as to spread costs. This would follow the concept of joint sharing of burdens and would reduce the costs of expensive disaster-relief payments.
- The development of risk-oriented models for determining the implications of a flood hazard should be promoted and funded. This would require an external source of funds additional to insurance, which could raise data-protection problems.

5.2 Risk Reduction

Success in managing flood areas depends on selecting suitable measures based on flood characteristics, physical and morphological characteristics of flood areas, economic and social conditions, political and environmental conditioning, or flood-control works planning. Structural measures cannot reach these objectives if they are used alone; non-structural measures such as land use control and planning can be tools not only to reduce flood risk, but also to develop a sustainable approach to flood management. Risk reduction is one of the main goals in flash flood management. It can be dealt with in two ways: prevention strategies and mitigation strategies. The following section describes different approaches, tools, and activities for flash flood risk reduction.

Watershed management[9]

Watershed management has both structural and non-structural components. Non-structural components can be important measures in reducing flash flood risk. Watershed management is a cross-cutting exercise closely related to socioeconomy and development. Watershed management should consider a number of basic principles related to runoff and erosion including soil, topography, land cover and use, and farming practices.

[9] This section includes contributions from Keshar Man Sthapit, ICIMOD.

The following measures in a watershed can significantly reduce the risk of flash floods (Figure 27):

- **Agricultural measures:** Agricultural activities should minimise the generation of runoff and sediment. Contouring and terracing of upland farms is a good measure to ensure this. Crops should be selected to ensure longer coverage, especially in rainy periods. Conversion into arable land should be avoided where slopes exceed 25%. Agricultural practices that increase organic matter in the soil should be favoured.
- **Remodelling of agriculture:** Agriculture in flood-prone areas should be conducted in ways that minimise the flood damage to crops. Assam, where floods occur regularly, provides a good example of what can be done. The successive waves of floods from the Bhrahmaputra and Barak rivers and their tributaries cause extensive damage to agriculture (Figure 28):
  - The ahu crop (rice) is damaged before the harvest.
  - The sali or main crop of rice cannot be transplanted in time as the seedlings are damaged either in the nursery or after transplanting, sometimes even destroyed in the field.
  - The jute crop is damaged or quality is adversely affected, and so on.

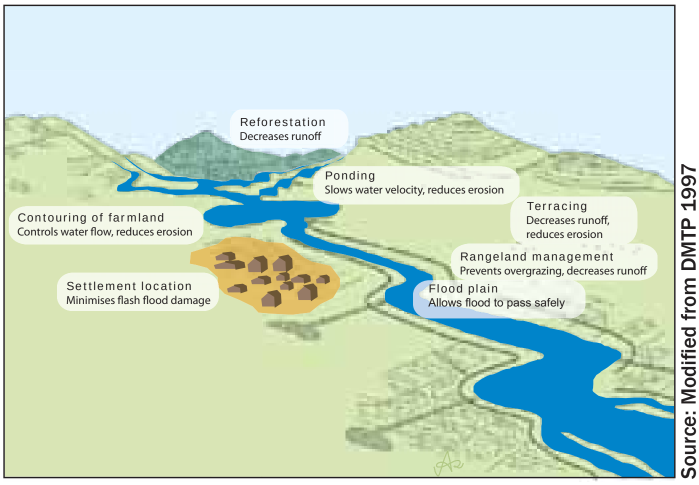

Figure 27: Some aspects of watershed management

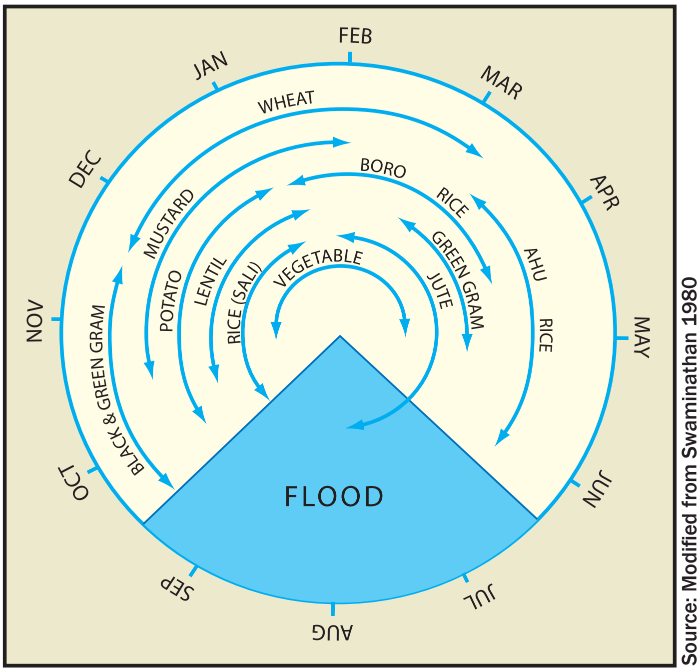

Figure 28: Modification of cropping pattern to suit flooding period

Various strategies are used related to remodelling of land use to minimise the adverse effects of recurrent floods (Swaminathan 1980):

- **Multiple cropping:** Cropping of medium tall ahu rice with deep-water rice in low-lying areas as an insurance so that if the ahu rice is damaged, there will be some production from the deep-water rice.
- **Restructuring of the cropping pattern:** The safest way to assure crop production in flood-prone areas is to use the flood-free period for growing crops. Figure 28 shows the flood-free period and the potential for growing crops in this period.
- **Forestry:** Reforestation can be a good measure to decrease runoff. Tree species that do not prohibit undergrowth should be selected. Logging should be carried out during non-rainy seasons. Plan for log-skidding tracks, as they might trigger flash floods. Favour mixed, uneven aged, and autochthonous woods by selective thinning and coppicing.
- **Rangeland management:** Pasture renewal through fire should be avoided as this reduces soil organic matter. Grazing should be regulated through the correct assessment of optimum livestock numbers. A more homogeneous distribution of livestock and use of rotation grazing methods should be encouraged.

- **Floodplain management:**
  - Floodplain management includes flash flood hazard mapping, which shows the areas that will be impacted by a flood of a particular return period and enables delimitation of flood areas. Flood hazard mapping can be conducted to different degrees of detail. A very simple flood hazard map shows the area of inundation. In addition, the depth of inundation, the velocity of flood water at a given location, elements at risk, and others can be provided. A simple exercise on GIS-based flood hazard mapping is provided in Annex 2[10].
  - One important activity is the delimitation of flood areas and securing of flood plains. Based on the technical study on flash flood hazard mapping, streams should have adequate buffer areas to safely cater for flood waves. The floodplain can be divided into: 1) critical zone (waterway); 2) restrictive zone; 3) regulatory zone; and 4) warning zone (Figure 29). Zone 1 is the waterway/river channel that gets flooded every year and where any human interference should be prohibited. Where a river has right of way, humans should stay out of its way. Zone 2 gets flooded every three to five years, and construction should be restricted and only agriculture permitted. Every 3-5 years one crop will be lost due to flood and there will be harvests in flood-free years. In Zone 3, construction should have adequate protection measures such as embankments, flood proofing, and so on. Zone 4 experiences flooding more rarely, averaging once every 25 years. Construction in the area should have tolerance against flash floods. Flood warning plays an important role here.
  - Natural ponds in the watershed retain the runoff and dampen the peak discharges in the stream. The ponds should be maintained properly and filling the depressions for development purposes should be avoided.
  - Incentive policies should be created and promulgated to achieve better control of building in flash flood-prone areas. Examples of such an incentive policy would be granting building permits that are linked to runoff conditions, and relocation grants to move houses from the floodplain.
  - Watershed committees. Legislation should incorporate flash flood related issues within the framework of watershed committees. This is important because of the interdisciplinary implications of flash flood management.

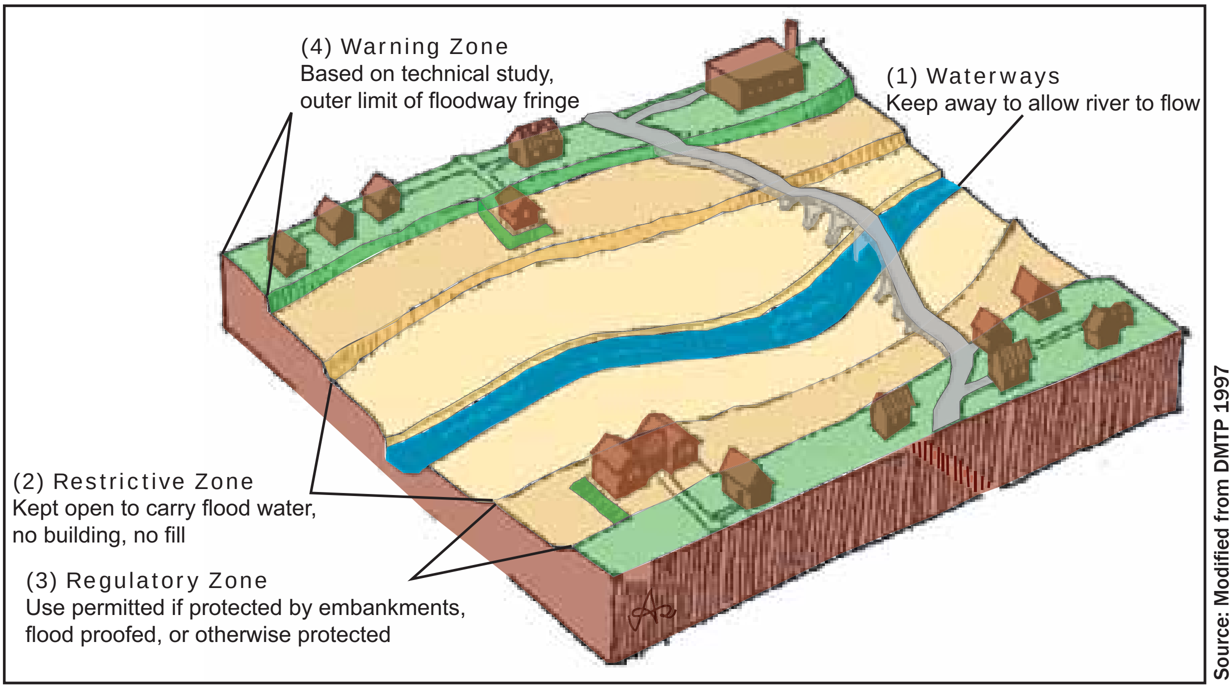

Figure 29: An example of floodplain zoning

[10] The exercise was developed by the Asian Disaster Preparedness Center (ADPC) based on a case study from Sri Lanka. The exercise is based on ILWIS software. An open source version, ILWIS 3.4 Open, can also be used. It is freely downloadable from <http://52north.org/index.php?option=com_projects&task=showProject&i d=30&Itemid=127>.

- **Land use control:** Land use control has much in common with floodplain management; it should also be implemented in conjunction with a technical study on flash flood hazard mapping. Land use regulation is designed to reduce danger to life, property, and development when flash floods occur. The following elements should be addressed while implementing land use control in a watershed. Many of the elements mentioned here are directly related to planning and policy makers, although flash flood managers should also have a good understanding of these issues.
  - Reduction of densities: In flash flood prone areas, the number of casualties is directly related to the population density of the neighbourhood at risk. If an area is still in the planning stage, regulation of densities may be built into the plan. For already settled areas, especially squatter settlements, regulation of density can be a sensitive issue and has to address the socioeconomic implications of resettlement. Unfortunately, many situations exist where dense unplanned settlements are located on floodplains. Planners must incorporate measures to improve sites and reduce vulnerability.
  - Prohibiting development in areas of high risk: No major development should be permitted in areas subject to flooding once every 10 years on average. Areas of high risk can be used for functions with a lower risk potential such as nature reserves, sports facilities, and parks. Functions with high damage potential such as hospitals should be permitted in safe areas only.
  - Relocation of elements that block the flood passage: In addition to the obvious danger of being damaged or washed away, buildings and other structures blocking the floodway may cause damage by trapping floodwaters which then overflow into formerly flood-free zones.
  - Implementation of a building code: The design of buildings and choice of building materials should consider the probability and severity of flash floods.
  - Provision of escape routes: Land use plans should have clear escape routes and provide refuge areas on higher ground.

Integrated flash flood management

Paradigm change in flood management

Flood management has traditionally been problem driven, with more activities implemented after a severe flood. Actions generally have included structural and non-structural, physical and institutional flash flood management interventions implemented before, during, and after the flash flood or other event. Often flood management has involved conflict with other sectors such as building, agriculture, and water resource management. Flood has been treated as a negative phenomenon and its positive aspects largely ignored, although the ecosystem services provided by floods are very important. Some flood management interventions even adversely impact on riverine ecosystems.

Climate change projections suggest there will be an increased frequency and an increase in magnitude of flash floods, and a wider distribution of these events. The traditional methods of flash flood management may not be effective under changed circumstances, as present standard practices regarding infrastructure may become invalid. Conventionally, the risk of flooding is expressed in terms of the excedence probability of a flood of a given magnitude on a particular stretch of river. In recent times, emphasis has been placed on analysing the sequence of events and associated probabilities that result in flash floods – based on meteorological events themselves and the antecedent conditions (e.g., basin shape, solid moisture condition, and vegetation). The new convention on flood management emphasises risk management. It is now more accepted that there is a need to find ways of making life sustainable even in flash flood prone areas and floodplains, even if there is considerable risk to life and property. This can be approached through the integrated management of floods.

Integrated water resources management

According to the Global Water Partnership (GWP), integrated water resources management (IWRM) is a process that promotes the coordinated development and management of water, land, and related resources to maximise the resultant economic and social welfare equitably without compromising the sustainability of vital ecosystems (Figure 30).

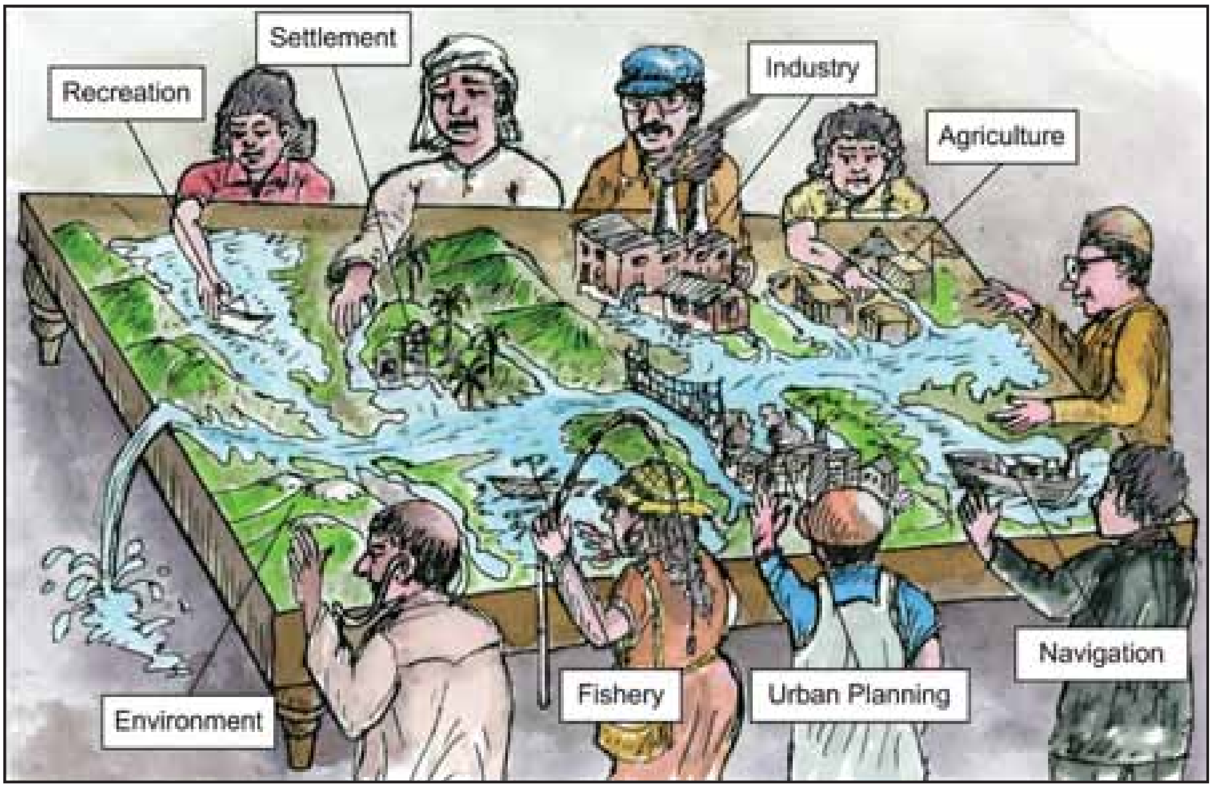

Figure 30: Integrated water resources management

Sustainable and effective management of water resources demands a holistic approach, linking social and economic development with the protection of natural ecosystems and appropriate management links between land and water uses. Therefore, water-related disasters such as floods and droughts, which play an important part in determining sustainable development, also need to be integrated within water resources management.

Integrated flash flood management

Integrated flash flood management (IFFM) is a process promoting an integrated rather than fragmented approach to flash flood management. It integrates land and water resources development in a river basin within the context of IWRM, and aims at maximising the net benefits from floodplains and minimising loss to life from flooding. IFFM includes four major components: water resources management, water quality management; hazard management; and land use management (Figure 31).

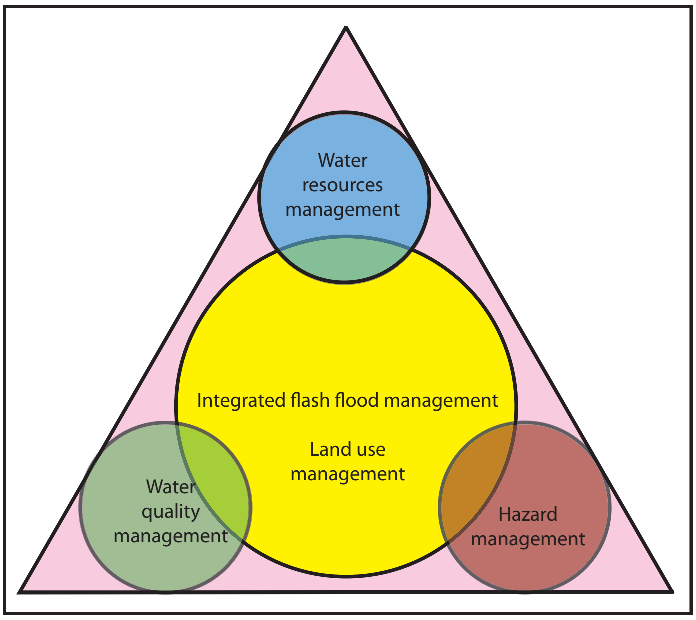

Figure 31: Integrated flash flood management model

Water is a finite and vulnerable resource; differentiation between water resources management, flood management, and drought management needs to be circumvented.

APFM (2004)

Integrated flash flood management recognises the river basin as a dynamic system in which there are many interactions and fluxes between land and water bodies. In IFFM the starting point is a vision of what the river basin should be. Incorporating a sustainable livelihood perspective means looking for ways of identifying opportunities to enhance the performance of the system as a whole. IFFM is not only used to reduce the losses from floods but also to maximise the efficient use of floodplains – particularly where land resources are limited. While reducing loss of life should remain the top priority, the objective of flood loss reduction should be secondary to the overall goal of optimum use of floodplains. In turn, increases in flood losses can be consistent with an increase in the efficient use of floodplains, in particular, and the basin, in general, (Brilly 2001).

An integrated flash flood management plan should address the following five key elements that would seem to follow logically for managing floods in the context of an IWRM approach:

- **Manage the water cycle as a whole:** Flood management plans should be intertwined with drought management through the effective use of floodwater and maximising the positive aspects of floods. Flood management should also be linked with groundwater management. As they are linked resources, the role of floodplains on groundwater recharge should be considered.
- **Integrate land and water management:** Land use planning and water management planning have to be combined in one synthesised plan through coordination between land management and water management authorities to achieve consistency in planning. Upstream changes in land use can drastically enhance flash floods and cause deterioration of water quality downstream of the basin. In fact, the three main elements of river basin management – water quantity, water quality, and the process of erosion and deposition – are inherently linked and are the primary reasons for adopting a river basin-based approach to IFFM.
- **Adopt a best mix of strategies:** Adoption of a strategy depends on the hydrological and hydraulic characteristics of the river system and the watershed. Three linked factors determine which strategy or combination of strategies is likely to be appropriate in a particular river basin: the climate, the basin characteristics, and the socioeconomic conditions in the region. Quite different strategies are likely to be appropriate in different situations and different countries. However, the strategies often involve a combination of complementary options – a layered approach. In many cases structural and non-structural measures can confer only partial safety. In such cases the strategy could be to reduce the vulnerability through disaster preparedness and flood emergency planning. Often good planning emphasises the long term. However, in the incidence of severe flash floods, short-term interventions are necessary. Therefore, the need is to include both long-term and short-term interventions in the overall plan.
- **Ensure a participatory approach:** IFFM should be based on a participatory approach, involving stakeholders, planners, and policy makers at all levels. The approach needs to be open, transparent, inclusive and communicative, requiring decentralisation of decision-making with public consultation and involvement of stakeholders in planning and implementation. A bottom-up approach is often considered best. However, an extreme bottom-up approach risks fragmentation rather than integration. On the other hand, top-down approaches involve a great deal of effort, subverting the intentions of the responsible institutions. It is important to use the strength of both approaches by using an appropriate mix.
- **Institutional synergy:** All institutions necessarily have geographical and functional boundaries. It is necessary to bring all the sectoral views and interests to the decision-making process. The challenge is to promote cooperation and coordination across functional and administrative boundaries.

Adopt integrated hazard management approaches

Communities are exposed to various natural and human-made hazards and risks. A wide range of activities and agencies are involved in the successful implementation of disaster-management strategies. IFFM should be integrated into a wider risk management system. This helps in structured information exchange and the formation of effective organisational relationships. Effective early warnings for all forms of natural hazards are best received by communities if they emanate from a single, officially designated authority with a legally assigned responsibility.

Financial measures

Financial support is provided after the occurrence of flash flood disasters to aid communities. In such cases, national and regional administrations should promulgate specific regulations to govern economic contributions in order to at least partially cover losses due to flash floods. Financial measures can be either an economic contribution or waiver of financial burdens, such as taxes, loan interest, or liquidation of a loan itself. Depending on the political structure and existing legislation of a country, there are many ways of providing financial support to individuals and local communities.

Financial support for planning, constructing, and maintaining structural interventions can be shared among national, provincial, and local administrative levels, with the total amount divided among them. The financial burden can be shared in two ways: burden sharing during planning and building, and burden sharing during maintenance. In general, the burden share increases progressively from local to provincial to national levels.

Another approach to financial support is to categorise interventions on river courses according to level of importance, which can also be used to regulate funding of hydraulic works of public interest. This categorisation defines who is to provide funds for the interventions and who must maintain them. The categorisation should be carried out on a case-by-case basis, according to the existing regulations of the country.

Financial measures can also be used to subsidise actions targeted towards reducing flash flood risks. The policy of subsidy should be operated in the context of IWRM and IFFM. Subsidies can incorporate forests, pasture, and rangeland management, and protection of water bodies. This can involve subsidies to community forestry user groups and other user groups or committees. Such financial measures can also target farmers to encourage environmentally friendly farming practices that reduce the risk of flash floods, such as contour farming, strip cropping, limited fallow land use, crops adapted to slopes, and terrace cultivation. This may also entice other farmers to farm in a sustainable manner.

5.3 Mitigation Strategies

The following sections provide some examples of non-structural measures that can be used to reduce the intensity, frequency, and impacts of flash floods.

Reducing discharge through natural retention

Studies on water flow have identified the early securing of areas for flood control purposes, so as to have them available in emergency situations, as a crucial aspect (Colombo et al. 2002). To this end, the following measures should be provided.

- Areas particularly suitable for water retention or that are needed to build earth dams or dikes should be singled out and marked as ‘devoted to special purposes’, which should also be reflected in land-use plans. If these areas fall within the private property of farmers, subsidies for loss due to deprived farming can be arranged.
- Advice from hydraulic engineering experts on passive flood control should be incorporated into regional development programmes and construction plans so that retention basins can be more easily identified and used for flash flood mitigation.
- Natural retention areas should be identified and improved, although this is in contrast with the desire to use them for industrial, economic, agricultural, settlement, and transport purposes. Hence, specific regulations should be made to avoid exploitation conflicts that may arise.
- To facilitate flood control measures or any other intervention entailing reduction of the retention surface of a floodplain, compensation measures can be adopted and subsidies introduced.

Monitoring, warning, and response system (MWRS)

Actions based on monitoring, warning, and response systems (MWRSs) can be a very effective form of non-structural flash flood management (IDNDR 1997; ISDR 2005). MWRSs include many components, all of

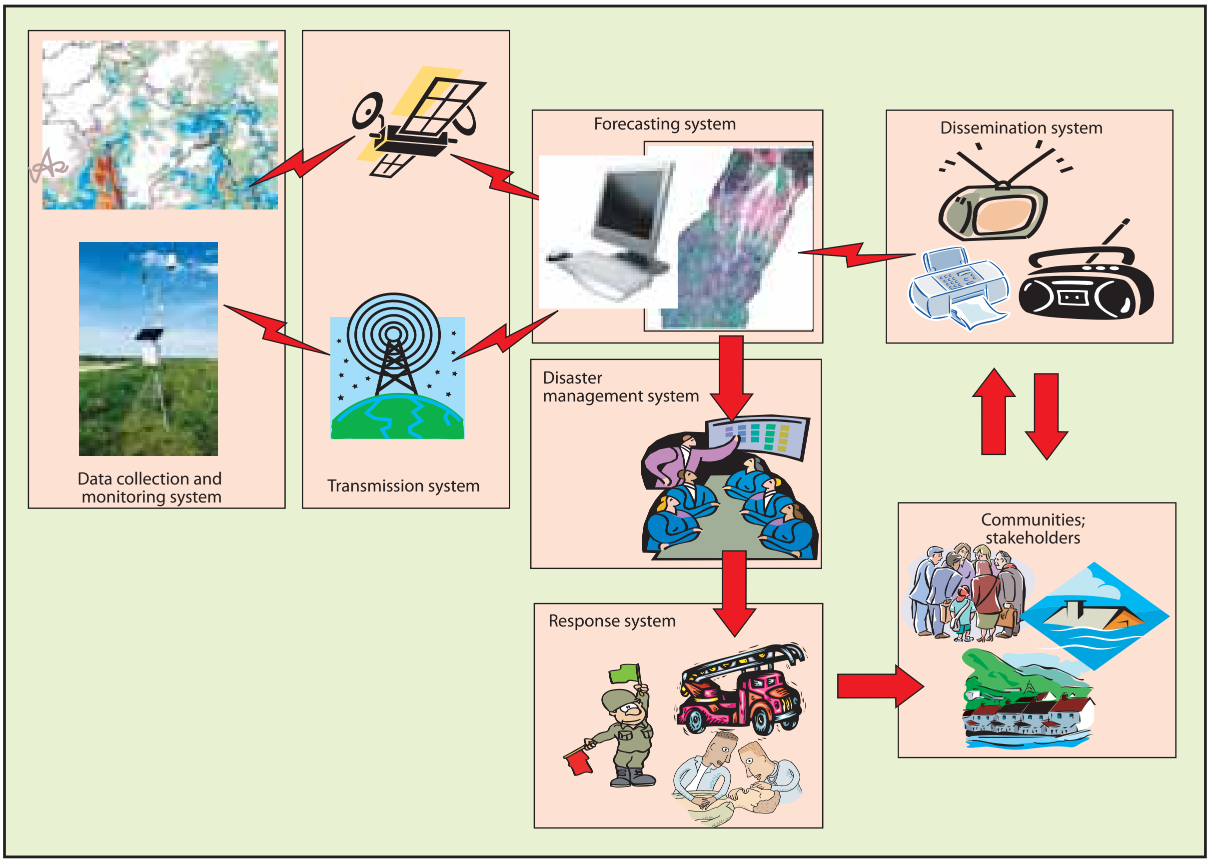

Figure 32: Scheme of a possible monitoring, warning, and response system (MWRS)

which contribute towards the mitigation of flash floods. MWRS is often referred to as an end-to-end flash flood mitigation system (Figure 32). Each component in the system is explained below. Failure of any of these components to function can hamper the effectiveness of the whole system.

Data collection and monitoring system

Monitoring extreme hydrometeorological events is the first step towards understanding what could happen in the future and choosing from possible alternatives. Collection of hydrometeorological data, such as rainfall, temperature, and streamflow, is essential for simulating the natural phenomena. Ground observation networks are commonly used to collect rainfall and other meteorological data. However, in many countries, satellite-based precipitation estimation may be the only source of rainfall data due to scarcity of hydrometeorological networks, long delays in data transmission, and lack of data sharing in many transboundary river basins. A ground-based network seldom has the density sufficient to reflect the natural spatial variability of precipitation, particularly in mountainous terrain as in the HKH region. Satellite estimation can be a valuable complement in such cases. On the other hand, satellite estimates are sometimes biased due to different limitations such as orographic effects and warm cloud processes. Thus, it is not possible to rely on satellite rainfall estimates alone. A combined satellite and surface-based rainfall estimate provides the best input for flash flood forecasting and early warning systems.

Data transmission system

An efficient data transmission system is necessary for timely data transfer from the monitoring site to the centre where the data are analysed. After analysis, the forecasts and warning messages should be relayed to end users in a timely manner. A wide range of data transmission systems are available. In some countries, transmission of manually read data by gauge readers using VHF radio or telegraph is still practised; this can result in errors in data reading and transmission. Automatic transmission of data from the gauge to the centre through different digital media such as terrestrial telephone, GSM, or satellite connections is more reliable, although the high cost of such systems can be a limitation. In Bangladesh, gauges for flood forecasting purposes are equipped with a special data collection unit with a punching device. The unit is brought to the radio room and connected to a high frequency (HF) radio, which transmits the data to the forecasting and warning centre. This system eliminates errors in data reading and transmission.

Forecasting system

Forecasting systems can also vary in complexity. Normally, a forecasting system consists of models (hydrological, hydraulic, and so on) that predict scenarios of potential flash flood events and closely follow the evolution of key parameters that could trigger them. The model may be complicated and can result in very accurate forecasting, but may be of no use if the computation takes so long that it does not provide sufficient lead time before the flood event. Flash floods are rapid processes and often lead time is very small. Further, lack of sufficient data regarding land characteristics hinders the application of sophisticated models. Flash flood managers should consider all these aspects while selecting models for flash flood forecasting. More simplistic models, such as flash flood guidance tables, may be preferable.

Warning system

The general public may not be able to interpret quantitative flash flood forecasts, in which case qualitative warnings have to be issued. Floods are classified into different categories of warnings, which communities and stakeholders should be able to interpret in terms of impact on them. The flash flood warning system for Central America established by USAID/OFDA in collaboration with National Weather Services (NWS) USA uses the concept of a flash flood guidance system (Georgakakos 2004; Figure 33). Flash flood guidance is the volume of rainfall in a given duration (e.g., 1 to 6 hours) over a given small catchment that is just enough to cause minor flooding at the outlet of the draining stream. Any rainfall in excess of the flash flood guidance is considered a flash flood threat.

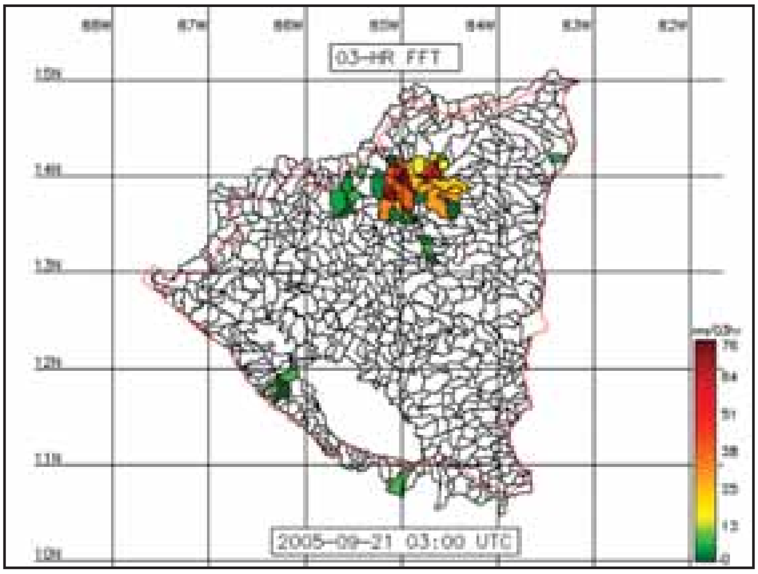

Figure 33: Example of Central America Flash Flood Guidance System product

> ***"More effective prevention strategies would save not only tens of billions of dollars, but save tens of thousands of lives. Funds currently spent on intervention and relief could be devoted to enhancing equitable and sustainable development instead, which would further reduce the risk for war and disaster. Building a culture of prevention is not easy. While the costs of prevention have to be paid in the present, its benefits lie in a distant future. Moreover, the benefits are not tangible; they are the disasters that did NOT happen."***
>
> Kofi Annan,
> "Facing the Humanitarian Challenge:
> Towards a Culture of Prevention"

Dissemination system

After a flood forecast and warning are prepared, they must be disseminated effectively. In the majority of cases, good forecasts fail to prevent damage and loss of life due to poor dissemination systems. The tsunami of December 2004 is a classic example. The forecasts and warnings should reach agencies related to the disaster management system in a timely and understandable manner. These agencies should issue forecasts and warnings by appropriate media such as radio and television and to different levels of disaster management units down to the lowest level. The warning should be clear and concise to be understandable by communities and should use language that will not cause unnecessary panic. The warning may be in text or use diagrams and maps. It is necessary to conduct community awareness raising programmes to help people understand the warnings. In some countries, small inexpensive radios are distributed to the communities in risk areas so that they have access to warnings.

Disaster Management System

Even where there is accurate and timely issue of forecasts and warnings, flash flood damage can happen. A disaster management system should be well-prepared for such events. The disaster management system should have an overall vision of the crisis situation. It is the task of the system to alert key action groups, which is part of the response system.

Response System

A response system consists of actions by groups such as

- police and fire brigade (e.g., assisting vulnerable groups such as the elderly and the handicapped in flood-proofing their houses, evacuation procedures, and so on)
- civil protection authorities (e.g., dissemination of targeted information)
- voluntary groups (e.g., assisting the injured, allocating resources)
- military (e.g., preparing sandbags, constructing temporary structures)
- media (dissemination of information).

Monitoring, warning and response systems (MWRSs) can differ in complexity. The system can be a simple manual with a community-managed system, or an advanced, state-managed system with high automation. MWRSs can be local, national, or regional. Integrating MWRSs into relevant policies is emphasised by the Guiding Principles for Effective Early Warnings (IDNDR 1997; Annex 3). Several groups must contribute to ensure the effective functioning of a MWRS, beginning with **members of vulnerable populations**, who should be aware of the hazards. Local communities should be sufficiently familiar with the hazards to which they are exposed and understand the advisory information received. **National governments** should exercise their sovereign responsibility to prepare and issue hazard warnings for their national territory in a timely and effective manner. **Regional institutions** have a role to play when the hazard and the MWRS are of a regional nature. Such institutions should provide specialised knowledge, advice, or the benefit of experience in support of national efforts to develop or sustain operational capabilities related to hazard risks. **International bodies** should provide means for the sharing and exchange of data and relevant knowledge among themselves to ensure the development and operational capabilities of national authorities.

Four case studies

Case 1: Tsho Rolpa GLOF early warning system

Tsho Rolpa lake is located in the Rolwaling valley of Nepal at an elevation of 4500 masl. The lake is 3.5 km long and 0.5 km wide, and in 2002 occupied 1.76 km^2 surface area and contained 92.4 million m^3 water (Shrestha et al. 2004). The lake is considered one of the most dangerous glacial lakes in Nepal (Reynolds 1999). The Department of Hydrology and Meteorology, Government of Nepal, commissioned an early warning system (EWS) downstream of Tsho Rolpa lake. The system was designed and installed by BC Hydro International, Canada and Metero Communication Corp, USA. The major components of the system are described below.

GLOF sensing system: Six water-level sensors are installed immediately downstream of the lake outlet. The system monitors the outburst flood itself and provides warning downstream that an outburst has occurred. The sensing system is fully redundant to mitigate issuance of false alarm, and multiple sensor failures would have to occur before the system failed to detect an outburst.

Communication system: The signal of an outburst is relayed to the warning stations by the communication system. The warning system relies on extended line of sight very high frequency (VHF) radio technology. A second component of the communication system is the meteor burst communication system. A meteor burst system uses ionized trails of meteors to extend the range of the transmitted radio signals to over 1700 km. For this, a meteor burst master station is located in Dhangadi, western Nepal. The VHF and meteor burst system together are totally redundant to communications failure.

Figure 34: Automated early warning system for Tsho Rolpa, Nepal

GLOF warning system: The EWS consists of 19 warning stations located in 17 villages along the Rolwaling and Tamakoshi rivers (Figure 34). The warning stations consist of an audible horn operated by a charged air cylinder. The horn is activated as soon as the outburst signal is received by the station via the communication system. The 80 dB air horn is audible up to 150m away under the most adverse conditions. As a backup, an electric horn is also installed. The warning stations are powered by a 12 V battery charged by solar panels. The warning station also acts as a relay station for the VHF system, which relays the signals to downstream stations.

The Tsho Rolpa EWS is a highly sophisticated and reliable system. The system functioned satisfactorily for several years. Later, due to security problems, regular maintenance of the components became impossible. Local vandalism of equipment and burglary has left many of the warning stations out of function.

Case 2. Earlier stage of Tsho Rolpa early warning system

Prior to the establishment of the automated EWS, army camps were set up at the lake site and in the villages of Naa and Beding, the first two villages downstream of the lake. The army camps were equipped with HF radio transceivers and were in contact with their headquarters in Kathmandu twice daily to inform the Disaster Cell at the Ministry of Home Affairs of the status of the lake. In addition to the HF sets, the camps were equipped with two satellite phones. In the event of a GLOF from Tsho Rolpa, Radio Nepal, the national radio service, would broadcast a warning message. As the broadcast is received at most of the locations along the valley, the people would be warned of the GLOF. This arrangement was in place until the automatic EWS was established.

Case 3: Bhotekoshi early warning system

The Bhotekoshi EWS was commissioned by Bhotekoshi Power Company Pvt. Ltd. The system is analogous to the Tsho Rolpa EWS and was designed and installed by BC Hydro International, Canada, and Metero Communication Corp, USA, although the number of warning stations are significantly less than those in the Tsho Rolpa EWS. There have been three GLOF events in this river basin in the past (1935, 1969 and 1981), and there are 139 glacial lakes in the basin, of which nine are potentially dangerous (Mool et al. 2005). The EWS's six sensors (two sets of three) are located at the Friendship Bridge at the boundary between Nepal and China. There are two warning stations at the intake site and two at the power house site. One more warning station has been added at the village slightly downstream of the powerhouse. It has been estimated that the travel time for a GLOF from the Friendship Bridge to the intake site is five minutes.

Case 4. Community-based early warning system

Practical Action Nepal has established a community-based EWS in Chitwan, Nepal. The system consists of a watchtower equipped with an alarm (Figure 35). A watchman monitors the river water level during the rainy season and turns on the alarm when the water level crosses the critical flood level.

G. Gurung, Practical Action, Nepal

Figure 35: Community-based early warning system in Chitwan, Nepal

The mountain communities of Pakistan have an old tradition of flash flood warning by burning a fire at strategic locations, often hilltops (Iturrizaga 1997; 2005b; Xu et al. 2006). Shepherds herding sheep in high altitude pastures sensed the occurrence of flash floods much sooner than villagers located in the valley and could provide warnings. This system has disappeared due to the decline in traditional community organisations and the decline in sheep herding in those communities. In some communities, the fire signal has been replaced by modern communication systems such as telephones and mobile phones.