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Towards Interactive Urban Flood Management: A Case of Dhaka, Bangladesh

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Summary

Geographically Bangladesh has a strong relationship with water resources. Flood is a recurrent event in Bangladesh and one of the most well known natural disasters. Dhaka, the capital, is located on the drainage path of the Ganges-Brahmaputra-Meghna basin and annually suffers from river flood due to spill over from the peripheral rivers and storm-water flooding by local rainfall during monsoon season. Since its early days it has faced a number of severe floods. The 1988, 1998 and 2004 were the most catastrophic. As to the urban situation in Bangladesh, the high rate of urbanization in Dhaka has put a serious strain on natural resources (water and land), infrastructures and built environment. To accommodate the influx of people, Dhaka has been steadily expanding on filled-up water bodies and wetlands without a concern for adverse environmental impacts and additional infrastructures and services required to sustain the new developments. The drastic reduction in natural water storage areas, inadequate drainage paths and their improper operation and maintenance are worsening the flooding situation. A planned management of Dhaka city needs an integrated and coordinated flood management. In this light, this research aims at the analysis of the interactive water resources management approaches on potential improvement for urban flood management in Dhaka.

Different theories on water resources management are studied to get insight of the concept and elements that are involved in its functioning. The literature study also focused on flood management theories, as it is an important subset of integrated water resources management. The Urban Flood Risk Management based on three concepts: IFM, Total Water Cycle Management and Land use planning. The focus of this concept is to mainstreaming flood risks into the development process.

The empirical part of this research is conducted by semi-structured in-depth interviews with open-ended questions regarding the urban flood management in Dhaka. The main finding of the research states that the urban floods in Dhaka are managed in ad hoc manner. Historically, the water resources management in Bangladesh is aimed at flood control to protect crops. This stand-alone approach is also applied in Dhaka to control flood aiming at reducing economic loss and saving human lives. The flood control projects in Dhaka exhibits only short-term economic development. A comprehensive approach for long-term perspectives on economic development with social, ecological environmental conservatory measures are left behind. In addition, the urbanization and flood prevention are closely interlinked in Dhaka. The top-down decision making process together with the less functional integration of the water institutions, failed to manage the urban floods in an integrated manner. The mainstreaming of the flood risks into development planning of Dhaka cannot stand-alone. The introduction of interactive flood management in Dhaka largely depends on the change in political decision-making process. For sustainable urban flood management in Dhaka, there is an urgent need for interaction with societal actors in decision-making process.

The interactive approach involves participation of both citizen and stakeholders. Thereby it combines top-down and bottom-up inputs of local knowledge and

objectives to develop local solutions to the water resources management. The continuous monitoring of the water system helps assessing management strategies and supports the decision-making process. This interaction helps to develop new policy approaches.

With response to the current situation of Dhaka, the water and flood mangers need to govern in an interactive way both with society and water system. A coordinated and comprehensive management approach along with strong institutional framework is very important for sustainable development in urban flood management of Dhaka.

Keywords: Water resources, Urban Flood, Urban Flood Management, Interactive Water Resources Management, Dhaka.

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Abbreviations

BWFMS	Bangladesh Water and Flood Management Strategy
BWDB	Bangladesh Water Development Board
CUMEC	Cubic Meter Per Second
DoE	Department of Environment
DAP	Detail Area Plan
DCC	Dhaka City Corporation
DMDP	Dhaka Metropolitan Development Plan
DSP	Dhaka Structure Plan
DWASA	Dhaka Water Supply and Sewerage Authority
FAP	Flood Action Plan
FC	Flood Control
FCD	Flood Control and Drainage
FCDI	Flood Control and Drainage and Irrigation
FPCO	Flood Plan Coordination Organization
FM	Flood Management
GoB	Government of Bangladesh
GIS	Geographic Information System
GBM	Ganges, Brahmaputra and Megna
IFM	Integrated Flood Management
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
MLGRDC	Ministry of Local Government, Rural Department and Cooperatives
MoWR	Ministry of Water Resources
msl	Mean Sea Level
NWMP	National Water Management Plan
NWPo	National Water Policy
RBM	River Basin Management
SPARRSO	Space Research and Remote Sensing Organization
SUDS	Sustainable Urban Drainage System
TWCM	Total Water Cycle Management
WRM	Water Resource Management
WARPO	Water Resources Planning Organization
UAP	Urban Area Plan
UWM	Urban Water Management
UFM	Urban Flood Management
UFRM	Urban Flood Risk Management

Glossary

Aman	A term used in India and Bangladesh for rice crop sown in monsoon and maturing after the monsoon
Aquifer	A stratum of permeable rock, sand, etc which contains underground water.
Biodiversity	The variety and variability among the living organisms including the genetic variability within species and populations, of their interactions and the ecological processes.
Boro	Rice sown, transplanted and maturing in the fry monsoon season.
Culvert	A structure that connects two waterways and passes underneath a road or railway.
Ecosystem	The basic ecological unit made up of a community of organisms interacting with their inanimate environment.
Infiltration	A process by which water on the ground surface enters the soil.
Khal	Bengali term for a drainage channel, minor river or a tidal creek.
Polder	Land enclosed by an embankment.
Regulator	A structure built to control water flow across an embankment at the head of a khal or a structure built in a river or khal to control water. Water is controlled by flap gates, vertical lift gates, fall boards or a combination of these.
Riparian	Belonging to rivers.
Sluice	A structure to convey water through an embankment only.
Storm water runoff	Unfiltered water that reaches streams, lakes, by means of flowing across impervious surfaces such as roads, parking lots, driveways and roofs.

Table of Contents

List of Boxes

List of Figures

List of Tables

Chapter 1 Introduction

"Water is an environmental resource and it is the basis for social and economic development." (Hooper, 2005)

1.2 Background

Water is a natural resource like air, solar energy, minerals, soil, fauna and flora. It is a unique substance for life and to sustain natural ecosystems. In human development, water has played a very critical role. As a resource, water is both a natural component of nature and a commodity (Lavkulich & Ulazzi 2008). For better livelihood, societies, communities and households seek to make the best use of the natural resources available to them. However, they are also subject to a variety of natural disasters like floods, droughts, storm surges etc.

Throughout the history, droughts and floods have periodically inflicted serious damage to society (Biswas 2006). In the developing countries, during the second half of the 20th century, the natural resources of earth became highly threatened by increasing population growth, rapid urbanization, inadequate levels of economic development and the absence of appropriate management and technical capacities. Statistics show that around 70 percent of all global disasters are linked to hydro-meteorological events (APFM 2004). Floods are some of the largest natural disasters known to human kind. Floods cause much misery, especially in developing countries where low-income economies are greatly stressed by their recurrence (APFM 2004). Flood loss is not limited to individual households; it has effect on the nation as a whole. The 1982 floods in Bolivia are reported to have resulted in a loss equivalent to 19.8 percent of the country's GDP (APFM 2004). In the flood history of Bangladesh, the 1988 and 1998 floods were catastrophic. In 1988, approximately two-thirds of the country and 85 percent of the capital city Dhaka was inundated. During the 1998 flood, about 56 percent of the city was inundated. Total economic damage recorded to nearly 3 billion dollars (US).

At present days, the general picture of global warming is reasonably clear. Climate variability has an impact on water resources and their management. Climate change is rendering its vulnerability to natural disasters. Bangladesh is likely to be one of the most vulnerable countries in the world to climate change, considering its low topography, disadvantageous geographic location, high density of population etc (Islam 2008). In Bangladesh the possible damaging impact of climate change will be increased frequency of floods, salinity intrusion, droughts, riverbank erosion, sea level rise and lack of fresh water in coastal zones (Mallick 2007) (Koudstaal et al. 1999). Bangladesh is located in the Ganges, the Brahmaputra and the Meghna (GBM) delta-the world's largest Delta. Due to its geographic location, Bangladesh is dominated by its water resource system. Dhaka, the capital and largest city of Bangladesh, is located on the eastern banks of the Buriganga River and the periphery is bounded by the distributaries of the Brahmaputra and the Meghna. The city is connected with the rest of the country through network of rivers.

The strategic location of Dhaka has played a significant role in the urbanization process of the city. After independence in 1971, Dhaka has experienced rapid expansion in size and population. At present, Dhaka is one of the most densely populated cities in the world, which accommodate more than 13.1 million, people within 1,353 square kilometre area (Alam & Rabbani 2007). The unprecedented rate of unplanned urbanization in Dhaka together with rural-urban migration has put serious strain on space, infrastructure and built environment. To accommodate the influx of population, Dhaka is expanding on filled-up water bodies, canals and wetlands without concern for adverse environmental impacts and additional infrastructures and services required to sustain the new developments. The disparity and unequal development and management of utility services and improper management of natural resources degraded the environment of Dhaka.

In Dhaka water resources are threatened due to both human activities as well as natural causes. Climate change is affecting Dhaka in two ways: through increased frequency of flood flows, drainage congestion and through heat stress. Because of its geographic location, Dhaka suffers from river floods annually. The city also suffers from frequent storm water flooding. The illegal encroachment of rivers, water bodies, lands fillings, the indiscriminate dumping of domestic and industrial waste into rivers and canals are accelerating the drainage congestion. As a result, Dhaka is facing storm water flooding during heavy rainfall leaving parts of the city inundated for several days and cause severe economic damages and health hazards. The city governments of Dhaka and the institutions empowered with various planning and management responsibilities are weak in developing innovative approaches and regime to manage and sustain development in this rapidly urbanizing city.

1.2 Problem statement

1.2.1 Problem definition: Vulnerability to Urban Flood in Dhaka

Threats to peripheral rivers of Dhaka date back to the early history of civilization and development. Dhaka was established by the Mughal Rulers on the bank of River Buriganga as a provincial capital. Besides its strategic location in the Bengal, the Buriganga River is important for riverine communication, water supply, and flood control and drainage capabilities. Until 1960s, Dhaka city was concentrated on the north and eastern banks of the Buriganga River (Khorshed 2003). After independence in 1971, Dhaka started to expand towards the North. Since then human interventions in peripheral rivers have greatly influenced the natural flow and function of those rivers. The real estate developers started to encroach the offshore lands, fill it with earth and other materials because of scarcity of land. Such expansion of the city is even further increasing the risk of floods.

Dhaka suffers from river flood and storm water flood annually. River floods generally take place in the low-lying fringe areas outside the protective embankments once in every five to ten years. Floods caused by local rainfall occur in the built-up areas of the city several times a year. In recent history, Dhaka has

experienced the largest and devastating flooding[1] in the year of 1988, 1998 (Figure 1.1) and 2004. The 1988 flood was the trigger for the total embankment of the city. Under the Dhaka Integrated Flood Protection Project (DIFPP) the Greater Dhaka West is protected from the river flood. But Greater Dhaka East remains

Figure 1.1: The Extent of 1998 flooding in Dhaka city
Source: Alam & Rabbani 2007

[1] Dhaka has experienced major floods in 1954, 1955, 1970, 1974, 1980, 1987, 1988, 1998 and 2004, due to overflowing of surrounding rivers.

unprotected. The embankment has increased the internal drainage problem of the city resulting into a management problem. The drainage is mostly dependent on the water levels of its peripheral river systems. During monsoon season from May to October river water levels generally remain higher than the internal drainage level. This affects the surface drainage system within the city. After implementation of the flood-control project in Dhaka West, unplanned urban expansion stretched rapidly towards low-lying areas and flood plains adjacent to this protection and river. Land development through land-filling in these areas has caused drastic reduction in water storage area (Huq & Alam 2003). The existing canals (khals) have poor drainage capacity causing long flood duration in inland areas and aggravated the flood damage. Inadequate drainage paths and their improper operation and maintenance mainly cause these floods.

Excessive rainfall and flood posing adverse effects on different sectors including infrastructure (road, rail, housing), industry (large, medium and small), physical and mechanical functioning, trade and commerce (through a disruption of communications), utility services (water supply and sanitation), sewage management and the supply of electricity and gas. The unprecedented and unplanned urbanization and the expected effects of climate change are causes for increasing vulnerability to floods. In order to address all these interrelated causes and effects of flooding, Dhaka city requires an integrated and coordinated flood management. The interrelation of causes and effects of flooding is reflected in the problem tree (figure 1.2) overview on the next page.

1.2.2 Rationale of the Study

It is evident from the above stated problems that the growing population pressure on the environment, leads to over-exploitation of natural resources particularly water resources whereas the unplanned construction of buildings and infrastructures has increased the effects of natural disasters in terms of human loss, physical and economic damages. Among the major risks, floods are considered to be of main importance with regard to their consequences (APFM 2004).

The present structure and method of operation of the national and local government is unable to create an environment suitable for human habitation and protection against the flood risks. A number of organizations are involved in water and different stages of flood management of Dhaka city. Although there are a number of laws and policies in place, the concerned organizations and regulatory bodies failed to reflect an integrated and coordinated management approach towards planned development of Dhaka including its flood management.

To deal with the emerging problems of peripheral rivers and canals to reduce the impact of urban flooding, requires an understanding of the existing institutional system and inefficiencies in water management approach. Dhaka is changing its landscape at a fast pace (Islam 2008) and the flood management approach has not evolved in pace with this change. This research aims to acquire a clearer understanding of all underlying causes related to the management process of flood protection.

The research is undertaken at the right moment, since the Government of Bangladesh is planning to implement an integrated project entitled the "Dhaka Integrated Flood Control Embankment Cum Eastern Bypass Road Multipurpose Project". The project is aimed at protecting the eastern side of the Dhaka. This research adds value by providing useful literature on Urban Flood Risk Management as an approach for sustainable Urban Flood Management, which has been adopted in various countries with various levels of success. This study highlights the social and institutional aspects associated with urban flood management in the context of Dhaka and aims to recommend some possible solutions that may serve as a guideline for implementing future Urban Flood Projects.

1.3 Research Objective

Theoretically Flood Management (FM) is an important aspect of Integrated Water Resources Management (IWRM). In available literatures on IWRM, however, the aspect is not well addressed. Water resources management trends are developed towards Interactive Water Resources Management (Interactive WRM) in which key concerns are to establish a dialogue between water managers and the policy subjects (participation of citizens, NGOs, and total water system dynamics) (Van Ast 2000).

Flood is a natural phenomenon and cannot be fully controlled. Hence it is imperative to develop interactive approaches to flood management, which can play an important role in sustainable development. The objective of this research is __

'To analyze the Interactive Water Resources Management approaches on potential improvements for Urban Flood Management in Dhaka'.

This analytical research work will contribute to further development of understanding on dealing with flood management issues within the context of Interactive WRM. This study will also reflect upon the approaches to reduce the vulnerability and risk by developing a participatory and transparent decision-making processes, particularly in terms of institutional integration in planning and implementation.

1.4 Research Questions

The research objective focuses on the analysis of the interactive approaches to urban flood management in Dhaka. This objective leads to the formulation of the following research question:

*"**Which elements of Interactive Water Management can improve Urban Flood Management in Dhaka?**"*

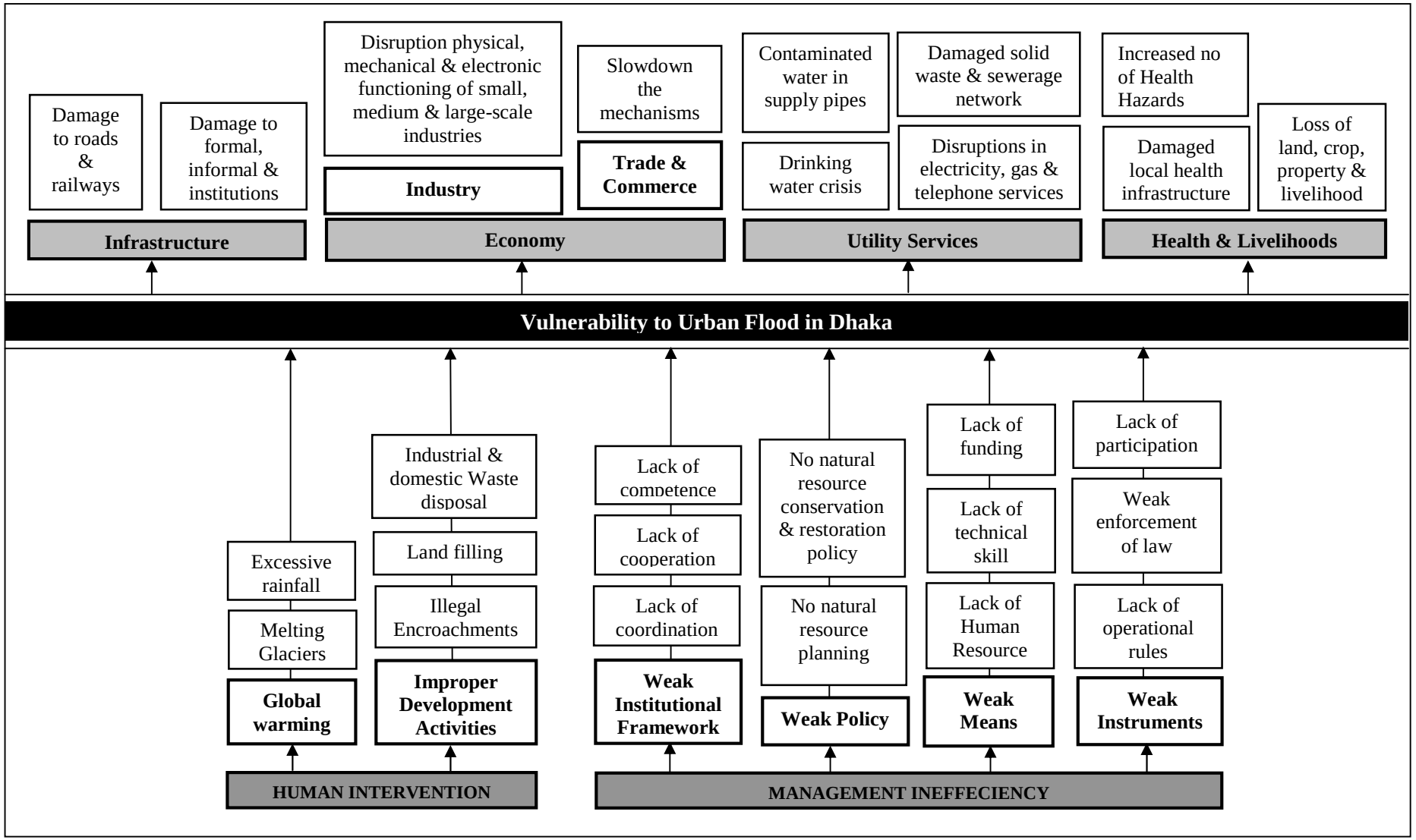


Figure 1.2: The Problem Tree

Five sub-questions are formulated from the main research question that together give a complete overview of all different aspects that form the main research question:

Sub-question 1:
The development towards interactive policy-making in water resources management is becoming essential to address the social and environmental inter connections and thereby sustainable management of water resources. Therefore, it is important to understand the concept and aspects of Interactive WRM approach. This understanding requires the following sub-question:

'What is Interactive Water Resource Management?'

Sub-question 2:
The sustainable management of floods in urban areas is increasingly becoming a challenge. Floods in urban areas are additionally influenced by human activities besides meteorological and hydrological extremes. The damage potentials of urban floods are high. Therefore, it is important to understand the different aspects of urban floods and its sustainable management. This appreciation is revealed through the following sub-question:

'What is Urban Flood Management?'

Sub-question 3:
When public participation is considered in management institutions, it becomes very complex and challenging. Institutional arrangements of water management are strongly connected to general trends in society (Van Ast 1999). To integrate a new water management approach in the near future, it is always important to understand the common trends in society. In Bangladesh the national water planning dates back to 1950s. Ever since the management system is changed considerably. To identify the possibilities of institutionalizing Interactive WRM in Bangladesh, the clear understanding of the development of the water resources management system is also important. This leads to the following research sub-question:

'What are the trends of flood management in Bangladesh?'

Sub-question 4:
One of the profound damaging impacts of climate change in Dhaka will be in the form of increased frequency of flood flows (Alam & Rabbani 2007). Therefore, it is imperative to strengthen the FM approaches in Dhaka to withstand the disaster. Thus it is important to understand the aims and approaches, existing institutional framework with respect to urban flood management, policies with legislation and instruments for its effective implementation within the framework of Interactive WRM. This understanding directs to the sub-question:

'What are the Urban Flood Management approaches in Dhaka in the context of Urban Flood Risk Management within the framework of Interactive Water Resources Management?'

Sub-question 5:
With the clear understanding of the Urban Flood Management (UFM) approaches, it is also important to identify the opportunities and challenges of the present management approaches to develop policy recommendations for possible improvements of UFM in Dhaka. This is explored through the following sub-question:

'What are the potentials and limitations of present Urban Flood Management in Dhaka?'

1.5 Description of the Research area
1.5.1 Bangladesh

Bangladesh is situated within the floodplains (Figure 1.3) of three great rivers: the Ganges, the Brahmaputra and the Meghna (GBM) and their tributaries, Teesta, Dharla, Surma. These three rivers also give Bangladesh 'one of the worlds' most complex river systems' (Jansen et al. 1989 in Khorshed 2003). The three river systems drain to the Bay of Bengal through Bangladesh. There are two hundred and thirty rivers including tributaries and distributaries criss-cross the country. Fifty seven of which are transboundary Rivers, of which fifty four including the Ganges, Brahmaputra and Meghna coming from India and three from Myanmar.

The delta growth is striving to keep pace with local relative sea-level rise, the people are repeatedly confronted by natural and human-made catastrophes such as cyclones, tornadoes, earthquakes, riverbank erosion, surface and groundwater pollution, air pollution, droughts, wetland loss, coastal erosion, and floods (Khalequazzaman n.a.). In Bangladesh there are two types of floods occur: annual flood (Barsha) that inundate up to 20% of the land area and low frequency floods of high magnitude inundates more than 35% area (banna) (Khalequazzaman n.a.).

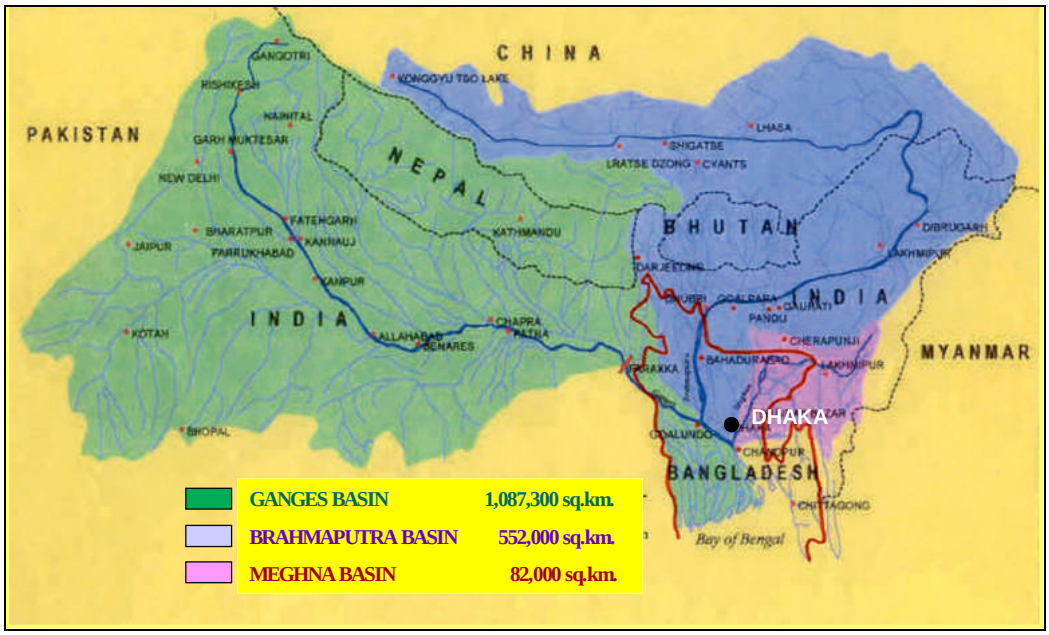


Figure 1.3: The Catchment areas of the GBM river system
Source: Hossain, 2007

1.5.3 Dhaka: The Capital City

Dhaka is the largest and capital city of Bangladesh. Dhaka is the central region of the flat deltaic plan of the three major international rivers, The Ganges, The Brahmaputra and The Meghna (GBM) which enjoys a distinct primacy in the national regional hierarchy. The Buriganga River on the south, the Balu and Shitalakhya rivers to the east, and the Tongi Khal to the north and Turag River to the west surround Dhaka (Figure 1.4). These rivers mainly belong to The Brahmaputra. The Meghna River System has also influence on the water level in the rivers. This network of rivers establishes its network with the rest of the country.

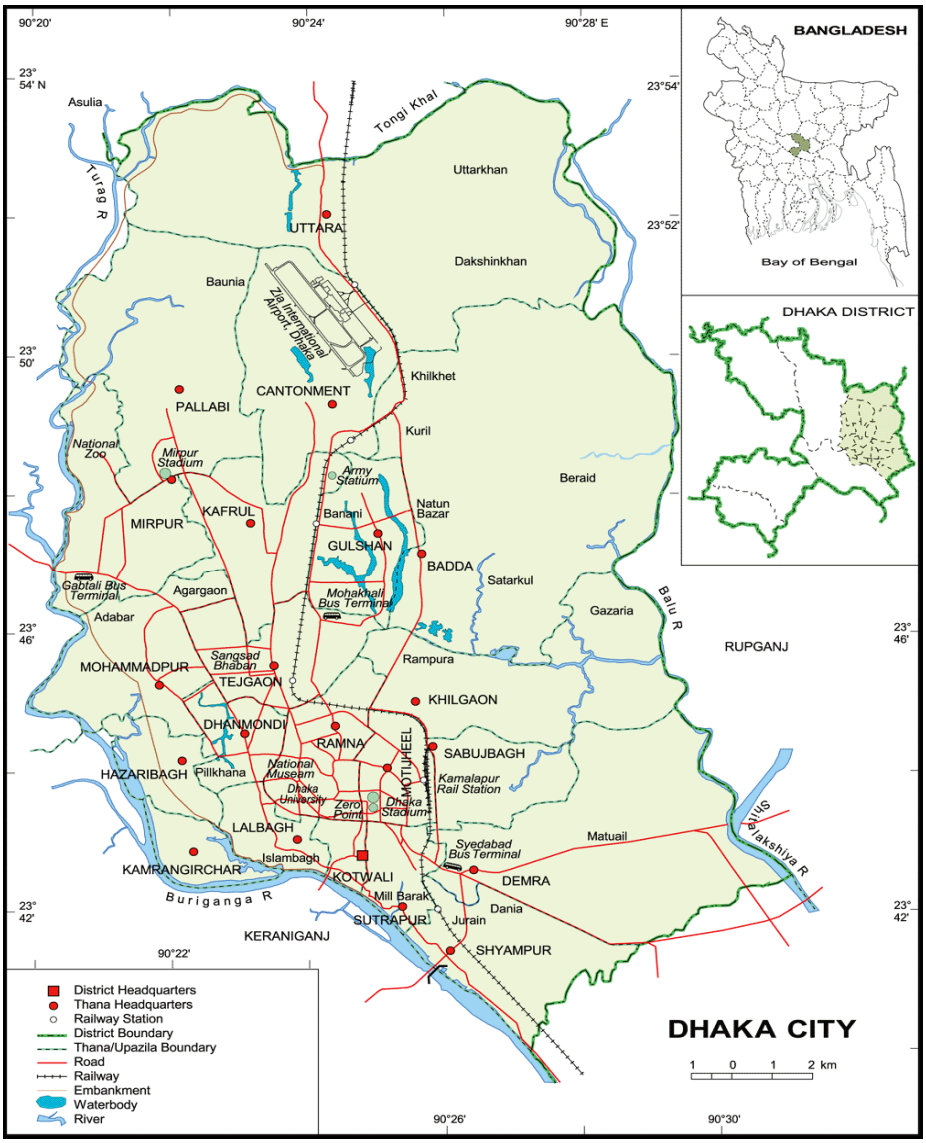


Figure 1.4: The Map of Dhaka City
Source: Ahmed 2007

Based on flood control infrastructures, the Greater Dhaka has two parts, Dhaka East and Dhaka West. The Greater Dhaka covers an area of 262 sq. km (Dhaka West 143 sq. km and Dhaka east 119 sq. km) (Rahman et al. 2005). Dhaka west is already urbanized and protected from flood by embankment. Dhaka East, the

floodplain of the Balu River is mainly a rural area. However, the urban growth is also evident in this floodplain.

In 1960 the population was 1 million. And at present Dhaka is the 11th largest city in the world with 13 million residents. The population statistics of Dhaka show that the annual growth rate was 2.9 percent from 1951 to 1961, 10.2 percent from 1961 to 1974, and 8.1 percent from 1974 to 1981(Huq & Alam 2003). Thereby it is expected that the population will increase to 23 million by 2015. As a mega city Dhaka is stretching around an area of 1,353 square kilometres. Rapid expansion in area and population took place in Dhaka, after independence in 1971. The high population growth is caused by the high rate of rural-to-urban migration. Presently 30 percent of the urban population are below the poverty level and live in slums, mostly the low-lying areas of the city. With such high growth rates, urbanization in Dhaka is to a large degree unplanned.

1.6 Thesis Structure

This research report is comprised of seven chapters.

Chapter one, entitled 'Introduction', introduces the research topic with the definition of problem. It also discusses the need for the given research in the light of possible improvements of UFM in Dhaka and states the objective with an intention to develop understanding on interactive dealing with FM within the context of IWRM. The research questions and brief introduction of the research area are also presented in this chapter.

Chapter two entitled ‘Development in Water Resources Management’ reviews and studied the theories on integrated, adaptive, ecosystem and Interactive WRM, River Basin Management and Integrated Flood Management that are studied for this research. Some relevant case studies and experiences are also presented due to their participatory approaches in flood management. The chapter is concluded with the brief discussion on water resources and flood management in Bangladesh.

Chapter three entitled 'Research Methodology' gives an overview on how the research process is designed and applied. It also contains details on the methods to answer the research questions, data collection and the analysis of data.

Chapter four entitled ‘Urban Food in the context of Dhaka’ describes the context of urban floods in Dhaka. The geographical setting, historical background, hydrological aspects of Dhaka city are discussed in this chapter. The chapter concludes addressing the relationship of Dhaka’s urban floods and impacts of urban floods.

Chapter five entitled ‘Perspectives of Urban Flood Management in Dhaka’ describes the aims and approaches of current FM practices. This also provides a short discussion on the institutional framework and the legislative framework of current FM.

Chapter six entitled ‘Analytical Perspectives of Urban Flood Management in Dhaka’, which analyses the research findings, based on acquired knowledge from literature reviews and fieldwork.

Chapter seven entitled 'Conclusions and Recommendations' is drawn from the reflection upon the reviewed literature and analysis. The research sub-questions are answered and in accordance recommendations are made for possible improvements in FM within the context of Interactive WRM. An outlook on possible future challenges for further research development will follow the conclusion.

Chapter 2 Development of Water Resources Management

2.1 Introduction

Water is a vital substance, essential for human existence and unique in its role on Earth; chemically, physically and biologically (Lavkulich & Ulazzi 2008). Water is one of the natural resources, like air and solar energy. Water resources are sources of water, which maintain ecological processes, sustain functions and thus provide services. As resource, water is also useful to humans for household, agricultural, industrial, recreational activities. Therefore, a planned development, distribution and use of water resources are essential and required. The water resource management (WRM) is about 'functioning of the water system'. The water system can be seen as a kind of reactor, directing the precipitation through different pathways (physical, chemical and biological processes) back to the atmosphere or sinks like deep groundwater (Meire et al. 2008). And the water management is about water chain (Meire et al. 2008) management. The water chain is the process of water uses like water supply, irrigation, wastewater treatment etc. A balance between the "functioning of the water system" and "the impact of the water chain" (Meire et al. 2008) is important to sustain the environment.

The emergence of new paradigms has brought substantial changes in WRM. The traditional approaches were primarily hydro-centric. In recent years the WRM is perceived as an integrated approach. It addresses the social and environmental interconnections. Resource management is also a decision-making process to allocate resources according to the needs, aspirations, and desires of people within the framework of society's technological inventiveness; political and social institutions; and legal and administrative arrangements (O'Riordan 1971, Hooper, 2005). As the limits of the physical and technical approaches to water resource management are becoming more and more transparent, policy attention is shifting increasingly towards institutional arrangement and reforms (Saleth 2006).

2.2 Integrated Water Resource Management

An integrated approach to water resources management emerged in 1980s. According to the Global Water Partnership (GWP), "Integrated WRM is a process which promotes the co-coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." This demands a holistic approach for sustainability linking social, economical development with the protection of natural ecosystems and land and water uses.

Integration is the central theme in WRM. The GWP considers this theme under two categories (GWP 2000):

- Integration of the natural system, with its critical importance for resource availability and quality and

- Integration of the human system, which fundamentally determines the resource use, waste production and pollution of the source, and which must also set the development priorities.

Integrated management is an approach to land and water resources planning and management. It implies the inclusion of physical, biological and socio-economic variables involved in natural system and human system, which addresses societal goals and functioning of the ecosystem and participation of stakeholders. It encourages participation to bring together a diverse array of knowledge of individuals as well as stakeholders include government entities, nongovernment organizations, community groups, business and industry with a particular interest in the system. According to the geographer Mitchell, integrated approach is more selective and focused (Hooper 2003). Through participation it produces strategies that are more coordinated, more cognizant of interconnections and more inclusive of the diversity of goals, support and commitment and also increases the likelihood of implementation (Hooper 2005). Thereby integrated approach is a coordinated management approach towards maximizing equitable socio-economic welfare along with the sustainability of ecosystems.

Add to the urbanization and the fast socio-economic development, the water resources all over the world is severely threatened. For example, in Australia, nation-wide, governments recognized that Australia's water resources are limited. Therefore, to ensure water supplies for both the environment and future generations, State and Territory water policies viewed water resources as potential resource and aiming at integrated management (Box 2.1) of all water resources.

Box 2.1: The Water Resources Management and Planning in Australia

In Australia, the water resources management is designed to ensure that water resources are managed to support sustainable economic development and conservation of the environment, for the long-term benefit of the community. The State water resource departments are responsible for water resource management and others like private landowners also undertake water management activities either based on their interests or to comply with the legal obligations. The major activities undertaken by the State encompasses the following water resources issues:

- Planning: the development of whole-of-catchment plans for the allocation and sustainable management of the resource;
- Water allocation: the allocation of entitlements to water users;
- Management and compliance: activities to ensure that water is being shared and used in accordance with the entitlements and water plans. Key functions include: water resource accounting, administering water entitlements and licenses, and facilitating and administering water trading.
- Monitoring: a range of water monitoring, water resource assessment and information management activities are undertaken to support water resource planning and management (eg reporting on progress against water plans, monitoring of ambient networks, stream gauging and water quality monitoring, and management and publication of water resource data).
- Assessment: review of water plans, and adoption of new plans.

In Australia, the water resource planning and management frameworks are a central part of the National Water Initiative (NWI) which aimed at nationally-compatible, market, regulatory and Planning based systems for managing surface and groundwater resources for rural and urban use that optimizes economic, social and environmental outcomes.

Source: (ACIL Tasman 2005)

2.3 The Ecosystem Approach in Water Resources Management

The concept of ecosystem has developed both as discipline and approach (UNU/IAS 2003). As an approach it addresses the environmental relationships across varying spatial, biological and organizational scales (figure 2.1), as compared to more traditional approaches looking at individual projects and single components of a plan or a single species (Szaro et al. 1998). The movement for ecosystem approaches in WRM started since 1970s. This new paradigm recognized river basins as large, complex, integrated ecological systems (Hooper 2003) to make sustainable use of water resources within a river basin. The fundamental concept is to integrate all physical, chemical and biological components and processes (the water and human system) which sustain the interactive phenomenon of environmental, social, economical, institutional factors. It is a comprehensive approach aimed to achieve balance between conservation, sustainable use and equitable distribution of benefits (Van Ast et al. 2008) among living things and non-living environments. Ecosystem management implies the involvement of different stakeholders and institutions in defining alternatives to establish the interactions between society and environments. There is no single way to implement an ecosystem approach in WRM. Because it emphasizes place-or-region based objectives, with scopes and approaches defined appropriately for each given situation (Szaro et al. 1998).

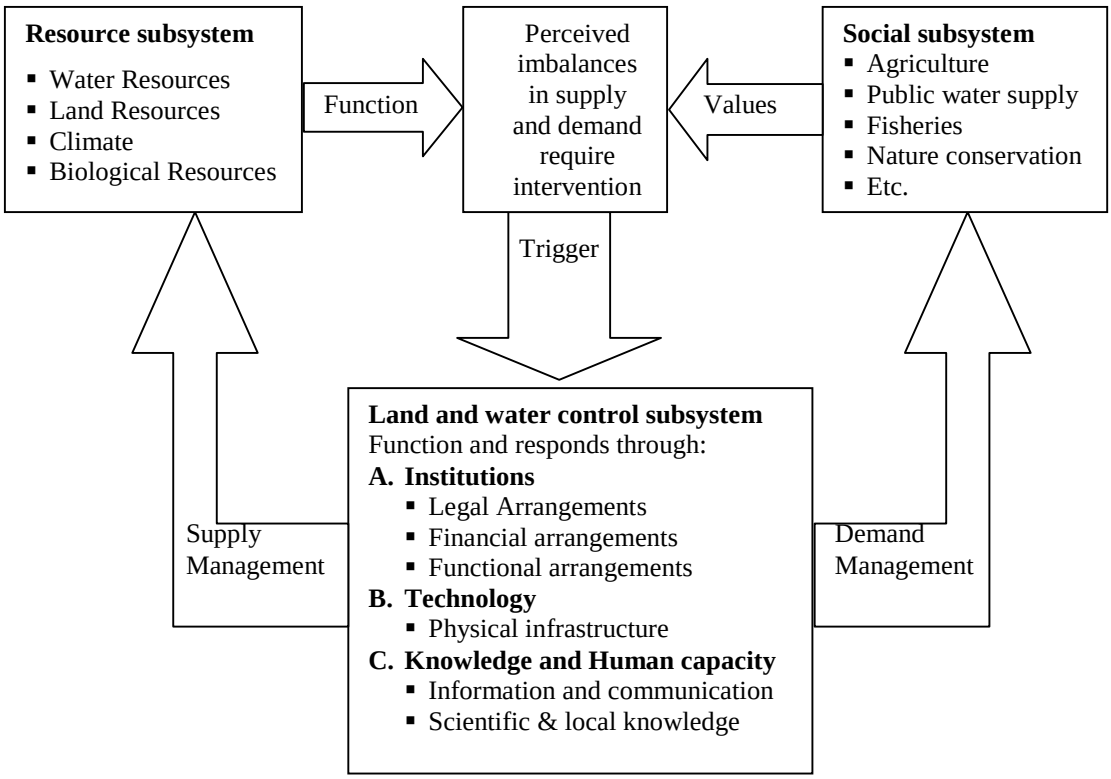


Figure 2.1: Three subsystem of the Socio-ecological System
Source: Chowdhury, 2008

2.4 Adaptive Water Resource Management

The concept of 'adaptive management' was developed by ecologists to shelter the uncertainty, the complexity and the coming of unexpected happenings in the natural ecosystems (Rosa 2008). The human beings are an integral part of the natural ecosystem. All organisms modify their environment and humans are not exception (Vitousek et al. 1997). Human alteration of earth is creating pressure on water resources. These are high rate of population growth and their increasing demands of available resources, changing land use, changing land use management practices and the climate change. All these changes have impacts on water cycle and which in turn having significant impacts across many sectors of the economy, society and the environment. Sustainable water resource management demands ecological integrity, social equity and economic efficiency. Thereby a more holistic approach is needed because the water systems should be understood and managed as living ecosystems, characterized by its great complexity and uncertain (Rosa 2008). Facing all the complexity, uncertainty inherent to ecosystems, Lee (1999) advocates for the adaptive approach to strengthen the ecosystems management strategies (Van Ast et al. 2008). This approach requires a continuous participation, capacity building and governance. Adaptive model demands choices and tradeoffs (Rosa 2008). This selection can be achieved through distributing the social responsibility among the different actors-authorities, stakeholders, experts-which contribute to all process by the information sharing, analysis, decision-making, planning, implementing and capacity building, monitoring and evaluating projects. In fact, adaptive management is a type of application, which enables learning through experience. In this approach the information is not just an initial input, it also pervades the decision-making process in all its phases. The monitoring information supports the assessing of the decisions and evaluating the efficiency of the management action. The monitoring based information can be integrated with the stakeholder based information. This brings together the local and scientific knowledge systems together into single structure information system. Adaptive ecosystem management facilitates the 'two-way' flow of information, which recognizes participation and capacity building to have collaborative knowledge in the local context to reduce conflict.

2.5 Interactive Water Resource Management

Interactive water resources management is relatively a new development in water management. This refers to the interactive dialogue (Figure: 2.2) between the water managers and the policy subjects. The basic elements are interaction, integrated approach, sustainability and water system approach (Van Ast 1999). Water managers are in interaction with the society in one hand and water system on the other hand. The interaction with the society is taking place in the form of participation of citizens and Nongovernmental organizations (NGOs) in decision-making process. The interaction with the water system approach refers to the concept of natural dynamics of river systems, to be taken into account.

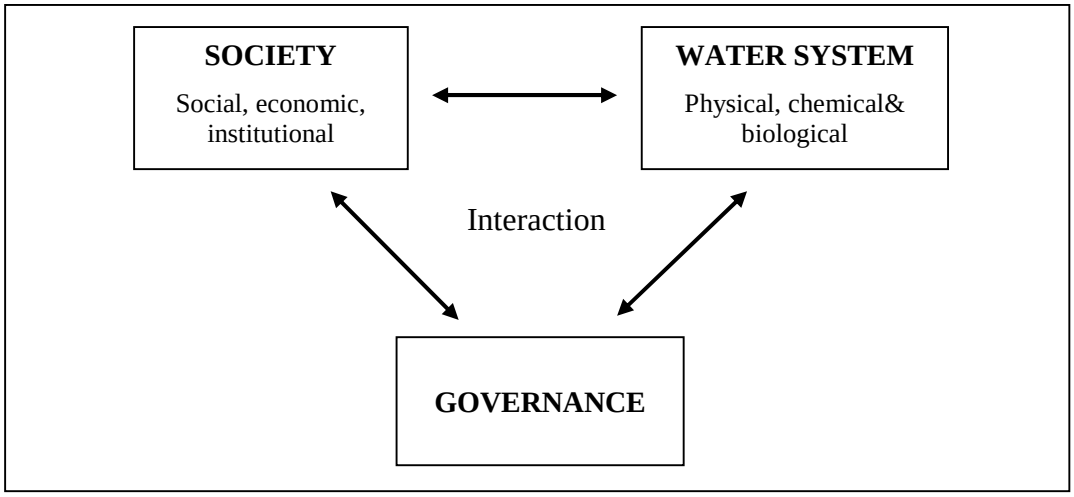


Figure 2.2: The Conceptual Model of Interactive WRM
Source: (Van Ast et al. 2008)

It is an attitude, a way of treating the both the natural and social environment. Integrated approach is also implied here but it is directed to water system and interactive approach is directed towards mutual working method. Interaction is the key element is this approach. The two different relations of this approach are:

- Interaction between water managers and the water system.
- Interaction between water managers and the different actors in society.

Firstly water managers are in a continuous dialogue with the different ecological parameters of the water systems. That's why water managers are constantly monitoring of a wide range of water system parameters. A large variety of factors influence the environment in many different ways. Secondly water managers should monitor the societal processes. This implies opportunities for the development of new of new policy. The interaction consists of information exchange with the public and involvement of stakeholders in the decision-making process. It offers mechanisms to the public to contribute to decision-making process (Van Ast 2000).

2.6 Flood Management

Flood management (FM) is an important aspect of WRM. Historically, floodplains have been a preferred place for human settlement and socio-economic development because of their proximity to rivers, guaranteeing rich soils, abundant water supplies and means of transport (APFM 2006). Floodplain landscape performs many hydrological, socio-economic and ecological functions (Chowdhury 2008). Floods replenish wetlands; recharge ground water and support fisheries and agriculture systems (APFM 2006). At the same time, floods have negative impacts on economy and human safety. In recent years it has been recognized that for sustainable development it is imperative to address both positive and negative impacts of floods in an integrated manner.

2.6.1 Flood and its nature

A Flood is a deluge. It is an overflow of water submerging land. Floodplains, in general, are the adjacent lands to rivers, streams, and lakes subject to recurring floods. Floods occur most commonly when water from heavy rainfall, from melting ice and snow, or from a combination of these exceeds the carrying capacity of the river system, lake, or ocean. The frequency depends on the climate variability. In a particular season, where there is substantial rainfall (monsoon), the floodplains experience flood nearly every year, like Bangladesh. Human activities on floodplain also influence flood. Flood in built environment is the consequence of both natural and man-made factors (Table 2.1). The different combination of casual factors results into four categories of flood namely local flood, river flood, coastal flood and flash flood. Any one or combination of any two of these floods contributes to the floods in urban areas. For example, urban flood in Dhaka is the combination of river flood and local flood.

Table 2.1: Factors contributing to Flooding

Meteorological Factors	Hydrological factors	Human factors aggravating natural flood hazards
Rainfall	Soil moisture level	Land-use changes
Cyclone storms	Groundwater level prior to storm	Occupation of the flood plain obstructing the flows
Small-scale storms	Natural surface infiltration rate	Inefficiency or non-maintenance of infrastructure
Temperature	Presence of impervious rate	Too efficient drainage of upstream areas increases flood peaks
Snowfall and snowmelt	Presence of impervious cover	Climate change affects magnitude and frequency of precipitations and floods
	High tide impeding drainage	
	Channel cross-sectional shape and roughness	Urban microclimate may enforce precipitation events
	Presence or absence of over bank flow, channel network	
	Synchronization of run-offs from various parts of watershed	

Source: APFM, 2008

2.6.2 Urban Flood Risk

Urban Flood risks are a function of exposure of people and economic activities along with the vulnerability of social and economic fabric (APFM 2008). Exposure refers to whether or not people or values are in range of flood water (APFM 2008). Unprecedented rural-to-urban migration has caused uncontrolled urban sprawl in cities of developing countries like Dhaka with increasing informal settlements, high concentration of industrial and economic activities, infrastructure development in riversides, wetlands, low-lying areas, retention ponds. In the case of Dhaka, the urban growth took place in filled-up water bodies, canals, flood-flow zones, sub-flood flow zones, and low-lying areas near embankment ignoring its impact on flood. Vulnerability of flood is crucial in terms of exposure to hazard, which may or may not constitute a risk that may actually result in a disaster. Physical vulnerability of people and infrastructure increases with urban development. This is also affected by socio-spatial segregation. With urbanization, land prices increase and as a result low-income

people are forced to choose flood prone areas. These people are always suppressed to get support from government for the betterments of their living conditions.

2.6.3 Urban Flood Risk Management

Traditionally, flood management has been problem driven. Flood management was largely focused on reducing flood and vulnerability to flood damage through variety of engineering interventions with very little or no long-term consideration for economic sustainability. The need for a paradigm shift from flood control to flood management has been recognized during the past decade. This shift is enshrined in the Integrated Flood Management (IFM) concept (APFM 2004). Floods, particularly in urban areas, are rising in terms of frequency and magnitude, due to urbanization process coupled with population growth. The development activities in urban areas, such as water supply and sanitation, housing settlements, pollution control, transport systems, industrial activities; health and social welfare etc., all influence and interact with each other and affect the flood risks to a large degree. To reduce this urban flood risks, it is imperative to mainstream flood risks in all these related activities, which requires a coordinated action to address and understand the following issues (APFM 2008):

- The affect of potential flood hazards on various development programmes and projects;
- How the policies and programs in other development sectors influence:
    - The magnitude of the flood hazards; and
    - The vulnerability of the society to the flood hazards

The conceptual framework of urban flood risk management (UFRM) (figure 2.3) is based on three concepts (APFM 2008):

- Integrated Flood Management (IFM);
- Total Water Cycle Management (TWCM);
- Land-use Planning

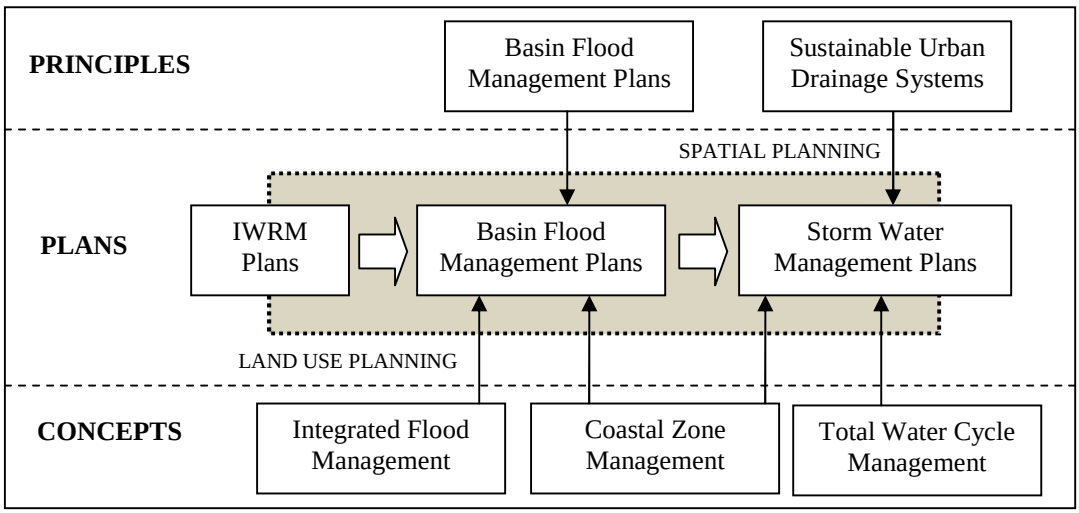


Figure 2.3: The conceptual framework of Urban Flood Risk Management
Source: APFM, 2008

2.6.3.1 Integrated Flood Management (IFM)

The insight of the IFM (figure 2.4) concept is the re-orientation of the social perception of floods (APFM 2006). It concerns more proactive responses than reactive responses towards floods.

> *IFM is a process promoting an integrated approach to flood management aimed at maximizing the net benefits of flood plains and minimizing the loss of the life from flooding in a river basin within the framework of Integrated Water Resources Management (IWRM).* (APFM 2004)

The aim of IFM is to put in place well-functioning integrated measures for flood management (APFM 2004). Integration, the defining characteristic of IFM, is perceived in terms of institutional integration and expressed in different forms as follows:

- Manage the water cycle as a whole;
- Integrate the land and water management;
- Adopt a best mix of strategies;
- Ensure a participatory approach;
- Adopt integrated hazard management practice.

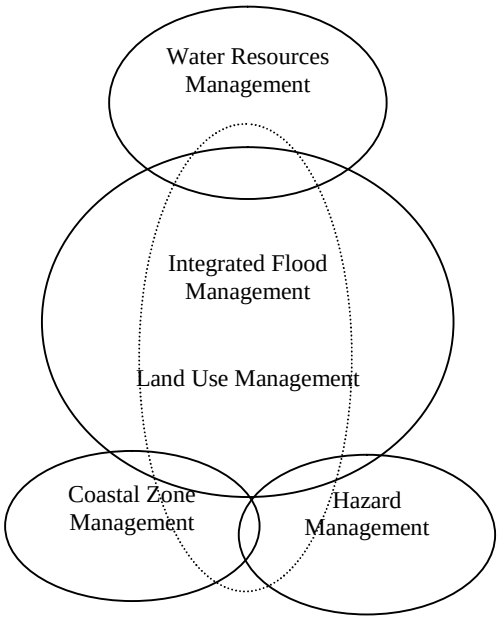


Figure 2.4: The Conceptual Model of IFM
Source: APFM, 2004

The IFM concept is based on integration of land and water resources management in a river basin. The rationale of this integration is that the three main elements of river basin management-water quantity, water quality, and the process of erosion and deposition–are inherently interlinked (APFM 2004). For example, the upstream urbanization causes an accentuation of flood peaks and their early occurrences in downstream. It also change water quality and sediment transport characteristics (APFM 2004). Therefore, the linkages need to be recognized and understood to adopt river basin based approach to IFM.

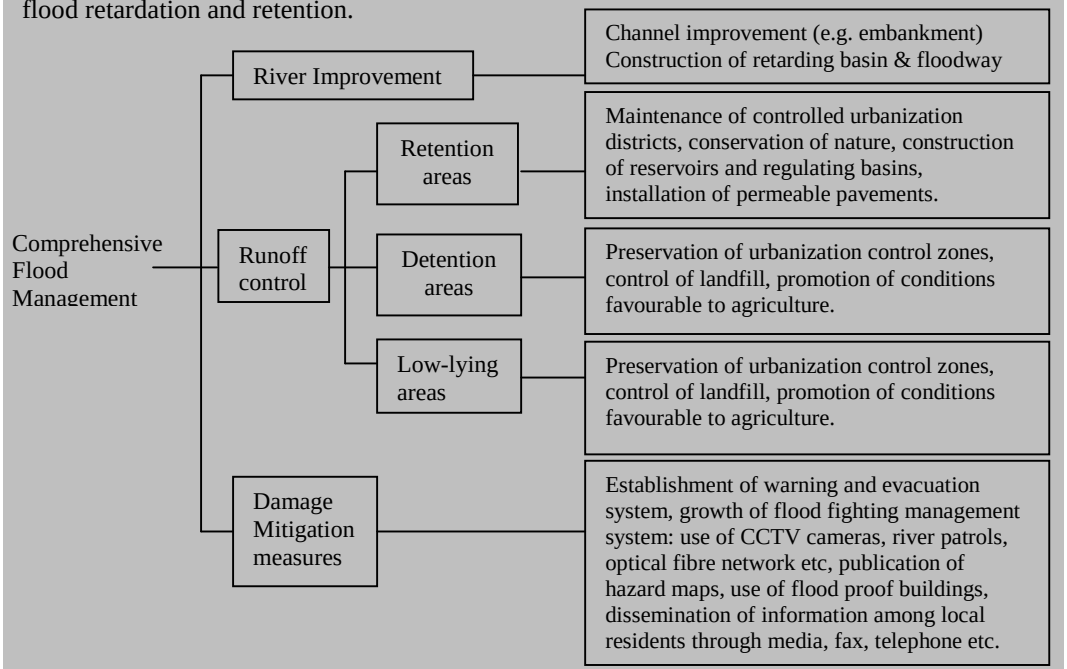
A participatory approach in decision-making process of flood management is an important key component of IFM. This includes the involvement of individuals and different ranges of stakeholders of all levels. This requires decentralization of decision-making with full public consultation and involvement of stakeholders in planning and implementation (APFM 2004).

To address all hazards holistically, the integrated natural hazard impact mitigation approach is required. The risk management strategy should integrate IFM. This facilitates structured information exchange and effective organizational relationships, which ensures efficient use of resources, and consistency in approaches to natural hazard management in all relevant national and local plans.

Both in developed and developing countries, the process of rapid urbanization brought change in the urban landscape. This has caused radical change in hydrological cycle and as a result flood risks are increased enormously. With response to this, the Japan government has adopted the policy of comprehensive flood management (Box 2.2).

Box 2.2: A Sustainable Integrated Flood Management in Japan

Japan applies both structural and non-structural measures for flood protection. The River Law & the Flood Fighting Laws is the main legislative instrument determining flood and water management policies within the country. The Basic Policy for River Improvement is enacted to accommodate public opinion. The Japanese comprehensive flood management is the combination of river improvement, run-off control and drainage mitigation measures. This comprises both conventional measures and innovative measures with special attention to flood retardation and retention.



Japanese introduced Experimental Sewer System (ESS), which is capable of controlling storm water runoff by adding infiltration and storage facilities to the conventional combined sewer system. In this process the ground water is also recharged. To increase the retarding capacity of the area Japan has constructed ponds and regulation reservoirs, such as stadiums and sports fields, such as tennis courts which are used for temporary storage.

Source: (Yoshitani et al. 2006), (Stalenberg & Kikumori 2008)

2.6.3.2 Total Water Cycle Management

The concept of Total Water Cycle Management (TWCM) (figure 2.5) is primarily based on two linkages; storm water management and water supply & sanitation. In present urban situation, storm water management cannot be separated from water supply management. Water supply, sewerage and wastewater disposal and surface run-off disposal are three basic fields of urban water management. The potential synergies of these components have to be factored in UFRM in an integrated manner to maintain urban hydrologic balance.

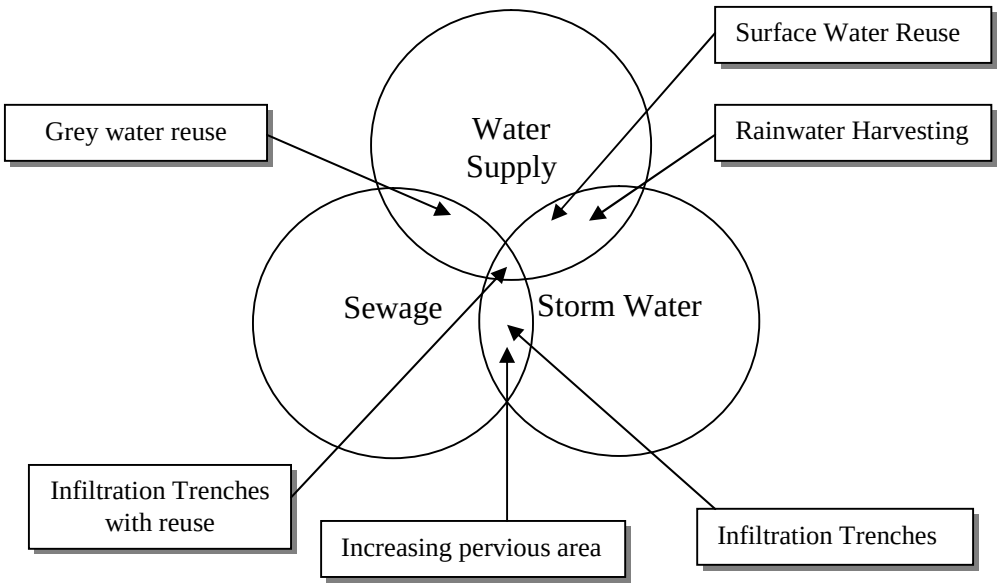


Figure 2.5: The Conceptual Model of Total Water Cycle Management

Source: APFM, 2008

Sustainable management of the urban drainage system is an essential element of TWCM to prevent future urban flood risks to both the site and its surroundings (APFM, 2008). Sustainable Urban Drainage System (SUDS) aims to reduce flood risk, improve water quality, recharge groundwater and enhance the potential biodiversity. The principle of SUDS comprises of run-off prevention, source control both local and regional results both from sources external to the development site and rain falling onto and around the site (APFM 2008).

2.6.3.3 Land use planning

To mitigate urban flood risks efficiently a mix of approaches, comprising spatial, technical and organizational measures are very important (APFM 2008). The concept of IFM and TWCM all lay emphasis on land use planning. Integration of flood management plan and land use plan is an important aspect of land use planning. The flood hazards and risks have to be factored in the land use regulations (Box 2.3). Such a combination of approaches and measures also has some secondary benefits (APFM 2008): land use planning supports water supply, ground water recharge, provides space for recreational activities, along with other concepts like IFM, TWCM also contribute to the general improvement of urban living conditions.

Box 2.3: Integrated Water Cycle Planning and Management in Australia

The water sector in Australian is giving attention to the concepts of Integrated Water Cycle Management (IWCM) and Water Sensitive Urban Design (WSUD), which emphasize the need to integrate the conservation and sustainable use of the various water sources in urban planning and development. To manage all water effectively and use optimally within a catchment resource, IWCM involves the integration of water supply, sewerage and storm water. The complex linkages between different elements of the urban water cycle both within the urban area and between the urban area and its water related catchment.

Water Sensitive Urban Design (WSUD) is the integration of urban planning and development with the management, protection and conservation of water within a consideration of the water cycle as a whole. It establishes links between water management and urban design, landscape and architectural considerations. This aims to keep the water balance in urban areas as close as possible to predevelopment values.

IWCM uses a range of tools to emphasize the different facets of urban water management:

- Water conservation and efficiency;
- WSUD;
- Utilization of non-conventional water sources including roof runoff,
- Storm water, grey water and wastewater;
- The application of fit-for-purpose principles;
- Storm water and wastewater source control and pollution prevention;
- Storm water flow and quality management;
  The use of mixtures of 'soft' (ecological) and 'hard' (infrastructure technologies);
- Education;
- Pricing incentives; and
- Regulations and restriction regimes.

As part of institutional and regulatory arrangements, the State Governments have adopted a wide range of initiatives under the ambit of sustainable water resource management policies, which is being pursued, by a range of parties across all jurisdictions. For example:

- State governments, water authorities and economic regulators are overseeing pricing reforms to better reflect the value of water (e.g. higher volumetric tariffs, often with increasing blocks as consumption rises);
- Public education programs promoting water conservation and efficiency are being undertaken;
- Increasingly stringent water restrictions are being adopted (e.g. 'permanent' water savings measure in Victoria prohibiting certain water uses);
- Governments across Australia have developed formal policies and/or action plans to promote recycled water projects, often with financial subsidies, public education and awareness programs, and in some cases through mandating specific targets for recycled water.

Source: (ACIL Tasman, 2005)

2.7 Participation

Public participation has become an important aspect to policy makers. The word participation comes from the Latin word 'Pars', which means 'a part', and the verb 'capere', which means 'to take' (Van Ast et al. 2008). In general participation means 'to take part'. Public participation is processes in which individuals, groups, and organizations have the opportunity to participate in making decisions that affect them, or in which they have an interest. In other words, it is the redistribution of power that enables the have-not citizens, presently

excluded from the political and economic processes, to be deliberately included in the future.

Table 2.2: The Ladder of Citizen's Participation

	Forms of participation		Role of participants	
Citizen Power	8	Citizen Control	Participants govern a program or an institution	▪ To provide have-not citizens handle planning, policy making & managing program. ▪ Citizens have full managerial power
	7	Delegated Power	Holding a clear majority of seats on committees with delegated powers to make decision.	▪ To assure citizens accountability to the decision-making ▪ Full participation with decision-making authority.
	6	Partnership	Establish negotiation between citizen & power holders.	▪ To share planning & decision-making responsibilities between citizen & power holders. ▪ Full participation with two way flow of communication (official-citizen-official) ▪ Conflict in planning & decision making
Tokenism	5	Placation	Power holders judge the legitimacy or feasibility of the citizens' advice.	▪ To involve the citizens in planning & policy making only to get their advise ▪ Full participation with one way flow of communication (official-citizen) ▪ Citizens have limited power.
	4	Consultation	Through attitude surveys, meetings, public hearings invites citizens' opinion	▪ To involve the citizens in planning & policy making only to get their advise ▪ Full participation with one way flow of communication (official-citizen) ▪ No channel for feedback.
	3	Informing	Informing the citizens of their rights, responsibilities and allow to advise	▪ To legitimate participation ▪ Full participation with one way flow of communication (official-citizen) ▪ Not assure the accountability of the citizens' ideas.
nonpartic ipation	2	Therapy	Achieve public support by public relations in the name of participation	▪ Not to enable people to participate but enable power holders to educate the participants ▪ Non-participative
	1	Manipulation		

Source: Arnstein, 1969

There are mainly two types of interactive policy-making processes. First the *Pluralistic type* in which the every citizen in a democratic society has the power to exert direct influence on decision-making processes. Secondly, the *Corporatist type* involves different stakeholders related to specific policy issues in decision-making process. In this case the representatives of specific interest group share more or less the same power/authority equal to government bodies. In an idealistic participative democracy, the citizens should enjoy the highest degree of interaction in policy-making process directly or indirectly at possible stages of the policy process.

Arnstein introduced the concept of 'A Ladder of Citizen Participation' (table 2.2) in 1969, which indicates the government's attitude towards participation. In the ladder, the roles of participants are understood as hierarchical steps on a 'ladder of participation'. The interaction between government and participants becomes intense with the every step up on the ladder.

The bottom of the ladder, the societal actors have no participation in decision-making process. At the first level the actors have the access to the information, which defines smallest degree of participation. In the second level, the role of government is consultative and they consult with society for possible action towards the solution of the problem. In the third level the society plays role of an advisor. At the forth level the actors become co-decision makers. At the fifth level, the society is treated as partners in policy-making. At the highest, the sixth level the society plays the role of initiator. From the third step up the interaction takes place in its true meaning, active participation of society in policy-making processes.

In Interactive Water Management, the relation between Government and other societal actors is much more horizontal (Van Ast 2000), i.e. individual and stakeholders can participate actively in decision-making process. The information exchange like sharing of visions, ideas, behavioural patterns and solutions to problems can be incorporated into the decision-making process. This offers empowerment to the public to contribute into decision-making process. Participation can be successful if it is well considered and embedded within a clear framework and right tools and methods are applied. In theory, there are two potential advantages of well-organized interaction:

- The high quality decisions, which incorporates different views and ideas.
- The exchange of information leads to better understand of the ins and outs of the specific situation thus contributing to public support.
- Clear understanding and identification of local needs, preferences and priorities.
- Promoting supports for the identified objectives and solution proposed.

Involvement of stakeholders should take place at the early stage of decision-making. The instruments, which facilitate interaction with the public, are community meetings, questionnaire survey, interviews and internet. Among all, internet is a new medium that facilitates the perfect open decision-making and also allows direct publication of relevant information.

2.8 Interactive Institutional Arrangements

Institutions are usually understood as sets of rules which structure the relationship between individuals by determining their range of actions in certain situations (Bressers & Kuks 2004). Institutional arrangements structure the activity domains and interaction among the actors (Borrett & Cowie 2005).

During the past decade the institutional arrangements governing water sector have experienced remarkable changes in many countries around the world. Water institutions can be defined as rules that define action situations delineates action sets, provide incentives and determine outcomes both in individual and collective decision setting in the context of water development, allocation, use and management (Saleth 2006). According to Saleth and Dinar (2004), the analytical categorizations of these rules are legal rules, policy rules and organizational rules. The institutional features have two implications. First, the technical features of institutions characterize different forms of institutional linkages in a structural and

functional sense (Saleth 2006). Second, the institutional system refers the various levels and contexts of institutions. Following this principle, water institutions can be decomposed into water institutional structure (governance structure) and water institutional environment (governance framework) (figure 2.6). The institutional structure can be decomposed into its legal, policy and organizational components (Saleth 2006). Water institutional structure includes the structurally nested and embedded legal, policy and organizational rules governing various factors of water resources management. And water institutional environment characterizes the overall social, economic, political and resource context within which the water institutional structure evolves and interacts with the water sector.

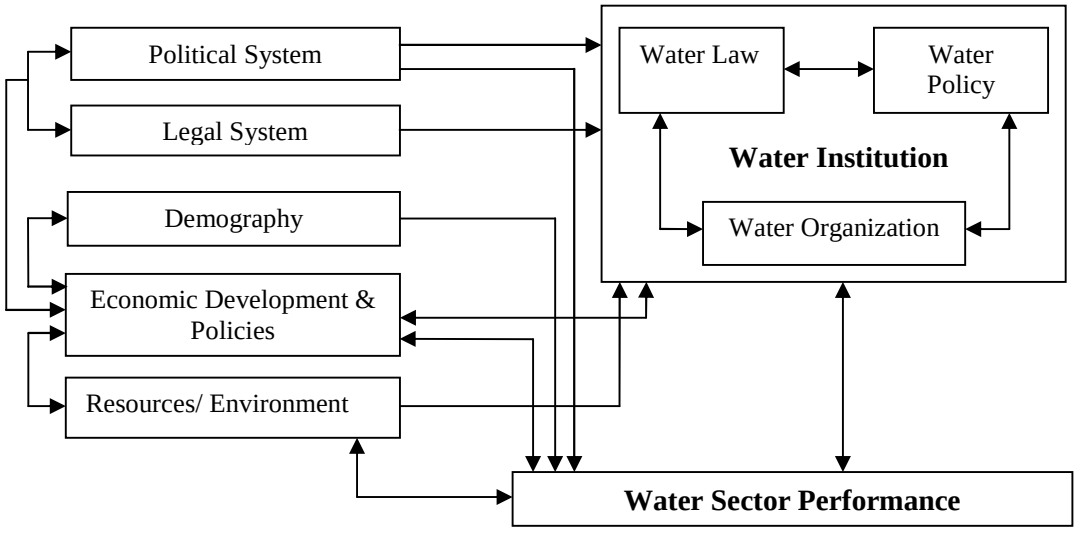


Figure 2.6: Water Institutional Environment

Source: (Saleth 2006)

The four basic elements of Interactive WRM; water system, integration, interaction and sustainability, can be perceived as the water system approach as a starting point, the river basin concept as a policy object, interactive management style and sustainability as a policy goal (Van Ast 1999). These combinations can outline the institutional arrangement (table 2.3) for water resources management. The underlying aspects of the four elements are connected with the main institutional elements: organization type, policy and instruments.

For effective governance, decentralization policies, strategies, instruments and activities must be conceived from two planes:

- The vertical plane, involves transfer of authority, functions, responsibilities and resources.
- The horizontal plane, involves empowerment of local communities.

Table 2.3: Interactive institutional arrangements for flood management

Main lines	Organization	Policy	Instruments
Starting point= Flood water use	National	Floodplain management	Floodplain regulation
Policy object= flood management in river basin	National multidisciplinary	Integration of regional planning	Floodplain location and resource use.
Style of management= interactive	Open & democratic	Mutual & communicative	Participation
Policy goal= sustainability	Long term	Strategical	Collective

Adopted from (Van Ast 1999)

Vertical decentralization requires shift in the central government policy, laws as well as institutional and structural agreements, which will lead to political and administrative decentralization. Horizontal decentralization may takes place without any adjustments in laws to socio-political economical and technical empowerment.

Box 2.4: Water Management Institutions in Different Countries

The seven commissions in China cover the six major international river basins and one lake basin. They are centralized agencies under the Ministry of Water with important planning and regulatory functions. The Yellow River Conservancy Commission also has specific responsibility for flood management in the lower Yellow River.

In India the Damodar Valley Corporation, began in 1948, has the responsibility of developing water and managing flood protection, irrigation and power. The commission focuses on integrated area development: promoting and operating schemes for irrigation, water supply and drainage, generation of electrical energy, flood control, navigation, reforestation and controls of soil erosion (Hooper, 2005).

Some of the basin authorities, like the Tennessee Valley Authority (TVA) in the United States, have very broad charter to develop multiple resources including water, power, navigation, etc. Others have more narrowly focused functions such as operation and maintenance of mainstream facilities for water supply and power generation.

The European Commission is the entity responsible for the enactment of the European Water Framework. Within this, the Directive on River Basin Management applies to river basins throughout the EU, therefore encompasses major and smaller river basins such as Rhine, Danube, Guadiana, Oder and Rhone. The aim is to maintain and improve the quality of the aquatic environment, in both national and international settings (Hooper, 2005)

Another common use of basin authority is to simply coordinate basin planning, operation and regulatory activities. In France, river basin committees have operated successfully for over twenty-five years doing long-term planning for developing water resources. Regulation and enforcement over there are conducted by various national ministries, while operation and maintenance of different components of the water system are left primarily to regulated private sector entities and public utilities.

Source: Faruqee & Choudhry, 1996

This bottom-up participation of inhabitants is found in the work of International Joint Commission between Canada and the USA (IJC, 1996, Dworsky et al. 1995 in Van Ast 2000). The Great Lakes Water Quality Agreement was a great success. In the early seventies the people who live in the Great Lake area addressed the issue to the concerned authority. The use of horizontal policy instruments was quite new at that time, still the experiences of the IJC were positive. This change in governance can be seen as a paradigm shift.

2.9 River Basin Management

The river basin approach is the key to IFM. A river basin is a dynamic system where a series of interactions between the land and water environment takes place. These interactions also involve sedimentation, pollutants. The functioning of the river basin as a whole is governed by the nature and extent of these interchanges (APFM 2004). Water quantity, water quality, the processes of erosion and deposition-the three main elements of river basin management are closely linked to each other. This interrelationship is the primary reasons for adopting river basin based approach to IFM.

Rivers and their source basins has been the site of human occupation and many cities and towns throughout the world have been established on the banks of rivers predominantly to take the advantage of riverine communication. So for many years the river basins have been focus of management. River basin management is macro-scale natural resources management (Hooper 2005). The expert group statement on Integrated River Basin Management for the 2nd World Water Forum and Ministerial Conference in the Hague, 2000, maintained,

> "*River basins are the paramount source of freshwater. To preserve and maintain this precious resource for present and future generations, there is the need for sustainable river basin management* (Hooper 2005).

River basin management (RBM) is the subset of IWRM. Integrated River Basin Management (IRBM) is defined as an integrated and coordinated approach to the planning and management of natural resources of a river basin, one that encourages stakeholders to consider a wide array of social and environmental interconnections, in a catchments context (Hooper 2005).

In RBM, river basin is the common pool where the natural resources are shared amongst multiple users. There are three levels of decision-making in river basin management (Hooper 2005): strategic/policy levels, implementation level and operational level. For instance, the peripheral river basins (the Buriganga, Balu and Turag River) of Dhaka are dominated by industrial activities. In this setting the three levels would be represented by industries (individual), environmental regulatory agency (Department of Environment, DoE), Dhaka City Corporation (DCC) (operational) and water Resource Planning and Organization (WARPO) sets policy (strategic). In all three levels the decision makers (individuals, NGOs, public and private organizations) functions vary in time and space. Their decisions are driven by market demand; government policy on resource use, political

processes and operation takes place within existing institutional setup and administration for resource exploitation and conservation.

2.10 Theoretical Framework

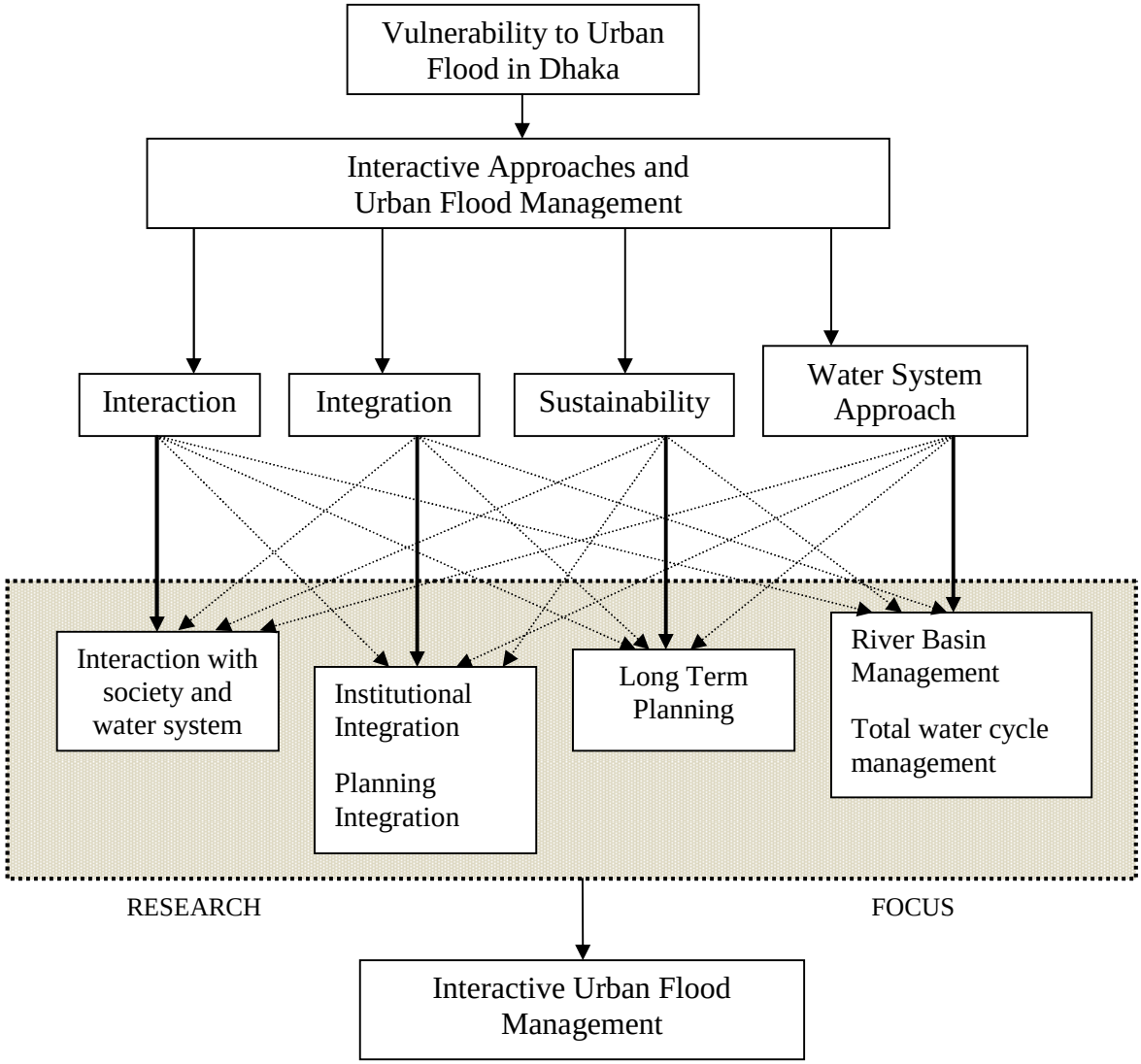


Figure 2.7: The Theoretical framework

The research focuses on two key elements: interaction and integration interactive to identify the possible opportunities to enhance the performance of UFM in Dhaka. The theoretical framework illustrates the interactive approaches and UFM in terms of interaction, Integration, sustainability and water system approach.

- Interaction is the defining characteristic of Interactive WRM. The research analyzes the degree of citizen and stakeholders involvement in decision-making process. This interaction offers a mechanism to the public to contribute to decision-making through exchanging information with the involved stakeholders. It also focuses on interaction between water managers and monitoring of the water system.

- The fundamental feature of UFRM is integration. This study identifies the institutional integration for FM at river basin scale. Institutional integration organizes the cooperation among all the stakeholders. It concerns relevant competences and means as an important support for the efficiency of the FM.
- Sustainable water resource development is perceived as long term and short-term interventions in planning. Therefore this research has focused the perspectives of long-term strategies in water resources and flood management and planning in Dhaka.
- The concept of Interactive WRM is based on water system approach, which recognizes river basin as a large and highest level ecosystem with the total of the water system. And UFM depends on the hydraulic balance of the urban water management components. This study analyzes these two key elements in the context of Dhaka.

Participation represents the required competences and contributes in decision-making providing basic information about the maximizing the positive aspect of floods. Institutional integration facilitates the decision-making process leading to IFM and implementation within the given institutional structure. This way both the elements affect each other and the whole management system. Therefore, in order to ensure effective, sustainable FM in the light of interactive WRM, widespread coordination between various institutions, interaction in terms of information sharing and networking of actors is imperative.

2.11 Water Resources and Flood Management Trends in Bangladesh

In Bangladesh, the major water management challenges are floods during the monsoon and water scarcity in the dry season. The floods cause damage to the cropping pattern, crop yields as well as fisheries, transportation, and economic activities. The water resources planning in Bangladesh were largely dominated by the flood control (FC) and irrigated agriculture to achieve the goal of increasing agricultural production to achieve national self-sufficiency. Bangladesh has approximately 14.8 million hectare of cultivable land, which is nearly 60% of country's total area.

The large public sector investments on water resources developments like FC, drainage and irrigation projects were implemented between the mid-1960s and late-1980s. The driving force was to protect floodplain agricultural lands from riverine floods and reduce damage of Aman (monsoon rice) production. In the 1990s, with the private sector initiatives, the dry season pump irrigation for the production especially the Boro (dry season rice) has risen sharply, resulting in near self-sufficiency in rice production (P. Wester & Bron, n.a.). The irrigation technologies for dry season irrigation includes irrigation from groundwater by deep tube well (DTW), shallow tube well (STW) and surface water bodies by low lift pump (LLP).

In Bangladesh, the national water planning started in the 1950s. Following the floods of 1954 and 1955, based on the United Nations mission (the Krug Mission)

recommendations the East Pakistan Water and Power Development Authority (EPWAPDA) was created in 1959 (P. Wester & Bron n.a.). The authority was responsible for the planning, design, operation and management of all water development schemes (DFID n.a.). In 1964, EPWAPDA prepared the 20-year Water Master Plan with United States Agency for International Development (USAID) assistance (DFID n.a.). The main concept of the Master Plan was Flood Control to increase agricultural production by the construction of embankments, pumping stations and canal irrigation. The bias towards agriculture meant that solutions tend to be in the form of flood control drainage and irrigation (FCDI) projects (DFID n.a.). However, in reality, the flood control was mainly emphasized and attention was given to the drainage improvement and irrigation for agricultural development.

Following the devastating floods of 1987 and 1988, the Government of Bangladesh (GoB) has formulated Flood Action Plan (FAP) with World Bank assistance. The five-year programme aimed at a long-term programme for achieving a permanent and comprehensive solution to flood problem. The GoB set up the Flood Plan Coordination Organization (FPCO) to coordinate FAP studies in 1990. The FAP study was highly criticised due to the absence of the active participation of civil society during the formulation stage. The study was culminated with the formulation of the Bangladesh Water and Flood Management Strategy (BWFMS).

Following the BWFMS, the National Water Policy (NWPo) and National Water Management Plan (NWMP) was formulated and approved by the GoB respectively in 1999 and 2004. Based on the recommendations of the BWFMS, the Guidelines for Participatory Water Management were formulated within the framework of NWPo in 1999, to ensure participatory water management in Bangladesh. According to the recommendations of the BWFMS, the FPCO was merged with Water Resources Planning Organization (WARPO) in 1996 for planning of water resources. After Independence in 1971, EPWAPDA evolved as Bangladesh Water Development Board (BWDB), which is responsible for implementation of surface water projects within a command area above 1000 ha (Chowdhury 2008). The Local Government Engineering Development (LGED) is responsible for areas of 1000 ha or less.

Different researches and studies on water and flood management projects in Bangladesh show that the projects failed to prove efficacy in long-term sustainability issues. The FC projects, aimed to prevent flooding of agricultural land and urban areas in floodplain have actually shifted the flood risk elsewhere rather than reducing risk such as the reduction of retention ponds, pumped drainage of rainfall-runoff from the protected areas increases flood level in the adjacent areas. A study carried by Rahman and Chowdhury shows that there is no significant correlation between the percentage increases in Amon production and FC coverage for the greater districts (Chowdhury 2008). The adverse impacts of these projects on WRM are due to lack of an integrated approach to WRM and coordination among the relevant organizations. Hydro morphologic features, socio-economic condition, and cultural heritage should be taken into account for sustainable WRM in Bangladesh. This requires participation of people in

planning and management of water resources. Although the GoB has taken some initiatives to develop WRM, including the formulation of the NWPo and the NWMP which consider social and environmental consequences of WRM interventions, the situation has not much improved. A detailed discussion on this is presented in chapter 6 of this report.

In recent years there is a major policy change took place in flood management in Bangladesh. The flood policy has shifted from its narrow focus on 'flood control' to 'flood management' and further to water management over 30 years. The Planning Commission of the Government of Bangladesh makes five-year plans providing guidelines for all development sectors including water resources sectors, as flood is considered the most important annual disaster at national scale. The Ministry of Water Resources management also formulates guidelines for Participatory Water Resources Management, though it is not practiced at full length. Therefore it is important that GoB to takes the necessary initiatives to create an enabling environment for participatory decision-making process concerning effective implementation of NWPo in order to ensure socio-economic and environmental sustainability.

2.12 Summary

The practical application of IFM is not universal. The hydrological and hydraulic characteristics of the river system and the regional characteristics refer to the adoption of particular strategies. It is suggested that the adoption of layered flood management strategy is often best strategy than the isolated one. This should be done in a way that it includes both the long-term as well as short-term interventions in the whole plan. The form of participation depends on social, political and cultural setup of the society. This is facilitated by the integration of institutions. Therefore the challenge is to promote co-ordination and co-operation across functional and administrative boundaries (APFM 2004).

Chapter 3 Research Methodology

3.1 Introduction

The research focuses on two important issues: interactive water resources management and integrated urban flood management. The strategic location of Dhaka in the GBM basin makes it vulnerable for flood flows. Besides river flood Dhaka also suffers from storm water flooding. A clear understanding of existing flood management practice in urban flood protection is necessary to reduce economic, physical and environmental impacts. Flood management is a subset of water resources management. This requires the study of water resources and flood management trend in Bangladesh. A case study approach is applied to study the current institutional framework with relation to flood management in urban flood protection. The concept of participatory water resources management and its interactive aspects are explored in chapter two to analyze the degree to which the interactive approaches exist in urban flood protection of Dhaka.

3.2 Research Design

The research design is summarized in figure 3.1 giving a general overview of the research process.

Figure 3.1: The Research Design

3.3 Research Framework
3.3.1 Definitions of variables

The following table 3.1 provides the operational definition of the variables.

Table 3.1: The variables and their operational definitions

Variables	Operational definitions
Water Resources Management (WRM)	Water Management refers to the process of water use i.e. the water chain (Meire et al. 2008). Water Resources Management refers to the functioning of the water system (Meire et al. 2008).
Integrated Water Resources Management (IWRM)	Integrated Water Resource Management is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resulting economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP 2000).
Interactive Water Management	A process in which the water institutions are in a continuous interactive dialogue both with the water system and the society system.
Integrated Flood Management (IFM)	Integrated Flood Management is a process promoting an integrated rather than fragmented approach to flood management. It integrates land and water resources development in a river basin, within the context of IWRM, and aims at maximizing the net benefits from flood plains and minimizing loss to life from flooding (APFM 2004).
Institutional arrangement	Institutions are usually understood as sets of rules, which structure the relationship between individuals by determining their range of actions in certain situations. Institutions are both the result of past actions and the framework within which new activities take place (Bressers & Kuks 2004). Institutional arrangements structure activity domains and interactions among actors (Cowie & Borrett 2005).
Participation In water resource management	The involvement or taking part of all people of a community in an equitable, efficient and sustainable use and management of available water systems (Van Ast et al. 2008).

3.3.2 Variables and Indicators

The following table 3.2 is a summary of the research framework outlining the strategies are used in answering the five (5) research sub-questions.

Table 2.2: The Variables and Indicators

Sl.	Research sub- question	Aim	Variables	Indicators	Data Type	Data Source	Unit of Analysis
1.	***What is Interactive Water Resources Management?***	To understand the concept of Interactive WRM.	Concept	▪ Concept of interactions	Qualitative	Literature study	
			Kind of features of Interactive WRM	▪ Elements of interactive WRM			
2.	***What is Urban Flood Management?***	To understand the concept of Urban Flood Management.	Aims & kind of approaches	▪ Concept of Urban Flood & floodnig ▪ Approaches to Urban Flood Management.	Qualitative	Literature study	
3.	***What are the Flood management trends in Bangladesh?***	To understand the development process of flood management in Bangladesh.	Development of Flood management practices	▪ Concept of flood management ▪ Institutional framework	Qualitative	Literature study	
4.	***What are the Urban Flood Management approaches in Dhaka in the context of UFRM within the framework of Interactive Water Resources Management?'***	To understand the existing flood management framework for urban flood protection of Dhaka.	Aims & kind of approaches	▪ Concept of flood protection ▪ Flood protection measures	Qualitative	▪ In-depth Interview ▪ Literature study	Water and Flood Institutions in Bangladesh
			Kind of Institutional framework	▪ Intuitional arrangement ▪ Rules and regulation			
5.	***What are the potentials and limits of present Urban Flood Management of Dhaka?***	To identify the possible improvements required in the present urban flood management framework of Dhaka	Kind of Interaction	▪ Flood managers & society - Actors: Public & Stakeholder Participation ▪ Flood managers & water system - Monitoring & modelling of physical system	Qualitative	▪ In-depth Interview ▪ Literature study	
			Kind of Integration	▪ Institutional integration ▪ Integration of land use and flood planning ▪ Integration of measures			
			Kind of Sustainability	▪ Long term vision ▪ Sustainable measures (economic, social, environmental dimensions)			
			Kind of Water System approach	▪ Basin approach ▪ Water cycle as a planning unit			

3.4 Research Methods and strategy

This is a qualitative exploratory and descriptive type of research, which leads to the identification of the elements of interactive water management approach that can contribute to the improvement of flood management in Bangladesh.

In this research the case study is used as a main research strategy. The concepts of interactive water resources management and its possibilities in Bangladesh are illustrated by a case study of flood management in Dhaka. As part of international case study Australia and Japan water and flood management approaches and institutional perspectives on public participation that are in practice are also studied through desk research. In addition to this, historical data are used to learn about the development of water management systems with a particular focus on flood management in the world in order to compare this with flood management in Dhaka.

3.5 Unit of analysis: Water and flood institutions

Unit of analysis for the research is the Water and flood institutions that are involved in water resources management in Bangladesh and flood management in Dhaka. The focus of the research is the understanding of the concept of Interactive Water Resource Management. The research aim is to analyze the interactive approaches that can be used in flood management in Dhaka. To be successful, IFM should be based on a firm legal framework and supporting institutional arrangements (APFM 2004). This requires the analysis of the existing institutional framework for flood management within the context of water resources management.

3.6 Data collection

This qualitative research is based on primary and secondary data collection to understand the trends of the water resources management in Bangladesh and to analyze the interactive approaches towards flood management and how such approaches can improve flood management in Dhaka.

3.6.1 Primary data collection

The primary data are collected through fieldwork between July 3 and August 31 in Dhaka, Bangladesh. The data are collected through in-depth interviews and observational study.

In-depth interview
In-depth interviews are conducted with open-ended and semi-structured questions. This is done to explore views and perspectives of the water resources management authorities. The interview is also carried out with urban planners, water managers, academicians, researchers (Annex 2) from government, private and international organizations, universities and research institutes to understand the trends of water resources management, flood management practices and to explore their way of

thinking towards how to integrate network of actors and institutions. The responses are recorded with written notes and audiotape.

Table 3.3: The list of Respondent Organizations

Respondent Organizations
Bangladesh Water Development Board (BWDB)
Water Resources Planning Organization (WARPO)
Flood Forecasting and Warning Center (FFWC)
Dhaka Water and Sewerage Authority (DWASA)
Local Government Engineering Departments (LGED)
Rajdhani Unnayan Katripakkya (RAJUK)
Center for Environment and Geographic Information Service (CEGIS)
Institute of Water Modelling (IWM)
The International Union for Conservation of Nature (IUCN), Bangladesh
Institute of Water and Flood Management, Bangladesh University of Engineering and Technology (BUET)

Observational Study

An observation study was carried by the author to observe the conditions flood control structures includes the western embankment, regulators and two Pump stations namely Goran Chatbari and Rampura Pump stations. The study focused on the conditions of the embankment, how the pump works and the surrounding land use development. These areas are purposively selected for observation. During field visit to the pump stations an unstructured interview is carried out with the Sub-assistant engineer of Goran Chatbari pump station and pump operator and Gauge Recorder of Rampura pump station. The interview with them was useful in gaining a perspective of the situation. A digital camera is used to keep record of observation for later analysis and illustration of the results.

3.6.2 Secondary data collection

The secondary data source for the research is literature study. Literature study includes published papers, theses, journal articles, government reports, books on water resources management, flood management, water governance, newspaper articles and internet sources.
Trends of water resources management, institutional arrangements, public participation, stakeholder participation, flood management of developed and developing countries are discussed in the theoretical part of this research.

3.7 Data quality

Qualitative data is used for this research. The data quality is evaluated through validity, reliability and its objectivity.

Validity: The fieldwork is demonstrated entirely by the researcher. The interviews are conducted with semi-structured questions. Audio recording is carried out during interviews with the respondents. Therefore it is expected that consistent and quality data is assembled. In addition to this, the validity of this qualitative research is controlled by the use of data triangulation (interview review, desk studies, and project reports) to measure the validity of the collected data.

Reliability: The nature of the interview questions intend to be based on real facts, not on subjective opinions. This is to ensure the collected information will not change over time.

Objectivity: The maximum neutrality is maintained in introducing the questions to ensure the objectivity of the instruments.

3.8 Research Population and sample

The population of the research is 13 million inhabitants of Dhaka city. Purposively selected sampling technique is implemented in the study to identify the interactive approaches to water resources management with a particular focus on urban flood management in Dhaka. This is a non-probability sampling and the interviewees are selected from government, private organizations and research institutions that are involved in water resources and flood management in Dhaka.

3.9 Instrument Design

Semi-structured questionnaire (Annex 1) is used to carry out the in-depth interviews. The questionnaire is designed in a logical order and organized it in a way to be able to answer the research sub-questions. Greater cares are taken to determine which questions are needed to measure the research variables and objectives, as well as to avoid leading questions.

3.10 Data analysis

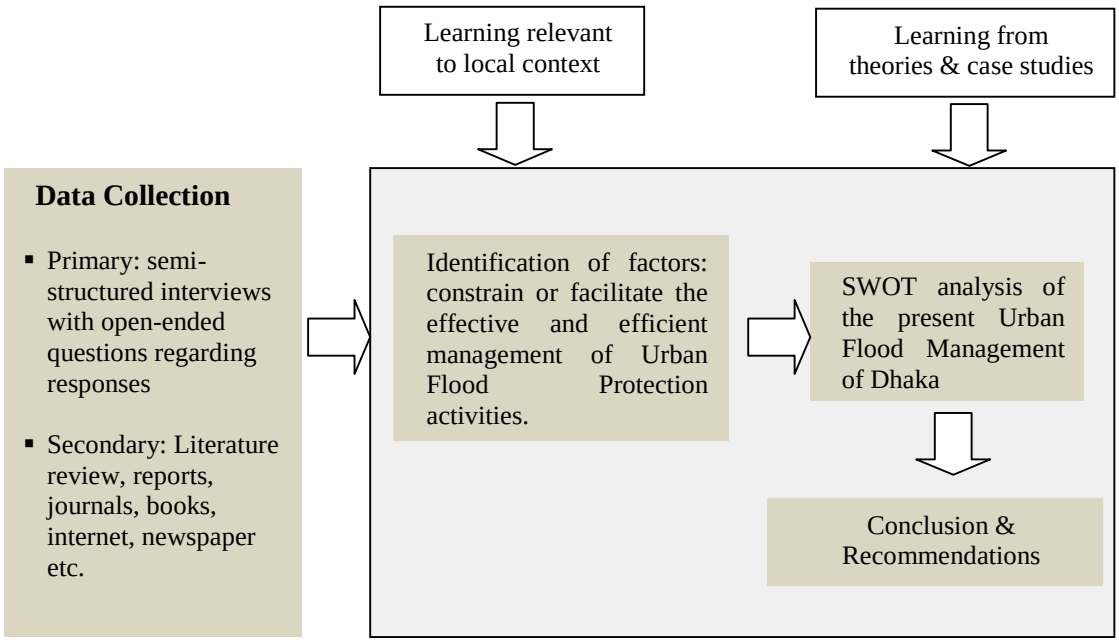


Figure 3.2: The Data Analysis Framework

This qualitative data analysis (empirical) part of the study has two stages;

1. First stage: At this stage the factors are identified that constrain or facilitate the effective and efficient management of UF protection activities in the light of Interactive WRM in Dhaka.
2. Second stage: The SWOT analysis is carried out to identify the potentials and limits of the current Integrated Flood Management based on literature study and in-depth interviews.

The analysis of the Interactive WRM approach is carried out to get insight of the approaches applied in Dhaka, with regards to UFM. The basic information about the functioning of the water systems and water chains are also revealed considering other different dimensions like participation, institutional integration, long term planning in the line of sustainability.

The data obtained from interviews and desk studies reveals the possibilities of developing policy recommendations on development of interactive flood management in Dhaka.

3.11 Scope and limitations of the study

The research has focused only on the defining interactive approaches in development of Urban Flood Management in Dhaka. This study can form a useful and important knowledge base for further intervention in water resources conservation, water services and flood issues.

The research is conducted in an extensive manner within a limited time period. The field work is carried out in the month of July. In Dhaka the monsoon (rainy season) is from May to September. And heavy rainfall occurs in June, July and August which is the peak time for urban flooding. Therefore the government officials were very busy in managing the flood situation and attending meetings. In that way the weather was not in favour of conducting the field work.

Chapter 4 Urban Flood in the Context of Dhaka

4.1 Introduction

This chapter begins with a brief description of the Dhaka city. It includes geographical context of Dhaka, its climatic features and a short discussion on history and urban expansion. This description is followed by a brief description of the hydrological features of Dhaka in the urban flood context. The chapter concludes with urban flood and its impact.

4.2 Geographic context of Dhaka

Dhaka, the capital of Bangladesh, is confined between latitudes 24°40' N to 24°54' N and longitudes 90°20' E to 90°30' E. The periphery is bounded by distributaries of the GBM basin. The elevation of Greater Dhaka ranges from 2 to 13 meters above mean sea level (msl) and most of the built-up areas are on elevation of 6 to 8 meters above the msl. The general slope of the city is visible towards the east west direction. The city and adjoining areas are composed of alluvial terraces and low-lying areas.

4.3 Climate of Dhaka

The climate of Dhaka is characterized by hot humid sub tropical climate. The city has four seasons: Pre-Monsoon (March-May), Monsoon (June –September), Post-monsoon (October-November) and Dry season (December-February). The city experiences cool and short winter and hot, humid and long summers. The temperature in summer varies from 21.1°C to 36.7°C and in winter from 10.5°C to 31.7°C. The monthly rainfall varies between 300 and 450 mm. In dry season the mean rainfall is about 50mm/day and 300-450mm/day from June to August. The mean monthly evaporation varies between about 80 mm in November and about 130 mm in August (JICA 1991).

4.4 History and growth of Dhaka

The history of Dhaka dates back to 7th century. Under Mughal rule in 1608 A.D., Dhaka, also known as Jahangir Nagar, was founded as the Provincial capital of Bengal. The city was established on the north-eastern bank of the Buriganga River. The Mughal Rulers were attracted to the Buriganga River for communication and defense against enemies. Since then, Dhaka city has grown mainly on the northern and eastern banks of the Buriganga River until 1960s, mainly because of easy transportation (Khorshed, 2003). In 1765 the city came under British control and Dhaka became the capital of Eastern Bengal and Assam province (1905-12). In 1947 the city emerged as administrative capital of East Pakistan. Later in 1972, after the victory in the War of Liberation in 1971, Dhaka became the capital of the People's Republic of Bangladesh.

At present, Dhaka is one of the most densely populated cities in the world. Dhaka accommodates the major share of 43% of total urban population (BBS 2003 in Islam 2008). In Dhaka city the urban population density is 4795person/sq.km (Islam 2008). Between 1947 and 1971, the city grew from an area of 1,800 ha to 18,000 ha, and by 1991, the city boundary embraced an area of almost 26,500 ha (160 sq km) (Khorshed 2003). Dhaka's population has grown from 4 million in 1980 to 6.5 million in 1990 and an estimated 10 million in 2001 (BBS 2001 in (Khorshed 2003). The table 4.1 shows the population of Dhaka since 1700s.

Table 4.1: Area and Population of Dhaka City (1600-2001)

Year	*Period*	*Area (Sq. m)*	*Source*	*Population*	*Source*
1600	Pre-Mughal Period	1	Islam, 1974	Unknown	--
1700	Mughal Capital	50	Taylor, 1840	9,00,000	Taylor, 1840
1800	British Town	8	Islam, 1974	2,00,000	Taylor, 1840
1867	British Town	8	Islam, 1974	51,000	Census of Bengal, 1901
1911	British Town	--	--	1,25,733	Census of Bengal, 1911
1947	Capital of East Pakistan	12	Islam, 1974	2,50,000	Census of Pakistan, 1951
1951	Pakistan Period	--	--	3,35,928	Census of Pakistan, 1951
1961	Pakistan Period	28	Census of Pakistan, 1951	5,50,143	Census of Pakistan, 1951
1971	Capital of Bangladesh	40	Census of Bangladesh, 1974	15,00,000	Census of Bangladesh, 1974
1974	Capital of Bangladesh	40	Census of Bangladesh, 1974	16,00,000	Census of Bangladesh, 1974
1981	Dhaka Municipality	62.4	Census of Bangladesh, 1981	24,75,710	Census of Bangladesh, 1981
1981	Dhaka SMA	155.4	Census of Bangladesh, 1981	34,40,147	Census of Bangladesh, 1981
1991	Dhaka SMA	--	--	69,50,920	Census of Bangladesh, 1991
2001	Dhaka SMA	--	--	99,12,908	Census of Bangladesh, 2001

Source: (Tawhid, 2004)

4.5 Hydrology of Dhaka

4.5.1 Surface Water Hydrology

4.5.1.1 Rainfall-runoff

Average annual rainfall ranges from 1700 to 2200mm. More than 80% of the annual rainfall occurs in the monsoon season (May to September). June, July and August are the months of heavy rainfall. The urban Dhaka has many impervious surfaces like paved roads and parking, roof of buildings, paved walkways etc. as a result the runoff rate is higher than in the rural areas. Even the rate varies between residential areas and commercial areas. It is seen that in the year 1996 and 1997 the commercial areas had 80% higher runoff ratios[2] than those of residential areas (Chowdhury et al. 1998b).

[2] Runoff ratio is the percent of impervious area and fraction of rainfall.

4.5.1.2 Drainage System

The low-lying areas, canals, lakes and ponds of Dhaka city act as detention basins (Figure 4.1) and perform the drainage function. The storm water is accumulated in the low-lying areas and lakes; flows through the storm channel i.e khals (Annex 3) and discharged to the surrounding rivers. The functioning of the drainage system depends on the water level of surrounding rivers. Generally during monsoon the surrounding river water remains high. Therefore, the drainage system is under the influence of backwater effect from surrounding rivers. The Greater Dhaka has more than 40 khals that drain 80% storm water of the city to the surrounding rivers (Khan 2006). The major khal systems are (Chowdhury et al. 1998b):

a) Degun-Ibrahimur-Kallyanpur khal system that drains to Turag River;
b) Dhanmondi-Paribagh-Gulshan-Banani-Mohakhali-Begunbari khal system that drains to Balu River;
c) Segunbagicha-Gerani-Dholai khal system that drains to Balu and Buriganga rivers.

The Dhaka west has 13 khals of total length of more than 31km and the Dhaka East has 27 khals of total length of about 60 km (Table 4.2).

Table 4.2: Major Retention areas of Dhaka City

Name	Length (m)	Avg. Depth (m)	Area (Km^2)	Volume (m^3)
Dhanmondi Lake	2,400	2.5	0.176	440,000
Ramna Lake	400	4.5	0.020	90,000
Crescent Lake	650	2.5	0.016	40,000
Gulshan Lake	3,800	2.5	0.480	1,200,000
Hateer Jheel	3,000	2.0	1.078	2,160,000

Source: (Khan, 2006)

In the master plan of flood protection Dhaka city is divided into 12 drainage zones for storm water drainage (JICA 1992). Dhaka Water Supply and Sewerage Authority (DWASA) manage 140 km^2 storm water drainage networks (Figure 4.1), from which the natural drainage system receives the storm water and drains through regulators at the embankment to the rivers.

4.5.1.3 River system

Dhaka is surrounded by rivers namely Turag River, Tongi khal, Balu River and Buriganga River (Figure 4.1). River Turag, Buriganga and Balu are connected with the Dhaleshwari River (Annex 4**).** The Turag and Buriganga rivers are distributaries of the Old Brahmaputra River and The Balu river is the tributary of the Lakhya River (Chowdhury et al. 1998b). The Tongi khal is connects the Turag River with the Balu River.

4.5.2 Ground Water Hydrology

The aquifer system of Dhaka is recharged by infiltration of rainwater, floods, leakage from urban water distribution and sewerage systems and water transfer. It is discharged by aquifer drainage to the rivers, direct evapo-transpiration, and ground water abstraction (BCEOM 1992 in Chowdhury et al. 1998b). Dhaka's

groundwater level has declined due to over extractions to meet the growing demand for water. In addition, the natural recharge has been reduced because of increase in impervious surfaces.

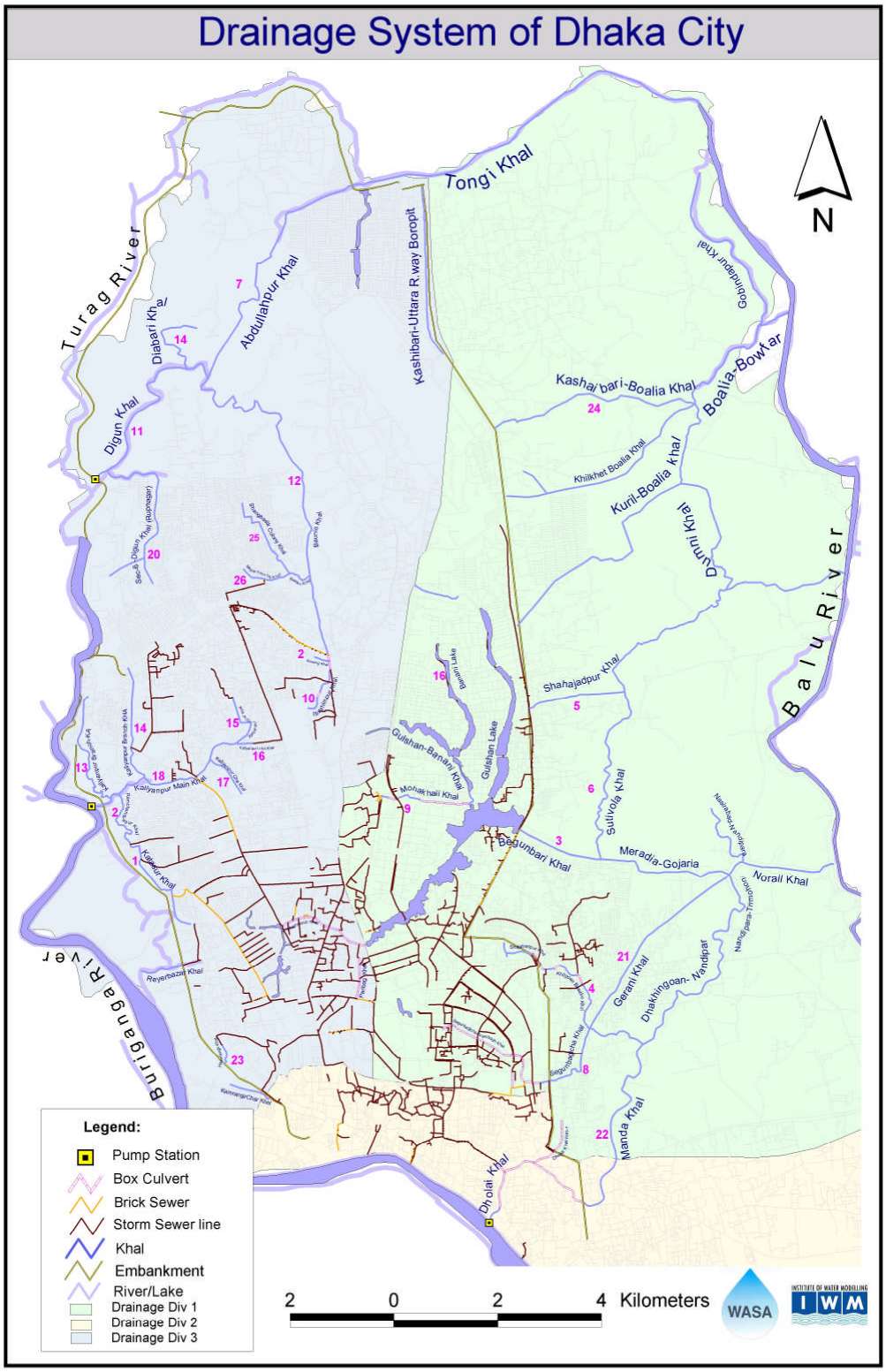


Figure 4.1: The present drainage system of Dhaka
Source: IWM, 2008

4.6 Urban Flood and its impact

Geographically Dhaka has a strong relationship with water resources like rivers, canals, lakes, and wetlands. Due to its location on the drainage path of The GBM basin Dhaka is subjected to annual flooding. One-fifth of Dhaka is categorized as flood free high ground with 38% being subject to annual flooding. The remaining 42% is subject to flooding at intervals between five and one hundred years (Alam 2004). During the month (June-August) of heavy rainfall Dhaka becomes inundated. In recent years vulnerability to flood has increased. During last 50 years Dhaka experienced significant urban growth. With this unplanned urban expansion Dhaka has gone through a drastic land use change. This change in land use reduced infiltration, storage area for storm water, construction of roads and buildings modified the pattern of drainage flow. Even with an hour long rainfall Dhaka inundates due to the poor conditions of drainage channels that are destroyed by encroachments and land-filling. As a result the degree of flooding has become a fact of life for the citizens of Dhaka.

The inhabitants of Dhaka are experiencing floods since its early dates. The disastrous floods affect physical settings, environment, quality of life and most importantly the economy of urban settlements. Dhaka being a capital city is the concentration of resources, infrastructures, service facilities, and economic activities. Consequently the impact of flood results in a high degree of economic loss, property loss, physical damages, and health hazards. The most vulnerable group in the city, the people living in slums are forced to live in flood risk areas.

In 1988, the most severe flood in the flood history of Dhaka, 2.2 million people were affected and the death toll was 150 (Huq & Alam 2003). Around 14000 institutions and 400000 houses were damaged in this flood (Annex 8). The damage costs were Tk. 4 billion for residential buildings and more than Tk. 400 billion for institutions (Alam & Rabbani 2007). In the flood of 1998 the damage costs were tk. 2.311 million (Huq & Alam 2003).

Figure 4.2: Flood affected streets in Kalachadpur,Dhaka
Source:
ochaonline.un.org/.../tabid/1775/Default.aspx

Figure 4.3: Water crises during flood

Source:
www.cnn.com/.../29/southasia.floods/index.html

Both flooding and water logging, cause serious damage to infrastructure like roads, railways, formal and informal housing and institutions. They also disrupt communication, slow down economic activities. The water logging especially

becomes a burden for the dwellers of Dhaka city as it poses challenges to social functioning, the environment and economic activities (Alam & Rabbani 2007). A report of DWASA states that during the flood of 2004, storm water flooding affected 250 schools, 681 garment factories and the garment sector lost Tk. 632 billion and road repair costs Tk 12.8 billion (Tawhid 2004).

Figure 4.4: Disruption in traffic movement
Source: The Daily Star, 24 September, 2007

Figure 4.5: Flooded Baridhara residential area
Source: http://commons.wikimedia.org

Figure 4.6: Flooded streets of Dhaka
Source: http://www.thedailystar.net/magazine/2004/09/04/cover.htm

Figure 4.7: Flood affected shopkeepers sit in Water logged shop
Source:http://news.bbc.co.uk/.../newsid_6923500/6923552.stm

4.7 Summary

Flooding in Dhaka is mostly seen as an unpleasant event. Flood affects almost all aspects of human life. In the flood history of Dhaka, the damages were enormous. As an economic centre of Bangladesh, flood prevention in Dhaka implies high priority. The process of urbanization has altered the natural system and accelerated the flooding vulnerability. Therefore measures to prevent flood events and measures, which reduce economical & social damage, are very important to be considered in development activities of Dhaka with regard to their consequences.

Chapter 5 Perspectives of Urban Flood Management in Dhaka

5.1 Introduction

This chapter starts with a brief background on urban floods in Dhaka and its nature. It also provides a short description of recent major flooding events of Dhaka. This is followed by a brief discussion on urban flood management practices in Dhaka. In addition, institutional framework, legislative and policy framework for urban flood management are also presented here.

5.2 Urban Floods and its Nature

Dhaka city suffers from two types of urban flooding: river floods and storm water floods.

5.2.1 River Flood

The main cause of river flooding in Dhaka is the spill over from the surrounding rivers: Turag, Buriganga, Balu, Tongi canal, Shitalakya. Once in every five to ten years river floods take place in the low-lying fringes areas outside the protective embankment of Dhaka. The water level of rivers flowing around Dhaka is affected by both discharge from the upstream rivers (Dhaleswari, Bangsi and Old Brahmaputra) and also by the backwater effect from downstream rivers (Daleswari, Meghna, Lakhya and Padma River) (Islam 2008). The Balu, Turag and Buriganga rivers are under the influence of tides in the Lower Megna and the recession of flood is delayed if peak flood occurs during spring tides (Chowdhury et al. 1998b). River flood generally occurs in the month of July to September. During this period the surrounding river stages remain high and cannot accommodate the water flow within the main watercourse.

5.2.2 Storm-water Flood

A flood caused by excessive rainfall is termed as storm-water flooding. The following are the causes of storm water flooding in Dhaka:

- During the monsoon season the water level of the surrounding rivers generally remains higher than the water level inside the city and gravity drainage is not possible;
- Inadequate drainage paths, improper operation and maintenance of the existing storm water drainage system;
- Increasing impervious areas reduce infiltration and in turn increase surface runoff;
- The existing drains are subjected to increased inflow of storm water and fail to carry the increased discharge due to the change in drainage flow by the construction of roads and other infrastructures;
- The catchment capacity to retain the excess runoff generation by heavy rainfall is reduced because of filling up low-lying areas and natural drainage systems (canal, lakes).

5.3 History of Urban Floods

By virtue of being surrounded by the distributaries of several major rivers, the city has been subjected to periodic flooding since its early days (Huq & Alam, 2003).

1988 Flood

The 1988 flood (Annex 5) was the largest ever recorded and catastrophic. This flood was mainly caused by inflows from the upstream areas, which caused a rise in the river water levels (Faisal et al. 2003). The flood peaks were higher in this flood compared to the 1998 flood but the areas surrounding Dhaka received less than average rainfall (Faisal et al. 2003).

1998 flood

In 1998, Dhaka (figure 5.1) was affected both by river and storm water flood. This flood was most severe in terms of extent and duration (two months) (Huq and Alam 2003). Excessive rainfall over the catchment areas of the GBM river basin caused the 1998 flood. The rainfall was 40% higher in July and 35% in August compared to normal rainfall in the July-August period (Faisal et al. 2003). The runoff generated by excessive rainfall could not flow to the surrounding rivers because the river water level was higher than the inside flow. During this flood the entire eastern part of Dhaka went under water. The protected western Dhaka was also flooded due to hydraulic leakage in incomplete flood wall in the southern Dhaka and flood water intrusion through open underground pipes and drains in the northern part. The failure in timely operation of the Rampura regulators and inadequate pumping failed to prevent the backflow from the Balu River and caused storm water flooding.

Figure 5.1: The Greater Dhaka east is flooded
Source: Shafiq Alam, Star Weekend Magazine, 10 August, 2007.

Figure 5.2: The commercial hub of Dhaka under knee-deep water.
Source: http://www.thedailystar.net/magazine/2004/09/04/cover.htm

2004 flood

During the 2004 flood Dhaka east was inundated by spill floodwater from the Balu River. In Dhaka West, the river flood was caused due to the intrusion of floodwater from Balu River through some unblocked culverts and unclosed regulators. In July 2004 storm water flooding occurred when the regulators were closed to protect Dhaka from river flood. A second spell of storm water flooding

occurred due to high intensity rainfall in the mid-September (Annex 6). The recorded highest daily rainfall was 341mm compared to mean monthly rainfall of 264mm in September (Rahman et al. 2005). Approximately 40% area of Dhaka West was inundated.

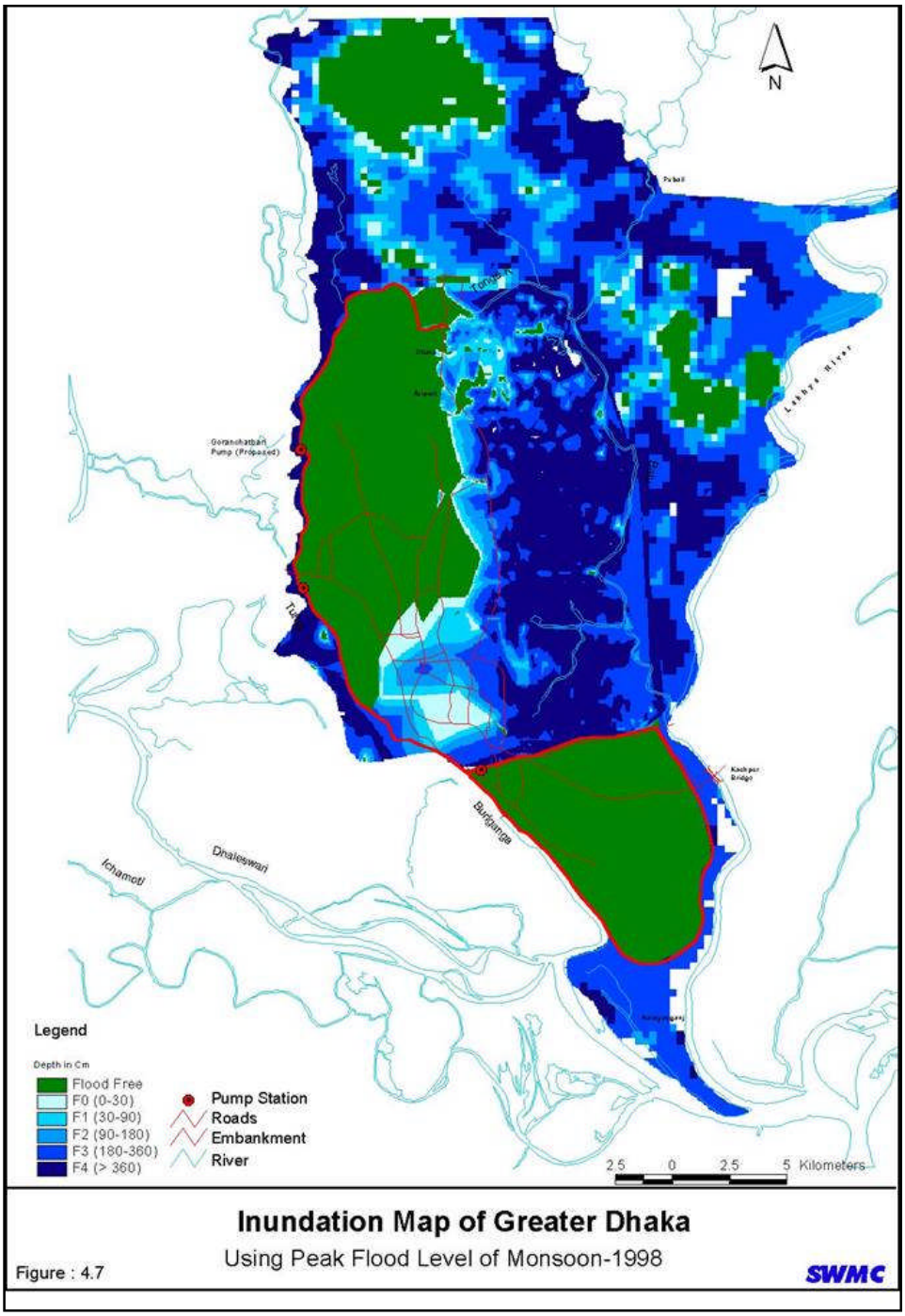


Figure 5.3: The Inundation map of Greater Dhaka: 1998 Flood
Source: SWMC (Presently IWM), 2008

5.4 Urban Flood Management: Aims and Approaches

The flood management in Dhaka aims to reduce the damages of properties, infrastructure and saving lives from river flood and also the improvement of drainage khal to reduce damage from storm water flooding. The flood management approaches that are in practice are mainly two types, structural and non-structural measures. The measures are mostly physical in nature.

5.4.1 Structural Measures

The structural measures are mainly to control the flood with the help of engineering interventions, which include construction of embankments, and flood walls (for dense area) with regulators and sluice gates on riverbanks to prevent over-bank spillage. The improvements of drainage condition are undertaken by various methods to protect storm-water flood, which include replacement of natural khal by concrete box culvert, pumping stations (permanent and temporary), and retention pond to accumulate the storm water. After the flood hazard in 1988, Dhaka west has been encircled by embankments, flood walls and raised roads to give protection against riverine flood. The protection comprises of the following components (Chowdhury et al. 1998b) (figure 5.3):

1. Approximately 30 km of earthen embankment along Tongi canal, Turag River and Buriganga River.
2. Approximately 37 km of raised road and floodwall.
3. A total number of 11 regulators at the outfall of canals to the surrounding rivers along the embankment.
4. One regulator and 12 sluice gates on the canals at the crossing with Biswa Road, DIT road, Pragati Sarani, Mymensingh road and railway line at Uttar Khan.
5. Three pump stations

The present storm water drainage network under Dhaka WASA covers an area of approximately 150 sq. km. the important components of the drainage network are:

1. 22 open canals having width of 10-30 m and total length of approximately 65km.
2. 250 km of underground pipes having diameter ranging from 450 to 3000mm.
3. 12 km of box culverts of sizes from 2.5m x 3.4m to 6m x 4.1m.
4. 3 pumping stations, of capacity of 22, 9.6, 22 cumec (cubic meter per second)
5. 151 temporary pumping stations of capacity of 25, 5 cumec.

In addition, the Dhaka City Corporation (DCC) has constructed and maintains approx. 2,460 km surface drains, which carry storm water to the main sewer lines. Rajdhani Unnayan Katripakkhya (RAJUK) also constructs roadside underground drainage lines during the construction of new roads.

5.4.2 Non-structural Measures

The non-structural measure are employed to improve the capacity to manage the consequences of floods and reduce the vulnerability of the flood affected people and their property. This includes: Flood Forecasting and Warning (FFW), Flood Plain management measures like flood proofing, flood-plain zoning.

The major activities FFW includes data management and processing, weather analysis, model operation and forecasting, flood maps generation, website update and information dissemination. The data is disseminated via Internet, email, fax, telephone, radio and television.

Flood proofing and flood plain zoning is not in practice in Dhaka. Dhaka Structure Plan (DSP) broadly demarcates the flood flow zones without detail planning proposal. The plan proposed actions for the preservation of the retention ponds around the city limits for rainwater retention and to maintain ecological balance. It also highlights the land use controls and building regulations but those have not been adopted. In terms of flood proofing Bangladesh National Building Code provides flood proofing measures to reduce physical vulnerability with reference to flood resilient housing, infrastructure, construction material etc. but unfortunately the codes are not well practiced.

5.5 Flood Mitigation Measures: Studies and Actions

Following the severe flood of 1987 and 1988, The World Bank initiated the Flood Action Plan (FAP) in 1989 to find a long-term strategic solution to deal with flooding problem. Under the FAP a number of projects were undertaken for the flood protection of Dhaka city.

The Greater Dhaka Flood Protection Project (FAP-8A) covers the highest priority areas like East Dhaka, the Dhaka-Narayanganj-Demra (DND) Project area and west Narayanganj. The DND project was developed as an irrigation project in 1968. But due to its proximity to the city of Dhaka and Narayanganj, the project area converted into residential area. Unplanned development took place and the agriculture has been largely abandoned. At present drainage and water logging has become a major problem for DND area.

The Dhaka Integrated Flood Protection Project (FAP-8B) covers about 262sq. km of the city. As part of this plan, the project was partially implemented in the Western Dhaka by construction of embankments and rising of roads to give protection from river flood. The plan has not been implemented in the remaining 124 sq. km of Eastern Dhaka to date primarily due to funding constraints.

After the second devastating flood of 1998 the government of Bangladesh gave high priority to reduce the extent of suffering and damages in the eastern part of the Dhaka city and pledged to implement an integrated project entitled ‘Dhaka Integrated Flood Control Embankment Cum Eastern Bypass Road Multipurpose Project’ to protect the Greater Dhaka East.

The table 5.1 and figure 5.4 provides the brief description of the above mentioned three flood projects.

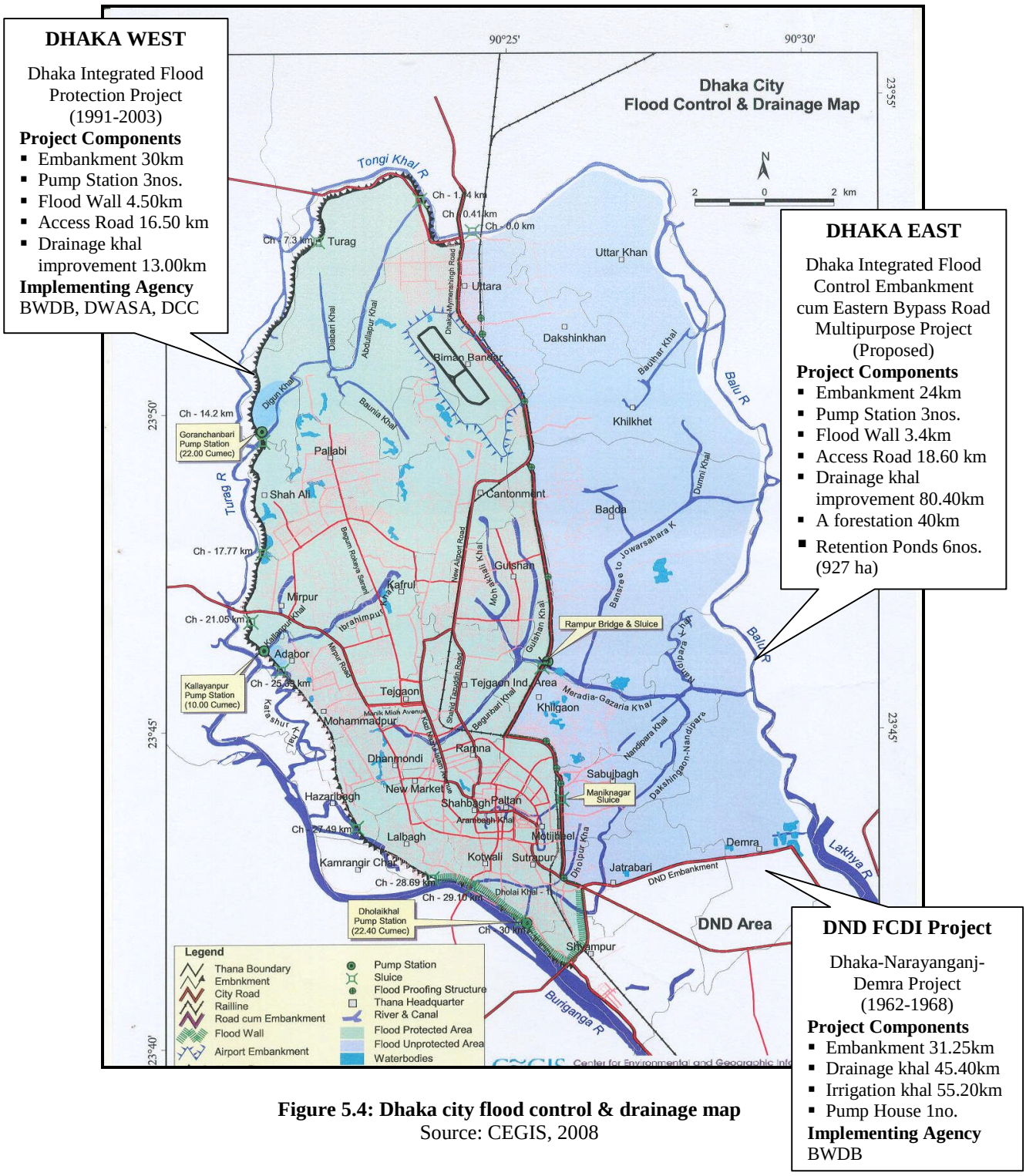


Figure 5.4: Dhaka city flood control & drainage map
Source: CEGIS, 2008

Table 5.1: The Flood Control and Drainage (FCD) and Flood Control Drainage and Irrigation projects of Dhaka

	DHAKA WEST	DHAKA EAST	DND FCDI PROJECT
	Dhaka Integrated Flood Protection Project (1991-2003)	**Dhaka Integrated Flood Control Embankment cum Eastern Bypass Road Multipurpose Project (Proposed)**	**Dhaka-Narayanganj-Demra Project (1962-1968)**
Objectives:	▪ Provide flood protection & Drainage improvement ▪ Deliver transport benefits	▪ Provide flood protection & Drainage improvement ▪ Deliver transport benefits ▪ Planned urbanization	▪ Provide flood protection ▪ Drainage improvement ▪ Irrigation
Project cost:	Tk 8369 million	▪ Tk 27504million (US$393million)	
Project Components:	▪ Embankment 30km ▪ Pump Station 3nos. ▪ Flood Wall 4.50km ▪ Access Road 16.50 km ▪ Drainage khal improvement 13.00km	▪ Flood embankment 24km ▪ Floodwall 3.4km ▪ Bypass road 18.60km ▪ Pump station 3nos. 165m^3/sec ▪ Khal improvement 80.40 km ▪ A forestation 40km ▪ Retention pond 6nos (927ha)	▪ Embankment 31.25km ▪ Drainage khal 45.40km ▪ Irrigation khal 55.20km ▪ Pump House 1no. 14.52m^3/sec
Benefits: (achieved/ expected)	▪ Flood protection improved ▪ Drainage Network Improved ▪ Employment & occupational opportunities improved ▪ Increased income level & reduced poverty level ▪ Communication network improved ▪ Environmental Management improved ▪ Benefitted population 10 million (Approx.) **Present Problem** ▪ Flooding due to congestion of storm water/waste water. ▪ Encroachment of drainage khal ▪ Pollution	▪ Flood protection and drainage improvement ▪ Urbanization would be accelerated in a planned manner ▪ Employment & occupational opportunities would be increased ▪ Increase level of income & decrease poverty level ▪ Communication network will improve ▪ Positive social and environmental impact ▪ EIRR 23.9% ▪ Benefit cost ratio 1.76 ▪ Benefitted population 23 million (approx.)	**Present Problem** ▪ Flooding due to congestion of storm water/waste water. ▪ Insufficient pump capacity ▪ Land use changed due to rapid urbanization ▪ Encroachment of drainage khal ▪ Pollution ▪ Lack of public awareness **Proposed solution** ▪ Comprehensive drainage management plan ▪ Rehabilitation of existing pump house ▪ Construction of new pump house ▪ Solid waste management & pollution control ▪ Eviction of unauthorized encroachments ▪ Benefited Population 1.2 million (approx.)

5.6 Institutional Framework for Urban Flood Management

5.6.1 Institutional Arrangements

A number of organizations from different ministry are responsible for Dhaka city flood protection and drainage management. At national level the Ministry of Water Resources (MoWR) and at local level Ministry of Local Government, Rural Development and Co-operatives is directly involved in flood management in Dhaka (Table 5.2).

Bangladesh Water Development Board

Bangladesh Water Development Board is the leading organization for water resources management and development. BWDB is responsible for flood protection and mitigation for the entire country including Dhaka. It constructs and maintains embankments and flood walls, operates regulators and pump stations. BWDB also deals with irrigation; river bank and town protection; flood forecasting and warning services; hydro-meteorological data management; land reclamation; protection against tidal surge. BWDB collects and maintains data on surface water (water level, discharge, sediment data, and water quality), groundwater (level measurement, quality), morphology (river cross section) and meteorology (rainfall, evaporation, climatologically station).

Flood Forecasting and Warning Center (FFWC)

Flood Forecasting and Warning Center (FFWC) was established in 1972. It works under Planning Wing of BWDB headed by chief engineer hydrology. FFWC has established hydrological monitoring stations on rivers across the country. The products of this centre are satellite image, Rainfall distribution map, Daily bulletin & river summary, Forecast bulletin & Hydrograph, Inundation Map, River situation map, Thana status map. The disseminate the data via internet, email, fax, telephone, radio and television to President's office, prime Minister's office, Ministry of Water Resources, Disaster Management Bureau, Public Information Department, news agencies, NGO'S & local administration. Their major limitations include insufficient Forecast Lead Time, Forecast in major rivers only, Weak dissemination up to village level, lack of Review and Response.

Water Resources Planning Organization (WARPO)

The Water Resources Planning Organization (WARPO) is an institution under the Ministry of Water Resources. WARPO is a key organization of the Government dealing with nationwide water resources planning and management and thus forming an apex body in the water sector. It is an institution for macro-level water resources planning. It provides administrative, technical and legal support to ECNWRC[3], and advises them on policy planning and regulatory matters of water resources and environment. The core tasks of WARPO includes: monitoring, implementation of the NWMP and its impacts, monitoring the application of

[3] According to National Water Policy 1999, WARPO is the secretariat to the Executive Committee of the National Water Resources Council (ECNWRC).

Guidelines of Participatory Management and update it etc. The periodic functions of WARPO include periodic update of NWMP, ad hoc advice on policy, strategy, institutional and legal issues assist other agencies in planning, monitoring, studies and investigations etc.

Table 5.2: The Institutional Framework for Flood Management in Dhaka

	Ministry	Organizations
Directly Involved Organizations	Ministry of Water Resources (MoWR)	▪ Bangladesh Water Development Board (BWDB) ▪ Water Resources Planning Organization (WARPO) ▪ Flood Forecasting and Warning Center (FFWC)
	Ministry of Local Government, Rural Development and Co-operatives	▪ Dhaka Water and Sewerage Authority (DWASA) ▪ Dhaka City Corporation (DCC)
Indirectly Involved Organizations	Ministry of Housing and Public Works	▪ Dhaka Capital Development Authority (RAJUK) ▪ Public Works Department (PWD)
	Ministry of Defence	▪ Bangladesh Space Research and Remote Sensing Organization (SPARRSO) ▪ Bangladesh Meteorological Department
	Ministry of Land	
	Ministry of Communications	▪ Roads and Highways Department (RHD)
Private Organizations	Center for Environmental and Geographic Information Services (CEGIS) An independent public trust running under the Ministry of Water Resources chaired by the Secretary of the MoWR.	
	Institute of Water Modelling (IWM) ▪ A centre of excellence and research in the field of Water Modelling, Computational Hydraulics and allied Sciences ▪ Also supports FFWC.	

Source: Author, 2008

There is a steering committee to ensure better services. These committees are formed of executives of different organizations and stakeholders. These committees take decision and monitor implementation. They establish coordination among the responsible organizations by arranging discussion.

Besides these committees there are Inter-ministerial Committee to take decision on urgent matters.

Dhaka Water Supply and Sewerage Authority (DWASA)

Dhaka Water Supply and Sewerage Authority (DWASA) manage the Water Supply and Sewerage network of Dhaka. DWASA was established in 1963. According to the Water Supply and Sewerage Authority Act 1996, the main functions of DWASA are: construct, improve and maintain water works for collecting, purifying, pumping, storing & distributing potable water, construct, improve and maintain sewerage works for collecting, pumping, treating and disposing of sanitary sewage and industrial wastes, construct and maintain drainage works for drainage facilities including storm water drainage and levy water, sewer and storm water rates. The drainage circle of DWASA is the key role

player in keeping the city free from drainage congestion. They are responsible for drainage and operation of the pumping stations. They also construct, maintain drainage infrastructures like deep drains, box culverts.

Dhaka City Corporation (DCC)

In 1990 Dhaka Municipal Corporation was renamed to Dhaka City Corporation (DCC). Prior to this, in 1978 Dhaka Municipality was awarded the status of Corporation. DCC is the key organization responsible for keeping the environment of Dhaka city healthy and comfortable. Elected Mayor and 90 City Councillors administer DCC. The administrative set-up is decentralized into ten (10) zonal offices. There are 16 departments headed by Chief Executive Officer (CEO). The other functions of DCC performs wide range of functions like public heath, public safety, urban planning, social welfare, education, public spaces (parks, gardens, forests, trees), water supply and drainage, street lighting, culture, development etc. According to its jurisdiction, DCC is also responsible for removal, collection and disposal of solid wastes, provide public drains, control, regulate and inspect surface drains and construction and maintains roads.

Dhaka Capital Development Authority (RAJUK)

Dhaka Capital Development Authority (RAJUK) is indirectly involved in flood management. RAJUK is an important agency under Ministry of Housing and Public Works who is primarily responsible for the planning and development of the Greater Dhaka and surrounding areas, a total of 1528 sq. km. In the year 1987 RAJUK was established by replacing Dhaka Improvement Trust (DIT). RAJUK control all the development activities of Dhaka City under the provisions of Town Improvement Acts, Building Construction Rules and Land Use Regulations within the area under its jurisdiction (http://www.rajukdhaka.gov.bd). RAJUK is the principal actor to guide and control urban expansion through the Detail Area plan. In RAJUK is also obliged to preserve the natural depressions and water bodies in urban areas.

5.6.2 Policies, Acts and Regulations

5.6.2.1 Water Sector Policies and Plans

In Bangladesh the major water issues are cross-sectoral, affecting almost all development sectors (Khorshed 2003). The ministry of Water Resources and Ministry of Local Government, Rural Development and Co-operatives have framed some policies and plan which act as guidelines to different organizations working in the field of water resources under the administration of relevant ministries. The table 5.3 presents the lists of water and flood related policies and plans. Both in National Water policy (NWPo) and National Water Management Plan (NWMP), the flood control and management issues are emphasized. The flood control issues, particularly urban flood, are discussed with reference to NWPo and NWMP.

Table 5.3:Water and Flood Related Policies and Plans

Ministry	Policies & Plan	Year
Ministry of Water Resources	Master Plan	1964
	National Water Plan	1986
	National Water Policy	1999
	National Water Management Plan	2001
	Integrated Coastal Zone Management	2005
Ministry of Local Government, Rural Development and Co-operatives	National Policy for Safe Drinking Water Supply and Sanitation	1998
	National Arsenic Mitigation Policy	2004
	Drainage Master Plan	2006

Source: Haque, 2008

National Water Policy

The Ministry of Water Resources published the National Water Policy to ensure optimal development and management of water. It is a guideline for all concerned ministries, agencies, departments, and local bodies that are responsible for the development, maintenance and delivery of water and water related services as well as the private users and developers of water resources. The key focus areas of the policy are follows:

- River Basin Management
- Planning and Management of Water Resources
- Water Rights and Allocation
- Public and Private involvement
- Public Water Investment
- Water Supply and Sanitation
- Water and Agriculture
- Water and Industry
- Water and Fisheries and Wildlife
- Water for Preservation of Haors, Baors and Beels
- Water for Hydropower and Recreation
- Water for the Environment
- Water and Navigation
- Economic and Financial Management
- Research and Information Management
- Stakeholder Participation

The policy aims to ensure progress towards fulfilling national goals of economic development, poverty alleviation, food security, public health and safety, decent standard of living for the people and protection of the natural environment. The policy addresses the issues with regards to flood management; some important issues include:

- Regions of economic importance, such as metropolitan areas, sea and airports, and export processing zones will be fully protected against floods as a matter of first priority.
- In future all national and regional highways, railway tracks and public buildings and facilities will be constructed above the highest ever-recorded flood level in the country.

- All plans for roads and railways embankment will adequately provide for unimpeded drainage.

National Water Management Plan

The National Water Management Plan is prepared to operationalize the directives given by the National Water Policy. The Water Resources Planning Organization (WARPO) prepared the plan in 2001 and was adopted by the Government is March 2004. The NWMP is a framework, spanning 25 years through which various organizations related to water will be implementing various programmes and projects in a coordinated manner. The plan has three phases: in the short term (2000-05), it considered a firm plan of ongoing and new activities: in the medium-term (2006-10) it is an indicative plan, and in the long term (2011-25) a perspective plan. The key objectives of NWMP are:

- Rational Management and wise-use of Bangladesh's water resources.
- People's quality of life improved by the equitable, safe and reliable access to water for production, health and hygiene.
- Clean water in sufficient and timely quantities for multipurpose use and preservation of the aquatic and water dependent eco-systems.

The Water Resources Planning Organization (WARPO) is responsible to monitor progress and impacts and draw to council's attention issues that require their further considerations. At national level the key issues of NWMP are:

- River Bank Erosion
- River Siltation
- Water Quality (Surface and Ground)
- Post monsoon drainage
- Shortage of water for Irrigation
- Encroachment of river, canal, beel, pond.

The plan comprises of 84 programmes, which are grouped into 8 sub-sectoral clusters, spatially distributed across 8 planning regions of the country. Dhaka is North Central region of Bangladesh. The north central regional key issues are:

- Bulk water supplies and pollution clean-up for Dhaka city
- Encroachment on Buriganga and other rivers
- Flood proofing in charlands and low-lying areas
- Flooding and drainage problem
- Environmental management of the Haor Basin
- Flash flooding and remedial actions for existing FCD schemes.
- Flood proofing of villages in the Haor Basin
- Erosion of old Brahmaputra left Bank

5.6.2.2 Water Sector Legislations

There are several acts and rules are in place in Bangladesh related to water sector. Some water sector legislations are dating back over a century. The table 5.4 provides the water sector legislations are in place in Bangladesh.

Table 5.4:Water Sector Legislations

Ministry	Legislations	Year
Ministry of Water Resources	The Canals Act	1864
	The Irrigation Act	1876
	The Embankment & Drainage Act	1952
	The Irrigation Water Rate Ordinance	1963
	The River Research Institute Act	1990
	The Bangladesh Irrigation Water Rate Act	1992
	The Irrigation Water Rate Rules	1992
	The Water Resources Planning Act	1992
	Bangladesh Water Development Board Act	2000
	The Irrigation Service Charges Rules	2003
Ministry of Local Government, Rural Development and Co-operatives	Water Supply & Sewerage Authority Act	1996
	The City Public Lands Protection Act	2000

Source: Haque, 2008

When a policy is enacted as a law in the legislative assembly of the country it becomes obligatory for the citizens within the notified jurisdiction (Haque, 2008). The laws are predominantly oriented towards the development of agriculture. The new policy encourages a revised system of water allocation giving greater priority to non-agricultural uses and securing both individual and community rights, whilst still ensuring that self-sufficiency in food is maintained (WARPO 2000). An appropriate legislative framework is fundamental for effective implementation of NWPo. The NWPo requires a National Water Code to be enacted to revise and consolidate the laws governing ownership, development, appropriation, utilization, conservation, and protection of water resources. The purpose of the National Water Code is to establish the Government's obligation to manage and administer the country's water resources. It is mentioned in NWMP where the legislations need to be reviewed and it make recommendations for change, or new legislation, where considered necessary. The summary of the National water Code is provided at the annex 9.

5.7 Summary

Flood prevention has been a high priority in Dhaka because of its pronounced vulnerability to floods during the monsoon season. A number of plans have been prepared. But the present UFM planning has not evolved with the pace of urban growth. The current institutional framework with legal loopholes is unable to coordinate with relevant organizations and lacks in adequate supporting mechanisms to implement plans taking into account the extent of urbanization. Proper planning and implementation of flood protection measures can largely reduce the vulnerability to urban floods in Dhaka.

Chapter 6 Analytical Perspectives of Urban Flood Management in Dhaka

6.1 Introduction

This chapter focuses on the analysis of the results of the sub questions obtained from the empirical study. The Sub questions no 4 and 5, namely '*What is the approach to manage Urban Floods in Dhaka in the context of IFM within the framework of Interactive WRM?', and 'What are the potentials and limits of present Urban Flood Management in Dhaka?'* are discussed collectively, as they encompass a range of related issues.

The analytical framework comprises of two parts: analysis of Dhaka Urban Flood Management framework and SWOT analysis.

6.2 Analysis of Dhaka Urban Flood Management framework

Dhaka UFM framework is analysed with respect to the elements of Urban Flood Risk Management within the framework of Interactive Water Resources Management. The analysis is based on the interviews conducted and a study of existing literature.

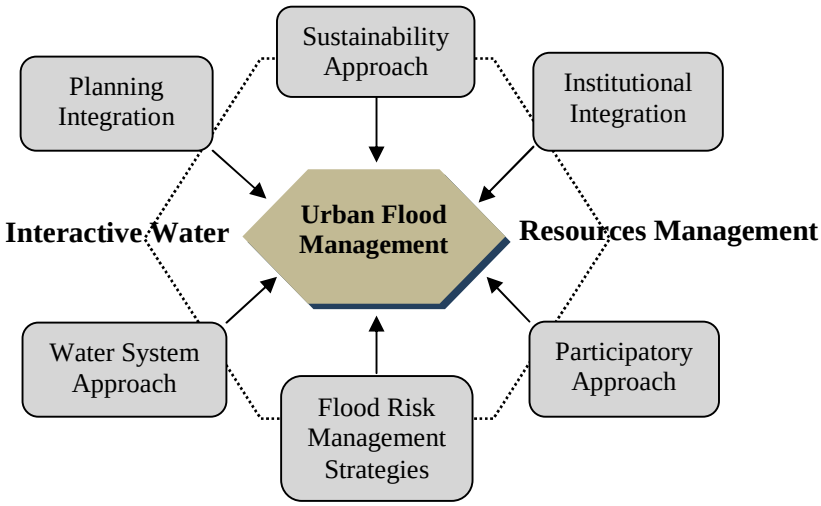


Figure 6.1: The Analytical Framework of Dhaka Urban Flood Management

6.2.1 Planning Integration

Water Resource Management is best conceptualized as a "Land-resource-management" interaction system (Hooper 2003). Any change in water regime creates land use opportunities. While in turn, the changes in land use also have impact on water regime and result in different demands.

Following the flood of 1987 and 1988 in Bangladesh, according to the Flood Mitigation and Drainage Master Plan, the greater Dhaka West was protected by

embankments from river flood and storm water flooding pumping stations with retention ponds. Since then Dhaka East remained unprotected to date primarily due to funding constrains. The preparation of the plan was meant to be bringing long term solutions for the flooding problem. From the research it is came into light that the implementation of the master plan is largely depend on donor funding. The existing capabilities are not taken into consideration during the preparation of the plan. Therefore it can be said that the future implementation of the plan in Dhaka East will be further delayed, as the funds are not yet available. In this regard a researcher said,

> *"The full implementation of the plan was hindered due to the absence of fund. The plan was not realistic in terms of implementation. Implementation of any plan should be based on existing capabilities and source of fund. The plan itself is a question, which requires a critical review. Moreover, there are number of deviations from the original plan." (Personal conversation with a researcher, July 12, 2008)*

Moreover, the embankment of Dhaka West triggered the land use opportunities of the western part (figure 6.2). The proper risk and damage assessment and socio-political considerations in local context are also absent in the master plan (Khan, 2006). The false sense of security from flood has led to a high degree of unplanned urbanization (figure 6.3), which has altered landscape of western Dhaka.

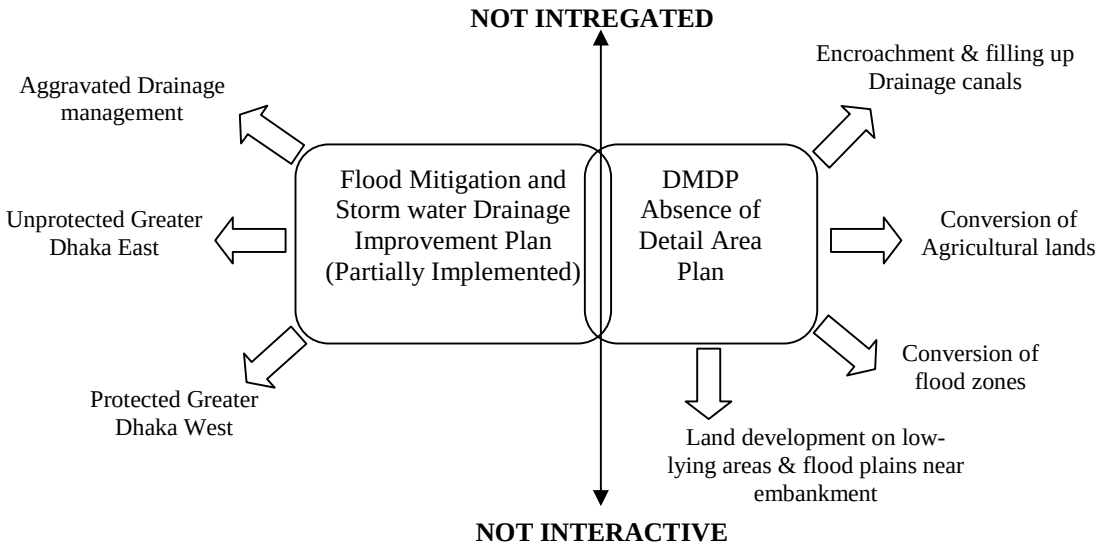


Figure 6.2: The non-interactive, non-integrated relationship between drainage plan and DAP and their consequences

The Dhaka Metropolitan Development Plan (DMDP) (1995-2015) was a comprehensive urban planning process at three levels: sub-regional (Dhaka Structure Plan), urban (urban Area Plan) and sub-urban (Detailed Area Plan). Dhaka Structure Plan has provided zoning for various activities in urban areas. The Detail Area Plan, which is the lowest tier of DMDP, is suppose to provide detail planning of each plot. As evident from the research that the preparation of DAP is delayed over 10 years by RAJUK because of institutional failures and meagre planning capacity. As a result the urbanization in Dhaka, took place with the absence of DAP (figure 6.4). In the absence of DAP, the land use management

functions are supposed to be governed by the DSP and UAP. An interview with an urban planner states that,

> *"These plans only demarcate the broad areas for future development but without clear delineation. These loopholes in development plan have allowed the illegal encroachment of rivers, canals, lakes, land development in low-lying areas, flood flow zones and aggravated the storm water flooding." (Personal conversation with an urban planner, 16 July 2008)*

Although the NWPo recommended formulating rules, procedures and guidelines for combining water use and land use planning, until now no such step has been taken. In Dhaka, the urbanization process and flood prevention strategies are closely interlinked (Oosterberg et al. 2005). This requires integrated approach towards land use and flood management aiming at efficient use of floodplains and reduction of physical vulnerability and loss of human lives.

Figure 6.3: The encroachment of the Gulshan Lake and unplanned urbanization

Source: http://flickr.com/photos/tanbir/332007922/

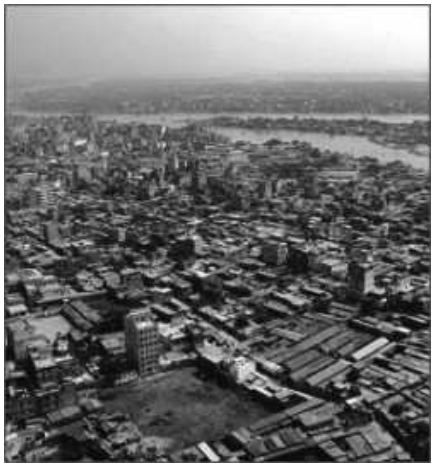


Figure 6.4: The absence of DAP turned Dhaka into a concrete jungle

Source: Syed Zakir Hossain, The Daily Star, 8 June, 2008

6.2.2 Sustainability Approach

Water resources developments, land use, infrastructure development, ecosystem all are interdependent and part of socioeconomic development. But unfortunately, not only in Dhaka but also in whole Bangladesh, all the flood control projects are executed with the aim of short-term economic development. The economic, social, ecological and environmental conservancy measures are neglected from the long term perspective. Presently, the valuable natural resources of Dhaka such as water resources, land, and habitat are seriously threatened due to absences of long-term planning for flood management. Based on the gathered information, the consequences of shortcomings of the short-term planning are discussed below.

The implementation of DIFPP in the Greater Dhaka West has also added value to the drainage problem. Additionally, as part of drainage master plan, the natural canals like Dhanmodi canals, Dholai Khal, Paribagh Khal, Mahakhali Khal, Begunbari khal, Segunbagicha khal, are converted into box culvert (Annex 7) (figure 6.5) without considering its negative environmental impact. This has

altered the natural drainage system. With reference to this, a recent report appeared in the national daily newspaper entitled *The Daily Star*, in Bangladesh is presented below.

> *"In the last 17 years, the DWASA authorities spent more than Tk 300 crore in the name of development of canals and the drainage system of the city. Under two development projects the authorities turned several natural canals into box culverts to 'develop' the city's storm sewerage system. Currently the WASA authorities are implementing a project titled The Project for Ending Water logging in the Capital. But the idea of making box culverts proved to be wrong as the city continued to be inundated every year during monsoons even after conversion of open natural canals into box culverts. "Natural open canals are better than box culverts, maintenance of those is easier. On the outskirts of the city we keep the canals open but in the city it is not possible for us to protect open canals from encroachers," said Md Zahurul Alam, superintendent engineer of DWASA and project director of The Project for Ending Water logging in the Capital."*
> (Roy 2007).

Figure 6.5: The Gopibagh Canal turned into road
Source: The Daily Star, 24 August 2008

Figure 6.6: The Mohammadpur Canal filled with garbage
Source: Haque, 2008

The water demand and waste production has increased in the urban and peri-urban areas. The urban population is subjected to water shortage. 95% water supply of Dhaka comes from underground and its average annual decline within the city area during 1995 to 1999 varied from 1.02m to 2.46 m (Islam 2008).

After reviewing the report, '*Impact of 1998 flood on Dhaka city and Performance of Flood Control Works'*, it became clear that the urbanization has resulted in substantial increase in impervious surface and reduces infiltration which in turn causing high surface runoff (table 6.1). High storm-runoff coupled with inappropriate drainage infrastructures; Dhaka city is facing rising storm water flood hazards.

Table 6.1: Imperviousness of land surface and runoff ratios for some areas in Dhaka city

Location	Land use	Sewer type	Impervious area (%)	Runoff ratio
New Elephant Road & adjoining area	Commercial cum residential	Under ground sewer	85	.04-0.8
Dhanmondi & Shatmosjid Road	High class residential	Under ground sewer	65	0.4-0.7
Zigatala	Unplanned high density residential	Under ground sewer	90	0.3-0.6
Azimpur	Planned and unplanned residential	Surface drain	80	0.2-0.5
BUET	University campus	Surface and subsurface	55	0.1-0.3

Source: (Chowdhury et al. 1998a, Chowdhury et al. 1998b)

The water quality of the peripheral rivers is also deteriorated due to disposal of domestic wastes and industrial affluent. From a study by Khan and Chowdhury 1998, has showed that the sediment samples collected from storm sewers show presence of polythene bag, plastic, cloth, rubber, metal strips, glass, paper, sticks, leaves, bones and brick and stone chips (figure 6.6) (Chowdhury et al. 1998b). In addition, the lack of maintenance of the drainage infrastructure also deteriorated the situation.

The agricultural value of the land is destroyed with the land use change. These lands are used for cultivation in the dry season and in the wet season these lands become fishing grounds for the fisherman. The loss of natural canals has significantly affected the local ecology and biodiversity. The vast flood plain areas at the periphery of Dhaka city play a significant role as a recreational site. But it is evident from the research that these sites are ill maintained, illegally encroached by land grabbers and slums, and turned into dumping site for liquid waste (Islam 2008).

With the construction of embankment the surrounding rivers: The Buriganga, The Turag, The Tongi khal, have lost connectivity with the flood plain and exchange of nutrients and carbon with flood plain. Before the construction of the embankment the contaminants of the Hazaribag Tannery Complex and other industry wastes were washed into the Buriganaga River (figure 6.7) by annual flooding (www.sos-arsenic.net). The natural way of pollution assimilation capacity of the river is hindered with the embankment. The impact is severe water and air pollution.

Figure 6.7: Pollution and encroachment is choking the Buriganga River

Source: http://www.sos-arsenic.net/english/environment/index.html

The aim of short-term objectives has positive impacts on certain sectors for certain period such as; the western embankment is protecting Dhaka from river flood and saving human lives, reducing economic, social damages from flood. But as discussed above, these short-term economic gains jeopardized by catastrophic environmental, social, biodiversity malfunctions in one hand and on the other hand imposing high investment to upgrade the deteriorated infrastructures, environment to achieve sustainability.

6.2.3 Institutional Integration

6.2.3.1 Weak Institutional Arrangement: Its Shortcomings and Gaps

A Good institutional framework stands out as a prime factor for proper urban flood management. This includes proper institutional arrangement, organizational structures and strong legislative framework.

From the research it is evident that there are six different ministries and a total of 10 different organizations are directly and indirectly involved in river flood and storm water flooding management of Dhaka. It is evident in the research that there is hardly any cooperation/coordination exists among these ministries. According to an interviewee from DWASA

> *'The power exercise of these ministries and their organizations are different from each other which results in poor inter-agency coordination.'* (Author, 30 July, 2008)

The rigid institutional framework has hindered the effort for coordination as well as information sharing which often leads to undesirable conflicts among the organizations. The following newspaper article published in the national daily newspaper entitled *The Prothom-alo*, regarding the preparation for the 'Urban Flood 2008' shows more light on the fact:

> *DCC claimed that the DWASA has broken the DCC drainage channels while maintaining the storm sewer lines. The channels have been filled up with mud. On the contrary, DWASA is claiming that DCC has unauthorized connection with storm sewer line. This creates the blockage in the storm sewer line and storm water cannot drain out through these. The DCC has approx. 2500km surface drains around the city, which are not being maintained for long time. This is causing blockage in the storm sewer and therefore water logging in the city. The coordination meeting is taking place regularly but implementation is not happening.* (Datta 2008)

The implementation of any development plan requires coordination among relevant agencies. RAJUK, BWDB, DWASA, DCC all the concerned organization should work together to implement the plans. The present haphazard urban development advocates their lack of coordination in management and cooperation in implementation. The implementation of plans also depends on the ability to enforce plans in terms of financial and institutional capacity. In general, all these organizations suffer from inadequate manpower, funding and logistics. The existing strength of these organizations is inadequate to cope with the present urban growth.

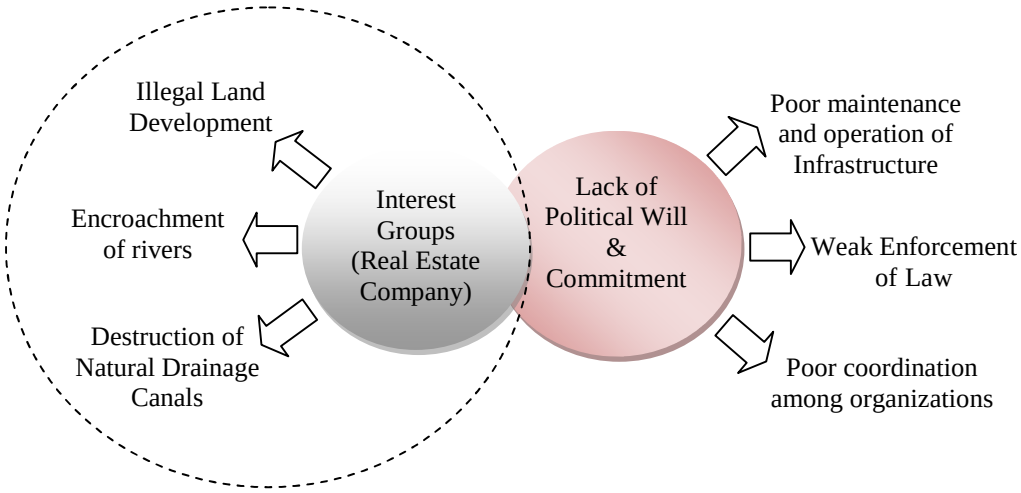


Figure 6.8: The consequences of politics on UFM in Dhaka

A large part of physical, functional and managerial gaps in urban flood management are also because of weak political system and administrative bureaucracy. No formal mechanism (figure 6.8) is evident in urban development and flood management of Dhaka. In general, the performance of government and the elected representatives is perceived as unsatisfactory due to lack of political will and commitment. The effective implementation of plans and policies, enforcement of existing law, efficient management of the overall flood management is largely depends on the political system.

RAJUK, the most important agency in planning and development of the Greater Dhaka, poses meagre manpower. Moreover high rates of corruption are evident. Due to the influence of interest groups, the organization is basically serving the upper-income group. With its weak planning capacity, RAJUK has failed to control the land development.

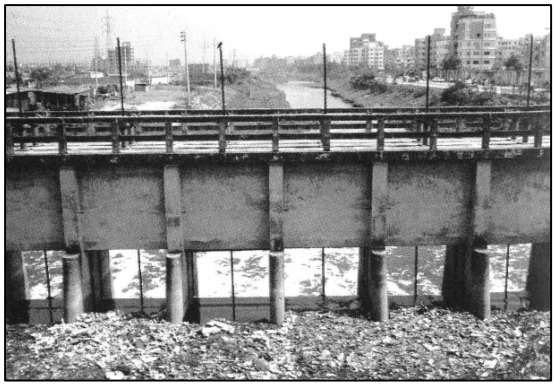


Figure 6.9: Polluted discharge through the Rampura Reguator
Source: Haque, 2008

Figure 6.10: The clogged surface drain

Source: Author, 2008

The development and provision of drainage system in Dhaka is inadequate. Due to lack of coordination between DCC and DWASA, the drainage system is ill maintained. 50% of city's domestic and municipal waste is collected by the DCC. Lack of innovative ideas, modern equipments and manpower, the conservancy department of DCC failed to manage Dhaka's solid waste. The DWASA also has not succeeded in performing its basic functions of providing sewerage and storm drainage system. Lack of systematic management efficiencies, weak planning and implementation procedure contributed to DWASA's failure to provide growing demands of sewerage networks. Lack of financial and organizational strength, BWDB also failed to operate and maintain the flood infrastructures properly. There is no such apex body to monitor all activities related to planning, implementation of actions including the compliance with guidelines and legislation, and management at national level except some coordination committee that also failed in their role. In this regard, Ishrat Islam, an associate professor of the department of Urban and Regional Planning of Buet, during a discussion on conservation of wetlands at the city's Brac Centre Inn, stated that:

> *"An authority with executive power is crucial to conserve the city's flood plains, lakes, canals and wetlands as per the DMDP,"* (The Daily Star, 18 February, 2007)

Being a developing country, fund constraints are a common phenomenon for Bangladesh. The implementation of any development plan largely depends on the donor funding. As mentioned before, due to the funding constraints Dhaka East embankment could not be implemented. Any development plan should state clear, overall workable targets and measures (APFM 2008). The dearth of the water and flood institutions of Dhaka is inadequate funding. In general, the maintenance division of any development works occupies a small percentage of National Budget. The following statements delivered by water managers during a press meeting on 'Flood 2008 and its Probability' explain the above mentioned fact:

> *"For MoWR, the development work budget is approximately 3% of the National Budget. And the budget for maintenance division of BWDB is only Tk 200 crore/yr, whereas for RHD the maintenance budget is 800crore/yr and that of LGED is 300crore/yr, which is not compatible. If the flood prevention measures could have gained more preferences, the road maintenance cost would be relatively less. But we do the opposite. We always look for short-term solutions. Long term visioning requires institutional strengthening and substantial financial strength."* (Press meeting attended by author, 23 July 2008)

> *In our economic system financial allocation for maintenance purpose does not exist. The Ministry of Finance and Planning Commission make financial arrangement only for implementation of the project work. But subsequent maintenance cost is not allocated for those projects.* (Press meeting attended by author, 23 July 2008)

The proper maintenance and operation of the flood control structures are hindered due to shortage of fund. For instance, the drainage capacities of Dhaka city is inadequate and are also need to be replaced. However, with the existing financial strength DWASA is simply unable to carry out these improvements (Datta 2008).

6.2.3.2 The Legal and Regulatory Framework

Legislation provides the basis for action by government or non-government entities and individuals (Faruqee & Choudhury 1996). The natural resources are owned by the state. Although there are number of laws are in place, the management practice does not reflects its proper application in right place. In general the legal framework for water and flood management sector is very weak.

It is evident from research that there is no law (chapter 5: table 5.4) within the existing legal framework for effective implementation of NWPo and NWMP. A policy cannot be implemented unless it is enacted as a law by the legislative assembly the country (Haque, 2008). There is some legislation related to urban flood management such as The Embankment & Drainage Act 1952, The Canal Act 1864, which are several years old. These acts hardly play any role in flood management.

Needless to say, the rapid urbanization and illegal encroachments have already altered the city planning. The dearth of necessary laws and planning has resulted in unplanned Dhaka city. The RAJUK is empowered to prepare master plan and regulate land use in the Metropolitan Dhaka city. But the findings of research have shown that the encircling rivers, natural canals, lakes being encroached and filled up with prior concern of RAJUK. The encroachers are not only politically and socially influential people; it also includes government organization like

Bangladesh Telecommunication Company Limited (BTCL) that has encroached the Buriganga River (figure 6.11). The following examples published in daily newspaper entitled The Prothom-alo are presented below.

The BTCL is constructing its office building on the encroached land from the River Buringanga. The states own the land. 30% of the river is filled up. According to the local people of Kamranggirchar elected politicians, city councilor are involved in this land development (Sarker, 2008).

Figure 6.11: The construction work of BTCL building in the Buriganga River
Photographer: Monirul Alam

Figure 6.12: A six-storied building on Kallayanpur canal
Photographer: Monirul Alam

The Shapla Housing Residential Area has encroached the both banks of Kallanyanpur Canal and constructed multi-storeyed buildings. Due to encroachment the DWASA could not implement the proposed 40foot wide box culvert in this canal (Datta, 2008).

Figure 6.13: Filling up the Rupnagar canal at Pallabi
Photo: Syed Zakir Hossain

According to the master plan of 1984, the western parts of the Rupnagar residential area allotted for the main drainage canal. This natural canal carries sewages and storm water of surrounding areas and discharges them into the river Turag. It also helps in groundwater recharge for the area. The canal has virtually turned into a sewerage line at several places (Sabuktagin, 2008).

To stop the unplanned urbanization, the Government of Bangladesh has formulated "The Private Housing Land Development Rules" in the year 2004. These rules are applicable only within RAJUK areas, which are of 1,528 square km. There are about 250 Real Estate Companies, which are active in and around

Dhaka city in housing development. According to this rule the housing companies across the country would have to get approval from the concerned authorities to develop and advertise their projects. It is needless to mention that this is a significant step of GoB towards regulating the activities of private housing development companies. But the implementation of this rule is much more important for future of Dhaka. In a discussion, director of BELA, Syeda Rizwana Hasan stated that,

> *"After the formulation of this rule RAJUK has used the rules as means to collect toll from the housing companies."*

According to the Wetland Protection Act 2000, development is prohibited on natural canals, lakes, water bodies, canals, lakes and flood plain zones and sub-flood plain zones. But the real scenario is opposite. Despite the act the city canals are depleting fast due to illegal land development by private housing companies (Figure 6.12) (figure 6.13). The practice of law and its enforcement is not systematic. Corruption, legal loopholes are also worsening the situation. While some initiatives such as eviction of the illegal constructions and reclamation of the dead canals etc, have taken by the government is welcoming and may improve the storm water flooding of Dhaka.

6.2.4 Participatory Approach

Rigid, inefficient bureaucratic practice, procedure orientation and lack of public participations all these events resist the formation of alternatives to manage floods in Dhaka city and its consequences by the decision-makers. A guideline for Participatory Water Resource Management is prepared by WARPO. But it is not in practice. There is limited and in most cases no participation is evident in planning, policy and decision making phases.

The flood management of Dhaka is driven by top-down decision-making. The flood control measures are planned without the participation of the affected people and other stakeholders. The conventional public participation can be perceived as consultation to improve the project details that the authority has designed them. The existing informal practice of participatory planning process is not based on principles of participation. Due to lack of participation, the development plans fail to address the people need and integrate their demand in the plan. The absence of public involvement in operation and maintenance of control measures and lack of awareness about their role often pose problem in proper management of the flood. It is noticed that people often attempt to open sluice gates, or force pump operators to run the pumps even though pumping is not required (Khan 2006). It is needs to be mentioned that, according to some interviewees, *the inhabitants are not willing to participate in city development.* If this is the case then the government should take some initiatives to motivate people to increase their involvement in decision-making process. Participation of stakeholders other than government is not evident in decision-making process.

In general it can be said that public participation and stakeholders participation in the decision-making of flood management is limited only to discussions with civil

society. Although few discussions take place among different stakeholders but their views are often not considered in planning.

Figure 6.14: The land filling in low-lying areas neat the western embankment.
Source: Author, 2008

Figure 6.15: illegal structures on the western embankment

6.2.5 Flood Risk Management Strategies

An integrated approach to flood management means the best mix of structural and non-structural measures. These measures are mostly physical in nature. Though urban flood in Dhaka is managed by both the measures, integration between them is not noticeable. Flood control measures are emphasized than the non-structural measure.

Figure 6.16: The temporary pump station at Rampura with 20 sluice gates

Source: Author, 2008

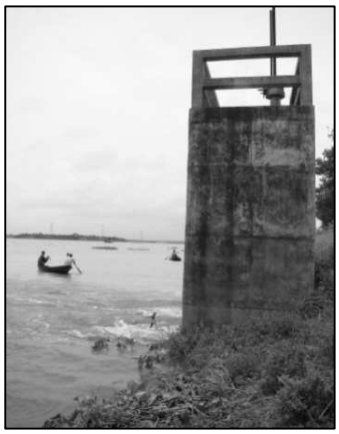


Figure 6.17: The Sluice gate near Goran Chatbari pump station

Dhaka is protected from river flood by earthen embankment and floodwall. According to the experts, the construction quality of the embankment is not standard. Moreover the embankment is subjected to frequent breaching. From field observation it is noted that embankment itself is also not beyond encroachments (figure 6.15). Illegal settlements, temporary small sheds, loading & unloading of goods are happening without the concern of embankment. BWDB, who is responsible for the maintenance of the embankment, is reluctant in these unauthorized constructions. The embankment top is used as road. The future plan of government is to covert it into 80 feet wide raised road. However, according to the water experts and engineers the embankment was not built with proper

engineering strength. Then the question arises, what is the future of this flood protection embankment? Further, it is noticed from the field observation that manually operated regulators (figure 6.17) are still in use. These regulators were designed in 1968. There is no such measure undertaken till date to improve the technology of these regulators in last 40 years.

To mitigate the internal flooding electric pumps are used. There are three permanent pump stations in Dhaka West at Goran Chatbari, Kalyanpur and Dholai Khal. The combined pumping capacity of these pumps is $54m^3/sec^{-1}$ compared to estimate peak storm runoff of $140m^3/sec^{-1}$. The required capacity is $180m^3/sec^{-1}$. So the pumping capacity is not compatible for the extreme situation. There are several temporary pump stations (Figure 6.16) in Dhaka at different location having a total capacity of $70m^3/sec^{-1}$, which is also inadequate. Retarding pond is also being encroached by the private housing developers. In Dhaka, the storm sewer network of DWASA has 225 km of underground pipes and 8 km of box culvert (Khan, 2006). The conveyance capacities of these storm sewers are very low because of accumulation of solids from the sanitary sewerage. The large portion of these solids includes construction debris, solid waste dumped in the catchment areas (Chowdhury et al. 1998b). The storm sewer water also contains pollutants. The indiscriminate dumping of solid wastes into the surface drains, overflow due to blockage, sanitary sewer breakdown, unauthorized connection of storm sewer and sanitary sewer are largely accounts for the storm water quality degradation as well as water logging problem in the Greater Dhaka. The lack of regular maintenance of the surface drainage lines (approx. 2000 km.) of DCC also adds to the problem (Figure 6.18). Even though approximately taka 40 crore investment was made in the last six years to improve the storm and sanitary sewerage system, the situation remains the same (Datta 2008).

Non- Structural Measures

The Flood Forecasting and Warning is the one of important non-structural measures that has been in practice since 1972. The Flood Forecasting and Warning Center under BWDB is forecasting 72 hrs forecast of flood situation. According to the experts the 24 hours forecasting is more reliable compared to 72 hours forecast. The information dissemination medium is English, which is not understandable to general people. Adding to that the use hydrologic terminology in the forecast often arise confusion among the people, media and other organizations due to wrong interpretation of the information.

Among other non-structural measures Flood Proofing, Flood Zoning and Flood Insurance are important. But Flood Insurance is not yet in practice. Bangladesh National Building Code 1993 provides regulations with reference to building elevation and flood resilient construction in flood prone areas. However, the practice and enforcement of these codes are absent. Flood zoning is important to reduce to exposure. In DMDP the flood-plain zones and sub-flood plain zones are embarked. But the juridical delineation of these zones has not been ensured and therefore unplanned development in these zones is going on (figure 6.14). The absence of Detail Area Plan forms a major bottleneck in reducing exposure.

Figure 6.18: The inefficient drainage management

Source: Author, 2008

Figure 6.19: The Pollution of The Buriganga River

Source: The Daily Star, 2008

6.2.6 Water System Approach

River basin management approach is not yet in practice at full length. Basin management is hard to apply in Bangladesh. The rivers are transboundary. It needs regional cooperation with India. Though some action has been taken place like Ganges treaty at Farakka. This treaty has been signed by India and Bangladesh in 1996 for sharing dry flow of the Ganges at Farakka. A recent concern is the River Link Project of India that transfers of water from basins of the Brahmaputra and the Ganges to Haryana, Rajasthan and Gujrat in the west and peninsular region in the south (Chowdhury 2008).

In terms of Water Cycle Management (WCM), the urban water management components in Dhaka are not interlinked. There is no long-term resource utilization scheme has developed in the system to make the best possible use of the floodwater. Often there is mismanagement observed in planning, implementation and maintenance of the entire water management system. The TWCM requires integrated framework, participation from of the potential users, stakeholders both public and private organizations, industries.

6.3 SWOT Analysis

The development of flood management requires an assessment of the existing urban flood management of Dhaka. As a result the SWOT analysis is carried out in the context of Urban Flood Risk Management, within the framework of Interactive WRM. Based on the empirical findings, the internal strengths and weaknesses and external opportunities and threats of the present urban flood management practices are identified. Internal strengths and weaknesses consider a number of factors related to the capacity of the institutions involved in urban flood management, their interrelationships and management efficiency. The external opportunities and threats consider the outside factors that have an impact on its functioning.

STRENGTH	WEAKNESSES
▪ NWPo & NWMP ▪ Drainage Master Plan ▪ Structural and Non-Structural Measures ▪ Water Modelling & Flood Mapping ▪ Skilled Water Managers	▪ Lack of political good will & commitment. ▪ Top-down decision-making process ▪ Corruption ▪ Lack of Accountability ▪ Lack of transparency of activities ▪ Weak institutional arrangement ▪ Lack of institutional integration ▪ Less accessibility to information ▪ Lack of land use planning ▪ Lack of integration between land and water resource management ▪ Lack of legal framework ▪ Weak enforcement of law ▪ Fund constraints ▪ Weak monitoring of the physical system ▪ Lack infrastructure maintenance ▪ Lack of participatory approach ▪ Lack of integration between structural & non-structural measures ▪ Lack of water system approach
OPPORTUNITIES	**THREATS**
▪ Increasing public awareness ▪ Policy advocacy of the civil society ▪ Growing number of water professionals	▪ Political unrest ▪ Unprecedented Rural-urban migration ▪ Rapid urbanization ▪ Land development through land filling process ▪ Illegal encroachment of river, canals, lakes. ▪ Indiscriminate dumping of industrial, clinical, domestic waste into rivers, canals, lakes, roads. ▪ Climate change

Figure 6.20: The SWOT Analysis

Chapter 7 Conclusions and recommendations

7.1 Introductions

Based on empirical findings and insights in literature, answer is provided for the research question, which is revealed through the answers of five research sub-questions. Reflection on the literature and recommendations are put forwarded.

7.2 Conclusion

Under this section the research sub-questions are listed below are addressed subsequently.

Interactive Water Resources Management

The concept of interactive WRM demands for a dialogue between the water manager and society on the one hand, and with water systems on the other hand. Keeping into account the important aspects like integration, sustainability and water system approach, the interactive relation makes it possible to respond to opportunities for the development of the new approaches. Principally, it is a learning process in which two different types of tools should be employed: monitoring and participation.

In an interactive management perspective, monitoring establishes the relationship between water managers and the water system. Monitoring is the primary tool for learning about the hydrological functions of the floodplain landscape and the effects of land use activities on the hydrologic functions. This helps assessing management strategies. In flood management monitoring plays a significant role in terms of flood warning since it reduces the vulnerability of the people and build up capacity to manage the consequences of floods. Monitoring information is required to support the decision-making process, evaluate the management efficiency and the development of new policy approaches.

Interaction between water managers and the society can be achieved through participation. The society is made up of citizen and all stakeholders with particular stake in WRM or FM, including government entities, NGOs, private organizations (business & industry), community organizations and others. The participation as a platform combines elements of both top-down and bottom-up inputs of local knowledge, needs and objectives to jointly develops local situations to water resource problem.

Urban Flood Management

The urban flood management approaches advocate for mainstreaming flood risks into development activities. In order to achieve this, an integrated and comprehensive management is imperative for urban flood. Human settlements, economic activities and in particular urban water infrastructures like water supply, sewerage, drainage etc. in urban areas have additional influences on floods beyond meteorological and hydrologic factors. In urban flood management, urban hydrologic balance is the key factor. The potential synergies in UFM can be achieved through integrated urban water management; drinking water supply, sewerage and waste water disposal and surface run-off disposal. Broadly the water

processes is recognized as Total Water Cycle Management. Being a subset of IFM, UFM embraces all its principles. IFM lays emphasis on the integration between land use and water resources, which enable the proactive approaches towards a flood management.

Water and flood management trends in Bangladesh

Historically, the water resources management issues in Bangladesh are mainly flood control and agriculture oriented. The main objectives of these projects were to increase agriculture production (Aman, monsoon rice), controlling floodwater by constructing embankments on both banks of the river and establishing drainage facilities to drain out excessive rainfall during monsoons. Although, the instantaneous and short-term objectives of these projects have brought some positive impacts in certain sectors, the long-term perspectives of economic, social, ecological and environmental sustainability of the city were left behind. The management approach rather fragmented than integrated and holistic. This stand-alone approach to flood control rather than flood management caused aquatic imbalance, pollution, arsenic contamination, lowering ground water table in dry season and loss of aquatic habitat. In general, the FC projects have failed to address the other sectors related to water resources utilization and developments in line with Integrated WRM.

Urban Flood Management in Dhaka

In urban flood management, the GoB has followed the same ideology as explained above. Flood control used the flood mitigation measures, which are similar to other FC projects around the country. The main objective is to reduce economic loss and to save human lives. In line with these objectives, structural measures like embankment constructions are given more emphasis than non-structural measures. This has added complexity to the rising storm water-flooding hazard in Dhaka. The non-structural measures like land use planning, flood zoning and other non-water sector issues are not taken into account in flood management. Moreover, lack of integration between urban water management and urban flood management, is equally creating stress on urban water infrastructures and the overall flood situation. In general, it can be said that urban flood management issues are not mainstreamed into the urban development activities of Dhaka city. Urban floods in Dhaka are managed in an ad hoc manner. The encroachment of wetlands, unplanned development, inadequate infrastructure, lack of appropriate legislation and enforcement, all illustrate the inability of the responsible organizations to manage the urban floods in a coordinated manner. This is mainly due to a poor institutional framework, a lack of institutional capacity within the responsible organizations, and above all, the political decision-making process. There is no central authority at national level that coordinates the organizations and fosters the cooperation among them in implementation of plans, policies, and management. Moreover, the role of national government in policy development also shows signs of bureaucratic rigidity. The power relation of the state with the society does not support participatory water resources management in Dhaka.

bureaucrats and government officials in decision-making, all together have made the entire flood management of the city inefficient.

Opportunities and challenges for potential improvements of UFM in Dhaka

Opportunities

The GoB has formulated the Wetland Protection Act 2000 and The Private Housing Land Development Rules 2004. This legislative progress can be seen as a strength which has made it possible to protect the natural canals and to prevent the real estate developers from land development on low-lying areas and in flood-flow zones. The formulation of the Private Housing Land Development Rules 2004 can also be seen as an opportunity for the government to take into account the extent of urbanization through control over the activities of private housing developers.

The civil society of Dhaka has undertaken the policy advocacy for many important issues including flood management. They initiated public litigation as a mean to preserve and conserve flood zones. Public awareness is also increasing concerning urban flooding problem. The print media has played an important role in this matter. Though the awareness is still rather low, it is encouraging that people recognize the consequences of filling up canals and low-lying areas and its impact on urban flooding.

Although the urban flood problem is in acute state, Bangladesh is well known for her qualified water managers. The dialogue among the water managers, urban planners and government organizations has increased; but the flood management situation is not yet improved accordingly. The quality of flood and water related research is improved. Different water and flood research institutes have carried out a number of model studies. The Institute of Water Modelling provides services in water modeling by means of tools such as GIS, MIKE 11 etc., computational hydraulics and allied sciences for integrated water resources management.

Challenges

Commitment of political leaders plays a key role in development of urban flood management in Dhaka. The effective implementation of flood mitigation and storm water management plans largely depend on strong political good will and commitment.

The city administration and the responsible organizations in flood management face numerous institutional challenges in terms of funding and institutional capacity. To make them more interactive towards effective urban flood management, the institutions require vertical and horizontal integration among and within the organizations, skilled leadership, and transparency in actions. This requires capacity building of the institutions.

7.3 Learning from literature

In recent years, there have been substantial changes in water resources management approaches. The hydro-centric concept shifted to complex-physical system such as river basin orientation. The concepts of water resources management mainly advocates for the concept of integrated and interactive management of land, water and natural resources. The main objective is to achieve in economic, social, environmental sustainability. According to theories, the various issues like institutional organization, communication, stakeholder's involvement, information sharing, legal framework, financial means, ideally each of these is to be fulfilled, but in practice this is hardly be the case.

There is always a large gap between theory and practices. The applications of these theories are context specific. Political, socio-cultural setups have great influence on their application. The concepts like IWRM, interactive WRM, adaptive WRM, ecosystem approach, all are inevitably ideological. In practice, these concepts have limited role to play. The concepts prioritize the issues to link up with the worldview and values of individuals or organizations. The management process involves judgment, preferences and commitment to achieve desired output. The implementation requires technical and political knowledge and skills.

The Review of all these concepts has provided with a deep insight of the development in water resources management and also helped to critically analyze the current flood management practices in Dhaka. The promotion of Interactive resource management demands participation from all levels of society. With regard to Arnstein's 'ladder of participation', public participation in flood management in Dhaka stands at the bottom level of the ladder i.e. literally no participation at all. At this level people are enabling to participate but only to enable the power holders to cure the participants. The informal practice of public participation reaches the third level of the ladder, when the policy makers consult with them to improve the plan they have prepared for them. This is a one-way flow of communication without any feedback.

In the context of Dhaka, the implementation of Interactive WRM largely depends on political decision-making process where political good will and commitment is the key concern. Platforms to establish negotiation between citizen and power holders is needed to mainstream water and flood management in the development activities.

7.4 Recommendations

The research shows that the urban flood in Dhaka is managed in an ad hoc manner. It is not only the very nature of the urban development activities, but also the management inefficiencies of the relevant organizations and their individual piecemeal strategy is unlikely to provide any effective solution to the urban flooding problem. Hence, in the light of current situation, the following some actions (figure 7-1) are recommended for urban flood management in Dhaka to achieve potential developments.

- **Strengthening Institutional Framework**

Intuitional arrangements

A strong institutional framework is the prerequisite for efficient water management**.** Strong cooperation and a coordinated, comprehensive management approach towards urban floods are possible only with strong institutional arrangement and legislations. The current state of flood management in Dhaka strongly demands for the involvement of the national authority with strong, competent leadership. An apex level organization (Figure 7.2) namely Executive Body at national level may bring good results in establishing coordination among the responsible organizations from both national and municipal level, uniting efforts in formulation of policies, and implementation of plans, monitoring the management activities and in creating an enabling environment for participation from society.

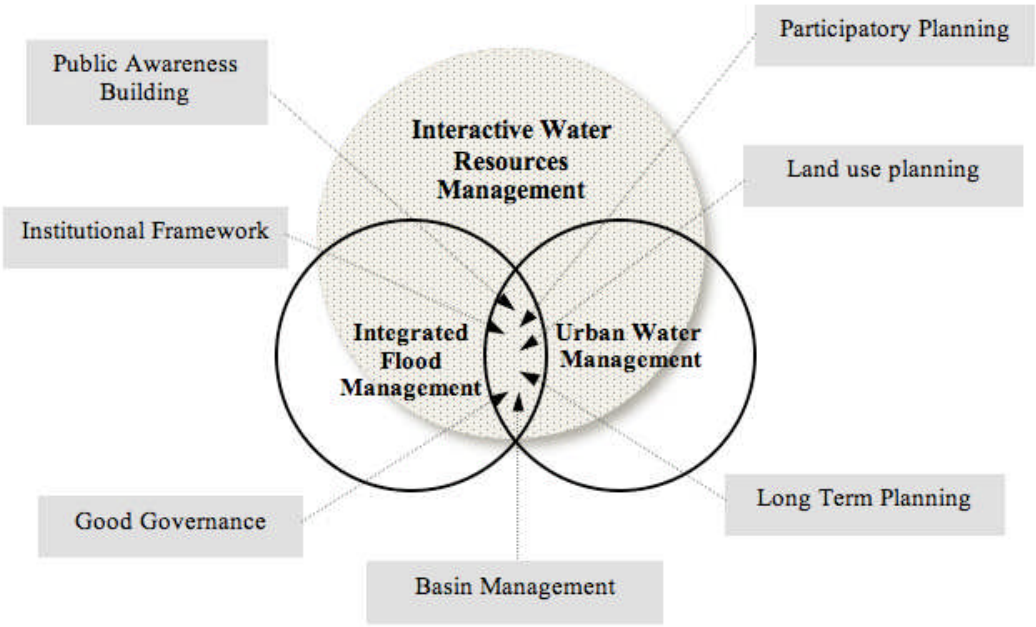


Figure 7.1: Conceptual Framework for UFM in Dhaka

Content of urban flood management policies and plans

The responsible organizations should give attention to the content and quality of flood management policies and plans from long-term perspectives. The beneficial aspects and negative socio-economic impacts of flood should be taken into consideration during the preparation of the flood management plan, for example, by optimizing long-term utilization of floodwater. This can be done by means of:

- Construction of retention ponds to retain and store water flows during flood to reduce the flood damages as well as meet users need during dry seasons and thereby maintaining the aquatic ecosystem;

- Stored water can also be used for hydropower generation, which may contribute to the dearth of the current electricity problems in Dhaka.
- Rainwater harvesting can be adopted in Dhaka city to supplement the water supply, replenish the groundwater table and its quality improvement, and increase soil moisture levels for urban greenery and above all to mitigate urban flooding.

Implementation process

The implementation of policies and plans depends on the responsible institution's ability in terms of financial and organizational capacities. The organizations, which are responsible for urban flood management in Dhaka, need to be strengthened financially and organizationally. Capacity building programmes like training and workshops should be arranged in a regular manner to properly equip the organizations in all respects; policy making, planning, implementing, operating and maintenance, evaluating the management activities.

Legislative framework

An appropriate legislative framework is fundamental for effective implementation of the National Water Policy. Some of the existing laws, such as Embankment and Drainage Act 1952, Canal Act 1864 etc., date back over a century and also do not complement the need of the city. These laws need revision. Moreover, most of the existing laws are agriculture oriented. Thus new laws for non-agricultural uses are needed securing both individual and community rights. The government has already taken the initiatives to formulate The National Water Code should consolidate the laws governing ownership, development, appropriation, utilisation, conservation, and protection of water resources. With a strong legal framework, systematic enforcement of the law can be ensured.

- **Participatory Planning**

MoWR in Bangladesh formulates the guidelines of participatory water resources management but these have not yet put into practice. Participatory planning can contribute to public acceptance and support avoiding potential conflicts. From the institutional perspective, the Local Government administration of Bangladesh is very week. In order to ensure participation of all relevant stakeholders, the government should take the following initiatives:

- Ensure empowerment of the local government administration with proper a institutional framework;
- Carefully identify relevant stakeholders who have direct and indirect stakes in urban flood problem;
- Arrange special means to encourage urban area people for participation.

- **Basin management**

  An integrated basin wide approach to flood management is essential. A river basin is a large, complex, dynamic system. The large-scale urbanization and indiscriminate water use activities have impact on flood flows in Dhaka. The improvements in functioning of the river basin largely depend on the interactions between land use and water environment.

  Moreover, geographically Bangladesh is a lower riparian country. The unilateral water use activities by the upper riparian are depriving Bangladesh from their legitimate use of the shared watercourse. Therefore, regional cooperation should be strengthened to employ basin level management for development in water resource utilization and conservation. This is also important for dealing with possible impacts of climate change.

- **Land use planning**

  Land use planning and regulation together with building and infrastructure codes and design practices can substantially reduce the vulnerability of the people and other urban activities. The Structure Plan and Urban Area Plan of Dhaka only demarcate the broad areas of future development but without clear definition of development principles. The completion of the Detail Area Plan (DAP) can prevent the loopholes for manipulation and encroachment of the low-lying areas and flood flow zones. The land use legislation is also not strong to establish standards for the use, development control and protection of land. Though a number of legislations have been formulated like Wetland Protection Act 2000, The Private Housing Land Development Rules 2004, their enforcement is not yet strong due to weak enforceable directives. Therefore RAJUK should take necessary initiatives to ensure the completion of DAP for effective management of urban flood. The land use legislations should be strengthened to enforce Bangladesh National Building Code (BNBC) in building and infrastructure constructions in flood prone areas.

- **Long term planning**

  For sustainable water resources development and integrated flood management the long term and short term planning should be incorporated. The factors rendering the vulnerability to floods should be identified and prioritized concerning immediate response and planning should be carried out accordingly.

- **Practice of Good Governance**

  The local government administration is very weak in Bangladesh. No matter what approach is employed for effective management it will not work unless the principles of good governance are being practiced. This includes transparency in actions, delegation of power, and decentralization of decision-making through participation, optimal mix of bottom-up and top-down approaches, accountability and equity. These principles support the effectiveness and sustainability of responsible organizations.

- **Building public awareness**

  Environmental education should be emphasized to build civic responsibility among the citizens. There should be a regular awareness campaign to build up public awareness towards environment. Environmental education should get emphasis in the education system of Bangladesh. Environmental education and development of environmental expertise is needed for future sustainability of Bangladesh.

7.5 Questions for Further Research

This research is a macro-level study on interactive approaches to urban flood management in Dhaka. The interactive approaches are conceptualized in two ways: participation and monitoring. Previously there is much research has carried out on different types of monitoring in water resources and flood management. So this study can be linked with further micro-level study on participation within the context of Bangladesh, such as institutionalization of interactive water resource management. This will be useful continuation of this research since Integrated Flood Management strongly advocates for participatory approach in flood management.

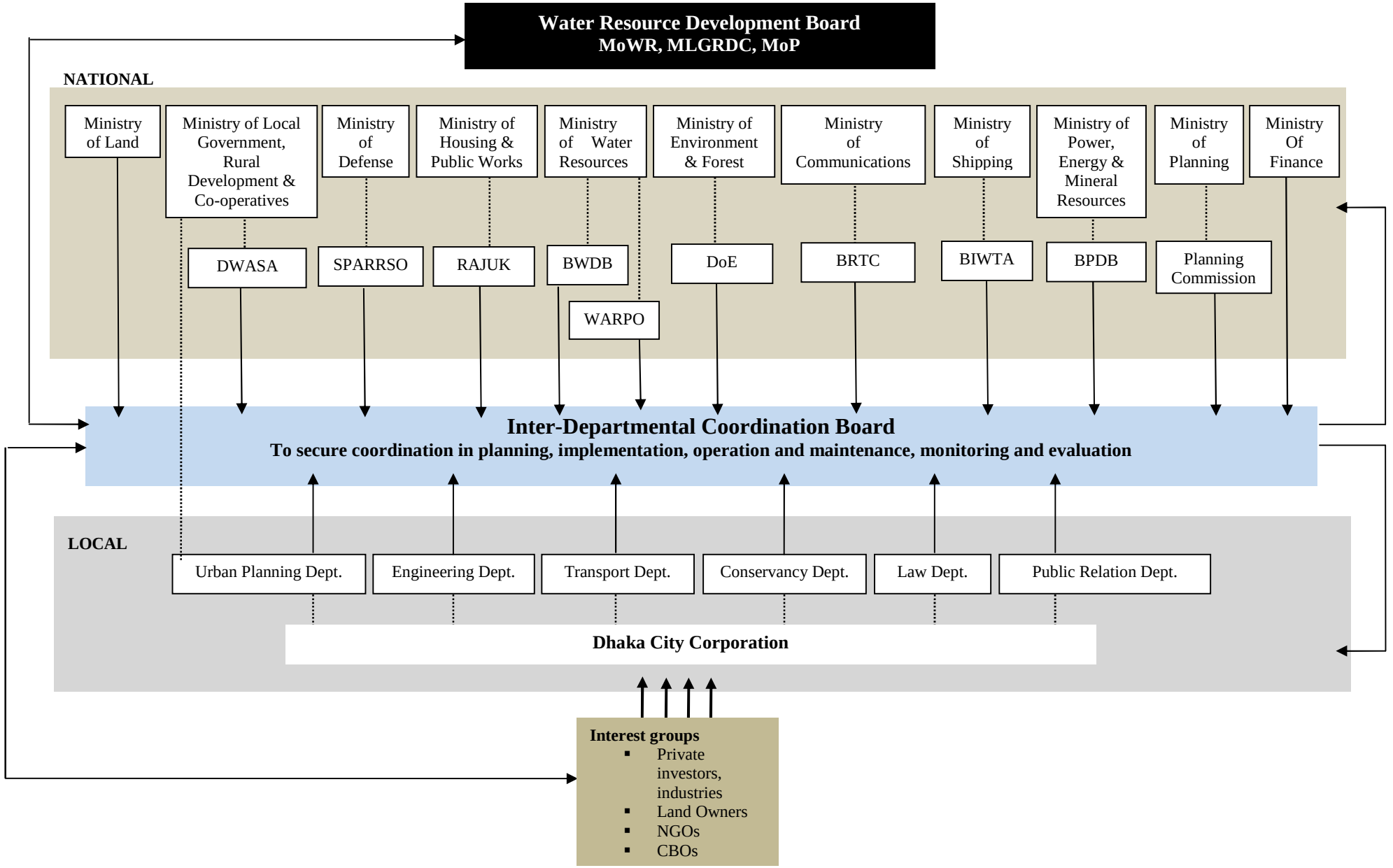


Figure 7.2: The conceptual Institutional Framework for Interactive UFM in Dhaka

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Annexes

Annex 1 Interview Questionnaire

This questionnaire is a research instrument of the research on **"Towards Interactive Flood Management: A Case of Dhaka, Bangladesh".**

This survey is strictly confidential and your answers will only appear as totals combined with those of other respondents for academic purposes only.

Purpose of the interview:
_ To understand the trends of water resources management in Bangladesh and
_ To identify the potentials and limits of the current flood management system.
_ To analyze the interactive approaches in flood management in Dhaka.
_ To analyze the institutional arrangements of the water and flood institutions.
_ To know how the present institutional arrangement is dealing with the flood Management in Dhaka.

Date and time of interview: _
Background of the interviewee:
Name:
Telephone:
E-mail address:
Name of organization you work for:
Type of the organization:
Your position in the organization:
Location of the organization:

Water resources management:
1. What elements of water resources are given more emphasis while formulating water policies?
2. What issues and conflicts do you face related to water policy, planning and project development?
3. What are the existing water instruments?

Flood management:
1. What are the key concerns of flood management? (River basin approach)
2. What is the application of flood management?
3. How flood issues are addressed in Flood Management?
4. How is the flood management issues dealt within the framework IWRM? (Measures)
5. What development has occurred in the flood management of Dhaka?

Water and flood Institutions:
1. What is the goal of your institution?
2. What is your approach towards achieving the goal?
3. What is your organizational structure?
4. What are the organizations dealing with flood management? Please explain their roles & responsibilities.

5. How do the organizations deal (co-operation, co-ordination & integration) with the flood management?
6. Which organizations are involved in decision-making processes in planning and policy formulation for flood management and how much control do they have?
7. How do you evaluate the involvement of the organizations in decision-making process?

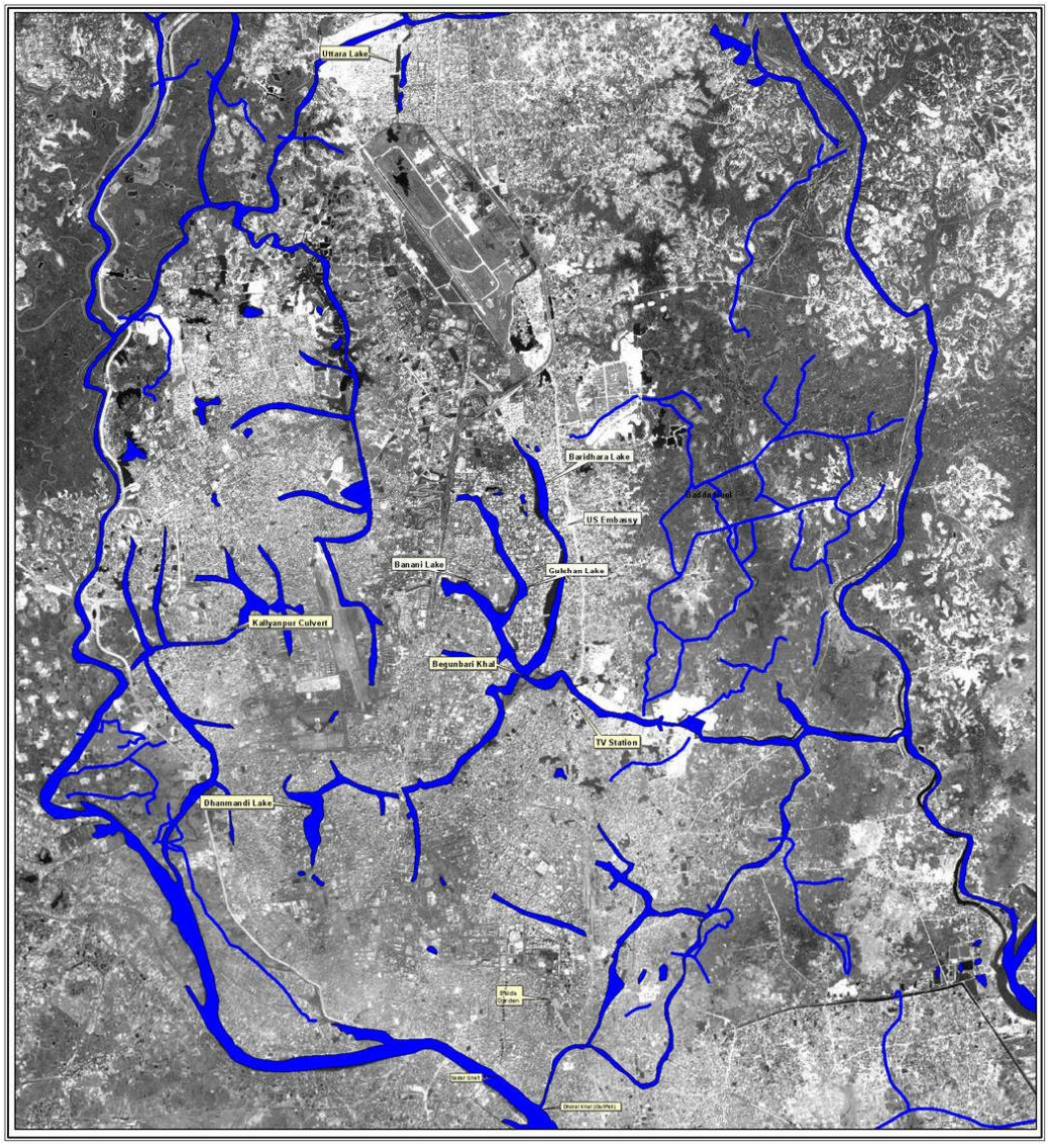
Participation:
1. Who are the actors in water resources management?
2. At which level and to what end do you involve the actors?
3. Does your organization involve individuals/ encourage public participation in decision-making process? If so please explain how?

Opinions:
1. What are some of your concerns regarding water resources management/flood management?
2. How can the interaction among water managers/flood managers, water system/(of river basin) and society be improved?
3. What is your perception regarding public participation in flood management?
4. How can flood management be more interactive?

Annex 2 List of Interviewee

	Organization	Respondents
1.	BWDB	Chief Planning
		Director Planning-1
		Superintending Eng, O&M Circle
		Executive Eng., FFWC
		Assistant programmer, FFWC
		Sub-assistant Engineer, Goran Chatbari Pump-station
		Gauge Recorder, Rampura Pump-station
2.	DWASA	Deputy Managing Director, O&M
		Deputy Managing Director, R,P&D
		Executive Eng., O&M
3.	RAJUK	Chief Town Planner
4.	DCC	Chief Town Planner, Urban Planning Department
		Additional Chief Engineer
		Superintending Eng., Environment circle
5.	WARPO	Principle Scientific Office
6.	BIDS	Senior Research fellow and Project Director
7.	CEGIS	Executive Director
		Head Database/IT Division
8.	IWM	Executive Director
		Principal Specialist & Head, Flood Management Division
9.	IWFM & Urban Planning Department, BUET	Professor
10.	IUCN	Country Representative

Annex 3 The drainage map of Dhaka city (50 year back)



Dhaka used to have about 40-50 canals. At present 17 canals out of 43 canals are filled up and rest 26 canals have narrowed down due to unplanned urbanization.

Annex 4 The River System of Dhaka City

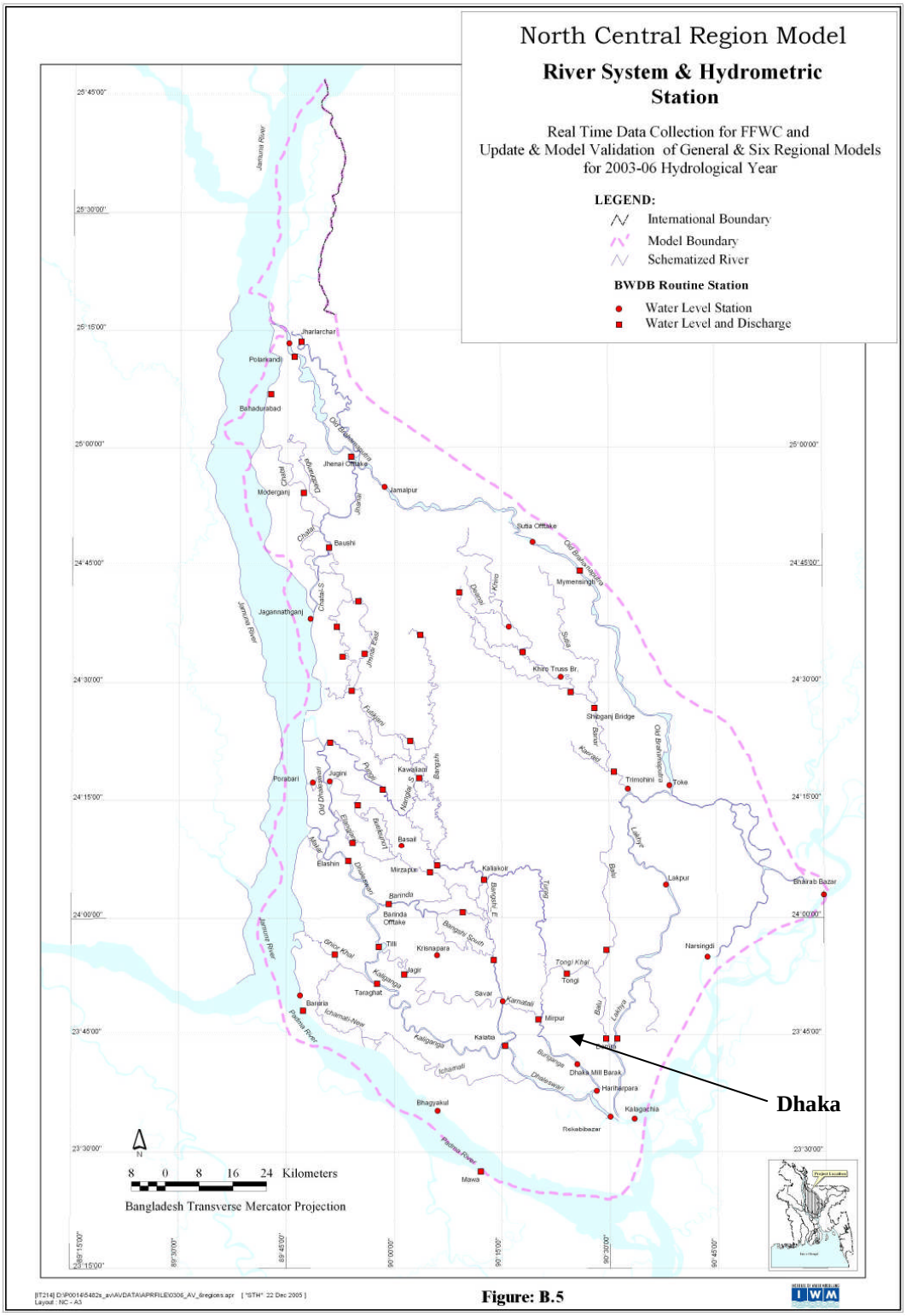
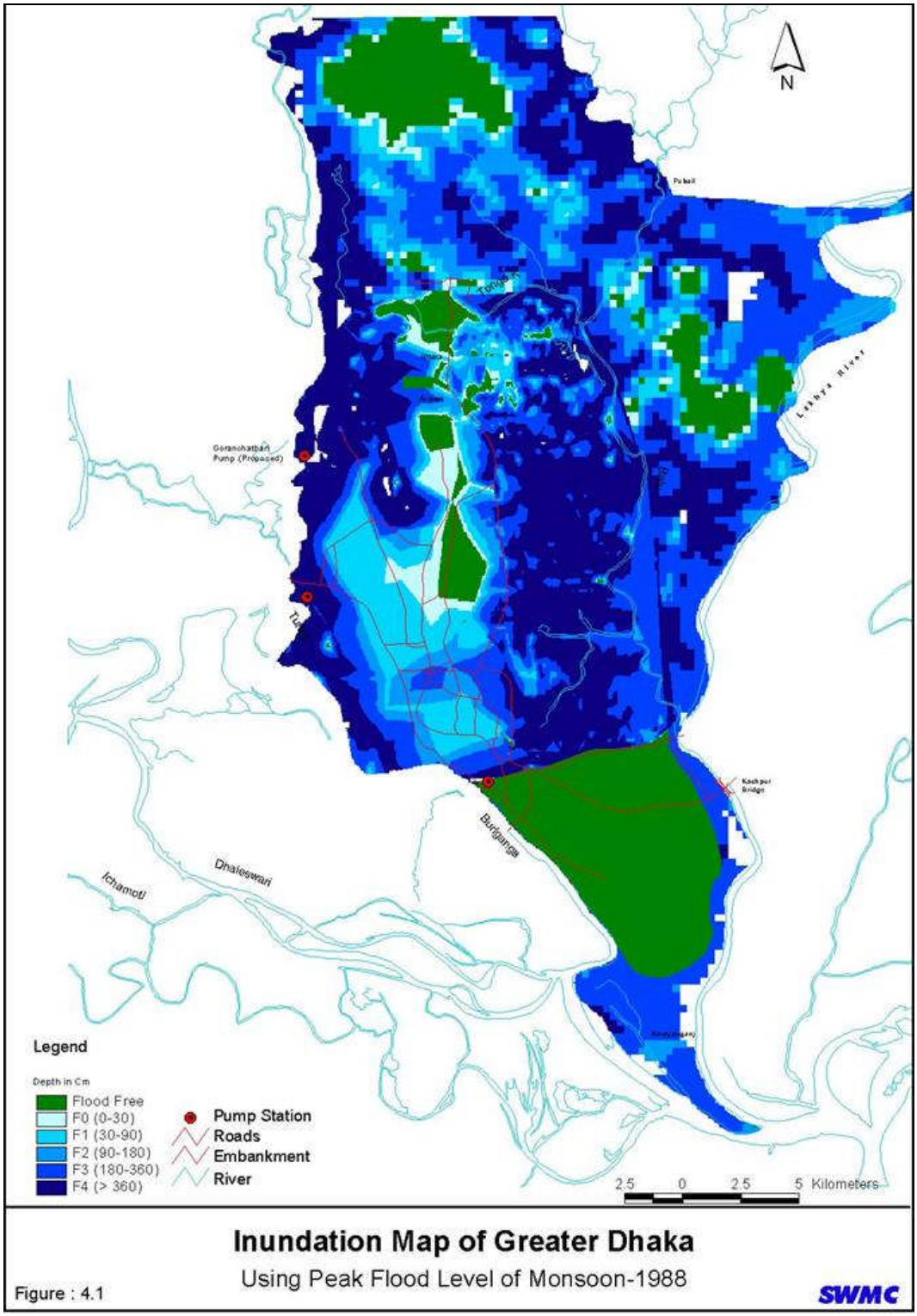
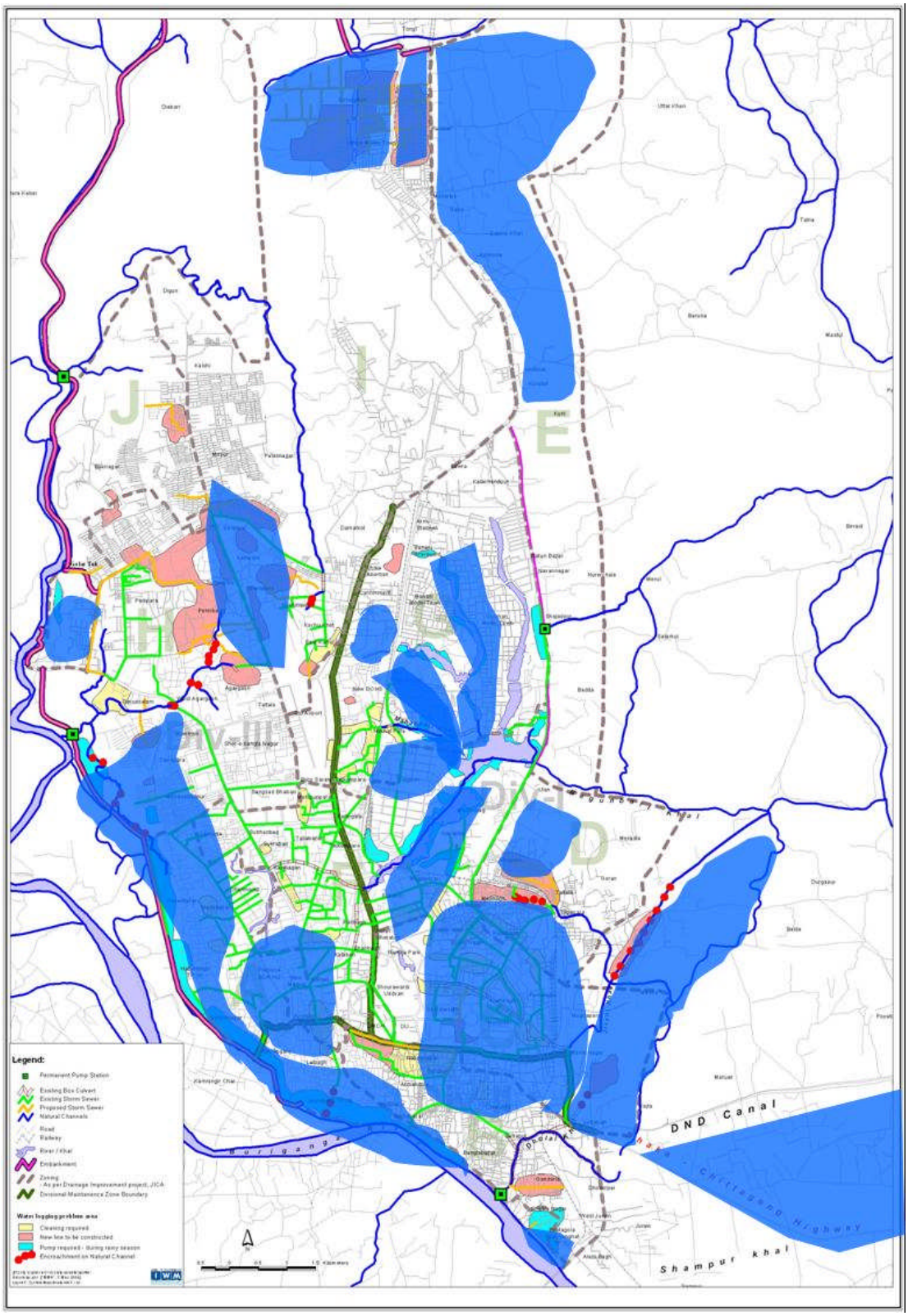


Figure: B.5

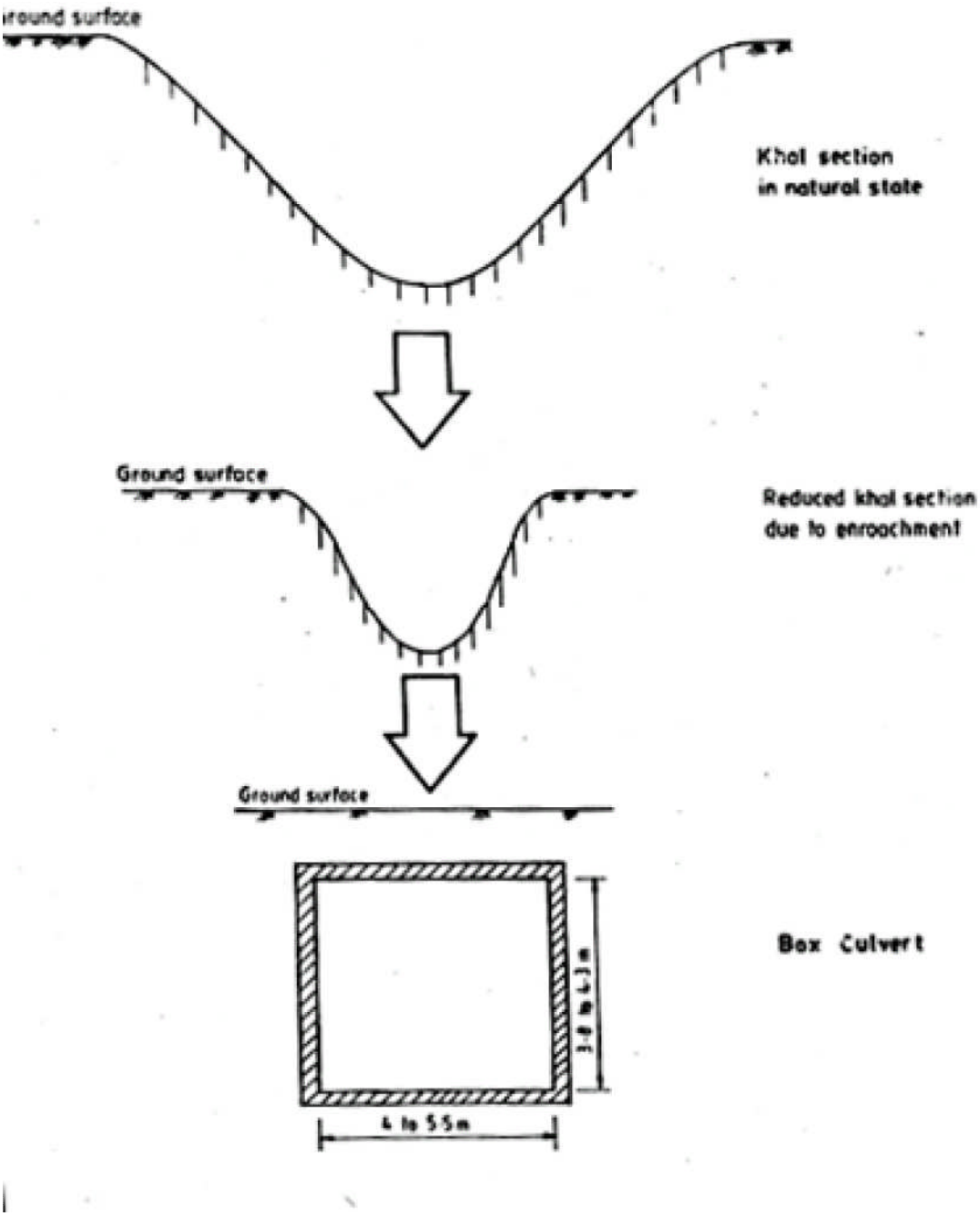
Annex 5 The inundation map of Greater Dhaka: 1988 Flood



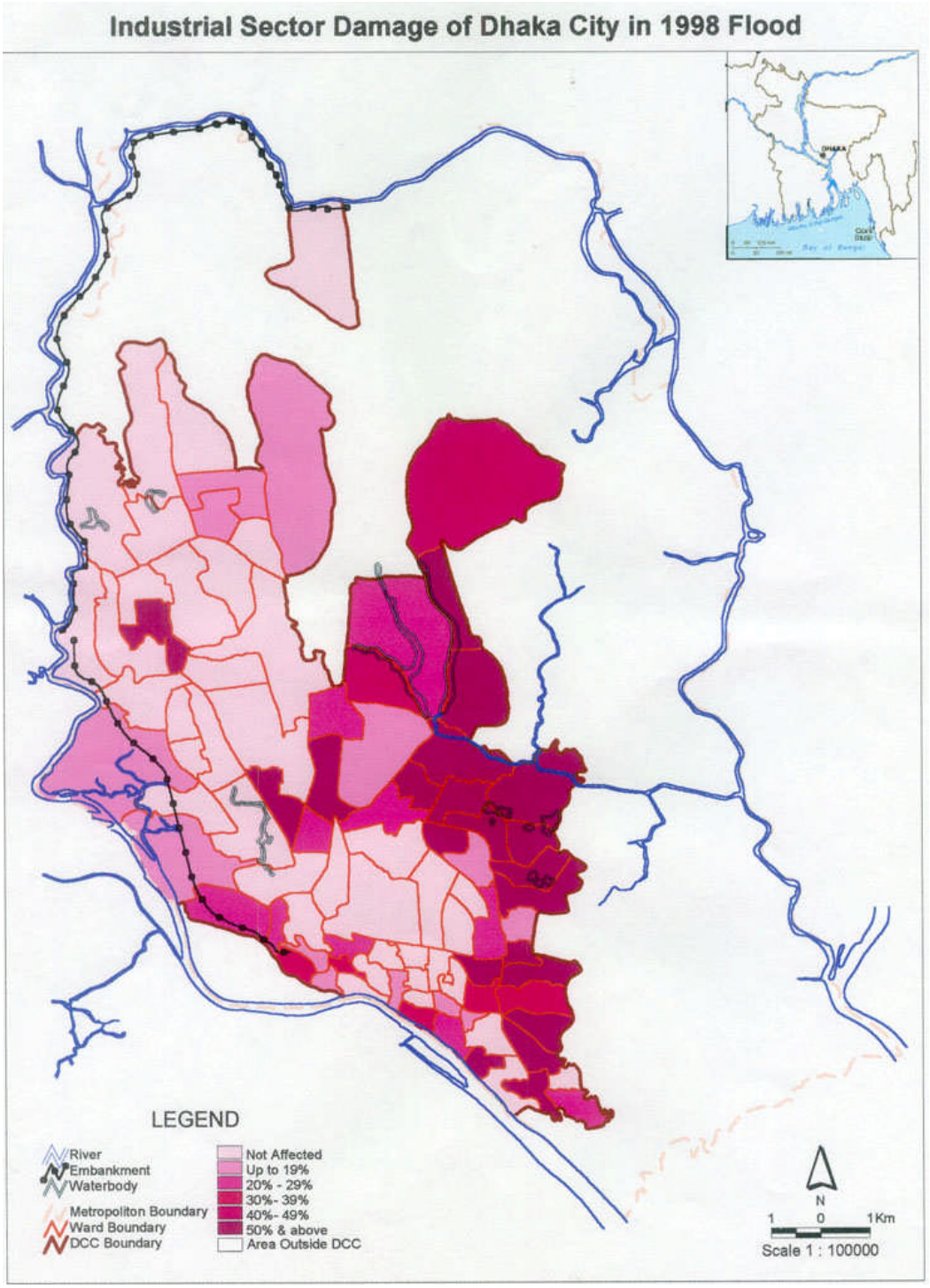
Annex 6 The inundation map of Greater Dhaka: 2004 Flood (September)



Annex 7 The Conversion of Drainage khal to Box Culvert



Annex 8 The Industrial sector damage map of 1998 flood



Annex 9 National Water Code

As a code it is expected that The National Water Code will take precedence over all former legislation and replace the Water Resources Act of 1992 (WARPO, 2000). It will promote the rational management and use of water by providing a framework that would allow for:

(i) the progressive introduction and application of appropriate standards and techniques for the investigation, use, control, protection, management and administration of water resources;

(ii) the co-ordination of all public activities which may influence the quality, quantity, distribution, use or management of water resources;

(iii) the co-ordination, allocation and delegation of responsibilities amongst Ministries, Local Government and public authorities for the investigation, use, control, protection, management and administration of water resources;

(iv) the participation of all concerned people and parties in the planning, development and management of water resources, including a framework for rules governing public consultation;

(v) the rights, responsibilities and standards by which non-government agencies and the private sector may engage in the development and management of water resources in their own capacity or acting on behalf of Government agencies or local communities;

(vi) the usufruct rights of individuals and communities to access to and use of water;

(vii) the ownership and the rights of transfer of ownership of publicly and privately owned water-related assets such as acquired and developed land and structures thereupon;

(viii) the constitution, responsibilities, authority, independence and powers to impose penalties of regulatory bodies;

(ix) conservation, protection and enhancement of water resources;

(x) the provision of a clean, safe and sufficient supply of water for domestic purposes to all persons;

(xi) the orderly development and use of water for other than domestic purposes, such as the watering of livestock, irrigation and agriculture, industrial and commercial uses, the generation of hydroelectric energy, navigation, fishing, preservation of flora and fauna and recreation;

(xii) the collection, treatment and safe disposal of sewage;

(xiii) the control of pollution and the promotion of safe storage, treatment, discharge and disposal of waste which may pollute water;

(xiv) The collection, processing, storage and dissemination of data and protection of rights in this regard.