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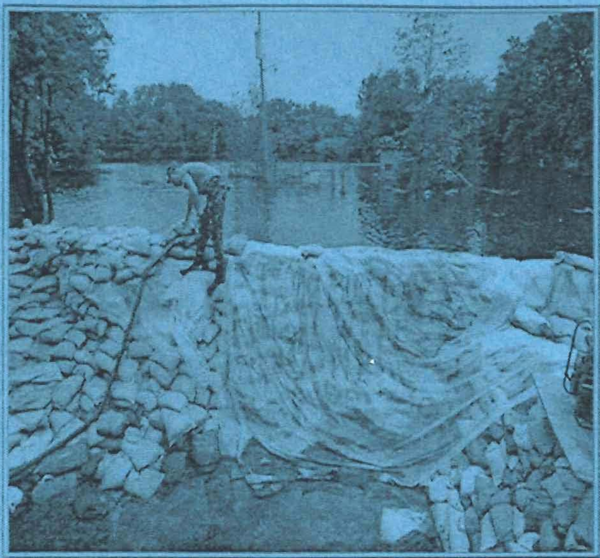

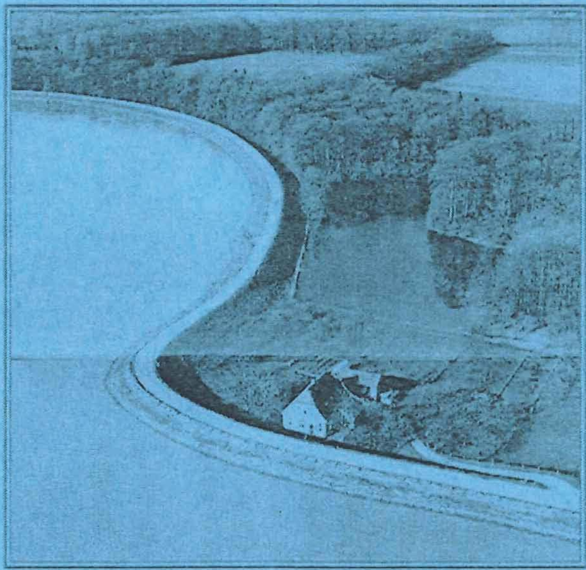

Coping with Floods - A Comparative Analysis of Strategies used in Vietnam (Red & Mekong Rivers), China (Yellow River), and USA (Mississippi River)

J. Wainaina Mburu

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May 2001

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INTERNATIONAL INSTITUTE FOR INFRASTRUCTURAL, HYDRAULIC AND ENVIRONMENTAL ENGINEERING (IHE DELFT)

Coping with Floods

A Comparative Analysis of Strategies used in Vietnam (Red & Mekong River), China (Yellow River), and USA (Mississippi River)

By

J. Wainaina Mburu

An M.Sc. Thesis submitted to the Department of Hydraulic Engineering, International institute for Infrastructural, Hydraulic and Environmental Engineering (IHE Delft) in fulfillment of the requirement for the Degree of Master of Science in Hydraulic Engineering

May 2001

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ABSTRACT

Throughout history, rivers have provided people with ideal settings for development, which includes fertile farmland, water supply, convenient waterway for transportation and commerce, waste disposal and energy generation, which are essential for the expansion of human civilisation. Ironically, rivers often flood their banks, threatening the safety of the societies they support and causing, according to statistics, about one third of all deaths, one third of all injuries and one third of all damage from natural disasters.

So how have societies coped with river floods in the past? What are the strategies and measures used and what are the historical, cultural, social, technical, managerial, economic and environmental justifications? What lessons can be learnt from their experience?

To investigate this, 3 cases – Vietnam (Red River & Mekong River), China (Yellow River) and USA (Mississippi River) – with a long history of floods and whose economies can respectively be categorised as developing, newly industrialised and developed, were studied and a comparative analysis made. With topography comparable to the Netherlands, which is renowned for its success in coping with floods, the cases also offered an opportunity to see how population density and political situation may affect the strategies and measures adopted.

The results of the study showed that living-with-flood, non-structural, and structural strategies are all used to cope with floods. The non-structural measures adopted by the 3 cases are essentially similar but differ substantially in content. Vietnam (Mekong) and China (Flood Storage Detention Areas) utilise the living-with-flood strategy more than USA, which has a strong preference for the structural strategy. In China, greater emphasis is laid on non-structural and structural strategies compared to the living-with-flood. This is best described by their catch-phrase "Retain water in the upper reaches, Release it in the lower reaches and Detain it along the banks of the river".

History, culture, political state, state of the economy, environment, and the way the society views flood control and water management were found to affect the strategies and measures adopted to cope with floods. The more the people appreciate the benefits and cultural values of the river and the land, the more likely they are to apply non-structural strategies and measures. When viewed mainly as key to economic development, prosperity and quality of life, there is a stronger emphasis on structural strategies and measures.

There were 4 phases observed in the development of strategies and measures to cope with floods: a formation phase, growth phase, completion phase and perfection phase. These are respectively characterised by a predominance of the living-with-flood strategy; a combination of simple non-structural and structural strategies; a predominance of structural strategy; and a balanced combination of structural, non-structural and living-with-flood strategies. The phase of a particular society is a direct function of the level, strength and state of its civilisation. A comparative analysis of more case studies was recommended to investigate whether the above 4-phase-development model is also applicable to them.

The study concludes that the Netherlands, as well as Kenya, can learn from the above case studies. One of the lessons learnt is that though flood dangers and impacts can be mitigated or alleviated by decreasing the probability of a flood value to be as small as economics and policy of coping with floods can justify, floods cannot be eliminated or avoided completely, as this probability can never be zero. However, by carefully studying each particular flood situation and focussing more on the Perfection phase, where the most suitable combination of measures from the 3 strategies are applied, we can continually improve the way we cope with floods.

The findings, interpretations and conclusions expressed in this thesis do not neither necessarily reflect the views of the International Institute for Infrastructural, Hydraulic and Environmental Engineering (IHE Delft), the individual members of the examination committee nor their employers.

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To my loving mother, my beloved wife, my loving children, family and friends: I thank you all for your love, prayers, patience and encouragement.

None of the above would have been possible at all without the Almighty and Divine Hand of Jehovah God, the One and Only Creator and Eternal True Parent of Humankind. To Him Be All the Glory and Honour Forever.

Dedication

This thesis is dedicated to my loving mother, Wambui; my beloved wife, Wanjiru, and our lovely children, Wambui, Mburu and Mumbi.

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List of Abbreviations and Acronyms

AD	After Common Era
ASFPM	Association of State Floodplain Managers
BC	Before Common Era
CAP	Community Assistance Program
CCFSC	Central Committee for Flood and Storm Control
CFDPC	Central Flood and Drought Protection Command
CRS	Community Rating System
DDMFC	Department of Dike Management and Flood Control
DDSMS	Department of Development Support and Management Services
DHA	Department of Humanitarian Affairs
DMU	Disaster Management Unit
FEMA	Federal Emergency Management Agency
FIA	Federal Insurance Administration
FMA	Flood Mitigation Assistance program
FSDA	Flood Storage and Detention Area
IAHS	International Association of Hydrological Sciences
IHE	International Institute for Infrastructural, Hydraulic and Environmental Engineering
MARD	Ministry of Agriculture and Rural Development
MD	Mitigation Directorate
MR&T	Mississippi River and Tributaries Project
MRC	Mississippi River Commission
NFIP	National Flood Insurance Program
NFIRA	National Flood Insurance Reform Act
NFPC	National Flood Proofing Committee
NWS	National Weather Service
SBA	Small Business Administration
TVA	Tennessee Valley Authority
UNDP	United Nations Development Programme
USA	United States of America
USGS	United States Geological Survey
YRCC	Yellow River Conservancy Commission

List of Symbols

cm	Centimetre
Dfl.	Dutch Guilders (1 US \$ = 2.2 Dfl.)
ha	Hectare
Kg	kilogram
km	kilometre
km^2	square kilometre
m	meter
m^2	square metre
m^3/s	cubic metre per second
m^3	cubic metre
US\$	United States Dollar
VND	Vietnamese Dong (1.0 US\$ = 14,000 VND)

1 INTRODUCTION

1.1 Definition of flood

A flood is generally defined as a body of water which rises to overflow land that is not normally submerged (Ward, 1978). A river flood, which is the focus of this study, may be defined as a discharge that exceeds the channel capacity and then proceeds to inundate the adjacent flood plain (Smith, 1979).

1.2 Definition of the term 'Coping with floods'

'Coping with floods' is defined as all those measures, with necessary policies and strategies of implementation, which a society might apply to alleviate the consequences of flood events (Rossi, 1994). It may also be conceived more or less as a synonym to the commonly used terms such as 'flood control', 'flood mitigation', 'flood alleviation' and 'flood defence'.

1.3 A Historical perspective of floods

Throughout history, rivers have provided people with ideal settings for development, which includes fertile farmland, water supply, convenient waterway for transportation and commerce, waste disposal and energy generation, which are essential for the expansion of human civilisation. Ironically, rivers often flood their banks, threatening the safety of the societies they support so well.

Floods and droughts and other such hazards have always been with us. Indeed, flooding appears to be part of the dynamic nature of healthy rivers and ecosystems. The intermittent war between humankind and floods has been going on for thousands of years, and although humans have gained some ground, this has not been without serious and sometimes catastrophic consequences. Experiences from the distant past show clearly that flood dangers and impacts can be mitigated or alleviated but they can't be eliminated or avoided completely. This means that the probability of a flood value can be decreased to be as small as economics or policy of coping with floods can justify, but that this probability can never be zero (Rossi, 1994).

Water has the power to be extremely destructive. Statistics show for instance that between 1963 and 1992 floods caused about one third of all deaths, one third of all injuries and one third of all damage from natural disasters (Figure 1.1). It is therefore imperative for humankind to find ways and means to minimise the damages (Leavesley, 1997).

In the past, the visibly reassuring approach to flood management has been to build tangible structures like dams and their reservoirs, retaining basins, channels, levees, and dikes, among others. All these structures have indeed helped civilisations to manage and utilise the rivers around them, depending on the level, strength and state of development but along with their benefits, these structures have many costs that are often not taken into account.

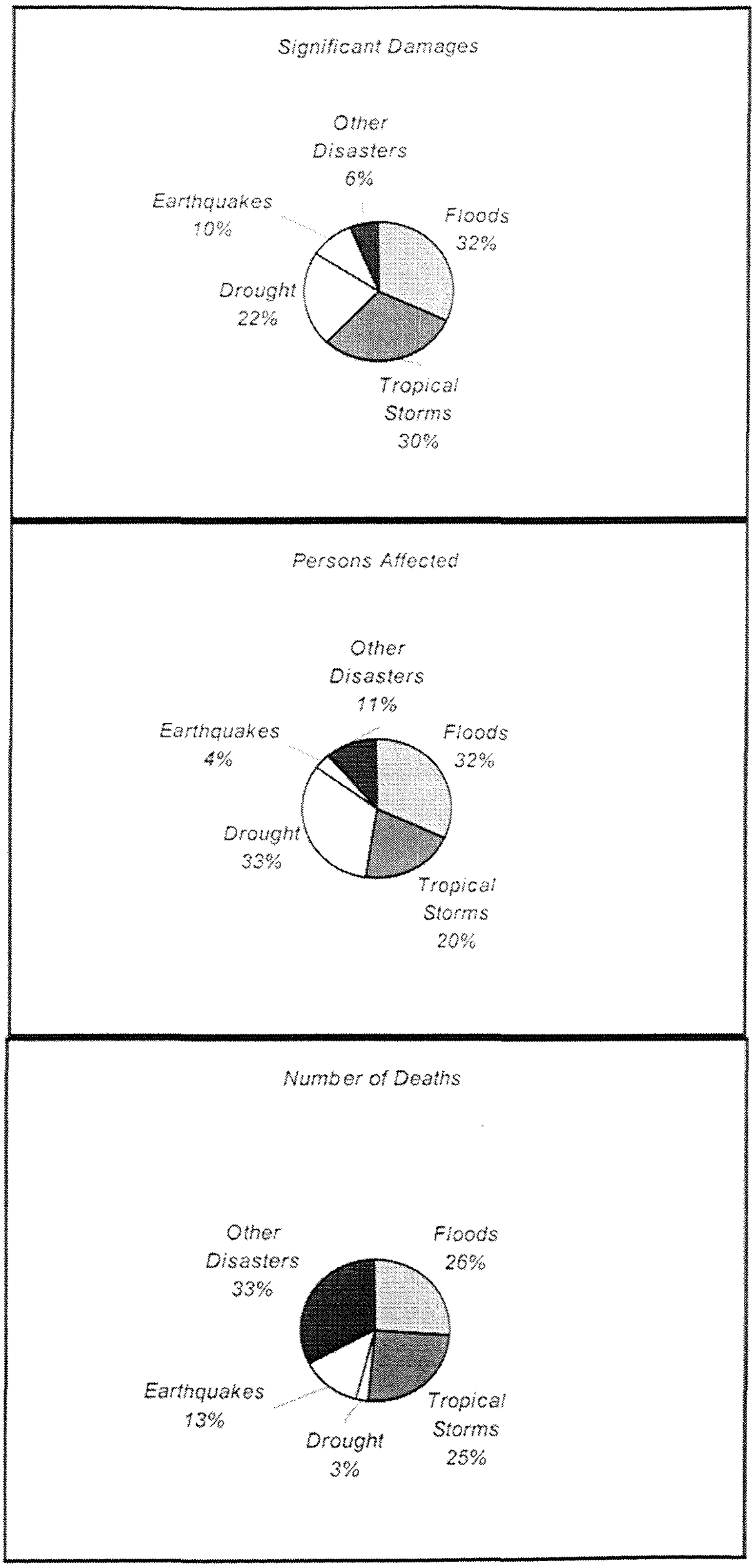


Figure 1.1: Significant damages, persons affected and number of deaths from natural disasters

Source: IAHS Publication no. 239

In order to solve some of these problems and find more beneficial ways of coping with floods, it is necessary to observe situations and strategies of flood management from around the world. This will not only enable us to analyse the productive and counterproductive effects of various strategies, but also to use this knowledge to better understand the problems of flood control and to find more ideal solutions for future implementation.

1.4 Benefits arising from floods

Why are some of the oldest civilisations found along the river valleys despite their vulnerability to flooding? Do floods bring any benefits? Normal floods that are regular and expected bring benefits not only to the riverine communities but also to the environment.

Some of the benefits brought about by the floods are:

- Large floodplains offer flat land for development e.g. the Rhine, Nile, Euphrates, Tigris and the Mississippi valleys
- Provides large amounts of water for domestic consumption and irrigation especially those crops that require large quantities of water
- Flood-borne sediments deposited in the floodplains or the deltas produce some of the most fertile farming areas
- Forms a floodplain corridor useful for construction of roads and rail communication
- Up-market residential developments along the rivers due to the scenic beauty
- Fishing and river navigation e.g. Rhine, Nile, and Mississippi rivers
- Infiltration and percolation from floods to the groundwater table below alluvial channels is an important mechanism for recharging the local aquifers and regional groundwater
- Regular annual floods provide abundant water resources to replenish lakes and ponds
- Flushing away the salts where weathering, capillary movement and evaporation lead to accumulation of highly soluble salts in the surface soils during the dry periods, resulting in the amelioration of saline soils (Choudhari & Sharma, 1984; Rinne, 1975; Fisher & Minckley, 1978; Hill, 1981). This has been observed to be the case in Luni basin, India; Salt River and Sycamore Creek, Arizona; and in Western Australia
- Help to preserve marshes and swamps which provide storage against damaging flood flows
- Maintains the high biological diversity in the floodplain ecology and wetland vegetation
- Provides in the marshes and swamps important resting, feeding and nesting areas for many waterfowl species
- Floodplain vegetation and soils serve as water filters removing excess nutrients, pollutants and sediments from the runoff before it reaches the river, thus reducing costly water treatment

(Smith, 1997)

1.5 Problems arising from floods

As stated in Section 1.3, the rivers' ideal settings for the development of civilisation has always attracted people to settle in the valleys despite the threat to safety posed by the floods. When water flows as a flood, it has a great destructive power. It will normally damage property and endanger the lives of humans and animals (Figure 1.1).

The effects of a flood could be direct or indirect, tangible or intangible, and primary or secondary. Direct losses occur immediately after the event as a result of the physical contact of the floodwaters with human and with the damageable property. Indirect losses, which may be equally or even more important, are less easily connected to the flood disaster and often operate on long time scale.

Depending on whether or not these losses are capable of assessment in monetary values, they are termed as tangible or intangible. Tangible and intangible losses can also be divided into primary or secondary categories where primary loses result from the event itself while the secondary losses are at least one causal step removed from the flood.

Even in highly industrialised countries, there is an increasing concern at the economic losses caused by flood disasters and this is being reflected in the insurance industry (Anon, 1994).

Some of the main problems arising from the floods are:

- Disruption of economic and social activities
- Damage to crops, livestock and the agricultural infrastructure such as irrigation systems, levees, walls and fences
- Damage to road transportation infrastructure due to high runoff causing traffic delays and interference with drainage and economic use of lands for agriculture or industrial purposes
- Damage to bridge abutments, bank lines, sewer outfalls, and other structures within floodways, navigation systems and hydroelectric power infrastructure.
- Soil erosion as well as sediment deposition problems downstream caused by rapid runoff
- Destruction of spawning grounds for fish and other wildlife habitat.
- Physical and mental ill-health caused by injury, emotional stress and disease after disaster

1.6 Objective of the study

The main objective of the study is to make a comparative analysis of the strategies, measures and methods used to cope with river floods in three different Case Studies and to assess the lessons that can be learnt from their experience. The study will, in particular, look at the historical, cultural, social, technical, managerial, economic and environmental justifications for using those strategies.

1.7 Scope of the study

The study has focussed on three Case Studies of countries with a history of floods and topography comparable to the Netherlands. The strategies, measures and methods used to cope with river floods in those countries and especially the historical, cultural, social, technical, managerial, economic or environmental justifications for those methods were examined to find out how they have been coping with floods. The following are the main questions addressed in the study:

I. What strategies, measures and methods are being used to cope with river floods in those countries?
II. What are the historical, cultural, social, technical, managerial, economic, or environmental justifications for using those strategies?
III. Are those strategies, measures or methods different from those used elsewhere?
IV. How have those countries been dealing with changing hydraulic conditions?
V. What lessons can we learn from their experience?
VI. How relevant are those lessons or strategies to the Netherlands and the Kenyan situation?

1.8 Importance of the study

The study will make it possible to understand more clearly why people prefer to use different strategies to cope with floods as compared to others. It will also 'open the eyes' of people who are confronted by similar flooding problems to other possible, sustainable and more acceptable solutions to cope with floods in the future by not relying heavily on the dikes system or their 'traditional' methods only. This is particularly the case where the following conditions exist:

- The flood discharge capacity downstream of the river is not adequate to cater for higher return period floods or anticipated changes in hydraulic conditions
- It is not socially, technically or economically feasible to construct dikes or raise and widen existing dikes without limits
- It is not socially, technically or economically feasible or rational to use scarce resources to construct and maintain more reservoirs or other flood control structures, for the control of rare great flood that may occur

1.9 Research methodology

The following was the research methodology followed:

I. Selection and detailed examination of 3 Case Studies from different countries

II. Literature research from the libraries and the 'Internet' on the strategies used by the reference countries to cope with floods and the historical, cultural, social, technical, managerial, economic and environmental justifications

III. Contacts through E-mail and discussions with professionals in the water and flood management field especially those that have firsthand experience with the case studies or the countries to find out more details on the strategies being applied and the justifications

IV. Discussions with some of the IHE alumni members and current Masters programme participants at the IHE from the reference countries and their friends

V. Compilation of the results of the literature research and discussions

VI. Comparative Analysis of the Case Studies and drawing up of conclusions and recommendations on the lessons that can be learnt

1.10 Outline of the research

The study has been presented in 5 chapters including this introductory chapter. The issues raised above are dealt with in the chapters as follows:

- **Chapter 1:** This chapter gives a brief introduction to the subject of the thesis and sets out the objectives and scope of the study.
- **Chapter 2:** This chapter gives the background information on the strategies, measures and methods adopted to cope with river floods around the world. It also looks at a brief history of floods in the Netherlands, as an example of one of the developed countries in the world renown for its success so far in coping with floods from its rivers and also the sea. The strategies, measures and methods adopted are briefly examined and later used to assess the other Case Studies.
- **Chapter 3:** This chapter looks in detail at three case studies namely Vietnam (Red & Mekong Rivers), China (Yellow River) and USA (Mississippi River), which have a history of floods and topography comparable to the Netherlands. The strategies, measures and methods adopted so far to cope with the floods in these cases are examined for their historical, cultural, social, technical, managerial, economic and environmental justifications.
- **Chapter 4:** In this chapter, a summary of the 3 case studies is first given and a comparative analysis is then made. The lessons of coping with floods that can be learnt from the Case Studies are also assessed and a hypothesis arising from the observations made is advanced. Finally, the lessons that are applicable to the Netherlands and the Kenyan situations are proposed.
- **Chapter 5:** This chapter summarises the study and gives the most relevant conclusions and recommendations of coping with river floods based on the above case studies.

2 BACKGROUND

2.1 Definition of terminology used

The 3 key words strategy, measure and method have been used frequently in this report. Their meaning in reference to coping with floods is hereby defined for ease of understanding and some examples given in Table 2.1:

STRATEGY: This is the approach, system, or scheme used to cope with floods

MEASURE: This is the action, move or steps taken to cope with floods

METHOD: This is the actual procedure, routine, process or technique adopted

Table 2.1: Example of strategies, measures and methods

Strategy	*Living-with-flood*	*Non-structural*	*Structural*
Measure	Give the river space	Flood forecasting & warning system	Floodwater detention
Method	Build houses on higher ground or raise them above highest flood level	Operating, maintaining and linking a hydro-meteorological network	Build dam & reservoir or use a detention basin

2.2 Strategies and measures used to cope with floods around the world

2.2.1 Classification of strategies

As stated in Section 1.3, the rivers' ideal settings for the development of human civilisation has always attracted people to settle in the valleys despite the threat to safety posed by the floods. So how have the societies being coping with the floods?

In coping with floods, strategies that have been or can be used by societies throughout the world may be generally classified into 3 groups of alternatives (Rossi, 1994) namely:

1. Living-with-floods strategy
   - Do nothing, either structurally or administratively
   - Adjust to some known or new way to flood phenomenon
   - Leave floodplains mainly to agriculture
   - Leave the floodplain to be inundated and take advantage of the flood benefits

2. Non-structural strategy
    - Only measures for alleviating the flood impacts are implemented
    - Regulate the use of floodplains and other flood prone lands
    - Carry out reactive flood defence
    - Use insurance, when feasible, to spread the flood risks

3. Structural strategy
    - Intensive and extensive physical measures which change a flood generating environment are used e.g. reservoirs, levees, dikes, new channels and river training & diversion

Any combination of the above 3 strategies could also be implemented as a reactive or proactive measure. Reactive measures could be improvised defences from floods while proactive measures could be well-prepared and planned flood defences and evacuation activity prior to flood occurrence

In all the above strategies, the catchment size is an important parameter for the floods since unit area flow in floods of the same risk decreases with an increase in catchment area, influencing forecast, warning, response, defence and the strategies used to cope with the floods.

2.2.2 Classification of measures

Literature contains several classifications of measures used to cope with floods (Rossi, 1994). These classifications are done with reference to some standpoints that lead to the selection of the mixture of measures. Five of these basic classification standpoints are:

- Adjustment to natural hazards (direct or indirect adjustments)
- Flood damage prevention viewpoint (corrective or preventive measures)
- Flood damage reduction viewpoint (individual or national actions)
- Flood policy making viewpoint (individual or national action)
- Basic category of individual measures (prevention, prediction, proofing, physical control and insurance)

In this report, the individual measures and methods have been grouped, classified and described according to the strategy they are considered to fall into i.e. Living-with-floods, non-structural or structural.

Historical records on various human societies and related civilisations show that people have often fought to decrease the negative impacts of floods and to benefit and improve on the positive flood consequences. The strategies and measures used to mitigate the undesirable flood impacts and to benefit from its useful effects have been a direct function of the level, strength and state of a civilisation.

2.2.3 Living-with-floods Measures

2.2.3.1 Flood acceptance

For rivers with a high degree of seasonality where there is already a high dependence, either ecologically or economically, on the annual flood pulse, a living-with-floods strategy is most suitable. This is the situation most commonly found in the rural flood-prone areas of the less developed countries. The floodplains, which are mainly for agriculture, are left to inundate therefore taking advantage of the flood benefits.

2.2.3.2 Living at two levels

Where people have learned to live with floods and the shallow inundation continues for long periods, like in some parts of Vietnam, living at two levels becomes an attractive option. The lower floor is used during the no-floods periods and the upper floor is used in the time of flooding. Movement around the area is done using boats and canoes.

Other examples are Thailand or Malaysia where houses in the floodplains are built on stilts 1.0 to 1.5 m high to allow people to live there even during floods (Chan, 1995). In the more developed countries like the USA, some buildings are elevated so that the lowest floor level is located above the design flood stage, which is typically the 100-year flood. In Lismore, New South Wales, over 90% of the 2000 flood-prone houses of weather board construction have been raised on columns by as much as 3 – 4 m in what has been seen as a cost effective flood proofing response (Penning-Rowsell, 1987)

2.2.3.3 Forest land control

Through the centuries people have created a flood problem by cutting down trees and digging up the vegetable cover of the soil, thus increasing soil erosion and runoff. Cultivation decreases the ability of the soil to retain water and increases runoff. The Forest land control measure requires the maintenance of forests or reforestation of suitable lands to control erosion by improving water retention and infiltration.

2.2.3.4 Grassland control

Grass cover increases rainfall retention, delay of runoff, and hence increases water losses through evaporation and evapo-transpiration. This also helps to reduce soil erosion decreasing bedload sediments in the rivers thus helping to maintain the flood flow capacity of the river.

2.2.3.5 Arable land control

Vast land areas along the headwaters of rivers throughout the world have been laid waste by intensive cultivation and subsequent erosion. Flood control in such areas is directed at restoring vegetation and tree belts for wind protection and instituting efficient methods of soil management, such as crop rotation, contour ploughing, terracing, grading and protecting the slopes. These hydraulic-affecting measures mean a larger and longer surface water retention in the catchments, more infiltration and still water outflow delay, and an increased evaporation and evapo-transpiration. The combined effects then tend to decrease both the flood peaks and the flood volumes (Rossi, 1994).

2.2.3.6 General soil control

These are measures taken in the catchments which usually lead to a decrease on sediment supply to the watercourses thus keeping the flood channel capacity constant or improved due to riverbed erosion.

2.2.4 Non-structural measures

2.2.4.1 Floodplain zoning

Using the flood risk, vulnerability to flood damage or the danger of the loss of human lives as criteria, the use of the floodplain is zoned by regulation or agreement. Through this, the local jurisdictions can restrict occupancy of the floodplain to uses that will suffer little or no damage during the floods (Linsley, 1987). Furthermore, this reduces the risks involved in the occupation of the flood-prone land and deters further invasion of such areas (Keith, 1997).

2.2.4.2 Code of regulations

A code of regulations with policies and programs affecting the design and location of services and utilities in the floodplains is used to protect the flood-prone areas. These may be building codes, sanitary and well codes, setbacks from the shore, density of structures in the floodplain, restrictions or prohibitions on certain kind of constructions.
(http://floodplain.org/c-access.html)

2.2.4.3 Changing people's attitude on floods

This is achieved through a community or nationwide program to educate people on floods and what can be done to alleviate flood impacts in order to change their attitudes on floods. The education could be on the forecasts, warnings, evacuation, defence from floods, zoning the area, coding and any other measures in the people's interest. Keeping the people well informed will get them prepared and readily positive to cope with floods and reduce any ensuing losses.

2.2.4.4 Submersible dikes

These are low dikes also known as summer dikes that are constructed to control minor (early) floods on land in the floodplain. The dikes are however submerged when the major floods occur thus allowing supply of the much-needed fertile sediments into the floodplain (Liakath, 1995). This method is commonly practised in the Netherlands, Banglandesh and South Vietnam to protect crops from the summer or early flash floods until harvesting has been done.

2.2.4.5 Flood forecasting

Data from good stream-gauging network is used in flood forecasting. Accurate flood forecasting in both fluvial and coastal environments is very useful in providing reliable flood warning schemes.

According to Keith (1997), the most significant advance in non-structural flood mitigation measures recently has been the provision of more accurate flood forecasts. Advance in the technology of data collection and in computer-based online data handling now make it possible to accurately forecast the downstream timing and magnitude of the flood peaks in major river basins. Enough arrangements and preparations can therefore be made to withstand the forecasted floods thus reducing losses and damages considerably (Rossi, 1994). Care should however be taken to avoid erroneous forecast of the flood stages or of the time of arrival of flood conditions as this may lead to under-preparation or over-preparation on the part of the affected people. This would lead to avoidable damages occurring or to unnecessary expense, anxiety and loss of credibility of the system (Keith, 1997).

2.2.4.6 Flood warning

The method involves the utilisation of accurate flood forecasts to give timely warning on the incoming floods. A good flood warning should not only provide advance information magnitude, location, and timing of the flood but should specify the nature of the loss-reducing actions to be taken. In terms of content and delivery it should be tailored to achieve an optimal behavioural response from a targeted group of recipients. Some of the floods warning systems include:

- Floodplain maps to identify flood prone areas
- Early flood warning systems
- Alert, Watch and Warning bulletins from the meteorological office
- Automatic real-time warning systems using observation, river gauges and radio transmission
- Community operated warning system at bridges, water channel or towers

2.2.4.7 Evacuation

This is one of the most typical non-structural methods of coping with floods. Successful evacuation of people, animals, and material goods from floodplains ahead of flood events depends on the accuracy, timeliness, dissemination of forecasts and the credibility of the warning (Rossi, 1994).

2.2.4.8 Organised or improvised defence from floods

This is normally an emergency measure that involves the reinforcement of the floodplain property to better withstand the flood impact. Temporary defence works may also be built in case of occurrence of rare large floods to protect other flood control structures like levees, dikes and dams from overtopping or breaching by piping or erosion.

2.2.4.9 Flood proofing

This is a flood response strategy whereby the properties are raised above the flood level, or are sealed so that floodwaters cannot enter (dry flood proofing), or floodwaters are allowed to enter the building but ensuring minimal damage (wet flood proofing). The vulnerability of buildings to flooding depends on their resistance to the force of the moving water and the response of building materials to water.

Where existing structures are exposed to recurrent floods of comparatively shallow depth and short duration, householders may be willing to live with the inconvenience associated with seasonal inundation like in United Kingdom, New South Wales and Malaysia.

2.2.4.10 Snow management

Where rivers cease to flow after freeze-up thereby allowing substantial depth of snow to accumulate as a plug in the channel, small floods having high short-lived peak discharges may occur when the snow plugs break either due to rise in pressure or change in the air temperature. In such cases, an incision may be made in the channel to reduce the effect (Caine, 1995).

2.2.4.11 Rainfall suppression

This method involves the attempt by humankind to suppress excessive rainfall by interfering with the atmospheric variables, which may decrease the precipitation intensity and duration. The cloud seeding technology may be used to initiate the precipitation before the clouds become too heavy thus reducing flooding hazards due to reduced rainfall. A drawback to this method is the costs involved and uncertainty as to the effect on the biological life of rivers and soil fertility of the floodplains (Rossi, 1994).

2.2.4.12 Modification of large storms

Attempts have been made to modify the eye of the flood-producing large cyclonic storms, thus decreasing the widely spread rainfall intensities. This method would not only require the use of great expertise and highly sophisticated weather monitoring technology but would be too expensive to implement (Rossi, 1994).

2.2.4.13 Strict control of floods induced by human

These types of flood occur when wrong judgements by humans, an incorrect action or operation on flood control structures like spillways, intentional break of dikes or reservoirs, either create or intensify floods. The risk can be minimised through application of strict operational controls and instructions, regularly repeated and exercised (Rossi, 1994).

2.2.4.14 Insurance

Insurance is not a flood control measure but a non-structural measure to cope with the impact of the floods. It is a compensatory scheme to help people recover their normal lives after experiencing damaging floods (Rossi, 1994).

In this scheme, people at risk join forces with a large financial organisation to spread the cost burden from one major flood disaster over a number of years through the payment of an annual premium. The money is then used to compensate the minority who may suffer loss in an individual year (Keith, 1997). The insurance may be in the form of:

- A government disaster fund usually specified in the annual government budget
- A compulsory government insurance program for all inhabitants and property owners in floodplains

- A mixed public-private insurance
- A private insurance with government guarantee for compensation of damages beyond a given fixed sum, or
- A wholly private insurance especially for urban flood damage that is not connected to floods of large rivers

Whichever insurance scheme used in a country depends on the level of damages or losses (level of accepted risk) anticipated.

2.2.5 Structural measures

2.2.5.1 Dikes and Levees

Dikes are mainly earth structures along the sea or river constructed in order to protect littoral lands from historically known or specified large floods. Levees are raised earthen banks constructed along and parallel to the main river in order to defend the floodplains from all the floods except the large ones. These structures require protection from erosion, breaches, piping, and overtopping during the large floods. The protected land must be provided with pumped drainage system during the flood.

Levees are normally constructed on one side of the river but double embankments as near as possible to the natural river channel can also be used to protect the entire floodplain. A consequence of their construction is an increase of downstream flood peaks and flood volumes due to reduced space for natural attenuation of flood peaks and a decrease of flood volume. This could lead to more flooding downstream and long-term sedimentation in the channel after the flood peaks have passed.
The height and strength of a levee (dike) depends on the property being protected. Urban levees tend to be designed for the 100 year floods or greater whilst agricultural levees are designed for the 50 year flood or less.

2.2.5.2 Floodwalls

A floodwall is a permanent or temporary vertical structure that has the same function as a levee or dike. As a permanent structure it is usually made of wood, masonry, concrete or steel. When used as a temporary structure, it may be made of floating inflatable rubber or from lightweight aluminium members lined with rubber gaskets placed horizontally between vertical steel H-piles.

2.2.5.3 Dams and Reservoirs

Dams are engineered structures built across river channels for water control purposes. When constructed for flood mitigation, the aim is to impound water in a reservoir during periods of high flow and then release it later when the downstream conditions allow in order to maintain, as far as possible, downstream discharges within the safe carrying capacity of the channel. Although often called flood control reservoirs, these structures can only mitigate flood flows. In all cases, it is necessary to determine the degree of protection required. For the safety of the dam, there is an emergency spillway to protect the dam from being overtopped. Some types of dams are described below:

I. Retarding dams and detention (retention) basins

These simple structures have no permanent impoundment and the reservoir space is held empty by a low-level ungated outlet the size of which is set at a specified maximum outflow rate. The most basic type has an automatic discharge controlled by a spillway or a series of outlets at different elevations in the dam. It is a self-regulating system and the reservoir automatically empties after each flood and is then ready to receive the next inflow.

The system is quite effective for small floods but for the large floods, much of the storage space is taken up before the peak arrives so the reduction of the peak is not as much. The land within the detention (retention) basins can be used for agriculture or other low-intensity purposes during the no-floods season but its not suitable for buildings or similar investments. The basin has other benefits as it improves infiltration, traps river sediments thus making the soils within fertile, and also raises the water quality downstream (Keith, 1997).

II. Storage dams

These structures have gates or valves for regulating the outflow of the reservoir according to a set of operating rules. Such schemes may be operated for flood control only (single-purpose) or flood control and other uses (multipurpose), such as water supply or hydropower generation.

Single-purpose reservoirs

Single-purpose reservoirs are built exclusively for the purpose of flood control. The received floodwater is emptied completely or released down to the fixed low level prescribed by the recreational use, as soon as the downstream flood conditions permit.

The advantage of these types of reservoirs is that they permit the immediate discharge of the early, non-damaging part of the rising hydrograph thereby maximising the storage available for any subsequent storm rainfall. However, this can only function efficiently if accurate flow forecasts are available for if the reservoir operation leads to outflows in excess of the natural discharges, and if these coincide with tributary peak downstream, flood conditions would be worse.

Multipurpose reservoirs

Multipurpose flood control reservoirs retain a permanent pool of water for a variety of uses with the special upper storage space reserved exclusively for flood control. The requirements for optimum operation of a multipurpose reservoir are often in conflict. For maximum benefits, flood control requires an empty reservoir before the onset of floods; however power generation and navigation require the water level to be kept as high as possible for maximum production. On the other hand, irrigation requires a seasonal release of water during the growing period and recreation needs a full pool during the recreation season. This calls for strict operational guidelines for good water management.

2.2.5.4 Channelisation

Channelisation is the process of increasing the carrying capacity of the natural river channel in order to contain flood peaks, facilitate land drainage or improve navigation of the river. This can be done in several methods including increasing the river slope, widening or deepening the river channel to increase the cross-sectional area.

Relief channels can also be provided for flood flows and hydraulic conditions may be further improved by decreasing the roughness coefficient through clearing boulders and other obstructions from the natural riverbed. Channelisation can provide less environmental disturbance than other flood engineering measures such as dam construction, provided that the geomorphological equilibrium is not radically changed. It can mainly be done in three ways: channel re-sectioning, channel re-alignment and bank protection.

I. Channel re-sectioning

This is the term given to the deepening or widening of the river channels in order to increase the flood carrying capacity. The aim is to provide the channel with a cross-sectional area, which provides the maximum flow efficiency with a minimum of excavation, although factors such as bed porosity and bank instability can make this difficult.

Channel deepening can be achieved by either narrowing the river channel or by dredging. This approach avoids the problem of lowering flow depths and reducing hydraulic efficiency in the channel. Usually, no extra land is required and bank-side vegetation is preserved. On the other hand, there could be disturbances to the river regime and channel habitat with the possibility of some headward recession of the bed. The existing bed levels downstream should be matched to the deepened channel levels upstream.

Channel widening tends to avoid the problems of bank instability associated with channel deepening, especially in erodable materials, but creates shallower depths of flow with the attendant risk of increased siltation. In urban areas, it may be difficult to acquire the additional bankside land required and the shallower flows can lead to unsightly dry riverbeds in some cases (Keith, 1997).

Channel clearing is done to remove the obstacles and the associated accumulation of silt from the river channel. Aquatic vegetation normally reduces the channel capacity. The regular removal of the large weeds and trees, especially willows, is an important means of retaining channel capacity and reducing roughness.

II. Channel re-alignment

Highly sinuous and meandering river courses are prone to flooding because of their low hydraulic efficiency and the backwater effect on the beds. Straightening or re-aligning the channel by artificial cut-offs shorten and steepen the section, thereby increasing the flow velocity, which in turn reduces the flow stage. Diversion or relief channels are used to bypass existing urban areas where re-sectioning by channel widening is not possible. Such channels may act as flood overflows only, with the natural channel carrying the normal discharge (Keith, 1997).

III. Bank protection

Bank protection is necessary where there may be abrasion and landsliding that may be an obstruction to the river flow. Wooden piles, groynes or quick-growing plants like willows have been used to slow the near-bank velocity of the river and encourage sedimentation. In some cases, it may be necessary to place the river in an artificial channel lined with concrete.

Such works reduce the channel roughness, avoid the need for more land, and reduce the maintenance costs. These may however be expensive to construct, severely damage the river ecology, and present a harsh visual appearance especially at low flows.

2.2.5.5 Diversion channels

Diversion channels or tunnels for the excess floodwaters have been often used in the case where there is a lake, reservoir. Dry valley another river or the sea nearby to accept these diverted floodwaters without damage.

2.2.5.6 Floodways and detention (retention) basins

Floodways serve two functions in flood mitigation and alleviation. First, they create large, shallow reservoirs that store a portion of the floodwaters thus decreasing the flow in the main channel below the diversion. Second, they provide an additional outlet for water from upstream, therefore increasing velocity and decreasing the stage for some distance above the point of diversion (Linsley, 1997).

The topography of the valley and the availability of low value land, which can be used for the floodway, limit opportunity for the construction of floodways (Figure 2.1). Floodways are ordinarily utilised only during major floods therefore the area may be used for agriculture but no fixed developments of high value should be permitted within.

Admission of water into a floodway can be achieved in a number of ways. It may occur over a low spot in the natural bank or a gap in the levee line. A low section of a levee (fuse-plug levee) which when once overtopped, will wash out rapidly and develop full discharge capacity into the floodway, can also be provided. A concrete sill or weir could also be provided so that the overflow occurs at a definite river stage. This offers certain advantages when overflow occurs frequently since it prevents the need for replacement of a levee section each time flow into the bypass occurs.

Dynamiting a section of the levee when the situation warrants is another possible way of admitting water into the floodway. A more complete control could be obtained with a spillway section with openings closed by stop logs, needles or gates. Diversion may then be limited to the amount required to reduce flows to the capacity of the channel. Controlled spillways are relatively costly and are ordinarily used for the protection of major cities (Linsley, 1997).

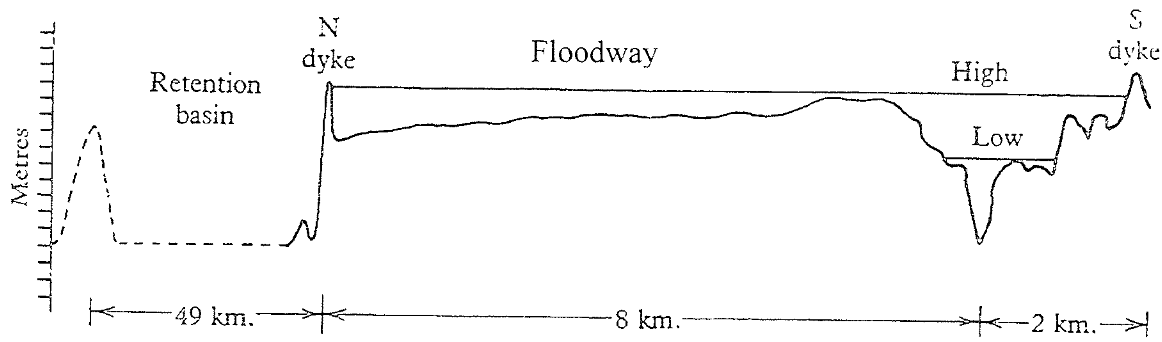


Figure 2.1: Section across a river, a floodway and a Retention basin

2.2.5.7 Floodplain platforms

A floodplain platform is an earthen structure with the platform level much above the level of the largest protection flood. It is an alternative solution to protect the location of important facilities like industries (thermal power plants, smelters, brick factories etc) and small settlements within a floodplain. Though it has to be protected from erosion by the floods, it offers a better solution than dikes or levees which would require a drainage system and pumping facility to ensure that the area is not inundated during floods by internal and external seepage.

2.2.5.8 Geo-membrane barriers

This is a flood control measure that is still under research. It consists of geo-membrane tubes that are filled with water in-situ and rely on the weight of the water and anchoring for stability against flooding. It offers quite an interesting use in emergency situations as they are portable, very expedient, can be emptied and re-used, and require limited manpower. The expense could however limit their use.

2.3 *Coping with floods in the Netherlands*

2.3.1 Introduction

The Netherlands is one of the countries most renowned for its success in coping with floods both from the river and the sea. As Ven (Ven, 1993) puts it, "the history of water management in the Netherlands shows how the original natural landscape was transformed into a man-made landscape in a never-ending struggle with the water." Before looking at how Vietnam, China and USA cope with floods, the case of the Netherlands is briefly described, as a comparator, in order to see what these 3 countries can learn from it or vice-versa.

2.3.2 Specific features of the country and its rivers

2.3.2.1 Geographical features

The Netherlands is situated on the delta of three of Europe's biggest rivers: the Rhine, the Maas and the Scheldt (Figure 2.2). With a total area of 41,526 square kilometres which is approximately 27 percent of the country and a home to over 60 percent of the population of 15.8 million people, the delta is actually below sea level. The country, as a whole, has an approximate average elevation of 11 m above sea level with Prince Alexander polder lying 7 m below sea level. For these reasons, the construction, management and maintenance of flood defences are essential conditions for the safety of the population and development of the country.

Along the coast, protection from flooding is provided primarily by the dunes but where dunes are absent or too narrow, or where sea arms have been closed off, flood defences in the form of sea dikes or storm surge barriers have been constructed. Along the entire Rhine and along parts of the Maas, river dikes offer protection from river floods.

The strategic location of the Netherlands has allowed it to become a major physical distribution centre. Rotterdam, the largest port in the world, has access deep into the heartland of Europe through River Rhine. Using low-cost river-barge transport, an efficient network of highways and the third largest cargo airport in Europe, the country serves as a base for a highly developed logistics industry capable of offering wide-ranging services to local and foreign companies.

The climate is temperate, with gentle winters and cool summers, and an average rainfall of 790 millimetres with the highest being in summer and autumn and the lowest in springtime.
(http://www.geography.about.com)

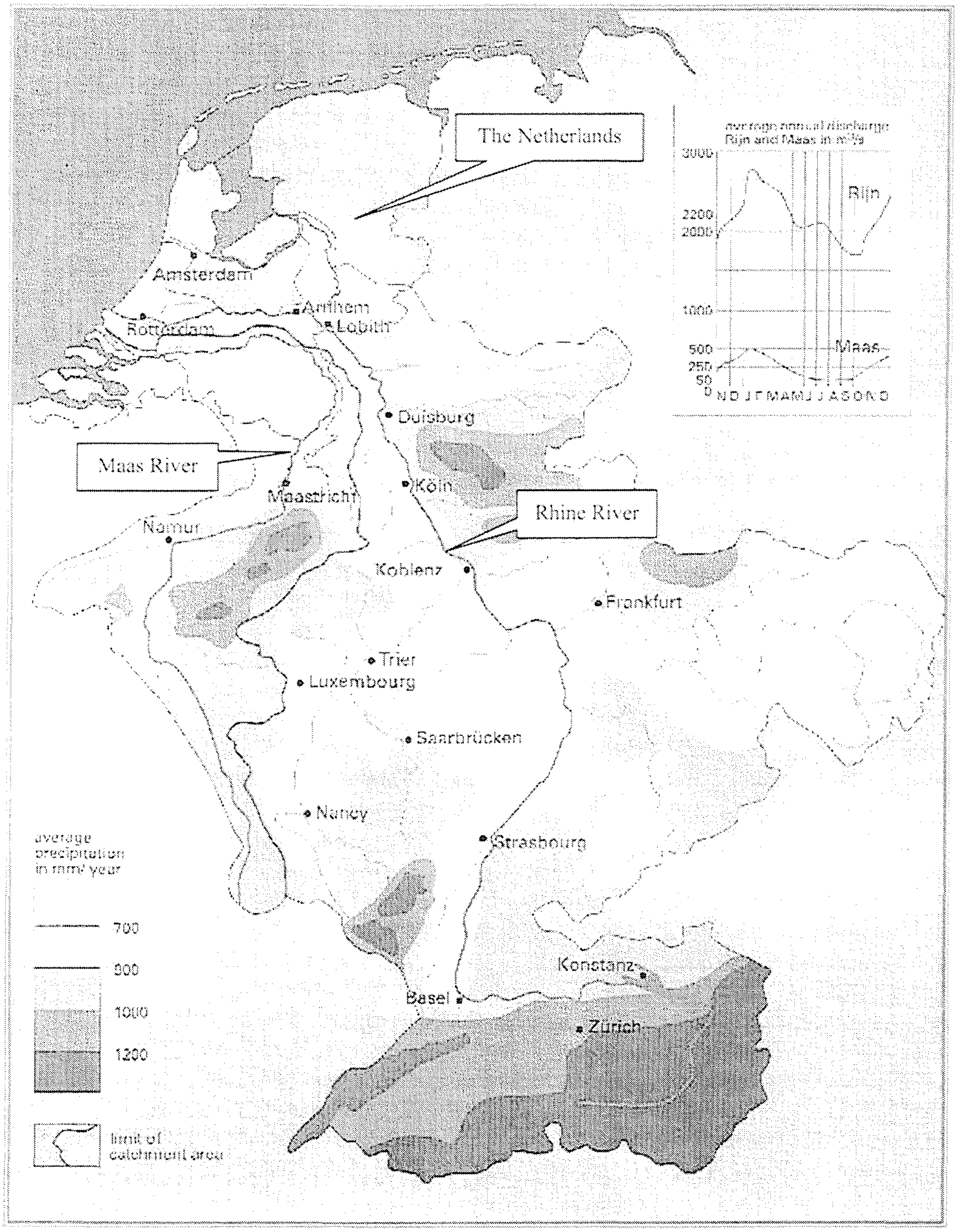


Figure 2.2: Catchment area for Rivers Rhine & Maas

2.3.2.2 Hydrological features

Rhine River and Maas River are of great importance for the hydrology of the Netherlands. The greater part of the Dutch surface waters originates from those rivers.

Rhine River

The Rhine River (Figure 2.2) is the major river and waterway of western Europe. It rises in two small head streams in the Alps of east-central Switzerland and flows west and then north and north-west through Germany-France border for about 1,390 km to enter the North Sea at the coast of the Netherlands. It is a snowmelt and rainfed basin with a catchment area, including the delta area, of about 220,000 km^2 with the Dutch part being approximately 25,000 km^2. The maximum known discharge at Lobith, where it enters the Netherlands, is 12,280 m^3/s. There the Rhine breaks up into several branches notably the Lek and the Waal. With the Netherlands' completion of the huge Delta Project in 1986, these main branches were closed off, and the river's waters now reach the North Sea via sluices and channels. The New Waterway Canal at Rotterdam is the main navigational link between the Rhine and the North Sea.

The Rhine has been an international waterway since the Treaty of Vienna in 1815. In its lower and middle course the river is an integral artery of the richly interconnected inland waterway system of Germany, north-eastern France, and the Low Countries. Its chief ports are Basel, Strasbourg, Mannheim, Cologne, Duisburg, and Rotterdam, which transship using barges mainly coal, petroleum products, metallic ores, cereals and containers. In the late 20th century the Rhine was navigable overall for 870 km and was navigable to ships larger than 5,000 tons dead weight as far as Rheinfelden on the Swiss-German border. The Main-Danube Canal, which allows barge traffic between the North Sea and the Black Sea via the Rhine, Main, and Danube rivers, was completed in 1992. The hydroelectric potential of the river in its upper reaches has been heavily utilised in the Swiss Alps (Ven, 1993).

River Maas

River Maas, the second largest river in the Netherlands, has its source in France and flows to the Netherlands through Belgium (Figure 2.2). It is a typical rainfed basin with a length of approximately 900 km, a catchment area of approximately 33,000 km^2 and a known maximum discharge of 3,000 m^3/s at Borgharen. The river is subject to floods arising from sudden rise in its water level (up to 4 m) due to the relatively steep upstream and downstream topography. However, because of its low discharge, the floods have not been as many as in the Rhine (Ven, 1993) but when the floods do occur, they cause more problems and inconveniences as it is not protected by dikes along the whole length. Only after the 1993 and 1995 floods were some dikes constructed in several sections following intense political pressure.

2.3.2.3 History of floods

In the Netherlands, flooding has been a major concern for the people, especially since approximately one third of the country is below sea level and around 70% of it can potentially flood. There were at least 140 floods with casualties recorded between 1200 and 1953 AD in the Netherlands. The most recent memorable flood disaster from the sea was in 1953 in the province of Zeeland where 1,620 km^2 of land was inundated, 1,800 people died, over 70,000 people were evacuated and material estimated at over 1.1 billion Dutch Guilders (Dfl.) was damaged (Delta Committee, 1962).

The reaction to the flood was a nation-wide movement to upgrade the level of security against flooding from the sea, which culminated with the birth of the Delta Plan project (Fordham, 1994). Since then, laws have been passed to construct and maintain embankments, sea dikes, barrier dams, beach walls and storm surge gates to ensure at least a minimum safety level, defined by its frequency of inundation. In the Flood Protection Act, 53 geographic areas were defined as dike rings, which are areas that would be flooded if a dike failure occurred. Dike rings, made of sea dikes, dunes, river embankments and other flood alleviating structures, cover the whole low-lying part, which is about 50% of the country. The total length of the flood protection dikes is about 3,400 km (Fordham, 1994).

The Dutch and their ancestors have been working to hold back and reclaim land from the North Sea for over 2000 years. The Frisians, who first settled the Netherlands, began over 2000 years ago to build artificial mounds of earth (terpen) 6 to 8 m high on which they built their structures protected from the water. In 1287, the terpen and dunes that held back the North Sea failed at some sections and seawater flooded the country (Shetter, 1987) creating a new bay, Zuiderzee, over former farmland. For the next few centuries, the Dutch worked to slowly push back the water of the Zuiderzee, building dikes and creating polders while using canals and windmill pumps to drain the fertile land and to keep it dry.

The first river flood recorded in historical sources is the bursting of the Noorder lekdijk in 1233 AD. Before then, no direct records of river floods existed possibly because the rivers were not diked yet and also because the overtopping of the banks by a river was not considered a disaster (Ven, 1993). Until well into the 19th century, attention in the Netherlands was mainly focussed on the prevention of river floods. The need for river improvement to prevent floods and for international shipping interests was therefore acknowledged but it was not until after 1850 when relative political and financial stability was realised that serious work could start. In 1809, 1820, 1855 and 1861, large parts of the river area were flooded stirring a lot of commotion in the Dutch society each time it happened.

Towards the end of 1993, a flood from River Maas occurred in France, Belgium and the Netherlands. This flood and inundation in the Netherlands part resulted in over 8,000 people being evacuated and an estimated material loss and damage of Dfl. 250 million. Later in 1995, floods occurred in the Rhine and Maas River basins. On the Dutch part, several summer dikes which are designed for 1 / 30 years flood were overtopped and polders behind them were flooded.

After a geotechnical evaluation of the summer dikes was made and assessed as risky, it was decided to evacuate over 250,000 people and millions of livestock with the direct and indirect damage being assessed as Dfl. 200 million and 1.5 billion respectively. This flood was assessed as the most serious since the 1953 floods and even though the dikes were later found to have been safe, because of the social problem created, this experience also gave birth to a massive river-dike improvement plan along River Rhine and River Maas (Wijbenga, 1995).

2.3.3 Measures adopted to cope with floods

2.3.3.1 Non-structural measures

I. Safety and risk

The risk of flooding is a real threat to the Netherlands. The continuous monitoring of existing levels of protection, the unflagging concern for timely response to weakened spots and the actual commitment of all parties along the hazard chain to contribute to further safety improvements are essential.

Before 1953 flood disaster, the question of desired safety of national flood defences was always approached fairly pragmatically. Dikes were built at a level just above the highest known water levels. In the current approach, the cost of construction of the dike and the risks of flooding are balanced. Reducing the probability of consequent damage is the essential benefit of the level of safety inherent in the flood defences.

More scientific approach to the design of flood defences was implemented after the 1953 flood disaster. Failure probability for the sea dikes was fixed at 1/10,000 and for river dikes at 1/1,250 per year. The Flooding risk, the product of the probability of an event multiplied by the consequences of the event, is reduced by creating compartments within the dike ring areas and constructing vulnerable elements on relatively higher grounds (Jorissen, 1998). In many cases, such construction or improvement of the flood defences means damage to the countryside, natural life or local culture. For this reason, demands that are made on the level of protection against high waters have to be based on a balancing of social costs against the benefits of improved flood defences.

Research to improve the methods of assessment of flood risks is still going on. This will make it possible to approach safety based on the risks of flooding per dike ring area and thus adjust the protection as close as possible to the actual calculated risk.

II. Evacuation

Evacuation was used in the 1993 and 1995 floods of River Maas and Rivers Rhine & Maas, when 8,000 and 250,000 people were respectively evacuated. Though the Maas and the Rhine achieved seriously high levels in 1995, the damage along the Maas was significantly less than in 1993, which was attributed to the better state of preparedness of citizens and the authorities at that time. Even so, the local water authorities along the Rhine considered the 1995 situation so serious that the security against flooding of various polders could no longer be guaranteed.

On this basis and after an evaluation of the risks of a possible dike collapse, it was decided on the preventive evacuation of more than 200,000 people and many millions of animals. The mass evacuation gave rise to some considerable social unrest grounds (Jorissen, 1998).

2.3.3.2 Structural measures

The Dutch flood defence system mainly consists of dunes, sea dikes, storm surge barriers, sluices, and river dikes. Dikes play a crucial role in flood protection in the Netherlands.

I. Raised Ground (mounds or terpen)

As early as 500 BC, people were living in the lower areas of what is now the Netherlands. The people eventually began to build their villages on artificial mounds of earth (terpen) to protect themselves and their livestock from floods. By 17th and 18th centuries, another way of combating flood that was widely used was raising the floor level of several rooms of the farmstead 1.0 to 1.5 m above the ground level. Access was by way of a flight of steps

II. Dikes

In the 1st century, people began to construct small dams along the rivers. Later, dams were also constructed to connect several mounds to protect the land from regular floods. By 1200 AD, they were using dikes and by 1450 AD windmills were helping to drain the land throughout the Netherlands. The storms and floods of 1916 provided the impetus for the Dutch to start a major project to reclaim the Zuiderzee. From 1927 to 1932, the 30 km long Barrier dike was built, turning the Zuiderzee into the IJsselmeer, a freshwater lake.

Before 1953 flood disaster, the question of desired safety of national flood defences was always approached fairly pragmatically. Dikes were built at a level just above the highest known water levels. More scientific approach to the design of flood defences was implemented after the 1953 flood disaster with failure probability for the sea dikes being 1/10,000 and for river dikes being 1/1,250 per year.

A relatively unique solution for the Netherlands has been the construction of the dike rings whereby the surrounding dikes protects the land areas they enclose from floods. Of the 3,400 km of dikes, about 570 km pass through villages and towns, forming a unique dike landscape culture.

III. River channel improvement

The construction of river dikes was done concurrently with the improvement of the river channels, both to prevent floods and for international shipping interests. This was more so after 1850 when relative political and financial stability was realised in the Netherlands. These river improvements included channel deepening, widening, straightening, canalisation, weirs, locks and re-channelisation where deemed necessary.

IV. Storm-surge barriers and sluices

In the southwest, the disastrous gales and spring tide of February 1953 accelerated the implementation of the Delta Plan, which closed most of the sea inlets, shortened the coastline by 620 km, and allowed the development of the islands through roads that were constructed over 10 dams and two bridges.

The largest of these dams, crossing the 5 km wide Oosterschelde estuary, was built in the form of a storm-surge barrier incorporating 62 sluices that can be closed in the event of a flood from the sea. The barrier is normally open, allowing seawater to enter the estuary and about 75 percent of the tidal movement to be maintained, limiting damage to the natural environment there.

In the interests of the commerce of the ports of Rotterdam and Antwerp, no dams were constructed across the Westerschelde, an approach to Antwerp, Belgium and the New Waterway, which links Rotterdam to the North Sea. At the New Waterway, a massive steel storm surge barrier that can be closed when necessary was constructed instead. The dikes along these waterways were strengthened to increase the flood safety. (http://www.library.thinkquest.org)

2.3.4 Socio-cultural Justifications for the methods used to cope with floods

2.3.4.1 Safety and risk

The Netherlands taken as a whole posed a wide variety of different challenges to settlement and required an equal variety of responses for successful survival. In the older time, agrarian life determined the forms of villages that developed on high land, marshy land, along dikes, at dams and around fortification mounds. Today the agrarian life has been overtaken and nearly inundated by the modern industrial society but much of it still contribute to the individual's sense of cultural society (Shetter, 1987).

Given the risk of flooding, there is quite a strong general feeling in the society that the higher, stronger and more reliable the flood defences, the smaller the probability of their failure. Reducing the probability of damage is therefore seen as the benefit side of the consideration of the safety level of flood defences improvement even though this may mean some damage to the countryside, natural life or local culture. The demands that are made on the level of protection against high waters therefore are also based on a balancing of social costs against the benefits of improved flood defences (Jorissen, 1998).

2.3.4.2 Environmental perspective

From about 950 to 1350 AD, a strip of coastal lowland (Rijnland) was transformed from an uninhabitable marsh into a thriving commercial agricultural centre that gave the first real thrust to a prosperous culture in the Netherlands (Shetter, 1987). The settlers replaced a natural landscape with a cultural one thus demonstrating an intimate understanding of the ways of their environment, and established a harmony with it that has been characteristic ever since.

This was evident recently when river-dike improvement plan along the rivers Rhine and Maas caused large-scale protests in the Netherlands due to its perceived harmful impact on the riverine landscape and the natural and cultural values of the river dikes. The government's Becht Commission of 1977 was set to assess the river-dike improvement policy such as the required safety level, the design methods, and procedures used to involve local and general interest groups in the design process. It advised that the design discharge be reduced to 16,500 m3/s with a return period of 1,250 years (Wijbenga, 1995).

2.3.5 Flood protection Policy

The present flood protection policy is based on safety and risk with the approach to safety being based on the probability of a certain high water level occurring not on the probability of flooding (Jorissen, 1997). The probability of failure for the sea dikes has been set at 1/10,000 and for river dikes at 1/1,250 per year. The safety of the flood protection structures is assessed quite regularly, at least once every 5 years, against the current safety specifications. This frequency of safety assessment allows local managers to adapt to changing conditions and maintain the required safety standard. Figure 2.3 shows how the risk concept and the safety assessment interact (Jorissen, 1998).

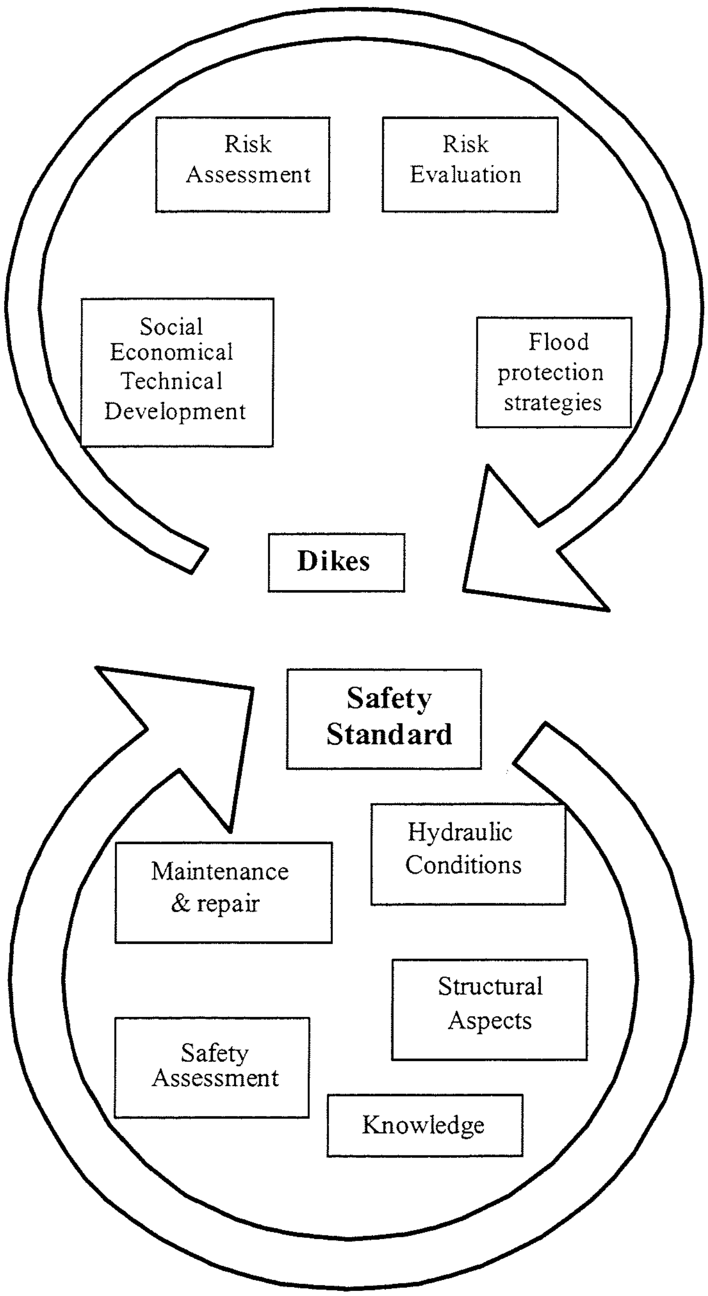


Figure 2.3: Safety and risk assessment policy

However, through the ongoing research efforts to improve the methods of assessment of flood risks to allow the adjusting of the protection as close as possible to the actual calculated risk, the policy for the next decade might change as provided for by the Flood Protection Act (Jorissen, 1997). Together with the "rivier*en*land" (river and land) approach being promoted this may entail giving more space to the rivers and restoring the rivers' natural habitat at the same time, as opposed to continually heightening the dikes.

The Rivier*en*land project, started by the Ministry of Transport and Public works, is exploring strategies to cope with floods in the future which will not depend on the dike system only, while still ensuring a good quality of life for the society in all its aspects. Faced with the threat of rising water levels due to climate changes and lowering of land due to oxidation of organic soils at the same time, it is estimated that the difference between land and water levels may increase to nearly 10 meters within the next 300 years. Though the project does not aim at providing a new policy at the moment, it may as well be the genesis of some policy changes in the future.

3 SELECTED CASE STUDIES

3.1 Introduction

Vietnam, China and USA are 3 countries with a history of floods and topography comparable to the Netherlands. Moreover, the 3 countries whose economies can respectively be categorised as developing, newly industrialised and developed, offer an opportunity to see how the growth of the economy and other factors such as population density, culture and politics could affect the strategies or measures adopted to cope with the floods. This chapter starts by giving brief introductions of the 3 cases and then looks in more detail at the strategies, measures and methods adopted so far to cope with floods including the historical, cultural, social, technical, managerial, economic and environmental justifications.

3.1.1 Case Study 1: Vietnam

Vietnam has one of the most abundant water resources in the world. It has developed as a nation by mainly exploiting the low-lying river deltas and coastal lands for wet-rice agriculture; it is no wonder then that most of the population lives in areas susceptible to flooding in the north (Red River) and in the south (Mekong River). Even the mountainous part of the country suffers from flash flooding from the monsoon rains. Consequently, water-related disasters are the most serious in Vietnam and cause regular and substantial suffering, loss of life and economic damage. Floods cause the worst damage, particularly when accompanied by typhoons.

Faced by annual losses from serious flooding and other disasters, the Vietnamese developed for over 1000 years a traditional culture of disaster and flood protection. This flood protection culture has largely been successful in coping with floods for two millennia. It is in this light that Vietnam was selected as a case study to investigate what the world can learn from the experience of the Vietnamese on flood management strategies.

3.1.2 Case Study 2: China

China is one of the world's oldest civilisations. The nation has traditionally oriented itself not toward the sea but inland, developing as an imperial power whose centre lay in the middle and lower reaches of the Yellow River on the northern plains. As a result, it has a deep history of river flood control with some of the earliest Chinese efforts to tame rivers dating as far back as 2200 BC. Historical records of the Yellow River, from 602 BC to 1949 AD, show that there were more than 1,500 floods recorded, 7 big avulsions in the lower reaches and almost 2 dike breaches every 3 years (Brush, 1989). No wonder people living along the river have always chanted with pain, "Nine years out of ten see floods from the Yellow River; homes are gone, crops are gone, life is spent on the edge of a knife" (Zhu, 1997).

Yellow Valley is recognised as the cradle of Chinese civilisation. It is the root of the Chinese nation. Thousands of archaeological findings provide evidence about the Shang dynasty, which endured roughly from 1700 to 1027 BC. Its civilisation was based on agriculture, augmented by hunting and animal husbandry. In view of the above, China was also selected as a case study, to investigate what the world can learn from the Chinese experience on flood management strategies.
(http://lcweb2.loc.gov/frd/cs/cn.html)

3.1.3 Case Study 3: USA

Flooding is recognised as one of the natural hazards in the United States. Flood threats are experienced throughout all the four seasons of the year. For example, between 1973 and 1979, 193 natural disasters and 77 declared emergencies occurred of which approximately 80 percent involved flooding (Kellan, 1997). More than 650,000 km^2 of land in the United States lies in the floodplains where over 6 million dwellings and a large number of non-residential buildings exist.

The Mississippi River, whose system drains 41 percent (2,979,000 km^2) of the continental United States, has a long history of flooding. The river plays a central role in the exploration and economic development of the continental United States as a principal artery for bulk freight, carrying more than any other inland waterway in North America. As a result, efforts to control floods along the river and its tributaries have been going on for a long time. Between 1936 and 1965 for instance, the United States government constructed 260 reservoirs, 10,000 km of levees and 13,000 km of channel improvement, all at a cost totalling 7 billion dollars. Considering the above, and with the United States being one of the developed economies, Mississippi River was selected as one of the case studies.

A summary of various aspects of the rivers is given in Table 3.1:

Table 3.1: Summary of the rivers' aspects

Attribute / River	Rhine	Mississippi	Yellow	Red	Mekong
Length (km)	1,390	5,970	5,460	1,200	4,220
Catchment area (sq.km)	220,000	2,979,000	750,000	155,000	795,000
Delta area	√	√	√	√	√
Port(s) along river	√	√			
Navigation	√	√	√	√	√
Industrial area	√	√	√	√	
Rainfall (mm)	790	1200	900	1,650	1,500
Flood potential	Very high	High	High	High	Very high
Flood disasters	√	√	√	√	√
Flood history	>2000 years	>500 years	>4000 years	>1000 years	>500 years
Dike system	√	√	√	√	

3.1.4 Strategies being used to cope with floods

As explained in Section 2.2, the strategies that have historically been used or could be used by societies around the world to cope with floods, may be classified into 3 groups of alternatives (Rossi, 1994) namely:

1. Living with floods strategy
2. Non-structural strategy
3. Structural strategy

The strategies, measures and methods (Section 2.1) used in each of the above case studies as well as the historical, cultural, social, technical, managerial, economic or environmental justifications, have been investigated in this chapter and analysed in the next chapter.

3.1.5 Key words

In the study of the 3 cases, the following key words were selected as set out in the scope of the study (Section 1.7) and used to structure the presentation in this chapter:

- benefits (arising from the floods)
- problems (arising from the floods)
- objectives of flood control and management
- strategies
  - Living-with-flood strategy
  - Non-structural strategy
  - Structural strategy
- measures
- methods
- historical perspective
- cultural perspective
- social perspective
- environmental perspective
- economic perspective
- political perspective
- disaster preparedness and mitigation
- public awareness and participation
- post-flood hazard mitigation
- population growth and urbanisation
- relationship with the natural environment
- floodplain land-use and spatial planning
- flood protection policy

It is important to note these key words, as they will be used later in chapter 4 in the comparison and analysis of the case studies.

3.2 *Case Study 1: Vietnam*

3.2.1 Specific features of the country and its rivers

3.2.1.1 Geographical features

Vietnam has a total surface area of approximately 330,000 square kilometres. It shares borders to the north with the People's Republic of China, to the west with Laos and Cambodia and to the east and south with the South China Sea. The coastline is shaped like the letter S and is over 3,000 km long (Figure 3.1).
The land is principally agricultural with a central tropical rainforest. Mountains account for 40 percent of the land, hills 40 percent and level land 20 percent but the forests covered 75 percent of the land in the early years (Section 3.2.3.7). The North consists of highlands and the Red River Delta; the south is divided into coastal lowlands, central mountains with high plateau and the Mekong River Delta.

Because of differences in latitude and the marked variety of topographical relief, the tropical monsoon climate in Vietnam varies considerably from north to south. Annual rainfall is substantial in all regions and torrential in some, ranging from 1200 millimetres to 3000 millimetres. Nearly 90 percent of the precipitation occurs during the summer. Tropical monsoons occur from May to October. It is almost totally dry throughout the rest of the year. However, the annual rainfall averages about 1,830 mm with high humidity (85-88%) throughout the year.

The average annual temperature is generally higher in the plains than in the mountains and the plateau. Temperatures range from a low of 5°C in December and January, the coolest months, to more than 37°C in April, the hottest month. Seasonal divisions are more clearly marked in the northern half than in the southern half of the country, where, except in some of the highlands, seasonal temperatures vary only a few degrees, usually in the 21°C-28°C range.
(http://lcweb2.loc.gov/frd/cs/vntoc.html)

3.2.1.2 Hydrological features

Vietnam's water resources can be considered in 16 major basins. The two largest basins are the Red River in the north and the Mekong River in the south (Figure 3.1 and Table 3.2). The deltas of the two rivers are also the most populated regions in the country. These are the main two rivers considered in this study.

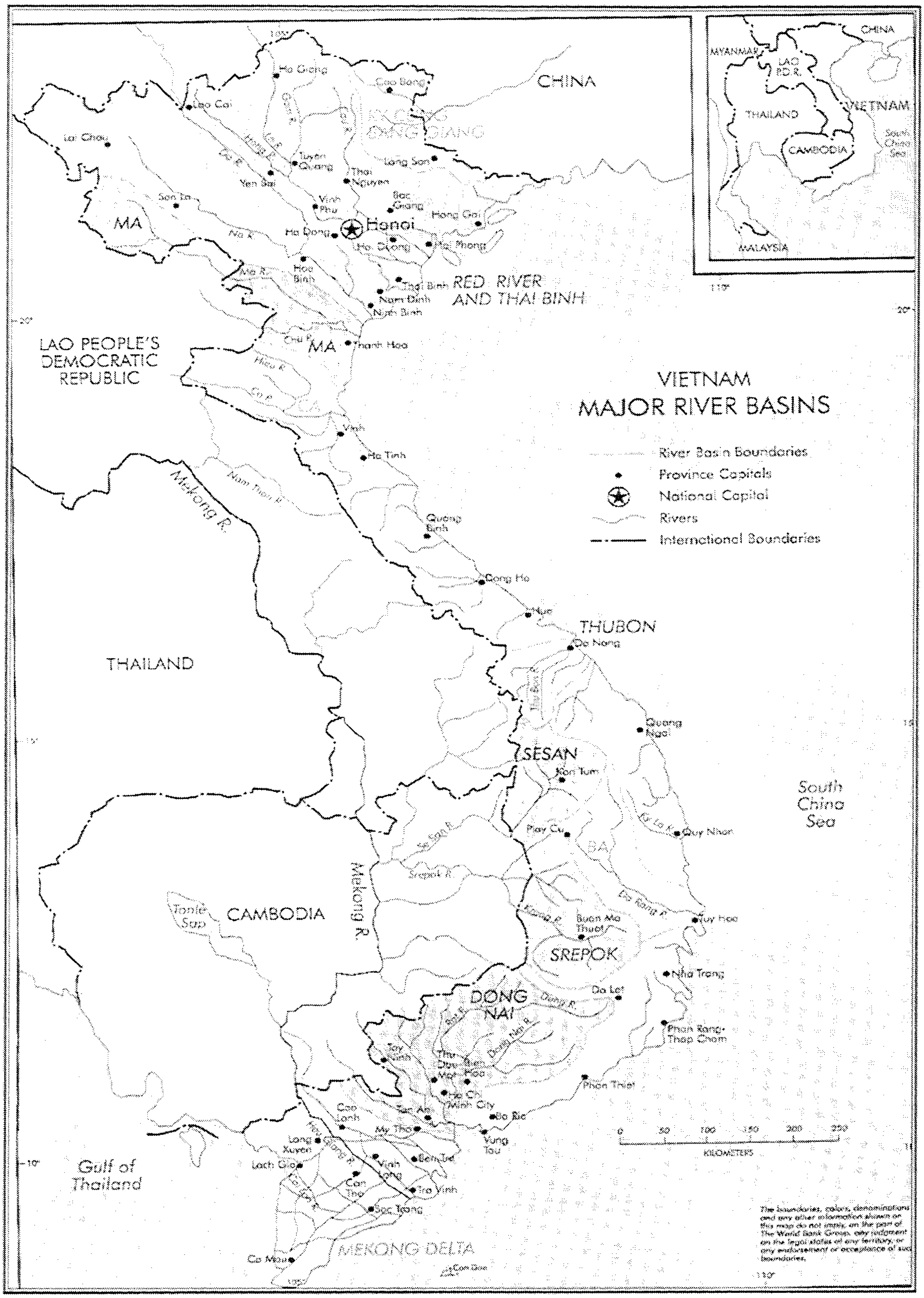


Figure 3.1: Major river basins in Vietnam

(Source: World Bank report, 1996)

Table 3.2: Major watersheds in Vietnam. **(Source: UNDP, 1994)**

Major watershed	Drainage area		Mean Rainfall (annual) mm	Mean Runoff (annual) (10^9m^3)	Monthly Runoff	
	Total (km^2)	Vietnam (km^2)			Max. (10^9m^3)	Min. (10^9m^3)
Mekong	795,000	72,000	1,500	475.0	95.0	6.2
Red	155,000	72,700	1,650	121.0	25.4	2.4
Ma	28,400	17,700	1,400	16.6	3.2	0.4
Ca	27,200	17,730	1,700	21.9	4.6	0.5
Sre Pok	17,300	17,300	2,000	14.5	3.2	0.2
Dong Nal	14,900	14,900	2,400	17.3	4.8	0.1
Da	52,900	26,800	1,600	8.0	2.6	0.1
Ky C-B	13,000	12,400	1,400	7.9	1.9	0.2
Giang	12,700	12,700	1,550	8.7	2.2	0.2
Thai Binh	11,450	11,450	2,400	11.2	1.8	0.3
Se San	10,000	10,000	2,800	15.8	0.6	0.4
Vu Gia-Thu	7,510	7,510	2,400	8.5	2.1	0.1
Bon	7,000	7,000	2,600	11.1	3.3	0.2
Be	6,000	6,000	2,300	6.1	1.5	0.1
Thach H-Huong	4,680	4,680	2,400	8.0	2.0	0.1
Tra Khuc Cianh						

A. The Red River

The Red River ('Song Hong' in Vietnamese), rising in China's Yunnan Province, is about 1,200 km long. Its two main tributaries, the Song Lo and the Song Da, contribute to its high water volume, which averages 500 million m^3/s. This may, however, increase by more than 60 times at the peak of the rainy season. The entire delta, a flat, triangular region of about 3,000 square kilometres, backed by the steep rises of the forested highlands, is no more than 3 m above sea level, and much of it is 1 m or less.

Recognised as the ancestral home of the ethnic Vietnamese, it is smaller but more intensely developed and more densely populated with population density ranging from 600 persons per square kilometre in the upper delta to more than 1000 at the lower delta region. At the Mekong River Delta, the population density ranges from 400 to 1000 persons per square kilometre. Archaeological findings indicate that settlers in the Red River Delta may have been among the first peoples in East and Southeast Asia to practice agriculture.

The area is subject to frequent flooding. At some places the high-water mark of floods is 14 m above the surrounding countryside. This hindered extensive settlement on the plains for a long time until people learned how to cope with the floods and to drain the swamps. For centuries, flood control has been an integral part of the delta's culture and economy. An extensive system of dikes and canals has been built to contain the Red River and to irrigate the rich rice-growing delta.

Modelled on that of China, this ancient system has sustained a highly concentrated population and has made double-cropping wet-rice cultivation possible throughout about half the region. The delta accounted for almost 70 percent of the agriculture and 80 percent of the industry of North Vietnam before 1975.

(http://lcweb2.loc.gov/frd/cs/vn.html)

B. The Mekong River

The Mekong River is one of the 12 great rivers of the world and is approximately 4,220 kilometres long. From its source in the Xizang plateau, the river flows through the Xizang and Yunnan regions of China, forming the boundary between Laos and Burma as well as between Laos and Thailand. It then divides into two branches, the Song Han Giang and Song Tien Giang, below Phnom Penh and continues through Cambodia and the Mekong basin before draining into the South China Sea through nine mouths or nine dragons (cuu long). The river is heavily silted and is navigable by seagoing craft of shallow draft as far as Kompong Cham in Cambodia.

A tributary entering the river at Phnom Penh drains the Tonle Sap Lake, a shallow fresh-water lake that acts as a natural reservoir to stabilise the flow of water through the lower Mekong. When the river is in flood stage, its silted delta outlets are unable to carry off the high volume of water. Floodwaters back up into the Tonle Sap, causing the lake to inundate as much as 10,000 square kilometres. The flow of water reverses and proceeds from the lake to the sea when the flood subsides. This effect reduces significantly the danger of devastating floods in the Mekong delta, where the river floods the surrounding fields each year to a level of 1 to 2 meters. Habitation of the delta remained restricted by these stagnant waters until canals could be constructed to drain the water directly into the sea, especially under French direction at the end of the 19^{th} century.

The Mekong delta, covering about 40,000 square kilometres, is a low-level plain not more than 3 m above sea level at any point and criss-crossed by a maze of canals and rivers for transport, irrigation, drainage and flood control. About 15 million people live within the delta with 3.5 million living in the urban centres. So much sediment is carried by the Mekong's various branches and tributaries that the delta advances 60 to 80 m into the sea every year. The estimated amount of sediment deposited annually is about 1 billion cubic meters or nearly 13 times the amount deposited by the Red River. About 10,000 square kilometres of the delta are under rice cultivation, making the area one of the major rice-growing regions not only in Vietnam, where it accounts for 40% of the national food production, but also of the world. Most people living in the delta are engaged directly or indirectly in agriculture. All developments on the main stream as well as the tributaries are co-ordinated by an inter-riparian Mekong Committee (Laos, Thailand, Cambodia and Vietnam) to prevent detrimental effects to any of the riparian countries.
(http://www.anu.edu.au/asianstudies/mekong/flood.html)

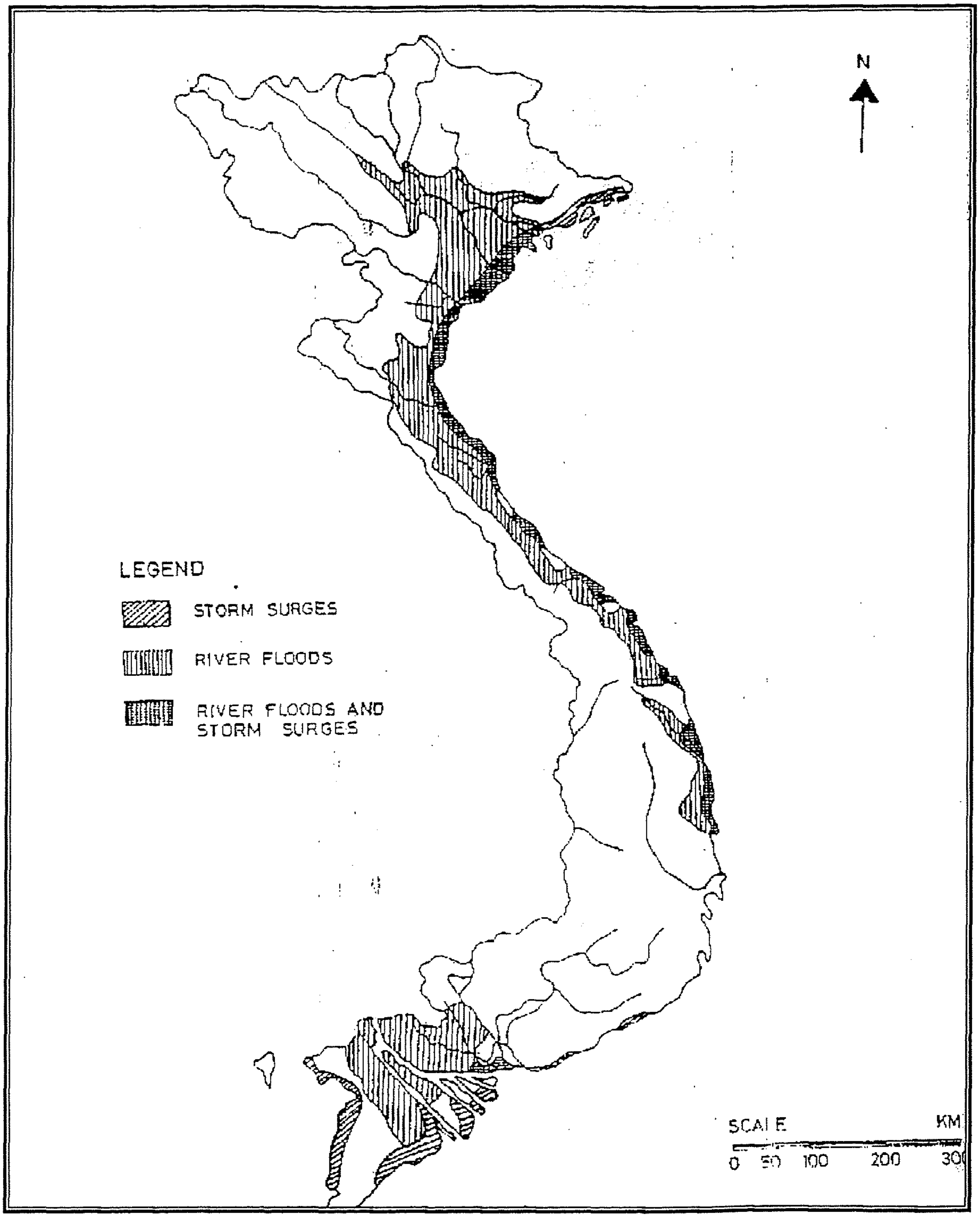


Figure 3.2: Areas subject to flooding in Vietnam

Source: http://www.undp.org.vn/dmu

3.2.1.3 History of floods

Water-related disasters are the most serious in Vietnam (Figure 3.2) and cause regular and substantial suffering, loss of life and economic damage as can be seen from the recent severe floods in 1998 and particularly the extreme floods of 1999. For example, annual losses from flooding in the Red River Delta and along the Central coast are estimated on average to reach more than $130 million (UNDP, 1994).

The torrential rains that accompany typhoons mostly cause flash floods, which come upon settlements unawares, and regularly submerge low-lying areas inundating valuable cropland. The runoff from these typhoon rains when added to rivers that have already swollen by monsoon rains creates floods that endanger river dikes and threaten to devastate millions of households.

Why are the water disasters so serious in Vietnam? Why does most of the population live in areas susceptible to flooding? The answer to these questions lies in the fact that Vietnam has developed as a nation by exploiting the low-lying river deltas and coastal lands for wet-rice agriculture and settlement. Big towns and urban centres are also located within or just next to the floodplains. Thus both the broad Red River and Mekong River deltas and the narrow connecting coastal strip of the country, which are the most populated regions in the country, are prone to flooding from monsoon rains and typhoon storms. Further, the remaining three-quarters of the country are mountainous and suffer from flash flooding. As a result, over 70% of the population of Vietnam is at risk of water disasters.

The flood disasters have been aggravated by inappropriate human activity. Along the coast, mangroves have been cut down and coral reefs have been mined, exposing coastal settlements to ever-greater destruction by winds and waves. In the hills and mountains, deforestation has substantially increased erosion, siltation and runoff, so that peak flood levels are higher and reach downstream sooner than they used to. Because of the extra runoff in the rainy season, there has been less water infiltrating into the ground. This reduces dry-season flow downstream and ironically leads to severe water shortage in the central highlands and seawater intrusion along the coast especially in the Mekong delta. In addition, rivers whose floodplains are protected by dikes like the Red River have higher flood water levels than they had formerly. At present, during the wettest months, the Red River near Hanoi can have water levels 5 or 6 metres above ground level, whereas 1,000 years ago waters only rose 2 to 3 metres above ground level.
(http://www.undp.org.vn/dmu)

Table 3.3: Typical historical flood records

Year	Area inundated (km^2)	People displaced or killed	Property damage
1997	750 (paddy)	>51 killed	>15,000 houses
1996		>1000 killed	>25,000 houses
2000 (Nov & Dec)	870 (paddy)	944 killed 286,372 evacuated	> 335 million US$

3.2.2 Measures and methods used to cope with floods and the justifications

3.2.2.1 Living- with-Floods measures

I. Giving the river space

Red River Delta

The 'living-with-flood' strategy has been applied in Vietnam for a long time. In the centuries before the dikes were built along the Red River, the flood level rarely exceeded 2 to 3 metres so that any land that was higher above 3 m was essentially free. Moreover, each farmer had much more land than is the norm nowadays thus they could afford to use different land at different time of the year (UNDP, 1994).

The strategy that was developed to cope with the floods at that time was to plant one crop of rice per year on each parcel of land depending on the season. There were three varieties of rice that were used in different grounds:

- A variety planted in the wet season on high ground
- A strain planted in winter on low ground and harvested just before the rainy season, and
- A quick growing type planted in winter-spring in low, damp fields or floods prone sandbanks and harvested during the rainy season before the floods would rise up very high.

Even today, the floodways of the Red River Delta are not protected against floods. They are therefore extremely fertile because of the annual deposition of sediment by the rivers during monsoons producing 2 crops of rice a year. The occupiers of this land have adapted well to their circumstances and are well prepared for the floods. When they receive a flood warning, they quickly complete their harvests, store their crops above flood level and remove flood-liable property to safe locations (often on top of the dikes). Unfortunately, these people have to live in tents on public land during the rainy season until the floodwaters subside. They also sometimes suffer serious losses when the first floods come too early before the crops are ready for harvesting. This experience has made them to construct low-level dikes to protect their crops from the early small floods (UNDP, 1994).

Mekong River Delta

As a government policy, Mekong Delta is largely unprotected except for some low dikes that provide partial protection to agricultural production during the early part of the rainy season. For this reason, flooding is different from that in the Red River delta. It is characterised by widespread, uncontrolled and prolonged floods (World Bank Report, 1996). Canals that are widened and deepened occasionally are used for transportation and also to drain the excess water directly into the sea.

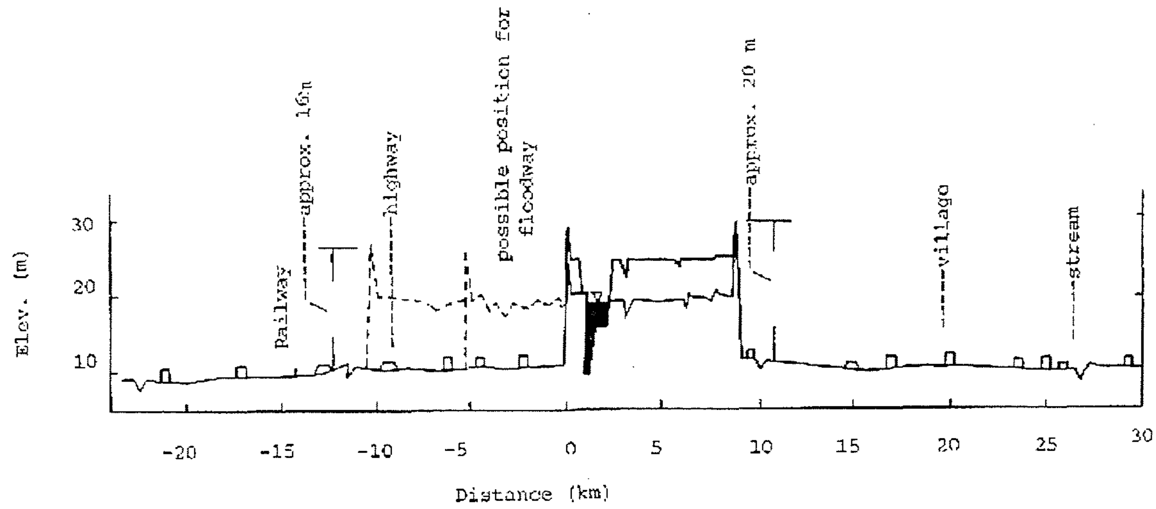


Figure 3.3: Typical section across the Red River

Cropping patterns and lifestyles have adapted to this situation over the years and people are not generally afraid of the floods (Figure 3.4 and Figure 3.5). In normal years, a gradual rise of up to 0.5 m in the water level does not cause serious problems. However, a rise in the water level up to 2 - 4 m in some areas is common, and the damage is significant.

This also causes disruption to normal life leading to some activities like schools being suspended from 1 to 1.5 months. While on the one hand there is an urgent need to protect human life and property in the delta, people appreciate the benefits that come with the floods. Floods also allow sediment deposits into the lowlands and bring nutrients and fish from the upstream into the inland fisheries. The annual floods also flush the acid soils making it useful for agriculture. Moreover, there is some concern that the construction of high dikes in the Mekong delta would confine the floodwaters and cause higher floods upstream in Cambodia (UNDP, 1994).

II. Houses on stilts

In the Mekong delta, the houses are built on stilts or raised foundations above the flood level using bamboo or reinforced concrete anchor piles. Because it is the government policy to live with the floods, the Ministry of Agriculture and Rural Development (MARD) and the Ministry of Construction are assisting the people to put up appropriate floodproofed houses. New floating-house designs are being introduced to the people and model houses (20 to 25m^2), schools and hospitals have already been put up. Alternatively, the houses are situated at high places such as along the canal banks, roads or the ridges but during the high floods, they may still be flooded. The occurrence of floods is rather stable and the water level increases or decreases gradually at 20 to 60 centimetres per day hence the floods are said to be inconvenient, especially as regards sanitation and availability of fresh water, but not too dangerous. Boats are used for communication during the floods.

Source: www.undp.org.vn/dmu

Figure 3.4: Living with flood in the Mekong delta (2000)

Source: www.undp.org.vn/dmu

Figure 3.5: Flooded school in the Mekong delta (2000)

3.2.2.2 Non-structural measures

I. Flood forecasting and warning systems

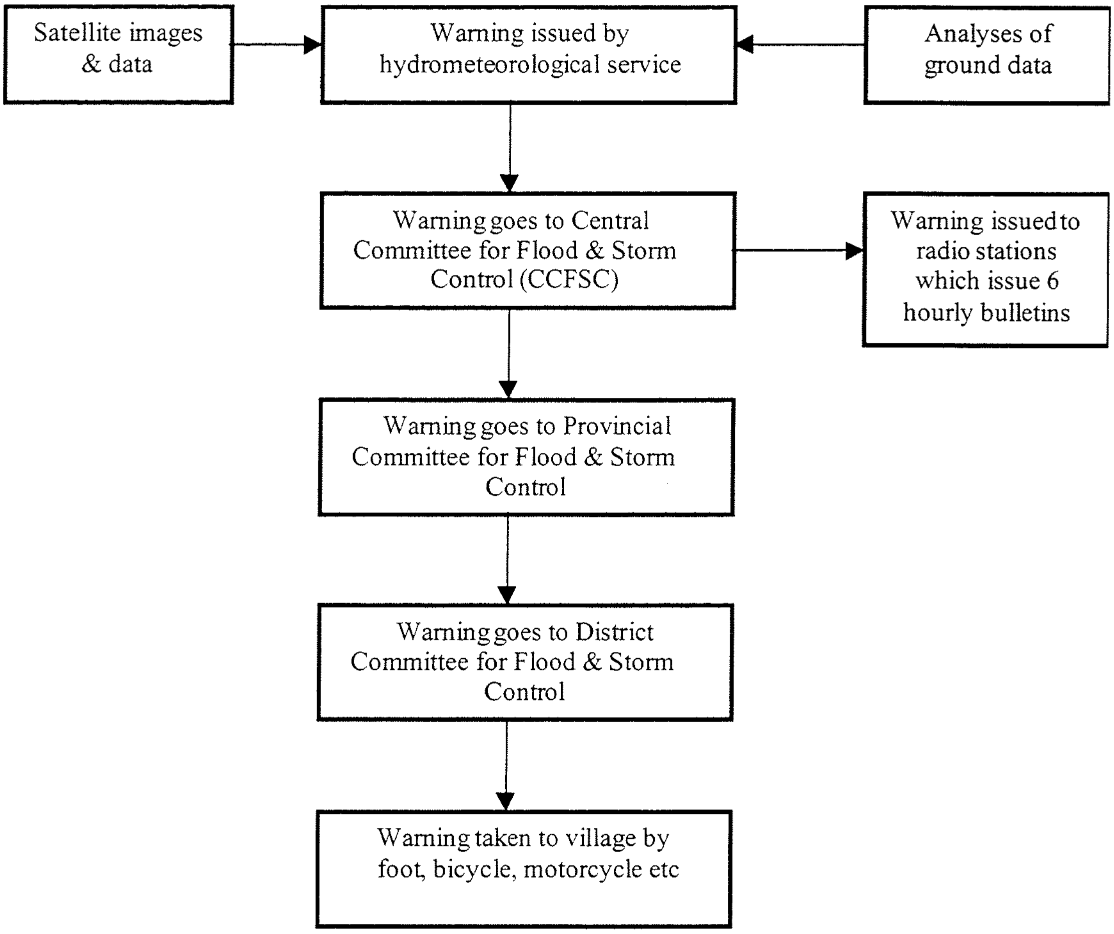


Figure 3.6: Current system of issuing warnings

Flood forecasting and warning systems are in use (Figure 3.6) and in fact are being upgraded in some provinces (Quang Binh, Quang Tri and Thua Thien) with the help of UNDP funds. Traditionally, drums and horns were used to sound the flood warning but now a more reliable modern system is centralised in Hanoi through the Disaster Management Unit (DMU) project (Section 3.2.4.1) and connected to the neighbouring countries. Hitherto, the contention had been that the equipments are mostly outdated or lacking altogether rendering the facilities unreliable. Emergency is declared by the CCFSC in a top-down order (Figure 3.6) and takes about 1 day to reach the village level. Evacuation when required is mainly co-ordinated and carried out by the army.

II. Institutional management (**Central committee for flood and storm control)**

Flood control and management has remained a priority policy issue that has received constant attention and allocation of resources to ensure stable socio-economic development (Le, 2000). It is widely accepted that flood control and management programmes should ultimately lead to improvement in the quality of life by reducing the impact of flooding on individuals and by reducing flood damage in the private and public sectors.

Over the years, the country developed a comprehensive, typical hierarchical structure to deal with floods and storms, which developed into a system of management, communication and reporting (Figure 3.7). These structures have evolved over centuries as the Vietnamese population developed the agricultural potential of its great river deltas. It is notable that even as early as 1472, the Emperor Le Than Tong appointed two mandarins, one to look after the dikes and the other to look after the irrigation systems. These mandarins then delegated other mandarins to look after the dikes and irrigation systems at different levels right down to the level of the village thus initiating a management structure that can be seen to this day.

The main organs involved in the management structure are:

1. Central committee for flood and Storm control (CCFSC) responsible for emergency response during storms and control of the multipurpose reservoirs for flood control purposes
2. Department of dike management and flood control (DDMFC) to plan and manage major flood control facilities
3. Vietnamese hydraulic Investigation and Design Company responsible for studying and designing most of the departments projects
4. Construction Management Department to build facilities through its subsidiary construction companies
5. General Department of Hydrometeorology responsible for flood forecasting

The army plays a very important role during disasters as the centre for emergency response and rescue (World Bank Report, 1996).

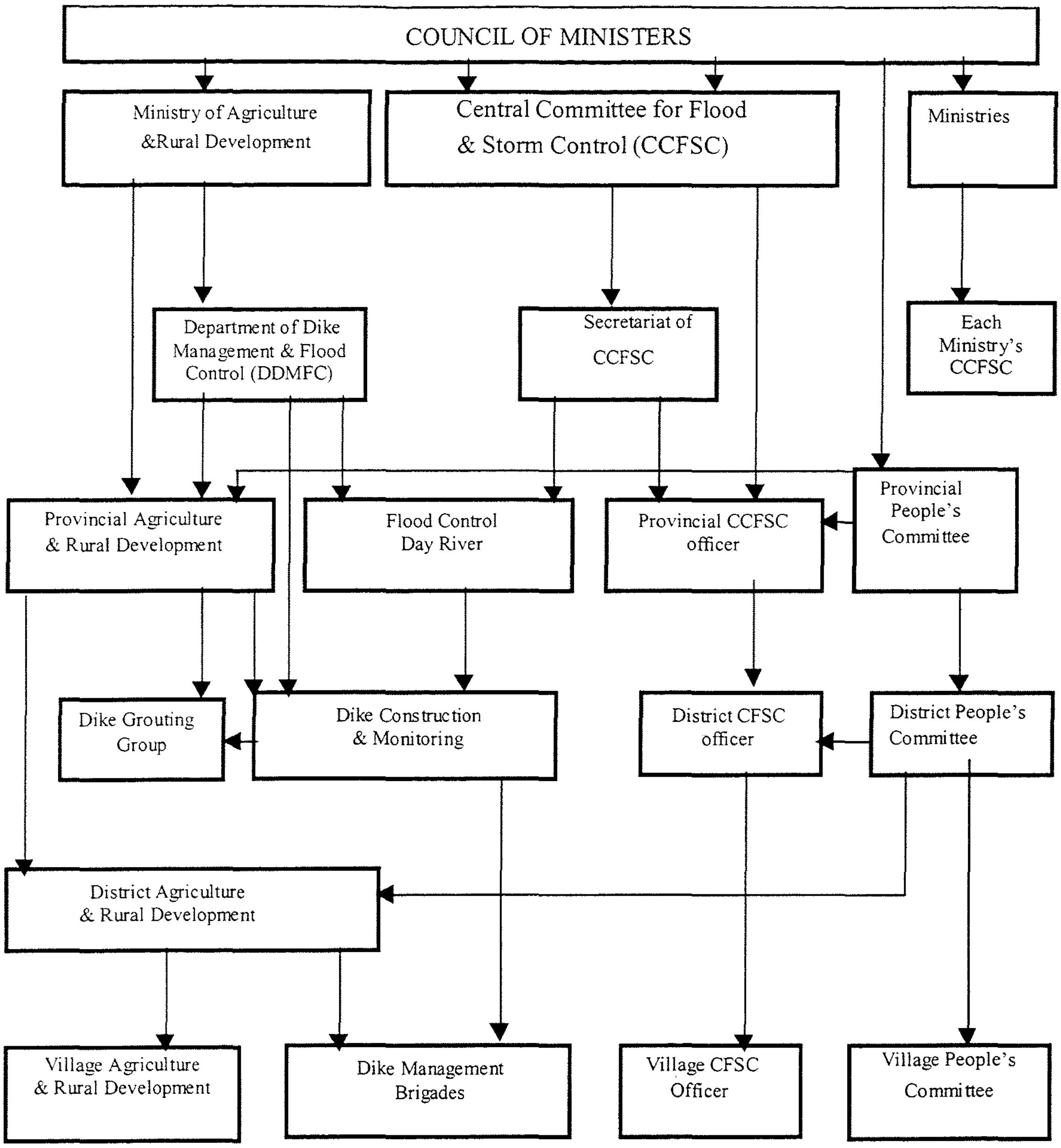


Figure 3.7: Vietnam institutional structure for combating flood and typhoons

(Source: UNDP, 1994)

CCFSC: Central Committee for Flood and Storm Control

DDMFC: Department of Dike Management and Flood Control

The CCFSC is chaired by the Vice-Prime Minister. The Minister for Agriculture and Rural Development is responsible for emergency responses just before, during and after the onset of the disastrous event. Its representatives are drawn from relevant government and non-government organisations.

III. Land management and planning

Strategies for water-disaster mitigation that do not rely on structural measures are gaining greater emphasis in Vietnam reports Le Huu (Le, 2000). For example, there has been a problem of population pressure causing unauthorised settlement in annually inundated floodways and in hazardous coastal areas e.g. Ba Dinh district and Hoan Kiem district in Hanoi. The rapid growth of economies and urban areas has also resulted in tremendous pressure on the management of land and water resources thus necessitating changes in the land-use planning concepts and particularly in flood control and management practices (UNDP, 1994).

In response, the government recently promulgated Statutes on Dike Management, Flood Mitigation and Typhoon Mitigation, which set out the responsibilities and power of the authorities for controlling developments in flood-prone lands and for preparing for floods and typhoons. However, the land-management authorities still need to develop the ultimate power to enforce appropriate land-care practices, and to specify matters such as minimum floor levels and structural requirements for houses in disaster-prone areas.

Through these controls, the authorities strive to ensure that an effective and comprehensive legal and administrative system is adopted which addresses the problems of land degradation, environmental protection, and the maintenance of ecosystems. Furthermore, for the system to be consistent with the principles of sustainable resource development, it will require an integrated approach to the management and protection of natural resources, including land, water, vegetation and human activity, undertaken on the basis of the total watershed. This approach recognises that changes to the natural environment in the upper watershed will influence conditions in the downstream areas (Le, 2000).

IV. Public awareness

Public awareness training and education are important for enabling people to use the warnings most effectively and maximise their safety response to the forecast emergency. Apart from those communities living near or having to care for the dikes, public awareness of the threat of water disasters is low even though the risk of flooding is very high in most parts of Vietnam. Furthermore, water-disaster mitigation is complicated by lack of adequate expertise to assess damage and emergency relief requirements. There is therefore a need for improved awareness of the threat of water disasters at all levels.

For emergency purposes each level from the Province, District and the village has some materials stored for emergencies e.g. gabions, geotextiles, bamboo etc. Drills are performed every year for the officials at all levels before the flood season sets in and every home in the flood prone area keeps two empty sacks for emergency sand filling. Radio and school programs are also used to educate the people.

V. Compensation and insurance

There is no flood insurance scheme for the people affected by a disaster. However, there are official government guidelines for providing emergency to people and their families. This varies from VND 300,000 (US$ 20) for injuries to VND 1.0 million (US$ 70.0) for dead relatives, VND 500,000 (US$ 35) per family for damaged houses to VND 2.5 million (US$ 180) for collapsed houses and 10 kg rice per person for up to 3 months. The Agricultural Development Bank also gives small low interest loans to farmers.

3.2.2.3 Structural measures

I. Dikes

The major physical method used to mitigate water disasters in Vietnam has been to build river and sea dikes. Dikes have been built in Vietnam for more than 1000 years to protect crops and other property against floods. The dike system in Vietnam has developed so that today there are approximately 5,000 km of river dikes and 3,000 km of sea and estuary dikes. These dikes are considered essential for the protection of the infrastructure and increased agricultural production, as adequate rice production for the increased population would be impossible without them. However, the use of dikes and floodwalls, in the rural areas and the urban areas respectively, has created a false sense of security about the degree of protection provided in the land area immediately behind them. People have as a result settled in the floodplains causing disastrous loss of life and property whenever floods exceeding the dike's level occur.

In the Red River Delta in the north, people have built 3,000 km of river dikes and 1,500 km of sea and estuary dikes to protect against flooding. Many of these dikes are old and are reported to be suffering distress due to local slumping, under-seepage and piping. Some authors attribute this to poor materials and inadequate compaction from the manual construction technology used. Dike grouting groups are each responsible for the geo-technical repair and strengthening of 50 km of the dikes. The construction of dikes has gradually reduced over-bank areas which used to be available for excess flood flows, with the result that river levels have become higher and higher as explained in section 3.2.1.3. Up to 1971, the river dikes were built to the highest flood level known. These were then raised when higher floods were experienced. However, that policy changed with the 1971 flood, estimated to be of 1/125 years magnitude, when it was decided that the height of the dikes would not be increased again. Rather, more emphasis would be put on flood diversion schemes (UNDP, 1994).

In the Mekong Delta, which is largely unprotected and therefore characterised by widespread, uncontrolled and prolonged floods, some low dikes provide partial protection to agricultural production during the early part of the rainy season. A system of drainage channels and pumping stations are used to make agriculture possible.

Ring dikes and submersible dikes

For cities and towns like Hanoi that are situated near the rivers or in the floodplains, and where there is high population and high value property at risk, ring dikes are used for flood protection. Submersible dikes (low dikes) like those in Mekong delta are used to protect crops against early flood damage before harvesting.

II. River training works

River training works are used in various sections of the rivers to modify the hydraulic conditions of the watercourse or the floodplain and/or flood channels constructed within the floodplain. Riverbank protection works have also been implemented to minimise the impact of changes in meandering river channels (UNDP, 1994).

III. Floodways and river diversion

Flood and river diversions are being increasingly accepted to protect major cities or urban areas. However, the topography of the area and the availability of low-value land that can be used for the floodway limit opportunities for the construction of flood diversions (Le, 2000).

For example, a 20 km canal diverts floodwater when the level rises above 13.65 m from the Red River southwards at Son Tay, some 35 km upstream of Hanoi to the Da River (Figure 3.8). A dam was built under the French to regulate this flow but was only upgraded to an adequate standard in 1975. The Da Channel carried only 60 per cent of the flood diversion capacity of 5,000 m^3/s when bypass flood-way was installed. However, because of infrequent use of the diversion, people have overlooked its hazardous nature and settled in its floodplains. With a population in this area of about 500,000 people, the amount of flow that can be diverted to the river has now been restricted thus reducing the effectiveness of the system.

Duong River is a 63 km diversion canal (939 m^3/s) 200 to 300 m wide excavated over 600 years ago just above Hanoi city to divert up to 30% flood waters from Red River (3710 m^3/s) to Thai Binh River.

In the Mekong delta, 7 main canals like the Vinh Te canal divert floodwaters directly into the sea.

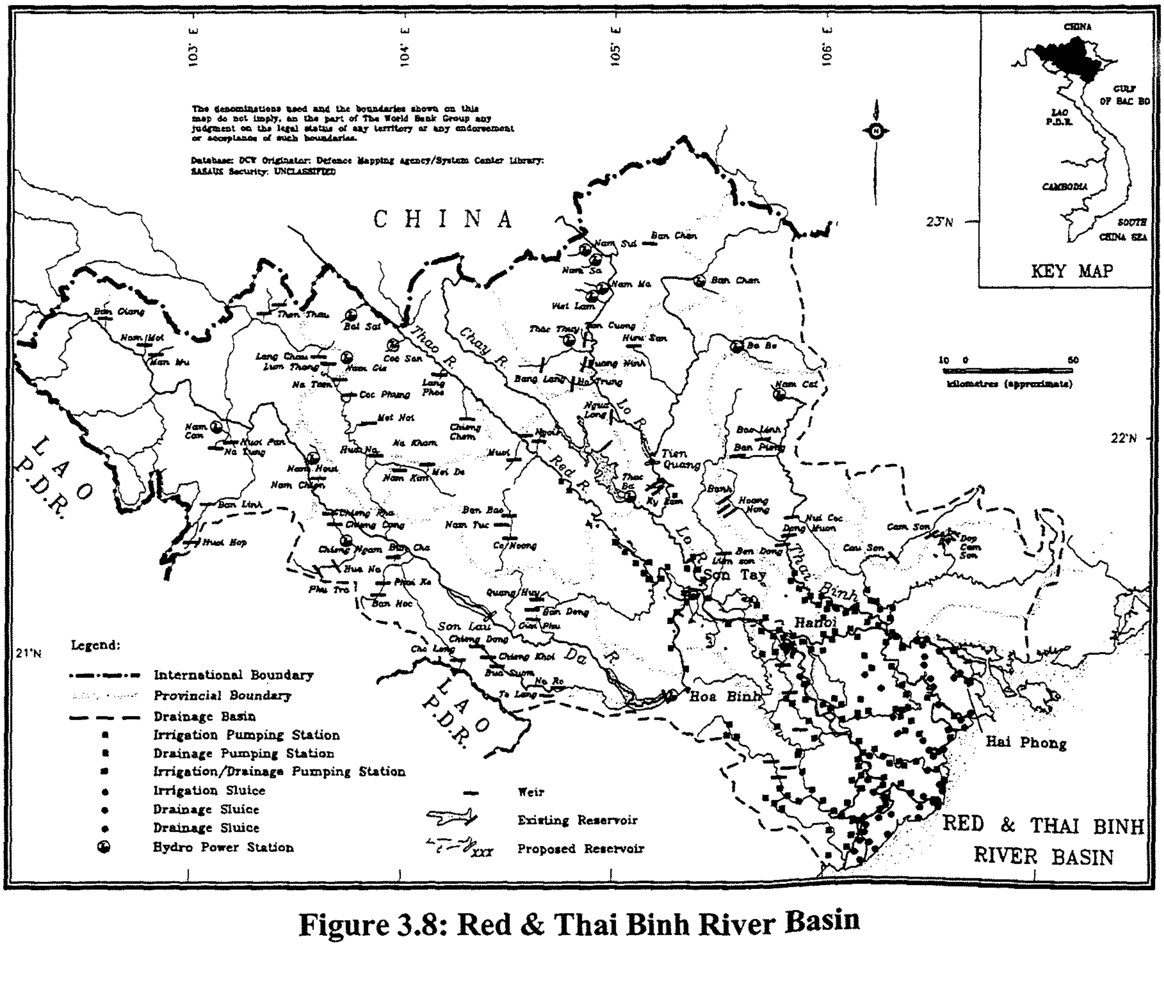


Figure 3.8: Red & Thai Binh River Basin

IV. Flood mitigation reservoirs

Flood mitigation reservoirs like Hoah Binh on the Da River (Figure 3.8) were the most commonly adopted measures for flood control in the Red River region prior to the 1980s (UNDP, 1994). The construction of major reservoirs for multipurpose use has been reported to lead to better regulation of the flow regime minimising the flooding potential downstream. However, the large areas of land required to store the flood flows of major rivers are generally no longer available, especially where they involve the flooding of valuable agricultural lands. Many sites that are geologically and topographically suitable for reservoir construction are densely populated and therefore require very considerable and expensive land acquisition and the displacement of large populations. This can generally only be justified where the reservoirs protect heavily developed urban areas and only if they are the only practical means for reducing flood damage significantly.

In the central provinces and the northern mountainous areas, flash floods are a frequent phenomenon. The area lacks flood control and drainage infrastructure but because of the problems associated with the dikes in the north, provincial authorities are focussing more on forecasting and warning systems, and multipurpose reservoirs upstream (Figure 3.8) like Thac Ba, Dinh Binh, Dau Tieng and Don Duy reservoirs.
(http://www.undp.org.vn/dmu)

V. Retarding basins and flood storage areas

Flood storage and retarding basins are used to reduce the flood peak at downstream locations and confine flooding to areas within the flood control system. These simple structures have no permanent impoundment and the reservoir space is held empty by a low-level, ungated outlet, the size of which is set at a specified maximum outflow rate. The most basic type has an automatic discharge controlled by a spillway or a series of outlets at different elevations in the dam. It is a self-regulating system and the reservoir automatically empties after each flood and is then ready to receive the next inflow.

The system is reported to be quite effective for small floods but for the large floods, much of the storage space is taken up before the peak arrives so the reduction of the peak is not as much.

The low lands along the Da River and natural depressions on the floodplain are utilised for the off-river storage of floodwaters. The land within the retention basins is used for agriculture or other low-intensity purposes during the no-floods season but is not suitable for buildings or similar investments. This flood mitigation method is being increasingly adopted to mitigate urban flooding, flash flooding and riverine flooding as the retarding basins also play a role in the improvement of water quality by removing the floating debris and allowing the sediment to settle (Le, 2000).

3.2.3 Socio-cultural justifications for the strategies used to cope with floods

3.2.3.1 Historical perspective

Vietnam has developed as a nation by exploiting the low-lying river deltas and coastal lands for wet-rice agriculture. Rice is a primary staple food for the Vietnamese people. It sets the basic rhythm of the land thus much was placed upon ceremonies dealing with rice and the agricultural cycle. Rice is Vietnam's treasure, the prize sought by all its conquerors, either directly or indirectly (Walter J. Sheldon, 1969). It grows in the two vast fertile deltas and in most outlying areas more plentifully than in most other parts of the world. In the Mekong River delta for instance, about 10,000 square kilometres are under rice cultivation, making the area one of the major rice-growing regions of the world.

The Mongoloid Vietnamese tended to settle on the coast and in the valleys to fish or raise crops quite oblivious of the floods. The Chinese, attracted by the rice, went to Vietnam in 111 BC, overthrew the Kingdom of Nam Viet and made it a province of China. They imposed Chinese laws, brought Chinese agricultural methods and introduced Chinese religious practices. So strong were the Chinese that their influence was not only felt in such scientific improvements as the use of the plough and water buffaloes and the employment of more elaborate methods of irrigating the rice fields but also in the cultural matters.

3.2.3.2 Cultural perspective

I. Mythology

The cause of the floods and their inevitable acceptance has been justified over the generations by way of a mythology. Mythology has it that the heavy rains and the typhoons are caused by the Mountain King who has supernatural powers to create storm surges and raise mountains, and the Water King who has supernatural powers to make strong winds and heavy rains. They have been fighting over the beautiful daughter, Princess Mi Nuong, of the 18th King of the Hung Dynasty, whom they both wanted to marry but she was married to the Mountain King. Each year, the Water King sends heavy rains and typhoons and every year the Mountain King resists this.

II. Way of Life

Before the late 1800s, nearly all the people of Vietnam lived in villages and the cultivation of wet rice was the principal economic activity. Flood management structures have evolved over centuries as the Vietnamese population developed the agricultural potential of its great river deltas.

III. Chinese Cultural Impact

As mentioned above, the Chinese, attracted mainly by the rice, went to Vietnam in 111 BC, overthrew the Kingdom of Nam Viet and made it a province of China. In order to facilitate administration of their new territories, the Chinese built roads, waterways, and harbours, largely with corvee labour (unpaid labour exacted by government authorities, particularly for public works projects).

Agriculture was improved with better irrigation methods and the use of ploughs and draft animals, innovations which may have already been in use by the Vietnamese on a lesser scale. New lands were opened up for agriculture, and settlers were brought in from China. After a few generations, most of the Chinese settlers probably intermarried with the Vietnamese and identified with their new homeland.

3.2.3.3 Social perspective

The following are some of the factors that have made the Vietnamese adopt the 'living-with-flood' strategy:

- Rice is a primary staple food for the Vietnamese people. Rice sets the basic rhythm of the land. It grows in the two vast fertile deltas and in most outlying areas more plentifully than in most other parts of the world. These same areas happen to be prone to flooding. It is no wonder then that most of the population lives in areas susceptible to flooding.
- Community participation in social activities considered a key factor for success.
- Problem of population pressure is causing unauthorised settlement in annually inundated flood-ways and in hazardous coastal areas e.g. Ba Dinh district and Hoan Kiem district in Hanoi.
- Social and economic development strategies centred on flood control experience and practices (Le, 2000).

Though the people have by and large accepted to live with floods, it has not been always easy for many of them to cope. With limited social security, the social consequences of a disaster are even more profound than in developed countries. The families suffering a loss of household property frequently also have their crops destroyed and as a result their employment and livelihood are impaired. Such families have to move away temporarily or even permanently to live with their relatives thus causing disruption and disorientation. Further, the health of the community is also affected as floodwaters invariably carry infectious diseases and there is frequently a shortage of potable water and food following a flood (UNDP, 1994). Worse still, many people who suffer a water disaster already know that this may recur next year. They therefore live in constant apprehension of the effects of such a disaster.

3.2.3.4 Political perspective

The government of the day has always been directly involved with flood control matters given the importance of agriculture in Vietnam:

1) It is the backbone of Vietnam's development strategy
2) Rice is Vietnam's greatest resource accounting for 40% of the national food production
3) Rice grows more plentifully in the two vast fertile deltas that are subject to flooding
4) Social and economic development is centred on rice

It is notable that as early as 1472, Emperor Le Than Tong, who ruled the traditional society with the "mandate of heaven", appointed two mandarins (scholar-officials); one to look after the dikes and the other to look after the irrigation systems. These mandarins then delegated other mandarins to look after the dikes and irrigation systems at different levels right down to the level of the village.

Even today, the Government is involved in formulating relevant strategies to meet the needs of the community in the face of the rapid social, economic and technical changes currently taking place as the country moves from a planned to a market economy. Only a few years ago, people protected by the dikes were required to donate 20 workdays per year to maintain the dikes, which was a demonstration of their social commitment. In 1993, that commitment had fallen to only 10 days and is expected to continue falling. It is evident that economic pressures on the government and alternative economic opportunities for labourers have made this level of human resource commitment difficult (UNDP, 1994). Consequently, according to the UNDP report, the government has now focussed on the following water-disaster mitigation tasks:

- Improving forecasting and warning systems and the public awareness
- Improving preparedness and mitigation at the national, provincial and community levels, and
- Strengthening the systems of emergency response and relief

The Minister for Agriculture and Rural Development chairs the Central Committee for Flood and Storm Control (CCFSC) that draws it representatives from relevant government and non-government organisations.

3.2.3.5 Technical perspective

Historically, thousands of trained water professionals and millions of labourers have worked annually to maintain the flood infrastructure. The traditional Vietnam culture of disaster protection has also over the years provided willing, dedicated and motivated disaster mitigation officials at all levels of government with the necessary capability to apply the technology, teach, instruct and conduct actual field testing to make it effective.

This has not been without its problems though. Many of the existing earth dikes, which were constructed manually, are old and are no longer adequate to cater for the magnitude of floods being experienced today. The channelling of major rivers has also confined the floodwaters so that they are now higher than before. This puts increasing loads on the dike systems causing them to suffer from piping, slides and local collapse in spite of the strengthening and repair work done every flood season (UNDP, 1994).

3.2.3.6 Economic perspective

The overall objective of Vietnam's Socio-economic Development Strategy, as stated by the government, is to put people at the very centre of development. While stability is the highest priority of the State, it is recognised that in order to ensure stability, economic growth needs to continue, be equitable and benefit all levels of society.

Losses from flooding are a serious annual event in Vietnam. In studies for the UNDP, it was estimated that the average annual losses in the Red River Delta and along the Central coast could reach substantially more than US$130 million. For Hanoi alone, a subsequent, more rigorous Asian Development Bank study for the area protected by the dike found that the average annual damage from flooding amounted to well over US$50 million per year (UNDP, 1994). The extent and cost of disastrous flooding have been increasing as a consequence of growing populations, denser occupancy of floodplains and other flood-prone areas and the expansion of unwise forms of watershed land use (Le, 2000).

In spite of the above, lack of funding from the general government budget has of late been a major constraint in improving the warning system and flood protection (World Bank Report, 1996). The Government views flood protection as a service to the general public and thus no special tax exist at the local, provincial or national level for the flood control purposes. Rather, the finances have been coming from the general budget. However, because the Government budget is severely constrained, a new Flood and Typhoon Control Fund has recently been established and so far 42 out of 61 provinces have agreed to participate. Under this scheme, all people protected by flood mitigation works must pay 14,000 Dong (1.0 US$) or 5 kg of rice each year. All these funds will be used for maintenance of the flood control structures and disaster relief.

The strength of the economy has been instrumental in considering the strategies to be adopted. In the Mekong delta where the floods are prolonged and widespread because the area is largely unprotected, the 1994 Master Plan (UNDP, 1994) concluded that it was neither economically justified nor environmentally sound to provide complete flood protection. It instead recommended:

- Low embankments in the deeply flooded lands to protect against early floods
- Full dikes in shallow flood agricultural areas to protect against 10-year floods
- No dikes on land that has potentially serious acid-sulphate problems

With alternative economic opportunities for the labourers, the cheap labour that used to be easily available is now scarce. As noted elsewhere in this report, only a few years ago people protected by the dikes are no longer able to donate 20 workdays per year to maintain the dikes as before. This calls for a new approach in the mitigation of water disasters in Vietnam.

3.2.3.7 Environmental perspective

I. Deforestation

Natural water disasters in Vietnam have been aggravated by environmental degradation. Forest cover in the country, for example, shrunk from 44% of the total national land area in 1943 to about 28%. The quality of the forest in terms of diversity has also deteriorated drastically with the indigenous forests reducing at the rate of 100,000 to 200,000 ha per annum.

In the hills and mountains, deforestation has substantially increased erosion, siltation and runoff, so that peak flood levels are higher and arrive sooner than they used to. Because of the extra runoff in the rainy season, there has been less water infiltrating into the ground. This reduces dry-season flow downstream and leads to severe water shortage and seawater intrusion.

Along the coast, mangroves and coral reefs have been removed exposing coastal settlements to more typhoon winds and waves than before. Two existing dams along the Mekong River have been reported to have a negative effect on the environment flooding certain areas and destroying fish habitats, which has affected the fishing industry of the native villagers (World Bank Report, 1996).

For these reasons, activities on water-related disaster reduction are conceived as an important part of an environmental management strategy for sustainable development and account for a major share of resources allocated to the national programme on water resources management. The authorities appear to have noted seriously the fact that unless consistent and co-ordinated strategies for water-disaster mitigation are developed and implemented, the annual water-disaster related losses are bound to increase (UNDP, 1994).

II. Acid-Sulphate soils in the Mekong Delta

In the Mekong delta, acid-sulphate soils cover 40% of the Vietnamese part. From an environmental point of view, these wetlands could best be left untouched thus the delta is largely unprotected except for some low dikes that provide partial protection to agricultural production during the early part of the rainy season (UNDP, 1994).

III. Global climatic changes

Global warming could have serious consequences for it is likely to cause sea level rise, changes in the intensity and the potential for extreme weather events such as typhoons, floods and cold outbreaks. Studies by Vietnamese scientists have shown that the northern region, especially the Red River Delta, is the most sensitive to present-day climate variability. Rainfall fluctuations are strongest in this area causing unpredictable drought and flooding. The vulnerability of southern regions is likely to rise as global warming develops.

It is anticipated that the number of heavy storms and typhoons to hit Vietnam will increase both in number and intensity with global warming.

3.2.4 Flood protection policy

The Government through the Ministry of Water Resources of Vietnam has been at the forefront in formulating a flood protection policy. In order to gain a better understanding of water-disaster problems in Vietnam, the Ministry has been working together with the United Nations Development Programme (UNDP), the United Nations Department of Development Support and Management Services (DDSMS/DESD) in association with the United Nations Department of Humanitarian Affairs (DHA/UNDRO). For example, in June 1992, an international workshop on flood mitigation, emergency preparedness and flood disaster management was organised in Hanoi. A multidisciplinary team of water-hazard experts synthesised the results of the workshop and prepared a Strategy and Action Plan for Mitigating Water-Disasters in Vietnam, which the government and the UNDP later adopted this as the official flood policy.

3.2.4.1 The Recommended Strategy

The adopted strategy and action pan for water-hazard mitigation in Vietnam has the goal to foster the sustainable development of areas prone to water disaster as set out in the following objectives:

1. **Social:** To reduce the loss of life, injury, trauma and social disturbance caused by water disasters to an acceptable level.

2. **Economic:** To increase the economic benefits from the use of areas prone to water disaster.

3. **Environmental:** To improve the environment by restoring the degraded areas.

For the strategies to be relevant to the needs of the community, the Government sees the work of water disaster mitigation as being a three-fold task:

- ♦ Improving forecasting and warning systems and the public awareness
- ♦ Improving preparedness and mitigation at the national, provincial and community levels
- ♦ Strengthening the systems of emergency response and relief

Projects have therefore been formulated for funding and implementation depending on whether the task is 'physical' for those that are predominantly to do with equipment, structures and materials or 'non-physical' for those that are concerned with such matters as attitudes, organisational structures, procedures, investigations and training.

I. Forecasting and warning systems

The project aims at providing physical warning systems for the flash-flood prone mountains, for the monsoon-prone deltas and for the typhoon-prone oceans to give up to 12 hours or more of time to prepare endangered populations and property for the impending water emergencies. This is expected to provide reliable and early water-disaster forecasting which will substantially reduce loss of life and property damage.

Non-physical methods of public awareness training and education will also be provided to enable people to use the warnings most effectively. In this way they can maximise their safety response to the forecast emergency.

II. Preparedness and mitigation

Historically, water-control structures have been the method used in Vietnam to protect against flooding, and much work is required to maintain and to improve these structures. The project is involved with physical construction, upgrading or rehabilitation of water-disaster control structures such as dikes, the control of the behaviour of waterways, watershed management and setting up of an emergency communications system to speed up the repair of these structures under conditions of impending failure.

Non-physical activities at the national, provincial and district levels are planned for preparing and promulgating water laws to limit unsustainable development on disaster-prone lands. In addition, they are to introduce insurance against loss inflicted by water disasters, schemes for generating funds for the self-financing of mitigation works in disaster-prone areas and institution building for water-disaster preparedness.

III. Emergency relief

Case histories show that affected people carry out over 50% of their own relief work after a disaster often before relief workers can get to the site. To promote and strengthen this capability, the project proposes the physical stockpiling of equipment and repair materials combined with training in their use at regional disaster centres located adjacent to the most water-disaster prone areas of the country. The Disaster Management Unit is responsible for developing manuals for preparing emergency plans, procedures for mobilising the population and for emergency repair (UNDP, 1994).

IV. Disaster Management Unit

The Vietnam Disaster Management Unit (DMU) is the mechanism chosen by the Government of Vietnam and the United Nations Development Program to join together over 1000 years of Vietnamese flood protection culture with twenty-first century western technology. Its main objective is to protect in a better way the entire population of Vietnam against the annual natural disasters that ravage the country (http://www.undp.org.vn/dmu).

Through the DMU, the UNDP supplied the following technology: a computer based emergency warning and disaster damage reporting system (DMUnet), a GIS based information system of disaster management and relief needs data (DMUgis) and a Web based public information system (DMUweb). The new technology utilises modern strategies for decision making to better deliver emergency relief and to better allocate scarce resources for rehabilitation.

3.2.4.2 The Recommended Action Plan

To achieve the maximum benefits from the recommended strategy above, it was proposed that the natural synergies between the tasks be fostered. This would achieve more in mitigating water-disasters than if each task was undertaken in isolation (UNDP, 1994).

To this end, the first goal of the Action Plan was to introduce the Strategy and Action Plan to domestic and external agencies concerned with water-disaster mitigation. This was fostered by the preparation of project profiles that outline for each task area the objective, background, duration, justification and resources needed to achieve water-hazard mitigation.

The second goal of the Action Plan was to enhance sustainability. This was done by building into each project a component of self-financing of ongoing operations and maintenance.

The third goal of the Action Plan was to help protect the environment. This was achieved by integrating medium-term and long-term Vietnamese environmental goals into the project profiles.

All goals of the Strategy and Action Plan were enhanced through ongoing co-ordination and co-operation between domestic and external agencies working in the water sector of Vietnam. The Action Plan provided a mechanism for this co-ordination and co-operation.

In addition, the following measures were recommended for long-term development after the severe flood in 1998 and particularly the extreme floods of 1999.

- Prepare plans for residences after the floods, of which the top priority is residences for people in frequently deep-in-flood area of the Central. Increase household prevention and response capacity. All the schools, clinics and headquarters of communes need to be built solidly
- Increase the height of the road surface and widen the aperture of roads, sluices, and bridges for faster flood drainage
- Protect reservoirs (especially the big reservoirs) and increase the solidity of the important canals, protect the large residential and urban areas, and implement the safety-increasing programs
- Implement afforestation and forest protection measures and ban forest resource exploitation.
- Increase the response capacity at all levels to immediately cope with flooding situations and increase self-help ability at all levels

These strategies are to be reviewed and updated every 5 years.

3.3 Case Study 2: China

3.3.1 Specific features of the country and its rivers

3.3.1.1 Geographical features

China, which has an area of approximately 9.6 million square kilometres, stretches some 5,000 kilometres across the East Asian landmass in an erratically changing configuration of broad plains, expansive deserts and lofty mountain ranges, including vast areas of inhospitable terrain (Figure 3.9). The eastern half of the country, its seacoast fringed with offshore islands, is a region of fertile lowlands, foothills and mountains, desert, steppes, and subtropical areas. The western half of China is a region of sunken basins, rolling plateau and towering massifs, including a portion of the highest tableland on earth.

The total population estimated (official estimate) at the end of 1986 was 1.1 billion with 1.4 percent annual growth. Urban population was also officially estimated at 382 million by end of 1985, or 37 percent of total. About 94 percent of population live on approximately 36 percent of Land.

Most of the country is in the temperate belt with complex climatic patterns ranging from cold-temperate north to tropical south. Precipitation varies regionally with alternating wet monsoon in summer and dry monsoon in winter. For example, Qin Ling in the south of China experiences abundant rainfall, most of it coming with the summer monsoons. To the north and west of the range, however, rainfall is uncertain. The farther north and west one moves, the scantier and more uncertain it becomes. The Northwest has the lowest annual rainfall in the country and no precipitation at all in its desert areas.

Temperatures range from minus 30°C in the north in January to 28°C in the south in July. Monsoon winds, caused by differences in the heat-absorbing capacity of the continent and the ocean, dominate the climate.
(http://lcweb2.loc.gov/frd/cs/cn.html)

3.3.1.2 Hydrological features

The Chinese mainland consists of seven major rivers namely the Yangtze River, Yellow River, Pearl River, Haihe River, Huaihe River, Liaohe River and Songhuajiang River (Figure 3.10). All these principal rivers rise from the Himalayas and the Kunlun Mountains, and the Gangdise Shan (Kailas) and the Tian Shan ranges. In all the seven river basins, flood disasters happen widely during the flood seasons and may concentrate either in the south or in the north (Zhu, 1999).

Figure 3.9: Map of China

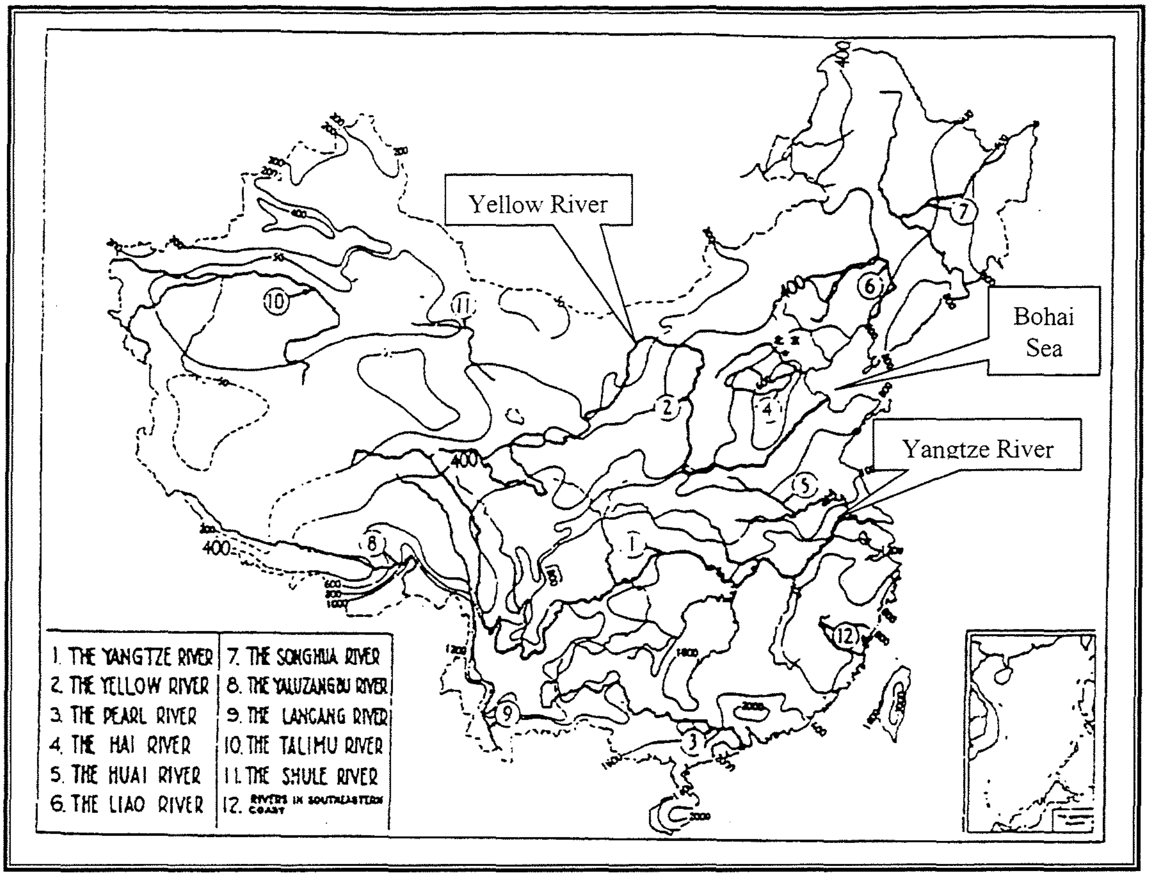


Figure 3.10: Major Rivers in China

I. Yangtze (Chang Jiang) River

Yangtze River in china is the longest river of Asia measuring approximately 6,300 km in length. It rises in the Kunlun Mountains in the southwestern section of Qinghai Province (an elevation of about 4900 m), and flows generally south through Sichuan Province into Yunnan Province, where, in the vicinity of Huize, it bends sharply to the northeast. Then, it flows generally north-east and east across central China through Sichuan, Hubei, Anhui, and Jiangsu provinces to its mouth in the East China sea, about 23 km north of Shanghai (Figure 3.10).

Yangtze River is the most important waterway, navigable over much of its length and has a vast hydroelectric potential. Oceangoing vessels may navigate the river to Hankou, a distance of almost 1000 km from the sea. For about 320 km inland from its mouth, the river is virtually at sea level. It drains an area of 1.8 million square kilometres before emptying into the East China Sea. Over 300 million people live along its middle and lower reaches mainly cultivating rice and wheat.

During periods of heavy rains, two lakes - Dongting Hu and Poyang Hu - receive some of the overflow of the Yangtze. Despite these outlets, floods caused by the river occasionally have caused great destruction of life and property. In 1994, construction began on the massive Three Gorges Dam near Yichang. Scheduled for completion in 2009, the dam will measure about 180 m high and about 2.5 km wide.

The dam is expected to help control the flooding of the Yangtze River valley; in addition, river flows will make the Three Gorges complex the largest electricity-generating facility in the world. A lake about 650 km long will form behind the dam, forcing the relocation of more than 1 million people and permanently flooding many historical sites.

II. Yellow (Huanghe) River

Yellow River is the second largest river in China after the Yangze, with a total length of 5,500 km and an area of 752,000 km^2. The Yellow River rises in northern China in a series of springs and lakes in the Kunlun Mountains in Qinghai Province, south of the Gobi Desert and passes over the largest Loess Plateau of the world (Figure 3.9 and Figure 3.10) where it collects a lot of silt.

Figure 3.11: Alluvial plains of the Lower Yellow River

At the city of Kaifeng, the river enters the plains and changes from a torrent to a meandering stream with a broad channel enclosed by dikes. The dikes were built over a period of centuries to control the river and prevent floods. With time, the large amount of sediment carried by the river mainly during the flood season has silted up the riverbed raising the level of the river by 3-5 m on the average in the last 50 years, thus increasing the risk of flooding. As a result, in many portions of the lower or east course, the river is as much as 21 m above the surrounding plain and when the river level rises, disastrous floods occur as the flood-carrying capacity of the river decreases with the increasing height of the riverbed. Deforestation of the mountains in the upper part of the course of the river has also contributed to the flooding problem through increased runoff and thus increased flood heights.

The floods of the Yellow River are mainly two types: rainstorm-caused floods and ice floods. The rainstorm floods cause the greatest hazards in the Lower Yellow River and have been so frequent and so devastating that the river has often been referred to as 'China's sorrow'- a river of misery (Zhu, 1997). The worst flood in the history of the river occurred in 1931 when some 88,000 km^2 of land were completely flooded and about 21,000 km^2 more were partially flooded between July and November. About 80 million people were reported homeless and about 1 million died in the flood itself and in the famines and epidemics that followed. As a result, efficient flood protection measures were sought to prevent breaching and overflowing of the dikes without necessarily having to heighten the dikes frequently in order to maintain the flood-discharging capacity of the channel.

With a total drainage area of 752,000 km^2, the Yellow River valley has abundant resources and a large population. The Han people have farmed the rich alluvial soils since ancient times as confirmed by thousands of archaeological findings which provide evidence about the Shang dynasty, which endured roughly from 1700 to 1027 BC.

The social and economic development in this area occupies a decisive position in the overall national economy, as it is an important base for the production of grain, cotton, energy, and heavy and chemical industries.
(http://lcweb2.loc.gov/frd/cs/cn.html)

The basic characteristics of the Yellow River are the small volume of water and the high concentration of sediment claimed to be as much as 70%. Actual observations made at Huayuankou near Zhengzhou City show an average annual discharge volume of 47.0 billion cubic metres and sediment discharge of 1.6 billion tons - 3 times that of Yangtze (Brush, 1989). The unbalanced proportion of water and sediment and the nature of high sediment concentration are the fundamental causes for the continuous deposition of sediment in the lower part of the river and the problems with flooding, dike breaches and avulsions. Moreover, major floods originate and are concentrated in the mountainous and the rolling areas on the middle reaches of the river. The lower Yellow River adds only 3% to the total catchment since the section of the river is suspended and floods on the lower reaches do not occur at the same time as the major floods from the middle reaches.

III. Other rivers

The Haihe, like the Pearl River (Xi Jiang) and other major rivers, flows from west to east. Its upper course consists of five rivers that converge near Tianjin, then flow seventy kilometres before emptying into the Bo Hai Gulf. Another major river, the Huaihe, rises in Henan Province and flows through several lakes before joining the Yangtze (Chang Jiang) near Yangzhou. These rivers (Figure 3.10), though having a flood problem too, are short and have a smaller catchment area compared to the Yellow and the Yangtze Rivers and therefore were not selected as case studies.

3.3.1.3 Flood control capability of the seven major rivers

With the existing flood control measures, the seven major rivers have the capability to accommodate flood for various recurrence periods as given in Table 3.4 below: The cities on the other hand are mostly protected to withstand 100-year recurrence flood.

Table 3.4: Flood recurrence interval (years) of the rivers

River	Flood Recurrence (years)
Yellow (lower) 22000 m^3/s	60
Yellow (upper)	100 after Xiaolangdi project
Yangtze (lower)	10 – 20
Haihe	50
Huaihe	40
Pearl	20
Songhuajiang	10 - 20
Liaohe	10

3.3.1.4 History of floods

As stated in section 3.1.2 above, China, as one of the world's oldest civilisations, has a deep history of flood control. According to historical records, some of the earliest Chinese efforts to tame rivers date as far back as 2200 BC when the Great Emperor Yu was credited with saying, "Whoever controls the Yellow River controls China." Legend therefore has it that he was made Emperor for being the first to "tame" the River. Evidence of Yu's insight can be seen throughout Chinese history, as rulers gained and lost power in concert with their control of the river. Control over the river system has proven to be an integral part of China's history (Cohen, 1997).

Based on historical records (Table 3.5, Table 3.6), 1029 times of heavy flood disasters and 1056 times of drought disasters happened during 2155 years from the year 206 BC to 1949 AD. In the old days, each time a large flood disaster occurred, it affected several million to several 10 million people due to flood induced epidemic diseases and homelessness often leading to long term social disturbances. In the last 50 years, about 4.6 million ha of farmland are flooded each year reducing the grain production by over 30%. For example, the 1954 Yangtze flood killed 31,000 people, destroyed 2.2 million houses and inundated 1.8×10^6 ha of cropland. However, since the 1960s, with the more emphasis on flood control projects, ordinary floods have been preliminarily controlled and the flood-affected areas greatly reduced (Li, 1999).

Table 3.5: Statistical flooding data of Yongding River

Dynasty	Year (AD)	Burst	Overflow	Change of course
Liao	907 – 1125		1	
Jin	1115 – 1234	3	1	
Yuan	1271 – 1368	8	9	
Ming	1368 – 1644	20	9	1
Qing	1644 – 1916	44	34	8
Republic of China	1912 – 1949	6	6	
Total		81	60	9

Source: Li, 1999

Table 3.6: Typical historical flood records of the Yellow River

Year	Maximum discharge (m^3/s)	Area inundated (km^2)	People displaced or killed	Property damage
1117			>1,000,000 killed	
1761	32,000			
1843	36,000			15,000 villages
1887		750,000		
1889			1,000,000	1,500 villages
1933	22,000	8,600	3,600,000 (18,300 killed)	3,000 villages
1938		40,000	3,900,000 (890,000 killed)	
1958	22,300	1,700 villages		

3.3.2 Measures and methods used to cope with floods and the justifications

Many outstanding persons have made proposals over the years on how to deal with floods in China thus contributing to the historical experience of harnessing the Yellow River.

Mr. Jiarang who lived about 6 BC was against the use of the old dikes to defend against the floods (Brush, 1989). He instead proposed that the old dikes be discarded and the river channel be directed northward to empty into the sea. Another way would be to divert the floodwaters and scatter into depressions.

Mr. Wangjing proposed in 69 AD the dredging of the waterways, removal of obstructions, renovation of the dikes and reconstruction of canals and the sluice gates.
Mr. Panjixun in the 16th Century proposed a dike system for correcting and concentrating the river flows to carry the sediment. He created the dike system for training the river; interior levees for the channel control and the exterior dikes for flood control.

The Yellow River Conservancy Commission (YRCC), which was started in 1946, now advocates the strategy: *"Retain water in the upper reaches, Release it in the lower reaches and Detain it along the banks of the river"* (Zhu, 1997). These strategies and measures and their justifications are investigated here below:

3.3.2.1 Living- with- flood measures

I. Living in Flood Storage and Detention Areas (FSDA)

Flood Storage and Detention Areas (FSDA) generally refer to the low lands and lakes outside of river dikes where historically flood frequently inundated, and therefore can be used for temporary storage of the excess floodwaters. It is an important component within a river flood prevention system and also an important measure to safeguard crucial regions from flood calamity and alleviate flood damages.

It is said to be a realistic and economically effective means to regulate flood in rivers where the following factors prevail (Li, 1999):

- Due to the low discharge capacity of the major rivers (only able to meet 30 to 40-year recurrence flood), it is impossible to discharge greater flood by only relying on river embankment
- When flood discharge capacity downstream of the river is not adequate to cater for higher return period floods
- When its not technically and economically feasible to raise and widen dikes without limits or construct more reservoirs upstream to control rarely occurring great floods
- It is not rational to use scarce resources to construct permanent but seldom used works

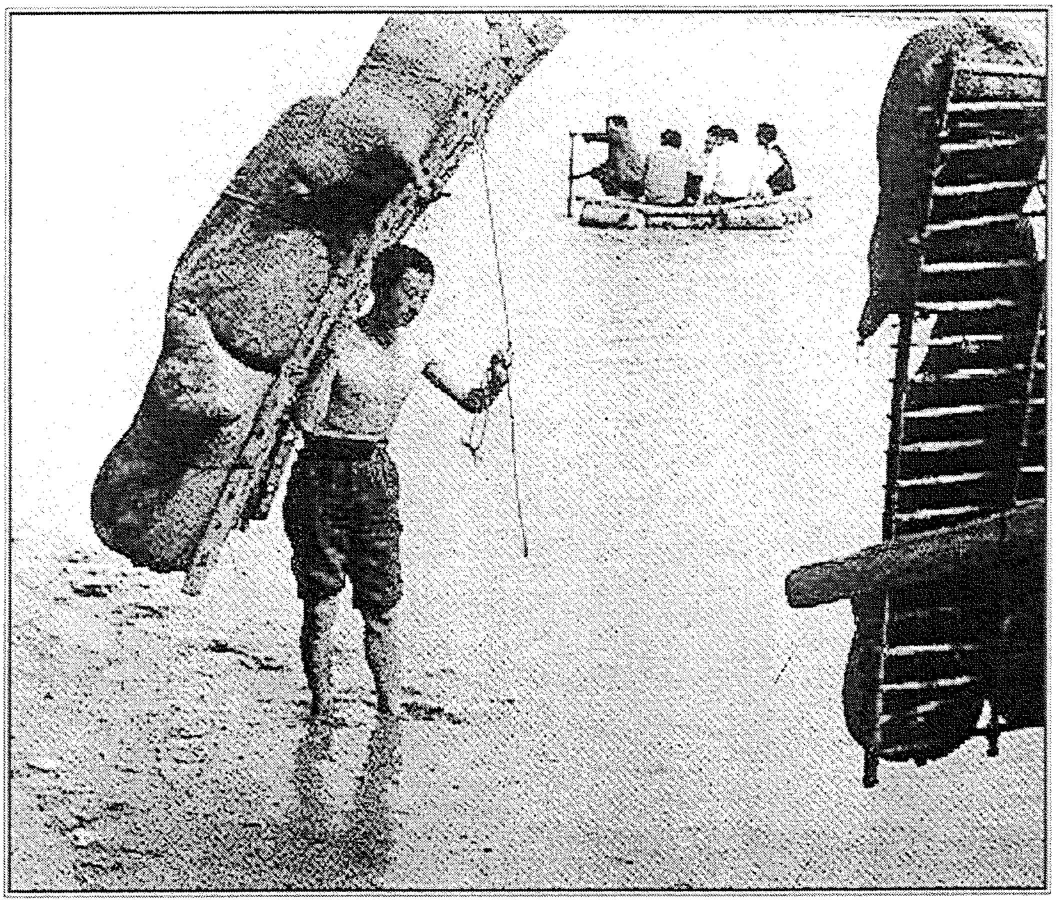


Figure 3.12: Living by the Lower Yellow River using goatskin raft

China has a long history of using existing lakes and lower lands along the rivers for flood storage and detention (Li, 1999). As early as the Warring States period, some persons proposed that the places without grass be used as bags - meaning to store water. There are 98 FSDA with a total flood storage capacity of 100×10^9 m^3 along the Yangtze River, Yellow River, Huaihe River and Haihe River, covering 34,500 km^2.

A total of 26 million people (522 persons per km^2) are living along the lower parts of the Yellow River (Figure 3.12), its floodplains and the FSDA cultivating 2 million ha of land. There are 5 FSDA in the lower Yellow River, namely Fenqiu Dagong, Beijindi, Dongpinghu, Beizhan and Nanzhan with Beijindi and Dongpinghu being the most important. At least 1.57 million people live in the Beijindi FSDA alone (Figure 3.13) with properties estimated at US$ 1.57 billion (1 US$ = 10 Yuan) and many important enterprises as well as mines and oilfields. For the Xiaoqing River FSDA of the Huaihe watershed, 300,000 people live there and local properties value reach up to US$ 3.7 billion.

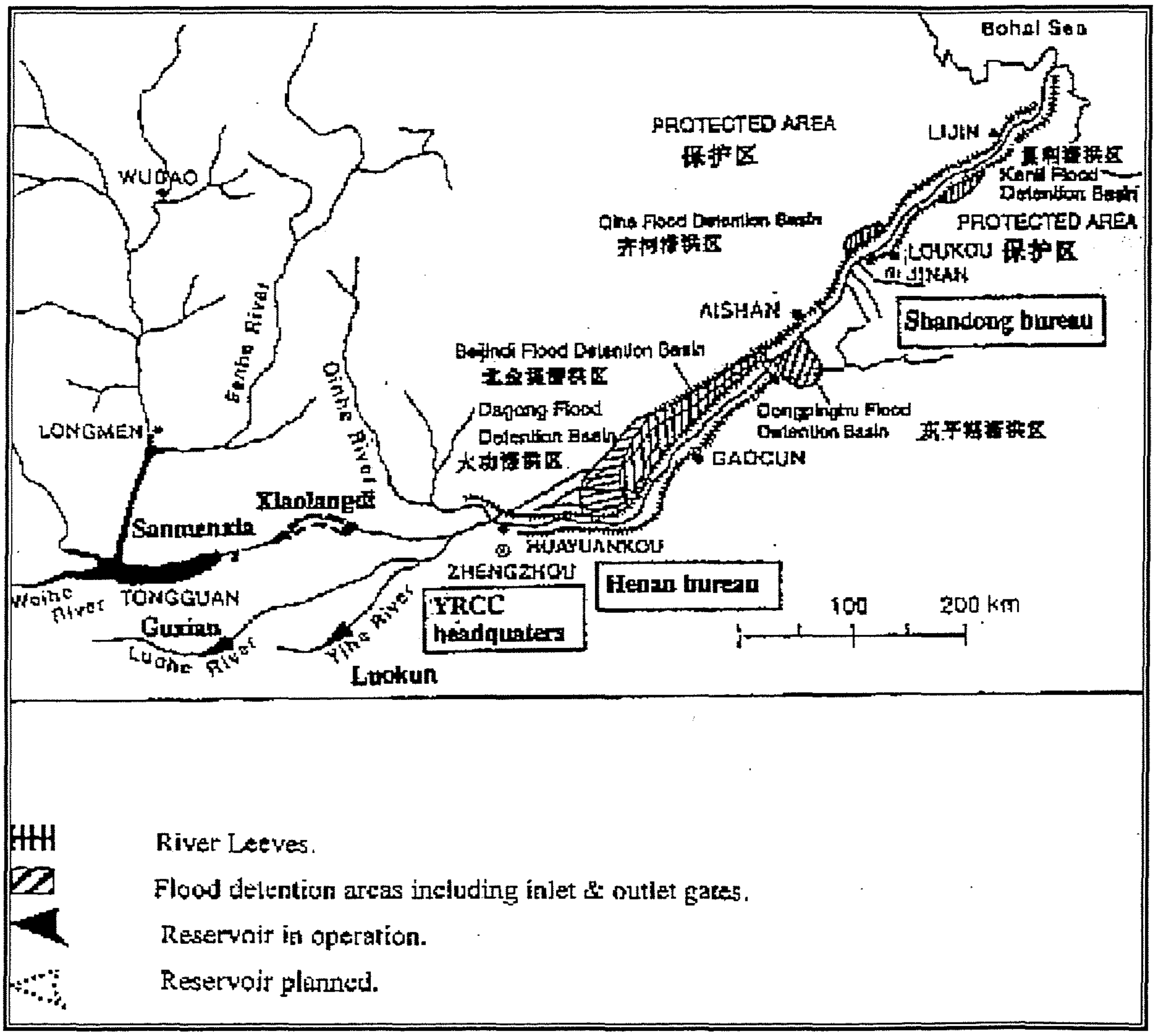


Figure 3.13: Flood Storage and Detention Areas (FSDA) in Lower Yellow River

a) Problems and challenges facing FSDA

i. Settlement

According to Xu of Beijing Flood Control Office (Li, 1999), settlement within the FSDA has increased the cost of utilising them for flood control purposes due to the rapid growth of population and economy. When the use of FSDA is required, it has become difficult to move all the people out of the area and safeguard the properties in time, as well as provide adequate safety platforms, safety buildings, safety areas, and withdrawal roads and bridges. For example, during the 1998 great floods in the Yangtze River, just to get ready for the flood diversion, the local government and the People's Liberation Army only managed with great efforts to temporarily evacuate several hundreds of thousands of people.

ii. Safety

Safety of all the inhabitants of the FSDA when a flood diversion is carried out is very important. At present safety buildings and other life saving facilities have been constructed within the FSDA but these can only offer temporary refuge to less than one third of the local residents. In the early years, each family living in the FSDA had a boat for emergency purposes provided by the Yellow River Conservancy Commission (YRCC) but this is now not possible with so many people. There is an urgent need to make available more temporary shelters for all the evacuees.

iii. Compensation issues

Except for some low-level compensation from the state, there are no compensation policies for the utilisation of FSDA. This has, in many ways, affected the way the local governments respond to flood diversion into the FSDA preferring to delay the diversion time as much as possible hoping that it would not be really necessary. This, according to Xu (Li, 1999), has often resulted in dike bursts causing uncontrolled flood diversion. He therefore argues that a compensation policy for the people affected in the FSDA is required to deal with the aftermath of flood diversions.

The Ministry of Water Resources in 1998 prepared a draft of the Compensation Methods for FSDA Use but this is still to be approved. It is anticipated that this will stimulate more agricultural and other stable and moderate economic development in those areas so that the people can become more aware of the need to protect against flood.

iv. Engineering

Engineering works to provide efficient inlet and outlet diversion gates are lacking. Among the constructed FSDA all over the country, Xu reports that only a few like Jingjiang of the Yangtze River, Beijindi and Dongpinhu of Yellow River, and Mengwa and Chengxihu of the Huaihe River, have proper intake and outlet gates. Most FSDA only rely on digging the embankment to divert flood making it difficult to divert floods on time and to quantify the flood diverted.

v. Poor Planning and Management

Poor management or lack of organisation in most FSDA has compromised the intended use of these facilities. Except for the important FSDA like the ones mentioned above, Xu observes that most have no management organisation. This is the main reason behind the uncontrolled development and population growth in the areas (Li, 1999).

The need to strengthen planning and management to include population and economic growth control, flood diversion works and safety facilities management has been noted. For the resettlement of the people, there is a new planning concept "Resettlement and Town Building Project" whereby small towns are built near the FSDA to settle the migrated people. Since there is rapid urbanisation in China, the small towns have attracted more farmers to engage in secondary and tertiary industry. For example, after the 1998 great flood, Hunan, Hubei, Anhui and Jiangxi provinces implemented the project which, according to Xu (Li, 1999), proved to be effective thus gaining approval of the masses and the local governments.

b) Utilisation of FSDA

Recent cases when FSDA were greatly utilised were in 1954 and 1991 when floods occurred in the Yangtze and Huaihe River watersheds. The floodwaters were diverted into the FSDA thus safeguarding important embankments, cities, enterprises and mines along the rivers. For the Yellow River, any flood bigger than the design flood of 22,000 m^3/s at Huayuankou and 10,000 m^3/s at Aishan makes use of the FSDA along the river. Huayuankou is the upper boundary of the lower reach while Aishan is the point from where the Yellow River is trained by embankments on both sides and channelled to the Bohai sea. An exception can, however, be made like in 1958 when a maximum flood of 22,300 m^3/s occurred at Huayuankou but a decision was made to safeguard the dikes and not to use the detention area.

In the last 39 years, 10 floods that exceeded 10,000 m^3/s and 18 that were between 6,000 and 10,000 m^3/s were recorded but were not big enough to warrant the use of the FSDA.

i. Yangtze watershed FSDA

The Jingjiang FSDA in the Yangtze watershed was designated in 1952 covering 921 km^2 and with a storage capacity of 5.4×10^9 m^3. In 1954, a great flood occurred in the Yangtze River watershed. The Central Government decided that from July 22 to August 22, the floodgates be opened 3 times in order to divert a total flood of 12×10^9 m^3. The biggest diversion flow reached 7700 m^3/s, lowering the water level of the river at the Jingjiang section by up to 0.96 m. and removing the threat of flood damage to the Jingjiang embankment, the Dongting Lake downstream, the Jianghan plain and Wuhan city.

ii. Huaihe watershed FSDA

In summer of 1991, a rarely great flood also occurred in the Huaihe River watershed. To mitigate the flood situation, besides using upstream reservoirs to store the flood, 3 FSDA (Figure 3.13) and 11 flood diversion areas were used to divert a flood of about 4×10^9 m^3. The flood stored by Mengwa FSDA was 1.1×10^9 m^3 while Chengxi Lake FSDA stored 2.6×10^9 m^3. The use of these FSDA and the flood diversion areas safeguarded important embankments, cities, enterprises and mines along the Huaihe River.

3.3.2.2 Non-structural measures

I. Flood forecasting and flood warning system in the Lower Yellow River

Flood warning information in the lower Yellow River begun in 1574 during the Ming dynasty. At that time, riders on horseback sent the hydro information at a possible speed of 250 km/day. Later in 1765, during the Qing Dynasty, water record stakes were set up to measure the rising water levels at Wanjintan in the main stream of the river, Gongxian in the Yiluo river, Wuzhi in the Qing river and Shanxian. Since then, the system of flood forecasting and flood warning has been developed and now consists of hydro-information stations, a forecasting centre, a headquarters for flood protection, administration of reservoir releases, water conservancy projects and communication stations (Figure 3.14).

In 1949, there were only 148 hydrometric stations in the country, 203 water-level posts and 2 rainfall posts, all poorly equipped. By 1986, these had increased to 493 hydrological stations, 220 hydrometric stations, 25 stage stations and 248 rain gauge stations.

Later in 1992, there were 3192 hydrometric stations, 1149 water-level posts, 15,386 rainfall posts and 8525 flood reporting posts, forming a rather complete network which can mainly master the rainfall and flood information in the principal river reaches and important areas (Zhu, 1999). These, according to the hydrological department, are able to provide timely and accurate information on the flood control system.

According to Chen (Brush, 1989) of the Hydrology Bureau, flood forecasting has played an important role in flood protection. This is despite the difficult situation on the lower Yellow River caused by the complicated nature of floods resulting from the influence of sediment, unsteady riverbed and human activities. Emphasis is now been laid on hydrometric services, flood forecasting, organising and educating the people on Flood protection. An improved system of precipitation and stage telemetering and on-line real-time flood forecasting between Sanmenxia and Huayuankou on both banks of the river has been installed.

An example of how the flood forecasting and flood warning system has been put into good use is the case of the extreme flood of 23,000 m3/s that occurred at Huayuankou in the lower Yellow River in 1958 (Brush, 1989). During that flood, hydrological information, flood forecasts, and flood warnings were dispatched and sent without delay. The forecasting was rather accurate throughout the lower reaches. A flood peak of 22,000 m3/s and water level of 94.40 m was forecast and a flood peak of 22,300 m3/s and water level of 94.42 m was observed. Because of the forecast, a decision was made to safeguard the dikes and not to use the detention area. Two million people fought their best against the flood and won the victory of flood protection and the inundation of a population of 1.4 million and 3 million of land in the detention basin was avoided.

II. Flood control command system

A flood control commanding system – the Central Flood and Drought Protection Command (CFDPC) – was set up with each level from the central government to counties having a clearly defined flood-controlling task (Figure 3.14).

The governors at each level are the commanders and the chief officials are drawn from the army, department of water, meteorology, planning, finance, police, commodities, civil affairs, transportation, telecommunications, electric power, sanitation and health, etc. The headquarters is stationed in the department of water to carry out daily work.

For example, when extreme floods occur, the detention basins are used. In this case the General Headquarters Office and the Provincial Command of the Yellow River Flood Protection in Henan and Shandong urgently send the flood warning by telegrams, telephones and radio to relevant units, such as to people living on the floodplain, along banks and in detention basins. These warnings, indicating the amount of rain, stage, discharge and the area that might be inundated, enable the people to take appropriate flood protection measures.

The establishment of a flood control command system combined with the Decision Support System was reported to have ensured victories in successive flood combats. Taking the 1991 Huaihe River flood as an example, no breach occurred along the main channel of the river and no one was killed during the retreat of one million people from the inundated areas (Brush, 1989).

III. Information Management and Communication system

The observed hydrological information is collected, processed, stored and sent by microwave, cable, radio or electronic mail communication system that has been set up. The State Flood Control Headquarters, as its centre, links the flood control headquarters of 21 out of 32 provinces, autonomous regions and municipalities, and the authorities of the major rivers, lakes and reservoirs under the Ministry of Water Resources. For the Yellow River which traverses 9 provinces, when it is forecast that the peak flow may exceed the pre-assigned warning level at Huayuankou station, the forecasting centre at the YRCC in Zhengzhou city notifies Henan and Shandong Provincial Command office which then make complementary forecasts. The complementary forecasts are sent immediately to each service and sub-service of the flood protection so that they may be ready to fight against the flood.

IV. Flood insurance

Flood insurance as defined in Chapter 2 refers to the compensation measures available after the flooding in which the risk of flood loss is distributed among the whole society and the flood hazard is prevented or remedied. This allows the society to stabilise and the production systems to recover quickly after a disaster.

Flood insurance is a newly emerging flood mitigation measure in China (Li, 1999). People have been used to relying on compensation from the government after the flood in line with the planned economic system in place for a long time now. Several experiments have been done since the 1980's in Nanren flood detention areas of Huaihe River in Anhui province and then six other areas.

For the FSDA, different systems are used for the enterprises, the agricultural crops and the living houses. For ordinary crops, only production costs or 50% of harvest value are insured. For living houses, insurance value is estimated per room.

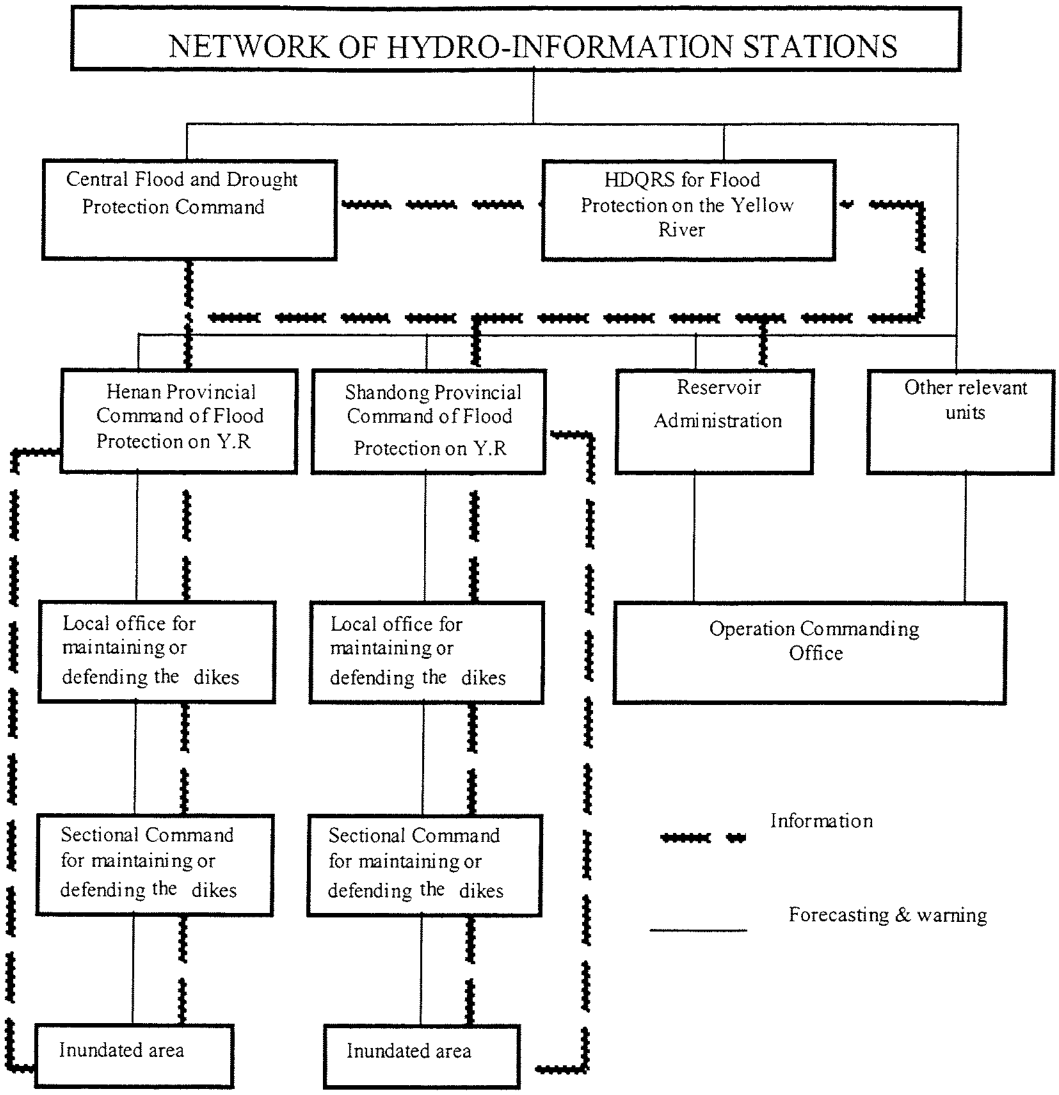


Figure 3.14: Flood forecasting and flood warning command system

(Source: Li, 1999)

3.3.2.3 Structural measures

I. Dikes and Levees

Prior to the 1950's, the measures used to restrain the river were primarily simple dikes and levees put together using China's abundant supply of peasant labour and simple implements like shovels and wheelbarrows to build the structures. The first flood protection dike system along the lower reaches of the Yellow River was built after the Xihan dynasty in about 200 BC. Since the Yellow River deposits so much silt, the height of these dikes and levees had to be raised often to keep up with the increasing height of the water levels.

Without this, the dikes and levees are breached often necessitating constant temporary repairs with brush and loose soil, which makes the standard of construction appear inadequate especially the foundations, when compared with newly constructed dikes elsewhere.

After the founding of the People's Republic of China, there was rapid development of physical flood control structures. Comprehensive plans were drawn up for the principal rivers emphasising flood control. The simple levees were reinforced with spurs and stacks that extend from the levee into the river, causing eddies in the current that slow down the water flow thus reducing stress on the levees. These were also supplemented with concrete revetments to cut down on the erosive side effects of eddies (United Nations, 1983).

Over 250,000 km of dikes (1,400 km in the lower reaches of Yellow River) were constructed and reinforced, river courses dredged and regulated and new river outlets excavated. This has been given as the main reason that no major dike breaches have occurred in the last 39 years in spite of 10 floods that have so far exceeded 10,000 m^3/s and 18 that were between 6,000 and 10,000 m^3/s. However, though this protected over 34 million ha of farming land, it also contained the silt that would have been deposited in the floodplain outside the riverbed thus reducing the fertility of the area.

Dikes for the prevention of flooding have been built along the lower reaches of the Yellow River from Zhengzhou to the estuary (Brush, 1989). The population living in the area protected by the main dikes is approximately 100 million people.

II. River Channel improvement

Though not a very successful exercise because of the high siltation, dredging is used in the Yellow River as an auxiliary flood control measure. Training of the banks is also done to improve the flow of the water.

III. Dams and reservoirs

Prior to the 1950's, there were only eight large dams in China (McCully, 1996). With the founding of the People's Republic of China, there was rapid development of physical flood control structures especially for the Yellow River. The number of dams rose from only eight to over 319 large ones and 2,252 medium ones (Figure 3.15). The construction of these reservoirs on the main streams and tributaries in the middle reaches of the river was mainly aimed at controlling the floods thus effectively alleviating the threats of floodwater along the entire lower reach and generating electricity.

So far, more than 86,000 large, medium and small reservoirs have been built after 1949 with a total capacity of about 450×10^9 m^3. Unfortunately, it now appears that most of them were built without a full evaluation of their effects on the environment arising from the sediment in the rivers. For example, the Yellow River is heavily laden with sediment. With the dam blocking the flow of the river, the sediment in the water is deposited in the reservoir, gradually reducing the capacity of the reservoir by as much as 2.3 percent every year (McCully, 1996).

The proposed Xiaolangdi multipurpose project along the Yellow River (Figure 3.15) could ease the problem of flood control in the lower reaches. When completed, the reservoir will have a storage capacity of 12.65×10^9 m^3 including a flood control capacity of 4.05×10^9 m^3 that can handle a flood of a 50-100 years return period

For the Yangtze River, a massive multipurpose project is underway. When completed, the Three Gorges Multipurpose project, will have a reservoir with a storage capacity of 39.3×10^9 m^3, including a flood control capacity of 22.15×10^9 m^3. It is designed to protect 322 million people in China's Hubei and Hunan provinces up to a flood of 10-20 years return period.

IV. Floodwater diversion

According to Chinese legends, the Great Yu was a representative who conducted work on harnessing the Yellow River by floodwater diversion around the year 2000 BC (Brush, 1989). His tactic was to use the land gradient for the water discharge by removing obstructions in the river channels and enlarging the outlet of the river with multi-bifurcations. In addition, he used depressions to store and to retard the diverted floodwater. More than 100 diversion and detention areas along principal rivers were made with a storage capacity of 120×10^9 m^3. Flood diversion and detention projects such as Dongping Lake and Sanmenxia have been completed. However, after more than 4,000 years, the Great Yu's tactics against the Yellow River are now restricted by the dense population along both sides of the river course.

V. Flood Detention Basins

Beijingdi and Dongping Lakes form the flood detention basins (Figure 3.15). Dongping Lake serves to cut down the peak flow of Weihe River. Luhun (on the Yihe River) and Guxian (on the Luohe River) reservoirs serve only as auxilliary measures. The Beijindi flood detention basin has an estimated population of 1 million and given the presence of Shengli oil field within the area, the use of the detention basin has become very undesirable.

Samenxia reservoir (Figure 3.15) commands 92% of the drainage area of the Yellow River and is used mainly for the regulation of the major floods. It plays an important role in controlling floods from 2 of the 3 major regions of flood sources i.e. from the areas between Shanxi and Shaanxi provinces, and the middle reaches' tributaries - Jiang He, Luo He and Wei He (Brush, 1989).

The characteristics of the floods from different parts of the basin of the river are different, hence different measures for flood control have always been considered. Main floods are to be found in the upper-reaches and the middle-reaches. For the floods occurring in the upper and the middle reaches, the flood detention reservoirs upstream of Sanmenxia reservoir (Figure 3.15) are used to decrease the flood peaks and to mitigate the threat to the lower reaches of the Yellow River.

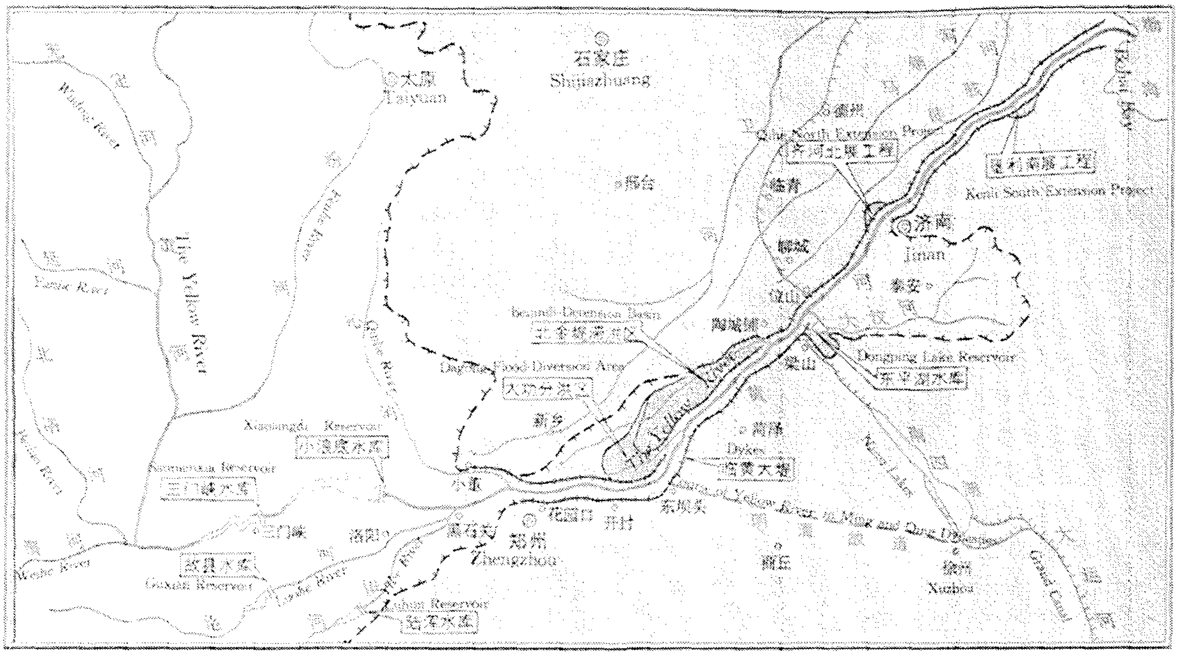


Figure 3.15: Map of major dams and reservoirs on the Lower Yellow River

(Source: Zhu, 1997)

3.3.3 Socio-cultural justifications for the strategies used to cope with floods

3.3.3.1 Historical perspective

In spite of many good harbours along the approximately 18,000- kilometre coastline, the nation has traditionally oriented itself not toward the sea but inland, developing as an imperial power whose centre lay in the middle and lower reaches of the Yellow River on the northern plains.

Over the years, with the increase of human activities, deforestation and wars damaged the vegetation and worsened soil erosion thus increasing the frequency of flooding. According to the recorded history, from 900 AD to 1900 AD, the number of flooding shows a direct relationship with the increase of human activities (Table 3.5). Due to the long history of flooding, the agrarian communities practised irrigation and flood control over centuries. Recent discovery of an ancient stone dike along the Yongding River dating back to about 1400 AD demonstrated the high level of design and construction of flood control works that existed hundreds of years ago. On a foundation of baked 200mm diameter cypress piles, gray bricks measuring 490mm × 230mm × 170mm and weighing 34kg were used to construct the body of the dike with the waterside facing made of rectangular slabs of stone each weighing about 500kg (Li, 1999).

3.3.3.2 Cultural perspective

The eastern half of the country is a region of fertile lowlands, foothills and mountains, desert, steppes, and subtropical areas. The nation traditionally oriented itself inland, with the imperial power centre lying in the middle and lower reaches of the Yellow River on the northern plains, which are recognised as the cradle of Chinese culture and civilisation.

With its culture and civilisation centred on the cultivation of wheat, rice and maize which form the principal economic activity, the river is seen as the root, pride and continuity of the community. The cultural and legal traditions of the people therefore affect the government's perception of flood mitigation as a national, regional or local problem and influence the flow of resources (Zhu, 1997).

3.3.3.3 Social perspective

In ancient times, agriculture was a fundamental part of the national economy. Its yields had direct influences upon the social development and the stability of the government (Zhou, 1991). The quest for more food and living space for the growing population has caused the government to build more new reservoirs to free up more farmland on the floodplains even at the cost of displacing many people from their ancestral homes (McCully, 1996). This living along the banks of the river for agriculture purposes has lead to damages to property and misery to people whenever big floods occur.

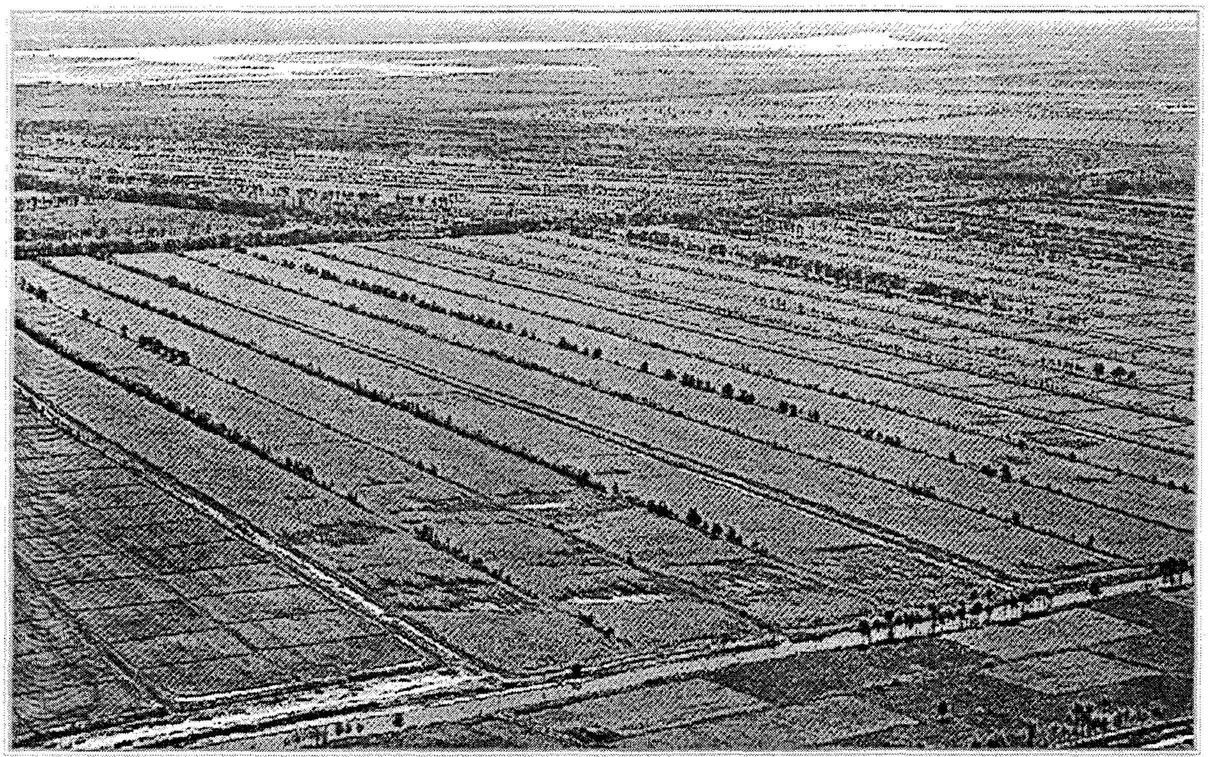


Figure 3.16: The rich Ningxia plains

But in the last 50 years, the story has changed (Zhu, 1997). The river has brought water, good harvests and an affluent life to the countryside along the river as vast semi-arid areas have been turned into green lands (Figure 3.16). Many new houses have come up, and towns and industrial cities like Lanzhou, Baoton, Shanxi and Zhengzhou have grown; thanks to the numerous dams and hydropower stations like Yanguoxia, Tianqiao and Longyangxia that have been constructed making the Yellow River live to its symbol as the pride of the people.

3.3.3.4 Political perspective

As stated elsewhere in this report, some of the earliest Chinese efforts to tame rivers dating as far back as 2200 BC are credited to the Great Emperor Yu. It was quite clear to him that "whoever controls the Yellow River controls China." And he made great political capital out of it for legend has it that he was made Emperor for being the first to "tame" the River (Brush, 1989 and Cohen, 1997). Evidence of Yu's insight can be seen throughout Chinese history, as rulers gained and lost power in concert with their control of the river.

The government has been so much involved on river flood control that the rapid dam construction programme was reasoned in some quarters as imprudent and mainly political, especially when more than ten million people were displaced (McCully, 1996) and Soviet financing and engineering expertise was used.

It was argued, for instance, that Mao Zedong and the new Communist regime was perhaps too anxious to follow the ancient advice of Emperor Yu, hoping that massive damming of the Yellow River and other rivers would be a tangible manifestation of power.

However, as stated in section 3.3.3.3, the government's aim was to control the floods and free up more farmland on the floodplains so as to provide more food and living space for its burgeoning population (Cohen, 1997). Indeed, Mao is credited as having said in 1947 when he came to the Yellow River; "Without the Yellow River, we have no nation". He vowed to use the river to irrigate lands, generate electricity and bring happiness to the people once the country was liberated (Zhu, 1997).

3.3.3.5 Technical perspective

The Chinese, with their deep history of flood control, have now gained a lot of experience in building reservoirs. Natural lakes as found alongside the Yellow River have been converted into detention basins that divert water in the event of a flood. During the dry season, lower water levels separate the basin from the river, thus avoiding the problem of sediment accumulation. But when the river threatens to flood, water flows into the basin and is held there by a dam (United Nations 1983), (Cohen, 1997).

This was not case with dams. Initially, big dams were constructed mostly with Soviet financing and engineering expertise, and according to Carin (Carin, 1962), they almost universally failed to account for China's heavy sediment accumulation in the reservoirs. Most of the dams developed cracks later and on assessment were found to be structurally unsound as the foundations were made of loosely packed and in most cases unstable material. The same problem was observed with the levees that were breached often and were repaired with brush and loose soil. The problem became worse when the levees had to be raised constantly to keep up with the rising level of the riverbed.

3.3.3.6 Management perspective

Providing structural or non-structural flood control solutions is simple, but managing those measures requires a clear management policy. One must consider all the factors, all the benefits and disadvantages that come with making a policy. This is where economics and politics come in and the practical way of solving or alleviating problems has to be found.

The Yellow River Conservancy Commission (YRCC) has managed flood control and prevention in the Yellow River basin since 1946. Its specific mandate in regard to flood control is:

- to formulate basin-wide policies and regulations
- to practice, supervise and inspect water law and the water conservation law
- to formulate strategic programming and long term plan on development conservancy of the Yellow River watershed
- to formulate the scheme of flood prevention of the Yellow River watershed

In the last 50 years, it has been guided by the strategy; *"Retain water in the upper reaches, Release it in the lower reaches and Detain it along the banks of the river"* (Zhu, 1997). YRCC now boasts of 1,400 km of dikes in the lower reaches of the river that have been strengthened and heightened 3 times, 320 floodplain protection projects, 8,800 dams built, Sanmenxia, Luhun and Guxian reservoirs, Dongpin Lake and Beijindi detention basins (Zhu, 1997).

3.3.3.7 Economic perspective

The social and economic development in the Yellow River valley as stated in Section 3.3.1.2 occupies a decisive position in the overall national economy. It has abundant resources and a large population and is an important base for the production of grain, cotton, energy, and heavy and chemical industries (http://lcweb2.loc.gov/frd/cs/cn.html).

Economics play a major factor when deciding on the flood management solutions to be implemented. If the country does not have the resources to build dams, dikes or levees, then most structural and non-structural solutions will not be attempted. For China, financial and educational assistance is still needed because although the country is developing rapidly, it is still lacking some critical components associated with a developed country (Cohen, 1997). That appears to be the reason why to build the dikes and levees, China used its abundant supply of peasant labour, which required mainly shovels and wheelbarrows, and initially utilised Soviet financing and engineering expertise in the construction of dams.

Between 1946 and 1996, the river experienced many floods but due to the flood protection measures carried out recently, it has been estimated that up to US$ 36.0 billion loss was avoided, excluding the direct and indirect social consequences (Zhu, 1997). Overall, it is claimed that the nation has spent US$ 1.0 Billion on flood control and saved US$ 500 billion in flood losses (Chen, 1999).

3.3.3.8 Environmental perspective

The Yellow River is heavily laden with sediments. This is one of the greatest challenges to flood control of the river. Not only does the sediment silt up and clog the lower reaches forcing the river to change courses many times; it also raises the riverbed thus increasing the risk of flooding. Dams and reservoirs have not been spared either. With the dams blocking the flow of the water, the sediment in the water is deposited into the reservoir which gradually reduces the capacity of the reservoir by as much as 2.3 percent every year (McCully, 1996)

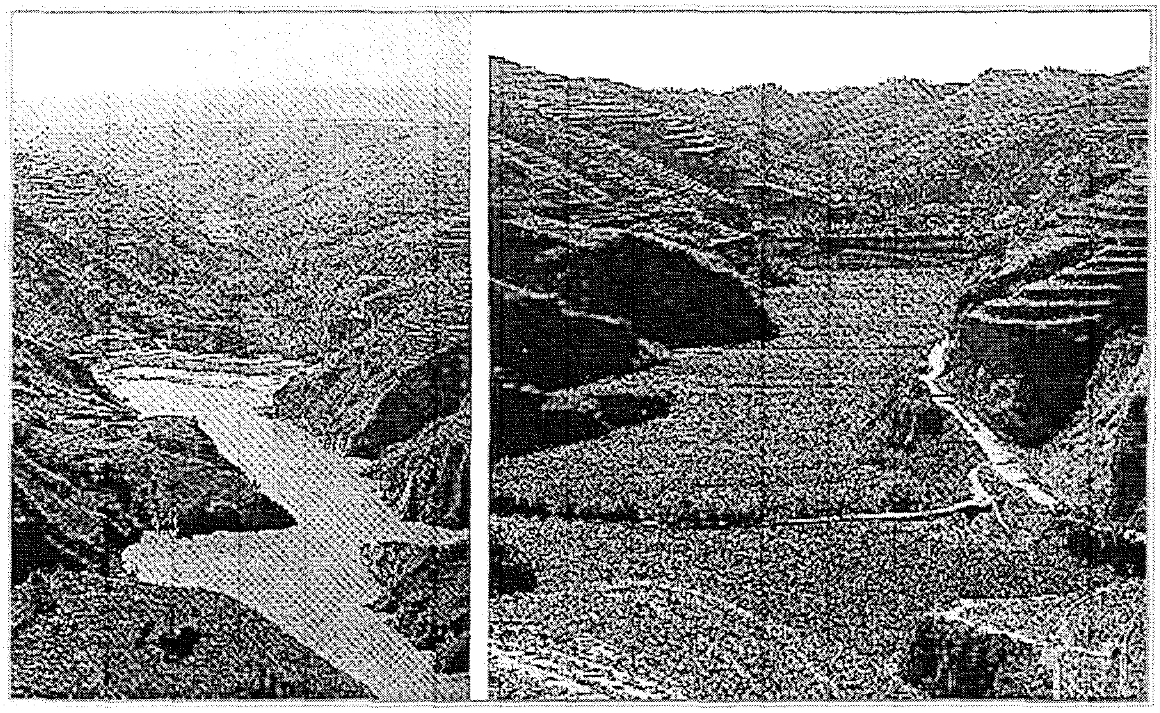


Figure 3.17: Soil & water conservation along the Yellow River

Some of the wide floodplains and the lowlands behind the levees in the middle reaches are used for warping as there is a natural capability for deposition by means of flood detention. This replenishes the land with nutrients making it fertile and more productive (Brush, 1989). Large scale warping along the middle and the lower Yellow River is done to retard deposition on the downstream part of the river, and to strengthen and heighten the dikes. So far, 1,400 km of dikes in the lower reaches of the river have been increased and heightened to 100 m wide on each side (Zhu, 1997). In addition, some dredging is done in the navigable sections of the river to maintain the cross-section of the channel. While this has been effective in the short run, it has been found not to be economically sustainable so soil and water conservation measures (Figure 3.17) are being enhanced using vegetation cover and check dams as a long term measure (Zhu, 1999).

3.3.4 Flood protection policy

3.3.4.1 Flood control strategy in China in the 21st Century

The following are proposals for flood control strategy in the 21st Century, made by the office of State Flood Control and Drought Relief Headquarters in China (Li, 1999):

- Flood control to be combined with the resolution of water shortage and improvement of ecology, environment, people's life and production.
- Construction of flood control structures to be combined with the establishment of social security system for flood control, flood control and disaster reduction system in terms of economy, policy, laws and regulations such as compensation measures for using flood detention areas.
- To construct flood recharge network to recharge the groundwater aquifers. This will solve such problems as ground water exploitation, ground surface subsidence and water shortage.
- To construct canals in plains in the shape of a leaf to divert flood water and reduce pressure on the rivers and fully utilise floodwater resources and inter-basin flood diversion.
- To draw flood risk maps based on a flood risk analysis, and formulate relevant management methods for each area based on the flood frequency, administrative, legal and economic circumstances.

3.3.4.2 Current flood prevention measures proposed for the Yellow River

Several flood prevention strategies have been considered over time by both the government and the scholars in order to harness the Yellow River. The Yellow River Conservancy Commission as stated above now advocates the strategy; "Retain water in the upper reaches, Release it in the lower reaches and Detain it along the banks of the river" (Zhu, 1997). Only the plans proposed in the recent years (Brush, 1989) are discussed in this report:

I. Enhance soil and water conservation measures in the middle reaches

Though this would take a long time and is difficult because of large population, poverty, and low precipitation, the benefits are many. Reforestation, re-vegetation, land terracing and gully control works reduce the runoff and at the same time improve production and the standard of living of the farmers. According to historical records, there was once a luxuriant forest and clear water within the river catchment, which played an important role in the ecological environment. Thousands of small check dams have been constructed in the middle reaches of the river to enhance water and soil conservation.

II. Strengthen non-structural flood control measures

This will involve the improvement of nation-wide flood warning, forecasting system, decision-making and emergency rescue preparedness, flood insurance, flood control levy system, and social education on flood control and disaster reduction (Zhu, 1999).

III. Changing the river course

A proposal has been made to make a new channel where the Yellow River would flow within the best topography and shortest distance. This would require the abandonment of 534,000 ha of cropfields, the movement of up to 3 million people and the reconstruction of irrigation systems, drainage and communication.

IV. Raising the height of the dikes

As the river is steadily subject to channel accretion, the height and strength of the dikes will require to be increased to maintain the flood-discharging capacity of the channel.

V. Building reservoirs on the main stream and the tributaries

With the experience gained in the operation of Sanmenxia Reservoir, plans have been made to build 3 other reservoirs in succession on the mainstream, Xiaolangdi, Longmen and Qikou. The total capacity of the 4 reservoirs would be about 50×10^9 m^3. About 30-40% would be available as live storage for flood control, water conservation as well as power generation. During the flood season, the minor floods would be stored in the reservoirs and carefully discharged later. This operation will also help in sluicing the silt in the river channel. This is considered a good option, as it will control flood, regulate siltation and reduce river sediments.

VI. Opening up flood relief channels at the lower reaches

This will increase the flood control capacity from the projected 22,000 m^3/s to the maximum probable flood of 46,000 m^3/s with a recurrence period of 60 – 100 years.

VII. Transferring the Yangtze River water into the Yellow River

The whole of the Yellow River basin is located in a water deficient area. Demand for water along the river for industry and agriculture has caused an imbalance between the water and the silt. This imbalance is expected to increase with increased development. If the planning of the Yellow River regulation is combined with transferring water from south to the north along the middle course, the project of transferring the Yangtze River water into the Yellow River will be realised. After the diversion is completed, the proportion of water and silt will be balanced, and the flood prevention and water requirement at the lower Yellow River can be satisfied.

3.4 ***Case Study 3: USA***

3.4.1 Specific features of the country and its rivers

3.4.1.1 Geographical features

The United States of America (USA) has a land area of approximately 9,159,000 km^2. It consists of 48 contiguous States and the non-contiguous states of Alaska and Hawaii. The focus in this study was in the Midwestern and Southern States of the USA that make up the catchment area for the Mississippi River and its main tributaries notably the Missouri River, the Illinois River, the Ohio River, the Arkansas River and the Red River (Figure 3.18). The Mississippi forms the eastern border of most of the states of Minnesota, Iowa, Missouri, Arkansas and much of Louisiana; and the western border of most of Wisconsin, Illinois, Kentucky, Tennessee and Mississippi.

The estimated population for the year 2000 was 275 million, third in the world behind China and India.

The Climate is mostly temperate for the continental states. It is semi-arid in the great plains west of the Mississippi River, arid in the great basin of the southwest and wet in the south and some of the higher mountain areas.

3.4.1.2 Hydrological features

The Mississippi River

The Mississippi River system as stated in section 3.4.1.1 is comprised of the Mississippi River and its tributaries (Figure 3.18). Its Drainage Basin is shaped like a huge funnel and drains 41 percent (2,979,000 km^2) of the continental United States. It is the largest drainage system in area in North America and the third largest in the world. Its discharge, which averages 16,800 m3/s, is the sixth largest in the world.

The Mississippi River, from Lake Itasca in Minnesota to the Gulf of Mexico, is 3,770 km long. However, if the river system is measured from the headwaters of the Missouri River, the Mississippi's longest tributary, to the Gulf of Mexico, its length totals 5,970 km. Its natural channel could carry about 28,000 m^3/s of water but during heavy rainfall seasons, the runoff from the drainage area could be as much as 56,000 m^3/s of water or more. The excess water over the flow in the natural channel therefore spreads into the basins of the floodplain of the River (Humphreys, 1861).

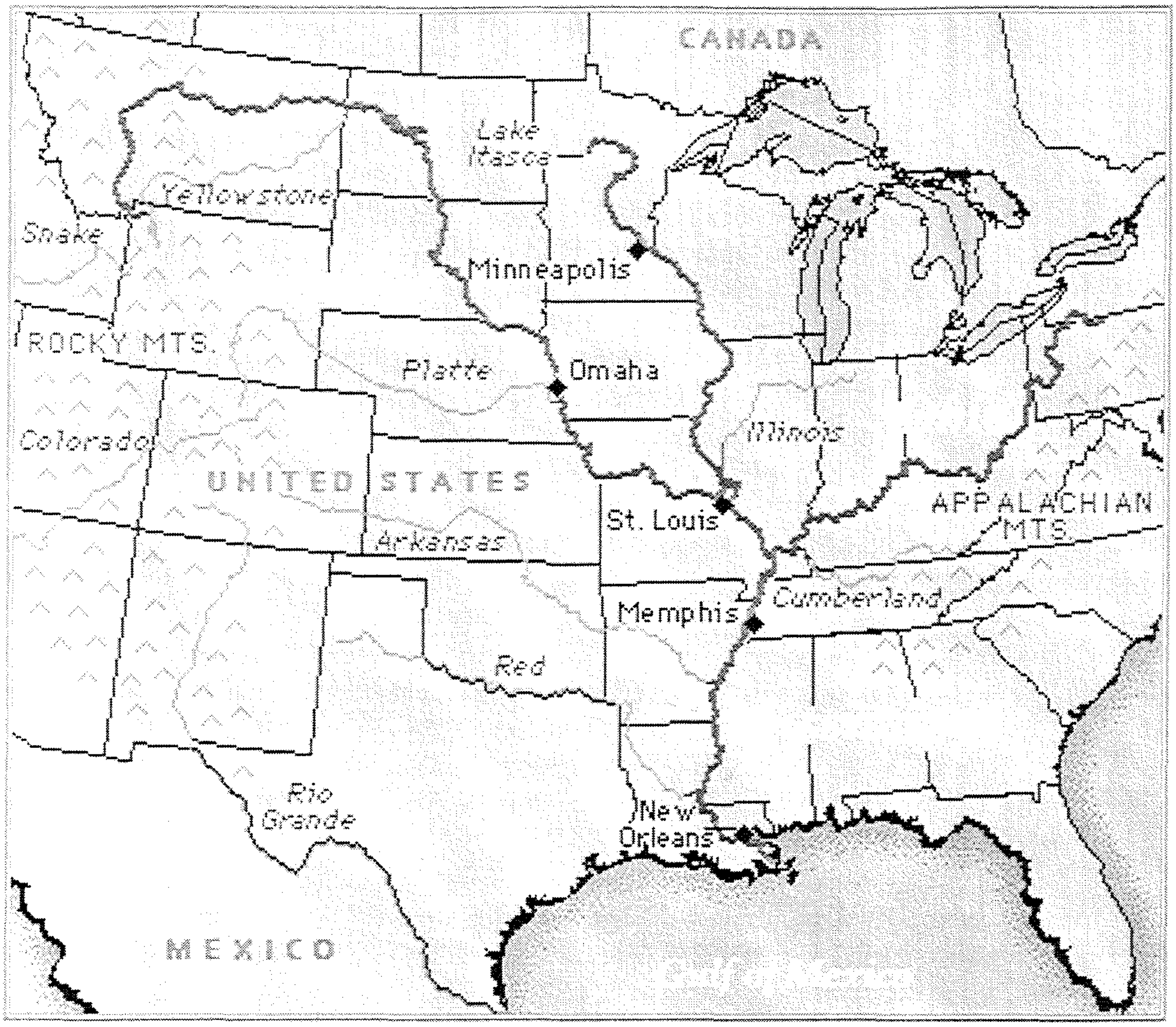


Figure 3.18: Mississippi River Basin

The river, which forms a common border between 10 states (Figure 3.18), plays a central role in the exploration and economic development of the USA, being a principal artery for bulk freight, carrying more than any other inland waterway in North America. The first steamboat on the river, the New Orleans, ushered in the era of powered shipping in 1811. Waterborne commerce on the Mississippi is reported to have rose from 30 million tons in 1940 to almost 400 million tons in 1984.

The most important cargoes on the river are bulk items such as coal, petroleum products, sand, gravel, and grain. In addition, many pleasure craft from all parts of the country now use the Mississippi for vacation and travel. Many manufacturing, service, and transportation centres began along the Mississippi River and developed into large cities and towns and continue to depend on the river for their economic base. These include Saint Louis, Missouri; Saint Paul, Minnesota; Memphis, Tennessee and New Orleans, Louisiana.

The Mississippi Valley has rich alluvial soils, formed by thousands of years of erosion and deposition by the meandering river. In its lower course, the river meanders through a floodplain that is 60 to 110 km wide and which supports agriculture in the rich farmlands, especially feed grains and soybeans in the north and cotton, groundnuts, and rice in the south. The floodplain includes extensive wetlands, especially in the delta area, which is the largest area of wetlands in the United States. These wetlands form an important habitat for migratory birds.

The Mississippi River is said to be one of the most heavily engineered natural features in the United States. Levees and floodwalls have been constructed in several sections along the river, which has changed the character of the floodplain to accommodate agriculture and urbanisation (http://encarta.msn.com ©1997-2000).

Missouri River

This is the longest river in the United States and one of the primary tributaries of the Mississippi River. From its source in the Rocky Mountain region of Montana, it flows 4,100 km and drains an area of about 1,370,000 km^2. The upper Missouri traverses a mountainous terrain covered with dense coniferous forests. The middle and lower river valleys are lined with grasslands and forests.

In order to enhance navigability and provide flood control, hydroelectric power, and irrigation, the Missouri River Basin Program was created in 1944. Under this program, a series of dams, reservoirs, and locks were built on the river (http://encarta.msn.com ©1997-2000).

Ohio River

The Ohio River, which drains the Midwest and the northern segment of the Appalachian Mountains, supplies nearly half of the Mississippi's flow. An important tributary of Ohio River is the 1,050 km Tennessee River that drains much of the southern Appalachian Mountains before it joins the Ohio in western Kentucky. From Cairo to New Orleans Ohio River is generally 1,000 to 1,600 m wide with a navigation channel 3 to 4 m deep. More than 800 km of the Middle Ohio Valley is a major heavy-manufacturing district, centred on the inexpensive transportation offered by the river and a series of 13 dams with locks that ensure safe passage of commercial and other vessels.

Compared with other major rivers in U.S.A, the management of the Tennessee River is claimed to be the best example of a regional approach to watershed development. The federal government created the Tennessee Valley Authority (TVA) in 1933 partly in response to the desperate economic situation created by the Great Depression of the 1930s. The TVA built more than 20 dams on the Tennessee River and improved navigation as far upstream as Knoxville, Tennessee. As a result, the Tennessee Valley became one of the most important hydro-electricity producing areas of the United States.

This inexpensive power attracted industries to the region, which has developed as a diversified manufacturing centre in cities such as Knoxville and Chattanooga in Tennessee and Huntsville in Alabama. Due to improved flood controls and extensive conservation measures, agricultural output also improved in the Tennessee River Valley, especially in the Great Valley of East Tennessee.

(http://encarta.msn.com ©1997-2000)

3.4.1.3 History of floods

As stated in section 3.1.3, flooding is regarded as one of the natural hazards in the United States. Some authors report that floods have actually caused a greater loss of life and property and have disrupted more families and communities in the United States than all other natural hazards combined (Section 1.3).

The Mississippi River has flooded several times in recent history. The largest flood recorded in the lower valley occurred in 1927 while the largest in the upper Mississippi occurred in 1993 (http://encarta.msn.com © 1997-2000).

Records indicate that the 1927 floods inundated over 67,000 km^2 in seven states, killed 246 people and drove over half a million people from their homes. Amidst a national outcry on the loss of life, extensive suffering and devastating economic damage, President Hoover at that time described it as the greatest peacetime disaster in the history of the United States! Moved by the flood disaster, Congress responded by enacting the comprehensive Flood Control Act of 1928, which provided new approaches to the persistent flood problems of the Mississippi River. This included conditions on the use of federal funds and an adoption of a plan to include in the flood control measures floodways, reservoirs, channel re-alignment and other features to complement the traditional levees (Harrison, 1993).

In the 1993 flood, Larson (Larson, 1993; Leavesley, 1997) reported that hundreds of levees failed along the Mississippi and Missouri Rivers with about 600 river-forecast points in the Midwestern United States being above flood stage at the same time. The flood was widespread covering 9 states, nearly 150 major rivers and tributaries and over 1.0 million km^2.

At least 10,000 homes were totally destroyed and tens of thousands of people evacuated; hundreds of towns were impacted with at least 75 towns totally and completely under floodwaters. Over 15 million acres of farmland were inundated and transportation was severely impacted. Barge traffic on the Missouri and Mississippi Rivers was stopped for nearly 2 months and bridges were out or not accessible on the Mississippi River from Davenport (the only town not protected by a floodwall), Iowa, downstream to St Louis, Missouri and on the Missouri River, from Kansas City, downstream to St Charles, Missouri. Numerous interstate highways and other roads were closed, 10 commercial airports were flooded and all railroad traffic in the Midwest was halted. Numerous sewage treatment and water treatment plants were destroyed. At least 50 deaths occurred and the damage approached US$15 billion. The flood equalled or exceeded the 100-year flood recurrence interval along major portions of the upper Mississippi and the lower Missouri Rivers.

Between 1927 and 1993, other floods of lower magnitude occurred. These, like the 1937 flood, according to Leavesley (Leavesley, 1997), were safely conducted through the valley without causing much damage. However, the flood of 1983 was significant in its duration by producing above-bank full stages at various gauging stations nearly continuously from December of 1982 to June of 1983, with the major stages occurring in the latter part of the flood. Emergencies occurred at a number of locations along the river, private levees failed, and millions of acres were inundated in backwater areas and behind flood control reservoirs and detention structures.

Congress established the Mississippi River Commission (MRC) in 1879 for the principal purpose of improving the navigation of the river. It was not until after the great floods in 1912 and 1913, which produced many deaths and left hundreds homeless, that Congress authorised it to carry out flood control works. It was again not until after the 1927 floods that Congress, in 1928, directed the Engineering Corps to develop a flood control system that would prevent such massive flooding from ever occurring in the future. From the 300 competing flood control plans put forth, Congress adopted a proposal by the Chief of Engineers Eng. Edgar Jadwin. The Jadwin Plan had two principal innovations: floodways to divert peak flows and hold down stages in the main channel and a "project flood" for all works. The "project flood" was a flood larger than the record flood of 1927, which was estimated at 67,000 m^3/s at Cairo.

Every flood in the Mississippi Valley demonstrates some of the hazards inherent in the settlement and development of the floodplain.

Table 3.7: Typical historical flood records

Year	Maximum discharge (m^3/s)	Area inundated (km^2)	People displaced or killed	Property damage
1927	67,000	67,300	>600,000 (246 killed)	
1972			238 killed	US$ 500 million
1993		1,000,000	>50 killed	US$ 15 billion

3.4.2 Measures and methods used to cope with floods and their justifications

3.4.2.1 Living-with-flood measures

I. Giving the river space

The earliest measures used to prevent local floods and flood damage included seasonal evacuation and building on stilts mainly through private initiatives thus giving the river its natural space. People adapted to the periodic flooding by limiting their investments in flood-prone lands or making sure their investments were on high ground and out of harm's way (http://encarta.msn.com ©1997-2000). Even in the earlier years of the settlement of the Delta by European settlers following the Louisiana Purchase in 1803, communities and plantations were located on higher lands (Harrison, 1993). Farming was largely confined to well-drained ridges or where drainage was a relatively minor problem.

II. Wetland restoration

The Mississippi floodplain included extensive wetlands, especially in the delta area, which is the largest area of wetlands in the United States. These wetlands acted as natural storage reservoirs for floodwaters; they absorbed water during heavy precipitation and released it slowly thus reducing run-off to streams and decreasing flood volumes. For many centuries numerous Native American groups lived along the banks of the Mississippi and coexisted with the river.

However, since the settlers went to USA, almost 120 million acres of the wetlands have been destroyed for agriculture and development, more than half of what existed before the conquest. For example, Missouri, Iowa, and Illinois have over 85 percent of their wetlands destroyed thus affecting flood control. Most of the destruction apparently followed the legislation of the Swamp Act that allowed drainage of the swamps and massive new settlements on the floodplains.
(http://www.sierraclub.org/sierra/199905/floods.frame.html)

The experience of the 1993 floods has, however, instigated changes on approach to flood control with more emphasis now being laid on non-structural measures. This has included the acquisition and restoration of wetlands and riparian habitat, stricter limits on development in floodplains and even a farm policy that discourages the conversion of wetlands to cropland (Harrison, 1993). Now the Department of Agriculture's Wetland Reserve Program is buying up marginal cropland and restoring it as wetlands.

III. Relocation

Increasingly, communities are reported to be opting out of the flood-and-rebuild cycle. For example, after a 1972 flood killed 238 people and caused $500 million in damages, Rapid City in South Dakota used federal funds to buy 1,400 pieces of property and created a greenway. Similarly, after the town of Valmeyer, Illinois, was flooded in 1993, 600 residents used $35 million in state and federal aid to move to higher ground.

In St. Charles County, Missouri, a similar relocation after the 1993 flood saw a reduction in damage and the cost of disaster relief when the river flooded again in 1995. Soldiers Grove, Wisconsin, has also avoided disaster by moving its business district away from the Kickapoo River and creating a new town center. And in Napa, California, where flooding costs have averaged $15 million a year since 1960, citizens rejected a plan by the Army Corps to dredge the Napa River and build more levees. Instead, a broad coalition campaigning on the slogan "a living river" mustered the necessary two-thirds vote to restore 600 acres of marshland, move levees back from the river, and relocate more than 60 structures off the floodplain.
(http://www.sierraclub.org/sierra/199905/floods.frame.html)

In the states affected by the Midwest floods, the Federal Emergency Management Agency (FEMA) (Section 3.4.2.2) helped buy out or relocate more than 20,000 properties at a cost of $480 million. The motivation behind its action, FEMA's says, has been that every dollar spent saves two on future disaster-relief costs thus the agency is prepared to acquire more. In this regard, it has proposed measures to discourage building and living in the danger zone, such as refusing to issue flood insurance to property owners who have filed two or more flood claims.
(http://www.fema.gov)

3.4.2.2 Non-structural measures

I. Flood forecasting and flood warning system

Flood warnings and river forecasts are used as one of the important elements in the nation's program to reduce flood damages. Timely warnings and forecasts are used to save lives and aid disaster preparedness, which according to some statistics decreases property damage by an estimated $1 billion annually. The 1993 Midwest flood is often quoted as a good example of the usefulness of early and accurate river forecasts. Although the economic damages caused by the flood were large, the loss of human lives was relatively small. Comparatively, a smaller flood in 1903 claimed 100 lives. Most of the savings in human lives were therefore attributed directly to the early and accurate river forecasts that were made possible by recent advances in remote stream-gauging telemetry and data-intensive river-flow modelling, as well as to the other flood-control measures.
(http://water.usgs.gov/wid/FS_209-95/mason-weiger.html)

The National Weather Service (NWS), which is part of the National Oceanic and Atmospheric Administration, is charged by law with the responsibility for issuing river forecasts and flood warnings. The issuing of these warnings and forecasts is done jointly with several Federal, State, and local agencies. River-flood forecasts are prepared by 13 NWS river-forecast centres and disseminated by NWS offices to the public. During periods of flooding, the NWS river-forecast centres issue forecasts for the height of the flood crest, the date and time when the river is expected to overflow its banks, and the date and time when the flow in the river is expected to recede to within its banks. These forecasts are updated as new information is acquired.

Hydrological Network

The U.S. Geological Survey (USGS) is the principal source of data on river depth and flow. As part of its mission, the USGS provides practical information about the nation's rivers and streams that is useful for mitigation of hazards associated with floods and droughts and defines the hydrologic and hydraulic characteristics needed for the design and operation of engineering projects, such as dams and levees. The primary source of this information is the USGS streamflow-gauging station network.

The USGS operates and maintains more than 85 percent of the nation's stream-gauging stations, which includes 98 percent of those that are used for real-time river forecasting. Currently, this network comprises 7,292 stations dispersed throughout the nation, 4,200 of which are equipped with earth satellite radios that provide real-time communications. The NWS uses data from 3,971 of these stations to forecast river depth and flow conditions at 4,017 forecast-service locations on major rivers and small streams in urban areas.

Mississippi River stage data once collected manually is now gathered in real time from 300 stations and instantly transmitted via satellite links. The data is used to forecast floods and give warnings when the situation demands. This has, according to some authors, substantially reduced the losses due to floods.

II. The Federal Emergency Management Agency (FEMA)

The Federal Emergency Management Agency (FEMA), an independent agency reporting to the President, is the agency tasked with responding to, planning for, recovering from and mitigating against floods, amongst other disasters. It has is a 2,500-person agency supplemented by over 5,000 stand-by disaster reservists with the mission to provide leadership and support, reduce the loss of life and property, and protect the nation from all types of hazards.
(http://www.fema.gov/about/history.htm)

FEMA's organisational structure (Figure 3.20) mirrors the functions that take place in the life cycle of emergency management: mitigation, preparedness, and response and recovery. It also contains the U.S. Fire Administration, which supports the nation's fire service and the Federal Insurance Administration, which provides flood insurance to property owners nation-wide.

III. Compensation and Insurance

The federal government provides financial assistance for uninsured losses through FEMA, and the U.S. Small Business Administration (SBA). FEMA supplies relief workers to help with repairs in damaged areas (Figure 3.19), as well as distributing grants to those whose homes are damaged to the point of being uninhabitable. For those with lesser damages, SBA provides the bulk of federal assistance in the form of low-interest long-term loans. Loans of up to $200,000 are available to homeowners for real estate repairs, while renters are eligible for loans of up to $40,000. Larger loans of up to $1.5 million are available to businesses of all size as well as non-profit organisations. Even the Internal Revenue Service (IRS) chips in by providing flood victims with an income tax deduction for damaged goods. Any loan applicants who are deemed incapable of repaying government loans are automatically referred to the state assistance programs.
(http://www.fema.gov)

Source: www.fema.gov

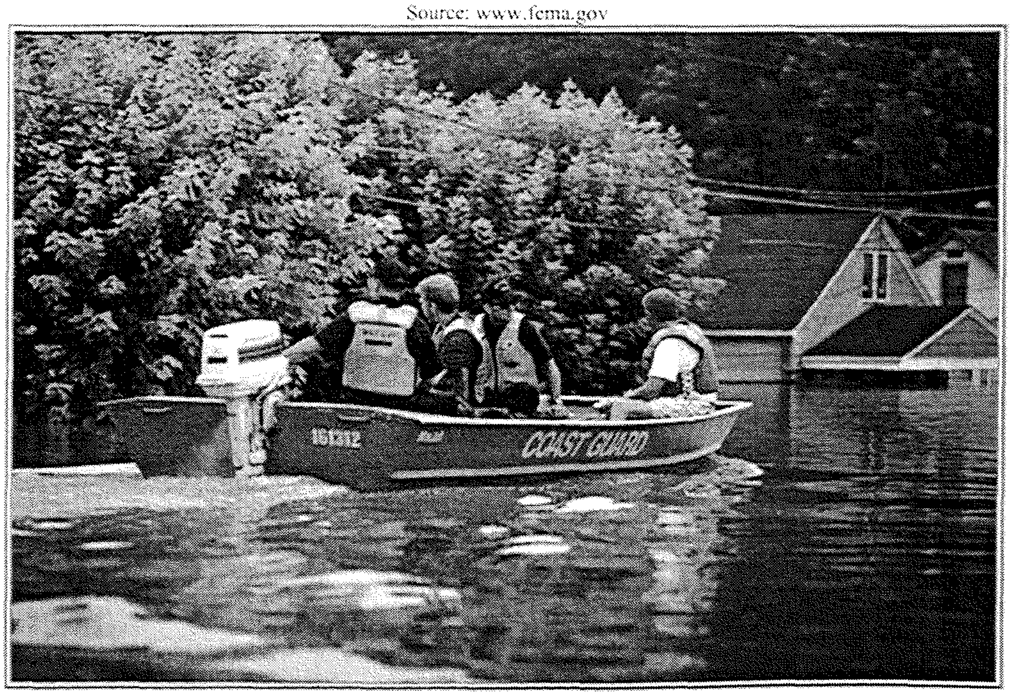


Figure 3.19: Damage survey (1993 floods), St. Geneveive, Missouri

The National Flood Insurance Program (NFIP)

The National Flood Insurance Program (NFIP) managed by FEMA's Federal Insurance Administration (FIA) and Mitigation Directorate (MD), is one such program that gives additional government help. It was created by Congress in 1968 and mandated to do the following:

- To reduce flood losses and disaster relief cost by guiding future development away from flood hazard areas where practicable
- To require flood-resistant designs and construction, and
- To transfer costs of losses to floodplain occupants through flood insurance premiums

It is a completely self-supporting and non-profit making organisation. The FIA manages the insurance component of the NFIP, and works closely with FEMA's Mitigation Directorate, which oversees the floodplain management aspect of the program. People purchase an annual flood insurance policy (average $124,089) at an average cost of $353 (as of April 30, 2000) which are accumulated into a pool until they are needed.

However, because of its non-profit mode of operation, NFIP can only cover a limited number of claims within this pool. When the funds run out, it has a $1 million credit limit with the federal government that it uses in the form of a loan and later reimburses through money received from the payment of the claims (Kellan, 1997).

NFIP claims that through its partnerships with communities, the insurance industry, and the lending industry, it helps reduce flood damage by nearly $800 million a year. Further, buildings constructed in compliance with NFIP building standards suffer 77 percent less damage annually than those not built in compliance. And, every $3 paid in flood insurance claims saves $1 in disaster assistance payments.
(http://www.fema.gov/nfip/about.htm)

The Flood Disaster Protection Act of 1973 strengthened the NFIP by requiring the purchase of flood insurance as a condition for receiving any form of Federal or federally related financial assistance, such as mortgage loans from federally insured lending institutions. Risk is the biggest factor in determining the cost of flood insurance. As a result, NFIP has worked with the community leaders to map floodplains in over 20,000 communities and over 18,400 communities now participate in the program.

There are two programs for insurance coverage; the first, the standard flood policy, covers buildings on a 100-year floodplain. The second, the preferred risk policy, covers buildings on a 500-year floodplain. The rates for these two programs are the same across the whole nation.

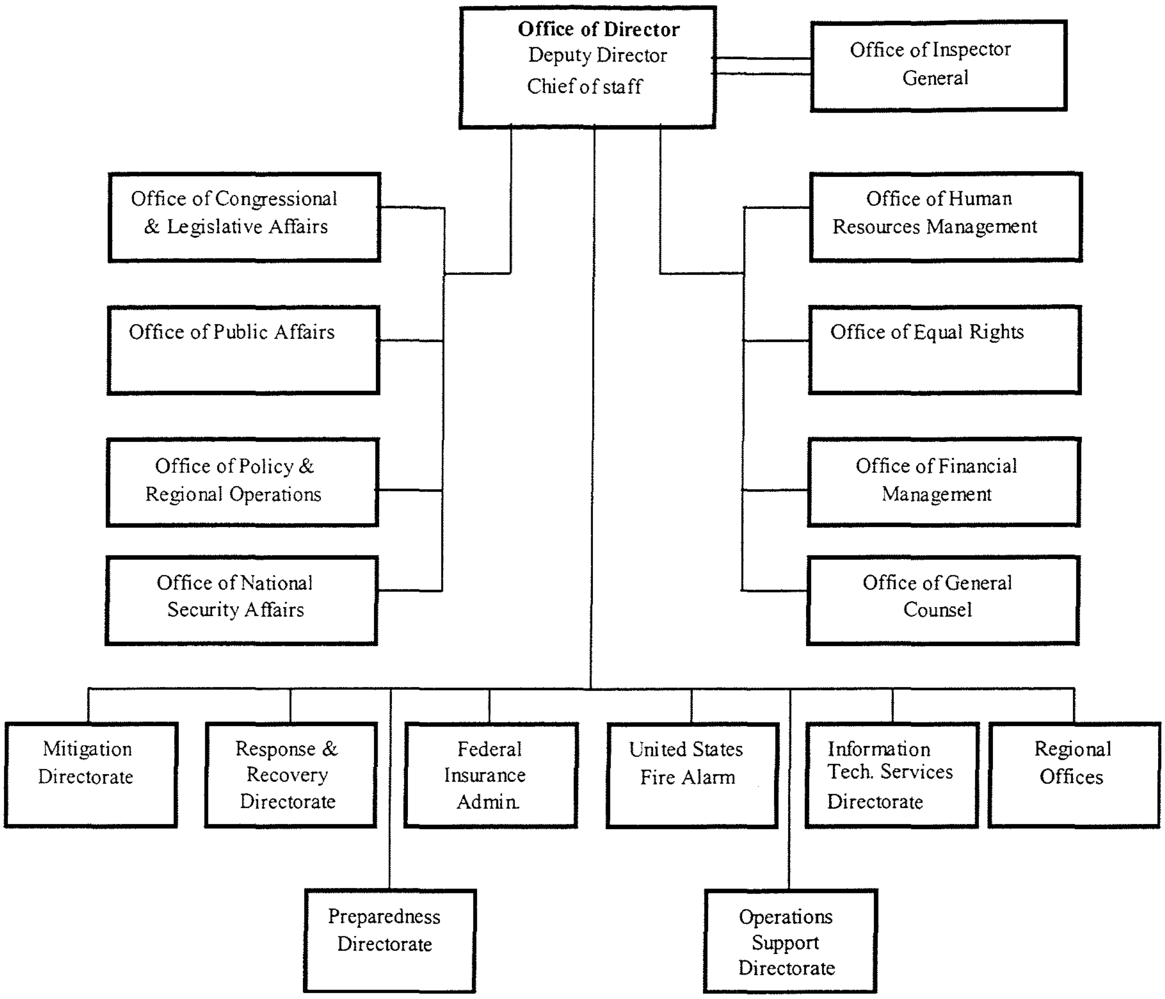


Figure 3.20: FEMA's organisational structure

According to FEMA records, approximately 60 percent of flood insurance claims are filed on just two percent of properties that have suffered multiple losses. More than 5,600 properties have collected claims that exceed the total value of the property itself.

For this reason FEMA has developed a National Flood Insurance Plan Repetitive Loss strategy that is focused on properties that have had at least two losses of $1,000 dollars or more within any 10-year period. Amazingly they have identified 7,300 properties that have had either four or more flood insurance claims or had two to three claims that exceeded the total value of the property. Flood damage to these properties alone cost $200 to $300 million dollars each year. FEMA has been buying out such properties or elevating the structures but in exchange, the owners must take responsibility for their choices. If they decide to stay put, they must bear the full actuarial cost of flood insurance.
(http://www.fema.gov/pte/gosspch69.htm)

Table 3.8: Community rating system

		Premium Reduction	
Credit Points	Class	SFHA (%)*	Non-SFHA**
4,500+	1	45	5
4,000 – 4,499	2	40	5
3,500 – 3,999	3	35	5
3,000 – 3,499	4	30	5
2,500 – 2,999	5	25	5
2,000 – 2,499	6	20	5
1,500 – 1,999	7	15	5
1,000 – 1,499	8	10	5
500 – 999	9	5	5
0 - 499	10	0	0

*Special Flood Hazard Area
** Does not receive premium rate credits because it already has a lower premium than other policies
Source: http://www.fema.gov/nfip/crs.htm

Community Rating System (CRS)

The NFIP's Community Rating System (CRS) was implemented in 1990 as an incentive program for recognising and encouraging community floodplain management activities that exceed the minimum NFIP standards. The National Flood Insurance Reform Act (NFIRA) of 1994 strengthened the NFIP further by providing for mitigation insurance, establishing a grant program for State and community flood mitigation planning projects and codifying the CRS. Under the CRS, flood insurance premium rates are adjusted to reflect the reduced flood risk resulting from community activities that meet the three goals of the CRS: (1) reduce flood losses; (2) facilitate accurate insurance rating; and (3) promote the awareness of flood insurance.
http://www.fema.gov/nfip/crs.htm

There are 10 CRS classes (Table 3.8): class 1 requires the most credit points and gives the largest premium reduction while class 10 receives no premium reduction. The CRS recognises 18 creditable activities, organised under four categories numbered 300 through 600:

- Public information; which credits programs that advise people about the flood hazard, flood insurance and ways to reduce flood damage
- Mapping and regulations; which credits programs that provide increased protection to new development, preserve open space, enforce higher regulatory standards and manage storm water
- Flood damage reduction; which credits programs for areas in which the existing development is at risk. Credit is given for a comprehensive floodplain management plan, relocating or retrofitting floodprone structure and maintaining drainage systems
- Flood preparedness; which credits programs for flood warning, levee safety and dam safety

Approximately 940 communities are currently participating in CRS with their representing over 60 percent of all NFIP flood insurance policies currently in place (Kellan, 1997).

IV. Flood proofing

The National Flood Proofing Committee was established by the Corps of Engineers through its Floodplain Management Services and Coastal Resources Branch to promote the development and use of proper flood proofing techniques throughout the United States. It is comprised of a group of highly qualified Corps of Engineers' employees experienced in floodplain management and selected from various Division and District offices nation-wide. It is responsible for:

- Providing a source of technical expertise on flood proofing
- Conducting research and development on new, innovative, and/or unique materials and technologies for flood proofing
- Developing flood proofing workshops, seminars, and short courses to educate state agencies, local officials, and private citizens
- Working with state and Federal agencies and local officials to develop and conduct workshops and counselling sessions which provide individual flood proofing information
- Documenting flood proofing activities and disseminating flood proofing publications

Local, state, and federal government agencies perform a variety of activities that complement or support flood proofing. The most common way government agencies support flood proofing is by providing publications and general information to interested property owners. Several federal and state agencies have published manuals on the topic that are available to individuals and to state and local governments for free distribution. Many local governments have prepared their own brochures that address local flooding and building conditions. Often these are distributed free to all residents of the floodplain or, particularly in the case of basement flooding, to all residents of the community.

The National Flood Insurance Program (NFIP) also requires structure specific flood proofing for a building not in the floodway that is substantially improved or substantially damaged. Houses that have been substantially damaged or are being substantially improved (renovated) must be elevated to or above the 100-year flood level. Non-residential buildings must be elevated or dry flood proofed.

V. Floodplain management

Floodplain management, a decision-making process that aims to achieve the wise use of the nation's floodplains, is being used to achieve a reduction in the loss of life, disruption, and damage caused by floods, and the preservation and restoration of the natural and cultural values and functions of floodplains. This is mainly being done through:

- avoiding the risks of the floodplain
- minimising the impacts of those risks when they cannot be avoided
- mitigating the impacts of damages when they occur; and accomplishing the above in a manner that concurrently protects and enhances the natural environment

To help reach these goals, there are several community based groups like the Association of State Floodplain Managers (ASFPM) that foster communication among those responsible for flood hazard activities. They provide technical advice to governments and other entities about proposed actions or policies that will affect flood hazards, and encourage flood hazard research, education and training.

For example, it is reported that ASFPM was instrumental in heightening interest in reforming the National Flood Insurance Program in early 1990's. Over a six-year period, Congress frequently requested assistance from the Association in preparing this reform legislation, which resulted in the ultimate passage of the National Flood Insurance Reform Act of 1994.
(http://www.floods.org/history.htm)

3.4.2.3 Structural measures

I. Dikes and levees

Dikes and levees are used in the Mississippi River to confine the river to a single low-water channel, reduce excessive widths and develop desired alignments in the interests of flood control and navigation. They are made of dirt, clay or sand and designed for a flood frequency of 1 in 50 years to 1 in 100 years (Harrison, 1993).

Even before the 1927 flood of Mississippi River, a vast system of levees had been built in order to limit damage from flooding (http://encarta.msn.com © 1997-2000). These levees, which are continuous except where major tributaries enter the Mississippi or where natural high ground makes them unnecessary, protect many areas in the upper valley and virtually wall in the river south of Cape Girardeau, Missouri (Figure 3.18).

Source: www.fema.gov

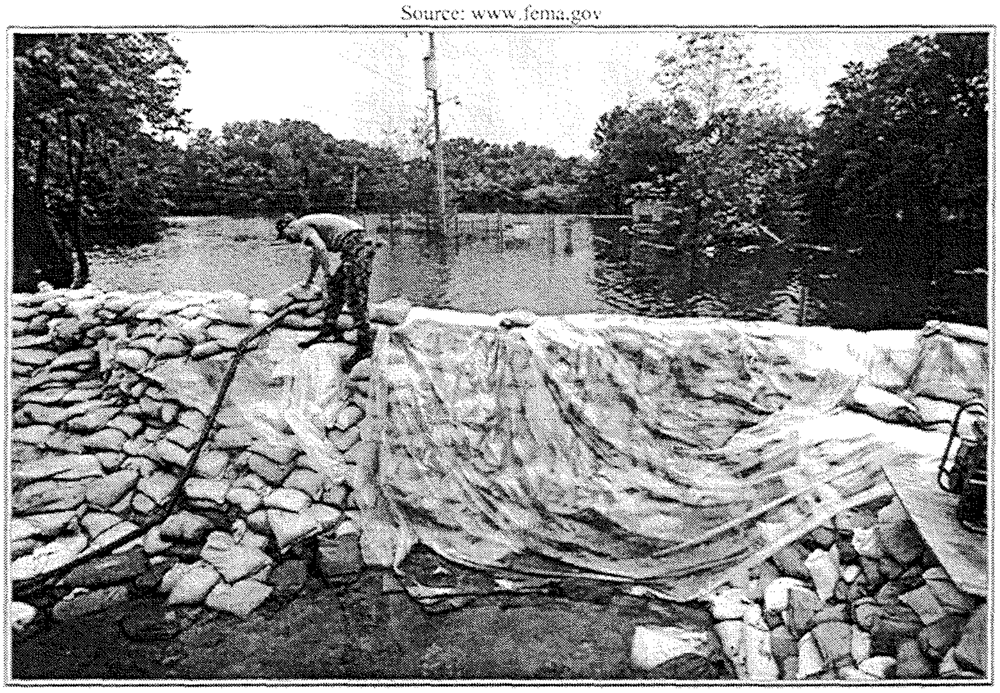


Figure 3.21: Sandbag levee in St. Genevieve, Missouri (1993 floods)

These levees have constrained flows in most floods, but in both the 1927 and 1993 floods, many levees broke (Figure 3.21) and large areas of the floodplain were inundated. U.S Hydrologists believe that the floods may have been worsened by the levees and consequently some of the levees broken in the 1993 flood were not be rebuilt.

On the main stem of the Mississippi River, 2500 km of levees are in place. They are constructed by the federal government and maintained by the local people, except for government assistance as necessary during major floods. Periodic inspections of maintenance are made by personnel from the U.S. Army Corps of Engineers and from local levee and drainage districts as it is essential that the levees be maintained in good condition for their proper functioning in the flood control plan.

II. Dams and reservoirs

There are no large dams and reservoirs for flood control on the main Mississippi River but there are some to control water level for transportation purposes. The majority of flood control structures (dams, reservoirs, control structures, canals, and pumping plants) have been constructed on its tributaries.

In the Upper Mississippi basin they are located in the Missouri River basin. There are 20 flood-control reservoirs on the upper-Mississippi, controlled by three Corps of Engineers Districts: St. Paul, 16; Rock Island, Illinois, 3; and St. Louis, 1 (Harrison, 1993).

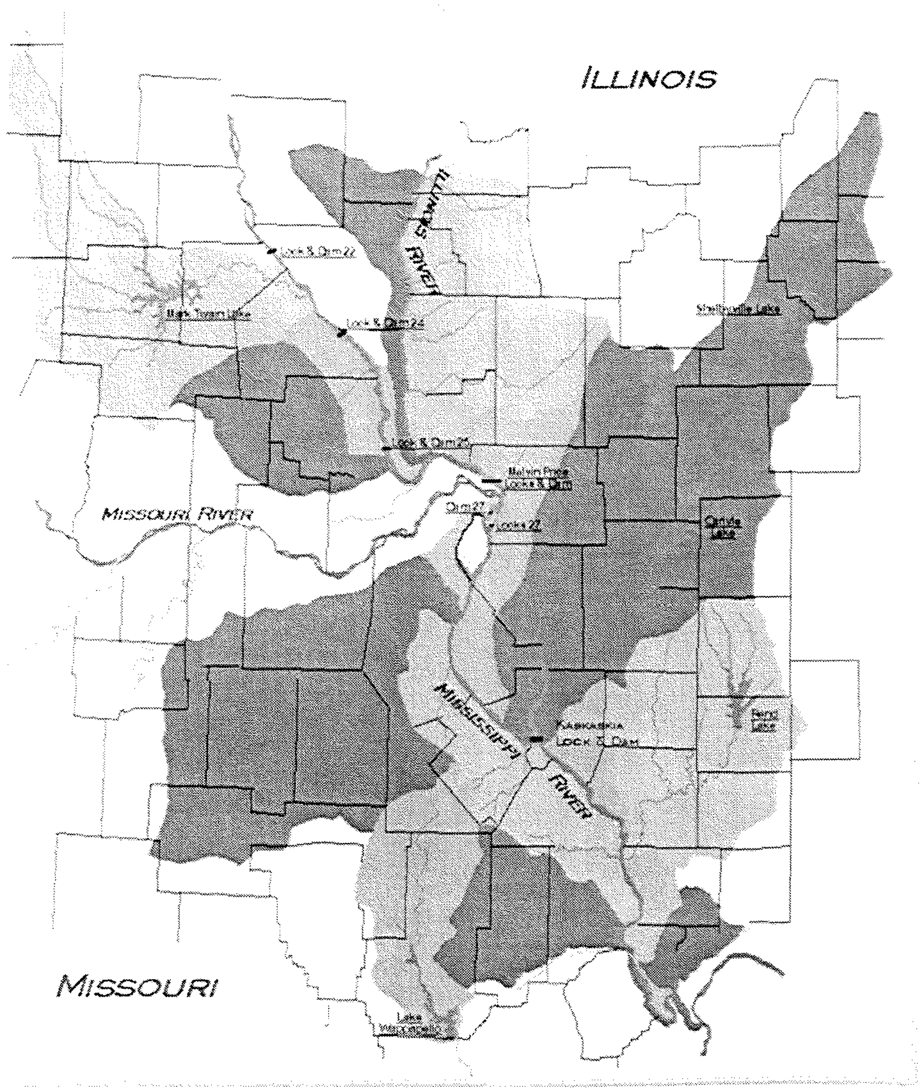


Figure 3.22: Dams and reservoirs in the upper Mississippi

Since 1937, the number of flood-control reservoirs, floodwalls, and levees throughout the Ohio basin has grown, and the number of flood hazards is said to have reduced. Dams constructed in the Appalachian region, were built largely for flood control.

Several dams have been built along the Arkansas River for flood control and irrigation and to create hydroelectric power. One of the most impressive, the John Martin Dam in southeastern Colorado, was built in 1948.
(http://encarta.msn.com © 1997-2000)

Within the 4 major drainage basins in the lower Mississippi River Valley Project (St. Francis in east Arkansas; Yazoo in northwest Mississippi; Tensas in northeast Louisiana; and Atchafalaya in south Louisiana), there are 5 flood control reservoirs. The Lakes are Wappapello in the St. Francis Basin (Figure 3.22) and Arkabutla, Sardis, Enid, and Grenada in the Yazoo Basin (Figure 3.23). The hillside reservoirs constructed through the Yazoo Headwater Project have had a dramatic impact on flood conditions in the Yazoo Basin (Harrison, 1993). They are designed to provide protection to cities downstream from the 100 year high water level.

Even though the condition of the downstream channels does not allow the reservoirs to be operated at their design capacity, the interval between serious floods now seems to have been widened from about every 3 years to about every 10 years. It is also estimated that the reservoirs reduced flood damage in the Delta by $161 million in the single flood event of 1983, an amount nearly four times the original cost of the reservoirs.
(http://www-geology.ucdavis.edu/~GEL242/elsewhere.html)

III. Floodways

Since the disastrous flood of 1927, the Congress authorised the establishment of floodways to divert water at critical points along the river such as the Cairo-New Madrid, Atchafalaya, and Morganza floodways and the Bonnet Carre Spillway at New Orleans, which diverts the Mississippi River waters only at extremely high stages into Lake Pontchartrain. For example the Cairo-New Madrid floodway was operated in 1937 and is said to have been of material aid in reducing flood heights at and above Cairo.
(http://www.mvd.usace.army.mil/Nwsinfo/MRTBrochure.htm)

IV. Channel improvement

Channel improvement is done through the Mississippi River and Tributaries (MR&T) project to stabilise the river banks to a desirable alignment and to obtain efficient flow characteristics in order to increase the flood-carrying capacity of the river, provide an efficient navigation alignment, and protect the levees system. Improvement dredging is also employed to adjust river flow patterns and maintenance dredging to deepen shallow channel crossings that tend to form during low water thus increasing the river's flood-carrying capacity. Cut-offs were also made in the 1930s and 1940s that shortened the river by some 240 km and reduced flood stages.
(http://www.mvd.usace.army.mil/Nwsinfo/MRTBrochure.htm)

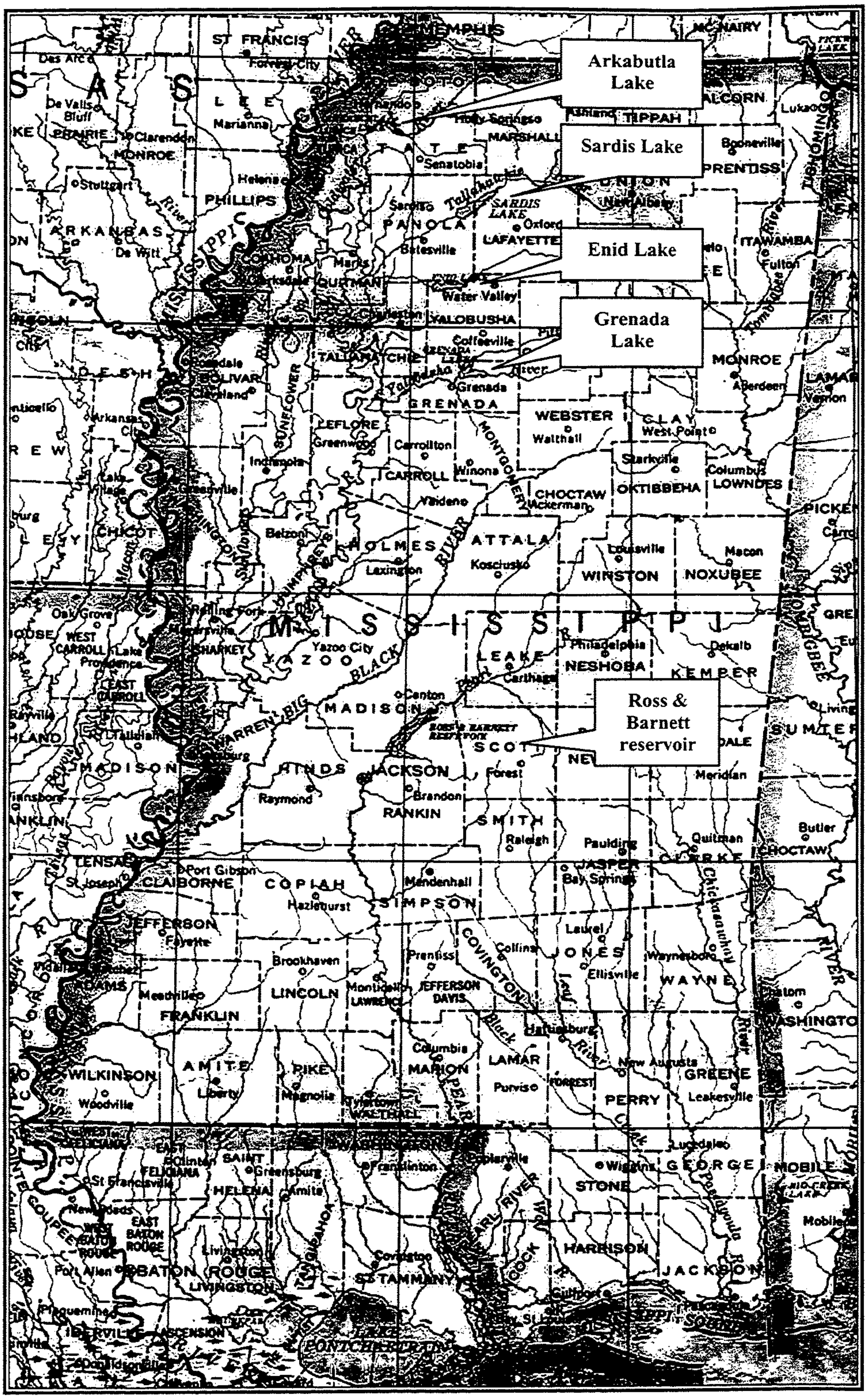


Figure 3.23: Flood Control reservoirs in the lower Mississippi

3.4.3 Socio-cultural justifications for the strategies used to cope with floods

3.4.3.1 Historical perspective

Numerous Native American groups (the Ojibwa, Winnebago, Fox, Sac, Choctaw, Chickasaw, Natchez, and Yazoo) lived along the banks of the Mississippi for centuries before the settlers went to USA. They traded with one another mainly through the river, farmed the floodplains, fished the waters and gave the river its name – "Misi sipi" meaning "big water".

Beginning in the 16th century, the first Europeans arriving by sea in the United States settled in the valley and explored inland mainly through the river and its tributaries. They recognised that the water posed a mixed blessing to their lifestyle and aspirations (Harrison, 1993); the rich alluvial soils and adequate rainfall produced abundant crops and a good living but heavy rains and river floods produced destruction, sickness, and even death. They therefore learned and began to apply flood control and water management strategies that were considered beneficial at that time for the economic development and prosperity of the delta, the local area, the state, and the nation (Harrison, 1993).

In the earlier years as stated in section 3.4.2.1, communities and plantations were located on higher lands while farming was largely confined to well-drained ridges where drainage was a relatively minor problem. By the 1890's, many new farmers had come to the Delta and settled on the lower lying interior lands and individually or in small local groups, did what was necessary to provide drainage for their particular areas (Harrison, 1993). For this, Harrison reports that a lot of effort and funds were concentrated on construction for drainage, flood control, and reclamation to make the lands more productive.

3.4.3.2 Cultural perspective

"Living with floods isn't easy", says Garland from Louisiana State (Garland, 1997). "Talk to anyone who has ever been through one and they will tell you it is a horrible experience". Even worse, flood victims say, is the heartache of losing treasured photographs and family mementoes and the hard and time-consuming physical labour of cleaning up the mess and rebuilding (Figure 3.24).

So why do people stay in houses that have flooded, or buy houses known to flood? According to Garland, the answers vary:

- Some lived in their houses for years before drainage patterns changed and they began getting hit with floods. Without the resources to keep their houses from flooding, they learn to live with floods and how to work with the National Flood Insurance Program.

- Others buy houses known to flood precisely because the price is so low. They view the hassle of occasional floods as an acceptable trade off to get a house they can afford.

Source: www.fema.gov

Figure 3.24: Home owner hoses mud from his house, Kansas City, Missouri

- Those who want to move out often find they can't get a good enough price for their house to make selling worthwhile. Moreover, the emotional ties to the house where one's family was raised are an even bigger factor. "It's not a matter of just picking up and moving," McMichael said. "All your feelings and sentiments are right there. Your whole life is involved in it. How would your grandparents handle moving?" he asked.

- But others are not fully aware before they buy the property that they will be exposed to repeat flooding as demonstrated by the case of Shows. "We were told it hadn't flooded since 1983," Shows said. "If I knew it flooded two or three times a year, I would never have bought this house." If Shows had had access to flood insurance program records, she would have discovered 13 flood claims had been filed on the house between 1982 and when the family bought it in 1993.

  Paradoxically, Shows could not have got the details on the number of flood damage claims from FEMA even if she had tried. FEMA officials say that records on the number of claims at a specific address are covered by privacy laws and are not subject to public release! Her advocate only obtained the records by address from a state agency that gets the information from FEMA, even then over objections from FEMA, after the newspaper filed a request under the state's public records act for access to the information.

3.4.3.3 Social perspective

Responsibility for flood control and water resource development in the Mississippi Delta in the days of the early settlers rested solely upon the local people. In the present day, local interests, the Federal Government and the State share the responsibility. Many see flood control, drainage and proper water management as the key to economic development, prosperity and quality of life in the Mississippi Delta. For example, they claim that relief from floods made railroad and highway systems possible, providing access to markets, consolidation of school systems and development of new industries. Improved drainage reduced sickness, increased crop production, and allowed development of wastelands (Harrison, 1993).

But not all share the same standpoint. Harrison further points out that co-ordinated opposition developed to the Upper Yazoo Projects (Lower Mississippi) and other features of the Yazoo Basin Project at three different levels: Nationally, State level and Locally.

Nationally, numerous congressional leaders and environmental groups opposed funding for flood control and water resources projects and proposed Acts that imposed cost sharing and post-facto mitigation all aimed at halting any further development of wetlands.

At the State level, environmental groups joined the clamour because of their perception that all Corps of Engineers projects are harmful to woodlands and fish and wildlife habitat.

Locally, a group of landowners voiced opposition and formed a local club to join forces with the Mississippi Wildlife Federation and National Wildlife Federation to halt the projects.

3.4.3.4 Political perspective

Harrison (Harrison, 1993) observed that a philosophy of governmental involvement in flood control and water resource development matters has evolved slowly but with profound effects. At first, state government placed flood control burdens directly on the riparian landowners. The impracticality of that approach caused state government to extend the burden to the riverfront counties. The modest success achieved by that approach only drew attention that flooding along the Mississippi was both a State and a Federal problem as well. Now a working relationship has evolved between local agencies, State agencies, and the Federal Government.

The greatest strides in flood control and water resource development were made when the three levels of government were working in harmony and to a common purpose. This is most evident in the impact of the Swampland Acts of the 1850's, the creation of the Mississippi River Commission in 1879, and the Flood Control Act of 1928. Many other interventions have followed after that with only a few mentioned below.

Initial involvement of the state in flood control matters can be traced back to 1819, when the second session of the Mississippi General Assembly adopted an Act to erect a levee in Warren County near the village of Warrenton. The Act provided that the construction costs were to be raised by a manner of county tax to collected by the Sheriff of Warren County.

Prior to Federal involvement in the problems of the Mississippi River through the creation of the Mississippi River Commission in 1879, senators and congressmen from the State of Mississippi were influential in the passage of the Swamp Lands Acts and other pertinent federal legislation. After formal federal involvement, their role became increasingly important in defining the legislation and plans for dealing with navigation and flood control throughout the entire valley.

In 1917, the U. S. Congress adopted what is conceived as the first true flood control act to relieve Mississippi River overflow by setting standards for higher and stronger levees (Harrison, 1993). The Act provided for cost sharing between the federal government and the local districts with the local districts being responsible to furnish rights of way and maintenance. Moreover, the levee districts and states on each side of the river were joined together in a common cause to make the entire valley safe from floods (Harrison, 1993).

After the devastating floods of the lower Mississippi Valley in 1928, Congress responded by passing the Lower Mississippi River Flood Control Act to provide federal funds for the region. Eight years later, Congress passed the Flood Control Act of 1936; an act that declared that flood damage was a national problem and should be aided by federal funds. The result of this legislation was that it shaped policy for 30 years by directing federal efforts towards preventing floods by controlling the flow of water in the major rivers. This was accomplished with the construction of dams, levees, and channel improvement.

In 1965, Congress passed the first of many laws updating federal flood policy. This provided a shift in emphasis of federal programs to non-structural strategies. It also "required more involvement from local governments, placed more emphasis on protecting the environment, increased the attention on coastal flooding, and redistributed the financial burden of flood losses from the general public to the individual users of flood-prone property"

The Flood Disaster Protection Act of 1973 changed the NFIP from a voluntary to a mandatory program. The act made it a requirement to purchase flood insurance for any federal project and for any project in a flood-prone area that relies on federal mortgage guarantees. Furthermore, the act prohibited the payment of disaster relief funds, excluding emergency relief, in communities that were not participating in the NFIP.

The most recent is an Executive Order in 1977 titled "Floodplain Management," that advocated the protection of floodplains as natural phenomena and provided explicit support for non-structural measures wherever possible (Kellan, 1997).

3.4.3.5 Technical perspective

In 1824, the Corps became involved in water resources basically because West Point was the only source of trained engineers in the nation. Indeed the first recorded attempts to study the Mississippi River were made by two West Point graduates, Captain Humphreys and Lieutenant Abbot, who published their study on the physics and hydraulics of the Mississippi River in 1861 (Harrison, 1993). Their report contained a lot of data and stated that levees were the only solution to the flooding in the valley, suggesting that other approaches were not feasible. The Humphreys & Abbot report was used as the main guide of Mississippi River improvements for six decades before subsequent flood events revealed its shortcomings.

Construction of small levees to protect against the annual overflows begun in 1803 when settlers began to come into the Delta to develop farming land along the banks of the Mississippi River. They built 1 m high levees using mainly farm labourers and ordinary farm tools. However, the responsibility for flood control projects at that time was placed under public officials. These officials had broad powers for locating levee lines, for requiring that landowners assist in constructing them and for requiring that non-resident landowners be billed for their share of costs. With time, improved construction standards became necessary so efforts were made to obtain trained and adequately compensated engineers and levee inspectors.

Before the Flood Control Act of 1928, the Levee Boards were responsible for levee construction and flood fighting. They had engineers, technicians and draftsmen to plan, design, and construct works. They also had field crews experienced in construction principles and flood-fighting techniques and also substantial number of local labourers for emergency situations. However, after the Act, the Levee Boards became more dependent on the Corps of Engineers and scaled down the size of the local technical team.

Now the Mississippi Valley Division (MVD) of the Corps of Engineers is responsible for preparing engineering studies and design, constructing, operating, and maintaining flood control, river and harbour facilities and installations. It is also responsible for administering the laws on civil works activities and the mobilisation support of military, natural disaster, and national emergency operations.

3.4.3.6 Management perspective

The first management board for flood control work on the Mississippi River was established in December 1858, when the Mississippi Legislature established a Delta-wide levee district (known as the 1858 Levee Board). Later in 1879, the United States Congress created the Mississippi River Commission for the purpose of improving the navigation of the river and to prevent destructive floods (Harrison, 1993).

Initially, the Mississippi River Commission was not mandated to deal with flood control but levee construction could be approved where it had a direct impact on maintaining the navigation channel. Nonetheless, the local interests interpreted this action as evidence of the growing recognition of Mississippi River problems as national problems.

After the disastrous 1927 floods, the consequent 1928 Flood Control Act created the Mississippi River and Tributaries Project (MR&T). The Act assigned responsibility for developing and implementing the MR&T project to the Mississippi River Commission, which in effect changed its mission. The MR&T project provided for:

- Control of floods of the Mississippi River from Head of Passes to vicinity of Cape Girardeau, Missouri
- Control of floods of the tributaries and outlets of the Mississippi River which are affected by its backwaters
- Improvement for navigation of the Mississippi River from Baton Rouge, Louisiana, to Cairo, Illinois. This includes improvements to certain harbours and improvement for navigation of Old and Atchafalaya Rivers from the Mississippi River to Morgan City, Louisiana
- Bank stabilisation of the Mississippi River from the Head of Passes to Cairo, Illinois
- Preservation, restoration, and enhancement of environmental resources, including but not limited to measures for fish and wildlife, increased water supplies, recreation, cultural resources, and other related water resources development programs

3.4.3.7 Economic perspective

Between 1960 and 1985, the federal government spent $38 billion on flood control, yet average annual flood damage-adjusted for inflation-continued to increase, more than doubling. In the next 10 years (1985-94) floods cost the US on average $3.1 billion annually in damages. Since 1990, damages have averaged more than $5 billion a year. The long-term (1925-88) annual average of lives lost is 95, mostly as a result of flash floods. For this reason, many see flood control, drainage and proper water management as the keys to economic development, prosperity and quality of life in the Mississippi Delta and therefore are in support of flood control measures (Harrison, 1993).

3.4.3.8 Environmental perspective

For thousands of years, the Mississippi River and tributaries deposited silts and sands into a vast alluvial plain stretching from Cairo, Illinois to the Gulf of Mexico. This was a natural fish and wildlife habitat and an important habitat for migratory birds (Harrison, 1993). Abundant in fish, the river was known especially for several varieties of catfish, some of which were harvested commercially.

The upper valley contained vast shellfish beds, which were the basis of an extensive fishery in the 19th and early 20th centuries, but these, according to some reports, were severely depleted and are no longer commercially significant. There is now great concern, especially by environmentalists and those in the seafood industry, at the loss of 65-104 km^2 of marshland every year at the delta. Fish and wildlife populations are threatened as their natural habitat has been slowly disappearing with the loss being attributed to subsidence and a decrease in sediment largely due to the flood control measures upstream.

As a result, during the past two decades, the Corps of Engineers has reported a change in approach in their projects and programs with environmental considerations becoming a major part. They now reflect a broader range of considerations such as endangered species, wildlife habitat and wetlands. For example, the means are being sought to mitigate the loss of wetlands in southern Louisiana. The state encompasses 40 percent of the coastal marshes in the continental U.S., but experiences 80 percent of the loss.

Many studies are underway and the Corps is developing freshwater diversion structures to place freshwater from the Mississippi River into adjacent estuarine areas to combat saltwater intrusion. It is important for fish and wildlife specialists that floodwaters continue to go into storage at various locations throughout the basin during peak events thereby continuing to provide woodlands and wetlands benefits from the project (Harrison, 1993).

Since 1981, MVD has been engaged in a comprehensive environmental program to develop information on natural resources within the unprotected Mississippi River corridor from Cairo to the Gulf. Major objectives have included conducting an inventory of some 1 million acres within the floodplain and develop environmental design guidelines and criteria for the engineering works.

3.4.4 Flood protection policy

In the 20th century, the problem of flood control in the United States assumed national importance because of the increased frequency and intensity of floods in all of the great river valleys, which many people attributed mainly to deforestation (Harrison, 1993). In addition, agricultural and industrial development in these valleys necessitated a co-ordinated program of flood control. Federal legislation, as stated elsewhere in this report, was passed to aid the states in effecting adequate control measures. There is now a notable shift in emphasis away from structural measures to non-structural approaches as the way to prevent or reduce flood damages.
(http://www.lrd.usace.army.mil/gl/212.htm)

3.4.4.1 Flood Mitigation & Riverine Restoration

In 1999, Congress directed the Corps of Engineers to undertake a program for projects to reduce flood hazards and restore the natural functions and values of rivers throughout the United States. While the Corps had existing separate programs for flood protection and aquatic ecosystem restoration, this program ensured the co-ordination of local flood damage reduction or riverine and wetland restoration studies with projects that conserve, restore, and manage hydrologic and hydraulic regimes and restore the natural functions and values of floodplains. The studies and projects under this authority should emphasise, to the maximum extent practicable and appropriate, non-structural approaches to preventing or reducing flood damages.
(http://www.lrd.usace.army.mil/gl/212.htm)

3.4.4.2 Flood Mitigation Assistance

The Flood Mitigation Assistance program (FMA) is made available to a State on an annual basis. It provides grants to communities for projects that reduce the risk of flood damage to structures that have flood insurance coverage. This funding is available for mitigation planning and implementation of mitigation measures only.

The State is the administrator of the FMA program and is responsible for selecting projects for funding from the applicants submitted by all communities within the State. The State then forwards selected applications to FEMA for an eligibility determination. Although individuals cannot apply directly for FMA funds, their local government may submit an application on their behalf.
(http://www.fema.gov/mit/fldmitast.htm)

3.4.4.3 Mitigation Assistance Program

The Mitigation Assistance Program (MAP) provides financial assistance to States for the purpose of the development and maintenance of a comprehensive state-wide hazard mitigation capability for the purpose of implementing pre- and post-disaster mitigation.
(http://www.fema.gov/mit/fldmitast.htm)

3.4.4.4 Community Assistance Program

The Community Assistance Program (CAP) is a product-oriented financial assistance program directly related to the flood loss reduction objectives of the National Flood Insurance Program (NFIP). States and communities that are participating in the NFIP are eligible for this assistance. The CAP is intended to identify, prevent, and resolve floodplain management issues in participating communities before they develop into problems requiring enforcement action.
(http://www.fema.gov/mit/fldmitast.htm)

3.4.4.5 Floodplain Management Services

The Floodplain Management Services Program (Section 206, Flood Control Act of 1960, as amended) has been amended to enable the Corps to provide technical assistance to states, counties and cities in planning the prudent use of land subject to flooding from rivers and lakes. This service is available to state and local governments without charge, within the limits of available appropriations. The support is also available to other Federal agencies and private individuals on a fully reimbursable basis. Upon request, the Floodplain Management Services program provides a full range of technical services and planning guidance on floods and floodplain issues within the broad umbrella of floodplain management.
(http://www.lrd.usace.army.mil/gl/fpms.htm)

4 ANALYSIS OF THE CASE STUDIES

The main objective of the study as stated in Section 1.6, was to make a comparative analysis of the strategies and measures (Section 2.1) used to cope with river floods from the historical, cultural, social, technical, managerial, economic and environmental perspectives, and to assess the lessons that can be learnt from the results. The key words used in chapter 3 are also used here in the comparison and analysis of the case studies.

4.1 Comparison of the Case Studies

For comparison purposes, the key words found in Section 3.1.5 and expounded in Sections 3.2, 3.3 and 3.4 have been divided into four groups i.e. flood situation, strategies, justifications, and effects of flood on the way of life.

For the flood situation namely the benefits arising from the floods, the problems arising from the floods and the objectives of flood control and management in the 3 case studies; these are compared in Table 4.1.

For the strategies namely the strategies adopted in the 3 case studies, the measures, the methods and the flood policy; these are compared in Table 4.2.

For the justifications namely the historical, cultural, social, political, economical and environmental perspectives in the 3 case studies; these are compared in Table 4.3.

For the effect on the way of life namely the disaster preparedness and mitigation, public awareness and participation, post-flood disaster mitigation, population growth and urbanisation, relationship with the natural Environment, and floodplain land-use and spatial planning in the 3 case studies; these are compared in Table 4.4.

Table 4.1: Comparison of flood situation

	Vietnam (Red & Mekong River)	China (Yellow River)	USA (Mississippi River)
Benefits arising from the floods	1) Fertile soils for agriculture especially wet-rice 2) Flushing the acid soils especially in Mekong delta 3) Much fish washed downstream from Tonle Sap lake in Cambodia (Mekong) 4) Added nutrients to the inland fisheries	1) Fertile soils for agriculture especially rice and wheat 2) Abundant water to store for irrigation & power generation	1) Rich alluvial soils for agriculture 2) Abundant water to store for irrigation & power generation 3) Extensive wetlands that form an important habitat for migratory birds
Problems arising from the floods	1) Frequent inundation of up to 10,000 km^2 of farmland 2) Population displacement in thousands and loss of life in hundreds 3) Economic damage and loss (crops, property, infrastructure etc.) 4) Raised river bed in Red River (5-6 m, 14 m max.) due to heavy siltation which affects navigation	1) Frequent inundation of up to 80,000 km^2 of farmland 2) Population displacement in millions and loss of life in thousands 3) Economic damage & loss (crops, property, infrastructure) 4) Raised river bed (3-5 m, 11 m max.) due to siltation affecting navigation and raising the danger of flooding	1) Frequent inundation up to 67,000 km^2 of farmland 2) Population displacement in hundreds and loss of life in tens 3) Economic damage & loss (crops, property, infrastructure) 4) No problem with raised river bed
Objectives of flood control and management	1) Contain the rivers and secure the fertile land for agriculture 2) Protect settled land from floods (Red River) 3) Reduce flood damage & losses to life and property 4) Promote stable social & economic development in the area	1) Contain the river & secure the fertile land for agriculture 2) Protect settled land from floods 3) Reduce flood damage & losses to life and property 4) To promote stable social & economic development in the area	1) Contain the river & secure the fertile land for agriculture 2) Contain the river and enhance its navigability for commerce purposes 3) Provide protection from flood damage & loss of life and property to farms and cities along the river 4) To promote stable social & economic development in the area

Note: For the Vietnam case, Red River or Mekong River is specified when the situation is confined to one river only

Table 4.2: Comparison of strategies adopted

	Vietnam (Red & Mekong River)	China (Yellow River)	USA (Mississippi River)
Living-with-floods			
Measures	1) Giving the river space (Mekong) 2) Living in the flooded areas (Mekong)	1) Designating Flood Storage & Detention Areas (FSDA)	1) Giving the river space 2) Wetland restoration 3) Relocation
Methods	1) Unrestricted river overflow (Mekong River) 2) Building raised houses on stilts, above flood level or on higher ground 3) Shifting cultivation per season in the floodways 4) Communication by boats and canoes during floods (Mekong)	1) Provide safety platforms, safety areas & buildings, and withdrawal roads & bridges 2) Build semi-permanent structures or houses on stilts or piles 3) Build ring levee around very important property	1) Raised buildings above flood level, or on higher ground 2) Seasonal evacuation or permanent relocation to safer areas 3) Acquisition and restoration of wetlands and riparian habitat 4) Building regulations enforcement
Non-structural			
Measures	1) Flood forecasting & warning system 2) Institutional management 3) Land management and planning 4) Public awareness & mobilisation	1) Flood forecasting & warning system 2) Flood control command system (now known as Decision Support System) 3) Information communication system 4) Flood insurance	1) Flood forecasting & warning system 2) Flood disaster management through FEMA 3) Flood proofing vulnerable property 4) Compensation and flood insurance 5) Floodplain management
Methods	1) Operating and maintaining hydro-meteorological network 2) Flood & disaster management 3) Linking all flood control centres, major rivers, lakes and reservoirs authorities 4) Land management authorities 5) Training & education of the public	1) Operating and maintaining hydro-meteorological network 2) Co-ordination of emergency operation 3) Linking all flood control centres, major rivers, lakes and reservoirs authorities 4) Management of the river basin by the YRCC 5) Experiments on insurance systems	1) Operating and maintaining a modern hydro-meteorological network 2) Financial assistance through FEMA and insurance through NFIP 3) Research, development and promotion of floodproofing of properties 4) Research, education and training on wise use of floodplains through community based groups

Table continued in the next page...

Table 4.2 continued…

	Vietnam (Red & Mekong River)	China (Yellow River)	USA (Mississippi River)
Structural			
Measures	1) Dikes and levees (5,000 km river dikes) along the Red River 2) River channel improvement 3) Floodwater and river diversions 4) Flood mitigation reservoirs (Red River) 5) Retarding basins & flood storage areas (Red River)	1) Dikes and levees (1,400 km out of 250,000 km in lower reaches of Yellow River) 2) River channel improvement 3) Dams and reservoirs 4) Floodwater diversion and detention	1) Dikes and levees (2,500 km on main Mississippi) 2) River channel improvement 3) Dams and reservoirs 4) Floodwater diversion
Methods	1) Mainly manually constructed earth river and ring dikes (Red River) & submersible dikes (Mekong River). Designed for largest flood known up to 1971 for Red River (1/125 years) but 1/10 years flood in Mekong delta 2) Levees and revetments for river training in Red River 3) Floodways, canals & inter-basin water transfer channels 4) Dams & multipurpose reservoirs built (Red) 5) Use of low land or natural depressions along the river for flood storage (Red)	1) Mainly manually constructed earth structures using the abundant supply of cheap labour. Design flood frequency varies from 1/20 to 1/1000 years 2) Dams and reservoirs built in the upper and middle reaches of the river to protect the lower reaches 3) Floodwaters are diverted through canals to lakes, depressions and detention areas along the river 4) Floodwater detention basins are identified and designated	1) Dikes and levees made of earth, clay or sand. Design flood frequency varies from 1/50 to 1/100 years 2) No large dams and reservoirs for flood control on the main Mississippi River but constructed on its tributaries 3) Divert water at critical points through floodways and canals 4) Stabilise river banks to a desirable alignment to increase flood-carrying capacity of the river and provide efficient navigation
Flood policy			
Government policy	1) Reduce flood damage and losses to life & property to an acceptable level 2) Increase the economic benefits from the use of flood-prone areas 3) Improve the environment by restoring the degraded areas	1) Combine flood control with resolution of water shortage and improvement of economy, people's life and production, ecology and environment 2) Retain water in the upper reaches, Release it in the lower reaches and Detain it along the banks of the river 3) Formulate management methods for each area based on the flood frequency and risk analysis, administrative, legal and economic circumstances	1) Prevent flood damage and losses to life & property 2) Provide flood control, irrigation and hydroelectric power wherever possible 3) Provide protection to cities downstream from the 1/100 years flood 4) Restore the natural functions and values of the rivers

Table 4.3: Comparison of justifications

	Vietnam (Red & Mekong River)	China (Yellow River)	USA (Mississippi River)
Historical perspective	1) Red river delta is ancestral home of the ethnic Vietnamese 2) Fertile lowlands and plenty of water for wet-rice & irrigated agriculture 3) Rice is staple food for Vietnamese 4) Fishing in the rivers	1) River valley the cradle of Chinese civilisation 2) Fertile lowlands and plenty of water for rice & irrigated agriculture 3) Civilisation was based on agriculture	1) Native Americans lived along and traded through the river 2) Farmed the rich alluvial soils in the floodplains producing abundant crops 3) Fishing in the river
Cultural perspective (values)	1) Awareness and acceptance of the floods taught through a mythology 2) Vietnamese culture centred on rice 3) Cultivation of rice the principal economic activity	1) Cradle of Chinese culture and civilisation 2) River seen as root, pride and continuity of the community 3) Chinese culture centred on cultivation of wheat, rice and maize	1) Reverence of the river and nature by the Native Americans 2) Emotional ties to home and property 3) Culture mainly centred on privacy and individualism
Social perspective (values)	1) Social and economic development centred on rice 2) Rice sets the basic rhythm of the land 3) Growing population pressure forcing more settlement in flood prone areas	1) Yellow river is the pride of the people 2) Social and economic development centred on the river and agriculture 3) More food and living space required for the growing population	1) Flood control and water management key to economic development, prosperity and quality of life 2) Houses and property more affordable in the floodplains 3) Development in the wetlands that may interfere with fish, wildlife habitat and flora & fauna now being opposed
Political perspective or considerations	1) Agriculture is the backbone of Vietnam's development strategy 2) Rice is Vietnam's greatest resource and grows more plentifully in the two vast fertile deltas 3) Social and economic development centred on rice	1) To gain and sustain political power 2) Concern for people's lives, safety and well-being 3) Free up more farmland for settlement and food production for the rapidly increasing population	1) Relieve Mississippi River from overflow and make the entire valley safe from floods 2) Flood damage is a national problem 3) The manufacturing and service industry in the urban centres along the river are major economic centres

Table continued in the next page…

Table 4.3 continued…

	Vietnam (Red & Mekong River)	China (Yellow River)	USA (Mississippi River)
Economic perspective	1) Areas affected by flooding are centre of economic development 2) Losses from flooding are a serious annual event 3) Rivers useful for local navigation, transportation and trade 4) Weak economy instrumental in deciding on the strategies adopted	1) Abundant supply of peasant labour available which required only shovels and wheelbarrows 2) Economy based on agriculture that creates employment for its people 3) Cultivation of wheat, rice and maize the principal economic activity 4) Floodplains are important base for the national economic development 5) Land in the floodplain is free and no tax is paid	1) Flood control water management key to economic development, prosperity and quality of life 2) Agriculture in the rich farmlands a major economic activity 3) Transportation, manufacturing and service industry along the river are major economic centres
Environmental perspective	1) The silt deposited in the floodplain and delta replenishes the land with nutrients making it fertile and more productive 2) Annual flooding in Mekong delta flushes the acid-sulphate soils 3) Raised riverbed and changing river course in the lower reaches of the Red River due to heavy siltation 4) Deforestation in the watershed contributing to flash floods 5) Reforestation programme now in place to reduce flash floods	1) The silt deposited in the FSDA replenishes the land with nutrients making it fertile and more productive 2) Raised riverbed and changing river course in the lower reaches due to heavy siltation 3) Deforestation in the middle & upper basin contributing to flash floods 4) Reforestation programme now in place to reduce flash floods 5) Water & soil conservation measures using vegetation cover and check dams in place	1) Reverence of the river, nature and environment by the Native Americans 2) Loss of sediments and less annual floods causing destruction of wetlands and loss of natural habitat for fish, wildlife, birds and flora & fauna 3) New policy advocates environmental considerations for all projects 4) Raised environmental awareness responsible for new policy to restore the natural functions and values of the rivers

Table 4.4: Comparison of effects of flood on way of life

	Vietnam (Red & Mekong River)	China (Yellow River)	USA (Mississippi River)
Public awareness and participation	1) Good awareness for the people living in the floodways and the Mekong delta due to constant threat of floods. 2) Structural measures give a false sense of security to people protected by the structures (Red) 3) People's participation upon mobilisation during emergencies rated as good 4) Training and education on flood control and disaster reduction required	1) Efforts to tame rivers date far back into history 2) People previously directly involved in flood mitigation 3) Structural measures give a false sense of security to people protected by the structures 4) Social education on flood control and disaster reduction required	1) The NFIP's Community Rating System is raising awareness through community floodplain management activities 2) Several community based groups like the ASFM involved actively in floodplain management 3) Participation during emergencies is rated as good since people are more prepared through the flood warning system
Disaster preparedness and mitigation	1) National committee (CCFSC) formed to strengthen preventive and response capability 2) Disaster Management Unit formed to manage emergency plans, mobilisation and repairs 3) The army mobilised during disasters for emergency activities	1) Flood forecasting and flood warning command system formed 2) Information communication system being upgraded 3) Provision of good roads to ease evacuation especially in FSDA 4) The army mobilised during disasters	1) Flood forecasting and advanced flood warning system available 2) FEMA responsible for emergency management of all flood disasters 3) Corps of Engineers responsible for mobilisation support of military, natural disaster and national emergency operations
Post-flood disaster mitigation	1) No adequate expertise on damage and emergency assessment 2) Post-flood assistance hampered by lack of resources 3) Emergency assistance is slow. People normally carry out over 50% of own relief work	1) No flood insurance available yet 2) Low-level compensation available from the government 3) A project for the resettlement of affected people 'Resettlement and Town Building Project' in place	1) Financial assistance for uninsured losses through FEMA or by Presidential disaster declaration 2) Compensation through NFIP for insured losses 3) Low-interest long-term loans through SBA

Table continued in the next page…

Table 4.4 continued...

	Vietnam (Red & Mekong River)	China (Yellow River)	USA (Mississippi River)
Population growth & Urbanisation	1) High population in Red River (500 per km^2) and Mekong River delta 2) About 70% of population at risk of flooding 3) Growing population pressure causing settlement in flood prone areas	1) Rapid settlement in the floodplain and the FSDA (522 per km^2) due to population pressure 2) Approximately 100 million people living in the area protected by the main dikes 3) Flood control of the river has brought water, good harvests and an affluent life to the countryside along the river	1) Many manufacturing, service, and transportation centres along the river 2) The large towns and cities along the river depend on it for their economic base
Relationship with the natural Environment	1) Deforestation from 44% cover to 28% cover in 50 years causing increased erosion, siltation & runoff 2) Environmentally sound projects being encouraged 3) National awareness of need for environmental protection, conservation & restoration growing	1) Deforestation in the upper part of the river course contributing to flooding 2) Reforestation, soil and water conservation measures in the middle reaches being enhanced 3) Warping practised to replenish soils in the floodplains with nutrients and reduce deposition downstream of the river	1) Extensive destruction of wetlands done by settlers to create land for agriculture and development 2) Acquisition and restoration of the destroyed wetlands and riparian habitat now being done 3) A program to reduce flood hazards and restore the natural functions & values of rivers in place due to raised environmental awareness
Floodplain land-use and spatial planning	1) Mainly used for irrigated agriculture particularly rice 2) Population pressure causing change in management and land-use planning 3) People invaded the floodplains for agriculture and settlement	1) Mainly used for irrigated agriculture particularly rice & wheat 2) Uncontrolled development and population growth in most FSDA 3) Poor management or lack of organisation in most FSDA 4) Big cities and towns located in the floodplains	1) Mainly used for irrigated agriculture i.e. grains, rice, soybeans, groundnuts etc 2) Urban settlement & industrial centres 3) Being restored as wetlands and natural habitat for fish, wildlife, birds and flora & fauna

4.2 Analysis of the case studies

4.2.1 Flood situation

4.2.1.1 Benefits arising from the floods

The 3 cases benefit from the fertile soils deposited by the floodwaters (Table 4.1, Sections 3.2.1, 3.3.1 and 3.4.1). All the cases use the agricultural land intensively with agriculture contributing substantially to the national food production. China and USA have further increased their benefits by harnessing the floodwaters upstream of the rivers not only for irrigation but also for power generation, which, in addition to the flood control measures, has encouraged the growth of industrial towns along the floodplains that contribute enormously to their economic growth. In Vietnam, the topographical advantages necessary for hydropower generation within the part of the drainage basin of the Red and Mekong Rivers that lies in the country are limited.

4.2.1.2 Problems arising from the floods

The problems arising from the floods in the 3 case studies are essentially the same with the difference being only in the magnitude (Table 4.1, Sections 3.2.1, 3.3.1 and 3.4.1). For China, the high population pressure has been instrumental for the dense settlement in the floodplains thus displacements are in millions and loss of life in thousands whenever disastrous floods occur as compared to displacement in hundreds and loss of life in tens in the USA.

Similarly, the direct economic loss and damage in USA is greater than in China and Vietnam by a factor of 5 and 40 respectively, which can be attributed mainly to the difference in the scales of investments and the level of economic development of the 3 countries.

In regard to siltation, the Mississippi River is not having problems with raised riverbed partly due to the type of soils (alluvial soils) but mainly due to the numerous flood control dams upstream that have reduced the amount of silt reaching downstream. The 'suspended rivers' in Vietnam and China are a result of several factors: the loess soils upstream, land use pattern, deforestation and the levees that constrict the rivers. The recent efforts on soil and water conservation measures in both countries and especially China are expected to reduce the problem of 'suspended rivers' substantially.

4.2.1.3 Objectives of flood control and management

The objectives of flood control and management in the 3 cases are strikingly similar (Table 4.1, Sections 3.2, 3.3 and 3.4). Securing the fertile land for agriculture ranks first in all the cases but once the land is developed and large populations settle there to take advantage of the improved social and economic opportunities the land offers; reducing damage and losses to life and property takes priority.

While all the rivers were used for navigation at one time or the other, the importance placed on flood control to enhance navigability and commerce is best illustrated in the Mississippi River where a Commission was established in 1879 with the principal goal of improving its navigability for commerce purposes.

The growth of many manufacturing, service, and transportation centres along the Mississippi River that developed into large cities and towns like Saint Louis, Missouri; Saint Paul, Minnesota; Memphis, Tennessee and New Orleans, Louisiana; could be attributed to the success of the Mississippi River Commission.

China followed the same trend from 1946 with the formation of the Yellow River Conservancy Commission. Numerous dams and hydropower stations like Yanguoxia, Tianqiao and Longyangxia were constructed, which changed the story of the river from one of misery to one of hope. Vast semi-arid areas were turned into green lands through irrigation bringing good harvests and an affluent life to the countryside along the river. Rows and rows of houses have come up, and towns and industrial cities like Lanzhou, Baoton, Shanxi and Zhengzhou have grown.

4.2.2 Strategies

4.2.2.1 Living-with-flood measures

The 3 cases historically used similar measures in the living-with-flood strategy but differed with the passage of time (Table 4.2, Sections 3.2.2.1, 3.3.2.1 and 3.4.2.1). Building houses on stilts (raised floors), above flood level or on higher ground; shifting cultivation and seasonal evacuation are such similar measures all aimed at taking full advantage of the extremely fertile soils deposited annually by the floods.

In Vietnam's Mekong delta, the same measures are still being practised and respected by the government. The government's policy appears to be greatly influenced by the agreement with the riparian countries of Cambodia, Laos and Thailand to regulate developments, especially high dikes, that would have detrimental effects to any of the riparian countries. However, while the benefits from the floods are quite clear (Table 4.1), the disruption to social life that occurs annually has, in a way, negatively affected the level of development in the area when compared to other regions.

The FSDA in China offer an improved living-with-flood situation as they are used only occasionally for temporary storage of excess floodwaters. Since they are normally situated just outside the river dikes, which are designed for 30 - 40 year flood frequency, they enjoy a level of protection greater than that in Mekong delta in Vietnam where floods inundate the land every year. The effect of this can be seen in the number of people living in the FSDA, the growth of economy there and the value of properties they own. The uncontrolled development though, happening because of lack of effective planning and development, does not augur well for the FSDA inhabitants and the flood control authorities as the cost of utilising them keeps on rising and especially the cost of providing the safety infrastructure.

In USA, the cost and inconveniences of flood-and-rebuild cycle has made many people opt for relocation to safer areas. While that is possible in USA because of its strong economy, the relatively small number of people involved and the availability of abundant alternative land for settlement, this would be very difficult or nearly impossible to implement in either China or Vietnam. The same applies to the program to buy marginal cropland to restore it to wetlands.

4.2.2.2 Non-structural measures

The non-structural measures adopted by the 3 cases are similar in form but differ substantially in content (Table 4.2, Sections 3.2.2.2, 3.3.2.2 and 3.4.2.2). For example, while Vietnam and China are still expanding, upgrading and linking their flood forecasting and warning systems, USA is already employing the most modern satellite based methods.

The cultural norms of the Chinese and Vietnamese, where subordination of subject to the ruler is emphasised, appear to have influenced the evolution of the hierarchic flood disaster management systems now in place (Figure 3.7 and Figure 3.14). In both cases, the institutions are managed by committees whose members are drawn from other government departments, which has an effect on accountability and the decision making process. Furthermore, the relationships of the various levels is strictly top – down involving 5 and 4 decision levels respectively before reaching the affected people in the village.

In comparison, FEMA system in USA (Figure 3.20) is more independent as the director reports directly to the President. The director has his own officers and an organisational structure that mirrors the functions that take place in the life cycle of emergency management: mitigation, preparedness, and response and recovery. There are only 3 decision levels involved to reach the affected people in the village thus making it more responsive practically.

Compensation and insurance systems are still being developed in China and Vietnam. For this reason, compensations from the government are still considered minimal being less than US$ 200 for a totally damaged house in Vietnam. While this could be attributed to the relatively weak economies in the 2 cases, the system in USA is nevertheless worth noting. The system managed by FEMA through its numerous programs like the NFIP is more developed and useful in training and educating the public on flood damage and mitigation, and on wise use of floodplains through the incentives offered by the Community Rating System.

The NFIP system was subject to abuse for some time with even allegations that it was encouraging settlement in flood prone areas. However, a 'Repetitive Loss Strategy' focused on properties that had at least two losses greater than $1,000 dollars within any 10-year period was used to identify the victims and to close the loopholes. This was done by giving them an NFIP buy out option or otherwise to bear the responsibility and pay the full actuarial cost of flood insurance.

Research, development and promotion of the use of proper flood proofing techniques by the National Flood Proofing Committee and the making of flood proofing of property a requirement by NFIP, has been instrumental in the reduction of damages and losses.

Quick recovery and re-building is important after a flood disaster. In USA, it is possible to obtain long-term low-interest federal loans up to US$ 1.5 million for this purpose but this is not the case in China and Vietnam.

4.2.2.3 Structural measures

In China, the dike system is more expansive compared to Vietnam and USA mainly because of the long history associated with flood control and China's abundant supply of peasant labour that was used for the construction using simple implements like shovels and wheelbarrows (Table 4.2, Sections 3.2.2.3, 3.3.2.3 and 3.4.2.3). However, greater emphasis is now being laid on dams and reservoirs, floodwater detention and floodwater diversion as illustrated by the YRCC's catch-phrase *"Retain water in the upper reaches, Release it in the lower reaches and Detain it along the banks of the river"*. Through this, China is embracing both the 'Top – end' approach of delaying the runoff and reducing the flood peak, and the 'Bottom – end' approach of reducing the downstream risks through dike strengthening, creation of retention areas, and spatial planning by providing more space to the river. All this is aimed at "making better use of the Yellow River and bringing happiness to the people" (Zhu, 1997).

In Vietnam, different approaches are used in the north and the south. Along the Red River, which is the ancestral home of the Vietnamese, the emphasis is more on structural measures. There is more utilisation of inter-basin water transfers to cater for irrigation needs and to reduce the need to increase the height of the dikes any further. In the Mekong delta, which was settled more recently, the emphasis is more on living-with-flood measures (Section 4.2.2.1). Unlike the Yellow River in China or the Mississippi River in USA, the Mekong drainage basin lies in more than one country. Therefore, though the government's policy in Mekong could have been drawn from its negative experiences with the dikes system in the north, notably the raised riverbed and high maintenance costs, the concern by the riparian countries on the possible effect of developments within the basin has significantly affected the strategies and measures adopted.

In regard to the level of economic development, there is a noticeable difference in the north compared to the south. While this difference could be attributed to the influence of the historical development of the Red River delta as the ancestral home of the Vietnamese, the differences in the flood control and management practices, as many Vietnamese I talked to conceded, could be said to have contributed substantially. The town of Can Tho (Figure 3.1), the only big town within the Mekong delta, confirms this observation as it is situated on a relatively raised area which is not affected by the annual floods.

In USA, there has been a preference for structural measures towards flood control and floodplain management that overshadowed non-structural approaches, with the Mississippi River said to be one of the most heavily engineered natural features. Economics related to the navigability of the river appear to have played a major factor when deciding on the flood management strategies and the measures to be adopted. Beginning in the 1980s, however, there was a decline in the use of structural approaches and an increase in the adoption of non-structural approaches. This change was at first attributed to the increasing costs of structural solutions but the growing environmental concerns about their impact has played a more important role. Concern to restore key environmental areas that would promote bio-diversity and connections between habitats has greatly increased recently with programs like Hazard Mitigation Grant Program being started to buy people out of the floodplain and restore the areas to wetlands and natural open space.

4.2.2.4 Government policy

The 3 cases generally have the same flood protection policy centring on social, economic and environmental perspectives but differ on approach and emphasis (Table 4.2, Sections 3.2.4, 3.3.4 and 3.4.4).

Vietnam's approach has been more on the social perspective with emphasis on reduction of flood damage and losses to life and property to an acceptable level. This is possibly due to the political system that the country has been practising for the last few decades.

China's approach has been more on economy and environment with more emphasis on combination of flood control with resolution of water shortage, improvement of the economy, people's life and production, and environment, all aimed at "bringing happiness to the people".

USA's initial approach was on economy with emphasis on the navigability of the river and hydropower generation to bolster agricultural and industrial development, then social. Due to growing pressure from the environmentalists, the emphasis has now shifted to environmental aspects i.e. restoring the natural functions and values of the rivers.

4.2.3 Justifications

4.2.3.1 Historical perspective

In the 3 cases, the floodplains are recognised as the ancestral home of the ethnic communities that had settled there because of the availability of fertile land, abundant water for irrigation, domestic use, transport and fishing (Table 4.3, Sections 3.2.3.1, 3.3.3.1 and 3.4.3.1). Their sentimental attachment to the rich homeland made them develop strategies and methods suitable to live with the floods at that time. However, the increase of human activities and needs that followed the booming of Chinese population from 206 BC, the invasion of Vietnam by the Chinese in 111 BC and the invasion of USA by the Europeans in the 16^{th} Century, increased the need for additional flood control measures. As people occupied more of the floodplains, there were increased cases of flooding (Table 3.5) due to the increased land use, deforestation, damage to vegetation, and soil erosion that accompanied such activities.

4.2.3.2 Cultural perspective

The Vietnamese and Chinese culture which is centred on rice growing has been responsible for passing on the tradition of living with floods (Table 4.3, Sections 3.2.3.2, 3.3.3.2 and 3.4.3.2). In the Vietnamese culture, this has been done through a mythology that over the years taught the people to accept the floods as part and parcel of their lives while in China, the river is seen as the root, pride and continuity of the community.

In USA, 2 approaches are visible: The natives revered the river and nature and therefore lived with the floods as part of natural phenomenon but when the settlers went to the country in the 16^{th} century, they set to control nature by introducing structural flood control measures. They also introduced a new culture of privacy and individualism as illustrated by the overemphasis on privacy laws on property and any information considered private.

This has, in a way, complicated flood control especially when people become emotionally tied to their home and property and refuse to co-operate or disclose information such as flood history when required to do so.

4.2.3.3 Social perspective

With cultivation of rice being the principal social and economic development activity in Vietnam and China, family structure and unity modelled on Confucian norms becomes an important ingredient in the society (Table 4.3, Sections 3.2.3.3, 3.3.3.3 and 3.4.3.3). The 2 cases share much in common in the way the societies are closely knit together by the Confucian norms. These norms appear to have influenced the evolution of hierarchic and authoritarian societies where obeying the ruler or leader is an obligation and community participation in social activities is considered an honour and a key factor for success.

That cannot be said to be the same for USA. Though flood control and water management are seen as key to economic development, prosperity and quality of life, the cost of houses and property, which is relatively more affordable in the floodplains, is also a key factor for those settling there. For this reason, even the approach to flood control measures was more on the individual or basic family level rather than the societal level. The government became involved only when big problems occurred or a group of individuals sought its assistance. That notwithstanding, the strength of such an individualistic society is evident in cases such as the recent changes in flood control strategies from mainly structural to non-structural that followed strong opposition by environmental groups and floodplain managers to development of wetlands that interfere with fish, wildlife habitat and flora & fauna.

Based on the cultural theory (Appendix I) as applied to water perspectives in regard to flooding risks (Hoekstra, 1998), the Vietnamese and Chinese societies can be categorised as egalitarians as they exhibit more equal risk level (societal) characteristics. The USA society tends towards being hierarchists (individualists) as they exhibit divergent risk level characteristics.

4.2.3.4 Political perspective

The involvement of the government at the policy level, like enacting flood control acts and establishing river commissions, and at the macro scale like planning and implementing large scale projects, is visible in all the 3 case studies (Table 4.3, Sections 3.2.3.4, 3.3.3.4 and 3.4.3.4). Indeed, it is evident that the greatest strides in flood control and water resource development, especially in China and USA, were made when the government and the people were working in harmony and to a common purpose. For Vietnam and China, this was mainly driven by the government's concern to feed its people first, given the high agricultural productivity of the areas. Safety and well-being for the 3 cases followed later as the high economic potential of the areas became evident when large towns and industrial centres developed or more people settled there.

4.2.3.5 Economic perspective

The state of the economy or anticipated economic benefits is instrumental in deciding on the strategies to be adopted to cope with floods (Table 4.3, Sections 3.2.3.6, 3.3.3.7 and 3.4.3.7).

Without the benefits of a strong economy, Vietnam and China first depended on the abundant peasant labour available that required only simple implements while USA used the slave labour to construct simple dikes and levees. With fewer people to evacuate or less property to lose when floods occurred, the simple and limited flood control measures taken at that time were adequate. However, with the expansion of the economy in those areas, more was lost or at risk whenever floods occurred and therefore more large scale measures like dams and reservoirs that required more capital investments were sought.

While USA could afford it because of its strong economy, Vietnam and China could not. Subsequently, with the flood and water reasonably managed, USA was able to expand its economy much more, spurred by the transportation, manufacturing and service industry that developed along the river due to the availability of abundant hydropower generated from the dams. China was quick to learn and followed suit since 1946 and now the benefits are clearly being seen in the towns and industrial cities like Zhengzhou that have grown along the river since then.

4.2.3.6 Environmental perspective

There is an intrinsic relationship between the state of environment and the strategies used to cope with floods (Table 4.3, Sections 3.2.3.7, 3.3.3.8 and 3.4.3.8). For example, the effect of siltation as a result of deforestation in the watershed areas has been the main cause of raised riverbed and changing river courses in the Red River and Yellow River. As a result, dikes have to be used to contain the river and their heights raised regularly to keep up with the changing levels. Similarly, the system of no dikes in Mekong delta ensures that annual floods flush the acid-sulphate soils.

In the Mississippi delta, loss of wetlands and natural habitat for fish, wildlife, birds and flora & fauna has been attributed to loss of sediments and less annual floods arising from the dams and reservoirs constructed upstream for flood control and power generation. Now due to these environmental changes, the new government policy advocates environmental considerations for all flood control projects and the restoration of the natural functions and values of the rivers.

4.2.4 Effects of flood on way of life

4.2.4.1 Public awareness and participation

Most of the structural measures implemented have been observed in the 3 cases to give a false sense of security to the immediate beneficiaries (Table 4.4, Sections 3.2.2, 3.2.3, 3.3.2, 3.3.3, 3.4.2 and 3.4.3). There is relatively more awareness and participation in the areas that use non-structural measures or flood more frequently like the floodways and the FSDA than just behind the dikes where it floods occasionally.

In China and Vietnam, there are emergency drills every year before the flood season for the people who are directly involved in an emergency mobilisation but not for the general public. However, every home in the flood prone area in Vietnam keeps two empty sacks for emergency use while in China every home in the FSDA used to keep a goatskin boat.

In USA, the NFIP's Community Rating System is raising awareness by giving incentives of insurance premium rebates through community based floodplain management activities like flood proofing that are aimed at flood loss reduction.

4.2.4.2 Disaster preparedness and mitigation

Governments have a responsibility to protect their citizens from disasters and for helping them to recover when a disaster strikes. For this reason, flood disaster management organs have been formed in the 3 cases (Table 4.4, Sections 3.2.2, 3.3.2 and 3.4.2). As discussed in Section 4.2.2.2, the committee-based Vietnamese and Chinese management systems are not as efficient as the American FEMA system due to the many decision levels involved. The Vietnamese system was improved recently (1995) with the formation of the Disaster Management Unit (DMU) whose main objective is to protect the people against the annual natural disasters that ravage the country.

In all the 3 cases, flood forecasting and warning system is relied upon to initiate the emergency preparations but sufficient materials are stockpiled at strategic regional locations for initial emergency use. Good infrastructure is a prerequisite for efficient disaster mobilisation. For USA, the strong economy and availability of ample space makes it easy to achieve this except where private property or private interests are involved and some resistance or delay is experienced. China as a newly industrialised country has also made a good effort to provide roads especially in the FSDA to ease evacuation. Given its high population, this is an important achievement that was mainly possible because of the top – down government approach on all major decisions. For Vietnam, poor roads and scarcity of transport occasioned by the weak economy has been a limiting factor and much remains to be done.

4.2.4.3 Post-flood disaster mitigation

As stated in Section 4.2.4.2, in addition to the responsibility to protect the citizens from disasters, governments are under obligation to help them to recover when one strikes. In the 3 cases, the post-flood disaster mitigation measures in Vietnam and China were observed to be inadequate compared to USA (Table 4.4, Sections 3.2.2, 3.2.3, 3.3.2, 3.3.3, 3.4.2 and 3.4.3).

From the information available, expertise on damage and emergency assessment in Vietnam is inadequate. Emergency assistance is therefore slow and often hampered by lack of resources. People normally carry out over 50% of own relief work before external help arrives. Without adequate compensation or insurance (Section 4.2.2.2), it has been difficult to recover after disasters and therefore most people live in constant apprehension of the effects of such disasters.

In USA however, the financial assistance for uninsured losses through FEMA, compensation through NFIP for insured losses, low-interest long-term loans through SBA or presidential disaster declaration when the disaster is beyond the capabilities of the state and local government to respond, ensures that the people recover quickly from disasters.

4.2.4.4 Population growth and urbanisation

A similar pattern of rapid population growth, urbanisation and industrialisation has been observed in the 3 cases whenever effective flood control measures are implemented in an area. This was the case for the floodplains of the Red River, Yellow River and Mississippi River but not so for Mekong delta in Vietnam which still experiences annual inundation (Table 4.4, Sections 3.2.1, 3.3.1 and 3.4.1). However, increasing population pressure is causing settlement in flood prone areas like the FSDA in China and the floodways in Vietnam, leading to conflict in their use. Attempts to solve this problem by strict population control have not succeeded yet, as the land is fertile and also free from taxation as these areas are not officially recognised as settlement areas.

4.2.4.5 Relationship with the natural environment

Destruction of the environment especially deforestation and draining of wetlands which results in interference with the natural balance of nature has been observed to contribute to increased flooding (Table 4.4, Sections 3.2, 3.3 and 3.4). Effective flood control of an area has, on the other hand, been followed by extensive destruction of environment either through deforestation as in Vietnam and China or wetlands destruction like in the USA, as people invade the 'secured areas' for various uses. This has raised national awareness in the 3 cases on the need to conserve, protect and restore the natural environment for sustainable development. Indeed many efforts are now being made in the 3 cases to encourage environmentally sound projects, soil and water conservation, reforestation, and wetland restoration as the calls for 'green rivers' increase.

4.2.4.6 Floodplain land-use and spatial planning

The major land use in the floodplains is agriculture followed by settlement (Table 4.4, Sections 3.2, 3.3 and 3.4). With urban settlement becoming more attractive due to the changed economic situation and the industrial centres being located in or near the floodplains, the pressure of population increase is causing a change in management and land use planning.

For example, uncontrolled development and population growth in most FSDA in China has brought conflict in use of the area and there is now mounting pressure to abandon those FSDA that are not frequently used and allow normal development to take place.

In the USA, after extensively destroying the wetlands, there is now a new policy to restore the wetlands and the natural functions and values of the rivers. This shows that there is still need to strengthen spatial planning and management to include environment, population and economic growth control.

4.3 Lessons learnt from the case studies

4.3.1 Stages in the development of strategies to cope with floods

For as long as human civilisation has existed, people have fought to decrease the negative impacts of floods and to benefit and improve on the positive flood consequences. The strategies and measures used throughout history to mitigate the undesirable flood impacts and to benefit from its useful effects have always been a direct function of the level, strength and state of the civilisation. In the case studies described above, the following 5 stages in the development of strategies and measures to cope with floods were observed (Figure 4.1):

Stage 1
Starting with the natural rivers, some cultural and social activities take place along the river. These activities vary from place to place and depend on such factors as the cultural and religious norms of the people living along the river, its size, length and other characteristics. As the population increases, human activities like farming the fertile soils, irrigation, fishing, and navigation also increase in the floodplain, near the river or along it, with people generally living with the floods and accepting it as part of the natural phenomenon of the river.

Stage 2
As people attempt to harness the maximum benefits from the river, the floods or the floodplain by farming the fertile soils, irrigation, fishing or navigation, the need to control the behaviour of the river and the floods arises. At first, individual persons or families do this using their own resources but as other people notice the 'increased benefits', they become attracted and then copy and modify the control measures. With increasing population pressure, growth of settlements, towns, industries and economy, organised groups at the village or community level also become involved.

Stage 3
With increased utilisation of the floodplain due to growth in population, settlements, towns, industries and economy, there is increased risk of losses and damages from flood. To reduce the risk, the need for better and more reliable flood control measures arises. This calls for the formation of a river development agency (commission or authority) to implement these flood control measures. At first this is not realised until some flood disaster strikes and many people are displaced, injured or killed and a lot of property damaged or lost. Enactment of the river development and flood control policy then follows, which may or may not take into account all the historical, cultural, social, political, environmental and economic perspectives. A choice has to be made between living-with-flood, non-structural or structural strategies and measures, which is mainly influenced by the following factors:

- Perception of the flood hazard i.e. historical (frequency, stage, duration, and velocity of flooding), cultural and social aspects
- Land use and flood management experience
- Perception of the possible adjustments
- Technical feasibility of particular adjustments
- The economic efficiency of these choices
- The strength of economy at the time
- Level, strength and state of the civilisation
- Timing and incidence of decisions (by the private and public managers)

Stage 4

As more effective flood control measures are implemented, the general economy grows more rapidly and the living standard of the people improves. This affects the way of life of the people concerned. With fewer inundations being experienced, a false sense of security is created and thus the flood awareness and participation decreases. This is followed by more population growth, urbanisation and industrialisation in the area and an increased pressure to settle in more flood prone areas. Conflict in land use develops as the flood risk increases, which calls for more effective floodplain management, the formation of flood disaster management organs and the instituting of post-flood disaster mitigation measures.

Stage 5

As more of the natural river habitat and surrounding environment is destroyed through the development activities, and as a high living standard is realised, the environmental destruction becomes obvious and concerns for its sustainability increases. This leads to campaigns for formation of programs to conserve, protect and restore the natural river environment for sustainable development – or "green rivers". Cultural and social activities to restore the natural value of the river are promoted with people emphasising more on living-with-flood and non-structural strategies and measures to cope with the floods.

At this stage (Stage 5), an attempt is made by the people to recover as much of the environmental and natural value of the river as possible, as was found in stage 1 before the destruction, by adopting only those strategies and measures considered both economically and environmentally sustainable.

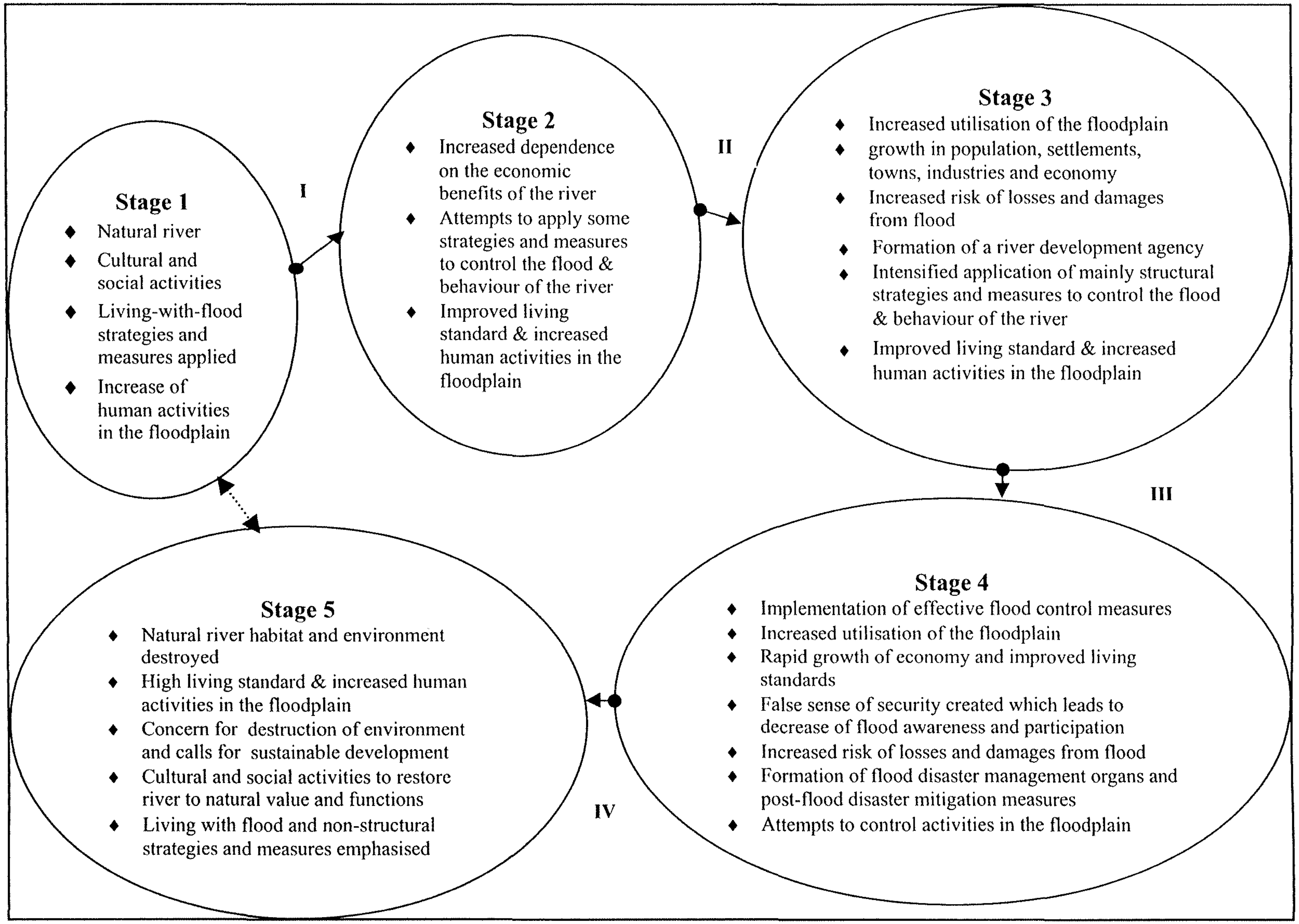
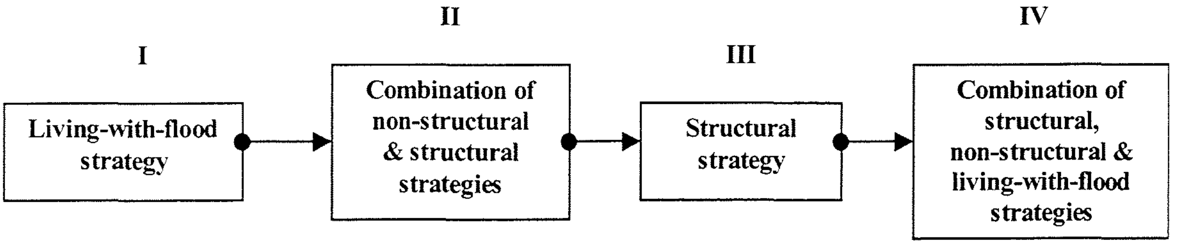


Figure 4.1: Stages in the development of strategies to cope with floods

4.3.2 Summary of strategy development pattern

The stages in the development of strategies to cope with floods (Figure 4.1) are summarised in the strategy development pattern shown in Figure 4.2. It starts with the living-with-flood strategy (**I**), progresses to a combination of simple non-structural and structural strategies (**II**), then structural strategy (**III**) and ends with a combination of structural, non-structural and living-with-flood strategies (**IV**), with more emphasis being laid on the non-structural and living-with-flood strategies.

When viewed against the 3 main strategies used to cope with floods (Section 2.2), this can also be defined respectively as the formation phase (**I**), the growth phase (**II**), the completion phase (**III**) and the perfection phase (**IV**) of the society in coping with floods (Figure 4.3). At the formation phase, the society's needs are met mainly through the living-with-flood strategy. At the growth stage, the society starts to try some basic non-structural and structural strategies as the needs increase. At the completion phase, the society's needs are met mainly through the structural strategy, which completes the society's trial of the 3 strategies. At the perfection phase, the society now tries to perfect the use of all the 3 strategies by using the best combination for each particular situation.



I: Formation phase, **II**: Growth phase, **III**: Completion phase, **IV**: Perfection phase

Figure 4.2: Summary of strategy development pattern observed

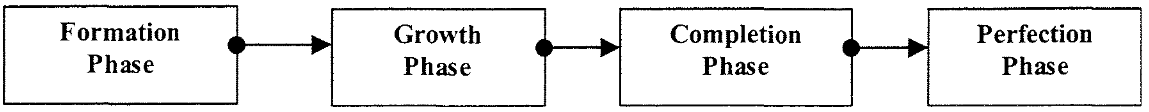


Figure 4.3: Development phases in coping with floods

Looking at the development stages in Figure 4.1, the transition from Stage 1 to Stage 2 corresponds to the formation phase of the society, Stage 2 to Stage 3 corresponds to the growth phase, Stage 3 to Stage 4 corresponds to the completion phase and Stage 4 to stage 5 corresponds to the perfection phase (Figure 4.2 and Figure 4.3).

For the 3 case studies, Vietnam can be said to be at the Growth phase (Stage 3), China at Completion phase (Stage 4) while USA has progressed up to Perfection phase (Stage 5).

4.3.3 The way forward

The question to be asked at this juncture is whether it is really necessary for the society to go through all the 4 growth phases. It can safely be concluded from the above observations that structural measures may be desirable as a strategy, in the short term, to effectively cope with floods, and to support a strong economy and a high standard of living. However, they are not the ultimate solution as they mostly have negative effects on the river and the environment. Moreover, they increase the overall risk while creating a false sense of security.

A more rational approach to coping with floods, as can be seen from the perfection phase and stage 5 in the development stages (Figure 4.1, Figure 4.2, Figure 4.3) is ultimately a balance between living-with-flood, non-structural and limited structural measures that would offer the same level of economic development, standard of living and sustainable environmental protection. Such carefully selected structural measures, like dams, reservoirs, and diversion channels, should have direct secondary benefits other than just the flood regulation.

4.4 ***Lessons applicable to the Netherlands situation***

As stated in Section 2.3, the Netherlands is one of the countries most renowned for its success in coping with floods. Given that dikes primarily provide flood protection along the entire Rhine and Maas Rivers, and that approximately one third of the country which is below sea level can potentially flood, the following questions are important when assessing the lessons that the Netherlands can learn from the above case studies:

1) Can river flood protection be maintained by relying on the dikes only?
2) Is there a potential for controlled flooding for mitigation of flood risks?
3) What are the opportunities provided by controlled flooding for the enhancement of other land use types behind the dikes?

Use of dikes has been encountered in all the 3 cases studied. The experience of the Vietnamese, the Chinese and USA is the same; that dikes alone cannot be relied upon in river flood protection. The experience has been that apart from the damage dikes impact on land, natural habitat, aesthetics or local culture, the probability of a flood value can be decreased to be as small as economics or policy of coping with floods can justify, but that this probability can never be zero. As a result other structural, non-structural and living-with-flood measures are incorporated to complement the dike measures.

The Vietnamese use river and flood diversion channels, and inter-basin water transfer in the north to minimise the dependence on dikes while no dikes are used in the south (Mekong) but people live with the floods.

The Chinese catch-phrase is "*Retain* water in the upper reaches, *Release* it in the lower reaches and *Detain* it along the banks of the river". Reservoirs are therefore used in the upper reaches of the river, FSDA in the middle and lower parts of the river while diversion channels are used at the delta. The FSDA provide a good example of the potential available for controlled flooding in the mitigation of flood risks and the opportunities provided for the enhancement of other land use types behind the dikes.

The Netherlands, like USA, has progressed up to the Perfection phase (Stage 5) in the development of strategies to cope with floods (Figure 4.1, Figure 4.2, Figure 4.3), but the emphasis is still more on structural measures which are considered necessary to provide the desired level of safety and risk (Section 2.3). However, through the ongoing research efforts to improve the methods of assessment of flood risks to allow the adjusting of the protection as close as possible to the actual calculated risk, the policy for the next decade might change. Together with the "rivier*en*land" approach being promoted this may entail giving more space to the rivers and restoring the rivers' natural habitat at the same time, as opposed to continually heightening the dikes.

In USA, there is an increase in the adoption of non-structural approaches. There are now stricter limits on development in floodplains and even a farm policy that discourages the conversion of wetlands to cropland while acquisition of marginal cropland and restoring it as wetlands and riparian habitat is being encouraged. Moreover community based floodplain management activities like the NFIP's Community Rating System (Section 3.4.2.2), that gives incentives of insurance premium rebates, has been observed to raise the awareness and reduce the flood losses substantially.

4.5 Lessons applicable to the Kenyan situation

Several rivers in Kenya especially Tana River, Sabaki River, Umba River, Yala River, Nyando River and Nzoia River have a history of flooding during the long rains but so far no meaningful flood control measures have been taken. Indeed, no year passes without a politician from some part of the country accusing the Government of being insensitive to the plight of flood victims in his area (Appendix II). For this reason, it is prudent to investigate the lessons that Kenya can learn from the above case studies.

Kenya is still at the Formation phase (Stage 2) in the development of strategies to cope with floods (Figure 4.1, Figure 4.2, Figure 4.3). It is still in the process of harnessing the maximum benefits from the rivers, the floods and the floodplains by farming the fertile soils, irrigation and fishing. The need to introduce flood control measures is there but this is still being done at individual or family level using own limited resources. There is increasing population pressure and growth of settlements in or near the floodplains (Appendix II), which is now forcing the community to call for government's assistance.

Unlike Vietnam and China, there is no serious scarcity of land in Kenya and unlike USA, the weak economy would not allow for intensive structural solutions to cope with floods, were the country to chose that strategy. There is therefore no need for people to settle permanently in flood prone areas though they can still take advantage of the fertile soils in the floodplains. Indeed, river valleys have always been the source of traditional crops and centres of cultural and social activities.

For temporary settlement within the floodplains, the case of living-with-flood in Mekong delta in Vietnam and the FSDA in China is worth considering. For a permanent solution to coping with floods, Kenya has an opportunity to learn from the experience of others. This would enable the country to avoid having to go through all the 4 phases of development (Figure 4.2, Figure 4.3) and still develop a sustainable strong economic structure, high standard of living and a sound environment policy. Therefore a careful study of each particular situation should always be made and the best combination of living-with-flood strategies, non-structural and structural strategies found with more emphasis on living-with-flood and non-structural strategies. That way, the country will be learning from the experience of others.

5 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations can be made with respect to strategies and measures, justifications, effect on way of life, and the lessons learnt from the case studies.

5.1 Conclusions

5.1.1 Strategies and measures

1. All the 3 cases use the living-with-flood, non-structural, and structural strategies to cope with river floods.

2. Vietnam (Mekong) and China (Flood Storage and Detention Areas) utilise the Living-with-flood strategy more than the USA (Section 4.2.2).

3. The non-structural measures adopted by the 3 cases are essentially similar but differ substantially in content (Section 4.2.2).

4. USA has more preference for the structural strategy compared to the other cases with the Mississippi River said to be one of the most heavily engineered natural features (Section 4.2.2).

5. In China, greater emphasis is now being laid on dams and reservoirs, floodwater detention and floodwater diversion as illustrated by the YRCC's catch-phrase *"Retain water in the upper reaches, Release it in the lower reaches and Detain it along the banks of the river"* (Section 4.2.2).

5.1.2 Justifications

1. The history and culture of the people affects the way they develop strategies and measures to cope with floods. The more the people are attached to the benefits and other cultural values of the river and the land, the more likely they are to apply non-structural strategies and measures to cope with floods (Section 4.2.3).

2. The way the society views flood control and water management also affects the way it develops strategies and measures to cope with floods. When viewed mainly as the key to economic development, prosperity and quality of life, there is a stronger emphasis on structural strategies and measures (Section 4.2.3).

3. The political state of the country, the state of the economy and the anticipated economic benefits are instrumental when deciding on the strategies and measures to be adopted to cope with floods (Section 4.2.3).

4. There is an intrinsic relationship between the state of environment and the strategies used to cope with floods in an area (Section 4.2.3). Those strategies that lead to destruction of the environment or radically interfere with the natural balance of nature should only be adopted as a last resort.

5.1.3 Effect on way of life

1. Most of the structural measures implemented give a false sense of security to the immediate beneficiaries. There is relatively more awareness and participation in the areas that use non-structural measures or flood more frequently like the floodways and the FSDA than just behind the dikes where it floods occasionally (Section 4.2.4).

2. An efficient flood disaster preparedness, post-flood management system and good infrastructure are a prerequisite for efficient disaster mobilisation and mitigation. Committee-based management systems are therefore not as efficient as the direct responsive systems due to the bureaucracy and many decision levels involved (Section 4.2.4).

3. Effective flood control measures in an area may lead to rapid population growth, urbanisation, industrialisation, and growth of a strong economy and a high standard of living. However, the increasing population pressure and settlement in flood prone areas often causes conflict in their use and results in substantial environmental degradation (Section 4.2.4).

4. There is need to strengthen spatial planning and management in the floodplains to include environment, population and economic growth control in order to minimise conflict in the use of the area (Section 4.2.4).

5.1.4 Lessons learnt from the case studies

1. There are 5 stages in the development of strategies and measures to cope with flood (Figure 4.1). The stage of a particular society is a direct function of the level, strength and state of its civilisation (Section 4.3).

2. The 5 stages can be summarised into 4 phases: formation phase, growth phase, completion phase and perfection phase (Figure 4.3). These are respectively characterised by a predominance of the living-with-flood strategy; a combination of simple non-structural and structural strategies; a predominance of structural strategy; and a balanced combination of structural, non-structural and living-with-flood strategies (Section 4.3).

3. A more rational approach to coping with floods, as seen in the Perfection phase and stage 5 in the development stages (Figure 4.1, Figure 4.2, Figure 4.3) is ultimately a balance between living-with-flood, non-structural and limited structural measures that would offer the same level of economic development, standard of living and sustainable environmental protection. Such carefully selected structural measures, like dams, reservoirs, and diversion channels, should have direct secondary benefits other than just the flood regulation. (Section 4.3).

4. The Netherlands can learn from all the 3 case studies that dikes alone cannot be relied upon in river flood protection (Section 4.4). In particular, it can be learnt from the Vietnamese in the Mekong delta how to live with floods without dikes; from the Chinese, the use of FSDA for controlled flooding in the mitigation of flood risks, the potential available and the opportunities provided for the enhancement of other land use types behind the dikes; and from the USA, the flood insurance policy (NFIP) and the community based floodplain management activities like the NFIP's Community Rating System.

5. Kenya is still at the Formation phase (stage 2) in the development of strategies to cope with floods (Section 4.5). By learning from the experience of Mekong delta in Vietnam and the FSDA in China, it should avoid having to go through all the 4 phases of development. A careful study of each particular situation should therefore be made and the best combination of living-with-flood strategies, non-structural and structural strategies found with more emphasis being put on living-with-flood and non-structural strategies.

5.2 Recommendations

1. It is recommended that Vietnam and China study the USA's National Flood Insurance Program, its Community Rating System, and the community based floodplain management programs and see how they can use these programs to raise the level of awareness of their people and reduce the flood losses.

2. It is recommended that a more detailed study be done on the different strategies used in the northern and southern Vietnam (Mekong) to cope with floods. The study could focus on the historical and effect on future prospects of the living-with-flood strategy on safety, way of life, economy, population growth, urbanisation and industrialisation.

3. It is recommended that a more detailed study be done on the effect of the Flood Storage and Detention Areas (FSDA) in China. The study could focus on the historical and effect on future prospects of the strategy on safety, way of life, economy, population growth, urbanisation and industrialisation.

4. It is recommended that a comparative analysis of more case studies be done to investigate whether the model of stages and phases of the development of strategies and measures to cope with floods concluded in this study (Figure 4.1, Figure 4.2, and Figure 4.3) is also applicable to them.

5. It is recommended that Kenya avoid going through all the 4 phases of development to cope with floods by learning from the experience of others such as Mekong delta in Vietnam and the FSDA in China. The government should carefully study each particular situation and implement the best combination of living-with-flood, non-structural or structural strategies that would minimise flood casualties and damages. It could for instance establish safe areas and warning systems that would enable people to live with floods without necessarily compromising the economic growth or the standard of living.

6 APPENDIXES

APPENDIX I: Cultural Theory as applied to water perspectives

In the cultural theory as applied to water perspectives by Hoekstra (Hoekstra, 1998), the hierarchist, egalitarian, individualist and fatalist perspectives in regard to flooding risks are described as follows:

Hierarchist perspective: Risks of flooding are if possible regulated by formulating maximum acceptable risk levels and improving dikes or other defences to conform to these levels. Acceptable risk levels vary for different areas, from relatively high in undeveloped areas to comparatively low in highly developed areas.

Egalitarian perspective: Risks of flooding should first be reduced in areas where risks are highest. They are most concerned with the protection of less developed regions, where poor but densely populated areas are exposed to regular flooding. In the case of increased flooding frequency as a result of land cover changes, erosion or climate change, preventive strategies are preferable to defensive strategies.

Individualist perspective: Reducing or accepting risks of flooding is an economic trade-off, which means that acceptable risk levels are a function of economic development.

Fatalist perspective: Risks of flooding are accepted and have to be handled because they do not feel that they can reduce them.

Table 6.1: The four perspectives on flooding risks

	Hierarchist	*Egalitarian*	*Individualist*	*Fatalist*
Flooding risks	Divergent risk levels	Equal risk principle	Economic trade off	Risk acceptance

Reference

Hoekstra, A. Y., 1998: Perspective on water: An integrated model-based exploration of the future. International Books, Utrecht, the Netherlands

APPENDIX II: Situation of floods in Kenya

Several rivers in Kenya especially Tana River, Sabaki River, Umba River, Yala River, Nyando River and Nzoia River have a history of flooding during the long rains but so far no meaningful flood control measures have been taken. Indeed no year passes without a politician from some part of the country accusing the Government of being insensitive to the plight of flood victims in his area. A few examples are quoted here below:

Tana River Delta

The Tana delta is a deltaic floodplain formed by the Tana River, the largest river in Kenya, and situated on the East Coast near Lamu. It is a triangular area encompassing 1300 km^2 of which 900 km^2 is inundated at peak floods. Flow peaks and the accompanying flooding of the delta occurs from April to June and in November and December. Upstream of the delta, there are 5 dams with 6 others planned. The reservoirs have already reduced the floods downstream for the 2 and 3 years return periods but larger floods do still cause disasters.

The Pokomo, who inhabit the area, practice irrigated agriculture in the floodplain growing mainly rice and maize as a recession culture. The riverbank is artificially raised over several short sections to control flooding. The farmers can induce flooding from the river into their farms at appropriate times.

Kano plains and Budalangi areas

Rangwe MP, Dr Shem Ochuodho, accused the Government earlier this year of being insensitive to the plight of flood victims in Kano plains and Budalangi areas. He claimed that "failure by the Government to find a lasting solution to the perennial flooding problem in Kano plains and Budalangi areas proves his point" and wondered why even the National Disaster Committee has not responded to the pleas for food, shelter and medicine from the displaced people.

He went further to remind the government that the Kano floods have been consistently experienced in the area for many years and the local people have been calling for dikes to be built and the implementation of other flood control measures, but little has been done. Proposals for dam construction in the upper reaches of the rivers have been made but the government has always said that lack of funds has hindered the implementation.

Similar claims were made by the National Development Party Leader Mr. Raila Odinga. He said that time has come for the Government to look for long-term strategies to contain the floods and called for the construction of dikes along Nzoia, Nyando, Sondu Miriu, and Kuja rivers, which burst their banks during heavy rains (Reported in the local press in January 2001).

Floods wreak havoc in Nyanza

Floods displaced more people and disrupted learning in many schools in Nyanza amid reports of outbreaks of water-borne diseases.

And as thousands of people fled their homes in Nyatike, Karachuonyo, Nyakach, Nyando and Winam divisions, the government came under criticism for ignoring the flood victims. More rivers burst their banks, flooding homes, schools and roads, with Kadem in Nyatike, East Karachuonyo, Kadibo and West Kolwa being worst hit. Government officials and victims estimated that close to 10,000 families had been affected by the raging floods.

"The government must find a lasting solution to Nyanza's flooding menace. It is shameful that the floods have been with us since independence and nothing has been done to stop them," said Mr Odoyo (Reported in the local press on Thursday, January 25, 2001).

Source: Daily Nation, January 25, 2001

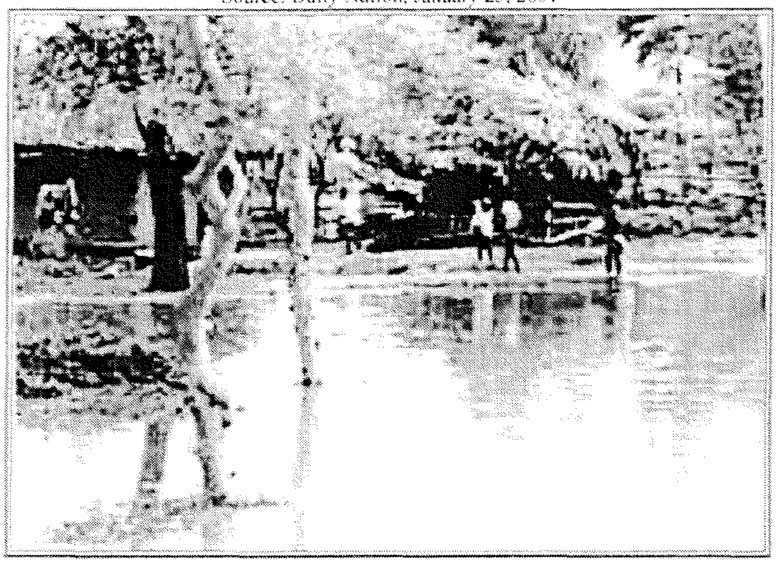


Figure 6.1: Living with floods in the Kano plains, Kenya

Nzoia River

The ever-increasing demand for food and settlement has led the communities living in the Nzoia catchment to settle along the river. The floodplains provide flat land for building and farming operations. For the period of 1961-1990 alone 13 major floods were reported of which 4 were very serious floods. The river rose out of its banks and inundated the natural floodplain, farms and villages, and disrupted transportation networks, daily activities and even causing loss of life for both human and livestock.

Sabaki and Kafuloni Rivers

Torrential rains wreaked havoc at the Coast and proved fatalistic when the seasonal Kafuloni River in Kilifi District burst its banks. About 40 people died in the tragedy, more than 700 families were left homeless and property worth millions of shillings was destroyed making it one of the worst floods disaster in Kenya.
Farmers along River Sabaki in Malindi also lost hundreds of acres of crops after the river burst its banks and inundated the farms.

REFERENCES

Andrews, Jean, (1993): Flooding: Canada Water Book. Ottawa, Tyrell Press.

Anonymus, (1994): A survey of insurance. The economist (London), 3 December 1994.

Brush L. M., M. Gordon Wolman and Huang Bing-Wei (eds.), (1989): Taming the Yellow River: Silt and Floods. *Proceedings of a bilateral seminar on problems in the lower reaches of the Yellow River, China*. Kluwer Academic Publishers, Dordrecht.

Caine, N., (1995): Snowpack influences on geomorphic processes in Green Lakes valley, Colorado Front Range, Geogrl. J. 161, 55-68.

Carin, Robert, (1962): River Control in Communist China. Union Research Institute, Hong Kong.

Chan, N. W. (1995): Choice and constraints in floodplain occupation: the influence of structural factors on residential location in Peninsular Malaysia.

Chen Xiaoguo, (1999): Flood Control Situation and Strategies in the Lower Yellow River. The Yellow River Conservancy Commission.

Cohen Julia, Holly Tuxson, Nick Wozmak, and Chu Xiong, (1997): A Critical Review of the Effectiveness of Some of the World's Flood Control Systems. http://www-geology.ucdavis.edu/~GEL242/floods.html.

Delta Committee, (1962): Report of the Delta Committee, State printing and publishing office, The Hague.

Drijver C. A and M. Marchand, (1985). Taming the floods: Environmental aspects of floodplain development in Africa. Centre for Environmental Studies, State University of Leiden.

Fordham, Maureen and Edmund C. Penning-Rowsell, (1994): Floods across Europe. Middlesex University Press.

Garland Greg, (1997): Floods are way of life for many in Louisiana, Copyright © 1997, The Advocate, All Rights Reserved.

Harrison R.W. and J. F. Mooney, Jr., (1993): Flood Control and Water Management in the Yazoo-Mississippi Delta. Social Science Research Centre, Mississippi State University, Mississippi state, MS 39762 (http://www.leveeboard.org/flood1.htm).

Hekal Nasr, (2000): An inventory of measures and solutions coping with floods around the world. M.Sc. Thesis, IHE Delft

Hoekstra, A. Y., (1998): Perspective on water: An integrated model-based exploration of the future. International Books, Utrecht, the Netherlands.

Humphreys, Capt. A. A. and Abbot, Lieut. H. L., (1861): Report Upon the Physics and Hydraulics of the Mississippi River; Upon the Protection of the Alluvial Region Against Overflow and Upon the Deepening of the Mouths, etc., Professional Paper No.4 of the Corps of Topographical Engineers, United States Army, Philadelphia. (http://www.leveeboard.org/flood1.htm)

Jorissen, Richard E., Cees-Jan van Westen, Peter J. M. Wondergem, (1997), Technical Advisory Committee for water retaining structures (TAW): Safety of flood defences. A brochure by the Directorate-General of Public Works and Water Management, Road and Hydraulic Engineering Division, Delft, the Netherlands.

Jorissen, Richard E., Stallen P. J. M. (eds.), (1998): Quantified societal risk and policy making (p19-33). Kluwer Academic Publishers, Dordrecht.

Keith Smith and Roy Ward, (1997): Floods, Physical processes and human impacts.

Kellan London, et al., (1997): Politics, Economics, and Public Policy on Flood Control.

Larson, L. W., (1993): The Great Midwest Flood of 1993. Natural Disaster Survey Report, National Weather Service, Kansas City, Missouri, USA.

Le Huu Ti, (2000): Experiences of Flood Control and Management in Asia Relevant to Economic and Social Development Strategies for Central Vietnam in the Twenty-first Century, United Nations Economic and Social Commission for Asia and the Pacific (ESCAP).

Leavesley, G. H. et al., (eds.), (1997): Destructive Water: Water-Caused Natural Disasters, their Abatement and Control, IAHS Publication no. 239.

Li Guifen, Wang Lianxiang, Gao Jing, (1999): Proceedings of 1999 International Symposium on flood Control, Beijing, China. Organised by Beijing Hydraulic Engineering Society (BHES) and China Institute of Water Resources and Hydropower Research (IWHR).

Liakath, A. (1995): Flood control and drainage improvement possibilities in the Bhanda Beel area, Surma-Kushiyara Basin, Bangladesh, M.Sc. Thesis, IHE, Delft.

Linsley, R. B. and J. B. Franzini, 1987: Water resources engineering, Flood damage mitigation, McGraw Hill, New York

McCully, Patrick, (1996): Silenced Rivers. Zed Books, New Jersey.

Penning-Rowsell, E.C and Smith, D. I., (1987): Self-help hazard mitigation: the economic of house raising in Lismore, NSW, Australia, Tijdshchrift Economic and Social Geography, p 78, 176 – 189.

Platt, R. H and G. M. McMullen, (1980): Post-flood Recovery and Hazard Mitigation: Lessons from the Massachusetts Coast, February, 1978, Publication No. 115, Water Resources Centre, University of Massachusetts, Amherst.

Rossi G. et al. (eds.), (1994): Coping with Floods. Kluwer Academic Publishers, Dordrecht.

Sheldon, W. J., (1969): Tigers in the rice. Crowell-Collier Press, Collier-Macmillan Limited, London.

Shetter, William Z. (1987): The Netherlands in Perspective. Uitgeverij Martinus Nijhoff, Leiden.

Smith, K. and Roy Ward, (1997): Floods, Physical processes and human impacts.

Smith, K. and Tobin G.A., (1979): Human adjustment to the Flood Hazard, Longman, New York.

U.S. Congress, (1993): Hearing before the Subcommittee on Water Resources and Environment of the Committee on Public Works and Transportation, House of Representatives. *The Midwest floods of 1993: Flood Control and Floodplain Policy and Proposals*. Washington, D.C., U.S. Government Printing Office.

UNDP, Department of Humanitarian Affairs (DHA) and Ministry of Water Resources of Vietnam, (1994): Strategy and Action Plan for Mitigating Water Disasters in Vietnam. United Nations, New York and Geneva.

United Nations, (1983): Flood Damage Prevention and Control in China. United Nations Publication, New York.

Ven, G. P. van de (ed.), (1993): Man – made lowlands: History of water management and land reclamation in the Netherlands. Stichting Matrijs, Utrecht.

Ward, R. C., (1978): Floods: A Geographical perspective, Macmillan, London.

White G. F., (1964): Choice of adjustment to floods. The University of Chicago, Illinois.

Wijbenga J.H.A et al., (1995): Delft Hydraulics Publication no. 494.

World Bank Report, (1996): Vietnam Water Resources Sector Review, Main Report, A joint report by the WB, ADB, FAO, UNDP, NGOs and The Institute of Water Resources Planning, Vietnam.

Zhou K. et al. (eds.), (1991): A concise history of irrigation in China. Chinese Hydraulic Engineering Society, Beijing, China.

Zhu Erming, (1999): Prevention and treatment of flood and drought disaster in China.

Zhu Lanqin, et al. (eds.), (1997): The Yellow River—Channel of Chinese Civilisation. The Yellow River Conservancy Press, Henan, China.

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http://encarta.msn.com © 1997-2000

http://floodplain.org/c-access.html

http://lcweb2.loc.gov/frd/cs/cn.html

http://lcweb2.loc.gov/frd/cs/vn.html

http://water.usgs.gov/wid/FS_209-95/mason-weiger.html

http://www.anu.edu.au/asianstudies/mekong/flood.html

http://www.fema.gov

http://www.fema.gov/nfip

http://www.floods.org/history.htm

http://www.geography.about.com

http://www.leveeboard.org/flood1.htm

http://www.library.thinkquest.org

http://www.lrd.usace.army.mil/gl/212.htm

http://www.mvd.usace.army.mil/Nwsinfo/MRTBrochure.htm

http://www.sierraclub.org/sierra/199905/floods.frame.html

http://www.theadvocate.com/library/flood/1020flod.htm

http://www.undp.org.vn/dmu

http://www-geology.ucdavis.edu/~GEL242/elsewhere.html