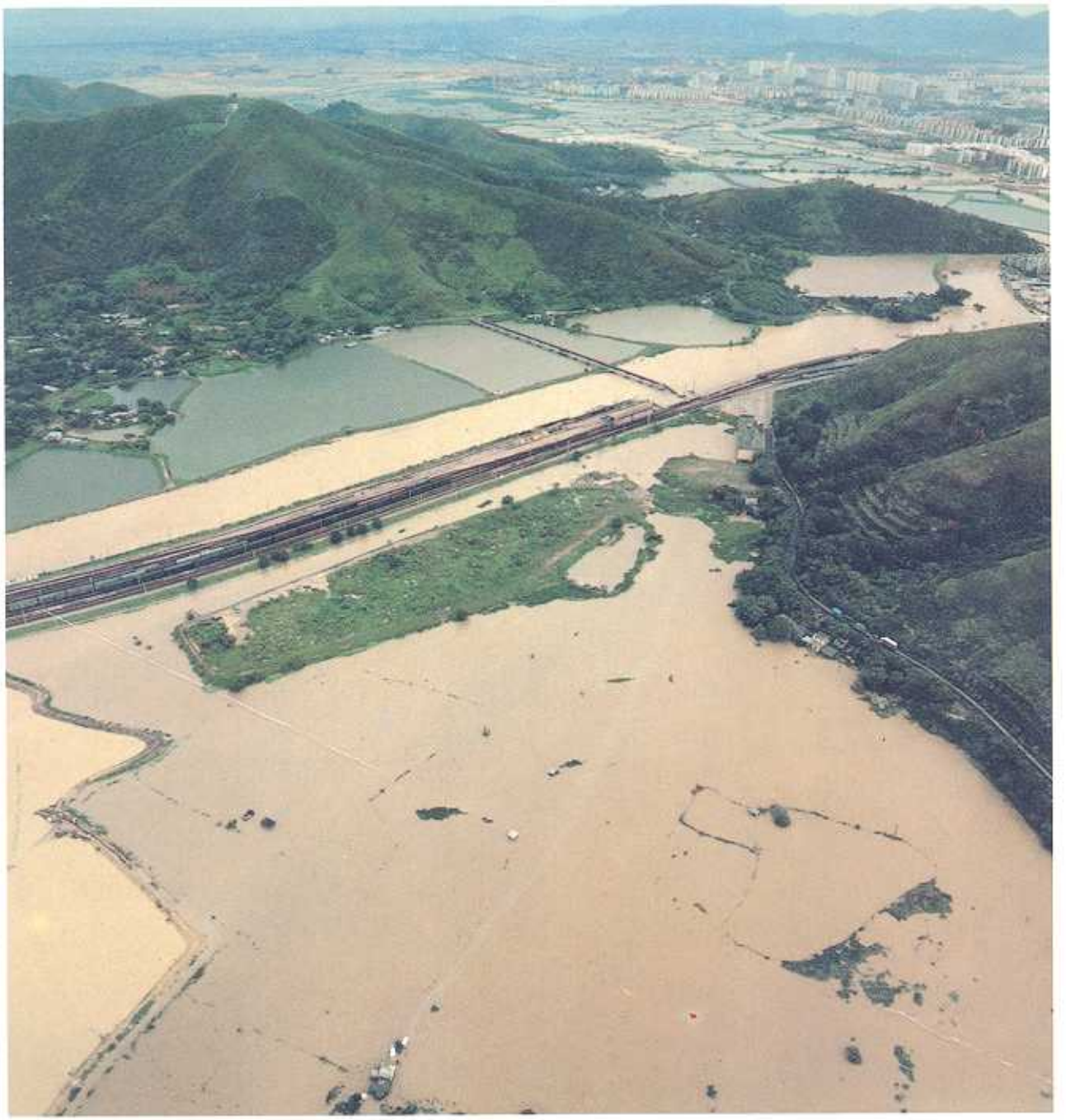
MANUAL AND GUIDELINES FOR COMPREHENSIVE FLOOD LOSS PREVENTION AND MANAGEMENT



ECONOMIC AND SOCIAL
COMMISSION FOR ASIA AND THE PACIFIC

UNITED NATIONS DEVELOPMENT PROGRAMME

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FOREWORD

Every year floods throughout the world cause considerable economic losses, untold human misery and suffering and loss of life. In the countries and areas of the ESCAP region flooding ranks amongst the worst of all natural disasters and inflicts massive economic damage and social disruption on vulnerable communities. Floods are continuing to impose a heavy burden on national economies of these countries and areas both in developing measures to combat their effects and in recovering damages.

Because of rapid urbanization and increasing population on flood-liable lands of the ESCAP region, the potential for flood losses is increasing dramatically. In most of the region the greatest concentration of population and national wealth is on these flood-liable areas, notwithstanding that such floodplains represent only a small fraction of the total land area. In spite of the flood threat, pressure to occupy floodplains will continue because they are generally the most attractive and easily developed of the available land areas. The magnitude of the flooding problem and its consequences will therefore continue to be a matter of grave concern to the affected countries and areas.

Disaster relief from losses, damage, adverse social and cultural consequences and demands on emergency services resulting from flooding can only be achieved through planned flood loss prevention and management techniques involving the recognition of flooding characteristics and the implementation of appropriate mitigation measures. Without the commitment of substantive funds and realistic levels of expenditure, very little can be achieved in the way of relief to the flooding problem.

The Manual and Guidelines have been prepared to assist the members of the Typhoon Committee in their efforts to reduce the social impact of flooding and to reduce the losses resulting from flooding.

To prepare the manual and guidelines missions for information collection and advisory services and a series of expert group meetings were organized from November 1987 to July 1990.

The advisory missions in November and December 1987 and March 1988 and the subsequent expert group meeting in October 1988 stressed that comprehensive measures comprising an appropriate combination of both structural and non-structural measures were essential to cope with the current flooding problems. A manual and guidelines, which identify concepts and principles of comprehensive flood loss prevention and management, were considered to be necessary for the implementation of such measures in the countries and areas concerned. The expert group meetings in July 1989 and July 1990 reviewed and finalized the draft manual and guidelines prepared by the secretariat.

This volume is composed of two parts. Part One: PRINCIPLES gives the conceptual picture and practical considerations on applying comprehensive flood loss prevention and management. Chapter I presents the philosophy and need for flood policy, chapter II is devoted to the development and implementation of comprehensive flood loss prevention and management systems, and chapter III deals with institutional arrangements for the realisation of comprehensive flood loss prevention and management measures.

Part Two: GUIDELINES is devoted to the more technical aspects of selected measures of comprehensive flood loss prevention and management. Chapter IV is an executive summary of the

Manual and Guidelines for Flood Risk Analysis and Mapping Applicable to Typhoon Committee Areas (first version), strengthened by other informative materials. Chapter V follows the *Floodplain Development Manual* of New South Wales Government, Australia, revised for use by Typhoon Committee members. Chapter VI is taken from *Guidelines for Disaster Prevention and Preparedness in Tropical Cyclone Areas*. Emphases have been placed on flood disasters.

It is hoped that those who are responsible in flood loss prevention and management will find the manual and guidelines of value in their efforts to solve flood problems and obtain wise and optimum use of the resources available.

This Manual and Guidelines have been prepared under the auspices of ESCAP in co-operation with the Typhoon Committee Secretariat and the World Meteorological Organization to promote comprehensive flood loss prevention and management techniques in the Typhoon Committee region. The contributions and guidance provided by experts who participated in expert group meetings on comprehensive flood loss prevention and management in development of the manual and guidelines is recognized. The individual contributions and assistance provided by the Typhoon Committee members is also acknowledged.

In addition to material collected from the Typhoon Committee members, the policies, experience and current practice in flood loss prevention and management in Australia and the United States of America were referred to in the text. In particular, publications issued by the United States Water Resources Council, the United States Department of the Interior, and the New South Wales and Victoria State Governments and the Federal Government of Australia have been useful.

Special acknowledgement is due to the United Nations Development Programme (UNDP) which financially supported this activity as a part of project RAS/86/175, "Programme support for the Typhoon Committee".

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Part One

PRINCIPLES

Plate I. An illustrative example of a flash flood that occured in a rural area of the Philippines.

I. INTRODUCTION

A. Nature of flooding

The size and frequency of a flood at any point depends on the volume and timing of run-off from upstream catchments and, in coastal areas, tidal effects and storm surge at the river mouth. Physical characteristics of the catchment itself are also important in determining the size of flood which can result from a particular rainfall. These include geographical features such as catchment area and topography and hydrologic features such as interception by vegetation, evaporation and infiltration. Artificial structures, such as large dams, can also affect the nature of flooding.

Most countries in the ESCAP region experience frequent and devastating floods. Because of the vast differences in topography, climate, and exposure to typhoons throughout the region, it is only natural that wide variations in the physical aspects and effects of floods will be experienced. These variations, which range from flash flooding in some countries to long duration flooding in others, engender different perceptions of flooding.

In the Typhoon Committee region, floods are mostly caused by convectional storms, which are mainly induced by monsoons, and cyclonic storms called typhoons. Convectional storm floods are associated with violent local storms caused by the convectional flow of air. They tend to produce flash floods in relatively small basins. They can produce very large property losses and sometimes major loss of life as well. This is especially so in certain urban areas. Typhoons are associated with the movement of large air masses from the oceans to land, and often cause devastating damage. These storms originate in the western north Pacific and South China Sea and move towards the Philippines, Japan, the Korean peninsula, China and the Indochina peninsula. The rainfall associated with them is generally more widespread and of longer duration than that associated with convectional storms. Typhoons tend to lose their force once they cross the coastline and are cut off from their source of moisture. Storm surges brought on by typhoons can be especially devastating at coastal areas.

Countries or areas located along downstream reaches of large rivers often suffer severe flooding resulting from rainfall on the upper catchment. From the viewpoint of those populations who suffer inundation from such floods, high river flows which overtop river banks or works are considered as being the cause of flooding.

Regional experience

Owing to its geographical location and size, China is one of the member countries most seriously affected by floods. Floods in China may result from heavy storms, typhoons, ice jams and landslides. Of these causes, the typhoons are the most frequent and significant. Typhoons occur along the whole Chinese coast and in areas adjacent to it. The eastern and southern coastal regions are very vulnerable to typhoon disasters and the inland area, except for the northwestern region, are also within the range of typhoon damage. Most of the typhoons affecting China cross the South China Sea, and the floods resulting from them cause damage along small rivers, large tributaries, major rivers and along the sea coast. Sediment loads accompanying flooding are also a major source of damage.

In Hong Kong, heavy rain is caused by either summer monsoon troughs or typhoons. Accompanying these are landslides, floods and storm surges. Most low-lying areas near the coast may be prone to flooding either by heavy rain or storm surges associated with typhoons or a combination of both. Intense rainstorms can cause flash flooding in most small catchment areas.

Japan is located at the north-eastern end of the monsoon region. The country has four distinct seasons, including three wet periods. In winter, the western side adjacent to the Sea of Japan experiences heavy snowfalls, especially in the northern part, while clear weather is experienced along the Pacific Coast to the east. The

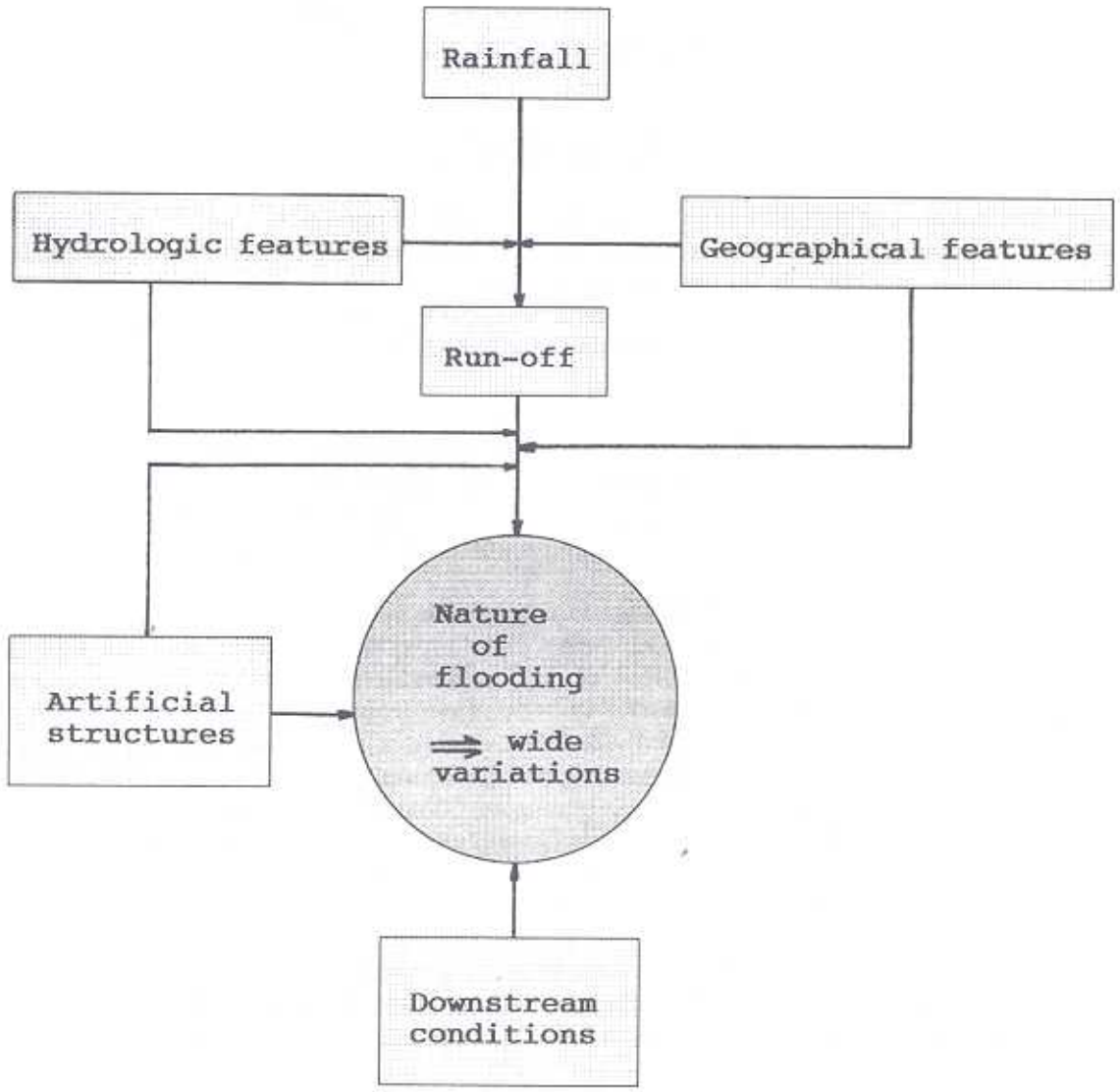


Figure 1. Factors contributing to nature of flooding

second rainy season from June to July is called "Tsuyu" when continuous torrential rainfall frequently occurs becaise of stationary fronts. From September to October, typhoons spawned in the Pacific Ocean south of Japan cause stormy weather. As a result Japan suffers substantial flood damage from a set of flood conditions ranging from flash floods on the short steep catchments to extended periods of overbank flow and storm surges in the lowland flood plains. All flooding is accompanied by severe damage from water-borne sediments associated with such flood flows.

Flood damage in the Lao People's Democratic Republic is caused firstly by overflowing of the Mekong river in its upper and middle reaches during the south-west monsoon season, from August to September. The floods in the tributaries are mainly due to tropical depressions or tropical storms.

On the east coast of Peninsular Malaysia and along the coastal regions of Sabah and Sarawak, floods are mainly generated by the north-east monsoon from November through February. Intense, localized and brief thunderstorms can cause flash floods in small and steep catchments along the west coast of Peninsular Malaysia. In urban areas during the monsoon period intensive convective thunderstorms are a frequent cause of flash floods, especially in Kuala Lumpur.

Most, if not all, of the weather-related disasters in the Philippines are due to tropical cyclones sometimes associated with south-west monsoons during the months of May to September, and the effect of cold fronts and north-east monsoons during the months of November to February. Strong winds, excessive rainfall and storm surges also cause destruction.

Climatically the Republic of Korea is located in the temperate monsoon zone. About two thirds of the annual rainfall occurs during the period from June to August. Typhoons and depressions which occur during those months bring heavy rainfall which occasionally causes major flooding. On average two typhoons a year hit the country and the resulting floods can be devastating in both the loss of life and property damage.

In Thailand, the south-west monsoons begin in May, producing great quantities of monthly rainfall over the main part of Thailand that reaches a maximum in September. The peninsular part of Thailand receives torrential rains from the north-east monsoons starting in November. In addition, tropical depressions and tropical storms can cause similar destructive flash floods in different parts of the country.

In Viet Nam, the north and central regions are often attacked by typhoons during the rainy season, mainly between July and October. Storm surges are also experienced along the coastal regions. Flash flooding occurs on the many small steep catchments in the central region, while major and protracted flooding is experienced in the Red River delta to the north. The Mekong delta region is subject to disasters caused by floods originating in the upper reaches.

B. The flooding problem

Natural disasters are caused only where interactions between nature and human activities exist. Even if the scale of a natural phenomenon is great, when it occurs in a place where there is no human activity, it causes no problem. Human activity, however, tends to concentrate in flood-liable areas which are often convenient and attractive locations for settlement and other economic endeavours. Probably all the floodplains in the Typhoon Committee region have concentrations of human activities upon them. Therefore, whenever a large flood occurs, it causes human misery.

Floods disrupt the social systems of countries. They cause many emergencies and at the same time consume valuable resources in responding to them. Death and injury have a strong emotional impact as does the destruction of houses, property, crops and personal belongings. Damage to roads and bridges and breakdowns in the communication system isolate people and compound the problem of providing emergency services. The disruption of services, particularly water supply, sewerage and power supply may lead to health and safety problems.

Floods cause enormous economic losses to both urban and rural communities throughout the region. Flood damage throughout the region continues to increase and the potential for damage to property will escalate if comprehensive programmes for flood loss prevention and management are not developed and implemented.

The interaction between the flood event and the human use of the floodplain is of a dynamic nature. While the flood event may be taken as a given parameter, the use of the floodplain is subject to dynamic changes so that the flooding problem also varies with time. In some cases the adoption of flood protection measures has initiated a change in the use of the floodplain. This has resulted in greater flood damages rather than the expected decrease in flood losses because of a misplaced confidence in the safety provided by the flood protection measures.

Regional experience

In China, the concentration of annual rainfall in a short period and the concentration of population and property in flood-liable areas contribute to the occurrence of flood disasters.

Floods in Hong Kong cause one of the more serious problems because of a critical combination of heavy rainfall and an abnormal rise in sea level as a result of storm surges during typhoons. Although the urbanised metropolitan areas are relatively free from flooding, significant flood problems are being experienced in the low-lying areas of the rural districts of the New Territories. As a result of recent developments in those areas which have reduced natural flood plain storage, flooding is becoming more frequent and severe.

In Japan the rapid urbanization of river basins has reduced the water retaining and retarding functions of the land, increased the volume of flood flows, reduced the time of flood concentration and increased the danger of flood disasters. Added to this fact, about fifty per cent of the population live, and seventy per cent of the nation's assets are located in flood-prone areas which occupy only ten per cent of the total land area. Under those circumstances, the flood problem in Japan now ranks amongst the worst disaster situations which afflict the country.

Flood damage in the Lao People's Democratic Republic is caused firstly by the overflowing of the Mekong River which brings heavy floods and secondly by the overtopping of its tributaries. The frequent flooding of the Vientiane Plain and the southern region caused by the Mekong River and its tributaries inflicts significant damage on important cultivated areas. Flash floods occur in many small steep catchments in the northern and southern region of the country. The city of Vientiane and the surrounding area can be flooded for periods of about two weeks. The cost of damages to urban and rural areas can amount to tens of millions of dollars.

Kuala Lumpur, the capital of Malaysia, has suffered flooding from the overtopping of the Klang River and its tributaries since the time of its establishment. The rapid urbanization of the city itself and the bowl-shaped topography of the area account for this.

In the Philippines, the flood situation is being aggravated by uncontrolled developments on floodplains, the exploitation of basin watersheds, the sedimentation of waterways and the reduction in wetland storage areas owing to rapid urbanization of metropolitan areas. Despite gains made in flood protection measures, the evergrowing flood problems and associated flood damages persist as a result of partially implemented schemes and insufficient protection measures. The annual damages resulting from flooding in the Philippines is enormous and ranks among the highest of all the member countries in both social and economic terms.

The Republic of Korea has frequently suffered disasters because of floods in some of the major cities. Insufficient capacity of both pumping stations and secondary drainage facilities and the rapid urbanization of rural areas have added significantly to the flooding problem. As a direct result of floods, many lives are lost annually, large populations are displaced and property damage amounting to many millions of dollars is suffered.

Floods constitute a severe hazard to the people of Thailand and exert a significant negative effect on the economic growth of flood-affected areas. Urban centres are particularly affected. On average, Bangkok suffers significant flood damage about once every five years caused by overland flow and local drainage problems which are often prolonged by high water levels in the Chao Phraya River. Apart from metropolitan Bangkok, most other areas in Thailand suffer from considerable flood damage.

Viet Nam has experienced many flood catastrophes throughout the entire country. The magnitude of flooding in urban and rural areas is such that it poses a significant problem for the Government to overcome, especially in areas where existing levee systems have failed.

C. Development of a flood policy

The ultimate goal of flood loss prevention is the improvement of the quality of life by reducing the impact of flooding and flood liability on individuals, and by reducing private and public losses resulting from flooding. This general aim may be specified as an objective such as the maximization of net economic benefits (benefits minus costs). There are, however, many objectives which cannot be expressed in monetary terms, such as preservation of environmental quality, or social well-being of all the people. A policy selects a certain combination of these objectives with various constraints which restrict realization within specified bounds. A policy that is optimal for the national economy is not necessarily the same as another policy that emphasizes

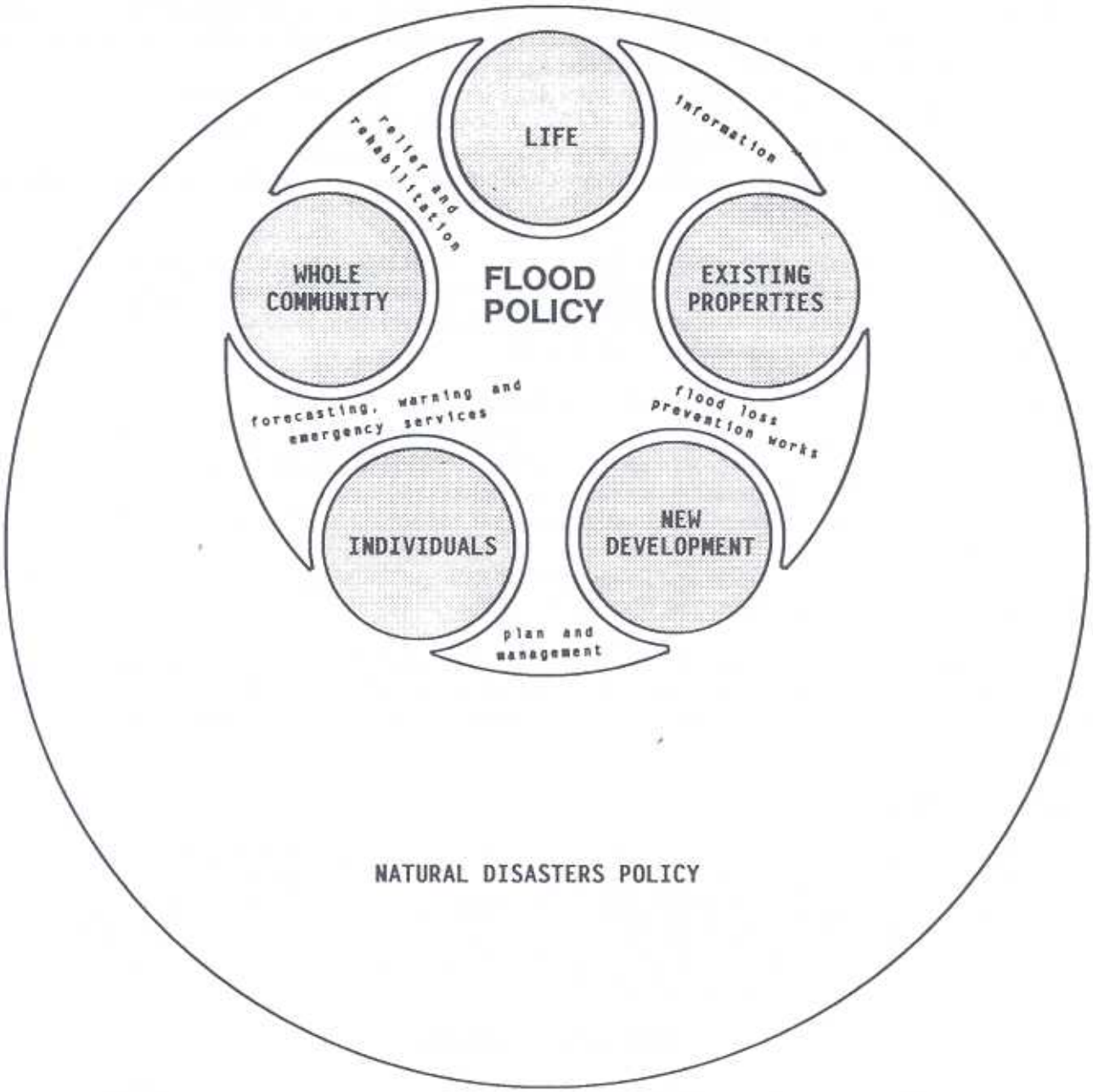


Figure 2. Flood policy development

environmental quality. Therefore trade-offs that increase some values at the expense of others would have to be considered in order to obtain an acceptable policy. This provides the conceptual basis for planning activities. It is essential that each country formulates a flood policy which promotes the reduction of flood losses.

The broad objective of a comprehensive and unified policy should be to reduce the social and economic costs to the community caused by flooding. This objective can be accomplished by incorporating into a policy the following principles:

(1) All reasonable flood loss prevention works and measures are taken to alleviate the hazard and damage potential to life and existing properties which are at flood risk;

(2) There is no significant growth in future hazard and damage potential resulting from the development on floodplains. The usage of flood prone land is planned and managed in a manner compatible with the assessed frequency and severity of flooding;
(3) Appropriate forecasting, warning and emergency services, and government assistance in relief and rehabilitation, are available in the event of future flooding. Information is provided to the public on the past flood events and the likely extent of possible future flooding;
(4) Consideration is given to the social, economic and environmental consequences to individuals as well as to the whole community.

To be effective, the policy must recognise the need to treat developed and undeveloped land separately. The impact of flooding and flood liability on existing developed areas should be reduced by flood mitigation works and measures, while the potential for flood losses in all new developing areas should be contained by the application of effective planning and development controls.

Other important features to be considered in the development of the policy include:
(a) Given the nature of flooding in relation to other land hazards such as earthquake, landslip, subsidence etc., it should be treated as part of the overall policy relating to natural disasters;
(b) A leading authority/organization should be nominated to take prime responsibility for the development and implementation of flood mitigation plans and for the control and development of flood prone land;
(c) Adequate political, technical and financial support should be provided to ensure that reasonable progress is achieved in combating flood problems.

One of the roles of Government in formulating a flood policy is to draw attention to the hazards to life, health and property in those areas where flooding has occurred and will occur. This, however, should not prevent development of flood-liable lands completely, but should ensure that such land is used only for flood-compatible purposes.

Regional experience

Over the past decade, Japan has been developing a comprehensive strategy for flood loss prevention which incorporates many of the principles mentioned above. On top of various structural measures, which are well maintained and protected in an emergency, advanced flood forecasting and warning systems have been established, many kinds of physical, financial and institutional measures to store water in the basin before it goes to rivers have been taken and inundation records and flood risk maps have been published. The comprehensive strategy for flood loss prevention in Japan is set out in figure 3.

D. Policy implementation

Implementation of the policy generally involves the formulation and execution of a flood loss prevention and management plan. This process may be thought of as a series of distinct but interconnected steps. These steps consist of:
(1) Identification of goals;
(2) Assessment of problems;
(3) Identification of alternative strategies;
(4) Identification of criteria;
(5) Evaluation of alternatives;
(6) Selection of an appropriate strategy;
(7) Implementation of the selected strategy;
(8) Review of necessity for the adjustment and updating the selected strategy;
(9) Operation and management.

The various steps are part of a continuous process, with the output of each phase providing the input for the next one. (See figure 4.)

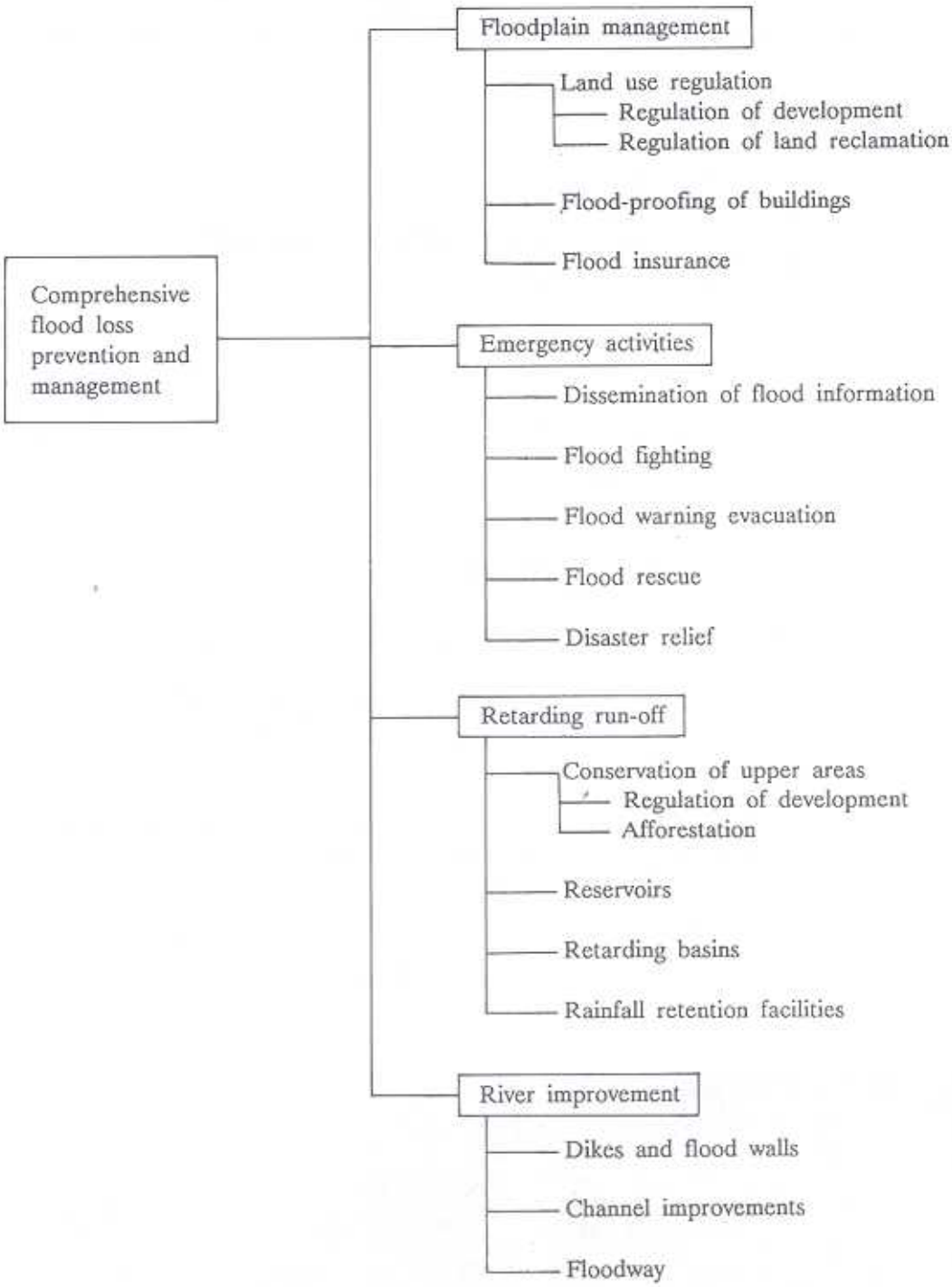


Figure 3. Comprehensive strategy for flood loss prevention in Japan

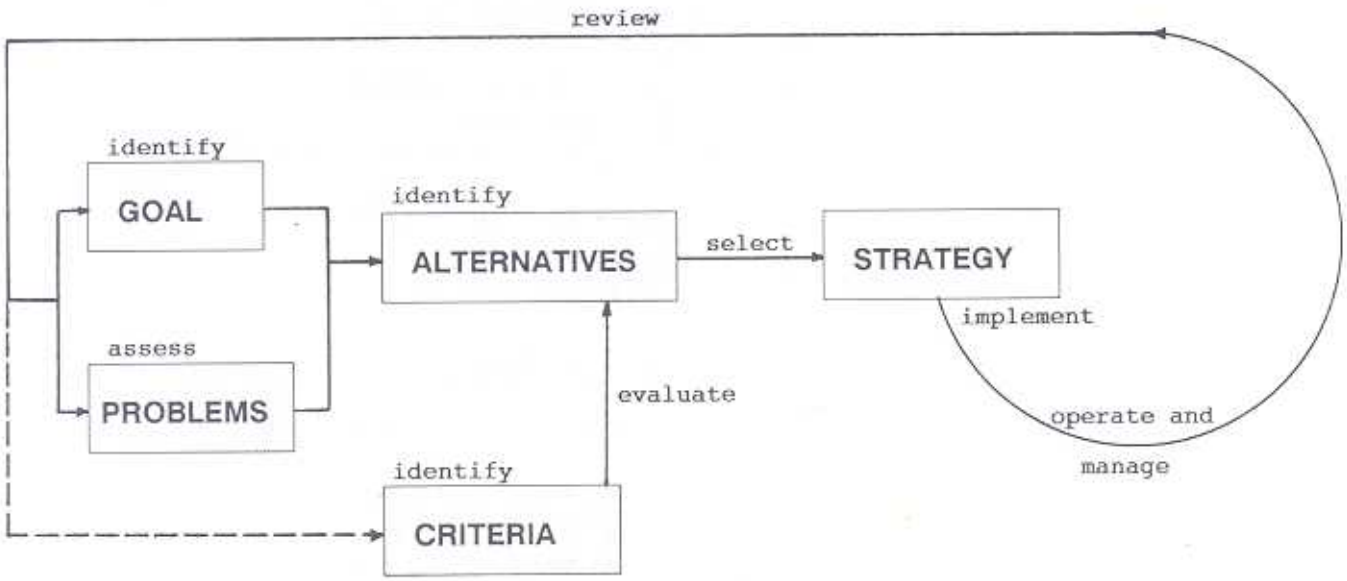


Figure 4. Policy implementation process

There should be constant communication among the participants in each phase of the planning process with information not only flowing forwards from one stage to the next but also being fed back to previous stages. The participants include those who would be directly affected by the plan (beneficially or adversely), all government agencies having jurisdiction, public interest groups, and other interested organizations and individuals.

The overall co-ordination of flood loss prevention and management plans should be entrusted to one leading authority/organization which assumes responsibility for legal, administrative and financial matters relating to the management of flood problems. The leading authority/organization should also have the necessary technical and institutional expertise for the setting of standards, provision of technical advice, and to ensure that the optimum mixture of both structural and non-structural options are considered in the development of a flood loss prevention and management plan. (Regional experience is described in chapter III, section A.)

Plate 2. In Japan the rapid urbanization of river basins has reduced the water retaining and retarding functions of the land.

II. COMPREHENSIVE FLOOD LOSS PREVENTION AND MANAGEMENT SYSTEM

A. Co-ordinated basin-wide management approach

Effective flood management needs to consider the whole basin and requires that any and all methods which can reduce flood losses should be considered and used when appropriate. In the broader sense, co-ordinated basin-wide management seeks to co-ordinate effectively the basin management activities of all authorities/ organizations and individuals to sustain the productivity and condition of the natural resources, address land and water degradation problems and preserve options for future land use. This is because changes in basin conditions, such as land use, urban development and even structural flood loss prevention measures, may cause an increase in the potential flood response in the adjacent area and the downstream reaches. The concept of comprehensive basin-wide management encompasses the entire range of flooding problems which originate from urban drainage, riverine flooding or a combination of both.

The basin-wide management approach can be achieved by various means, including the development of greater co-operation among agencies, authorities and individuals involved in the management of land-based natural resources. In particular, activities related to the management of soil, water and vegetation resources have a significant impact on water movement in the basin and consequently the nature and severity of flooding. Therefore appropriate management mechanisms and measures can minimize the adverse impacts of development on the basin's flood producing capability.

The extent to which the basin-wide management approach can be applied will depend largely on the nature of the ownership of land (i.e., government or private) and the available controls which can be imposed by the flood authority/organization over its development and management. In addition to strengthening co-operative management of the basin, there may also be a need to strengthen existing legislation to achieve these controls over the basin.

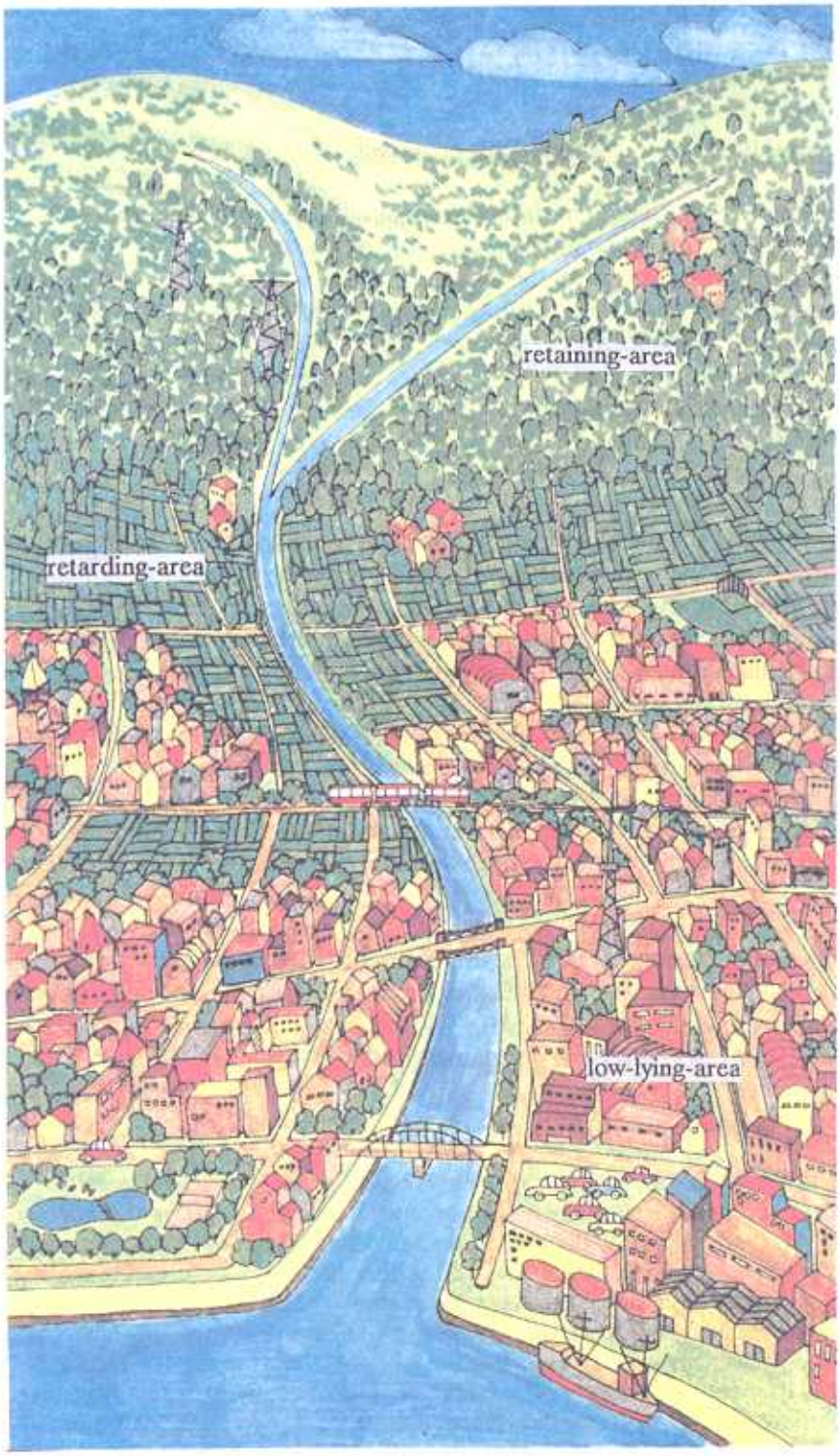
Difficulties in achieving co-ordinated management may be experienced on very large river basins or in the riparian countries of the international river systems. In the latter case, the principles of co-ordinated basin management should be included into the compact agreed to by the countries concerned and the implementation of these principles fostered by the co-ordinating organization.

Regional experience

In Japan, comprehensive flood loss prevention and management is based on the basin-wide management approach. It was recognized that proper basin-wide management techniques reduce flood damage by affording some degree of control over water in the land phase of the run-off cycle. These techniques are aimed at maintaining the natural water retention capacity of vegetation and soil within the basin or creating artificial measures to maintain this effect when development alters the natural situation. This concept applies to the management of the basin as a total system. The co-operative involvement of a number of agencies with an interest in flood loss prevention and management within the basins is heavily relied upon to develop and implement appropriate basin-wide management strategies. The basin is classified into a retaining area, retarding area and low-lying area according to the hydrological characteristics and land use, and measures particular to each area are taken to reduce flood loss. (See figure 5.)

B. Flood studies

The undertaking of flood studies is largely a specialized technical exercise aimed at determining the nature and extent of the flood hazard in a particular area. The flood study constitutes the first step of the flood management process.



River Basin

- Retaining area
  - Non-developed area
    1) Preservation of urbanization restraint area
    2) Preservation of natural retaining function
  - Developing area Storm water detention pond
  - Developed area Run-off control

  Hilly lands, terraced and mountainous areas.
  Capable of infiltrating and storing rainwater.

- Retarding area
  1) Preservation of urbanization restraint area
  2) Improvement of agricultural condition
  3) Control of soil disposal

  Less developed lowland along rivers.
  Capable of temporarily storing river flow.

- Low-lying area
  1) Inner water drainage plan
  2) Operation rule of inner water drainage pump
  3) Storage facility

  Developed area subject to flooding.

Figure 5. Basin-wide approach being taken in Japan

There are two major components of a flood study: the examination of flood discharges for floods of various sizes (hydrologic aspects); and the determination of water levels, velocities etc. (hydraulic aspects). These two components then serve as the hydrologic and hydraulic input to flood loss prevention and management plans formulated to combat flood losses. As well as documenting the studies undertaken to assess the frequency and extent of inundation, the flood study report also provides technical details on all other flooding aspects which must be considered when formulating a flood loss prevention and management plan.(See table 1.)

Table 1. List of flooding aspects to be considered

Hydrological/hydrometeorological data	Water management data
1. Rainfall (a) depths (b) intensities (c) duration 2. Stream flow (a) velocity (b) discharge 3. River water levels (a) mean (b) flood 4. Sediment load (a) bed materials (b) suspended materials 5. Storm surge 6. Tidal data 7. Wind data	1. Operation record of flood control works (a) dams (b) weirs (c) pumping stations (d) gates (e) retarding basins **Flood damage data** 1. Inundation (a) area (b) depth (c) flood water velocity (d) duration (e) volume 2. Damages (a) tangible damages (i) direct damages (ii) indirect damages (b) intangible damages

The flood study report should provide all the relevant information which is listed below in a comprehensive but succinct format:

(1) Physical setting of the river basin:
- Topography
- Soil and vegetation types
- Land use and cadastre
- Longitudinal stream profiles
- Channel cross-sections
- Channel roughness
- Coastal and estuarine bathymetry

(2) Nature of flooding
(3) Hydrological analysis
(4) Hydraulic analysis
(5) Potential flood damages

The study may include the preparation of a flood risk map which identifies the extent, severity and frequency of flooding.

Flood studies can take a variety of forms and sophistication depending on the nature and extent of development. Detailed studies involve comprehensive hydrologic and hydraulic investigations and extensive field surveys. Such studies are only undertaken for a community where the degree of flood affectation, its size and its rate of growth warrant the considerable effort involved. In densely populated areas, the extensive and costly detailed studies are generally necessary because a full knowledge of flood characteristics is required as a basis for dealing with both existing flood problems and future development proposals. In coastal areas, such studies are further complicated by the need to consider the impact of oceanographic and tidal phenomena. For smaller communities, or areas with less significant flood problems, reconnaissance flood study may be undertaken. These studies rely upon the inundation pattern for a large historical flood.

These flood studies can be used as a means of creating public awareness of flood hazard situations and an initial planning document prior to finalising detailed flood loss prevention strategies.

C. Flood standards

The flood standard, sometimes expressed by the return period, is the size of the flood adopted as the basis for planning the protection of and controlling the development on flood-liable land.

The appropriate flood standard should reflect a realistic level of flood risk and take into consideration the social, economic and environmental factors associated with a programme of flood loss reduction. The adopted flood standard will determine the trade-off between short-term costs and long-term damages. (See figure 6.)

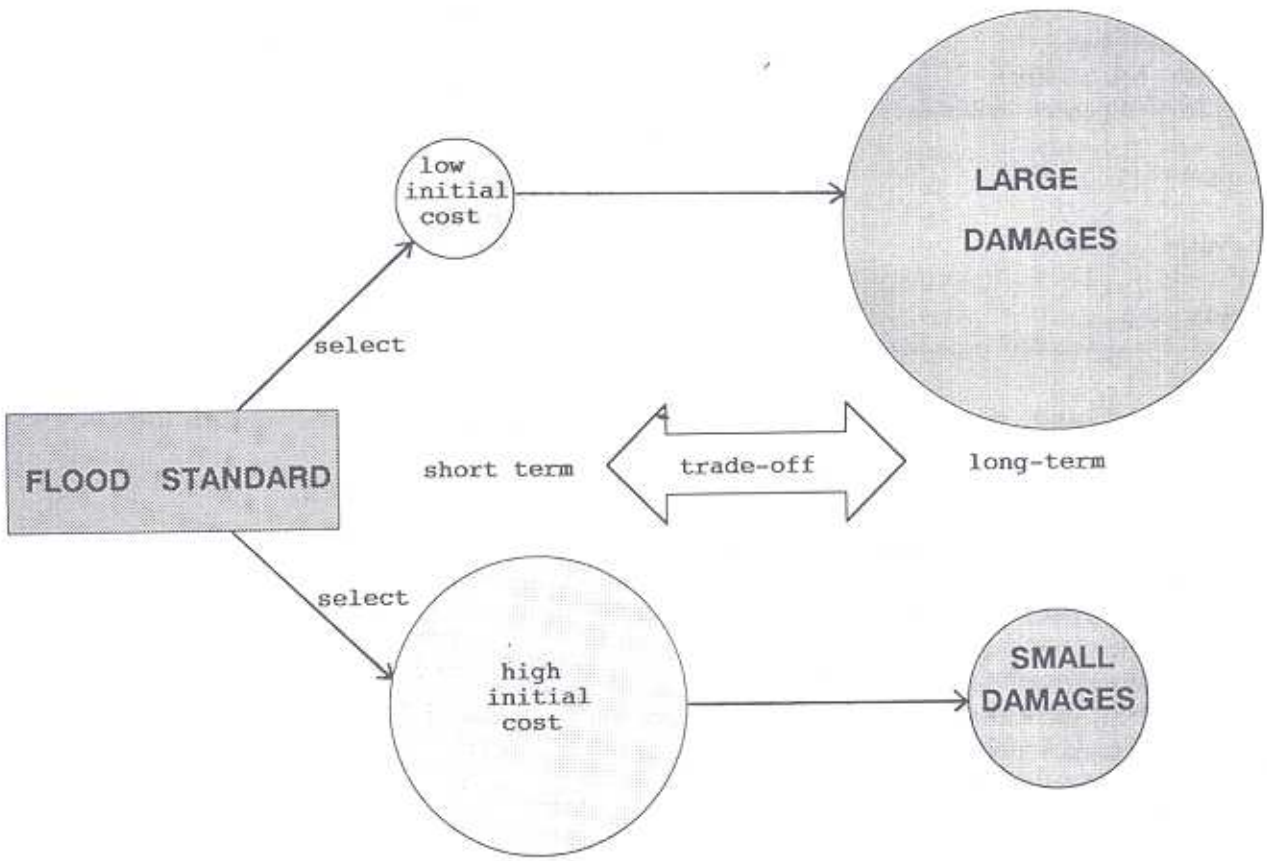


Figure 6. Selection of flood standards

For reasons of simplicity, expediency and administrative ease, many authorities adopt a uniform flood risk, such as the 1-in-100 year flood (1 per cent flood). In other cases, flood authorities have adopted the highest recorded or historical flood as the appropriate standard. Another alternative is to base each case on its merits where the selected standard for each particular area is determined by balancing social, economic and environmental considerations against the consequences of flooding so as to minimize potential flood losses.

Because of economic constraints and present community aspirations, many developing countries may opt for a lower flood standard in the short term and increase this standard in the future as additional resources become available.

Larger floods than the standard flood will occur and the completion of flood loss prevention measures or zoning of an area does not imply that flood damages will be eliminated forever. It can not be assumed that lands outside the limit of the standard flood or land protected up to that level will be free of flood damages.

An indication of the range of flood standards adopted by selected countries throughout the world is presented in table 2. The main source of information contained in the table was a review carried out by the International Commission on Irrigation and Drainage.

Table 2. Typical world flood standard – Design flood return period (years)

Country/Area	*Commercial*	*Industrial*	*Residential*	*Rural*	*Agricultural*	*General*
Australia	50-100	50-100	50-100		5-50	
Brunei Darussalam (3)	10		5			
Bulgaria	100-500			30-100	5-10	
China (2)	200			100		
Colombia						30
Czechoslovakia	100	50			7-10	
Hong Kong	50-200	50-200	50-200	10-200	2-5	
Hungary						60
India (2)	50				25	
Indonesia						5-20
Japan	10-200	10-200	10-200	10-200	10-200	
Malaysia (3)	5-100	5-100	5-100	5-100	5-30	
Philippines (2)	100			50-70		
Poland	1,000	500		100	20-100	
Singapore (3)	5	5	5			
Turkey	100-500	100-500				
Thailand	25-100	25-100	25-100	25-100	50-200	
UK	10-100	10-100	10-100		1-10	
USA	25-100	25-100	25-100		5-25	
USSR	1,000	100	50		10	
Venezuela						5-10
Viet Nam						20-50

Notes:

(1) Standards refer to river training and flood control.

(2) These standards are for levee design.

(3) Designs also check that 100-year flood line is below ground line of buildings.

Regional experience

The Japanese approach to flood loss prevention is to increase the level of flood protection in several phased planning stages until the design flood return period corresponding to the ultimate stage of urbanization is achieved. The final flood standard adopted depends on the classification of the river which in turn is determined by its economic and social importance. A flood standard equivalent to a return period of one in 200 years (0.5 per cent flood) is adopted for the design of flood protection measures on the most important rivers. This standard reduces to a return period of between one in 50 years and one in 100 years for the less important urban rivers; and for the least important river systems a return period of between one in 10 years and one in 50 years is adopted.

The recommended flood protection standards based on flood levels in Hong Kong are as follows:

(a)	Flood protection bunds for villages	200	years
(b)	Village drainage	10	years
(c)	Main catchment drainage channels	50	years
(d)	Urban drainage in developed areas	50	years
(e)	Urban drainage trunk systems	200	years
(f)	Intensively used agricultural land	2-5	years

High flood standards are adopted by the other mmbers of the Typhoon Committee for flood protection structures on major rivers. For example, the city of Seoul is protected against flooding equivalent to a return period of one in 200 years. However a design flood of one in 100 years return period is the usual standard employed for flood protection in the remaining capital cities of the members. The exception to the rule is Bangkok which currently adopts a one in 40 year flood as the standard.

All members adopt lower flood standards as the economic and social importance of the area decreases. For the less important areas a flood standard ranging between one in 30 to one in 50 years is the usual design criteria.

Selection of flood standards throughout the region has not been based on rigorous economic analysis of potential flood loss savings and the cost of implementing flood mitigation measures. Each member has made a pragmatic decision on an appropriate but variable standard based on its own perception of the prevailing flood hazard and the affordability of measures in social and economic terms.

D. Economic, social and environmental considerations

1. Economic factors

One of the first issues that arises in areas identified as flood-liable following selection of a flood standard is the need to evaluate the affected land in terms of the economic health of the community, both currently and for the future. A basic step in the development of a flood loss prevention and management plan is to evaluate the impact of flooding on existing economic activity, and then to develop a preliminary set of values to estimate the costs and benefits of measures that may be necessary to manage the flood problem. Further, an attempt should be made to evaluate alternative economic uses of the floodplain that may be compatible with the anticipated flooding threat and the environmental values of that area.

The most obvious benefits derived from flood loss prevention and management measures are those arising from the reduction in flood damage. The primary benefits which can be expressed in economic terms may include:

(a) Cost saving of replacing or repairing damaged property;
(b) Cost saving of evacuation, relief and rehabilitation of victims and emergency flood measures;
(c) Cost saving of disruption to commercial and industrial enterprises.

Because the flood damages avoided constitute benefits which must be compared with the costs of implementing the flood loss prevention and management measures, it is necessary to estimate flood damages as part of the appraisal of flood loss prevention and management proposals.

In general, total flood damages are usually referred to as tangible and intangible costs of flooding. It is then customary to further divide tangible into direct and indirect categories. The former results from the contact of flood waters with buildings and contents, crops, livestock etc.; the latter refers to the cost of disruption to business and of living conditions, cost of emergency services etc. Intangible costs include such losses as ill-health, both physical and psychological and inconvenience etc. (See figure 7.)

Damages arising from actual flood events are called actual flood damages, and these are estimated on the basis of a field survey. Estimates of damage based on an assessment of what would occur in the event of a certain flood are known as potential damages. Usually these are assessed via a stage-damage curve which shows the value of damage against the flood stage. It should be noted that potential damage estimates tend to be a maximum estimate, because in reality, individuals and communities undertake a variety of actions to reduce damage. A comprehensive method of flood damage analysis is presented as Annex E in the ESCAP publication *Proceedings of the Expert Group Meeting on the Improvement of Disaster Prevention Systems Based on Risk Analysis of Natural Disasters Related to Typhoons and Heavy Rainfall* United Nations, ESCAP, Bangkok, Thailand, 1986.

In the absence of actual data on the damages arising from different stages of the flood, generalised curves based on synthetic data are used to assess the potential direct damage for different enterprises. This synthetic data is based on individual damage components (residential, commercial, industrial etc.) and can be adopted for transfer from one region to another. Indirect damages are usually estimated as a proportion of direct damages.

Direct damage covers all damages which result from physical contact of goods, property and/or structures with floodwater, including damage from sediment, debris or other floating objects.

Direct urban damages are those occurring to structures, contents and other appurtenances of buildings, which include residences, commercial and industrial enterprises having household durables, food and other perishable commodities, fittings, plant (including vehicles) and equipment.

Direct rural damage includes losses of agricultural production, including the loss of livestock, cost of fodder required to maintain livestock production, the cost of replanting destroyed pasture, the loss of cash crops, extensive weed control following the spread of floodwaters over normally weed-free land, rectifying scour or siltation, supplemental feed for stock and resowing damaged crops. Losses of capital equipment, including fences, plant, equipment, levees, roadways and buildings, are also classified as direct rural damage.

Indirect damage covers all damages which result indirectly from the flood and may occur either during the flood or in the weeks or months following.

Indirect urban damage includes loss of sales and production for flood-affected commercial and industrial enterprises, lost wages, disrupted transport and communications systems, the costs of removing goods and services from flooded areas and returning them after the flood, monetary expenditure for cleaning up, constructing or establishing temporary facilities for families made homeless by the flood, and erecting temporary levees.

Indirect rural damage includes the costs of disrupted transport and communication systems and moving plant, equipment and stock onto higher ground.

Intangible damages cover those which might be classed more as social than economic. These losses concern items that are not normally bought and sold and for which market values do not exist, in contrast to

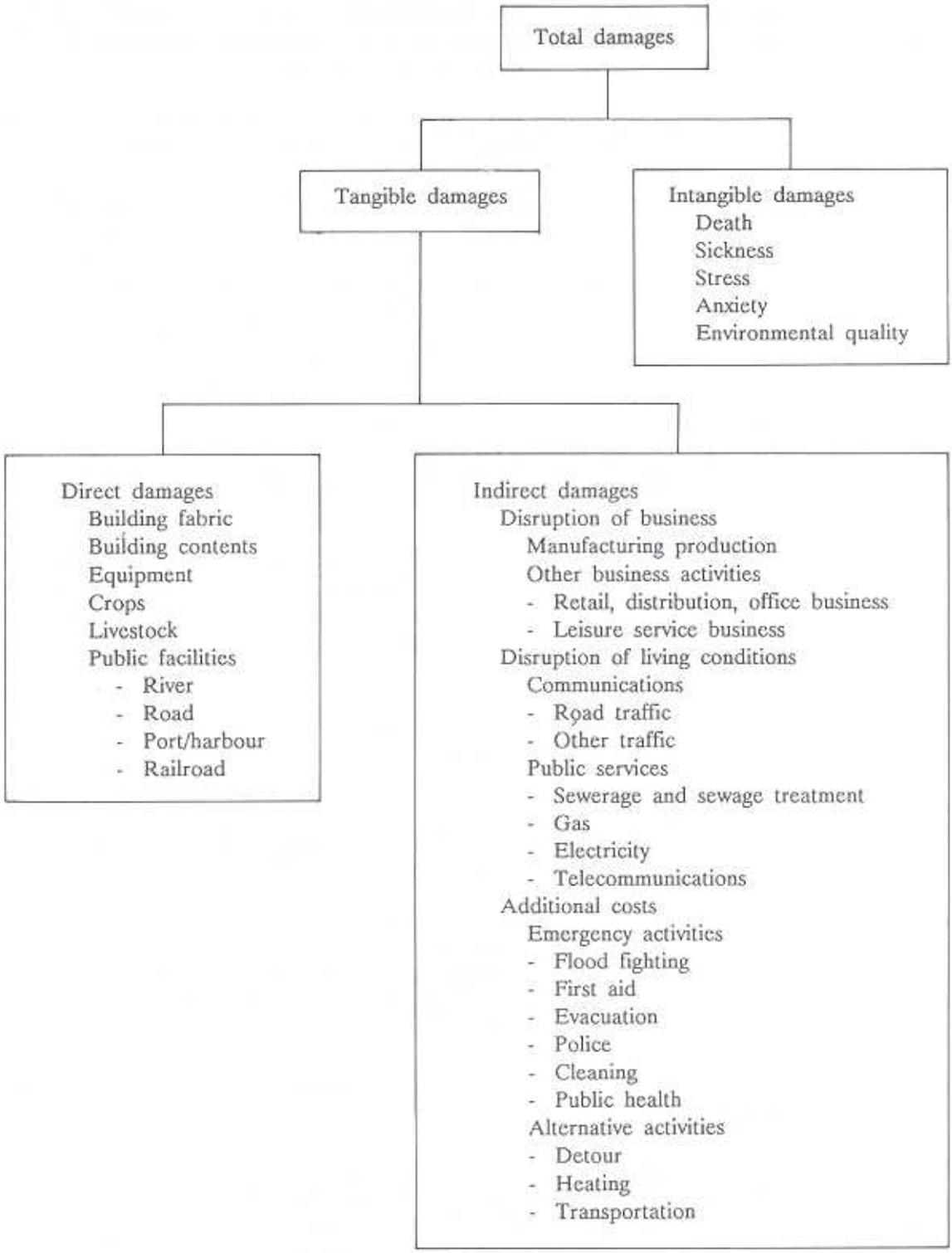


Figure 7. Damage categories

tangible damages which can be evaluated in monetary terms. The main intangible effects from floods are disruption to personal activities including cleaning up (where there are no cash transactions), to personal travel and to communication, loss of health including physical and psychological sickness, and risk to life.

The economic analysis of flood loss prevention options usually follows conventional cost-benefit analysis in making comparisons of flood protection schemes. This approach to project appraisal is appropriate where Governments, acting on behalf of society, wish to justify that the expenditure of public funds is in the best interest of society.

Widespread misuse of this technique has been identified, particularly the tendency to select a discount rate to yield the desired cost-benefit ratio. In addition, difficulties exist with the quantification of certain types of benefits. With flood loss prevention and management projects, these short-comings are more pronounced because of the difficulties in adequately quantifying risks and benefits which affect different groups of the population in different ways and include such intangibles as ill-health, both physical and psychological.

In theory, such an approach, whilst determining the most economic level of protection for each project, would result in quite different levels of protection being provided for projects in different regions and, in fact, for different parts of the same river valley. Consequently such an approach poses difficulties in application.

Traditionally, cost-benefit analysis has been used to determine whether or not the potential benefits of a given measure are likely to exceed its costs. In theory, this allows not only competition between other flood loss prevention and management projects but also projects with other calls on public funds. The analysis should not only limit support to the more worthwhile projects but should also determine for each project the most appropriate level of protection. If, as in many cases, a standard flood (such as the 1 in 100 year flood) is adopted, then cost-benefit analysis only has value in ranking competing projects.

In an effort to overcome the deficiencies of the strict cost-benefit analyses, the multi-objective planning approach requires consideration of social and environmental objectives as well as economic factors. This technique purports to allow non-quantifiable factors to be weighted in the analysis. Although the method allows for evaluation of indirect and intangible damages, there still remains subjective decisions to be made in quantifying the intangible objectives.

It is not unusual to proceed with flood loss prevention and management schemes on mainly social grounds. In fact it is often the experience world-wide, that these types of schemes are found to be uneconomic in straight cost-benefit terms. More often the cost-effectiveness approach is adopted. This approach specifies a goal and then examines the most cost-effective way of attaining that goal. First, a standard flood is adopted, then investigations seek to find the most cost-effective methods to provide protection against that flood.

The least-cost method of achieving the level of protection is then chosen. It should be recognised that use of this method will not necessarily result in the acceptance of the most economically efficient scheme. (See figure 8.)

2. Social factors

The social disruption caused by floods is perhaps the most significant effect to be considered. Loss of life has a dramatic influence on a community which experiences a flood disaster. Other consequences of flooding relate to psychiatric and physical illness. These conditions are generated by the trauma of flooding and the destruction of essential services, such as water supplies, sewerage services etc.

Other social problems induced by flooding relate to the dislocation and disruption of transport, public and commercial services including schools, medical services, food supply and retail shopping facilities.

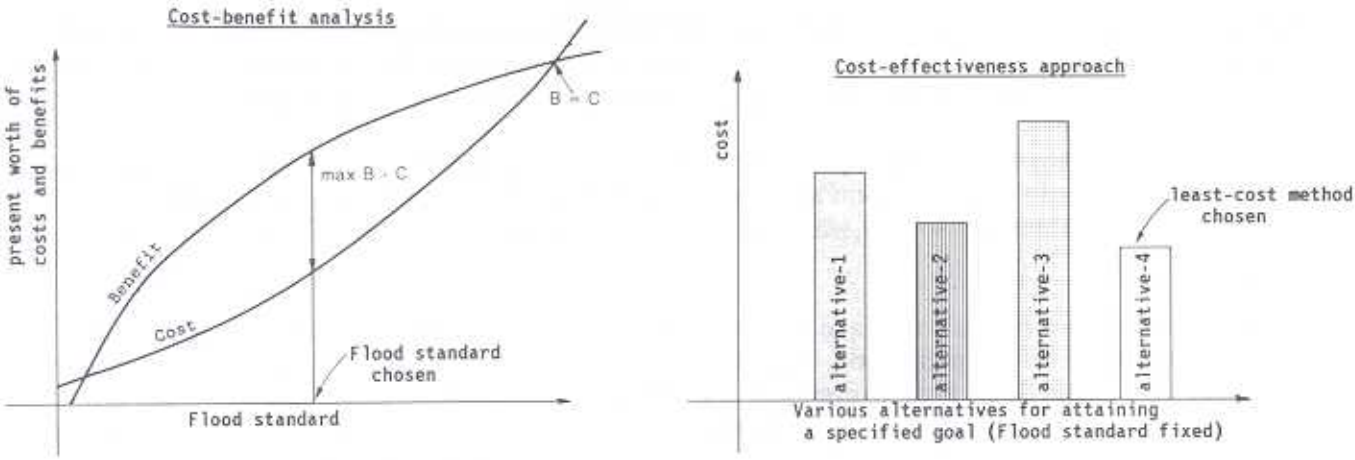


Figure 8. Cost-benefit analysis and cost-effectiveness approach

As with the economic aspects, social well-being effects will, to some extent, be dependent upon the flood loss prevention and management alternatives and their detailed identification becomes part of the formulation of the overall flood loss prevention and management plan. Some of the social consequences of flooding which the selected flood loss prevention and management measures should attempt to overcome include the following:

(a) Safety aspects: Each flood loss prevention and management measure will inevitably seek to reduce the flood hazards of death, injury and sickness;
(b) Public health aspects: Potential improvements in public health because of the reduction in the likelihood of breakdowns of water treatment plants or sewerage disposal systems will be included in this category, together with such aspects as the potential disease hazards following prolonged flooding and the housing of evacuees in cramped unsanitary quarters;
(c) Emergency preparedness: Beneficial effects relate to the provision of emergency food and water supplies, emergency medical services, maintenance of critical power supplies, improved emergency transportation etc.

Other factors to be considered under social well-being include the provision of evacuation accommodation, the problems of specially disadvantaged social groups, and a variety of other problems relating to the discomfort, inconvenience, financial hardships and general trauma of flooding.

The loss of employment is one of the most important of the social impacts caused by floods, and these effects may not be limited to the community of direct concern. There may be important employment effects outside the flooded area and even outside the community.

Accommodation situated on flood-liable land is often of poorer quality and occupied by people on low incomes. These groups often develop strong local patterns of activity and interaction and experience a feeling of attachment to their area. These groups are also most vulnerable to disruption of their community, both emotionally and financially. Where a decision is made to relocate residents of flood-liable areas, adequate compensation and relocation assistance should be provided, and necessary legislation should be formulated or amended, if necessary, to enable this to occur. Involuntary relocation can have negative social and economic effects for flood-affected residents and these effects should be taken into account when assessing appropriate flood loss prevention and management strategies.

Regional experience

In the Typhoon Committee region there exists a genuine concern by all Governments about the welfare and the post recovery of flood-affected populations. The organizational response to flood victims'

needs in the delivery of relief and rehabilitation services is highly effective and efficient. In fact, Governments are supported to a large extent by non-governmental bodies such as the Red Cross and Crescent and other charitable organizations which contribute significantly to the effective mitigation of the social impact of floods.

In China, for example, the different levels of government assume responsibility for the care and welfare of all flood victims. This care extends from safe evacuation of flood affected areas to the provision of adequate temporary shelter, food and medical services for all flood victims. In flood storage and retardation areas, the provincial governments exercise population control to reduce the number of flood-affected inhabitants. To achieve this control excess population is actively encouraged to emigrate to safer areas and offered inducements, such as preference in employment, to do so.

In Thailand, the Disaster Relief Division of the Department of Public Welfare has the nation-wide responsibility to provide assistance to flood victims. The form of assistance extended to the victims covers economic, material and welfare services. Financial assistance to defray funeral and medical expenses, to purchase lost farm animals and for repatriation purposes is provided. Materials for house reconstruction, medical supplies, kitchen utensils etc. constitute the assistance provided under this form of aid. Provision of temporary shelter and food supplies is an important aspect of the Department's responsibilities. To make the disaster relief services more accessible and efficient, the Department operates a number of regionalised relief centres. A well developed system of co-operation has been established with other national and international relief organizations. The mechanics of evacuation and the construction of temporary shelters for flood victims is the responsibility of the National Civil Defense Committee which comprises representatives of major government departments.

Malaysia through the Ministry of Social Welfare and Natural Security Council has similar mechanisms as Thailand.

3. Environmental factors

Floods have numerous effects on river and floodplain environments. For instance, fast-flowing, deep and turbulent floodwater in river channels may exceed their capacity, cause overbank flow, erode banks, transport large volumes of debris and deposit sediment both within the channels and on adjacent inundated land. In addition, floodwaters often cause damage to agricultural activities and seriously disrupt urban and commercial areas. These adverse impacts may be minimised by the construction of structural flood loss prevention measures, such as channel modifications, flood storages, levees etc., (section F).

Floodplain developments and flood loss prevention activities, in their many forms, have caused and will continue to cause impacts on the environment. These impacts can alter various components of the floodplain environment in both the short- and long-term which may prove to be beneficial in some cases and adverse in others.

The existing environment will be modified by normal wear and tear. If floodplains are not to be degraded unnecessarily, it is important for future development and other activities to be managed through proper environmental planning and control.

For this purpose an inventory of the community's principal environmental values should be developed. The inventory should include wetlands, fish and wildlife habitat, parks, natural and scenic beauty, water quality, and historic places. A general assessment should be made of probable impact of land use changes on existing environmental values in terms of enhancement or deterioration.

Environmental values must be examined early in the development of a flood loss prevention plan. Early attention to environmental evaluation will also have procedural advantages. When such concerns are raised after the plan has been developed, they are most likely to be approached from an adversary position. Preliminary analysis and evaluation can provide an initial step in the development of environmental impact

studies. These studies involve a survey of the environment of the area to determine the capacity for change or the need for conservation.

Environmental concerns may include some, or all of the following:
(a) The incidence, extent and severity of flooding;
(b) The extent of soil erosion on agricultural lands of the flood-plain;
(c) The extent of river bank erosion;
(d) The rates of stream sedimentation;
(e) The management of water quality standards;
(f) The management of suitable habitat for fish and wild life populations;
(g) The preservation of historical and archaeological sites;
(h) The retention of visual amenity of the natural river and floodplain environment.

It must be emphasized that environmental management, rather than environmental protection, is the desirable objective. In other words, the floodplain should be considered as a valuable resource and it should not be sterilized from development unnecessarily or left unsafe unreasonably. This requires that specific environmental management and enhancement goals be decided upon from the outset. It will not be sufficient to undertake piecemeal environmental impact assessments for individual flood loss prevention projects.

To fulfill the proper role of environmental management, consideration should be given to fostering and protecting the visual amenity of rivers and floodplains. As a general principle, artificial structures unless

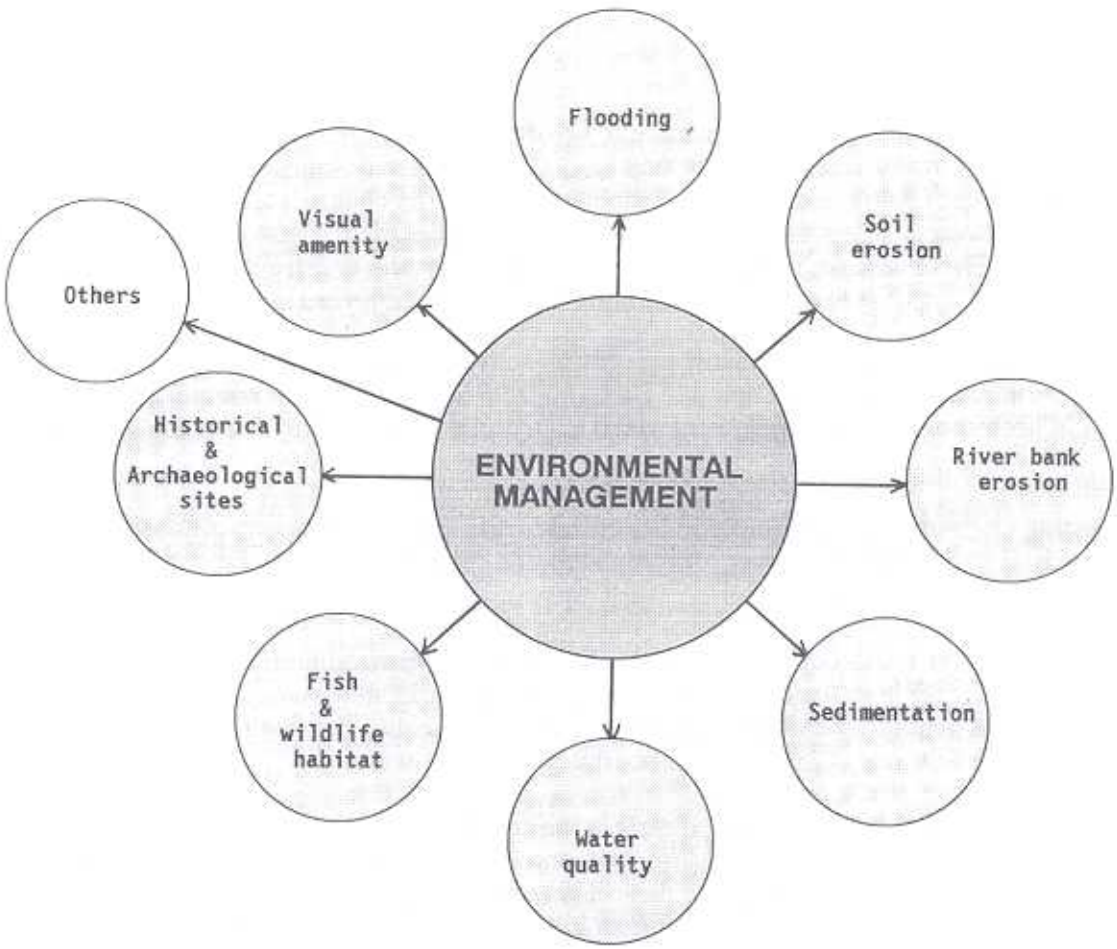


Figure 9. Environmental management considerations

carefully designed and built to fit in with their surroundings will tend to stand out and thus detract from the harmony of the natural environment. Consideration at the design stage should be given to help structural works blend into the landscape without adversely affecting visual quality.

Regional experiences

Throughout the Typhoon Committee region recognition of the importance of environmental issues is a comparatively recent occurrence and the concept of environmental impact assessment is still in the emerging stages. The principal concern of the already established environmental agencies in most member countries relates to the monitoring of water quality and the reduction of point-source and non-point source pollutants, such as the discharge of waste products and soil erosion. However, there is a growing awareness that controls are required to protect the environment and that flood loss prevention measures should satisfy environmental requirements. Because environmental assessment is largely based on subjective judgment and cannot be easily quantified in economic terms, its overall importance as a factor in flood loss prevention and management measures has attained different positions of significance in member countries.

In Japan for example, a concerted effort is made to improve the natural environment of the river domain as an integral component of flood loss prevention and management programmes. Environmental enhancement not only ensures that structural works harmonise with the river and its catchment but green belts of parks and open space are provided to improve both passive and active recreational opportunities. It is also recognised that water quality and quantity maintenance and the provision of a dynamic ecosystem with enhanced habitat qualities are basic to acceptable environmental management practices.

Other members, including Hong Kong, Malaysia and Philippines have established environmental agencies which apply a strong set of watershed protection guidelines to cover flood loss prevention and management projects. Under these guidelines proper regard has to be given to the potential ecological changes resulting from the construction of the work in order to balance the needs of development and the protection of the environment.

China has also adopted a pragmatic approach to environmental protection by passing a number of strong regulations to cover a range of topics related to the river and its floodplain. These range from the protection and restoration of lakes through to the imposition of boat speed limits to protect river banks from erosion by wave action.

Although the Republic of Korea does not experience many environmental problems related to its flood loss prevention and management activities, its environmental agency requires that environmental planning is incorporated at the development stage of flood mitigation programmes.

All members have, to a greater or lesser extent, formulated regulations governing pollution control and the maintenance of water quality standards.

E. Legislation, regulation and legal responsibilities

The constitutional power relating to flood loss prevention and management is usually vested in the national government with some degree of shared responsibility with provincial or local government, or both. To develop an integrated management system which achieves common objectives and purpose among these arms of government, a comprehensive body of legislation should be enacted. These legislative controls should empower relevant authorities to govern such aspects as funding, planning, development, social goals, disaster relief etc. The most important consideration in the framing of flood loss prevention and management legislation is the logical integration of functions and responsibilities among the levels of government.

Responsibilities for flood loss prevention and management are usually divided among the various levels of government. At the national level the concern is with broader issues, such as the disbursement of funds to the provincial and local governments for the construction of mitigation works. The national government may assume an overseeing role or it may, through its agencies, become directly involved with the formulation and

implementation of policies and programmes. If an overseeing role is adopted by the national government then the responsibilities for implementing flood policies will reside with the provincial and local governments.

Successful flood loss prevention and management must place emphasis on prevention strategies, including both structural and non-structural measures, as well as on preparedness strategies. To achieve this objective there should be available a body of comprehensive legislation which provides the framework for the efficient co-ordination of activities relating to the investigation, construction, operation and management of preventive measures. Indeed, experience has shown that voluntary regulation of development on floodplains does not work in either urban or rural situations and it is necessary to have legislative powers to achieve proper management goals.

If the existing legislation imposes constraints on the flood authority in achieving the control of flood-liable lands, the legislative system should be re-examined and modified so that there are no unwarranted impediments to the implementation of efficient and effective management measures.

In some cases, less formal controls in the form of regulations may be adopted. Regulations can confer appropriate statutory controls over such activities as zoning and the proclamation of flood-liable areas and provide adequate safeguards against legal challenges.

In some countries which operate under the English system of common law, the flood authority/ organization is not protected against claims for damages resulting from their issuing advice or granting approvals for flood-liable areas. To overcome this liability in negligence, legislation should be enacted which provides immunity against:

(1) Any advice furnished in good faith by the flood authority/ organization relating to the likelihood of any land being flooded or the nature or extent of any such flooding; or
(2) Anything done or omitted to be done by the flood authority/ organization in so far as it relates to the likelihood of land being flooded or the nature or extent of any such flooding.

This immunity should cover all aspects of flood management and exempt the flood authority, all its employees and its agents from legal claims.*

Regional experience

A number of members have well developed legislative provisions for dealing with the effects of flooding when the emergency occurs and to cater for the post-impact phase after the threat has subsided. Under this legislation the responsibilities and the emergency arrangements for implementing counter disaster plans and measures to deal adequately with the situation are clearly spelt out. These formalised responses by Governments have developed as a result of long experience with disasters, particularly flooding. Hitherto most of the attention given by Governments of the region to investigating the flooding problems has concentrated on organising relief activities and the institutional and legislative requirements relating to this task.

However, a number of countries and areas in the region have drafted or are in the process of drafting new legislation to give force to more effective flood loss prevention and management measures.

In Hong Kong for example, new legislation has been drafted which is intended to achieve the following objectives:

(a) The creation of a drainage authority with the powers to administer and enforce the provisions of the legislation;

* A relatively recent development in common law in Australia is that legal liability has been extended to individuals in the form of criminal negligence. Under this law an individual may be charged with manslaughter if death is caused as a direct failure of any works or structures for which he was responsible. It is not possible for government to enact legislation which provides immunity for the individual against such a charge.

(b) Establishing the obligation and responsibilities of riparian owners and Government for maintenance and improvement of land drainage systems;
(c) The demarcation of drainage reserves in terms of channels and designated floodplain areas;
(d) The right for the Authority to insist that owners or developers provide control of run-off from development sites;
(e) Allowing Government to undertake improvements to designated drains and watercourses without resuming land;
(f) The ability to control development on land adjacent to designated drains and watercourses.

In 1988, China undertook a major revision of its water law and promulgated a number of new regulations relating to flood loss prevention and management activities. Emphasis has been placed on the adoption of a comprehensive, integrated and efficient approach to planning for flood control. To achieve the specified improvements, responsibilities of the different levels of government, (central, state and local) are clearly enunciated as are the activities of the River and Basin Authorities under the control of the three tiers of government. Many of the adopted regulations embody the principles and aims of flood management advocated in this manual. Guidance has been provided on active flood plain management including the social, economic and environmental aspects. This body of water law has been supported by a comprehensive set of guidelines for the safety and construction of flood storage and retardation areas, which constitute a principal structural flood mitigation measure adopted by China.

It should be noted that in China criminal proceedings can be instituted against individuals or officials who act contrary to or violate regulations relating to flood loss prevention activities.

F. Comprehensive flood loss prevention and management measures

Floods are natural phenomena, and human communities must accept their inevitability. However, there are measures which can be used to mitigate flooding or its effects and thereby reduce the loss of life and damage to property.

Flood loss prevention and management measures attempt to lessen the impact of flooding on the social and economic conditions created by habitation of the catchment, and particularly the use of the floodplains. Comprehensive flood loss prevention and management includes both structural flood loss prevention measures, such as channel modifications, flood storages and levees, which are designed to reduce the incidence or extent of flooding and non-structural measures such as flood insurance, zoning restrictions and flood warning schemes, or combinations of these measures, which are designed to reduce the impact of flooding.

The conventional engineering approach for mitigating floods adopts one or more of the following methods:

(a) Reducing the rate of run-off from lands by catchment treatment;
(b) Storing water in reservoirs for release at controlled rates during the passage of a flood or after the threat of flooding has passed;
(c) Confining the river to a definite course by building levees;
(d) Improving flow conditions by channel improvements or by-pass floodways so that flood stages can be reduced;
(e) Discharging drainage water by pumping.

It is emphasized that some structural measures may reduce the flood plain storage. Any loss of natural storage may result in increased rates of flow unless compensated for by other measures, such as the provision of artificial storage.

The alternative non-structural measures, or management measures, do not involve major construction activity and hence have proportionately less environmental impact. The evaluation process for these measures

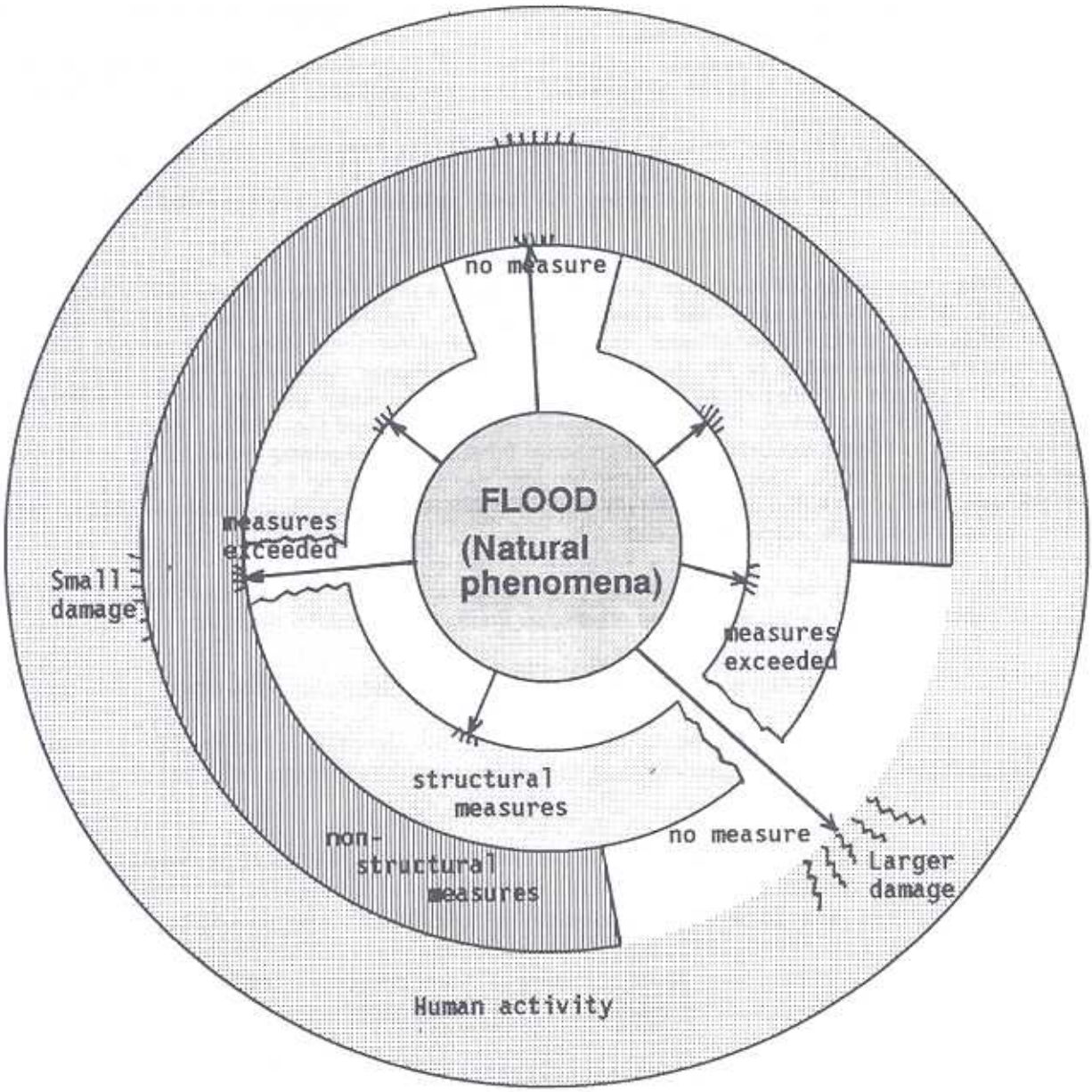


Figure 10. Comprehensive flood loss prevention and management

requires greater consideration than the more traditional structural measures. They usually involve greater economic, social, institutional and legal consequences than structural measures.

Non-structural measures modify flood susceptibility and flood impact. Land use planning, flood proofing and flood forecasting and warning and property acquisition are the principal measures employed to modify susceptibility to flooding. Flood insurance, flood relief and public awareness are the principal measures employed to modify the impact of flooding. If the future losses of property and life are to be reduced then emphasis should be given to those measures which have the highest capacity to achieve these aims.

The formulation of a well-structured flood loss prevention plan will involve the optimal mix of the various measures. These measures will usually include both structural and non-structural measures.

The effectiveness of the plan in reducing future flood losses will depend upon a number of factors, including the adopted flood standard and the motivation of responsible authorities/organizations in fully implementing and maintaining the plan.

1. Structural flood mitigation measures

(a) *Levees and floodwalls*

The principal purpose of levees and floodwalls is to confine floodwaters to the stream and a selected portion of the floodplain. These barriers protect only the area immediately behind them and only against the adopted flood height for which they were designed.

A major advantage of levees and floodwalls is the flexibility they offer to protect either a specific site or a larger area. For example, they can be used to protect a single community or a portion of a community. However, they can create a false sense of security about the degree of protection provided. Floods exceeding the levels for which levees and floodwalls are designed can cause disastrous losses of life and property.

Levees and floodwalls may increase flooding in other areas unless designed as part of a comprehensive programme. If they restrict the extent of flooding, levees and floodwalls tend to increase water surface elevation, velocity and maximum discharge within the confined stream reaches and also increase the rate of flood wave travel downstream. These structures may have undesirable environmental aspects such as destruction of natural habitat and the loss of scenic views.

The requirements for the design and construction of levees and floodwalls are governed by the hazard to life and property within the protected area and by site conditions. Levees are normally constructed of earth and require significant space to accommodate the required base width. Floodwalls are usually constructed of concrete or steel and take up far less room. They are more suitable for use in congested areas.

The intensity of investigation for levees and floodwalls depends upon the importance of the land being protected from flooding. Items covered by the investigation include levee location, determination of design water level, foundation conditions and embankment materials. Investigation required for levees also incorporates geotechnical investigations of suitable borrow pits for embankment material.

Because levees and floodwalls can fail by overtopping, undermining, slumping and excessive seepage, the design of these structures should attempt to reduce the possibility of failure from these hazards. Ample freeboard, which takes into account the settlement of levees, wave action, sedimentation of channel and inaccuracies in estimation of flood levels, reduces the possibility of overtopping of levees or floodwalls. Undermining is minimized by locating levees or floodwalls far enough away from channels to eliminate exposure to high velocity or scour. Proper side slopes and construction methods minimise slumping of earth levees. Excessive seepage can be reduced by the provision of seepage protection works. Damage is also caused by termites and burrowing animals. Regular inspections are necessary to locate and remedy the damage in an early stage of development.

The design height of the levee or floodwall should incorporate adequate freeboard above the standard flood height to allow for wave action and settlement in the case of earth levees. The freeboard allowance should be sufficient to prevent overtopping, otherwise adequate safeguards should be included in the design to protect the community against overtopping by floods larger than the design standard.

Levees and floodwalls complicate the drainage of land they protect and provision must be made for the discharge of internal drainage water unless adequate storage is available. Discharge through levees or

floodwalls can be achieved by gravity flow through pipes equipped with gates. When prolonged flood stages prevent gravity outflow, the internal drainage water must be stored temporarily, be removed by pumping, or disposed of by a combination of these two methods.

To be effective levees should be subjected to proper maintenance. Such maintenance extends to regular inspections and periodical patrols during and immediately after severe floods. Vegetation, grazing and traffic on earth levees should be controlled. Proper attention to any defects will help ensure against levee failure.

The following disadvantages which are associated with levees should be recognized:

(i) Economic and other constraints limit the height to which levees are constructed and it is usually statistically certain that rare flooding will result in overtopping;
(ii) Levees can create a false sense of security;
(iii) If overtopping does occur the resulting damage can be far in excess of that which would have occurred if the levee had not been constructed;
(iv) Levees tend to promote increased development in the areas protected which in turn leads to even greater damage if overtopping occurs;
(v) Levees can be unsightly and can divide communities.

For safety purposes, earth levees should be constructed with gentle backslopes to reduce the risk of scour and failure if they are overtopped by a large flood. Consideration should be given to the provision of measures which allow controlled overtopping and thus minimize damage if the design height of the levee is exceeded.

(b) *Channel modifications*

Most natural watercourses have a river channel of limited capacity, which may be exceeded annually, with excess floodwater being carried along a floodplain. Hydraulic improvements to the watercourse or to the floodplain, and/or flood channels within the floodplain, enable flood waters to be passed at a lower level than would occur naturally. Such works in urban areas also enable optimization of land use through improved residual drainage.

The various type of modifications include:

(i) Straightening, deepening or widening of the channel;
(ii) Removing vegetation or debris;
(iii) Lining the channel;
(iv) Raising or enlarging bridges and culverts which restrict flow;
(v) Removing barriers which interfere with flow.

All of these modifications contribute towards reducing the height of a flood. It is sometimes possible, by extensively reconstructing a stream channel, to contain major floods within the banks. Caution should be exercised, however, as channel modifications can facilitate the transfer of floodwaters downstream and impose problems on downstream communities.

Channel modifications are like levees and floodwalls in that they can be used to protect a specific site or region. They can provide the community with other positive benefits, such as improved navigation and recreation.

Channel deepening is not very well suited to major streams because sediments can quickly fill the excavated area. Frequent re-dredging is often necessary to maintain the deeper channels and this can become a significant maintenance cost.

Channel modifications are likely to be most effective on the steeper smaller streams with overgrown banks and narrow floodplains. Channel modifications are unlikely to have any significant effect in flooding

situations where there are extensive areas of overbank flooding or where flooding effects are dominated by tide levels.

Disadvantages related to channel modifications include the cost of maintenance, the destruction of riverine habitat for fish and wildlife and the potential to cause erosion.

(c) *By-pass floodways*

These serve two functions in flood mitigation. First they create large, shallow reservoirs which store a portion of the flood water and hence decrease the flow in the main channel below the diversion. Secondly, they provide an additional outlet for water from upstream, by improving flow characteristics and decreasing water levels for some distance below the diversion. Opportunities for the construction of floodways are limited by the topography of the area and the availability of low-value land which can be used for the floodway.

There are two types of by-pass floodways, natural and constructed. A natural floodway follows the course of an existing cross-country depression and carries floodwaters that can no longer be carried within the river channel. The land in the floodway is generally not different from other farmland, except that it may be low-lying. Some floodways have control banks across them and may be bordered by levees to control the spread of floodwater. Restrictions are usually placed on development of land in floodways to ensure that future loss and damage from major floods are reduced to a minimum and to ensure the floodway functions as designed.

When required, controls in the form of spillways and gates are provided at the entrance to a floodway. Spillways take the form of a section of levee which is designed to control the amount of floodwater diverted into the floodway from the river. As spillways can be overtopped for long periods by high velocity floodwater, they have to be specially designed to avoid failure. Protection can be provided by rock gabions or, where appropriate, the spillway is built with gentle backslopes which are well grassed.

If the floodway possesses comparatively steep bed-slopes, control banks may be built perpendicular to the direction of flow at intervals along the length of the floodway. These banks are similar in design to the spillway and form a series of basins which reduce the water velocity by dropping the floodwater in steps safely across the land.

Diversions are constructed to intercept flood flows upstream of a damage-prone area and route them around the area through an artificial channel. Diversions may either completely re-route a stream or only collect and transport flows that would cause damage.

Diversions sometimes offer the advantage of protecting several nearby communities with one major facility. They are, of course, subject to surcharging in floods exceeding their design capacity.

Diversions are particularly well suited for protecting developed areas because they do not usually require land acquisition or construction within the protected area. However, opportunities for diversions are often limited by the nature of local land formations and soil conditions. There must also be a receiving water body or stream channel with enough capacity to carry the flow disposed of through the diversion without causing flooding.

(d) *Retarding basins and flood storage areas*

Flood storage and retardation involves the practice of controlled flooding of designated areas in order to minimise flood losses. It permits floods greater than a specified magnitude to spread over low-lying lands situated behind levees in a controlled fashion by the operation of gated structures or spillway sections incorporated in the levees. The diversion of floodwater, when carefully controlled, will reduce the flood peak at downstream locations and confine flooding to within the flood control system.

Areas selected for flood storage and retardation are traditionally low-lying and have a history of flooding. By the formulation of proper controls it is possible to utilise these areas for habitation and agricultural purposes in the knowledge that they will be flooded periodically. This calls for the preparation of a comprehensive programme of flood operation, a knowledge of the level and extent of area inundated, imposition of controls to ensure predictable flood behaviour and a reliable flood forecasting and warning system for timely and safe evacuation. Special provisions are also required for the protection of emergency services and for flood refuge areas.

To reduce the damages associated with controlled flooding it is necessary to provide drainage works to evacuate the flood storage area as quickly as possible following the subsidence of main river flooding.

Retarding basins reduce downstream flood flows in both mainstream and urban drainage situations. They allow small flows to pass unimpeded but trap a portion of larger flows. In urban areas, retarding basins are most suitable for small streams which respond quickly to rainfall and/or stormwater flooding. However, they have a number of inherent problems which should be carefully evaluated for each particular situation, for example:

(i) Basins require a substantial area to achieve the necessary storage;
(ii) Long duration or multi-peak storms (when the basin is filled from a previous peak) can increase the risk of overtopping or breaching;
(iii) The impact on floods bigger than those for which they are designed is limited.

Although these basins can be very useful in reducing the flood problems of both proposed and existing development, it is particularly important to make provision for downstream management of the floodwater when the capacity of the basin is exceeded.

Sites for retarding basins in developed urban areas are generally limited. Available sites are usually restricted to established recreational areas, such as parks, playing fields and parking lots. Incorporating a system of retarding basins at the planning stage in new urban developments or re-developments results in effective flood protection of those areas.

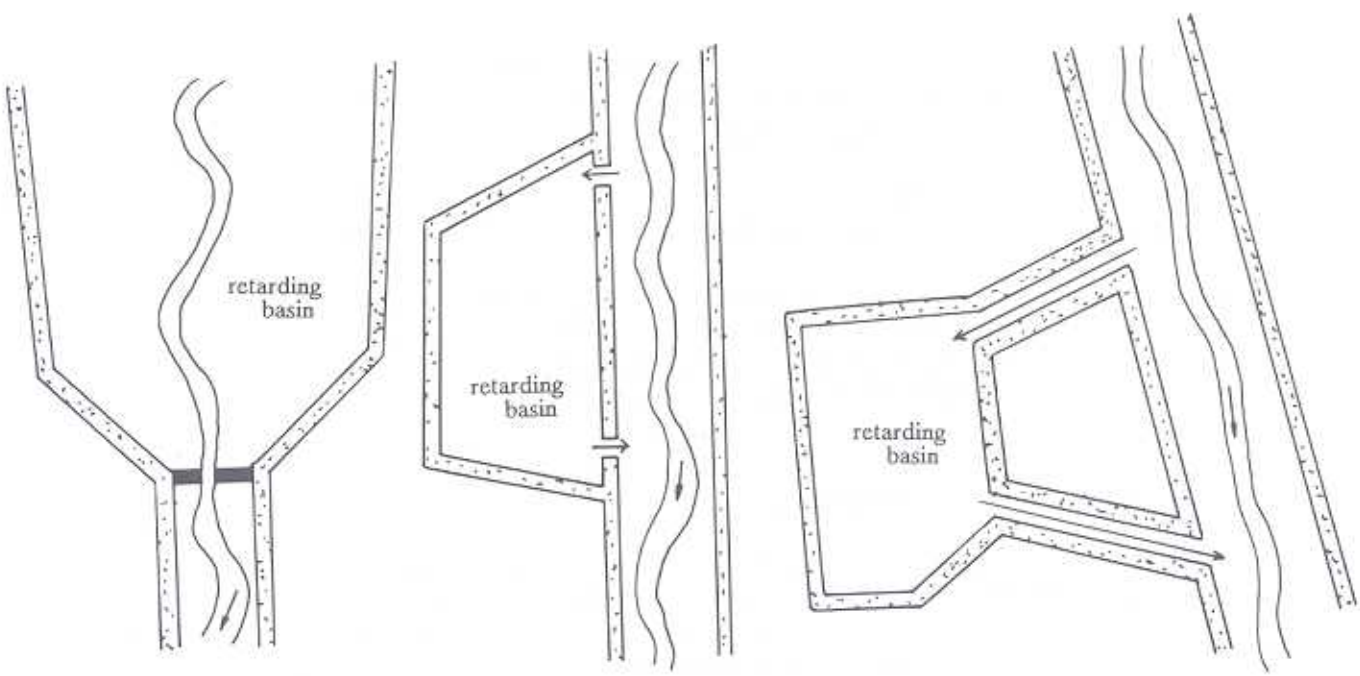


Figure 11. Different types of retarding basins

Retarding basins are sometimes constructed as an earth embankment across the watercourse with adequate outlet facilities to control releases to the capacity of the downstream channel. The outlet facility usually takes the form of a box or pipe culvert. If the construction of basin embankment involves the use of earth, the provision of adequate spillway capacity is essential to protect the basin from failure by overtopping from flows exceeding the design flood.

Retarding basins can play a role in the improvement of water quality by the removal of floating trash and the collection of sediment. Their effectiveness in this role depends upon the installation of special trash racks and sediment traps and continuous maintenance.

Land along the river and natural depressions on the floodplain are utilised for the off river storage of floodwaters. Flood flows are diverted into them for the purpose of reducing flood peaks downstream. The efficiency in operating these storages can usually be improved by providing suitable intake structures for filling the storage and outlet structures to allow releases when downstream conditions permit.

(e) *Flood mitigation reservoirs*

In appropriate circumstances dams can be constructed to create reservoirs which control major flood flows arising from existing catchment conditions, to offset the impact of proposed land use changes or for a combination of both purposes. These reservoirs capture and temporarily hold floodwaters upstream of the flood-liable areas. The amount of storage required depends upon the degree of protection needed and the downstream channel capacity.

The degree of mitigation provided by a flood mitigation reservoir depends on the combination of dam storage, spillway capacity and the pattern of flood inflows. The effect of storage is to decrease the flood peak without actually reducing the volume of floodwater. The reduction of the flood peak is at the expense of increasing the duration of dam releases at lower rates. For dams equipped with gates or valves, the way in which these controls are operated can affect the rate of release and the degree of downstream mitigation.

The protection afforded by a surface reservoir is greatest in the area immediately downstream of the dam. Protection further downstream is reduced by tributary flows and by run-off from land adjacent to the river. Protection may also decrease in time if the reservoir capacity is diminished by siltation. Surface reservoirs have the greatest potential to mitigate floods when they are empty.

Flood mitigation reservoirs are mostly used on small and moderate-sized streams. The large areas of land required to store the flood flows of major rivers are generally no longer available, especially where they involve flooding of good agricultural lands. Many sites that are geologically suitable involve considerable land acquisitions and the possible displacement of large populations. Moreover, the cost of large reservoirs can only be justified where they protect heavily developed urban areas and are the only practical means for significantly reducing flood damages. It is usual practice to reserve a component of available storage in multi-purpose dams for flood mitigation purposes. However, co-ordination is necessary for making flood mitigation reservoirs also serve a water supply or irrigation function.

A major disadvantage of flood mitigation reservoirs is that downstream residents do not recognise that they only control floods up to some particular size for which they were designed. Accordingly, land use controls should be enforced to prevent unplanned development and encroachment on the downstream floodplain.

(f) *Drainage evacuation systems*

Drainage water originating as run-off from the protected area behind levees or floodwalls may be disposed of by:

(i) Gravity flow through pipes fitted with gates during periods of low river flow;

(ii) Accumulation of drainage flow in storage areas;
(iii) Pumping of interior drainage water during periods when gravity flow is restricted by backwater.

Pumping is usually required for the disposal of interior drainage water whenever adequate discharge by gravity flow cannot be achieved because of limited outlets, insufficient storage capacity or because of backwater caused by flooding.

Preventing flooding of the low-lying areas behind the levees or floodwalls requires consideration of the entire drainage system which services the protected area. Optimum use of storage areas, channels, pipe systems and gravity outlets should be achieved so that the pump capacity, size and period of operation can be minimised. The efficient planning and design of pumping plants will include determination of the required water removal rate, the auxiliary drainage facilities for minimising the pumping requirements and the location of the pumping plant for an effective outlet to the entire drainage system.

The required capacity of the pumping plants to service the protected area is determined on the basis of direct hydrologic analysis. This analysis should give consideration to such factors as the size of the area served; the amount, rate and timing of rainfall and run-off; and the period of flooding when gravity flow is restricted. For protected areas in coastal plains which are located along rivers, the effect of tides should also be taken into account.

The period of pumping may be reduced by increasing the amount of available storage by excavation. Where this is not practical, adequate pumping capacity must be installed to remove that part of the drainage inflow in excess of the available storage.

Pumps suited to most drainage evacuation systems must operate efficiently while moving large quantities of water at low heads and may also be required to handle substantial amounts of sediment and rubbish in the effluent. Axial flow, mixed flow or radial flow centrifugal pumps are best suited for this purpose. It is advantageous to have two or more pumps to provide efficient pumping over a wide range of pumping rates so that a breakdown of one pump will not stop all pumping. Discharge of drainage water by gravity flow is achieved more efficiently by a battery of small gates rather than by one or two large gates.

2. Non-structural flood mitigation measures

(a) *Land use management*

Unlike structural measures, which modify flood behaviour by diverting floodwaters away from occupied areas, land-use management seeks to alter the pattern and mix of floodplain land uses in areas of future development. In such areas this measure has the greatest potential in reducing the overall flood losses.

Land use management may face the dilemma of the optimum use of restrictive land practices to avoid future flood losses and the development expectations of landowners of flood-liable land. Resolution of this problem will involve consideration of:

(i) The savings in potential flood losses which would accrue from a range of land use restrictions and zoning imposed on flood-liable land;
(ii) The ability to employ alternative and more cost- effective flood mitigation measures;
(iii) The extent to which economic, social and environmental objectives are met by this measure.

To be effective, land use management should not be restricted to the floodplain immediately adjacent to protected urban areas. The continued urban development of the headwater areas of small catchments can offset the benefits conferred by flood mitigation works already constructed to protect downstream urban areas. Unless appropriate land use controls are imposed or compensatory works are installed on the upper catchment, the peak discharge during future flood events will be increased. This will have the effect of reducing the degree

of security provided by the existing downstream works and measures and could result in catastrophic failure when design flood conditions are exceeded.

Land use management, or planning controls, employ two principal options, zoning controls and building and development controls, which can be usefully applied to both new and existing development to address the flood hazard. They need to be tailored to suit individual situations and they should have regard to the full range of flood risk.

Zoning controls permit the responsible authority to designate the type of activity which can be undertaken within the defined flood liable area. Zones defined for flood-liable land should be based on an objective assessment of hazard, economic, social and environmental factors.

At the development consent and building consent stages, appropriate conditions should be imposed to ensure development is compatible with the prevailing flood situation and that the overall level of flood damage is not significantly increased. The responsible authority should consider the risk to life and property, the measures needed to minimize risk, and whether the development or the measures proposed to minimize the risk of flood damage are likely to increase flood risk elsewhere. Detailed considerations might include:

(i) Whether the floor heights in the proposed development are above some standard flood level;
(ii) The suitability of proposed building materials;
(iii) The availability of flood-free access or whether it should be required;
(iv) Whether filling or some other similar activity is likely to interfere with flood behaviour.

Generally, it is not necessary to impose conditions on minor developments and minor additions to existing buildings. If the extensions are major and could lead to a significant increase in likely flood damage, or obstruction to flood flow, they should be subject to more stringent conditions. See chapter V, "Guidelines for flood plain development and management", for a more detailed discussion.

(b) *Property acquisition and floodway clearance*

Relocation of buildings and communities from the floodplain may have long-term economic, social and environmental advantages, but suffer disadvantages of very high costs and local objections to disruption of communities, loss of business and interruption to normal social life. However, in some areas voluntary purchase by Government may be justified, especially following disastrous floods to ensure that unwarranted expense is not incurred in restoring buildings and to enable owners to relocate from a hazardous situation.

Acquisition of vacant floodplain land in urban areas is difficult to justify on economic grounds and is usually unnecessary. Except in hazardous locations, a comprehensive flood loss prevention policy usually permits development, subject to appropriate safeguards. Obviously, there is a direct connection between the application of land use management and the purchase of land.

A general characteristic of floodplains is that all areas are not exposed to the same degree of risk in terms of flood depth or high velocity floodwater. As one moves across the floodplain from the river channel towards higher land the average frequency of inundation and the risk of damage in a given year both diminish. In recognition of this fact, many flood authorities/organizations employ definitions or special zonings to partition the floodplain into high and low risk areas.

Flood-liable areas are defined as the areas covered by the standard flood. A floodway is part of the flood-liable area within defined limits and which consists of the stream channel and the necessary portion of the adjoining floodplain, if any, that is required to provide for the passage of the standard flood. Where levees have been constructed on the floodplain, it is the area between such levees. (See figure 25.)

Most authorities hold the view that urban development is generally undesirable on any flood-liable land in high risk areas if there are alternative flood-free sites available. Their policy is to promote the long-

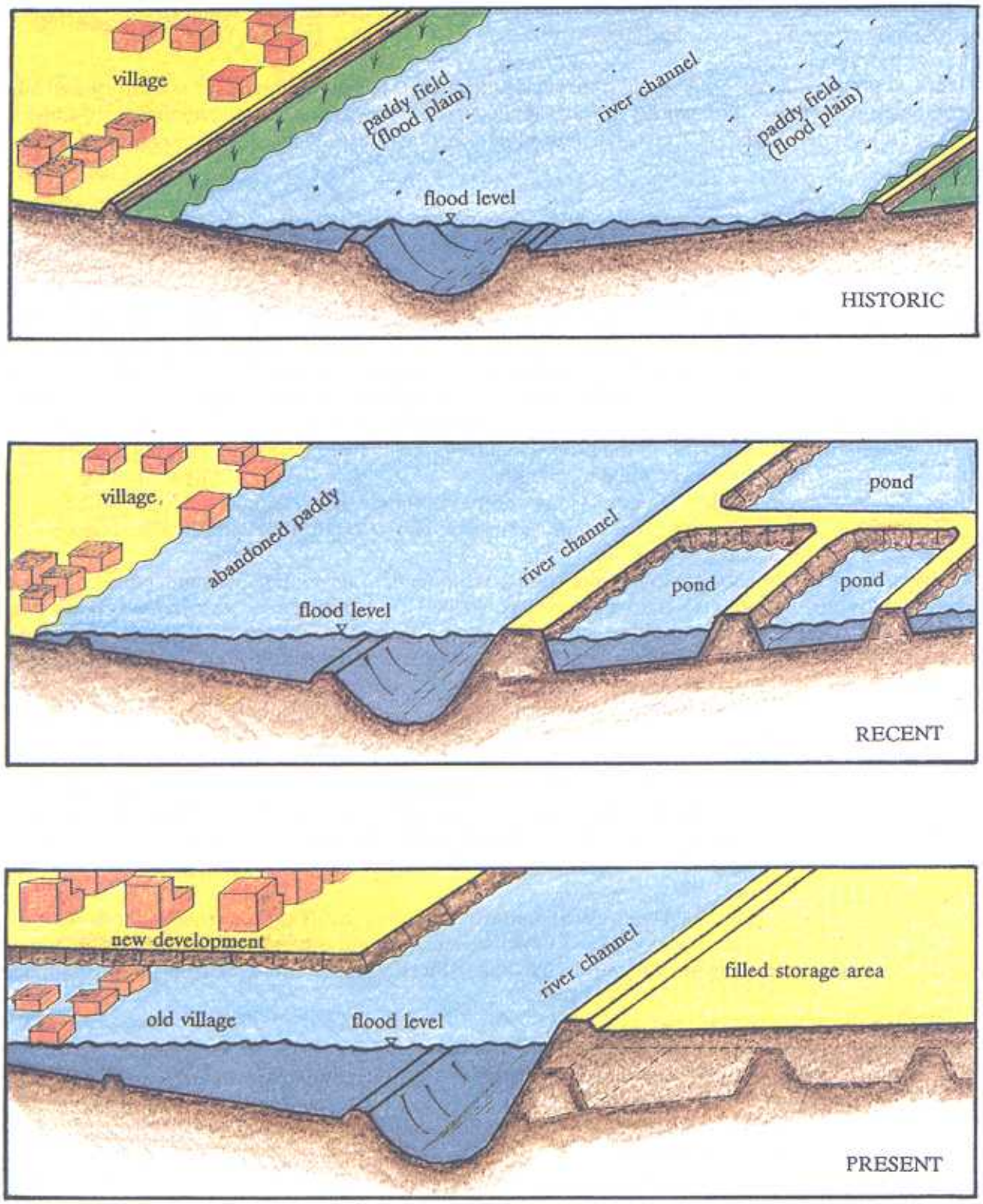


Figure 12. Without proper land use management, changes in flood plain conditions may increase the potential flood response in the adjacent areas and the downstream reaches. (Example of Hong Kong.)

term removal of urban development from flood-liable areas (where practicable and appropriate) and to clear the floodway of unnecessary obstructions to the free flow of floodwater.

In some cases re-zoning and relocation of highly flood-liable communities may be a more appropriate solution than structural works. While it is recognised that some social and economic costs may be experienced in the short-term, the long-term prospect of restricting development in such areas could be beneficial in alleviating personal suffering and financial loss. It is often the poor and underprivileged who are forced to live in flood-affected properties. Discouragement of further development and adoption of relocation schemes, provided that suitable alternative accommodation is available, will lead to better living conditions and less disruption and expense when floods occur.

However, relocation should only occur as a component of a properly prepared flood loss prevention and management plan, be identified and developed early in the design phase, and involve public participation. It may be categorised as the following:

(i) Imperative relocation: dictated by technical requirements of the flood loss prevention and management plan, such as obstruction to flood flows or threat to the life of the occupier or rescuer. In such cases adequate statutory controls are required to enable the relocation;

(ii) Desirable relocation: carried out where it is perceived to be in the long-term general interest of the landholder and the overall plan, although it is not essential to the performance of the plan. In such cases, the relocation should proceed voluntarily with the mutual co-operation and authority of the landholder.

Relocation is often necessary as a temporary measure following the occurrence of a flood. Flood-stricken populations rendered homeless as a result of destruction of their accommodation by floodwater require emergency, and subsequently, permanent settlement. When settlements located in floodways are identified as candidates for imperative relocation, steps should be taken to secure a suitable alternative site for development. The alternative site requires adequate planning to ensure basic services and to satisfy social and employment needs. Experience has shown that relocation exercises can only succeed when they are handled with a high degree of sensitivity.

Plate 3 It is often the poor and underpriviledged who are forced to live in flood-affected properties.

Regional experience

Most members recognise the problems associated with illegal squatters occupying floodway areas and have embarked on programmes of floodway clearance. However, while there is a need to expedite clearance programmes, there is a social requirement that Government implement resettlement schemes to re-house the squatters. The high cost of providing accommodation on alternative flood-free sites militates against a speedy resolution of this problem.

(c) *Modification of catchment conditions and on-site storage*

Flooding can be increased significantly by the run-off from lands which have been stripped of vegetation or covered with buildings, pavements or other impervious materials. Within smaller catchments these changes to run-off characteristics in respect to peak rates of flow, total volume of run-off and water quality can be significant.

Flood run-off from small urbanized catchments can be slowed by mimicking the storage phases of the run-off process. The following processes and run-off management measures may be adopted to slow the concentration of floodwater on small catchments (see figure 13):

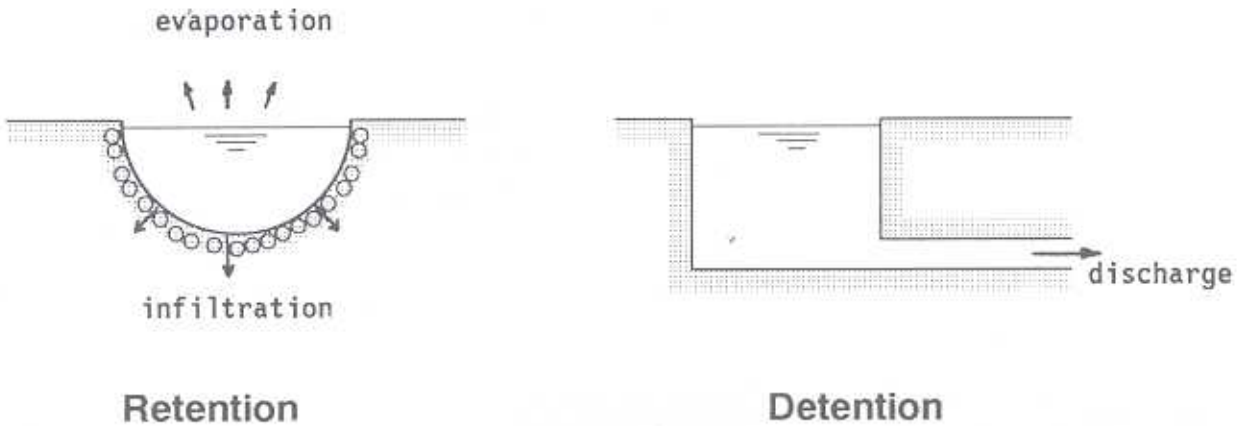


Figure 13. Retention and detention

(i) Retention: floodwater is held for considerable periods in the catchment and is slowly dissipated by infiltration, percolation and evaporation. Retention measures include rock-filled pits to catch run-off and the use of permeable pavements;
(ii) Detention: floodwater is held for short periods of time in the catchment to reduce peak flow rates and then is discharged in natural or artificial channels. Detention measures include roof storage, rainwater tanks, ponding in athletic fields and parking lots. (See plate 4.)

The main objective of on-site storage is to detain run-off at its source and release it in an orderly fashion so that the natural flood behaviour of a drainage basin is largely retained or improved. On-site storage can also improve water quality by trapping pollutants. The principal on-site storage measures involve the construction of small ponds on lands which are used for open-space purposes. These ponds can take the form of shallow grass-covered basins in parks or playing fields, or specially designed storage facilities in parking lots, roof-tops or other such areas. Other measures include the design of streets in hilly areas to prevent rapid run-off, incorporating small detention basins into landscaped areas, using rock-filled pits to intercept gutter run-off, and using permeable pavements to promote infiltration into the ground below.

In larger catchments, which will generally include major sections of forested or rural land, reafforestation operations, contour ploughing and channelling, together with an increase in fertility of the soil, have the effect

Plate 4. Artificial measures to maintain the natural water retention capacity of vegetation and soil is mandatory in Japan, if development significantly alters the natural situation. A detention pond is utilised as tennis courts in ordinary times.

of reducing run-off by increasing infiltration. However, these activities do not have any material effect on mitigating larger floods.

Regional experiences

In urban areas of Japan, drainage facilities such as trenches, gutters, wells, as well as pavements are specially designed not to drain rainwater to the channel but to infiltrate to the ground. They are basically composed of permeable sheets or nets, pipes with holes, and placed in a gravel envelope. Infiltration gutters and pavements use special permeable material on the surface. Such devices and detention facilities are shown in figure 14 schematically.

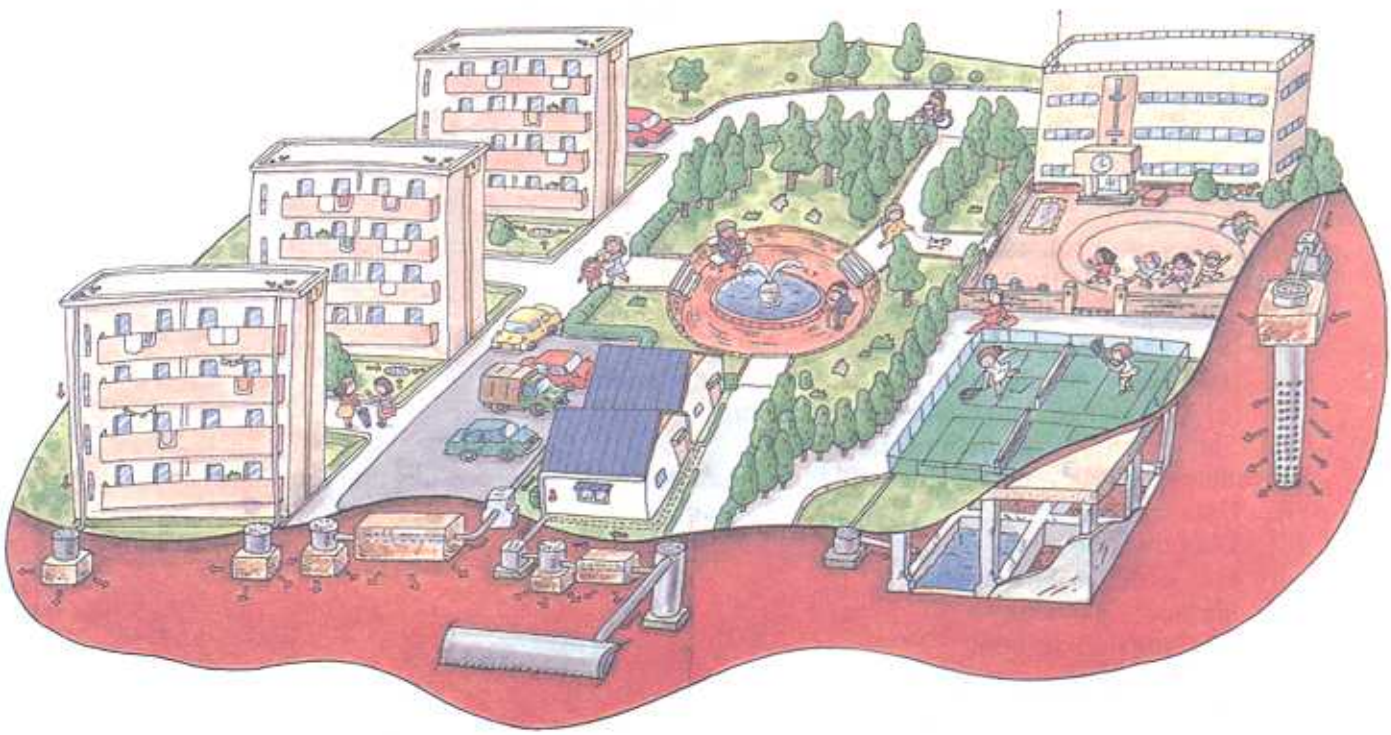


Figure 14. Storm water detention and infiltration facilities being introduced in Japan

(d) *Flood forecasting and warning*

Flood forecasting is the estimation of stage, discharge, time of occurrence, and duration of a flood, especially of peak discharge, at a specified point on a stream, resulting from precipitation and/or snowmelt. On the other hand, flood warning is the advance notice that a flood may occur in the near future at a certain station or in a certain river basin. To be an effective and valuable measure, forecasts must be timely and accurate and must be combined with a community awareness programme which teaches people what to do on receipt of the warning. This may involve action to protect possessions from flood damage or evacuation planning. In some situations, flood forecasting and warning can be the most important non-structural measure in the management of flood-liable lands and in reducing flood losses.

The value of flood forecasting and warning to the management of flood-liable lands is both direct, in that material damage to life and property can be prevented, and indirect through the minimising of economic and social disruptions. The direct benefits of flood forecasting and warning are achieved where it is possible to take action to save life and to reduce the potential flood damages. This action includes that taken by individuals to protect their own property as well as community action such as temporary levee construction and maintenance. Benefits also accrue when the operation of hydraulic structures associated with flood mitigation reservoirs and flood storage and retardation areas is based on flood forecasts. In general, the benefits are greatest in urban areas, although significant savings can be achieved in rural areas, particularly where livestock can be moved and crops harvested prior to the onset of flooding.

Flood forecasting and warning provides assistance to the planning of emergency measures such as the relocation of people to non-threatened areas and the logistics for flood-fighting activities. It also produces less tangible benefits such as minimising the economic and social costs caused by the disruption to communications and transport and the concerns within a community which accompany unpredictable flooding.

The effectiveness of flood forecasting and warning to reduce potential losses will depend upon the following factors:

(i) The effective flood warning time must be sufficient for flood-affected people to initiate protection of possessions or evacuation procedures;
(ii) The level of public awareness must be such that people will accept, and act on flood warnings and/or advice;
(iii) The reliability of the warning both in terms of accuracy and credibility of the warning authority is proven.

The choice of a proper method for flood forecasting and warning depends upon:

(i) The type of flood;
(ii) The degree of development of the forecasting service:
    (a) The observational network;
    (b) Telecommunication and data processing facilities,
    (c) The length and quality of data records.
(iii) The availability of qualified personnel.

In general the following activities will be common to all flood forecasting and warning systems:

(i) Data collection;
(ii) Data transmission;
(iii) Meteorological forecasting;
(iv) Forecasting model;
(v) Warning preparation;
(vi) Warning dissemination;
(vii) Receipt of warning and action;

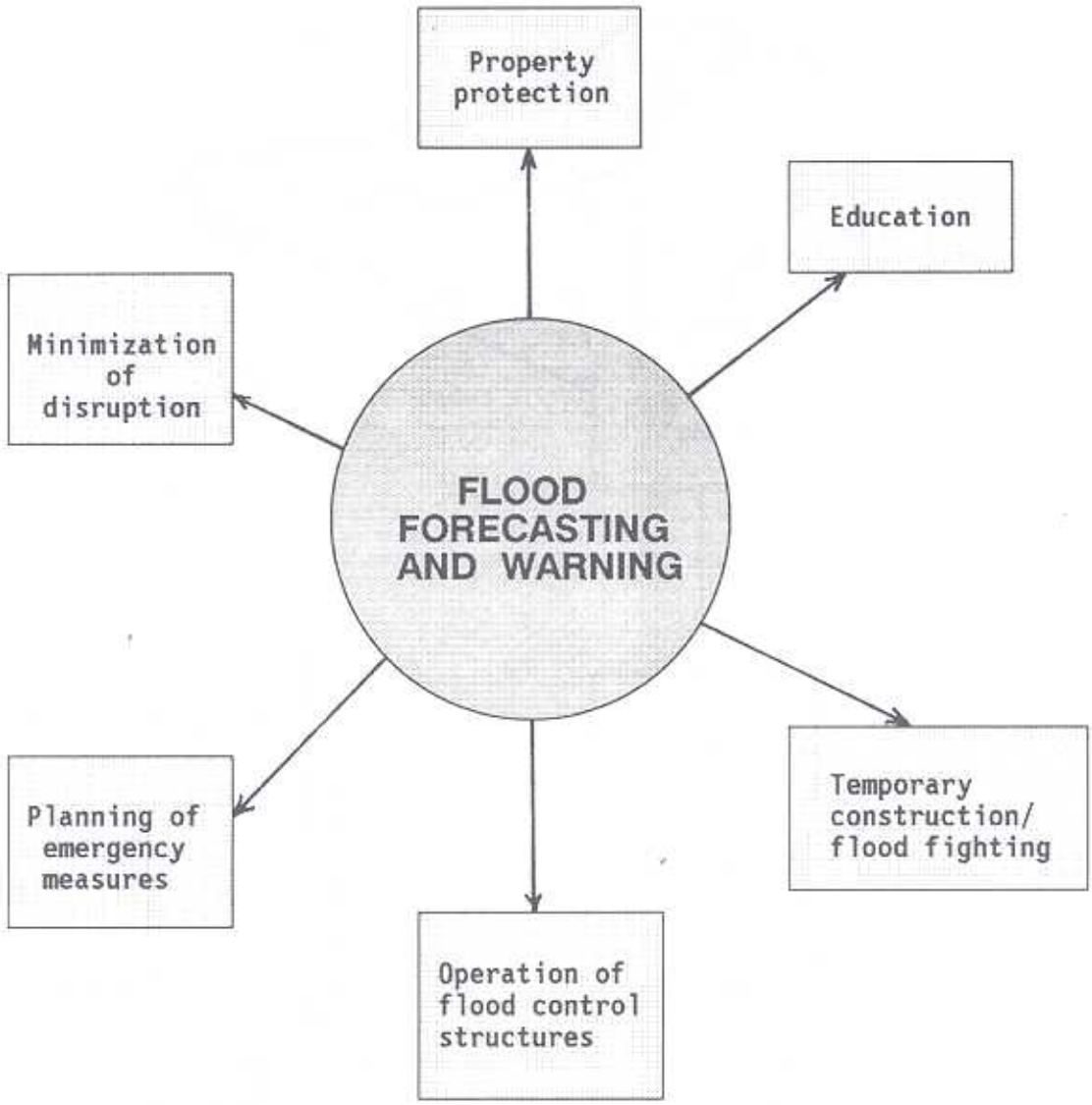


Figure 15. Benefits of flood forecasting and warning

(viii) Feedback on response to warnings.

The relationship between these activities is shown schematically in figure 16.

Regional experience

Over the last decade the Typhoon Committee members have been actively engaged in improving their flood forecasting and warning capabilities. Most of the major rivers throughout the Typhoon Committee area are already equipped with comprehensive forecasting systems operated by the national meteorological and hydrological services. These systems have reached a high degree of sophistication and form the principal non-structural flood loss prevention and management measure adopted by the individual members to reduce flood losses.

Impetus has been given to the establishment and operation of flood forecasting systems in the Typhoon Committee area by the Committee's activity under the hydrological component and the WMO Tropical Cyclone Programme. These activities have undoubtedly stimulated the growth in the number and quality of systems and led to an extension of this measure for forecasting floods on medium to small catchments.

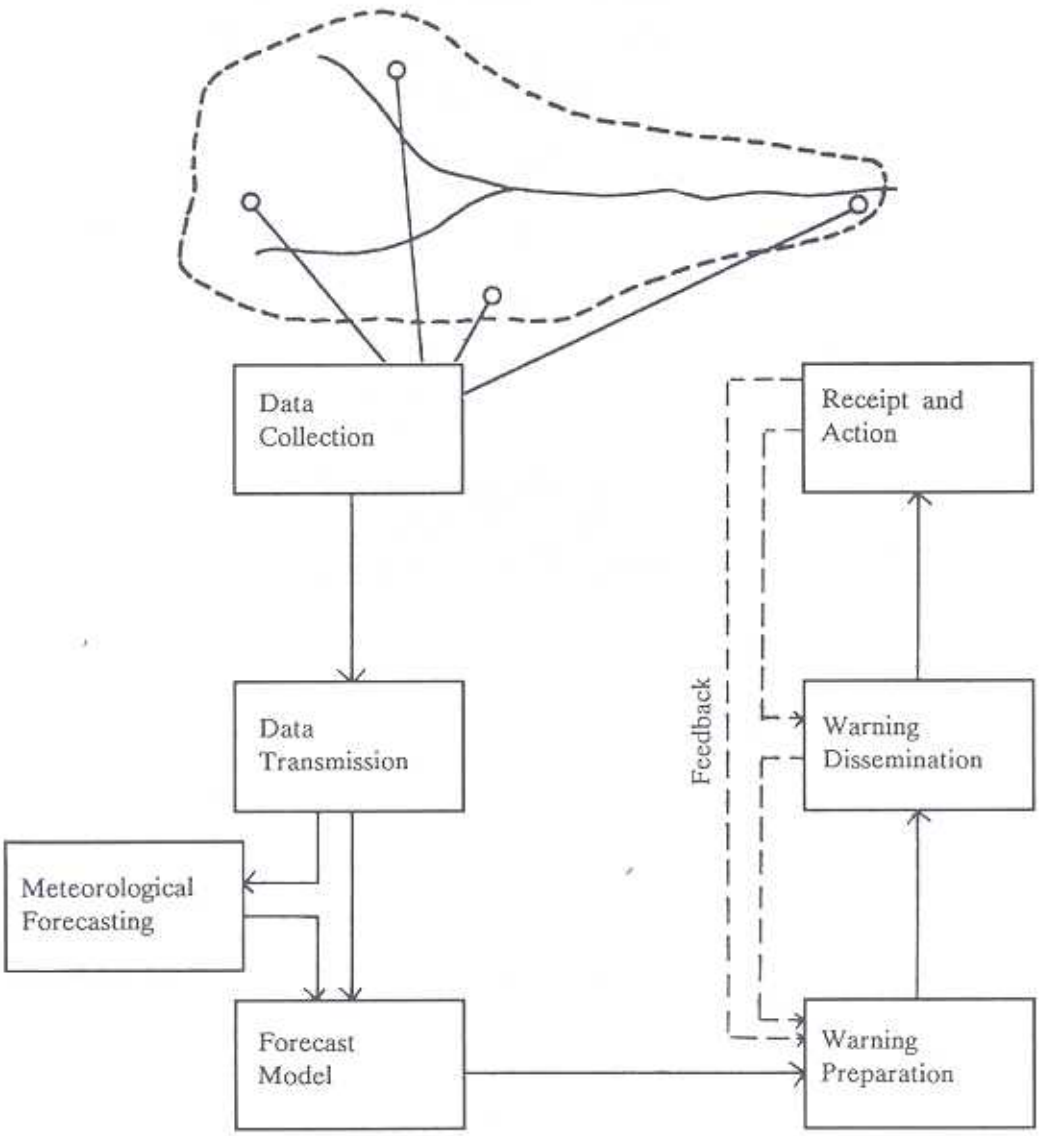


Figure 16. Activities involved in flood forecasting and warning operations

(c) *Public information and education*

Flood hazard information is a prerequisite to sound flood loss prevention. The development of needed technical information and public education, especially of the officials and planners who will have the major task of interpreting and applying it, is essential in an effective flood loss prevention programme. The development of readily accessible information, easily interpreted and of uniform quality, is one of the aims of floodplain delineation. Vital information includes the hydrology and hydraulics of small, large and very large floods on the areas subject to inundation, on the floodplain's resource attributes, on the role of the floodplain within its region, and on the potential impact of land use decisions on flood potential. From this information, alternative approaches can be formulated by the responsible decision makers. Better information on property at risk and probabilities of various levels of loss can help to translate the hazard into terms that stimulate appropriate local action.

Regional experience

Because structural protection against flooding cannot be provided immediately to protect vulnerable areas, some members have introduced programmes to provide information and educate the public on flood hazard situations.

In Malaysia, special steps are taken to issue local flood warnings through timely and appropriate dissemination of information based on changes in upstream river levels. For example, flood warning boards, normally established in flood-liable areas, aim to enable the local residents to make flood forecasts and assess for themselves what the flood situation would be in their locality upon receiving water level information from an upstream water level station.

The warning board gives the relationship between the local flood level to an observed upstream reference water level station. Before a warning board can be commissioned, calibration by means of simple stage correlation must be carried out. During the calibration period, it is first called a flood board. Peak flood levels are marked on the pole after each event and the correlated colour bands are marked on the board. Once calibrated it is called a flood warning board. (See figure 17.)

The newly formed Drainage Services Department of Hong Kong has adopted a policy to provide information to the public on floods and measures individuals can take to help them handle the problems created by floods. This information, which is presented as a series of easily interpreted illustrations, emphasises the measures

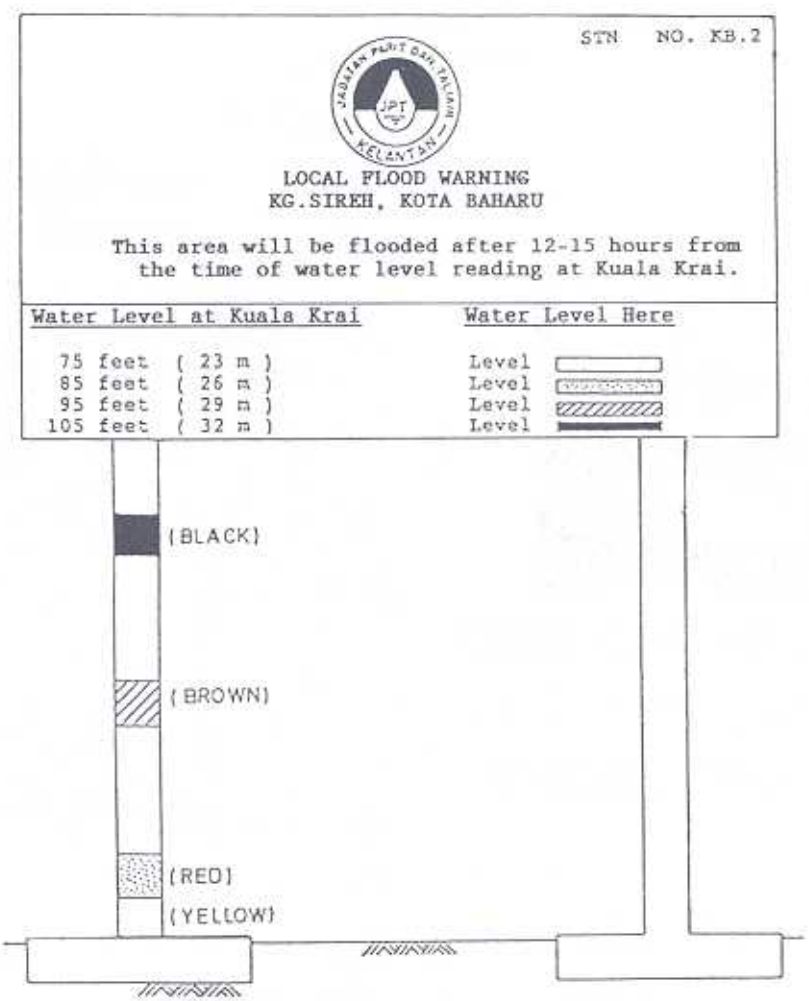
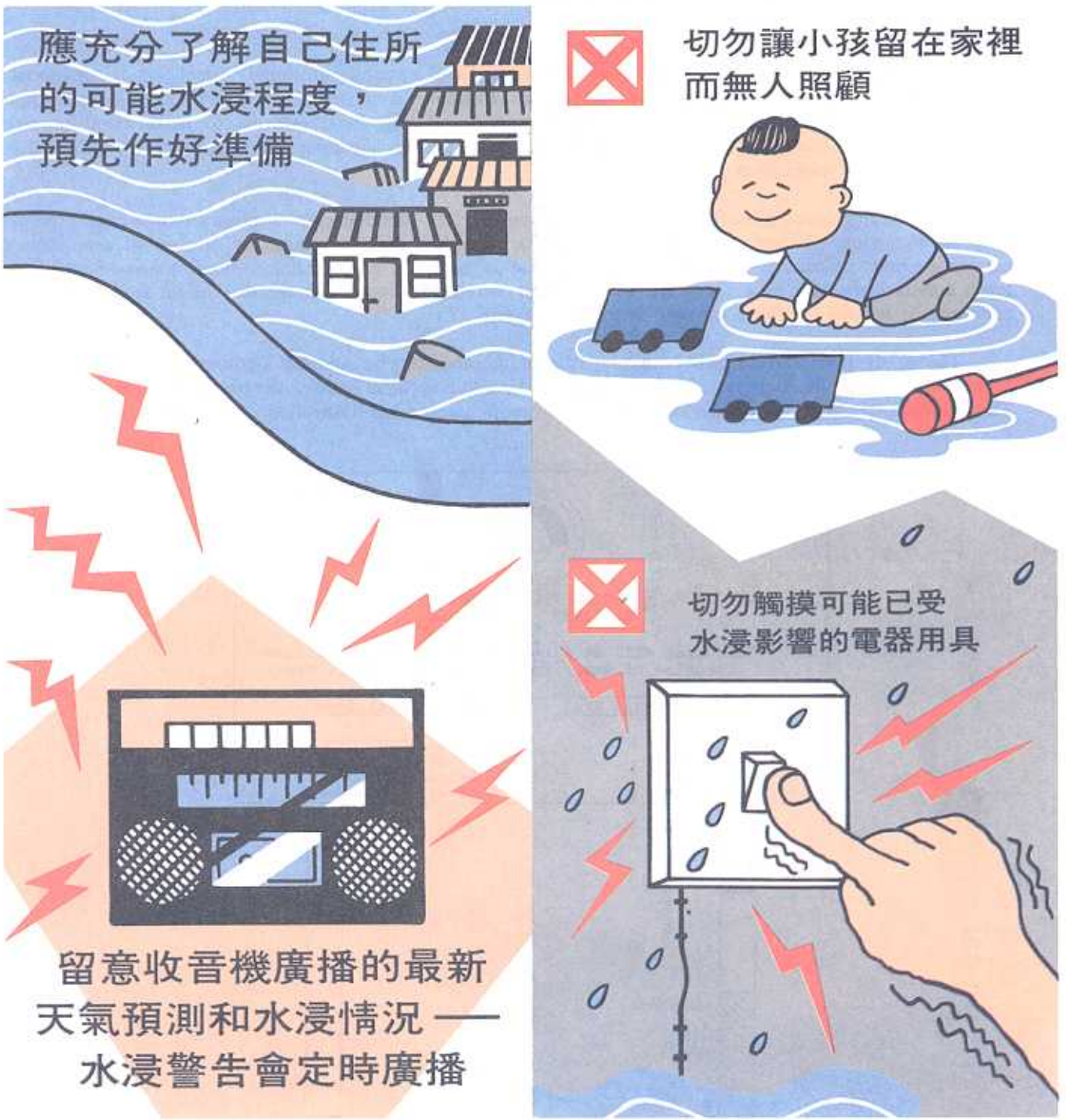


Figure 17. Flood warning board at Kelang Sireh in Malaysia

that should be adopted so that people can be prepared and react responsibly to the flood hazard. Examples of this information are presented as figure 18.



Upper left: Understand the extent of flooding. Your home is likely to be affected. Take precautionary measures.

Upper right: Never leave a child unattended at home.

Lower left: Pay attention to radio broadcasts on current weather forecast and flooding — flood warning will be broadcast at regular intervals.

Lower right: Never touch any electrical equipment which might have been affected by flooding.

Figure 18. Examples of illustrations in a brochure presented to the public on floods in Hong Kong

(f) *Flood proofing of buildings*

Some of the damages from flooding may be minimized by appropriate measures to prevent flood waters from entering properties. Such measures can include the provision of shutters to secure the building against the entry of flood waters, construction of buildings on elevated piers or earth mounds, construction of retaining walls around individual buildings, or the use of floodwater resistant materials.

In areas where floodwaters are shallow and slow moving temporary walls comprised of sandbags or masonry may be used to protect individual buildings. Structures with walls and foundations which are generally impermeable to water can sometimes be made watertight by blocking doorways and openings to a height above flood level by this method. (See plate 5.) The successful exclusion of floodwater from buildings reduces flood losses and promotes faster recovery from flooding.

Other than by elevating the buildings above flood level, examples of which can be seen in the Typhoon Committee area, effective flood proofing is usually difficult to achieve and maintain in areas of deep flooding.

Flood proofing is not a surrogate for land use control and should be used only in non-hazardous areas. This measure should extend to the consideration of appropriate structural design features to ensure the stability of buildings subject to hydraulic forces and for stopping sewer back-up.

Plate 5. Buildings can be made watertight by blocking doorways and openings to a height above flood level.

(g) *Evacuation from endangered areas*

When flooding is inevitable, the best way to reduce losses is the evacuation of people and property from the flood-liable area. While the main objective of evacuation is the saving of human life, it also involves the reduction of flood damage by the transport of removable goods from the area.

The key to a successful evacuation programme is an effective flood warning system. To be effective, however, a flood warning must be both timely and accurate. The degree of benefit achieved will depend upon the warning time provided to the floodplain occupants and the ability of these occupants to respond. As a general rule the longer the length of the warning period, the greater the possibility to reduce flood damages through the evacuation of both people and property. Even on small catchments effective flood warning systems can provide adequate time to carry out evacuation procedures to safeguard life.

Evacuation should be regarded as a short-term measure and can be divided into three phases, such as the pre-flood, flood and post-flood. The greatest potential for reducing the number of casualties and flood damages is during the pre-flood phase and as previously mentioned, the degree of success is related to the amount of time provided by the warning period. In large floods evacuations may be required during the flood phase for a variety of reasons including higher than forecast flood levels. The post-flood phase involves relief and rehabilitation of the flood affected area.

The major responsibility for undertaking evacuations usually resides with the established civil defense organization. To be effective, the area of potential flooding must be known and the evacuation procedure planned in advance of a flood event. In most countries, the responsibilities and activities of civil defense organizations are clearly defined by legislation.

One difficulty of evacuation planning is to maintain an adequate level of flood awareness during the extended periods when moderate to major flooding does not occur. Special effort is therefore needed to ensure maintenance of public awareness, particularly in the case of population turnover.

(h) *Flood fighting*

Flood fighting has been generally defined as the taking of precautionary measures against disaster at times of flood and storm surge. In particular it relates to those emergency actions taken during a flood to prevent inundation of land and property. Emergency measures include the construction of temporary controls to exclude floodwater, the moving of contents out of flood reach and emergency operations to maintain electricity and water supplies. It extends to emergency repairs to levees and other structural works caused by partial failure or limited overtopping by floodwaters. (See figure 19.)

Effective flood fighting relies on well-planned operations which are co-ordinated and implemented at the local level. Like flood evacuation activities, the effectiveness of flood fighting operations are enhanced if early flood warning can be provided.

(i) *Flood relief*

Government assistance for flood relief is usually provided under some natural disaster relief arrangements. These arrangements provide for financial assistance to help the local authorities meet the unpredictable and sometimes large costs of providing natural disaster relief. The main aim of flood relief is to provide for the immediate assistance to overcome personal hardship and distress, including essential repairs to houses and the repair and replacement of essential items of furniture and personal effects.

Flood relief can be looked upon as zero premium insurance and does little to reduce the impact of future flood losses. Under a policy which provides generous flood relief, there is a potential for flood relief payments

Plate 6. The main objective of evacuation is the saving of human life.

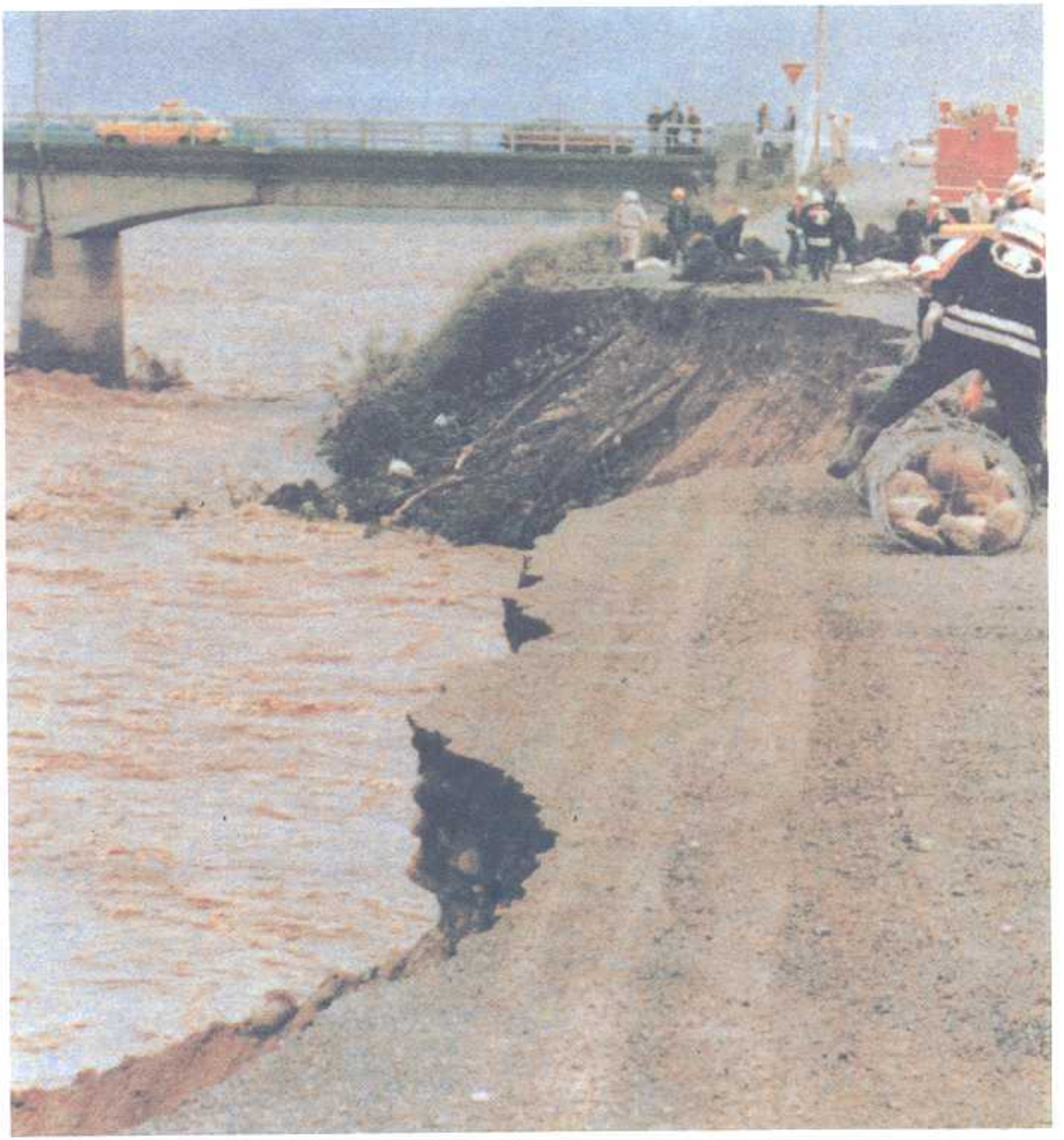


Plate 7. Flood fighting is one of the emergency actions taken during a flood to prevent inundation of land and property.

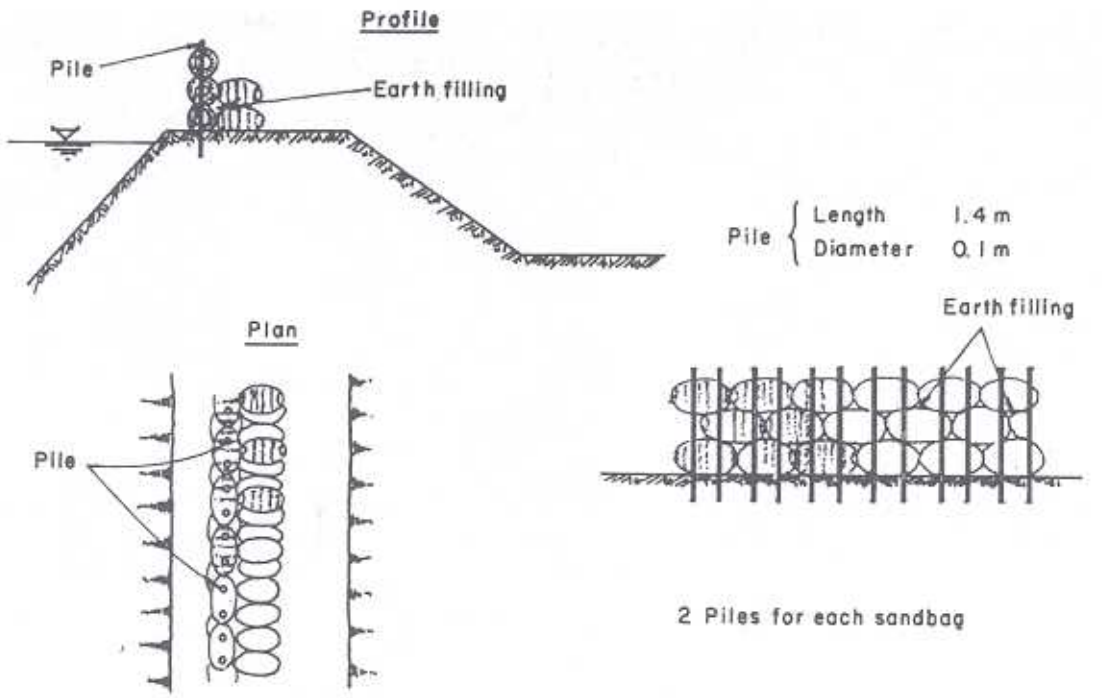


Figure 19. Example of flood fighting – sandbag stacking

to increase. Those local authorities which adopt a low flood standard or do not implement flood loss prevention measures or land use controls may contribute directly to the cost of future flood damages through increased flood relief payments.

(j) *Flood insurance*

Flood insurance is often perceived as having several advantages as a means of modifying the loss burden. It enables the individual property owner to spread an uncertain but potentially large loss over a long period of time. It also provides a mechanism for spreading flood loss over a large area and a large number of individuals.

Because flooding is locality specific the demand for flood insurance is therefore usually from those who reside in areas known to be flood-liable. The major issue is whether those at risk should fully pay for the cost of that risk or whether this cost should be shared among the whole community with those not at risk subsidising those who are.

One of the basic difficulties of providing private insurance protection against flooding is finding enough policy holders to contribute to the cost of protection at affordable rates but yet providing a large enough pool from which to pay claims for flood damage. For this reason the private insurance industry is usually unwilling to provide flood cover. To overcome this problem some countries have introduced national flood insurance schemes which are subsidized by Government.

In essence, the national flood insurance schemes aim to identify flood hazards and recognize the responsibility of persons located on the floodplain accepting the costs of living in such an area. Success of these schemes relies on the appropriate authorities identifying the physical extent of floodplains and the degrees of hazard associated with their occupation and the need for each property owner being mandatorily insured.

The national flood insurance scheme has been extensively used as a supplementary flood mitigation measure in the United States following the passage of the flood insurance act of 1968. Under this scheme

Plate 8. The main aim of flood relief is to provide for immediate assistance to overcome personal hardship and distress.

floodplain occupants are provided the opportunity to purchase federally subsidised insurance against flood losses. The insurance is available to all persons in areas in which the local government is participating in the Federal Government's flood insurance programme. To become eligible for participation, however, the local government must formally apply for enrolment in the programme and must agree to regulate new construction and development in areas subject to inundation by the 1 in 100 year flood. In this way the Federal Government is encouraging improvements in floodplain management at community level which translate into future saving of flood relief funds at the national level.

In the absence of a national flood insurance scheme, there usually would be insufficient premium income to spread the risk. Because the flood hazard is limited in its area of concentration, a single event could cause a loss of such magnitude that it could eliminate the premium pool and its reserves.

It should be noted that insurance can do nothing directly to reduce the severity of the natural hazards or to reduce the susceptibility to damage and disruption from the hazard. It merely spreads the loss over time and area. Its major role is in ensuring that, provided premiums are based on full actuarial rates, the insured bears the full cost of his locational decision. Thus, insurance provides an efficient and equitable way for individuals to bear losses.

However, flooding fails to meet the criteria for insurability in several ways, namely:

(i) Full cost of insurance in high risk areas is beyond the capacity of many homeowners to pay;
(ii) Lack of an assessment of risks on which to base premiums;

(iii) Lack of widespread demand, thus limited opportunity to average costs over area or time;
(iv) Inability to control continued unwise development in high risk areas;
(v) Difficulty in accumulating reserves for major catastrophes.

For insurance to be a practical option, the risk and hence the premium must be small. For many existing developments in a hazard-prone area, mitigation or other preventative measures will be required before this condition is met. In fact, insurance is a near-perfect strategy to cover the small residual risk remaining after mitigation measures have been adopted.

Irrespective of the level of protection provided in hazard-prone areas, there will always be a residual risk, for example, flood control levees can be overtopped. While this may be an infrequent occurrence it can have a devastating impact on those affected. It is essential that adequate and reliable information in the form of flood maps is available so that an actuarial assessment of insurance premiums and rates can be made. (See chapter IV. Guidelines for flood risk analysis and mapping.)

Regional experience

Flood insurance is not widely practised as a non-structural flood mitigation measure by the members. However, China has in place a number of flood insurance schemes operated by insurance companies. These companies are entitled to collect premiums and pay claims for flood damage. Any shortfall in the payment of damage claims is made up by the provincial government which is empowered to collect levies from beneficiaries within the proclaimed flood area.

In order to reduce the reliance on the flood relief funds provided by the central Government, provincial governments are being actively encouraged to implement flood insurance schemes in areas which experience a high incidence of flooding.

(k) *Flood adaptation*

The term "flood adaptation" relates to the need to develop community activities based on acceptance of the fact that living in a major floodplain must inevitably bring the consequences of sporadic flooding. Informing the public of the possible extent of the flood hazard in areas where they work or live, of heights reached in past floods, how to organize their home, farm, shop or factory in preparation for floods and of procedures in flood emergencies, are matters which require attention. Floodplain residents then undertake flood protection measures on their own initiative. Practical examples of flood adaptation include the construction of private levees and stock refuges.

In rural areas, farmers can take action to reduce susceptibility to flooding by modifying their land management practices. These actions should be directed towards maintaining the volume of natural flood storage and the removal of unwarranted obstructions on the flood plain. For example, the farming of low-lying or floodway areas should be avoided or restricted to the non-flood periods. If, for economic reasons, these areas must be farmed during the wet season then only an appropriate type of crop should be grown.

The choice of crops should be based on several factors. These include choosing a type of crop that:

(i) Does not unduly impede the passage of flood flows;
(ii) Does not cause a hazard to downstream areas if it were to become floating debris;
(iii) Can withstand waterlogging and extended periods of inundation.

Regional experience

Some members, such as China and Malaysia, have experimented with different crop types for the cultivation of flood-liable areas. Crops are selected on the basis of soil type and their ability to withstand inundation by floodwater.

In China specific guidance is given on the growing of appropriate types of crops in flood storage and retardation areas, with a particular preference being expressed for the growing of wheat crops.

3. Summary

The major advantages and disadvantages of structural and non-structural measures are summarised in table 3.

Table 3. Summary of structural and non-structural measures for reducing flood losses

Type of measure	*Major advantages*	*Major disadvantages*
A. Structural alternatives		
1. Levees and floodwalls	– Provides localized protection – Relatively low initial construction costs – Useful measure against flooding up to the design level – Permits further development of existing urban areas	– Usually requires land resumption – Can divert floodwater to other areas and raise flood levels – High maintenance costs – High damages occur when structures are overtopped – Can cause false sense of security in protected population – Can have adverse environmental impact
2. Channel modifications/By-pass floodways	– Increases main stream capacity – Provides localized protection – Small land requirements – Effects of construction are localized	– In built-up areas land costs can be expensive – Can cause problems of erosion and sedimentation – Construction costs may be high if existing infrastructure has to be modified – Can transfer flood problem to other areas
3. Retarding basins and flood storage areas	– Natural flood storage areas are used for flood mitigation purposes – Reduces downstream discharge – Flooded area is used for productive agricultural purposes during dry periods – Simple and cheap to construct	– Area suffers damage when flooded – Local inhabitants can be at risk unless operation is properly controlled – Effectiveness is limited by available storage capacity and residual drainage facilities
4. Flood mitigation Reservoirs	– Reduces downstream discharges – Provides protection to existing development	– Society as a whole bears cost while floodplain users enjoy major benefit – High construction costs – Requires resumption of land for reservoir storage and possible displacement of local population – Can create false sense of security within downstream communities

Table 3 *(continued)*

Type of measure	*Major advantages*	*Major disadvantages*
		– Can cause environmental problems such as water quality degradation and siltation
5. Drainage evacuation systems	– Provides protection against local flooding in area protected by levees	– High maintenance and operating costs
B. Non-structural alternatives		
1. Land use management Zoning controls/Building and development controls	– Reduces potential hazard and losses – Permitted land use is consistent with flood hazard – Ensures that the flood problem is not worsened by new structure in flooded areas – Environmental character of the area is largely preserved	– Can restrict legitimate development if controls are not consistent with flood hazard – Individual landowners are required to meet costs – Controls can be too restrictive
2. Property acquisition and floodway clearance	– Removal of obstructions can lead to the free flow of floodwater and reduced flood levels – Vulnerable development removed from flood hazard area – Reduces post-flood rehabilitation costs	– May not be readily accepted by residents – Acquisition costs can be inordinately high if carried too far – Needs to be undertaken in conjunction with a re-settlement programme if squatter populations are involved
3. Modification of catchment conditions	– Can reduce environmental factors by reducing erosion and silt transport – Can reduce downstream discharge by detaining rainfall	– Effectiveness reduces as flood magnitude increases – Individual landholders and developers are required to implement programme and meet costs
4. On-site storage	– Retains floodwater at point of origin – Reduces downstream flood peak – Relatively cheap to construct	– Opportunity to implement on a large scale is limited – Ineffective on large catchments – Landowner is usually required to meet cost
5. Flood forecasting and warning systems	– Minimises damage and danger to life – Alerts general public to take action – Generally cheap and quick to install – Useful in conjunction with other measures	– Feasible only for catchments with long response times – Limited usefulness for small catchments – Tends to be ignored if constantly inaccurate – Needs to be integrated with other measures
6. Public information and education	– Creates an awareness of flood hazard confronting communities – Generates more ready acceptance of flood loss prevention measures	– Can be a time consuming task for flood authority – Can be unproductive if community acceptance is negative

Table 3 *(continued)*

Type of measure	*Major advantages*	*Major disadvantages*
7. Flood proofing of buildings	– Reduces post-flood clean-up operations	– Suited only to particular types of buildings
	– Especially suited to commercial and industrial buildings	– Can result in high losses if flood height is exceeded – Landowner meets cost
8. Evacuation from endangered areas	– Reduces loss of life – Generally cheap to introduce	– Requires effective flood warning system – Requires detailed planning – Public awareness must be maintained
9. Flood fighting	– Reduces adverse impacts of flooding including casualties and damages	– Requires effective flood warning system – Requires detailed planning and trained personnel – High cost to Government
10. Flood relief	– Reduces financial burden on affected individuals – Reduces impact of post flood problems	– Funds are provided by entire community – Generous funds and assistance tend to promote continued occupation of hazardous areas
11. Flood insurance	– Can be helpful to cover individual flood loss or damage – Can reduce the total amount of flood relief funds provided to victims – Places responsibility on individuals who choose to reside in flood hazard area	– Hard to obtain from private insurance companies – Can encourage continued occupation of the floodplain – National flood insurance schemes require use of public funds
12. Flood adaptation	– Reduces potential flood losses to individuals – Individuals meet their own costs	– Only applicable in non-hazardous areas – May not provide protection against major flood conditions

G. Comprehensive flood loss prevention and management studies

The comprehensive flood loss prevention and management study will address the existing and future flood problems to minimize the effects of flooding in flood hazard areas by considering the best mix of flood management options available, i.e. the best combination of both structural works and non-structural measures, having regard to the extent and severity of the flood problem on the one hand and the social, economic and environmental benefits and consequences on the other. The possible mix of options may be drawn from the structural and non-structural measures, which have been discussed in detail in Section F. Often, no single management option will suffice and the optimum mix of measures should be sought from the possible range of measures.

Various alternatives of a set of structural and non-structural measures that meet the planning objectives, legislative and legal constraints and the planning criteria should be presented. Possible impacts on economic, social and environmental factors should be assessed for each alternative. The optimum set should be selected by analysing project performance and cost estimates.

The study should consider whether proposed measures might produce adverse effects upstream and/or downstream, and what modifications should be incorporated to lessen or compensate for such effects.

The basic responsibility for conducting the study should rest with the leading flood authority/ organization. The authority/ organization should possess sufficient expertise to deal with the complex engineering and planning factors associated with the task.

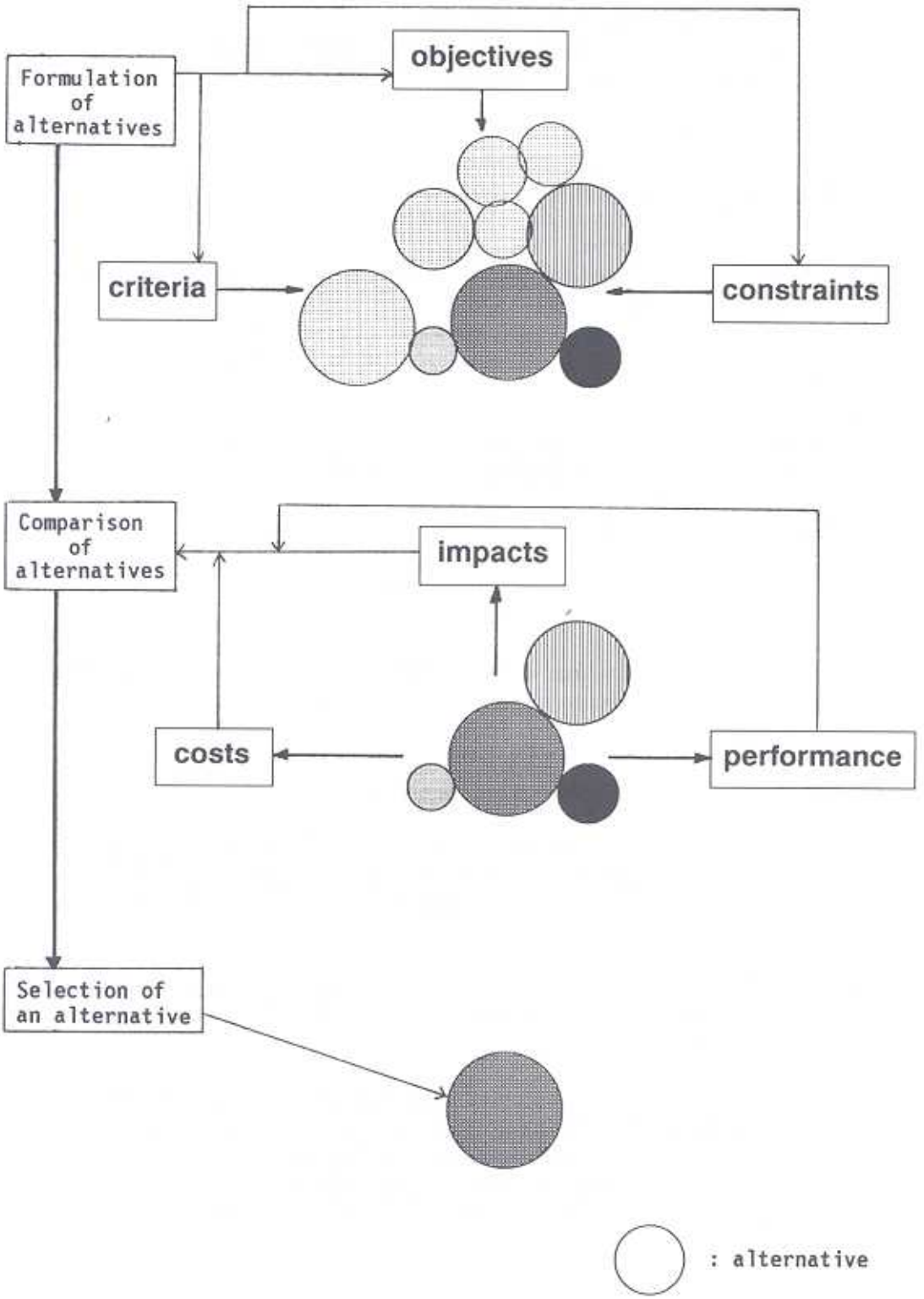


Figure 20. Comprehensive flood loss prevention and management studies

H. Comprehensive flood loss prevention and management plan

In preparing the comprehensive flood loss prevention and management plan, the following items should be included:

(1) The objectives of the plan based on the flood policy
(2) Legislative and legal requirements and constraints
(3) The general methodology of formulating the plan including planning criteria (e.g. cost-benefit)
(4) General setting of the planning area including:
    (a) Location;
    (b) Drainage area;
    (c) Political and geographic subdivisions;
    (d) General topography and vegetation;
    (e) Pattern of streams and other water bodies;
    (f) Important urban centres.
(5) Economic, social and environmental profile on existing conditions and projections for:
    (a) Population and employment;
    (b) Manufacturing, commerce, recreation and other activities;
    (c) Supporting infrastructure such as transportation, communications, water and power distribution;
    (d) Land use.
(6) Current status and projected situation of objectives stated in (1) above including:
    (a) Hydrological and hydraulic situation of the basin;
    (b) Hazard situation;
    (c) Flood mitigation works and measures.
(7) Assessment of structural and non-structural measures
(8) Alternative plans of structural and non-structural measures
(9) Selected plan

The leading flood authority/organization, which has the primary responsibility for formulating the plan, should disseminate the plan to the local community and occupiers of flood-liable land.

I. Implementation strategy

A schedule for the implementation of the various projects, which are usually staged to meet the needs, should be formulated. The required annual capital investments should be calculated. The institutional arrangements, professional personnel and outside consultants needed to implement the project should be assessed and secured.

While implementing the plan, the projections used in formulating the plan may turn out to be off the mark. The adopted plan may have unexpected effects. Review, feed-back and re-formulation of the plan, if necessary, should be carried out until its completion.

Responsibility for implementing the plan should rest with the leading flood authority/organization which should have all the resources necessary to complete the flood loss reduction programme. These resources include adequate funds, staff and legislative and legal authority. Assistance in the development and implementation of some non-structural measures such as flood forecasting and warning may be readily forthcoming from established government agencies such as the national meteorological and hydrological service.

III. INSTITUTIONAL ARRANGEMENTS

A. Organization and responsibilities

1. General

Floods can impose a high cost on the community in terms of loss of life, social disruption, hardship and damage to private and public property. The whole community bears these costs. The costs to flood victims are immediate, real and tangible; the cost to the general population may not be so readily discernible, but the taxes and rates, and subsidies used to fund relief and clean-up operations represent the community's contribution to flood damage costs. The damages and social and economical consequences of floods over the recent decades made some countries realize that some of their conventional methods of flood control were ineffective and some of their flood loss prevention and management practices were inadequate to contain the loss of life and widespread damage resulting from major floods. This realization precipitated a revision of flood policies and the institutional arrangements to implement these policies. There are no substantial differences in the flood policy objectives in the countries which have adopted a comprehensive approach to flood loss prevention and management. Neither are there major differences in the measures adopted to attain these objectives.

The responsibility for flood loss prevention activities in the countries of the ESCAP region is usually assumed by the central government of those countries. Provincial (or state) and local governments are only assigned a subordinate role in policy making and planning functions. In those countries with strong provincial governments the role allocated to those governments relates to the planning and commissioning of projects on less important streams and the normal planning and regulatory roles relating to the development of flood-liable lands.

One major advantage of concentrating the control of the management of flood loss prevention activities in the central Government is the ability to organize activities in respect of basin boundaries rather than political boundaries which in many cases bear no relationship to actual river basins. Other advantages include the application of consistent policies throughout the country, uniform technical standards, a better ordering of planning and construction priorities and streamlined administration.

The choice of institutional structure is less important than the requirement of providing a co-ordinated approach on a comprehensive catchment basis. It is believed that any of the available institutional models would be satisfactory as long as the comprehensive range of flood loss prevention and management principles are employed.

Regional experience

In China, the central Government is the leading authority for flood loss prevention and management activities. To develop policies and projects it has established a Central Flood Control Headquarters under the chairmanship of the Vice Premier. In addition, the Committee's tasks are to develop flood control projects on major rivers and provide funds to organizations under the control of the different tiers of government. Administration of the central Government's flood control activities is undertaken by the Ministry of Water Resources. Responsibility for less important rivers is relegated to the provincial, prefectural and county levels of government but these activities are overseen by the central Government. Although the central Government is the principal source of funding for the implementation of flood control works, the other tiers of government are required to make financial contributions, especially towards the maintenance of works.

In Hong Kong, the Planning, Environment and Lands Branch and the Works Branch are policy-making organizations within the Hong Kong Government and responsible directly to the Chief Secretary and the

Governor for the formulation of land use, land disposal, environmental protection and flood control policies for territorial application. In the context of flood control, the Drainage Services Department under the Works Branch institutes structural and non-structural flood mitigation measures to protect life and property in the flood-liable areas, all in accordance with the territorial flood control policy and strategy. It will become the responsibility of a drainage authority solely to discharge the functions as provided in the proposed drainage ordinance including among other things the control of watercourse maintenance and improvement and the control of land use in the flood plain and the river basin. Other government departments related to flood control include the Royal Observatory, the Territory Development Department, the New Territories Administration, the Buildings and Lands Department, the Environmental Protection Department, and the Agriculture and Fisheries Department. Plans are in hand to centralize the administration of the drainage functions under the Drainage Services Department in line with the drainage ordinance enactment.

In Japan, river systems which are important are designated as class A river systems and administered by the Minister of Construction, while others are designated as class B river systems and administered by prefectural governors. For small tributaries of class A and class B rivers, administration is done by heads of local administrations (cities, towns and villages). Smaller channels which are not considered as rivers legally are administrated by other ministries such as the Ministry of Agriculture, Forestry and Fisheries or by local governments.

In the Lao People's Democratic Republic, the Ministry of Agriculture and Forestry is the principal agency responsible for flood loss prevention and management activities. The Ministry is supported in this role by the Ministry of Transportation, Posts and Telecommunications which is responsible for disseminating flood warning information. Considerable technical assistance in the development of flood policies and programmes is provided to the central Government by the Secretariat of the Interim Committee for Co-ordination of Investigation of the Lower Mekong Basin. The central Government is also the main source of funds for flood mitigation activities which are largely provided by donor countries. A committee comprised of relevant departments of the Ministry of Agriculture and Forestry is the main body responsible for development of policy and formulation of flood control projects. Only small scale projects are undertaken at the prefecture level except for the Municipality of Vientiane which is responsible for the flood protection on Vientiane.

In Malaysia, there is no clearly defined law or regulation which confers the overall responsibility for flood loss prevention and management activities to any particular governmental organization or agency. However, the Ministry of Agriculture, through its Department of Irrigation and Drainage, is charged with the administration of the central Government's flood loss prevention policy. The policy objectives are largely achieved through the disbursement of project funds, including funds for projects initiated by individual state governments. As part of its policy, the central Government has supported a national water resources study which investigated the flooding problems in over 30 river basins throughout the country and recommended a range of measures to reduce future flood losses. It also assumes responsibility for flood forecasting activities throughout the country. Under the constitution, the state government can adopt the prime responsibility for implementing flood loss prevention programmes but their roles are usually subordinated to the central Government and limited to the control of developments on flood-liable land.

Although no unified flood loss prevention and management policy has been ratified by the Government of the Philippines, the responsibility for co-ordination of the flood control projects is undertaken by the National Water Resources Board. The Department of Public Works and Highways has the principal role in planning, construction and maintenance of flood control and drainage facilities nation-wide. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) provides flood forecasting and warning services. Other organizations involved in flood loss prevention and management activities and their co-ordination at the national level are the National Irrigation Administration, the National Disaster Co-ordinating Council and National Power Corporation. Their activities include flood forecasting and warning co-ordination, agricultural flood protection and drainage and flood fighting. Both the provincial and municipal tiers of government are allocated only minor roles in flood prevention.

In the Republic of Korea, the principal responsibility for flood loss prevention and management activities at the national level resides with the Bureau of Water Resources, Ministry of Construction. The Bureau is assisted in the task of policy development and flood disaster planning by the Central Anti-calamity Committee. Rivers in the Republic of Korea are classified into three types, namely class A, B and C. The administration

of important rivers is by the national Government and the less important rivers by provincial and county governments, respectively. For this reason, the Government provides the bulk of funds required for flood loss prevention activities. The provincial and county governments contribute on a share basis. The provincial and county governments assume responsibility for regulating building development in flood-liable areas.

In Thailand there is no leading organization with country-wide responsibility for planning, design, construction, operation and maintenance of flood control activities and works. Organizations related to flood control include the Royal Irrigation Department (Ministry of Agriculture and Co-operatives) for river sections which run through agricultural lands, the Public Works Department (Ministry of Interior) for urban drainage except Bangkok, the Meteorological Department (Ministry of Transport and Communications) for flood forecasting and warning. Bangkok Metropolitan Administration is responsible for the drainage and flood control of the Bangkok area.

The central Government of Viet Nam assumes full responsibility for the formulation of flood loss prevention and management policies in the country. Development of the policy and formulation of overall flood loss prevention plans resides with the Central Storm and Flood Control Committee which is comprised of representatives from all relevant central government departments. Actual implementation of projects is undertaken by the Ministry of Water Resources and it is supported by other organizations in this task.

In Australia, three tiers of government, federal, state and local, are involved in flood loss prevention and management policies. At the federal level, the concern is with the broader issues, such as the equitable distribution of funds among the states for the construction of mitigation works and for flood studies. The day-to-day implementation of flood loss prevention and management policies in the State is undertaken by various state and local government authorities.

In Australia the scheme of flood loss prevention and management typically involves local councils, a State drainage or rural water supply authority, such as a Water Resources Department, or a Public Works Department (called the "Flood Authority") and the State Planning Authority responsible for approving town plans and planning schemes, such as a Department of Local Government or a Planning Department. The Flood Authority is responsible for undertaking and supervising flood studies, for the preparation of flood maps, and for the delineation of floodway, flood storage and flood fringe zones. The core of government flooding experience, expertise and technical advice resides with the Flood Authority. The local council is responsible for implementing flood loss prevention and management measures.

The Flood Authority also provides hydrologic and hydraulic advice. The Planning Authority is responsible for ensuring that flood-liable areas are appropriately zoned on planning instruments so that effective land use development controls can be exercised through town plans.

The common feature of the flood loss prevention and management practices of the different States are:

(1) Flood loss prevention and management responsibilities are clearly divided and allocated on an integrated basis between State and local authorities;
(2) Land use and development controls are recognized as a major and fundamentalmeans of preventing the growth of the existing flood risk and damage problem.

2. Co-ordinated flood management

A major administrative problem may be experienced at the local government level when local government boundaries do not coincide with catchment boundaries. This situation leads to a disjointed administration and management approach to existing and future flooding and drainage problems. The emphasis placed on flooding by each separate local government would be influenced by many factors, including technical capability to deal with complex flooding matters and limited sources of funding.

To overcome this problem mechanisms should be employed to ensure:

(1) Co-ordination on a catchment-wide basis to address the flooding problems;
(2) Adequate funding for flood mitigation activities.

The success of a co-ordinated approach to reduce flooding depends upon the government agencies, local government and local residents working together towards common objectives.

Efficient administration would be achieved if a leading flood authority/organization is appointed to act as co-ordinator on a basin-wide basis (see chapter II, sections A and I). The co-ordinator need not be the implementing authority but should posses the management and technical abilities to be able to implement flood loss prevention and management plans on a comprehensive basin-wide management basis and supervise any major works required.

The appointment of a leading flood authority/organization can be made by either selecting a government agency or forming a consultative committee representing relevant government bodies and community interests.

The desirable features for an efficient and effective co-ordination mechanism are:
(1) A small administration with a minimum of bureaucracy;
(2) An ability to recognize the valid interests and roles of government agencies, local government, community and special interest groups;
(3) The Capacity to set priorities objectively on a catchment-wide basis and resolve demarcation and jurisdictional disputes;
(4) A responsive and flexible approach to local concerns and changing community perceptions;
(5) Reserve powers to control unwise development.

3. Programme monitoring

In order to ensure that effective implementation of flood loss prevention measures are achieved it will be necessary to undertake periodic reviews of the programme. A very close co-ordination between individuals, government and institutions is required if existing flooding problems are to be resolved through sound management principles. It is also necessary to take account of new planning concepts and to resolve legal and administrative difficulties which arise in the practical application of flood loss prevention and management policies.

Most countries which have adopted non-structural measures as a basic component of flood loss prevention and management encounter difficulties in the policy formulation stage and following the plan implementation stage. For example, some of the issues which may arise after the designation of flood-liable areas include:
(1) Compensation for depressed values of property in flood designated areas;
(2) Requests for reduced rates and land taxes of flood-affected properties;
(3) Attitudes of financial and insurance institutions to flood-prone properties;
(4) Appropriate legislation to protect flood authorities against court actions for damages.

To resolve these issues committees with representation from public authorities having an involvement in flood loss prevention and management may be established. An important task undertaken by these committees would be the formulation of flood loss prevention and management guidelines which establish the responsibilities of government and authorities to enable efficient and uniform implementation of the programme. These guidelines specify, among other things, the manner of plan implementation, the nature of permissible development and conditions to be applied to that development.

The committee would also consider the necessary government action required in relation to special land rates and taxes, project finance, provision of flood insurance, assistance in raising or relocating flood-affected properties and acquisition of properties in floodways.

4. Public participation

Public involvement in the planning exercise is seen to be desirable for two reasons. First, it can be argued that the community, which in the final analysis provides the funds used for public works projects, is entitled to some participation in the decision as to how those funds should be expended on what is alleged to be in the public interest. Second, the complex nature of modern flood loss prevention projects inevitably means that they impinge upon public interests in a variety of ways not easily recognized by the planner. Planned feedback from these interests can provide valuable guidance to the planner and assist him in avoiding unexpected adverse sociological and environmental impacts.

In recent years, some water resources agencies in the United States have developed public involvement procedures in the decision-making process. Notable among these has been the United States Corps of Engineers, which has developed and tested an innovative approach to public involvement.

This approach set out to achieve the following ends:

(1) Allow the public to establish its own goals and priorities early in the study;
(2) Allow the public to clarify and define the problem;
(3) Permit public participation in the development and investigation of alternatives;
(4) Allow open public debate of conflicting views;
(5) Encourage two-way communication between the planner and the citizenry;
(6) Demonstrate that public comment had an effect on the proposed action;
(7) Involve the public from beginning to end of the project.

Regional experience

In Japan, public participation is a basic requirement of comprehensive flood loss prevention and management. This participation involves every phase of the formulation and implementation stages of the flood loss prevention plan. The Ministry of Construction is appointed as the flood authority/organization to co-ordinate the activities of local government bodies and the private sector, including the residents.

The approach adopted by the Ministry of Construction involves initial consultation with the River Council, an advisory group specifically set up to assist in formulating national policy for comprehensive flood loss prevention and management. This step is followed by the establishment of a River Basin Council to formulate a plan for a specific river basin. This council consists of the Regional Construction Bureau of the Ministry of Construction and appropriate experts in all aspects of planning. The experts are drawn from the prefectural and local governments whose administrative areas cover the basin. The residents are consulted and their support is enlisted at all stages of the plan development and implementation.

In Australia, the practice of involving public participation in the formulation of flood loss prevention management plans has been generally adopted. The formal standing of consultative committees takes the following form:

(1) Every consultative committee consists of representatives of the flood authority/organization or public authorities and persons appointed as representing relevant interests in the area;
(2) The functions of every consultative committee are to advise the flood authority/organization on matters arising in connection with the drainage, flood mitigation or river management proposals in the area and to report to the authority/organization on any matters relating to the drainage, flood mitigation and river management referred to it by the authority/organization.

In addition, legislation has been enacted which specifically requires the authority/organization to consult with other agencies responsible for soil conservation, fisheries and wildlife in regard to any such proposals. In practical terms this is achieved by inviting these agencies to be represented on the consultative committee.

In respect to specific investigations, the committee does not itself undertake investigations but is the focal point for consideration of the outcome of studies. In summary, the basic functions of each committee for a particular study area are:

(1) To expose to all interested groups the relevant issues of the study;
(2) To provide an effective means for input of local knowledge as well as the view of appropriate agencies;
(3) To provide a means for all interested groups to be informed as to the progress and results of the study;
(4) To consider and comment to the flood authority/organization on the conclusions and recommendations of the study;
(5) To make such other recommendations in relation to the study area as the committee considers appropriate.

Experience to date indicates that an effective process of consultation is essential during the course of studies and also up to the point of implementation of the preferred strategy by the various agencies involved. The advantage of consultation during the course of investigation is that relevant information on flooding characteristics is available at the time of development of alleviation strategies.

B. Source of funding

It is common practice in most countries for individuals and communities to seek public funds to alleviate their flood problems which result from occupation of flood-liable areas. Because Governments exercise a regulatory role, to a greater or lesser extent over the management of flood-liable lands, it is traditional that they provide funds for minimizing losses and disruption caused by flooding.

Government financial support can be provided in the preparation of flood information and the development and implementation of flood loss prevention and management programmes, assistance by way of flood forecasting and warning and the provision of emergency services during flood periods, and the provision of flood damage and relief assistance during and after floods.

This assistance is provided under a variety of mechanisms and usually involves one or more levels of government. The funding formulae adopted normally relate to the nature of the project, the financial circumstances of the local government and whether it concerns urban or rural flooding. As flood loss prevention and management programmes are being developed to provide greater emphasis on non-structural measures such as the application of zoning and development controls and preservation of the natural water storage capacity of basins, the economic burden of flood losses is being transferred from government to private individuals.

Lack of funding is usually the major obstacle in addressing the flooding and drainage problems and the implementation of flood loss prevention and management plans. Many of the existing problems which rely on the provision of structural measures for their solution could be overcome with the allocation of adequate funds.

It is clear that any acceleration of current flood loss prevention and management activities will require an increase in the provision of public funding at a time when there are increasing pressures for public funding in other priority areas. It is becoming more difficult for governments of the region to provide the necessary levels of funding to satisfy high priority flood loss prevention and management programmes, particularly when there is competition from other public requirements such as transport, health, education etc.

In some countries greater reliance is being placed on the "user pays" principle as a means of funding capital works, including flood loss prevention works. One approach to generating additional revenue is by levying special drainage rates and taxes on the recipients of flood loss prevention and management programmes. The ratepayers are not required to contribute the full cost of the programme and the tiers of government continue to make substantial grants. The main features of this system are:

(1) A levy is imposed on flood-affected properties;
(2) Grants are made by the different tiers of government;
(3) Flooding is addressed on a basin-wide basis;
(4) Collection of the levy ceases on completion of the project.

In an economy where land is subject to planning controls the re-zoning on land and its development for a higher use are the result of a government decision. As any increase in value is generated by the public sector, it may be reasonably argued that those profits should be realised by the public sector instead of occurring as windfall gains to private owners.

In the conversion of land from rural to urban, for example, the increase in the value of land flows directly from the decisions to re-zone the land, and from public investment. Any gains in the land are made at the expense of the ultimate purchasers and the payers of taxes and charges generally.

On the basis of economic efficiency and social equity it is reasonable that the community obtain the capital increment resulting from the permitted changes in land use. The capital increment is not a tax on private economic activity but simply a redistribution of gains to the public sector which generate the gains.

In fact, a capital increment levy could be applied to any ratable land which had increased in value by the coming into operation of any provision of a planning scheme, by the granting of development consent or by the completion of any public works which enhance the value of that land. The proceeds of this levy could be directed towards the cost of providing flood loss prevention measures on flood-liable land.

Regional experiences

The source of funding in all members is largely derived from grants or subsidies provided by the central Government. In some countries both provincial and local governments are required to contribute towards the cost of flood alleviation schemes. Both the central and state level of governments of the most members of the Typhoon Committee have become increasingly involved in providing local governments with financial assistance for the implementation of flood loss prevention and management measures to lessen their contingent liability resulting from flood disaster relief payments.

Plate 9. Cinema-goers contribute to flood loss prevention and management in the Philippines.

In Japan, a system is in force which requires developers to implement water retention and detention facilities on the parcel of land being developed at their own cost. This approach has been proved to be efficient and deserves consideration as an alternative to raising specific taxes or levies if the types of measures being proposed are an appropriate solution to the immediate flood problem.

In China, the principal avenue of financing flood loss prevention and management activities is through public funds provided by the central and local governments. However, individual river basin authorities are empowered to collect fees for the construction and maintenance of flood loss prevention works. The full operation and maintenance costs of existing works are derived from rates levied on the beneficiaries of flood protection schemes. In some cases royalties charged for the extraction of sands and gravels from river channels are used for flood loss prevention purposes.

Although other members are contemplating schemes to derive additional funds through special taxes, rates and/or levies for capital works and for operation and maintenance of flood loss prevention activities, most have not yet put these schemes into effect. In the Philippines, however, a special tax is leveed on cinema attendance and the funds derived are utilized for flood loss prevention and management.

Plate 10. Significant flood problems are being experienced in the low-lying areas of the rural districts of the New Territories in Hong Kong.

Part Two

GUIDELINES

Plate 11. Bangkok suffers signigicant flood damage about once every five years caused by overland flow and local drainage problems which are often prolonged by high water levels in the Chao Phraya River.

IV. GUIDELINES FOR FLOOD RISK ANALYSIS AND MAPPING

A. Introduction

Essential to the formulation and implementation of appropriate flood loss prevention and management strategies is the task of flood risk analysis and mapping.

The first stage of any comprehensive flood loss prevention and management exercise must be the delineation of zones subject to inundation by floods of different magnitudes and different frequency. Flood risk analysis and mapping identifies the nature and extent of the flood problem by actually assessing the flood hazard by the process of flood risk mapping.

For a more comprehensive treatment on the theory and application of the methods of flood hazard mapping the reader is referred to *Proceedings of the Expert Group Meeting on Improvement of Flood Loss Prevention Systems Based on Risk Analysis and Mapping* United Nations, ESCAP, Bangkok, Thailand, 1988.

B. Method

The approach to flood risk mapping can be grouped into two general categories namely:

(1) Those which determine flood run-off, or peak discharge in a river and then determine the area inundated under peak level conditions;
(2) Those which define the flood hazard directly from recorded or assumed inundated areas.

The first group is referred to as the hydrological and hydraulic approach. In this approach one of the following methods of determining peak flows may be used:

(1) Flood frequency analysis;
(2) The regional flood method;
(3) Flood formulae.

Flood frequency analysis uses records of past flood events on the given river to define the statistical probability of floods of different magnitudes (discharges) in the future. Thus, for example, one can define the discharges of floods likely to occur or to be exceeded by a larger one, say once in 20, 50 or 100 years. The method is considerably demanding on both data and expertise in computation, but the peak flows so defined are extremely useful as a basis for all computation of flood risk, long-term economic damages, comparison of alternative flood adjustments and for detailed programmes of floodplain management.

Where gauge records do not exist or where the length of record is too short to be useful, discharges may be estimated by rainfall-run-off models or by statistical comparisons with other river basins where records do exist. When the peak flood discharge has been determined by any one of the methods, the discharge must be routed through the river reach to determine the areas of inundation and to produce a flood hazard map.

The geometric configuration of the stream channel and adjacent overbank areas are obtained by ground or aerial survey. This information provides a "cross-section" of the floodplain. The measurements of culverts, bridges, flood control structures and other encroachments in the floodplain are included with this cross-section information. Hydraulic analysis is used to determine how much of the floodplain is required to pass a given flood discharge and the associated flood elevations.

Using these methods, flood boundary maps can be prepared for flooding of different magnitudes, for example, the 10, 20, 50 and 100 year floods. Combined together they produce a flood risk map which

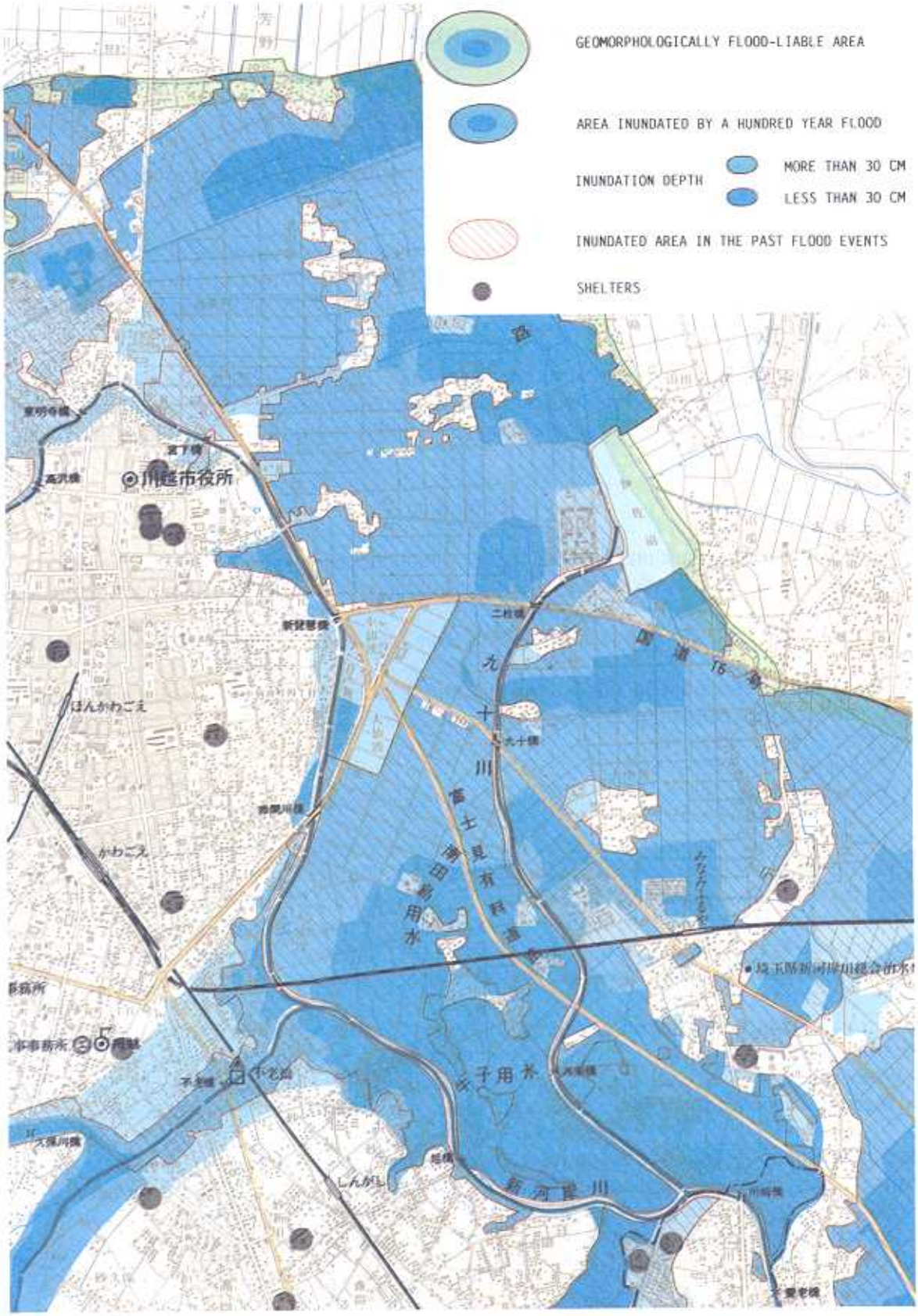


Figure 21. Flood risk map of the Shingashi River, Japan

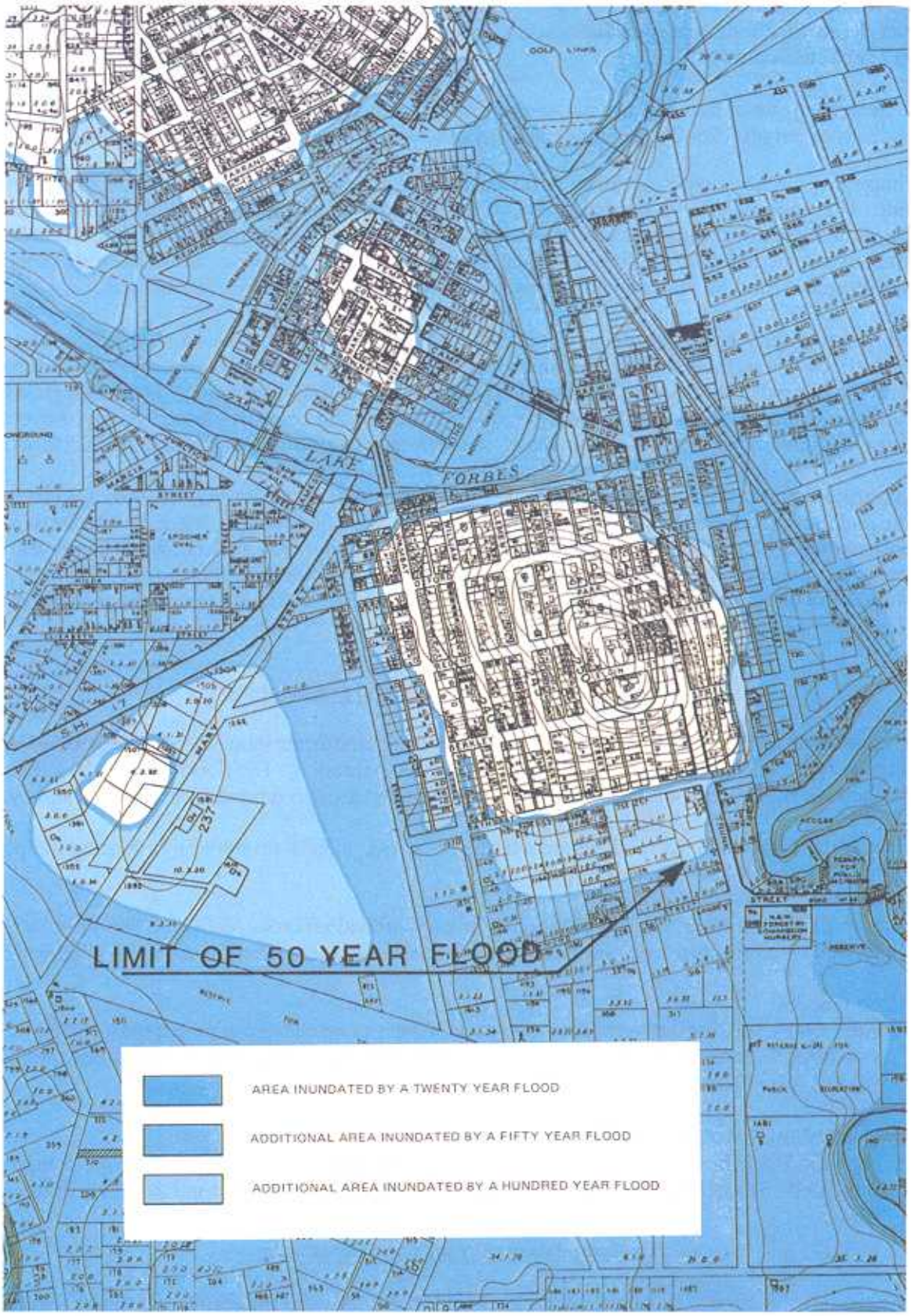


Figure 22. Flood inundation map of the Lachlan River at Forbes, New South Wales, Australia

delineates zones inundated by each of the above floods. Superimposed on topographic maps, they permit an estimate of depth of flooding at specific locations by subtracting ground elevation (shown by contour lines), from water surface elevation.

The second group of flood hazard mapping methods includes the methods based on the recorded flood (outline of former largest flood), geomorphological surveys, soil survey and intelligent guesswork.

Perhaps the simplest way to outline a flood hazard area is to equate it with the area actually inundated by a flood. The recorded flood outline defines the hazard area, but does not provide information on the magnitude of the flood nor about its recurrence interval. To be useful, the recorded flood should be a fairly large one, but it may not be possible to determine just how large it is in relation to other possible floods, as in many cases there will not be the streamflow records required for flood frequency analysis.

Aerial photographs or satellite imagery taken at the height of a flood can be most helpful in determining the flood outlines. Nevertheless, excellent maps can be compiled from past flood surveys, from information collected on the ground, although this approach is generally more time-consuming. However, ground survey has one major advantage, for not only can a record be made during or shortly after the flood event, but, if necessary the outlines of past floods can be mapped even a decade later using local information on former floods.

Geomorphological and soil mapping are generally useful where stream-flow records are lacking or are inadequate and they are especially suited to the study of large, wide floodplains where floodwaters may cover very extensive areas to varying depths and velocities. A study of topography and sediments can reveal much of the history of past floods in the valley and can indicate the patterns of flooding likely to occur in the future. A detailed survey can indicate the extent of the area submerged by large floods, the directions of flood currents and the incident of sediment deposits and erosion.

C. Delineation procedure of flood risk mapping

The geomorphological flood risk map is delineated from landforms indicated on the geomorphological map taking into consideration susceptibility of each landform to flooding. The flood risk map based on the past flood approach is delineated from the boundaries of the flooded areas obtained from the field survey.

For the hydrological and hydraulic approach, the flood risk map is prepared by adopting the procedure described in one of the following model types.

(1) One-dimensional flow model

The maximum water levels are obtained at each individual cross-section. The flood boundary is derived by connecting the maximum water levels at each cross-section as shown in figure 23.

(2) Pond model

The water levels and discharges are obtained for each pond and given time steps. The flood risk map is delineated on the topographical map by drawing the boundaries which encompass the maximum water levels as shown in figure 24.

(3) Two-dimensional flow model

The flood risk map can be delineated by using the rectangular meshes which are computed to be inundated. Smoothing the boundaries of the flood risk areas can be done as shown in figure 25.

D. Compilation of results and publication

The original objective of flood risk mapping is achieved only when the results are widely publicized and residents in the flood-liable land properly recognize the potential dangers of floods. Therefore, considerable effort must be made in publicizing the results.

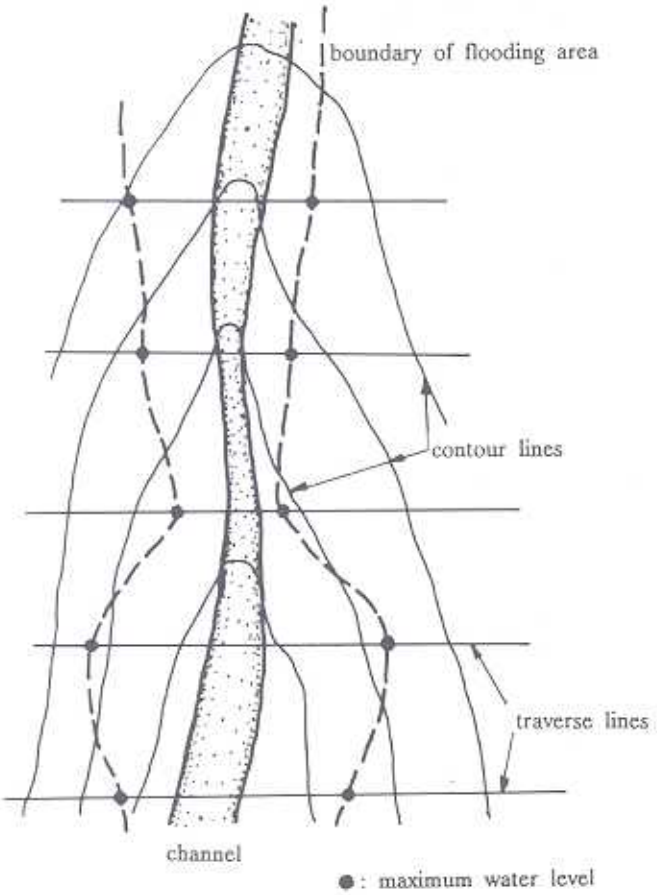


Figure 23. Delineation of flood risk map for one-dimensional flow model

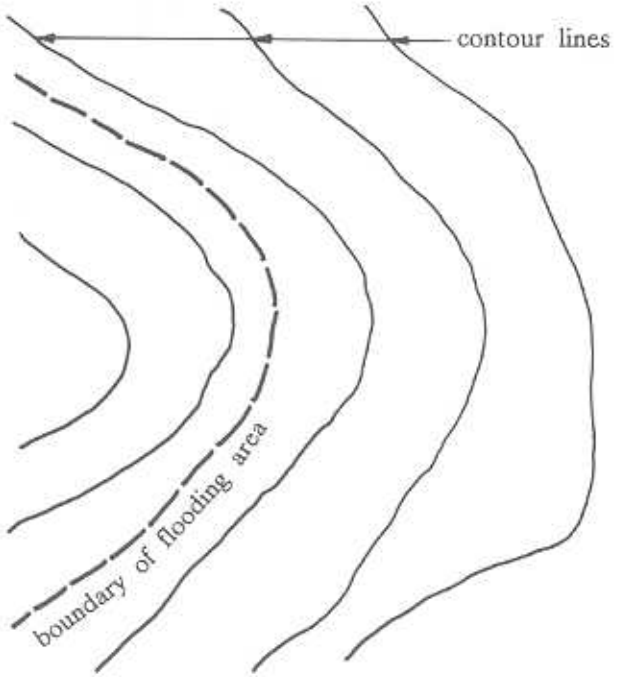


Figure 24. Delineation of flood risk map for pond model

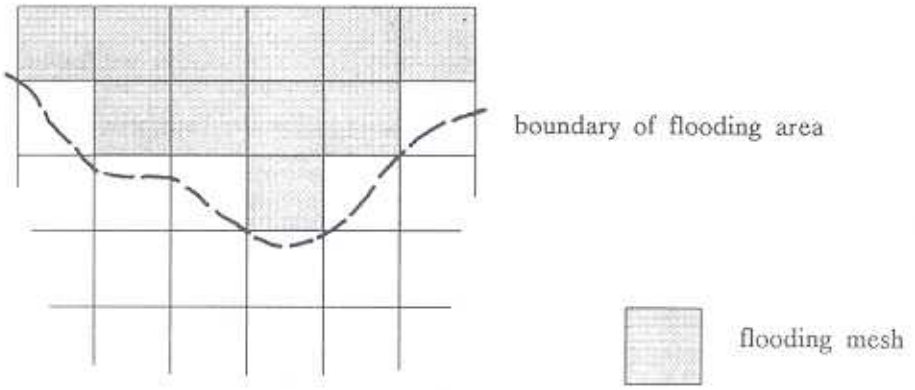


Figure 25. Delineation of flood risk map for a two-dimensional model

Some of the methods adopted for this purpose are described below, but other methods should also be devised and added;

(1) Report on survey of inundation areas

This report may contain all results of the survey and be plainly written, to make it easily understood by laymen. Inclusion of data obtained from residents with flood experience would also be valuable.

Large scale maps of probable inundation areas should be provided. Copies of the report should be provided to authorities concerned with disaster prevention activities.

(2) Publication of reports

To reach the widest audience in the flood-affected community, consideration should be given to the preparation and distribution of the survey results in pamphlet form. The proposed contents of such a pamphlet may be as follows:

(a) Text
- (i) Features of basin topography: With the aid of land condition maps or topographic classification maps of flood damage, the qualitative degree of flood danger in the basins is explained.
- (ii) Photographs showing flooding conditions during previous floods and descriptions from residents are printed to provide useful information to help residents in future flood planning.
- (iii) Commentary on the forecasting methods for inundation areas: Hydrologic studies used for calculating flood water levels are described.

(b) Drawings
- (i) Maps of probable inundation areas: Color coded areas are indicated on topographic maps of a large scale such as 1/25,000.
- (ii) Maps showing inundation water level: Estimated water levels should be indicated on cross-sections of the basin. In addition, photographs showing marks of estimated and actual water levels indicated on prominent buildings or electricity poles should be included.
- (iii) Longitudinal profiles of water level: Longitudinal profiles of flood water levels along the rivers are indicated to show the actual and estimated values.

(3) Floodwater level indicators

Floodwater level indicators may be posted on electricity poles or display boards at conspicuous points in flood-liable areas.

E. Practical considerations

The flood risk maps are intended to be planning guides to the approximate location of flood prone areas and floodways. Many problems occur when the maps are taken to be absolutely accurate and infallible. Several factors combine to reduce the accuracy of a map: the statistical nature of the discharge estimate, the spacing of cross sections for the backwater model, the contour interval of the map (usually 1 metre) and the scale of the map. Although typical vertical accuracy is plus or minus 0.5 metre and horizontal accuracy is 10 metres, assurecy of the latter will depend on actural terrain. For this reason, items such as the actual siting of individual buildings on a floodplain or the depth of fill, should be determined by detailed survey.

Another practical problem encountered with flood risk maps occurs if the various data bases are not contemporaneous. Quite often there are different years for the air photographs, contours, cadastre and calculations. A survey may be required to ensure that the flood limits accurately represent current conditions as affected by recent development.

F. Key issues

When a flood risk map is published, it influences affairs in many sectors of society. Some of the major issues are described below.

The intended effect of a flood risk map is to cause the revision of all planning maps for the area. Aside from development planning, it should also affect the planning of roads, services, parks and emergency services.

A flood risk map has several direct economic effects. On the negative side, it may lower property values in the flood-liable areas and may stop development intended (or already started) for the flood areas. Lending to be removed from floodways, and buildings on flood-liable land outside the floodways may have to be flood proofed.

On the positive side, the map prompts the construction of flood loss prevention structures along with better roads and better bridges, all of which combine to reduce future flood losses. It also alerts prospective owners of the potential flood problem.

There is a potential for legal disputes to arise after a flood risk map is published. A land owner in a flood-liable area may request compensation for a lowering of his property value from a government. A developer may try to dispute the flobd map in court in an effort to develop land in a floodway or to avoid implementing flood loss prevention measures.

A flood risk map can have disruptive social effects if it results in significantly lowered property values, or in a large number of people having to move out of a floodway.

A flood risk map can assist in achieving higher environmental quality in the urban areas of flood-liable communities, by indicating the location of open space land along the floodways to improve passage of flood flows. Often this land would be suitable for public recreation.

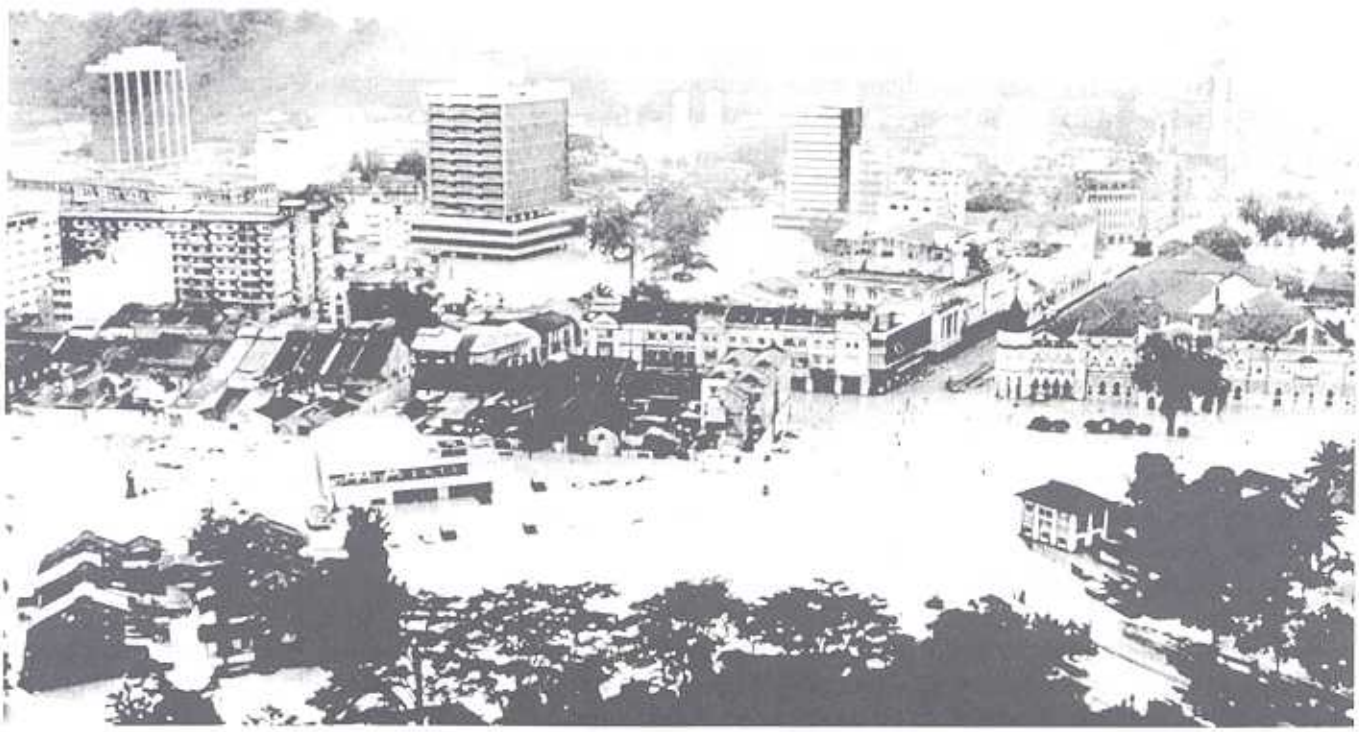


Plate 12. 1971 Flood - one of the most catastrophic floods in Kuala Lumpur, Malaysia.

V. GUIDELINES FOR FLOODPLAIN DEVELOPMENT AND MANAGEMENT

A. General

The purpose of this chapter is to present a methodology for the rational development of flood-liable areas. This methodology involves several basic steps:

(1) Partitioning the floodplain into different hazard categories;
(2) Establishing development categories of the types of potential development;
(3) Utilising established development guidelines to assess the compatibility of proposed development with the prevailing flood hazard.

It should be noted that preparation of any set of development guidelines is subjective in nature, and the proposed standards in this manual may be set too high or too low for any particular member. Accordingly, each member should give consideration to the establishment of suitable development guidelines for application in the country.

Further, it should be noted that existing development is specifically excluded from the assessment utilizing the following development guidelines.

B. Hydraulic categories of floodplains

A general characteristic of floodplains is that all areas are not exposed to the same degree of risk in terms of flood depth or high velocity floodwater. The risk of damage varies from high in the vicinity of the river channel to low on the margins of the flood plain.

The following terms are currently in use to describe flooding:

(1) Minor flooding: Causes inconvenience such as closing of minor roads and submergence of low level bridges. The lower limit of this class of flooding, on the reference gauge, is the initial flood level and the upper limit is determined by local conditions.
(2) Moderate flooding: Low-lying areas are flooded, requiring removal of stock or evacuation of some houses. Main traffic bridges may be covered. The range on the reference gauge is determined by local conditions.
(3) Major flooding: Extensive rural areas are flooded with properties and towns isolated, or appreciable urban areas are flooded. The threshold for this class of flooding is the upper limit of moderate flooding. Note that in most areas major flooding will have occurred well before the standard flood level is reached.

For planning purposes flood-liable areas are usually defined as the areas covered by the standard flood. It should be noted that lands outside the defined flood-liable area will not be free from flooding and this fact should be recognized when considering future development proposals.

There is widespread acceptance of the necessity to partition the floodplain into categories descriptive of the impact that development may have on floodwater and the impact floodwater may have on development. These categories are indicative of the flood hazard encountered at different locations on the floodplain and provide the basis for implementing development controls.

The floodplain may be partitioned into three hydraulic categories which are defined on the basis of hydraulic analysis. Flood hazard is a function of depth and velocity. The three adopted hydraulic categories of flood-liable land are **floodway, flood storage** and **flood fringe.**

The methods used to define the limits of the floodplain categories may differ, but the intention to define areas where development is subject to conditions to ensure safety and minimize flood damage is the same. Normally these categories are determined by detailed hydraulic analysis involving the use of a numerical model. However, several arbitrary approaches may be adopted such as flood frequency, encroachment limits or flood hazard.

Floodways are those areas where a significant volume of water flows during a flood. They are often aligned with obvious naturally defined channels. Floodways are areas which, if only partially blocked, would cause a significant redistribution of flood flows, which may in turn adversely affect other areas. They are often, but not necessarily, the areas with deeper flow or areas where the higher velocities occur. Where levees have been constructed on the flood plain, the floodway is the area between such levees for the conveyance of flood flows.

For practical purposes, floodways may be defined as those flood-liable areas:
(1) In which human life could be at risk from the passage of flood waters;
(2) Which are the main flow paths for floodwater once the river or stream has overflowed;
(3) In which developments may be adversely affected by the passage of floodwaters, other than by immersion.

Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwater during the passage of a flood. For example, if the capacity of flood storage area is substantially reduced by the construction of levees or by landfill, flood levels in nearby areas will rise and the peak discharge downstream may be increased. Substantial reduction in the capacity of a flood storage area can also cause a significant redistribution of flood flows, which may have the effect of altering the area otherwise defined as floodway. In general, all of the effect would be adverse, but in many cases they may not be significant. Much development in the flood storage area is only subject to damage by immersion.

Flood fringe areas are the remaining areas of land affected by flooding, after floodway and flood storage areas have been defined. By definition, the effect of development in flood fringe areas would not be significant.

The three adopted hydraulic categories of flood-liable land are represented schematically at figure 26.

Delineation of the floodplain categories may be achieved by careful modelling of the floodplain using mathematical or physical techniques. Boundaries of these categories are drawn to an appropriate scale on a cadastral map base which is termed a flood risk map. An example of an urban area flood map is presented at figures 21 and 22. The techniques uses for its preparation are presented in chapter IV, section C.

In rural areas, mapping is done to a large scale and shows the extent of major flooding, usually by drawing an envelope around the inundation patterns of historical floods. These maps serve to provide a general impression of the extent of the flood problem and its effects on transportation routes.

An alternative to the delineation of actual flood boundaries is the proclamation of an area on a map, which includes the area inundated by the designated flood. An area proclaimed in this way is usually protected by legislation.

Regional experience

In Australia delineation of the flood plain categories is usually based on a comprehensive hydraulic analysis which employs mathematical modelling techniques. These studies determine the variations of water depth and velocity across the flood plain for a range of flow conditions.

The hydraulic categorization of the flood plain usually defines three zones and these may be classified on the basis of hydraulic criteria determined by the product of velocity and depth. Any area which can be

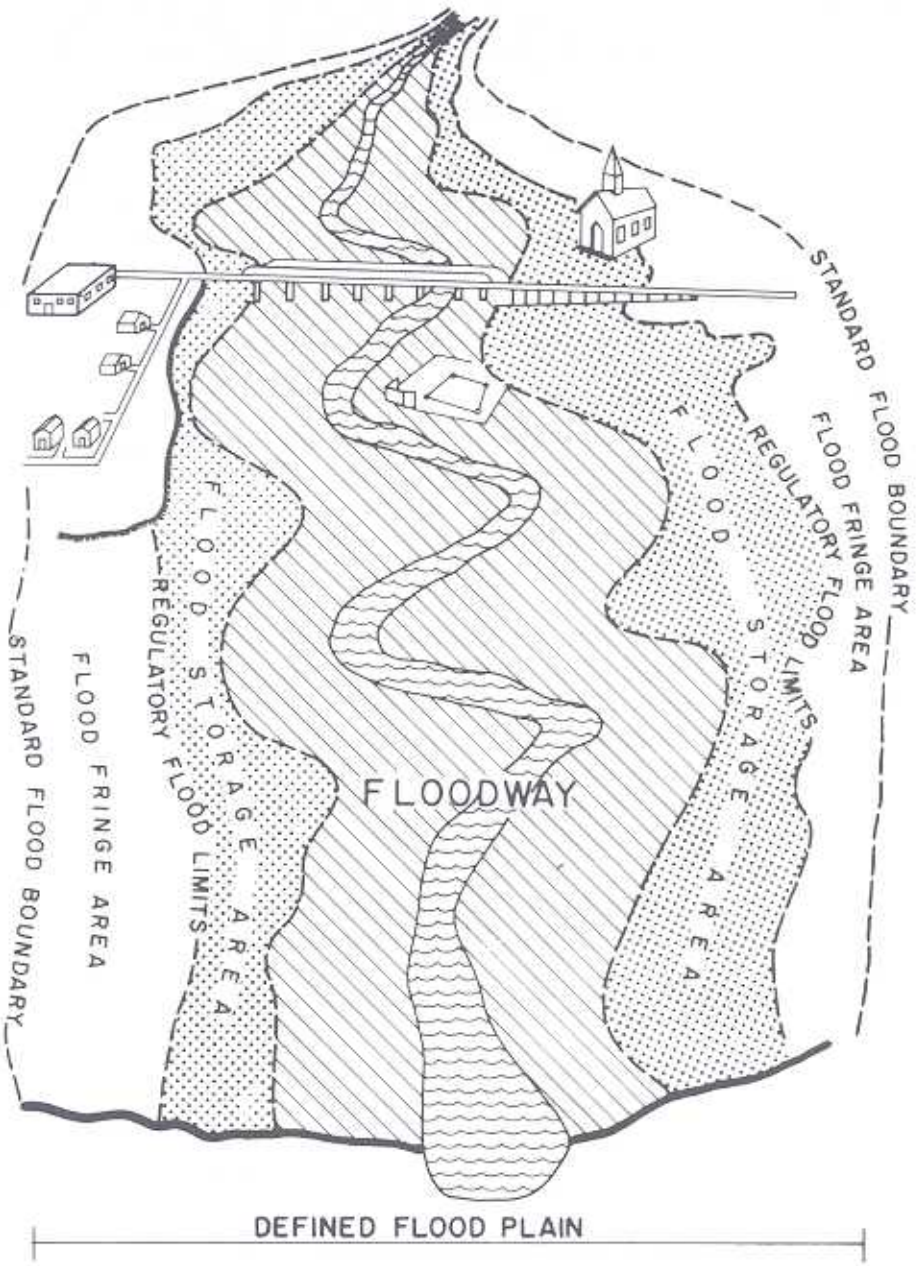


Figure 26. Schematic representation of hydraulic categories

identified as necessary for the conveyance of floodwater and where the product of velocity and depth exceeds one square metre per second is defined as being in the floodway. Areas experiencing velocity depth products of less than one square metre per second are classified as flood storage or flood fringe. Flood fringe areas are situated along the margin of the flood plain area and are zones of quiescent flow conditions.

As an alternative to defining the three hydraulic categories on the basis of the product of depth and velocity, the effects of encroachments into the areas of active flow which cause the adjacent upstream flood levels to rise by some specified amount can be adopted as the criterion to partition the flood plain. For example, if a reduction in the cross-section of active flow at a specified area on the flood plain which would cause an increase of say 0.1 metre or greater, then that area of active flow is classified as floodway. Areas outside that zone are classified as flood storage or flood fringe as the case may be.

C. Flood hazard categories

Flood hazard is a measure of the overall adverse effects of flooding. The term "flood hazard" incorporates the concepts of threat to life and limb, the difficulty and danger of evacuating people and their possessions during the flood, the potential of damage to the structure and contents of buildings, social disruption, loss of production, damage to public property etc.

The flood hazard varies across flood-liable areas because the type of properties, the depth and velocity of floodwaters, and the difficulty of evacuation all change from one location to another. Towards the edge of the flooded area, depths are generally shallow and water is slow moving. Consequently, such areas have a low degree of hazard. In contrast, floodwaters are generally deep and flow swiftly in the vicinity of the main river channel and other flow paths. These areas have a high degree of flood hazard.

It is important to note that the selection of the flood standard involves, among other things, consideration of hazard. The selection of an inappropriately low level for the flood standard may result in certain areas being classified as low hazard, when, in a larger flood, they may be subject to conditions associated with a high hazard area and experience deep and/or swiftly flowing floodwaters.

There may be the following three adopted hazard categories, **low, medium** and **high.** Under **low hazard** categories, should it be necessary, people and their possessions could be evacuated by trucks. Able-bodies adults would have little difficulty in wading and damage potential and the risk of death or injury would be low.

In **medium** hazard areas the damage potential and risk of death or injury would be moderate. Certain developments can be allowed provided appropriate measures, such as flood proofing and flood warning which render the development compatible with the known hazard are adopted. Development of a well-structured evacuation programme is required to ensure the safety of the affected residents.

In **high hazard** areas, floodwaters could cause structural damage to buildings and lightly constructed houses could be washed away. Evacuation by trucks or other means would be difficult or potentially dangerous. There exists the possibility of death and injury, and social disruption and financial losses could be high.

In determining the flood hazard applying to a particular area, the following prime factors need to be taken into account:

(1) Depth and velocity of flood waters;
(2) Effective evacuation time;
(3) Evacuation difficulties, including isolation of some areas as flood waters rise.

The process of defining flood hazard involves the preliminary determination of hazard category on hydraulic grounds. However, where hydraulic considerations are not dominant, provision is made for consideration of other significant factors such as warning time, flood awareness, rate of rise of floodwaters and evacuation problems. In these circumstances the preliminary categorization may be varied up or down as appropriate.

In the absence of hydraulic analyses, some authorities have tended to define floodways on the basis of flood hazard. This approach identifies different flood velocities, flood depths and combinations of these, which constitute a risk to personal safety. An example of this type of guideline is shown in figure 27. This figure will permit the appropriate hazard category to be specified in terms of both depth and velocity.

D. Land-use categories

The total amount of flood damage to developed properties depends upon the number and type of properties affected by floodwaters. This in turn depends upon development of flood-liable land, i.e. the location and extent of different land-use categories, such as residential, commercial, industrial etc.

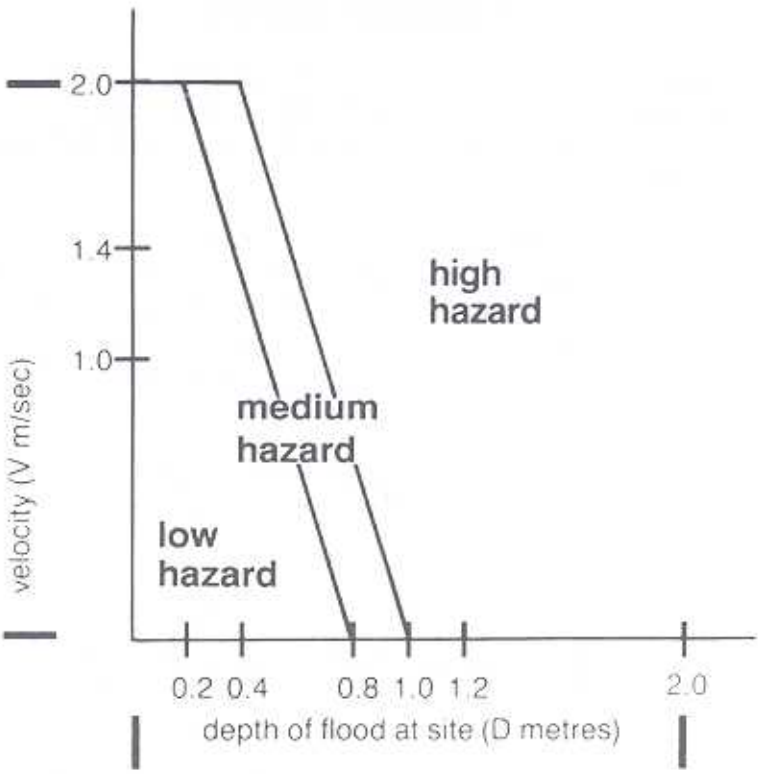


Figure 27. Example guideline for classification of flood hazard categories

To overcome flood hazards and protect development against flood damage, it is necessary to promote the division of flood-liable land into categories which safely support the development activities carried out in those areas. A detailed plan which illustrates the precise controls which will apply to a particular type of development in each land-use category should form part of the flood loss prevention and management plan.

Land-use categories may be classified into six general types for the purpose of exercising controls to achieve development compatible with the assessed hazard of flood-liable land. These categories are:

(1) Residential;
(2) Commercial;
(3) Industrial;
(4) Open space;
(5) Rural/non-urban;
(6) Special use.

Residential refers to those areas which are used essentially for dormitory purposes and are comprised of high and low density housing. These are a sensitive form of development as these buildings could be occupied in times of flood and their contents are highly susceptible to flood damage.

Commercial refers to shops, offices etc. This type of development could be subject to high flood damage but is not as hazardous as residential because it is not generally occupied at all times during floods.

Industrial refers to all industrial-related activities including factories, engineering workshops, garages, warehouses etc. Although flood damage in this category can be high, the flood hazard is low because of it is unusual for these premises to be occupied during floods.

Open space refers to areas specifically dedicated to outdoor recreation such as parks, golf courses etc. The small amount of development and type of use associated with this category is usually not significant in terms of flood hazard.

Rural/non-urban generally refers to areas used for farming activities. Building development associated with this category is assessed as low hazard.

Special use includes hospitals, schools, police and fire stations, telephone exchanges, electricity sub-stations, water and sewerage works etc. These buildings and services could be used for emergency purposes during a flood and their continued use after a flood may be important in reducing social disruption. Accordingly, these facilities wherever possible, should be located completely outside the flood hazard area so that such services remain operational during floods.

E. Development categories

The development of flood-liable land should not be arbitrary or unreasonably prevented, if the hazards of flooding can be avoided or reduced to an acceptable level. Following the categorizing of flood-liable land in terms of the likely degree of hazard to development, it is possible to specify the types of development permitted or prohibited within each hazard zone and the circumstances under which other types of development could take place.

To facilitate considerations of development proposals, the following development categories can be adopted:

(1) **Existing development;**
(2) **In-fill development;**
(3) **New development;**
(4) **Redevelopment;**
(5) **Major additions;**
(6) **Minor development and minor additions.**

Existing development refers to current development on flood-liable land. Buildings in this category are already at risk from flooding. Likely damage and social disruption in this category can only be reduced by flood mitigation works or measures (see chapter II, section F).

In-fill development refers to the development of vacant blocks of land that are generally surrounded by developed properties.

New development refers to development of a completely different nature to that associated with the former landuse, such as the urban sub-division of rural land. New developments typically require major extensions of existing urban services, such as roads, water supply, sewerage and power supplies.

Redevelopment refers to the re-building of an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require major extensions to urban services.

Major additions refer to major ground floor extensions of an existing building which is flood-affected.

Minor development and minor additions, as the terms imply, refer to the construction of small items such as fences, sheds and minor additions to existing buildings.

F. Development guidelines

The following section together with a set of associated tables has been prepared to assist foodplain managers in considering proposed developments in flood-liable urban areas.

The evaluation process for assessing the suitability of proposed developments and the development controls which may be imposed according to the prevailing hydraulic and hazard category of flood liable land has been summarised in the following set of tables. As shown in figure 28, there are a total of 9 tables (tables 4-12), one of which relates to each separate combination of hydraulic and hazard category.

In relation to the consideration of proposed developments on flood-liable land, the study should deal with the following aspects:

(1) The expected frequency of flooding of the site;
(2) The level, depth and velocity of floodwaters;
(3) The hydraulic and hazard category in which the site is located;
(4) The possible effect of floodwaters on existing or proposed development;
(5) Whether works or flood proofing could render the proposed development acceptable;
(6) Whether or not the development should proceed and, if so, under what conditions.

Development considerations indicated in tables 4-12 are as follows:

Consideration 1: Any portion of a building or structure subject to inundation should be built from flood compatible materials.

Consideration 2: A freeboard allowance above the standard flood should be required of habitable floors of new residences, including those associated with commercial and industrial development, and of normally occupied floors of special use developments. While this condition would generally apply to major residential extensions, the merits of the case should determine the need. The need to flood-proof commercial and industrial development should be determined on merit.

Consideration 3: The potential for damage to development or adverse impacts on flood behaviour may need to be considered in specific cases, which should be treated on their merits.

Consideration 4: The developer or property owner should demonstrate that any building or structure can withstand the force of flowing floodwaters, including debris and buoyancy forces as appropriate.

In approving proposed developments in the floodplain, the above considerations and the special considerations indicated in each table should be given.

It should be kept in mind that in general, it is neither practical nor appropriate to remove a major proportion of development from flood-liable areas. Much of the existing development, particularly in flood storage and flood fringe areas, is only subject to damage by immersion and is classified as low hazard. The least disruptive and most economical way to deal with the situation is to flood-proof the development by raising the habitable floor levels above flood level, either through the initiative of the owners or when re-development is proposed.

Development proposals in flood-liable locations which relate to in-fill development and major additions, i.e., the development of vacant land or the carrying out of additions or extensions to existing development, within localities that are substantially developed, require special consideration. If the proposal would worsen the impact of flooding on existing development or increase the flood hazard to any significant extent, it should be prevented.

Figure 28. Index to development guidelines

Table 4. Development guidelines for low hazard – flood fringe areas

land-use categories	development categories: in-fill development	new development	redevelopment	major additions	minor development and minor additions
residential, commercial, industrial, open space, rural/non-urban	considerations: 1 and 2				considerations: 1 and 3
special use	where necessary this form of development be sited on flood free land; on flood liable land, considerations: 1 and 2				

Note: Most developments are suitable, except for some special use developments which by their nature are sensitive to flooding or where the use is especially necessary in times of flooding.

Table 5. Development guidelines for low hazard – flood storage areas

land-use categories	development categories: in-fill development	new development	redevelopment	major additions	minor development and minor additions
residential, commercial, industrial	considerations: 1, 2 and SPECIAL			considerations: 1 and 2	considerations: 1 and 3
open space, rural/non-urban	considerations: 1, 2 and SPECIAL where warranted				
special use	where necessary this form of development should be sited on flood free land; on flood liable land, considerations: 1, 2 and SPECIAL				

Note: Most developments are compatible, except for some special use developments which by their nature are sensitive to flooding or where the use is especially necessary in times of flooding.

SPECIAL development considerations: If a new development in a flood storage area is likely to cause a significant reduction in storage capacity, the developer or property owner should be required to demonstrate to the consent authority that the proposal will not significantly increase flood levels. If the development would cause a significant increase in flood levels, the developer or property owner should provide adequate and acceptable compensating works to offset the increase.

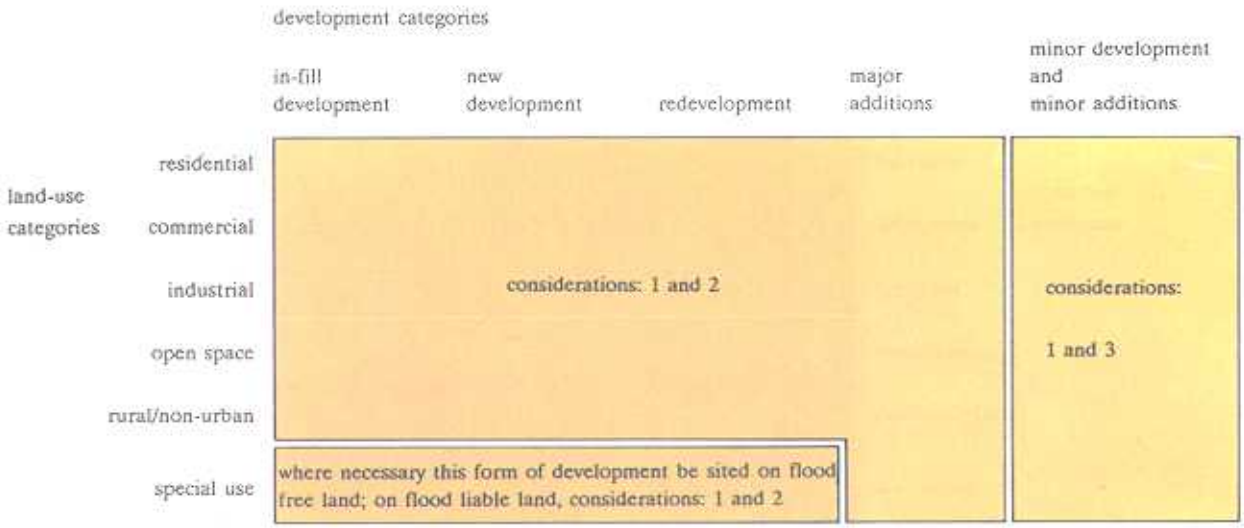
Table 6. Development guidelines for low hazard – floodway areas

land-use categories	development categories: in-fill development	new development	redevelopment	major additions	minor development and minor additions
residential, commercial, industrial	considerations: 1, 2, 4 and SPECIAL				considerations: 1 and 3
open space, rural/non-urban	considerations: 1, 2, 4 and SPECIAL where warranted				
special use	where necessary this form of development should be sited on flood free land; on flood liable land, considerations: 1, 2, 4 and SPECIAL				

Note: The impact of development on the floodway and therefore flood behaviour needs to be addressed.

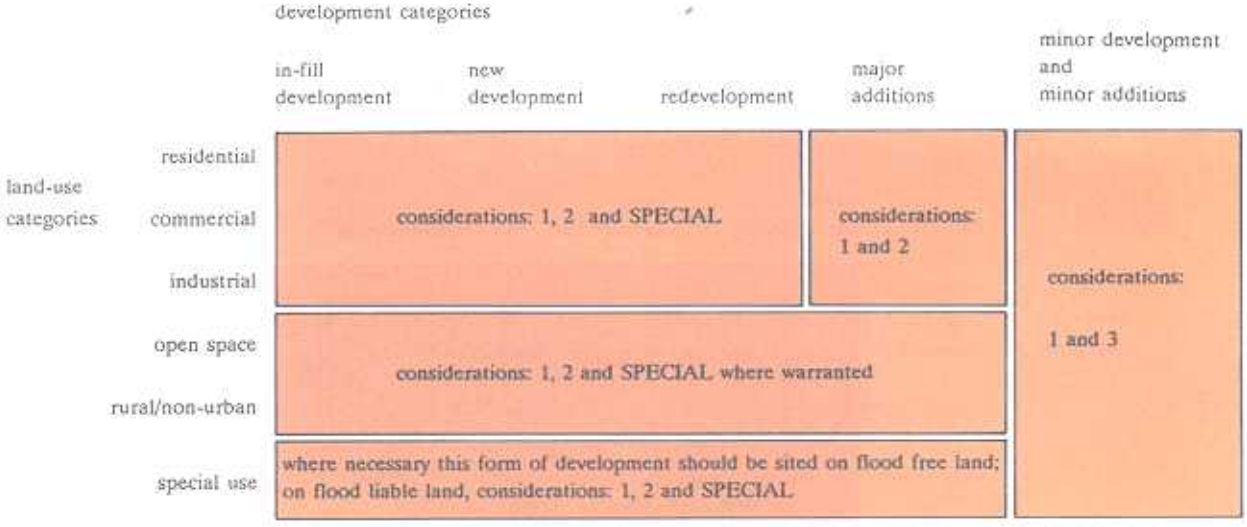
SPECIAL development considerations: In floodway areas, the property owner or developer should be required to satisfactorily demonstrate to the consent authority that the development will not increase the flood hazard or flood damage to other properties or adversely affect flood behaviour.

Table 7. Development guidelines for medium hazard – flood fringe areas



Note: Special use developments which by their nature are sensitive to flooding or where the use is especially necessary in times of flooding should not be located in this area.

Table 8. Development guidelines for medium hazard – flood storage areas



Note: Some new developments are compatible if areas of significant velocity are avoided. Special use developments which by their nature are sensitive to flooding or where the use is especially necessary in times of flooding should not be located in this area.

SPECIAL development considerations: If a new development in a flood storage area is likely to cause a significant reduction in storage capacity, the developer or property owner should be required to demonstrate to the consent authority that the proposal will not significantly increase flood levels. If the development would cause a significant increase in flood levels, the developer or property owner should provide adequate and acceptable compensating works to offset the increase.

Table 9. Development guidelines for medium hazard – floodway areas

land-use categories	development categories: in-fill development	new development	redevelopment	major additions	minor development and minor additions
residential, commercial, industrial	considerations: 1, 2, 4 and SPECIAL				considerations: 1 and 3
open space, rural/non-urban	considerations: 1, 2, 4 and SPECIAL where warranted				
special use	where necessary this form of development should be sited on flood free land; on flood liable land, considerations: 1, 2, 4 and SPECIAL				

Note: Although new development is not generally considered appropriate in this areas, it may be acceptable under special conditions. Such conditions should involve a detailed review of the impact of new development on flooding and of the potential hazard to new or existing development.

SPECIAL development considerations: In floodway areas, the property owner or developer should be required to demonstrate satisfactorily to the consent authority that the development will not increase the flood hazard or flood damage to other properties or adversely affect flood behaviour.

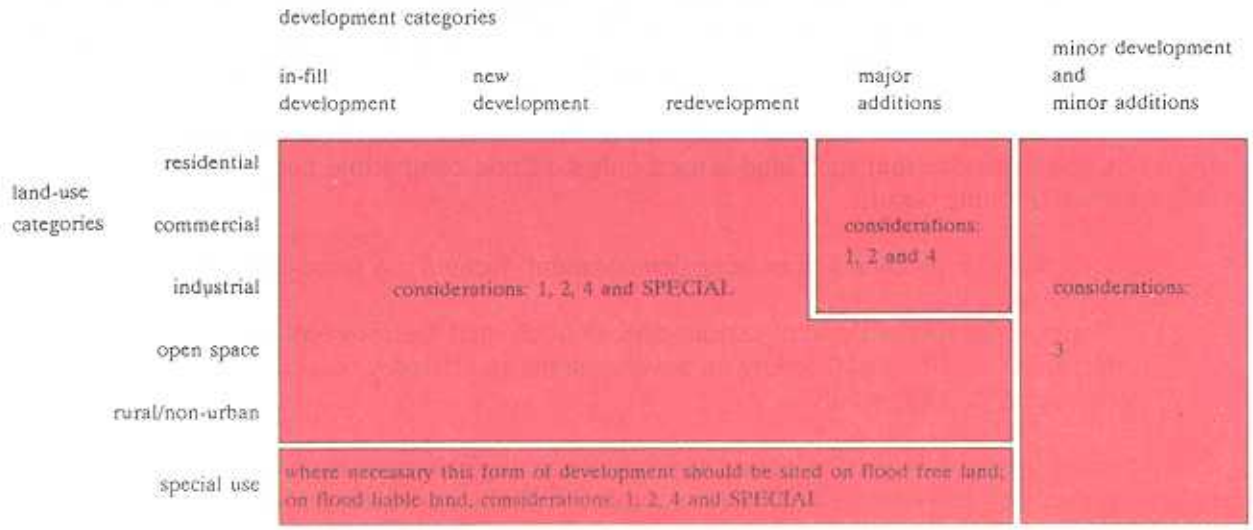
Table 10. Development guidelines for high hazard – flood fringe areas

land-use categories	development categories: in-fill development	new development	redevelopment	major additions	minor development and minor additions
residential, commercial, industrial	considerations: 1, 2, 4 and SPECIAL			considerations: 1, 2 and 4	considerations: 1 and 3
open space, rural/non-urban	considerations: 1, 2 and 4				
special use	where necessary this form of development should be sited on flood free land; on flood liable land, considerations: 1, 2, 4 and SPECIAL				

Note: It will not be necessary to check the effect of proposed developments on flood behaviour. Although new development is not generally considered appropriate in a high hazard area, it may be acceptable under special conditions. Such conditions should involve a detailed review of the potential hazard to the development itself.

SPECIAL development considerations: In high hazard areas, the developer or property owner should be required to demonstrate satisfactorily to the consent authority that permanent, fail-safe, maintenance-free measures are incorporated in the development, to ensure the timely, orderly and safe evacuation of people from that area, should a flood occur. In addition, it should be also demonstrated to the consent authority, that the displacement of these people will not significantly add to the overall cost and community disruption caused by the flood.

Table 11. Development guidelines for high hazard – flood storage area



Note: The impact of new development on flood storage and therefore on flood behaviour needs to be addressed. Although new development is not generally considered appropriate in a high hazard area, it may be acceptable under special conditions. Such conditions should involve a detailed review of the impact of the development on flooding and of the potential hazard to the development itself.

SPECIAL development considerations: In high hazard areas, the developer or property owner should be required to demonstrate satisfactorily to the consent authority that permanent, fail-safe, maintenance-free measures are incorporated in the development, to ensure the timely, orderly and safe evacuation of people from that area, should a flood occur. In addition, it should be also demonstrated to the consent authority, that the displacement of these people will not significantly add to the overall cost and community disruption caused by the flood. If a new development in a flood storage area is likely to cause a significant reduction in storage capacity, the developer or property owner should be required to demonstrate to the consent authority that the proposal will not significantly increase flood levels. If the development would cause a significant increase in flood levels, the developer or property owner should provide adequate and acceptable compensating works to offset the increase.

Table 12. Development guidelines for high hazard – floodway areas

Note: The impact of new development on flood storage and therefore on flood behaviour needs to be addressed. Although new development is not generally considered appropriate in a high hazard area, it may be acceptable under special conditions. Such conditions should involve a detailed review of the impact of new development on flooding and of the potential hazard to new or existing development.

SPECIAL development considerations: In high hazard areas, the developer or property owner should be required to demonstrate satisfactorily to the consent authority that permanent, fail-safe, maintenance-free measures are incorporated in the development, to ensure the timely, orderly and safe evacuation of people from that area, should a flood occur. In addition, it should be also demonstrated to the consent authority, that the displacement of these people will not significantly add to the overall cost and community disruption caused by the flood. In floodway areas, the property owner or developer should be required to satisfactorily demonstrate to the consent authority that the development will not increase the flood hazard or flood damage to other properties or adversely affect flood behaviour.

Generally, the approach to be adopted in implementing a flood policy should be to prevent the flood problem from becoming worse, through the application of appropriate building and development controls, and to reduce the extent and the severity of the problem, through mitigation works, flood proofing and where warranted, the removal of development from high hazard areas of the floodplain.

The policy should also be implemented in a way that does not seek to prevent new development on flood-liable lands, but to ensure that such land is used only for flood-compatible purposes which do not give rise to problems when flooding occurs.

Solutions for the problems of existing development located on flood-liable land generally involve the selection of measures that:

(1) Reduce the size of flood of various probabilities, and thereby reduce the damages they cause; or
(2) Reduce the effects of flooding on developments and thereby reduce damages without changing the nature of flooding itself.

The most systematic way of selecting appropriate management measures is through the comprehensive flood loss prevention and management study considered in chapter II, section G.

VI. GUIDELINES FOR FLOOD DISASTER PREVENTION AND PREPAREDNESS

A. Introduction

It can be asserted that if a nation prepares itself and takes all possible action for protection, flooding would cause much less loss of life and much less damage to property than if no precaution had been taken. Flood disaster could be prevented from occurring even if flood losses will not be eliminated totally.

The need for preparation and protection is of outstanding importance because some of the most populated areas of the world are affected by floods and potential for human disaster is enormous. Moreover, from the economic aspect, the damage caused to some countries by flooding may amount to a significant percentage of the gross national product. In developing countries the damage may be of such a scale as to cancel out much of the progress made in improving the standard of living of their peoples. For example, in 1988 Bangladesh experienced one of the worst floods in living memory. Of the county's 64 districts 53 were inundated to varying degrees and almost half of the total population of 110 million were directly affected by floods. In the rural areas, damage to crops, livestock, housing, roads, railways, water control works, social and other services was severe. Flooding reached unprecedented levels in Dhaka, which added to the difficulty of Government in coping with the national emergency. A joint United Nations/Government of Bangladesh team estimated the cost of a reconstruction and rehabilitation programme at $US1.1 billion.

Flood disaster prevention and preparedness consist of a wide range of measures, some long-term and others short-term, aimed at saving lives and limiting the amount of damage that might otherwise be caused. Prevention covers the long-term aspects and is concerned with policies and programmes to prevent or eliminate the occurrence of disasters. The corresponding measures are taken in such fields as physical and urban planning, public works and buildings. Short-term measures are designed to cover the action necessary during the approach of a possible flood disaster, during the existence of a disaster situation and in the ensuing period devoted to relief and rehabilitation. Flood disaster prevention and preparedness form a system of enormous scope which involves official and voluntary organizations at national, state and local levels, which involves the general public directly in a number of critical aspects and which includes activities on almost any time scale from a few minutes to several decades.

For more detailed explanations of the following items the reader is referred to *Guidelines for Disaster Prevention and Preparedness in Tropical Cyclone Areas,* prepared jointly by ESCAP, the World Meteorological Organization (WMO), the League of Red Cross Societies (LRCS), Geneva/Bangkok, 1977.

B. Flood disaster prevention

1. The role of flood disaster prevention in national planning

It would be grossly inadequate merely to plan and implement relief action to be applied after flood disasters have occurred. The actual and potential consequences of flood disasters are so serious that much greater emphasis should be given, nationally and internationally, to planning and prevention.

Priority should be placed on planning and prevention because of the dual phenomena of rapid urbanization and the high rates of population growth, particularly in the developing countries which have experienced frequent recurrence of large-scale flood disasters. The sheer magnitude of the human problem in flood-liable areas, especially the rapid expansion and concentrations of population in slums and squatter settlements, indicates that relief measures and post-disaster action alone are not sufficient.

To be successful flood disaster prevention planning must be based on a clear and forceful policy which is closely allied to economic, social and environmental policies. It should also receive the support of appropriate legislation. Basically legislation should be passed to enable governments (national, state and local) to enforce essential prevention measures. Flood disaster prevention requires considerable capital and human resources. In those member countries where such resources are still scarce, great weight should be given to policies and measures which will steer development away from high risk areas and diminish the vulnerability of new investments. For this reason, special use should be made of land-use control and building codes. However, due weight must also be given to the enactment of suitable legislation and the identification of flood hazard and risk to provide a suitable foundation for implementing these measures.

2. Legislation for flood disaster prevention

It is essential for each member to have legislation which firmly establishes responsibility for all necessary actions, whether of a long-term or short-term nature, which are related to flood disasters.

As suggested in chapter I, section C it should be prepared as part of the overall legislation rating to natural disasters which constitute a land hazard such as flooding, earthquake, landslip etc.

However, as some countries have found, it is a wise course to conduct a critical examination of flood disaster prevention legislation from time to time. Such a review can be expected to reveal any weaknesses that might exist. Among the questions to be considered are, apart from the adequacy of the legislation, whether responsibilities are clearly defined, whether participating organizations are properly co-ordinated, whether provision is made for overall direction and for forward planning, and whether it would be appropriate to integrate all relevant items of legislation into a comprehensive system covering all aspects of flood disaster prevention and preparedness (refer to chapter II, section E).

There are two basic types of legislation relating to flood disaster prevention and preparedness. They are legislation for long-term construction and reconstruction and for prevention purposes and legislation for preparedness, emergency and short-term recovery purposes. The former establishes the legal framework and directives for orderly and safe development or redevelopment in a fairly lengthy time scale; the latter facilitates immediate access to rescue and relief. This legislation should also clearly define the role and functions of the co-ordinating agency for long-term, pre- and post-disaster preparedness, planning and flood disaster relief and rehabilitation. Traditionally this role is assumed by the civil defense or state emergency services organizations.

3. Risk evaluation

Risk evaluation or, in other words, an assessment of a country's vulnerability to flooding, should be regarded as an essential element in the planning and implementation of measures which are designed to prevent or mitigate the disasters which floods may cause. Naturally, if a country is prone to flooding, action of various kinds should be taken in order to save lives and reduce damage even if detailed risk-evaluation studies have not been carried out. Such action is well worthwhile, and if it is based on a reliable stock-taking of past experience, it would probably be endorsed to a high degree by the results of any subsequent studies of flooding potential. However, while action should be taken which is thought to be necessary, this should be followed as soon as possible by a risk-evaluation study which offers the best means of ensuring that protective measures are comprehensive and economical.

The description and assessment of hazards should be regarded as an essential element of flood disaster prevention and mitigation. If sufficient data of acceptable quality are available, it may be feasible to estimate risks in quantitative terms for small areas, i.e., at local level. This procedure is called flood risk mapping. Such maps can play and essential role in economic and physical planning and in the equitable financing of insurance schemes. (See chapter IV: Guidelines for flood risk analysis and mapping.)

4. Land-use and zoning

Land-use control measures may be summarized under three main headings:

(1) Legal measures for the enforcement of zoning and other regulations for controlling function (type of activity) and density and pace of development;
(2) Taxation measures to steer development away from hazard areas;
(3) Government action to acquire land by compulsory purchase and to alter existing land use.

It is important to realize that land-use legislation and regulation control not only the type of development defined by hazard risk evaluation but also the rhythm or pace of development. A technical detail of considerable importance should be emphasized, namely that flood risk mapping is an essential input to land-use zoning in flood-liable areas. It should also be emphasized that land-use control should be supported by rigorous land-development policies and that land-use control for flood loss prevention constitutes one of the variables in the comprehensive framework of land-development policies and plans.

The rapid growth of urban areas in developing countries raises important problems with regard to flood disaster prevention. A consequence of this growth is that a number of paddy fields, ponds and swamps in the floodplains, which formerly served as natural reservoirs for floodwater are converted into impervious paved areas for residential, commercial and industrial buildings together with their associated facilities such as roads, shopping centres and car parks. It should be kept in mind therefore that increased urbanization in flood-liable areas must increase its vulnerability (see chapter V).

The pumping of ground water can become an additional factor increasing vulnerability in floodplains and low-lying coastal areas. If water is extracted to an excessive extent, subsidence may occur and the locality would experience a greater incidence of flooding. The increased flooding of Bangkok is an example of this phenomenon.

5. Building codes

Building codes should be regarded as an essential component of flood disaster prevention. Such codes, covering buildings and other structures, give specifications for design, construction, operation and maintenance, all related to the lifetime for which the building is required. Well-conceived building codes can have the effect of lessening property losses during floods and, even if damage is incurred, the buildings may not be seriously damaged and thus the toll of human suffering is less than it might be. In addition, buildings which are not severely damaged or destroyed can normally continue to perform the functions for which they were constructed, thereby facilitating their utilization in emergency conditions and contributing to a more rapid return to normal economic and social conditions following the abatement of flooding.

6. Flood control

Various structural measures are being employed in order to control an excess flow of water so that a flood may be prevented or, at least, its worst effects reduced. These devices include engineering works, embankments, detention reservoirs, river channel improvement and facilities for flood diversion etc. These measures have been fully described in chapter II, section F.1. It should be noted that structural measures tend to create a false sense of security in the population protected by the works. Although these works can provide complete protection against flood damage up to the level of the design flood, catastrophic failure may occur if the design level is exceeded. Therefore, special provision should be considered at the design stage to incorporate measures which will ensure that the effects of failure are minimized and that the associated damages and disruptions are made no worse than under the pre-protection situation.

C. Flood disaster preparedness

1. Flood disaster preparedness planning

Flood preparedness is seen as that action taken when flood conditions arise and impose the threat of a disaster. Preparedness encompasses a wide range of pre-emergency activities drawn from non-structural flood mitigation measures and include:

(a) Flood forecasting and warning;
(b) Evacuation and sheltering;
(c) Flood fighting.

These measures remain in force until some time after the flood conditions have passed because emergency action is required not only at the onset of flood conditions, but also during the flood and then in the aftermath.

Although these measures have been extensively described in chapter II, section F.2., some further explanatory details from the viewpoint of disaster preparedness are presented in the following paragraphs.

(a) Flood forecasting and warning

Basic to any programme for emergency action to prevent a flood disaster from occurring is an effective forecasting and warning system. The more accurate the forecast and the longer the warning time the better is the community able to react. Whether a flood disaster, especially loss of life, is prevented is directly related to the accuracy of the flood forecast. The flood forecasting and warning system should operate under three functional leadings: environmental monitoring, the preparation of the forecasts and warnings and finally dissemination of forecasts and warnings. These three functional areas are highly interdependent and must be fully co-ordinated. For example, the monitoring function must be based on the known requirements for forecasts and warnings to be used as a basis for making decisions in a flood emergency and giving instructions to the public. Furthermore, accurate forecasts and warnings would be useless if dissemination could not be assured to those who require them. In this connection operational communication facilities are of vital importance.

(b) Evacuation and sheltering

The most obvious way to prevent a flood disaster from occurring is to remove people and property from floodable areas. Evacuation is usually considered as a short-team measure taken just prior to or during a flood. However, evacuation needs and priorities should be established on the basis of flood intensity, potential damage, topography of the area and the degree of assessed flood hazard to existing buildings. A detailed study should be conducted of each flood-liable area to identify the number of people (and livestock) required to be evacuated under different levels of flooding.

It is necessary as part of the flood-preparedness planning to formulate detailed plans on evacuation so that people may be moved in good time, smoothly and efficiently. At the time when the warning service indicates the possible onset of flood conditions, one of the questions that will have to be considered by the authorities would be: which areas might have to be evacuated? The resulting decisions would be largely based on the forecasts of the areas likely to be flooded and anticipated depth of water and/or the likelihood of storm surge and coastal area to be affected.

When all these questions have been considered and conclusions reached, the organization for evacuation, already at full readiness, would be called into action. The effectiveness and operational efficiency of this organization can have a decisive influence on the success or failure of the whole system for flood disaster in conditions of actual emergency.

The evacuation of people has as its objective the saving of lives and is therefore one of the most crucial elements of flood disaster prevention and preparedness. In moving people, whether in large groups or in small numbers, numerous problems are bound to arise. Evacuation is therefore a facet of flood preparedness which calls for the most careful and exhaustive planning. Planning of a high standard will go far to ensure that in a flood situation the management of evacuation can proceed smoothly and, as unforeseen contingencies arise, they are handled knowledgeably and firmly, thus preventing such contingencies from reducing the whole operation to chaos.

An important element of the evacuation plan is meeting the appropriate transport and communication needs. The type of transportation will depend upon the depth and velocity of floodwater and may include large 4-wheel-drive trucks or motorised flood boats. Efficient communication facilities would include 2-way radios.

Another important problem revolves around the difficulties associated with sheltering persons whose dwellings are affected by floodwater. Flood shelters for evacuated residents assume an important role in flood preparedness. It requires that the need for adequate flood shelters be taken into account and that such shelters be located in suitable buildings, such as schools, on flood-free ground. The shelter management plan should include arrangements for feeding and medical care of the evacuees.

(c) Flood fighting

Although flood fighting has traditionally been thought of as a local, self-help responsibility, it has long been realized that when a flood constitutes a threat to a number of neighbouring communities, co-ordinated action under unified control is much more effective than independent action by each community.

Flood fighting should aim to prevent damage or to minimize its extent, to protect life, limb and property and, in general, to ensure the safety of the population. Successful flood fighting and the attainment of the above goals depend upon good organization, thorough advance planning, well-trained personnel and the effective co-ordination at national, state and local levels.

2. Public awareness

The public perception of risks and the efficiency of various options that are available will ultimately determine the success of any flood disaster prevention or preparedness programme. Thus, it is necessary to ensure that all people, not only those with actual experience, have an awareness of the dangers posed by floods. Since memories are apt to fade the awareness must be kept alive and up to date among those whose experience of flooding is not very recent.

Public information and education about flood risk, flood hazard and ways of coping with flooding must therefore be an essential component of flood preparedness. If the public is kept fully and constantly informed of potential flood problems, the organization and operation of a flood preparedness system should have every chance of functioning smoothly and efficiently. In this context education is the natural complement to the provision of information. An education programme, designed at appropriate levels for children and adults, should impart basic knowledge about the nature of flooding and the risks involved and about warning services and protective measures. Education programmes should be supplemented by campaigns through the press, radio and television. These campaigns should be made more intensive as a flood season approaches and posters and pamphlets in local languages should be displayed and distributed.

An important consideration is that public education and the provision of information should be designed so as to meet local requirements as closely as practicable. In this way the flood preparedness organization would have the best prospects of being effective at important times. However, it should not be assumed that educating the public and providing information are of themselves sufficient to ensure that

individuals will respond to warnings on the basis of their knowledge. Human response to threats of flooding reveals a very diverse pattern. Warning must therefore be supplemented as necessary by clear instructions telling the public what it should do. Then, provided the public is educated and well informed about the dangers resulting from flooding, there can be reasonable confidence that warnings and the accompanying instructions will receive a proper response. The objective is to create a partnership between government and people so that flood disaster preparedness is recognized as a joint responsibility.

3. Emergency operations and flood disaster relief action

There are a number of features which help to guide the action that must be taken in the emergency phase when preparedness plans are brought into action. These features may be summarized as follows:

(a) People are affected through death, injury or illness.

There is a considerable variation in the effects on survivors but most will suffer from grief and shock. Some may be reported missing. A whole range of personal losses may occur in regard to homes, household goods, clothing, land, employment, income, livestock, crops etc.

(b) Communities are affected.

They may suffer extensively from destruction or severe damage to public buildings such as schools and hospitals and also to factories etc. Damage to roads, bridges, railways, harbours and airports may seriously disrupt transportation. Damage to public utilities may cause severe dislocation of services and communication.

(c) Systems and services are affected.

Disruption of health and welfare services, the closing of schools and religious centres and breakdown in commerce and industry leading to loss of revenue can have large-scale effects on the complex organization which supports a community's activities.

4. Test exercises in flood disaster preparedness

It is essential that the planning and organization of flood disaster preparedness be kept under constant review. This task can be undertaken by regular meetings, at various levels, of responsible officials of the numerous agencies involved in flood disaster preparedness and also by holding exercises in order to test the readiness and efficiency of the organization as a whole or of selected portions of it. Meetings would serve the purpose of putting under close scrutiny the objectives and principles governing the planning and organization of flood disaster preparedness and would also help to ensure that the lessons brought out in exercises are properly learned and applied. Exercises serve the purpose of putting the organization under trial in a way that is both practical and as realistic as possible.

D. Flood disaster rehabilitation

1. Rehabilitation and resettlement

It is not uncommon for Governments to give funds to rehabilitate community services or individuals affected by flood disasters. In the case of flood disasters, the public at large may contribute funds or international aid may be forthcoming to help flood victims. In addition to money, material goods and medical services and supplies may be contributed.

The basic purpose of rehabilitation is to provide services and facilities which will restore to communities, families and individuals their former living standards while at the same time encouraging any necessary adjustments to drastic changes caused by the flood disaster that has occurred. If, as a result of the material damage suffered in a locality, a large-scale programme of rehabilitation is seen to be required, the aim might be to improve rather than merely restore the accustomed living standards and social conditions.

Morale is one of the most important factors in rehabilitation. This factor should be considered in relation to the community itself and also in relation to families and individuals. It is possible for people to emerge from a flood disaster in a hopeless and apathetic state of mind. If this attitude is allowed to persist, people affected will become over-dependent on welfare services and be a permanent burden on the nation. A spirit of high morale can be fostered by helping people to realize that the efforts made on their behalf are prompted by a regard for their value to the country and by the desire to promote feelings of self-reliance and a determination to participate in the work and social life of a community growing in prosperity.

Relocation is a potentially important component of a rehabilitation programme following a flood disaster. In the period immediately following the emergency phase of flooding, displaced populations need to be resettled as part of the process of rehabilitation. Relocation may occur either in the area or region of origin or, as often happens, in temporary sites pending further planning and reconstruction decisions. The authorities should be keenly aware of the fact that "temporary" settlements very soon become permanent. Therefore, all preparedness plans should identify suitable land on which to relocate flood-stricken and homeless populations in the short term and foresee the possible results of such relocation in the medium to long term. The problems of so called "temporary" relocation are extremely complex and the soundest approach in general terms may be, as part of preparedness plans, to earmark adequate land for long-term rehabilitation and reconstruction. Resettlement involves not only questions of location but also such aspects as availability of employment, transport and services. It is evident that the formulation of flood disaster preparedness (and rehabilitation) plans calls for close inter-ministerial and inter-departmental co-ordination at all levels of government. Ministries responsible for housing and urban development,public works, regional and physical planning etc., are important contributors to the state of flood disaster preparedness.

2. Assessment of damage

The effectiveness of action taken during an emergency and its immediate aftermath owes much to the preparation of situation reports based on damage surveys conducted during the occurrence of a flood disaster. These surveys, carried out in the unsettled conditions of the emergency, are necessarily somewhat hurried affairs. The aim is to provide a more or less instant picture of the situation and, since a number of surveys will take place in fairly rapid succession, the lack of completeness of any one survey is not of major importance so long as the main features of the flood disaster are seen and reported.

These surveys, therefore, serve an extremely valuable purpose. However, after a flood disaster, when conditions are more settled, it is essential that a review should be undertaken of all that is involved in the programme of flood disaster prevention and preparedness. Changes, improvements and extensions can then be made on the basis of the lessons to be learned. Therefore, soon after the emergency has ended, a comprehensive programme should be set up for the collection of data relating to deaths, injuries and damage which have resulted in various ways from the flood disaster.

A survey of damage should be carried out after each significant flood even if the country concerned has already assembled such information over many years. Where this has been done there will still remain some uncertainties or, at best, provisional estimates which might be improved by additional data.

The leading flood organization should be given the authority and resources for co-ordinating the post-disaster collection of flood-loss data. It should be given the task of evaluating flood damage at the national level so that informed estimates can be made and the worth of flood disaster prevention and preparedness measures properly evaluated.

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