Key Elements of Flood Disaster Management

2

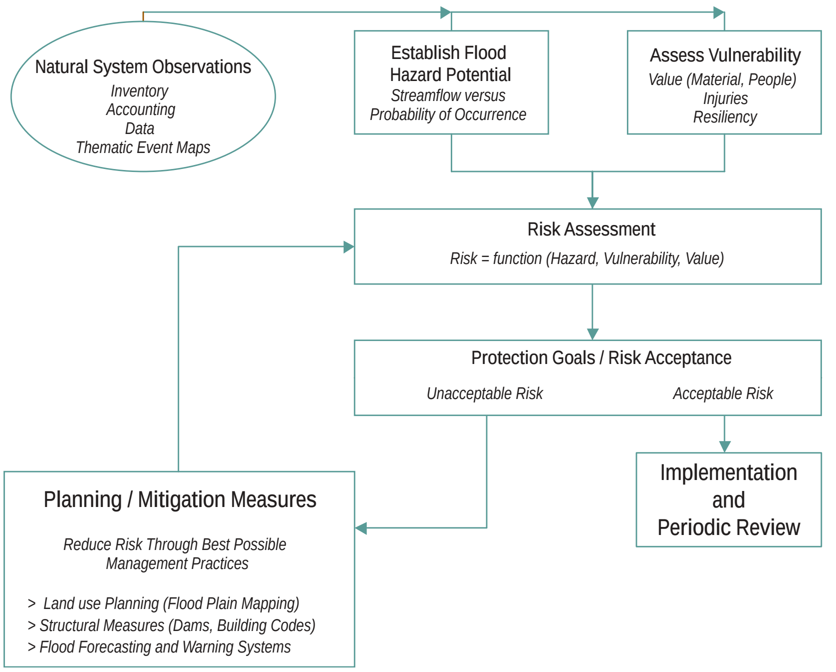
2.1 Risk Management and Flood Plain Delineation

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.