SAARC Workshop on

FLOOD
Risk Management in South Asia

9-10 October 2012, Islamabad,Pakistan

SAARC

Organised by

SAARC Disaster Management Centre, New Delhi

In collaboration with

National Disaster Management Authority Pakistan

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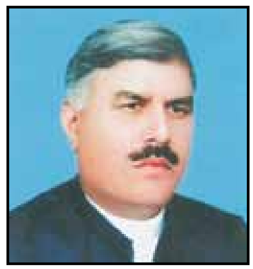

MESSAGE

As common citizens of the Himalayan region climate change is perhaps the greatest threat we face. Changing climate is making natural disasters, especially floods, less predictable and more destructive.

The situation is worsening each year. More than even we need to strategize climate change adaptation on regional canvas. We have a common natural heritage of mountains, river basins and monsoons. Nature now seems to be asking us to pull to together our common knowledge and resources to negotiate with common disasters.

Government of Pakistan realizes that we would not be able to manage climate change and the accompanying risks unless we cooperate and coordinate our efforts at the regional level. Disaster Risk reduction needs to be a priority for all of us to ensure uninterrupted economic development and happiness of our people.

The SAARC workshop on Flood Risk Management in South Asia is great opportunity for member countries to develop a common pool of knowledge and skills, and in the development of national and regional strategies to negotiate a problem that has been costing them dearly in recent years.

Rana M. Farooq Saeed Khan

National Disaster Management Authority Pakistan

CHAIRMAN

MESSAGE

Pakistan is vulnerable to wide-ranging hazards such as droughts, floods, earthquakes, mountainous region hazards such as landslides, debris flow, avalanches, heavy snow fall and coastal hazards such as cyclones, tsunami, flood etc. These hazards generate disasters that impede sustained economic growth by causing loss of lives and property.

Of all the hazards, floods have the most disastrous impacts on the lives of people in Pakistan as they not only cause loss to human lives and property but also have substantial negative effect on our economy by damaging agriculture and standing crops. Floods also have dire effects on public health and the environment, particularly water quality.

NDMA was raised amongst repeated disasters. It has been trying its level best to cope with them since its inception. Just to mention a few of them are 2005 Kashmir Earthquake that cost 73,000 precious human lives and assets worth billions. Then from 2007 onwards, Pakistan has been continuously faced disasters including Earth quake in Balochistan, floods and cyclones, Land sliding and the recent recurrent flood of 2010, 2011 and now in 2012. Floods of 2010 remained the most devastating of its kind in the 63 year's history of the country, where some 1,985 people lost their lives. The loss to public and private property and infrastructure amounted to more than 10 billion US Dollars.

Up till now, the Government and people of Pakistan fought bravely to minimize the devastating effects of frequent disaster with full support from the international humanitarian community. We have been able to develop an institutional base of Flood Risk Management system with National Disaster Management Authority (NDMA) at the centre and Provincial Disaster Management Authorities (PDMAs) and District Disaster Authorities (DDMAs) in all the provinces and regions.

There are many factors that are contributing towards global warming and resultant climate change across the globe. It has now become a cause of serious concern for everyone. Pakistan being located in the Himalayan region is facing threat from global warming which is causing great damage to Pakistan's environment. Among the impacts felt and seen are; increase in the extreme events resulting in increased frequency of hydro meteorological disasters particularly flooding, flash floods, drought, biodiversity loss, rise in the sea level, changes in freshwater supply, increased intrusion of saline water in the Indus delta adversely affecting coastal agriculture, mangroves and breeding grounds of fish, etc. Changing rainfall patterns and climate variability could also badly affect arid and semi-arid regions, leading to reduced agriculture productivity as well as increased demand for power generation. One of the challenges posed by climate change is the increased pressure on the country's limited capacity, both in terms of financial and human resource, to manage frequent disasters.

Sensing these implication and constraint, NDMA, in close coordination with the national, regional and international partners particularly the South Asian nations, is gradually endeavoring to adopt a comprehensive approach to reduce the impacts of climate change and enhance the adaptive capacity of the region. Holding this Workshop is also an effort in this direction for which all SAARC member countries especially SDMC deserve great applaud and appreciation.

Zafar Iqbal Qadir

SAARC DISASTER MANAGEMENT CENTRE, NEW DELHI

DIRECTOR

MESSAGE

South Asia is one of the most disaster prone regions of the world. Two thirds of the natural disasters in South Asia are related to Hydro-meteorology. Various studies indicate that climate change would further increase the frequency, severity and unpredictability of the natural disasters especially floods in entire south Asian Region. Seven out of eight countries of South Asia are prone to by floods due to a variety of factors, both natural and manmade every year. Last decade, some of the south Asian countries such as Pakistan, India, Afghanistan, Bangladesh, Nepal and Sri Lanka affected by catastrophic floods. Due to floods thousands of people lost their lives and properties in this region every year.

The severity of the floods, a result of active wet monsoon accompanied by a series of tropical cyclones reiterates that the impacts of hydro-meteorological disasters remain a serious concern to maintain sustainable development in the region. With the growing threat of climate change and increasing number of floods in the region, further investment on disaster risk reduction is critical.

In this regard SAARC supported by partners has taken a catalytic role to provide more understandable and action-oriented information to policymakers in the region. The problems and impacts of floods might go beyond national boundaries, and National & International cooperation is important in this region. The present SAARC workshop "Flood Risk Management in South Asia" is a step in this direction.

I understand that that the workshop will strive to develop a regional road map to deliberate on the practical steps necessary for implementing components of the Action Plan on Flood Risk Mitigation which are relevant to the mandate of the SDMC. I am happy that representatives of the member countries and experts from the region shall be assembling to develop this road map. SAARC Disaster Management Centre places its gratitude to National Disaster Management Authority (NDMA), Pakistan for hosting this workshop.

We are happy to bring out this publication to facilitate discussion in this workshop.
I look forward to the outcome of this important workshop and wish it all success.

Satendra

Background Paper
Flood Risk Management in South Asia

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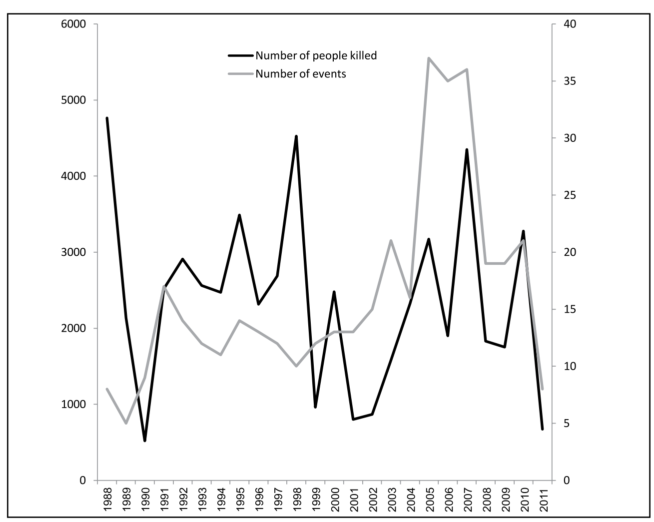
"I have witnessed many natural disasters around the world, but nothing like this": Ban Ki-moon, UN Sceretary General after the devastating floods in Pakistan, 2010.

Background

One of the oldest documented and known disasters, floods have been menacing the communities since ages. In addition to the natural, hydro meteorological factors prevalent in the region, human intervention in recent times has added a new dimension to flood hazard. Every year floods claim thousands of lives in addition to leaving millions homeless and inflicting considerable loss to property and infrastructure. South Asia has a long history of floods and for many of the countries in South Asia, combating floods is an annual feature. Floods can be of several types: riverine, estuarine, coastal, catastrophic, flash, hill torrential or, the recent trend: skewed urban practices. The floods lead to destruction of infrastructure, crops, vegetation cover and also erosion of landmasses besides land sliding. In addition to these, the flood events leave in their wake problems of water pollution, water borne diseases and epidemics in the affected area in addition to prolonged inundation. Loss of human life and livestock, escalation of prices, social insecurity and costs of rebuilding infrastructure are additional layers of constraints a country has to bear after floods in the longer run over and above the resource diversion on immediate response, rescue, relief and early recovery activities.

The analysis of number of flood events and people killed in these floods in South Asia for the period 1998-2011 shows a waxing and waning trend. It is generally observed that the trends for the number of events are synchronous with the number of people killed in these events which reflects a need for higher degree of preparedness and adoption of prevention & mitigation measures in the SAARC member countries. Two major windows are observed during this time series; the first between 1991 and 1997 and, the second one between 2003 and 2008. Though there has been a downward trend in the years after 2008, the region witnessed two subsequent devastating unprecedented flood events in Pakistan in the year 2010 & 2011 affecting over 29 million people.



Time seres analysis of South Asian Flood

Nature of floods in South Asia

Floods in South Asia are mainly driven by the unique hydro meteorological and monsoonal influences in the region. Two monsoonal windows are operational in the region: the southwest monsoon that follows the summer months and the northeast monsoon in the winter. The southwest monsoon generally prevails from June to September and accounts for nearly 70-80% of the rainfall in the region. Except for Maldives and Sril Lanka, which receive major share of their rains from northeast monsoon, the other member states are recepients of southwest monsoon influenced rainfall. Apart from these two major rainfall influences, some of the countries in the northern part of the region also receive rainfall from western disturbances and some of the parts in the southern periphery of SAARC region especially Sri Lanka have rainfall influences from Inter-Tropical Convergence Zone. The skewed distribution of available rainfall in the region, whereby 2/3rds of the rainfall is received in 4 months puts the water carrying capacity of the rivers under high degree of duress. The recent studies also show that the effetcs of sea level rise is also making the communities in the densely populated coastline of the South Asian countries highly vulnerable to coastal floods. On the other hand melting of glaciers in the Himalayan-Hindukush region, owing to the visible climate change impacts, may give rise to increase in flash floods in the mountainous regions and those places located at the foothills. Incidence of flash flood events due to localized meteorological conditions, cloud bursts etc. have also increased.

South Asia's geography makes it particularly susceptible to natural disasters. According to the recently published 2011 World Risk Report, countries like Bangladesh, India, Nepal and Pakistan exhibit a high level of vulnerability as demonstrated by their lack of coping capacities and adaptive capacities. In evaluating 173 countries for purposes of creating this year's World Risk Index, the report gave the following countries its global risk index ranking: Bangladesh (6), Pakistan (66), India (71) and Nepal (99). There is a high level of variation within South Asia itself, but these rankings should not be misinterpreted to undermine the risk faced by these countries—particularly the poor—in the face of natural disaster. As per the Index, Bangladesh has been declared the second most disaster-risk country in Asia—only after the Philippines—and sixth in the world after countries like Vanuatu, Tonga and Guatemala.

The 2007 South Asian floods had wide scale effects in India, Nepal, Bhutan, Pakistan and Bangladesh which resulted into death toll in excess of 2,000 in addition to affecting nearly 30 million people in the region.

Flood in South Asia

Afghanistan

The sources of most of the rivers in Afghanistan lie in the mountains and are fed by snow melt. The flow is more in spring and early summer and during other seasons the rivers may become dry or disappear entirely. This seasonal nature of rivers and streams also make the areas highly vulnerable to floods, mostly flash floods and landslides. The record of floods in the country is very old. The village of Gardi Gouse, Jalalabad Province has 700 year old history with a current population of 3500. The village is hit by floods every 2-3 years. Fifty five years ago, in a severe flood, the entire village was washed away.

Bangladesh

Bangladesh is one the countries with a unique settings for flooding. Most part of the country is low lying and 80% of the landmass is flood plain thereby leaving the country highly vulnerable to the threat of repeated floods. Historical and recent data shows that during past 50 years at least 7 major floods have taken place in Bangladesh, some the worst ones have occurred during the years 1987, 1988, 1998, 2004 and 2007. These floods are worthy of mention because in each of them 30% or more of the landmass were flooded. The pattern of flooding in the country also points towards an increase frequency of floods in the country.

In addition to the major share of floods received from the heavy monsoonal precipitation and heavy sediment charged water the rivers of Bangladesh carry, the coastal areas of the country are exposed to the storm surges and coastal floods. As the three major rivers; Ganges, Meghna and Padma receive peak flow from upper reaches at the same time this further compounds the problem of flooding in the country. The rapid deforestation in the upstream areas is increasing the surface areas for run off and leading to higher degree of erosion and inflow of sediments into the rivers. Being located in the lower stretch where the river floor gradient is very gentle, the rivers here aggrade very rapidly as a direct consequence of the heavy sediment load the waters carry. It has also been observed that the coastal areas of Bangladesh are witnessing rise in sea level. Rise in sea level consequently results in raise in base level of the rivers that drain into the sea. This in turn results in less flow of water into the sea and the rivers attempt to adjust the water volume by overflowing their banks.

Flood in Dhaka, Bangladesh ***(Source:*** *updatednews24.blogspot.com)*

Urban floods, Mumbai 2005 ***(Source:*** *www. asiabizz.com)*

Bhutan

Bhutan, where the rivers generally flow through narrow, deep gorges and not through low lying areas and cause less flooding due to monsoonal rains as compared to many other countries of the South Asian region. Being a country with low population density there are not many people settling on the riverbanks subjected to flooding. However, the major threat the country faces is from flash floods which carry boulders and water charged with high energy fractions that inflict damages to life, infrastructure and property. The country is also exposed to the threat of Glacial Lake Outburst Floods (GLOF) primarily due to melting of glaciers in the upper reaches. This is increasingly becoming a major threat to the communities in Bhutan.

India

Vast expanses of India experience flood every year. The majority of the flooded parts in India are in the plains of northern part of India. Nearly 90% of the damages to the life and property in this part of the country are caused by monsoonal floods. The coastal states are also exposed to the threat of floods and in such parts they are caused by monsoon, storm surges associated with cyclones or coastal inundation. Rapid urbanization and reclaiming of areas close to riverbanks has added a new dimension in the country as seen recently in Mumbai (2005) and the threats of urban floods in Delhi in the year 2011. It has been seen that the parts of India in the Himalayan region are periodically subjected to flash floods which may be a reflection on the deforestation in these parts. The states in India most vulnerable to floods are Uttar Pradesh, Bihar, Punjab, Assam, West Bengal, Odisha, Madhya Pradesh, Tamilnadu; many other parts of the country have also experienced floods in recent or historic past. Floods have caused loss of infrastructure and livelihood, led to large scale migration and, in some cases, relocation of affected communities.

Some of the major floods to hit India in recent past are the 2005 urban floods in Mumbai, 2008 Kosi flood in Bihar, 2009 floods in South India and 2010 flash floods in Leh.

Kosi floods 2008, India ***(Source:*** *The Hindu).*

Kosi floods 2008, Nepal ***(Source:*** *www.apdforum.com).*

Nepal

Floods are a common phenomenon every year in Nepal. There are more than 6,000 rivers and rivulets nationwide. Among these, snowfed rivers, such as the Koshi, Narayani, Karnali, and Mahakali, are perennial rivers. They originate from the Himalayas and, after descending from the hills, flow through the Terai plains. During the monsoon (June-September), these rivers swell and cause damage to the communities residing within their floodplains. Entire Terai, flood plain of major rivers in the areas near the river valleys are prone to flood. Historical data has shown that Nepal witnessed major flood in Tinao basin (1978), Koshi River (1980), Tadi River Basin (1985), Sunkoshi Basin (1987), and devastating cloud burst in Kulekhani area (1993) which alone claimed life of 1336 people. Recently, Koshi flood in 2008 affected about 200,000 people in the eastern Nepal.

*Pakistan floods, 2010 **(Source:** www. epacha.com).*

***Floodas in Sri Lanka (Source:** marianews.com).*

Pakistan

Like other SAARC member states, Pakistan also has long history of floods. In the past 60 years the country has faced 19 major flood events resulting into loss of 10,668 precious human lives, cumulative flooding of over 594,700 sq km area with 166,075 villages affected and total direct cumulative losses to the tune of about US $ 30 billion. Floods in Pakistan are generally caused by the heavy concentrated rainfall during the monsoon season, which are sometimes augmented by snowmelt flows in rivers. Occasionally destructive floods are also caused due to monsoon currents originally from the Bay of Bengal (India) and resultant depressions which often result in heavy downpour in the Himalayan foothills, which is sometime further augmented by the weather systems from the Arabian Sea (Seasonal Low) and from the Mediterranean Sea (Westerly wave). The monsoonal runoff discharging in the rivers is further augmented by the water received from melting of snow from higher reaches upstream of Tarbela Dam in northern Pakistan. Isolated and distributed flash flood events also occur in Pakistan. From 2005 onwards these have become a regular visitor during the monsoon season. Also urban floods which occur in the major cities of Pakistan including Islamabad, Rawalpindi, Peshawar, Lahore, Karachi, Faisalabad, Hyderabad etc. are also common in the monsoon season. Coastal floods in the southern provinces of Sindh & Balochistan occur when tropcial storms make landfall in the coastal areas of the country. The Makran coast and south eastern parts of Sindh bear the brunt of such floods. The most recent of such events occurred in 2007 (Yemyin cyclone) and in 2010 (Phet cyclone). The most worst and destructive flood Pakistan has faced were in 2010 which caused record destruction in the history of Pakistan including loss of 1985 lives. Floods of 2010 and 2011 have also manifested and strengthened the sea level rise estimates thus have further compounded the flood vulnerability.

Sri Lanka

Floods are more of common occurrence in Sri Lanka than the other natural disasters. Many of its rivers are vulnerable to floods. The increase in population and subsequent need for land have forced more and more people to live and work in these vulnerable areas, thereby intensifying the risk to life and property in the event of major floods. Heavy rainfall and runoff of the large volume of water from the catchment areas of rivers, deforestation, improper land use and the absence of scientific soil conservation practices are identified as the major factors for floods in Sri Lanka. Urbanization with the insufficient infrastructure facilities such as drainage system triggers the urban flash floods together with global phenomena like climate change, which has increased rainfall intensities. The districts of Kegalle, Ratnapura, Kalutara, Colombo, Gampaha and Galle are subject to floods on account of Southwest monsoon rains, while Ampara, Trincomalee, Badulla, Polonnaruwa, Batticaloa, Matale and Monaragala suffer from the Northeast rains. In Sri Lanka, major floods are associated with the two monsoon seasons. Heavy rainfall in the eastern and southwestern slopes is a principal cause of the flood risk. In addition, the drainage and topography of certain districts and land use patterns are also significant factors. The western slopes receive rainfall during September to January and May to August periods, and are prone to flooding in these periods. The eastern slopes of the country receive most of the rainfall during September to January. This is also the cyclone and storm season that can bring heavy rainfall in short time periods. Thus the two regions show distinct flood seasonality.

Flood management measures in South Asia

The recurring floods in South Asian countries inflict heavy degree of economic losses, loss of lives; disruption of community development processes; evacuation and in some cases rehabilitation of communities; renewed investment in developmental processes to name a few. The strategies for flood risk management in South Asia has been in the form of Flood prevention which reduces the risk of overbank capacity from being breached; Flood abatement by reducing storm flow and peak discharge rates and Societal responses whereby the communities develop strategies to cope and live with this hazard in areas of low recurrence interval and history of repeated flooding.

Various flood protection measures have been adopted in the region, which are mainly structural in nature. Construction of flood levees to reduce bank overflow, construction of dams to facilitate controlled flow of water downstream, check dams to reduce sediment discharge in the main course of the river, construction of spurs to train river flows, gabion walls and dykes to ensure aligned and directed flood water flows, bypass channels to relief main control structures from flood water pressure, effective flood discharge routing from dams etc. are some of the popular measures that have been around in the region for past century. Some non structural measures have also been adopted in the region for flood management. Afforestation or reforestation of the upper catchment areas is adopted by many countries to reduce surface run off. Terracing of the slopes and contour plantation are also attempted to meet this objective. One of the important non structural measures adapted to a large extent is advance flood forecasting and warning system. The system is a combination of rainfall runoff computer models, numerical models, weather surveillance radars, quantitative precipitation measurement radars, High Resolution Picture transmission system, High Frequency Radio transmission etc. by virtue of which rain and flood forecasting & warning is issued by mandated national agencies to facilitate evacuation of people from low lying areas likely to be flooded. For example Central Water Commission (CWC) issues flood forecasts and warnings and it issues forecasts and warnings through a network of more than 150 stations in India. In Pakistan, Pakistan Meteorological Department issues flood forecasts and warnings through a country-wide network of stations. Water and Power Development Authority (WAPDA) plays a major role in collection and transmission of river discharge data. National Disaster Management Authority (NDMA) ensures timely preparedness and dissemination of related forecasts and warnings to district administration through provincial disaster management authorities.

Gaps and future areas of focus

Flood has been identified as one of the major disasters in South Asia exposing the communities to very high degree of risk. However, it has often been seen that the measures undertaken are not enough and they fail at times to give way to flood hazards. Floods have occurred in the protected areas due to overtopping, breaching or in some cases, failure of the protection structures. Land use practices need to be projected with foresight keeping in mind the future areas of concentrated growth and their proximity to flood risk zones. It is also found that the flood related data collection and transmission networks need to be strengthened and augmented for generation of more effective flood warnings. The present information on various aspects of flood hydrology: rainfall runoff estimation, estimation of flood volume, alternate routing of flood water has much scope for improvement for dissipation of advanced real time data. The reservoirs, even most of the major reservoirs of the region are not adequately suited for the periods when the rivers are in peak discharges during flood. It is also seen that the operation of dams in many cases does not account for synchronization of downstream flood peaks.

The present flood risk management system in South Asia leaves much scope for improvement to counter the fast increasing menace of urban floods and flash floods. The recent incidences of urban flooding in Islamabad-Rawalpindi (2001), Mumbai (2005), Sri Lanka (2010) and major cities of Sindh, Pakistan (2011) very clearly manifest the urgent need of devising measures to combat urban floods. The preparedness for combating incidences of flash floods in the vulnerable areas is also inadequate as has been proved during the devastating flash floods in Leh, Ladakh (India) in 2010 and Khyber Pakhtunkhawa Province of Pakistan (2010).

South Asia has a very long coastline and many cities located near the coasts frequently experience coastal flooding due to concurrent swelling of major rivers draining into the sea during prolonged monsoon or storm surges. However, the existing coastal management plans need to be reoriented in view of the increasingly high concentration of settlements along the coastlines of South Asian countries. The need to intensify the process of institutional strengthening and capacity building initiatives in the region is a major thrust area in flood risk management in the region.

Future strategies and recommendations

In the backdrop of increasingly alarming flood risk in the SAARC member states it is necessary to design new development and coping strategies; modify the existing ones and make flood risk management an integral part of developmental plans.

1. The structural flood management system in the South Asian region in many cases has been designed several decades ago and in many cases are half a century old. Therefore, the existing facilities should be reviewed in the present flood risk perspective. The watershed and flood management practices in the countries need to be reviewed and evolved keeping in view the high rates of urban growth and stress on land use patterns.
2. The dominant trend of river management practices is only concentrated on the course of major rivers, high rainfall in tributary river basins has been an area that not always received adequate focus. This effect needs to be kept in view while preparing flood management plans at state/provincial/regional level.
3. The land use plans should be based on intensive assessment of flood risk in the region and it would be a better idea to make the land use plans based on multi hazard risk assessment for sustainable use of economic resources for development. The infrastructure and plans in major cities should be reviewed at regular intervals and should be designed to make room for improvements in future. The existing plans should be upgraded to withstand flood risk.
4. Loss of crops is a major concern in recurrently flood prone areas and in addition to economic loss to the communities influences the food security of the region. Crop insurance and livelihood generation programs should be made an integral part of the national, regional and local level plans. It would also be a good idea to provide and promote more sustainable and diversified livelihood opportunities to flood prone areas to elevate economic status of the communities.
5. One of the major areas of future focus should be the exchange and transfer of collaborative exercises to improve the existing flood risk management and preparedness mechanism in the region. The indigenous knowledge available with the communities in South Asia has been very effective in historical and ancient times in protecting the villages and towns from flood risk. It is imperative to document the wealth of indigenous knowledge available in the region and integrate them into the developmental and management plans of the flood prone areas.
6. Making the vulnerable communities aware of flood risk is a major area of focus in South Asia. A multi prong approach for spreading awareness: through print and electronic media, distribution of information material, community workshops, street shows should be made an intrinsic part of DRR activities in the member states in the context of flood risk management.
7. Livelihood options in frequently flooded areas are a major concern and affect the communities. The government policies should have scope for accommodation of economic diversification in the form of shifting economic and livelihood options.
8. The preparedness, rescue and relief contingency plans should have special emphasis on the vulnerable segment of the communities likely to be affected by floods: the poor, old, women, pregnant, children and the disabled.
9. One of the most intrinsic elements of flood risk management in the region is creation, maintenance and proper use of database including information on resources of the region.

This can be done by resource mapping; their regular review and updation; develop scenarios and prepare emergency plans. The local level participation in the process should be taken into consideration and promoted.

10. Community level participation is an important element to ensure flood resilience in the region. Therefore, a sense of ownership needs to be installed among the communities of vulnerable areas and partnership and participation of all stakeholders should be ensured through role distribution, regular meetings, evacuation drills, mock exercises and regular awareness generation upto the village level.
11. Mainstreaming DRR into the developmental plans is a must for long term flood risk resilience in the risk prone areas at national, regional and local level. Specific entry points and agencies have to be well defined and regular interaction of the stakeholders should be conducted for its effective execution.
12. Many of the floods of the region have trans-boundary effect and in the view of the impending flood risk to these countries it is imperative to develop strategies that encompass regional information database; technologies developed and available; indigenous knowledge of the communities of the region and even, the constraints that are inherent of the region to make future flood risk reduction endeavors in the region more effective and to minimize the economic and infrastructure loss in the region and loss to lives.
13. Apart from the traditional flood forecasting techniques there is a need to invest in more robust technologies to reach the last mile communities. Integrated Flood Alert System and Global Flood Alert System should therefore be adopted at the national and regional level.
14. A pool of flood management experts, managers etc. at the South Asia Region level may be developed with a view to address flood related issues in an integrated manner collectively within South Asian region.
15. In order to have more pragmatic approach to integrated flood management at the level of South Asian region all concerns on account of climate change impact should be researched, debated and adopted as an integral component of regional flood risk management.
16. Joint programs on effective flood risk management through flood adaptive approach should be designed and proposed for joint fund allocation through international forums (UNFCCC), Green Climate Fund, Adaptation Fund etc.

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Flood Control in Bangladesh through Best Management Practices

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Abstract

Analysis of historic data shows that the magnitude, intensity, and duration of floods have increased in Bangladesh during the last few decades. It also appears that most of the flood control embankments experienced breaching since their completion, and are not very effective in reducing the damage to the environment, economy, and property.

It is argued that solutions to flooding problems require an understanding of the long-term factors that contribute to increased floods, which include: unplanned urbanization, soil erosion, local relative sea-level rise, inadequate sediment accumulation, subsidence and compaction of land, riverbed aggradation, and deforestation. To mitigate flooding propensity in Bangladesh, both the government and people will have to adopt watershedscale best management practices (BMPs) – a series of activities designed to: (a) reduce the run-off, (b) increase the carrying capacity of drainage system, and (c) increase land elevations. Proposed BMPs are: floodplain zoning, planned urbanization, restoration of abundant channels, dredging of rivers and streams, increased elevations of roads and village platforms, building of efficient storm sewer systems, establishment of buffer zones along rivers, conservation tillage, controlled runoff near construction sites, adjustment of life-style and crop patterns, good governance, and improvement on flood warning/preparedness systems.

Introduction

At the present time the Ganges-Brahmaputra Delta and its 130 million people living in Bangladesh are facing a serious challenge. While 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. While some of these environmental degradations are not directly related to human activities and land-use practices (such as earthquakes, tornadoes, and cyclones), others are related to human interactions with the nature. Flooding is one such waterrelated environmental problem magnitude of which is very much dependent on land-use practices in the watershed of each rivers or streams.

Riverine floods occur when the amount of runoff originating in a watershed (the area that collects and directs the surface runoff into the rivers, streams and lakes that drain it) exceeds the carrying capacity of natural and constructed the drainage system. Flooding can occur due to river overflow or surface runoff. There are two types of floods which occur in Bangladesh: annual floods (barsha) that inundate up to 20% of the land area; and low frequency floods of high magnitude that inundate more than 35% of the area (bonna). While the annual floods are essential and desirable for overall growth of the Bangladesh delta and the economy, the low frequency floods such as those that occurred in 1954, 1955, 1974, 1984, 1987, 1988, 1993, 1998, and 1999 are destructive and cause serious threat to lives ([1, 2, 3, 4]). This paper analyzes the possible underlying causes of recent unusual riverine floods in Bangladesh in light of hydrodynamic principles that take place in watersheds and land-use practices. Other types of floods, such as local floods due to heavy rainfall, coastal floods caused by cyclones, are not considered in this study. Solutions to the flooding problems are offered in the context of watershed-scale BMPs.

Observations about Historic Floods

Documentation of floods in terms of flood depth, area affected, damage to crops, damage to infrastructures, number of people affected, and overall monetary damage started in 1953 [(3, 4, 5, 6]). Other major recorded floods prior to 1953 took place in 1787, 1917, and 1943 [(7)]. Based on the historic records, it is obvious that the frequency, magnitude, and duration of floods have increased substantially during the last few decades. For example, all major floods covering more than 30% of the country (total area of Bangladesh is 144,000 km2) occurred after 1974 only. Four floods of such great magnitude (1974, 1987, 1988, and 1998) took place during the last 25 years, averaging one in every 6 years. According to Elahi [(5, 7)], the floods of both1980 and 1984 covered an area more than 30%, making the number of such floods to be 6 since 1974 (i.e. one in every 4 years). In addition, the total area covered by major floods has been steadily increasing since 1974, with an exception of 1984 floods [(4)]. The data showing the total affected area varies widely from one source to the others (Table 1). The area affected by major floods has increased from 35% in 1974 to 68% in 1998. Variations in data pose a problem in analyzing the findings. However, all sources of data seem to show a general trend of increased flooding propensity.

***Table 1**: Area affected by floods 1953-1998. Total area of Bangladesh is 144,000 km2. Years for which flood affected area exceeded 50,000 km2 are shown in boldface*

Year	Area affected by floods (km²)		
	Elahi (7)	Shahjahan (3)	Islam (4)
1953		27,000	
1954		37,000	36,920
1955		40,000	50,000
1956		36,000	5,620
1962		37,000	37,440
1963		35,000	43,180
1964		10,000	
1966		33,000	
1968		37,000	37,300

1969		41,000	
1970		42,000	42,640
1971		36,000	36,475
1972		21,000	
1973		29,000	
1974	**90,650**	**52,000**	**52,720**
1975		17,000	
1976		28,000	
1980	**64,750**	35,000	
1981		12,000	
1982		23,000	
1983		11,000	
1984	**64,750**	48,000	**28,314**
1985		22,000	
1986		18,000	
1987	**88,000**	**60,000**	**57,491**
1988	**98,000**	**98,000**	**77,700**
1998			**84,000**

Flood Control Measures and the Outcome

Flood control measures in Bangladesh are mainly limited to building of earthen embankments, polders, and drainage. A total of 5,695 km of embankments, including 3,433 km in the coastal areas, 1695 flood control/regulating structures, and 4,310 km of drainage canals have been constructed by Bangladesh Water Development Board [(8)]. Embankments and polders have reduced floodplain storage capacity during floods, leading an increase in water levels and discharges in many rivers (9). Embankments can also create a false sense of security among residence living within embanked areas. For example, breaching of Gumti embankment at Etbarpur during 1999 flood caused substantial damage to the environment and property. Earthen embankments can easily breach and can be damaged by riverbank erosion. Most of the embankments in Bangladesh experienced breaching and erosion more than once since their completion. The effectiveness of embankments is being questioned in other countries as well. Flood control embankments along the Mississippi River are constructed using superior engineering designs and are maintained regularly by the US Army Corps of Engineers. During the floods of 1973, 1984, and 1993 these embankments and other embankments maintained by state governments in Illinois breached at many places and proved to be ineffective as flood control measures. During the 1993 flood, some 1,082 levees, out of 1,576 levees on the Upper Mississippi and Missouri River basins were either overtopped or failed [(10)].

Following 1988 flood the Government of Bangladesh (GOB) has adopted a World Bank sponsored flood action plan (FAP) that calls for the construction of hundreds of kilometers of tall embankments along the great rivers of the Bangladesh delta, enormous drains, and compartments on the flood plains [11, 12, 13]. The feasibility of the FAP has been criticized by numerous researchers on the basis of technical, economical, environmental, sociopolitical, and ecological grounds [6, 12, 13, 14, 15]. Dhaka Integrated Flood Protection Embankment cum Eastern Bypass Road Multipurpose Project, which is a component of the FAP, is underway at a calculated initial coast of 24758.21 million taka. The effectiveness of such embankment as flood control measure is debatable at best.

Despite flood control measures already administered by the Government of Bangladesh (GOB), the total amount of damage to economy, crops, and infrastructures due to floods has steadily increased during the period between 1954 and 1998 (Table 2). According to Shajahan [3], overall damage to economy ranged from $600 million dollars in 1974 to $1,200 million dollars in 1988; and crop damage has varied between 0.6 million tons in 1953 and 3.2 million tons in 1988. Another study by Elahi [5] estimated the economic loss to increase from 1,500 million taka in 1954 to 4,000 million taka in 1988, with a maximum of 20,000 million taka in 1974. Islam [4] determined that the total damage to the economy had increased from1,200 million taka in 1954 to 100,000 million taka in 1998. Further more, the number of deaths, have increased from 112 in 1954 to 2,379 in 1988 [4]. Elahi [5] estimated the death toll to be 28,000 and 1,600 for the floods of 1974 and 1988, respectively. Although the numbers vary somewhat, it is very clear that flood control measures did not make a significant impact in terms of reducing the flooding propensity and total damage caused by floods.

***Table 2**: History of breaching and erosion in major flood control embankment projects. Data modified from Rahman and Chowdhury (8), and Islam (4). Years for which flood affected area exceeded 50,000 km2 (>35% of the country's area) are shown in boldface.*

Year of completion	Embankment project	No. of years of breaching	Erosion	Flood damage (in million taka)
1953				
1954				1,200
1955				1,290
1956				900
1962				560
1963	Gumti	5 (* including in1999)	continuous	580
1964				
1966				
1968	Brahmaputra Embankment	9	continuous	1,160
1969				
1970				1,100
1971				
1972				
1973				
1974				28,490

1975				
1976	Hatiya	2	continuous	
1978	Alfadanga	2	once	
1980	Chandpur Sari-Gowain	0 2	none none	
1981				
1982	Teesta	5	continuous	
1983	Ganges-Kobdak Manu	1 2	none continuous	
1984	N'ganj-Narsindi	2	none	4,500
1985	Karnafuli	1	none	
1986				
1987	Chenchury Muhuri	30	twice none	35,000
1988	Salta-Bagda	0 none	100,000	
1998 ongoing	Chalan Beel	3 none	100,000	

The magnitude and duration of floods have changed during the last few decades. The duration of 1998 flood was 70 days. A prolonged flooding condition prevailed throughout much of the monsoon season in 1999. The obvious question is despite all the flood control measures taken and the money spent why is the flooding propensity in Bangladesh increasing, and what can be done to reduce such damage in the future? The answers to these questions lie in understanding of the long-term factors contributing to increased frequency and duration of floods. Once the causes of the problem are determined, then preventive measures can be taken to reduce future damage caused by floods.

Factors Contributing to Flooding Propensity

Flooding propensity in an area can vary greatly with a change in the: (a) amount of runoff that results from precipitation in a watershed, (b) water carrying capacity of a drainage basin, and (c) change in land elevations with respect to riverbeds and sea level. An increase in runoff component of the hydrologic cycle in a watershed, a decrease in water carrying capacity of a drainage system, and a decrease in land elevations will increase flooding propensity in an area. Therefore, the flooding problem and the solutions to such problems can (or should) be analyzed in the context of these three fundamental parameters: runoff, water carrying capacity, and land elevations. We need to analyze landuse practices in watersheds during the last few decades that have potentials to impact hydrodynamic behaviors of rivers, affecting three vital parameters mentioned above.

Unplanned urbanization: Rapid population growth creates extra pressure on the land of already overcrowded Bangladesh. Agricultural lands give way to housing developments and roads. This rapid development and urbanization must have aggravated the flooding problem in Bangladesh. Urban population has increased from 1.81 million (4.33% of total population) in 1951 to 25.2 million in 1990

(16). According to Islam (4), current urban population is more than 30 million (25% of total population). The urban population is projected to exceed 58 million (36% of total population) by the year 2010 [16].

Unplanned urbanization can adversely impact flooding situation in a watershed. Prior to urbanization there exists a greater lag time between intense rainfall and peak stream flow. After urbanization the lag time is shortened, peak flow is greatly increased, and the total runoff is compressed into a shorter time interval, creating favorable conditions for intense flooding. For example, in a city that is totally served by storm drains, and where 60% of the land surface is covered by roads and buildings (one like Dhaka City), floods are almost six times more numerous than before urbanization [17].

Following urbanization, it is necessary to adjust drainage capacity in the watershed to take into account the "Basin Development Factor (BDF)" in order to accommodate the extra runoff that results due to urbanization. The amount of adjustment in the carrying capacity of natural streams following urbanization depends on the degree of BDF. For an increase the amount of impervious surface by 10% in a watershed, a 23% increase in the drainage capacity by dredging or deepening of streams is suggested by Sauer et al. [18]. Dhaka City is located in the watersheds of Buriganga and Sitalakha Rivers. A significant increase in the amount of impervious surface in these watersheds has taken place due to expansion of Dhaka Metropolitan area over the last few decades. However, no attempts have been taken to increase the carrying capacity of these rivers to accommodate for the BDF. To the contrary, the internal drainage system consisting of tributaries to Buriganga and Sitalakha Rivers has been diminished due to unplanned landuse practices. For instance, it is apparent from topographic maps, Dhanmondi Lake and Baridhara Lake are remnants of tributaries of Bugiganga-Sitalakha Rivers. Also, filling up of Dholaikhali chnnel has also reduced the runoff capacity from Dhaka City. The lack of an efficient storm sewer system in Dhaka City also contributes to the reduction of water carrying capacity, causing water-logging throughout monsoon season. According to the reports published in national newspapers, Dhaka City has experienced serious water-logging problems during the wet months of July to October in 1999.

Riverbed aggradation: Riverbed aggradation is most pronounced for the Ganges and its distributaries. From the border with India to the point where the Ganges meets the Brahmaputra River, the riverbed has aggraded as much as 5-7 meters in recent years [19].According to a study done by Kalam and Jabbar [20], the average width of the Ganges has decreased from 1.27 km in 1973 to 1.01 km in 1985. Riverbed aggradation is so pronounced in Bangladesh that changes in riverbed level can be observed during one's lifetime. For example, the Old Brahmaputra River was navigable for steamers only about 30 years ago, and is presently an abandoned channel. This situation is true for many other distributaries of the Ganges and Meghna Rivers, such as the Madhumati, Bhairab, Chitra, Ghorautra Rivers, etc. Riverbed aggradation reduces the water carrying capacity of rivers, causing bank overflow. This recent increase in riverbed levels must have contributed to the increased flooding propensity in Bangladesh.

Soil erosion: Ploughing makes the land surface more susceptible to soil erosion. Surface run-off can easily wash away the topsoil from cultivated lands. This surface erosion reduces land elevations, which in turn increase flood intensity in an area. According to the Report of the Task Forces (RTF) on Bangladesh Development Strategies for the 1990s (16), soil erosion is a serious problem in many parts of Bangladesh. Hilly areas in Sylhet, Chittagong, and Chittagong Hill Tract districts are more susceptible to soil erosion. About 55% of Chittagong Hill Tract area is highly susceptible to soil erosion (16). Heavy monsoon shower removes the surface soil through runoff. Parts of eroded sediments are deposited on the riverbeds, reducing the water carrying capacity and increasing flooding propensity in a watershed. Soil erosion also reduces land elevations and increases elevations of riverbeds, contributing to increased flood depths. The land elevations in other parts of Bangladesh must have been reduced over time due to soil erosion. Aside from this, the tilling on the mountain slopes of the Himalayas is thought to be responsible for massive soil erosion in Nepal (21, 22, 23), which eventually causes rapid riverbed aggradation in Bangladesh (24)). Moreover, construction sites in cities can contribute to soil erosion if silt fences or retention ponds are not employed properly (25). In Bangladesh, no such measures are in practice at construction sites.

Deforestation in the upstream region: A rapid increase in population in the Indian Subcontinent over the course of the 20th century has resulted in an acceleration of deforestation in the hills of Nepal to meet the increasing demands for food and fuel wood (23). Deforestation of steep slopes is assumed to lead to accelerated soil erosion and landslides during monsoon precipitation, which in turn is believed to contribute to devastating floods in the downstream regions such as in Bangladesh. Deforestation within Bangladesh also contributes to the soil erosion. The amount of forest cover in Bangladesh has been reduced from 15.6% in 1973 to 14.6% in 1985-86, and eventually to13.4% in 1987 (16).). A minimum of 25% forest cover is suggested for a healthy ecosystem. The amount of forest cover in Bangladesh at the present time believed to be less than 10%.

Local relative sea-level rise: The ultimate destination of all rivers is the ocean. The land elevations are measured with respect to the sea level in an area. Therefore, any change in the sea level causes land elevations to change as well. At the present time the sea level is rising globally (26). If the sea-level rises in an area at rates faster than the rates of land aggradation due to sedimentation, then land elevations decreases over time. Any decrease in land elevations can cause increased inundation by rivers overflowing at bankfull stage. The rate of local relative sea-level rise is 7 mm/year in the coastal areas of Bangladesh (27). According to another study by Das (28), the local relative sea level at Chittagong Port has increased by as much as 25 cm between 1944 and 1964. The relative sea level in the Bay of Bengal is predicted to rise 83 to 153 cm by the year 2050 (15). An increase in the sea level raises the base level of rivers, which in turn reduces the gradients of river flow. As a consequence, the amount of river discharge decreases, creating a backwater effect further inland. The backwater effect caused by sea-level rise can result in more flooding of lands from "piled up" river water inland. This certainly seems to be one of the reasons for the increase in flood intensity in recent years in Bangladesh.

Inadequate sediment accumulation: A delta can prograde if sediment accumulation rates are greater than the rates of local relative sea-level rise. Limited data shows that the average sediment accumulation rates in the coastal areas of Bangladesh is 5-6 mm/year for the last few hundred years, which is not enough to keep pace with the rising sea level at 7mm/year (29). As a result, land elevations must have been decreasing over time in Bangladesh, resulting in more flooding inundation.

Subsidence and compaction of sediments: Sediments on a delta plain are rich indecomposed organic matters, and are subject to compaction due to dewatering and sediment weights. Most deltas subside due to the weight sediments, and due to overdraft of groundwater. Subsidence and compaction reduce land elevations with respect to sea level (26). No direct measurements of subsidence or compaction are known for Bangladesh. However, the groundwater table in Dhaka City has had a considerable lowering by as much as 9 to 12 meters over the last 3 decades. Experience in other countries indicate that it needs at least 9 meters of permanent lowering of groundwater table to cause 30 cm of land subsidence (16). Therefore, it is likely that land elevations in many parts of Dhaka City have been lowered by up to 30 cm, contributing to increased flood depth.

Best Management Practices as Flood Control Measures:

Flooding is a natural phenomenon, which cannot be prevented. Complete flood control is not in the interests of most Bangladeshi farmers (30). The flood control measures and policies should be directed to mitigation of flood damage, rather than flood prevention. Resources should be allocated to help people adopt a life style that is conformable to their natural environment (31, 32). Indigenous solutions through changing the housing structures and crop patterns can help reduce flood damage (33, 34, 35). Moreover, good governance, appropriate environmental laws, acts and ordinances will be necessary to achieve sustainable economic development and to reduce any environmental degradation (36). In addition, implementation of an improved real-time flood and drought control warning system can reduce damage caused by floods.

A greater understanding of the processes that contribute to increased flooding propensity, however, can help us mitigate the adverse effects on human lives, environment, and economy. To mitigate flooding propensity in Bangladesh, both the GOB and the people will have to shift their paradigms, as well as will have to adopt BMPs in agriculture, forestry, landuse planning, water resources management, and urbanization (14, 37). The BMPs pertaining to flood control are those activities that will help reduce the run-off, will increase the carrying capacity of drainage system, and will increase land elevations with respect to sea level or riverbeds (Allen, 1999). Table 3 summarizes the BMPs and the expected effects on mitigation of flooding problems in Bangladesh.

Conclusions:

Formulating solutions to flooding problems requires a comprehensive understanding of the geologic settings of the region, and a better knowledge of hydrodynamic processes that are active in watersheds. Only solutions that take into account the underlying long-term factors contributing to flooding problems can prevail. Such contributing factors are as follows: unplanned urbanization, soil erosion, local relative sea-level rise, inadequate sediment accumulation, subsidence and compaction of sediments, riverbed aggradation, and deforestation.

Table 3. *List of BMPs and their effects on mitigation of flooding.*

BMPs	**Expected effects on mitigation of flooding**
Dredging rivers and streams	Increase carrying capacity of drainage
Re-excavation of abandoned channels, ponds, and lakes	Increase carrying capacity of drainage; reduce run-off
Dispersal of dredged/excavated sediments on land	Increase elevations of earthen roads and village platforms
Conservation tillage	Reduce soil erosion and run-off
Establishment of vegetated buffer zone along rivers and streams	Reduce soil erosion, run-off, and bank erosion
Silt fence around construction sites	Reduce soil erosion and run-off
Sediment and run-off detention ponds in construction sites	Reduce soil erosion and run-off
Removal of coastal polders	Increase land elevations by tidal inundation
Efficient storm sewer system in cities	Increasing carrying capacity and reduce water-logging in cities
Planned urbanization and compact township	Reduce impervious surface and run-off
Watershed-scale landuse planning	Reduce run-off, soil erosion, and impervious surface; sustainable economic developments
Reforestation programs	Reduce run-off and soil erosion
Good governance, self-reliance, and implementation of environmental acts	Implementation of BMPs to mitigate flooding problems; sustainability in economy and environment
Integrated regional water resources development plan for Ganges-Brahmaputra- Meghna Basin in Indian Subcontinent	Flood/drought control; optimal uses of natural resources in the region; sustainable environment and development

Structural solutions, such as the building of embankments along the rivers and polders in coastal regions in Bangladesh, will not solve the flooding problems, but will result in many adverse environmental, hydrologic, economic, ecological, and geologic consequences. Solutions to flooding problems can be achieved by adopting and exercising watershed-scale best management practices that include: floodplain zoning, planned urbanization, restoration of abundant channels and lakes, dredging rivers and streams, increased elevation of roads and village platforms, efficient storm sewer systems, establishing buffer zones along rivers, conservation tillage, controlled runoff at construction sites, good governance, indigenous adjustment of life-style and crop patterns, and improvement on flood warning/preparedness systems.

Since Bangladesh is a small part of a larger hydrodynamic system that comprises several countries in the region, mutual understanding and cooperation among the co-riparian countries will be necessary to formulate any long-term and permanent solutions to the flooding problems.

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Disaster Research: Exploring Sociological Approach to Disaster in Bangladesh

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Introduction

Disasters are annual events in Bangladesh. These disasters range from ravaging tornadoes to devastating floods. Of all the disasters the problem of flood has aggravated most from 1955 to 2004 and become one of the main concerns of people in Bangladesh. Abnormal floods submerge about 60 percent of the land, damage crops, property; disrupt economic activities and cause diseases and loss of life. Similarly, cyclones, which are sometimes accompanied by storm and tidal surge, pose multiple threats to human society along with erosion of soils, riverbank and coasts. Surge water creates salinity problem in the coastal belts. Consequently, cyclones are very destructive of property and people and disruptive of economic activities. Another hazard, drought, affects the standing crops, water supplies and plant growth leading to loss of productions, food shortages and famine. (Nasreen and Hossain, 2002). Arsenic, a toxic element and a silent disaster, is teaching a bitter lesson to humankind, particularly to those in Bangladesh who have been suffering from arsenicosis. The excessive level of the presence of arsenic in drinking water is redefining water from 'life saver' to a 'threat' to human survival. Because it takes 10 to 20 years, depending on the amount of arsenic accumulated in the body, to be identified as arsenic patient, people's response to the disease is not so prompt. Because of its severity and frequent occurrence, floods have attracted wide attention and are well documented by the researchers. However, sociological research on disasters, even on flood, is scant in Bangladesh.

In this paper an attempt has been made to explore what research has been done to address disasters in Bangladesh and to what extent disasters are highlighted from social perspective? The paper, in the process, also tries to define disaster and identify approaches to disaster research. The paper looks at the major works completed on disaster from various approaches. It has been argued that application of sociological approach to disaster research is very limited.

Defining Disaster

'Disaster' is defined differently by different people: to some 'disaster' is a summative concept' (Kreps, 1984) or a 'sponge world' (Qurantelli and Dynes, 1970). Some researchers mentioned disaster as a 'collective stress situation' (Barton, 1969) while others identified it with 'social crisis period' (Qurantelli and Dynes, 1977). Britton (1986) argued that "disasters can be more easily recognized than they can be defined". Disaster is a severe, relatively sudden and unexpected disruption of normal structural arrangements within a social system over which the system has no firm control (Barton, 1974). A disaster may also be viewed as "a significant departure from normal experience for a particular time and place"(Turner, 1978). Disaster is also viewed as a mental construct imposed upon experience. This

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is because to understand disaster knowing the number of deaths, the value of property destroyed or the decrease in per capita income is not sufficient. The symbolic component requires knowledge of the sense of vulnerability, the adequacy of available explanation and the society's imagery of death and destruction (Barkun, 1977).

Approaches to Sociology of Disaster

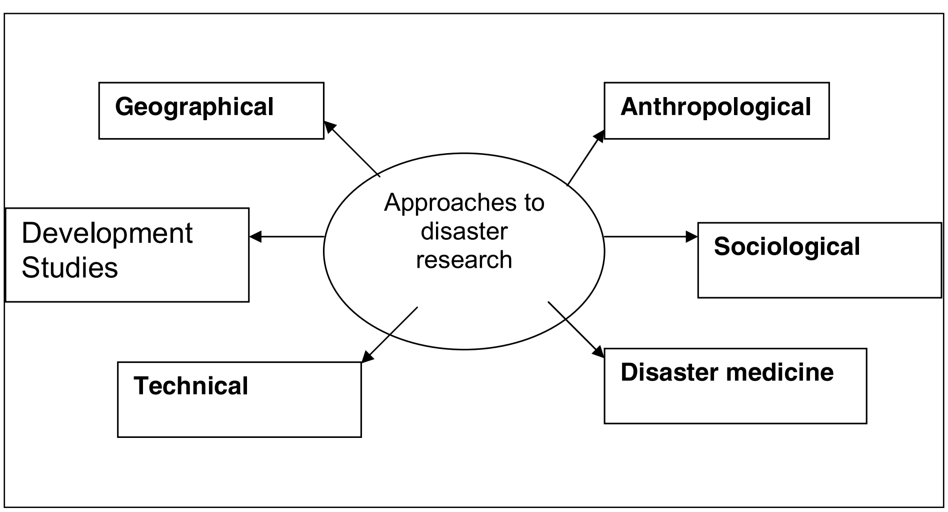
Although there is no coherent discussion in the sociological studies in the development of disaster research, attempts had been made to indicate some of the substantive trends in the development of sociology of disaster. Qurantelli and Dynes (1977) examined the sociological research of three decades on disaster and identified the following issues. (Box 1)

Box 1: Trends in Disaster Research

Efforts at codification
The development of a social organizational, rather than a social and psychological emphasis
The emphasis on groups, rather than individuals, as the basic unit of analysis
The increasing emphasis on the pre-impact period as the source of post-impact changes
The developing focus on functional and dysfunctional long range consequences and the initial attempts at model building
Source: Qurantelli and Dynes (1977)

Because disasters bring disruptions in the normal social life, create chaos, destroy social structure and contribute to replace social order, disaster research may be viewed as the study of 'social pathology' (Dynes, et al, 1978). However, Frtiz (1961) provided a sociological definition of disaster along with a rationale for which disaster should not be viewed as social pathology: "Disasters provide a realistic laboratory for testing the integration, stamina, and recuperative powers of large scale social systems. They provide the social scientists with advantages that cannot be matched in the study of human behavior in more normal or stable conditions".

***Figure 1**: Approaches to disaster research*



After surveying the general literature on disaster, Alexander (1993) identified six schools of thought on natural hazards and disaster studies: the geographical approach, the anthropological approach, the sociological approach, the development studies approach, the disaster medicine approach and the technical approach. (Figure 1).

The geographical approach (pioneered by Barrows, 1923 and White, 1945) deals with the human ecological adaptation to the environment with special emphasis on the 'spatio-temporal' distribution of hazard impacts, vulnerability and people's choice and adjustment to natural hazards. Social science methods are widely used in this approach.

The anthropological approach (Oliver-Smith, 1979, 1986; Hansen and Oliver-Smith, 1982) emphasizes the role of disasters in guiding the socio-economic evolution of populations. Anthropologists adopting this approach search for reasons why communities in the 'Third World' fail to provide basic requirements for their people's survival. They also discuss the 'marginalization syndrome' caused by impoverishment of disadvantaged groups in 'Third World' countries. The sociological approach (Dynes, 1970; Qurantelli, 1978; Mileti, Drabek and Haas, 1975; Drabek and Boggs, 1968; Drabek, 1986) discusses vulnerability and the impact of disaster upon patterns of human behaviour and the effects of disaster upon community functions and organization. Oliver-Smith (1996) developed three general themes as the major trends in anthropological research in disaster: behavioural response approach, social change approach, and political economic/ environmental approach. Oliver-Smith argues that disaster in developing world occur at the interface of society, technology and environment and is fundamentally the outcomes of the interactions of these characteristics. He has also reported that although occurrence of disaster is frequent, theoretical work in disaster research is limited.

The development studies approach (Davis, 1978; Knott, 1987) discusses the problems of distributing aid and relief to 'Third World' countries and focuses on refugee management, health care and the avoidance of starvation. The disaster medicine and epidemiology approach (Beinin, 1985) focuses on the management of mass casualties. It also includes the treatment of severe physical trauma and other diseases which may occur after a disaster.

The technical approach (Bolt et al. 1977; El-Sabh and Murty, 1988) focuses on geophysical approaches to disaster such as studied in seismology, geomorphology and volcanology and seeks engineering solutions.

Among these approaches two disciplines, geography and sociology, have dominated the field of disaster research since the 1950s and have emphasised the environmental and behavioural aspects of disaster. Drabek's (1986) findings on existing sociological literature are the significant contributions to the conceptual typology of sociological disaster research. He identified different areas of concern in disaster research such as planning, warning, evacuation, emergency, restoration, reconstruction, perceptions and adjustments. He discussed sociology of disaster under four major headings: preparedness, response, recovery and mitigation. However, most of the approaches and sociological research on disaster have been formulated and conducted for the developed world (especially the

USA). Their application to developing areas is problematic and very limited, as in the Bangladeshi cultural context. Moreover, there is almost no discussion of the gender response to disaster under any theoretical approach. In fact, only recently sociologists turned their attentions to the larger questions of social change related to disaster or the pre-impact conditions in disaster areas as sources of post-impact changes (Oliver-Smith, 1986).

Disaster research in Bangladesh

Disaster research in Bangladesh is conducted from six major approaches: geographical approach, behavioural approach, structural approach, historico-structural approach, sociological approach and anthropological approach. Although geographical and sociological approaches have dominated the field of disaster research in developed societies, disaster research in Bangladesh mainly followed the geographical approach. It can be said that disaster research from sociological approach in Bangladesh is done only in rare occasions.

Past research on natural disasters (such as, famine, river bank erosion, floods or cyclones) in Bangladesh has followed the geographical approach of the Chicago-Colorado-Clark-Toronto School of Natural Hazard Studies associated with Kates, 1962, 1971, White, 1964, 1974 and Burton et al., 1978. Disaster response studies (Islam, 1974; Paul, 1984; Alam, 1990, 1991) deal with people's behaviour, such as their perception, attitudes, beliefs, values, response and personalities. These studies fall in the first school of thought (i.e. geographical approach) described by Alexander. They are concerned with discovering people's choices, behaviour and adjustments to disaster, for example, how people viewed the hazard and how they perceived alternative opportunities available to them in coping with the hazardous events. However, social impact of disaster is also mentioned in some of these studies.

A recent publication, following geographical approach (Ahsan and Khatun, eds., 2004) in disaster focused on gender aspects during disasters. Various disasters such as flood, cyclone, riverbank erosion, earthquake, arsenicosis, famine and others have been discussed from geographical perspective. However, although in some of the writings in the study impact of disasters on people and coping with disasters have been emphasized, majority of them have only a geographical perspective.

Hossain et al (1987) examined, from behavioural approach, whether rural people in flood-free and floodprone areas adopted different survival strategies or not and also focused on the responses of rural people in general, but not on women's responses. Shaw (1989) highlighted the problems of poor women in a relief camp in Dhaka city. She noted how women bore the social burden of shame when living with strangers and drew attention to the difficulties women faced when trying to maintain parda during floods. In his study on riverbank erosion and floods Rahman (1988) argued that people's ability to adjust to hazards should be viewed as an extension of social and natural systems already existing in society. He also pointed out that there are differences in people's reaction to riverbank erosion and flooding according to their socio-economic location. Alam's (1991) study focused on the survival strategies of rural people on the flood-prone and relatively flood-free villages. The author observed that some middle and poor income households sold or mortgaged their lands and other assets to avert hunger during floods.

Research conducted following geographical and behavioural approaches are significant in relation to disaster studies but some of their interpretations regarding people's problems and behaviour are misleading (see for example, Islam, 1974). They see Bangladeshi people as 'traditionally fatalist'. This mistaken idea came from certain answers given by rural people in response to questions such as, "What do you do when flood hits your homestead?" and from the response, "Pray to God". The reasons for such responses were not studied carefully (Rahman, 1988). Zaman (1989; 1986) points out that behaviouralists fail to understand the socio-cultural background of adjustment for Bangladeshi people. Alam's (1991) study, however, discusses human behavioural factors in the context of existing social relations. He sees flood-prone people in relation to vulnerability and argues that people's behaviour differs by gender, age, ethnic group and economic status.

There are also structural (Brammer, 1975; Currey, 1978; Alexander, 1993) and historico-structural (Zaman, 1986) approaches to natural disasters. The structural approach sees disaster as a consequence of administrative or institutional weakness. This approach makes a valuable contribution regarding structural remedial measures to cope with disasters but lacks an understanding of people's own initiatives to cope with disaster. According to the historico-structuralist approach individual responses to disasters in Bangladesh should be viewed in a broad socio-cultural and historical context (Haque and Zaman, 1989). Some of the researchers (Latif, 1989; Custers, 1993) have pointed out that any steps to control disasters, e.g. floods, should emphasise both the structural (i.e. building of embankments) and nonstructural (i.e. people's initiatives) approach. They have discussed the problems and the negative consequences of floods and flood control projects for the environment, fisheries and many other aspects of life (Adnan, 1990; Boyce, 1990; Rogers et al., 1989; Pearce, 1991; Custers, 1993, Khalequzzaman, 1994).

Very recently (Hussain, 2001) anthropological approach to disaster has been discussed with only a few relevant ethnographic examples. The theoretical viewpoints of anthropological approach can be divided into four perspectives: human behavioural perspective, eco-feminist perspective, theories of vulnerability, and theories on women's oppression. The Flood Action Plan 14's (FAP-14) study (1992) on peoples' responses to floods was conducted under the auspices of the Bangladesh Flood Action Plan. Findings of 'The Gender Study' were included in FAP 14's draft final report (Hanchett and Nasreen, 1992). Using the case study method this study dealt with the experiences of a few women in female-headed households. It contributed significantly to the understanding of gender issues in floods through highlighting some of the major problems faced by women during floods.

Ahmed (1993) emphasizes the importance of kinship during disasters. The author conducted the anthropological study on the survivors of riverbank erosion and found that kinship, especially patriarchal, bonds are very strong in Bangladesh. In most of the cases the whole patrilineage becomes affected by riverbank erosion due to their proximity. The author argues that under such circumstances, it becomes difficult to seek support from patrilineage and many people depend on matrilineage for their family sustenance.

Like flood, cyclone is also a regular phenomenon, especially in the coastal areas and in offshore islands. In the Ain-E-Akbori of the 16th century cyclone is mentioned as a disaster in this belt. During the last three decades almost all of the coastal areas and offshore islands faced cyclones. Detail and in depth sociological study on cyclone is also limited in Bangladesh. Hossain et al (1992) conducted a research after the devastating cyclone of 1991. The cyclone extended from Teknaf in the southeastern seaboard to Barguna – a coast line of 644 kilometers. The study dealt with peoples' immediate responses to disaster in the context of providing support to the survivors, governments' relief operation, problems and contributions of women during disaster, warning system, support from NGOs, health, conditions of children and others. Although the researchers emphasized on some of the coping mechanisms adopted by the cyclone affected people and some of the social aspects related to disaster, they were not based on sociological approach and lack proper methods in social research.

Though useful, past studies did not take sociological approach into account. Although some of the abovementioned studies have considered socio-economic and cultural variables in assessing human responses to cyclones, riverbank erosion and floods, they have failed to provide a theoretical basis.

The pioneering disaster research (Nasreen, 1995) based on sociological approach portrait a detailed picture of a disaster experienced by rural households. It focused on the pre, during and post disaster activities performed by men and women during floods. The author argues that disaster affect both women and men but the burden of flood coping falls heavily on women. During floods men in rural areas lose their place of work while women shoulder the responsibilities to maintain households' sustenance. Nasreen (1995, 1999) argued that although poor rural women have very few options open to them to overcome their problems, their roles in disasters are obviously not simple: they relate to a complete range of socio-economic activities. During floods women continue to be bearers of children and responsible for their socialization, collectors and providers of food, fuel, water, fodder, building materials and keepers of household belongings: they also represent a productive potential which was not recognised earlier. The study argues that it is women's strategies, developed over the last few years, those are vital in enabling the rural people to cope with disaster. Government and many other bodies dealing with disaster management mainly communicate with wealthier, influential landowners who do not represent or serve the interest of the poor or of women. Nor does it seem to have occurred to policy makers that women might be involved in activities different from men or experience disasters differently than men.

Vast majority of the rural people is inextricably linked with the arsenic contaminated water for their daily survival. It is reported that most of these people neither had the idea of arsenic contamination, or the future impact of the catastrophe of *arsenicosis*. However, there has been very limited discussion on the socio-economic impact of arsenicosis in Bangladesh.

A sociological research (Nasreen, 2002) has been conducted on the problem of arsenicosis from a new environmental paradigm. It has been argued in the study that arsenic contamination in Bangladesh ground water is a widely recognized fact and that is causing suffering to millions. The author identified some of the social consequences related to arsenicosis such as social instability, superstition, ostracism, diminishing of working ability, increase of poverty, impact on women, disruption of social network and marital ties and causing death.

Hanchett (2003) argued that there is a gender side to the arsenic problem because women and men are affected in different ways. "Women who do know about the problem and wish to do something about it are faced with new demands on their time as they search for safer drinking/cooking water sources. Poor women also face insults – a problem they were able to avoid once they no longer needed to ask more affluent neighbors to share their safer wells".

Conclusion

Disasters are frequent events in Bangladesh. Disaster research in Bangladesh has been dominated by geographical approach probably because disasters are mainly considered as physical phenomena. However, although many disasters are related to physical phenomena, they mostly affect society, community, people, institutions and the overall environment. In this paper it is argued that less attention has been given to conducting in-depth research on disasters, especially from sociological perspective. In times of disasters government and other organizations pay attention to identify causes of disasters, mechanisms to control disasters and disaster mitigation instead of focusing on coping strategies. There is a need for timely and well-focused policy to solve disaster related problems. Raising of awareness regarding the coping mechanisms of disaster should be given priority. Sensitization of community people, law enforcement authority and policy makers to manage disasters and support to survivors are also necessary. Rehabilitation programme for disaster victims/survivors should be taken by all. Adopting Sociological approach is necessary to exhilarate any programme to manage disasters.

Sociological research is very much relevant to identify what attempts should be made to grasp the different issues relating to disasters, such as the problems, coping with the wounds and gender based differential impact of disasters on the survivors. It has been argued by the disaster research that women are the major victims of disasters due to their lower status than men in society. Thus attention should be given to special groups such as women and children. Programmes on disaster management will be most effective if they are backed by strong policy support and guidance. This paper lends support to the policy that a sociological perspective is necessary to involve disaster survivors in planning, that takes into account the disadvantageous position, especially of poor and of women and give priority to them.

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Women's Adjustment with Flood in Ganges Dependent Area of Bangladesh

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Abstract

The paper attempts to find out the adjustment practices of women with flood in Ganges Dependent Area (GDA) of Bangladesh. The study area is amongst the flood prone area of Bangladesh which is mostly dependent on the river Ganges (in Bangladesh, The Padma). The sources of the river are in the Himalayas, support rich ecosystems and irrigate million hectares of lands, thereby supporting some of the highest population densities in the world. The aim of this paper is to portray the adjustment procedures of women in Ganges Dependent Area of Bangladesh. Besides, the study also suggests some measures to deal with the flood disaster in the study area.

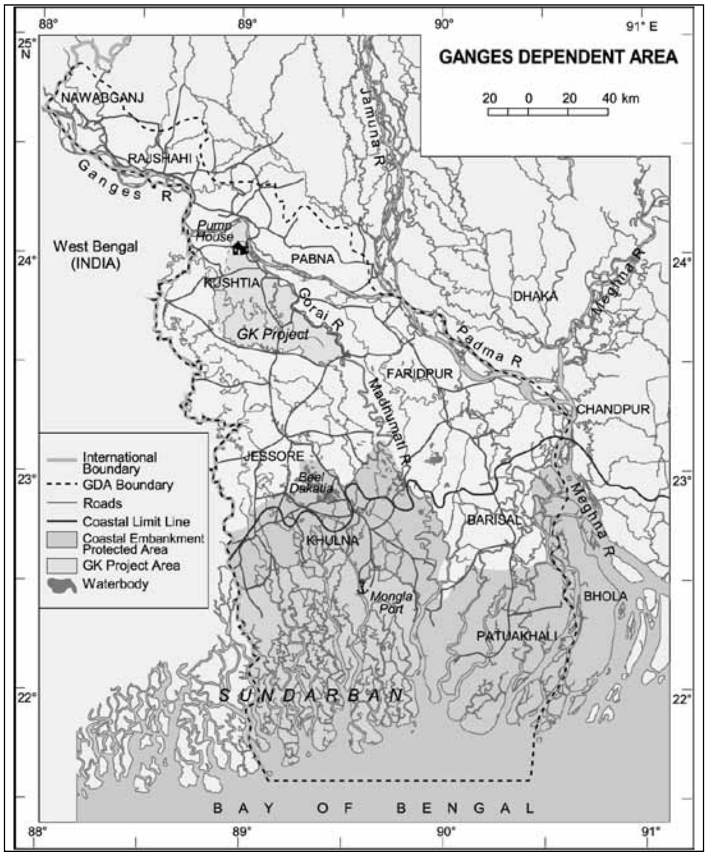
Key Words: *desertification, ecosystem, man-made disaster, river bed, salinity*

Introduction

Floods have visited Bangladesh more or less every year and often have been within tolerable limits and occasionally they become devastating. Each year in Bangladesh about 26,000 sq. km. (18% of the country) area is flooded. During severe floods, the affected area may exceed 55% of the total area of the country. In an average flood, 844,000 million cubic metre of water flows into the country during the humid period (May to October) through the three key rivers the Ganges, the Brahmaputra-Jamuna and the Meghna (Ahmad, 2005). The Ganges Dependent Area (GDA) is very prone to flood disaster in Bangladesh. Although the provision for women in disaster management strategies and national water policy of Bangladesh is not highlighted there are some coping strategies of the inhabitants; especially of women with flood disaster in the study area.

Study Area

Ganges Dependent Area (GDA) inside Bangladesh was considered asa study area in the present study. GDA covering almost 20% of Bangladesh is 30,000 sq. km inhabited by about 30 million people (Qazi, 1998). Nearly 35 million people in about one-third of the total area of Bangladesh are directly dependent upon the Ganges for their livelihood (Ganges River Controversy, 2009).



Map-1*: Ganges Dependent Areas (GDA) inside Bangladesh*
*Source**:** Banglapedia, 2008.*

Objectives of the Research

The research aims at the following specific objectives:

I. to portray the nature of flood in Ganges Dependent Area of Bangladesh;
II. to reveal the adjustment practices of women with the adverse effects of flood in Ganges Dependent Area of Bangladesh and;
III. to suggest some policy guidelines especially for women to cope with the problem of flood.

Methodology of the Research

The methods used for this study are a combination of questionnaire survey and case studies. Relevant data for this research were collected directly from the field by using a questionnaire which contained structured and open – ended questions containing the nature of flood, women's adjustment procedures with flood. The methodology adopted for the present study also makes extensive use of secondary material to build up and support the objectives of the study. Through reviewing available literature, broad outlines of the general setting under which the rural women have been operating under severe flooding have been gained.

Research approach was mainly based on household interviews. The sample size was 150 households with 10 case studies for the study. The household was the unit of the sample and each questionnaire was used for one household. The method of framing questionnaire is exclusively purposive. The key part of the questionnaire inquires the flood disaster scenario and the coping strategies at the household level response. They included all types of households regardless of profession, nature of work, academic attainment, social status, political attitude, land ownership, gender perspective and other components to get a respective opinion.

Floods in Ganges Dependent Area (GDA)

For a long time Satkhira, Khulna, Jessore and adjuring districts of Ganges Dependent Area of Bangladesh have been considered as flood free zone. But in recent years these districts have been inundated by floodwater almost successively. In September 2000, severe flood caused massive damage and sufferings in southwestern region (Uttaran, 2004). From September 9 to September 17 in the year 2009, excessive rain did fall upon in these districts due to low pressure and consequently deep low pressure in the sea (FPCO, 2009). Rain-fed floods generally happen in the deltas in the south-western part of the country. It should be noted that excessive rainfall also affected West Bengal and its adjuring states of Bihar of India. Excessive rainfall, high tide in the sea and water flow from India have created flood situation in Ganges Dependent Area of Bangladesh.

The causes of flooding and inundation in Ganges Dependent Area are various and multiple. As a result of high local rainfall and the historically eastwards progression of the mouth of the Ganges, the entire river system of GDA has evolved (Farzana, 2007). Only two rivers of significance remain connected to the Ganges-Padma, the Gorai- Modhumoti serving the GDA. The basins of rivers Kapatakha, Betrabati and Isamati have been affected by current floods in the study area. So far the basin of Kapatakha is the most flood-affected area. Because of ongoing inflow of flood water from India, the severity and damage of recent year's flood has increased significantly.

The flood has caused severe damage and sufferings for the people of this region. Millions of people have lost their homestead and lived subhuman life by taking shelter on embankment, roads and schools. The fishery and livestock sectors of this region have been severely affected by the floods. The marginal farmers were forced to sale their livestock at nominal price.

Adjustment Procedure of Women

In the study area, majority of the women live in rural areas and they contribute considerably to the household welfare. It is stated that poor women contribute about 45 percent of the total household income annually in rural Bangladesh (Khan, 1995). Regrettably, they are confined within the four-walls of households and incessantly face many nauseating situations and risks due to the male-dominated ideology and power structure. In fact, risks are the adverse effects of natural events such as flood, drought, salt water intrusion etc. or human activities such as deforesting, building dams etc. and shaped by culture. Traditional socio-cultural norms and practices affect women's access to formal and non-formal institutions such as educational institutions, cultural organizations etc. and services and reinforce their economic dependence on men (except the involvement of women in micro-credit). As a result, they are not completely able to cope with risks mostly arising from flood and to ensure their security and thereby leading them to the threat of relentless poverty.

They apply multiple strategies like defense mechanisms, problem solving and stress handling to face sudden risks, crises and periodic stresses in the household, which have not yet been systematically studied in Bangladesh context. Hence, it is important to explore properly the coping strategies selected by women to manage flood disaster risks arising from water under the complex circumstances. This study was, therefore, intended to address the following three key questions: a) what were the prominent risks to women in the household before, during and after flood? b) How did the women respond to these risks of flood? and c) What were the appropriate strategies for reducing women's household risks coming from flood? It was expected from this study that women could enhance their abilities to adapt with household adversities if productive resources and other relevant facilities were available to them by social and officially authorized institutions of the government during emergencies. It would lead to empower women through their enhanced self-confidence, bargaining power, income and assets.

The study reveals the determinants of household selection of three types of adjustments: i) current adjustment, ii) unsecured loans, and iii) secured loans. The general determinants set for both of the stages include incident of natural disasters, productive asset loss, health problems, and other income vulnerabilities. In addition, a number of household characteristics: education of household head, food security status (based on their occupations), and sex of household head, non food expenditure (as a proxy for household income level), variables measuring diversity of income sources and access to stable employment, value of household assets, are also included as explanatory variables for household choice of coping strategy.

The study points out ten (10) prime responses and also lots of small kind of adjustments by women before, during and after flood disaster in Ganges Dependent Area of Bangladesh. These can be classified in the following manner: I. Adjustments processes in small scale : includes collect famine foods, , collection of water, Sale of Women's Assets, taking care of family health care by women, Borrow grain from kin by the social network of women, repairing the house and surrounding with themselves, etc.; II. Adjustments processes in larger scale: includes sale of livestock, animals, tools and land (women's own land), female labor

Women and animals sharing the same room and as well as same destiny. ***Courtesy**: Asib and Salahuddin.*

Distribution of reliefs among men-

migration, use of credit and self employment, repairing their houses permanently with brick and cement and finally; III. Mass-migration.

The study also finds that small scale adjustment processes in GDA largely involved the activities of women, especially the poor categories. Women in poorer categories often acted as men did in making platforms, cutting bamboo, making bamboo bridges, protecting crops and livestock and engaging in income generating activities before, during and after flood in monsoon. In the study area the kind of food consumed, the sources of food for example, own gardens, markets, stores, food as wages, the amount and the frequency of food intake varied according to socio-economic category even when there was no food during drought condition. During floods there was a great difference in the kind of food, the amount and the frequency of food preparation and the sources of food among women in different socio-economic categories. The food supply of the poor undernourished and malnourished at the best of times, were further reduced during the floods. For adjusting with the household food consumption women play a significant role in the study area.

During the rain fed flood period this is very hard for women to collect drinking water. In Barisal and Patuakhali almost all the drinking water source (such as tubewell, well, pond, supplied water) went under water and poor as well as the middle class women had to take considerable risks to procure drinking water from great distances. Women had to walk through chest-high water or swim or sometimes they have small boat to collect fresh or clean water. Sometimes women helped each other to get water from tube-well using the indigenous practices. They put their water pots under the flat nozzles of tube-wells and started to pump, when they saw that the color of the water was different from the flood water, the raised the pots. But it was not always effective. Another technique but less successful was to hold a plastic bag over the sub merged nozzle of the pump. If there are some tube-wells at high land, women from the greater distances came there and collect water by lots of hard work.

It is evident from the study that without any healthcare facilities from government or other organizations during floods, it was women who provided health care for the sick especially to the children and old people. Only women had knowledge about certain medicinal trees and they used herbs, roots and barks to cure family members from different types of diseases during and after disasters. Men, on the other hand, rarely did such work because providing herbal treatment or nursing was not their gender-assigned role.

The study found that some assets, such as jewellary, livestock and household items, are more likely to be sold than others during flood crisis. This is common in the study area because these are assets which usually belong to women and they are often their only assets. Women's assets were used to meet the immediate needs of the households during hazards when men's assets were kept for the future.

Gender Disparities

After flood disaster women are more likely to rely on their own economic resources than before the disaster. Poor wives are treated as an economic liability after the disaster (UNDP, 2008). Studies show that government relief agents denied relief to women's as they were assumed to be supported by husbands. After losing the jobs directly or indirectly, it takes more time for women than men to be employed. In the post-disaster situation both men and women need income sources. But the main target for post-disaster relief and construction work project, targeted men over women.

Recommendations

In Bangladesh, disaster like flood, tend to be isolated in the perceptions of planners as a humanitarian issue to which ad hoc responses are made in the form of immediate relief, after which life goes on as before till the next crisis. It appears also to be a concern of geological and environmental scientists and activists but has yet to be integrated into an overall development perspective. Women in Ganges Dependent Area have not been fully mainstreamed in all policies and programmes at national and local levels in Bangladesh. It has yet to be recognised as a crosscutting issue even after four decades of international concern and advocacy by women's organisations. Women should be considered as an important factor in flood management in all policies and strategies adopted by Government.

Conclusion

Women are the major victims of environmental hazards especially floods that often damages their crops, livestock, fish stocks, property and lives. This article tried to have looked in the women's adjustment with disaster, based on the real experiences of women affected by flood in the Ganges Dependent Area of Bangladesh. To live with such vulnerable situations arising from flood disaster women needs to display enormous strength and capacity in managing risk to rebuild the damaged livelihoods and guarantee their family survival. Government can play a vital role to help women to cope with flood disaster in Ganges Dependent Area of Bangladesh.

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Flood Hazard and Risk Assessment in Mideastern part of Dhaka, Bangladesh

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Abstract

An inundation simulation has been done for the mid-eastern Dhaka (37.16 km2) on the basis of Digital Elevation Model (DEM) data from Shuttle Radar Topography Mission (SRTM) and the observed flood data for 32 years (1972-2004). The topography of the project area has been considerably changed due to rapid land-filling by land developers. So, collected DEM data has been modified according to the recent satellite image. The inundation simulation has been caonducted using HEC-RAS program for 100 year flood. Both present natural condition and condition after construction of proposed levee (top elevation ranges from 8.60 m to 9.00 m) have been considered for simulation. The simulation has revealed that the maximum depth is 7.55 m at the south-eastern part of that area and affected area is more than 50%.

Finally, according to the simulation result, a Flood Hazard Map has been prepared using the software ArcGIS. And risk assessment has been done and a Risk Map has been prepared for this area.

Keywords: *Inundation simulation, Flood Hazard, Risk Map*

Introduction

Dhaka is the largest and densely populated city in Bangladesh. The main natural hazards affecting Dhaka include floods, which are associated with river water overflow and rain water stagnation. In fact it is observed that some 60% of the Greater Dhaka East area regularly goes under water every year between June and October due to lack of flood protection in that area.

In 1991, JICA and ADB conducted feasibility study on this area. And in 2006, Halcrow Group Limited, UK, have done a study for updating/upgrading the Feasibility Study of Dhaka Integrated Flood Control Embankment. They divided the whole eastern part of Dhaka into three compartments. They proposed some structural measures which includes construction of embankment, flood wall, pump station and buildup of some pond area. But non-structural measures like preparation of Flood hazard map has not included. In this paper, middle part (compartment-2) is selected as study area and the main objective of this study is to do Flood hazard and risk assessment of that area.

Data

For this study two types of data have been used. Topographic data which includes DEM (Figure 1), satellite image (Fig.ure2) and river cross-section and hydrologic data covering rainfall, discharge and water level etc. And two software are used; ArcGIS (ESRI, 1999) for DEM data processing & mapping and HEC-RAS (Hydrologic Engineering Center, 2002) for hydrologic simulation.

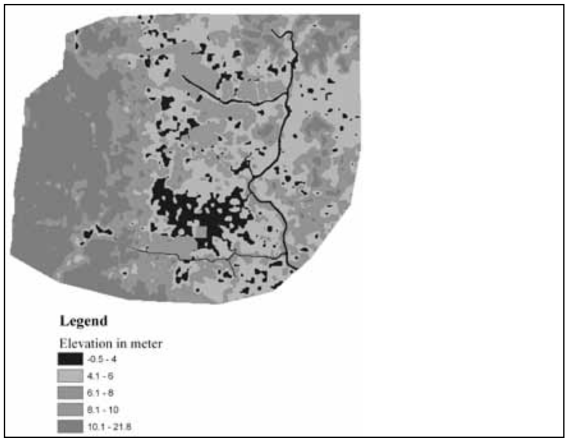

Fig. 1 *: Digital Elevation Model (DEM) of study area*

Fig. 2 *:Satellite Image of the study area*

Methodology

The methodology can be divided into three phases: Preparation Phase, Execution Phase and Verification & Flood Hazard Mapping Phase (Flow chart shown in Figure 3). Some important steps of these phases have been briefly described below.

Geo-referencing and Projection

Collected Satellite image has been Geo-referenced according to the geographic coordinate system (GCS_WGS_1984). DEM was also in geographical coordinate system. Geographic coordinate systems indicate location using longitude and latitude based on a sphere (or spheroid) while projected coordinate systems use X and Y based on a plane. Projections manage the distortion that is inevitable when a spherical earth is viewed as a flat map. Projected coordinate system used for this study is WGS_1984_UTM_Zone_45N which is suitable for Bangladesh.

DEM Modification

Grid resolution of collected DEM data is 90 m. The average width of the Balu river (passes through the study area) is around 100 m. So it is difficult to find elevation value on the river path line in that 90 m resolution DEM data. Another problem I faced was that the obtained DEM data was based on satellite image of year 2000. After that, a lot of land development work have been completed in this area which is observed in recent satellite image. So the DEM has been modified according to current topography. The steps are briefly described below.

1. In DEM, elevation values are integer format. So the DEM has been converted to float format.
2. The 90 m DEM has been re-sampled to 30 m resolution DEM using Bilinear interpolation method.
3. Then the DEM data through the river path has been extracted and converted into ASCII format and finally modified the elevation according to actual cross-section of the river in Microsoft Excel.

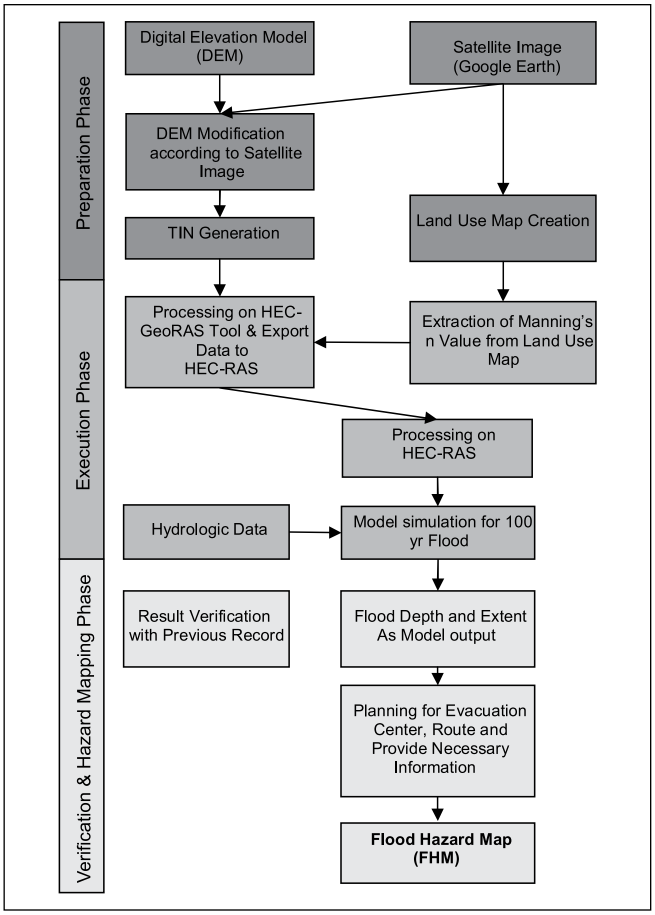

Fig. 3 *:Flow Chart of Methodology*

4. The DEM data of land filled area has also been extracted by observing recent satellite image and then raised the elevation.
5. Finally the modified DEM has been merged with the original DEM.

The DEM both before modification and after modification is shown in Figure 4.

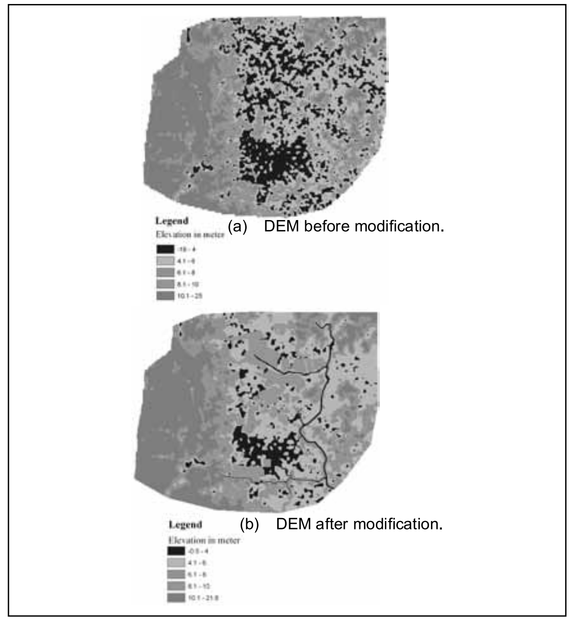

Fig. 4*: DEM for both before and after modification*

Processing on HEC-RAS

In HEC-RAS the geometric data has been imported which was exported from ArcGIS by HEC-GeoRAS tool. Main job in HEC-RAS is giving hydrologic data and assigning boundary condition and initial condition. From historical record it is observed that water level in this area reached maximum in 1988. The maximum water level has been input here as boundary condition. At upstream given water level is 7.2 m and at downstream it is 7.05 m. Initial flow 100 m3/s is given as initial condition. According to this condition a maximum inundation depth in every 20 m has been calculated for this area. Then this data has been exported to the ArcGIS.

Simulation result and observations

Obtained simulation result (shown in Figure 5) has been verified with observed inundation depth of 1988 flood and satellite image of just after cyclone "Sidr". It is observed that inundation depth ranges from 1 to 3 m covers most of the area (64 % with respect to total inundated area). But southern part of the study area is relatively low-lying where inundation depth is more than 3 m. However, buildup area located in western part is mostly unaffected due to higher topography. Percentage inundated area in the study area (compartment-2 shown in encircled by red line) is 54.5 %. Result obtained from this analysis is presented in Table 1.

***Table 1** :Percentage area inundated according to varying inundation depth*

Inundation Depth	Inundat ed area (sq. km)	% with respect to total inun- dated area	% with respect to whole area
4 m or higher	1.09	5	3
3 to less than 4 m	3.33	16	9
2 to less than 3 m	7.01	35	19
1 to less than 2 m	5.84	29	16
Less than 1 m	2.97	15	8
Total	**20.24**	**100**	**54.5**

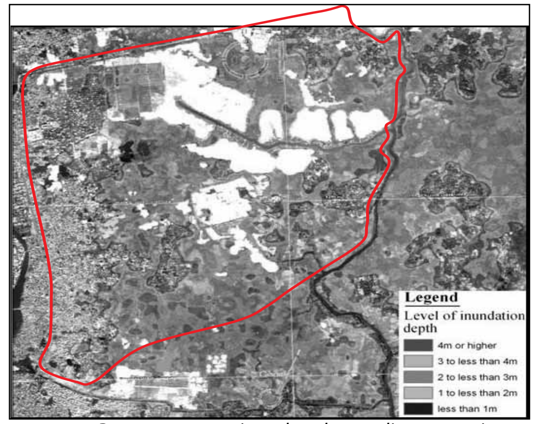

***Table 1** :Percentage area inundated according to varying inundation depth*

Flood Hazard Mapping and Risk Assessment

Preparation of Flood Hazard Map

A Flood Hazard Map has been prepared using the inundation status which was found from hydrologic simulation, as shown in Figure 6. According to inundation depth the whole area has been divided into five categories. Some evacuation centers have been proposed in the high area. Some important places such as hospital and police box have been marked in this map which are identified from satellite image.

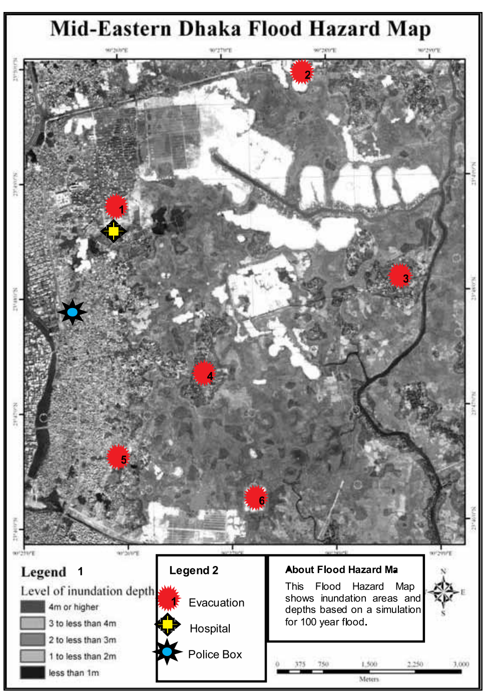

***Fig. 6** :Flood Hazard Map of Mid-eastern part of Dhaka*

Risk Assessment

The risk faced by people must be seen as a crosscutting combination of vulnerability and hazard. Disasters are a result of the interaction of both; there cannot be a disaster if there are hazards but vulnerability is (theoretically) nil, or if there is a vulnerable population but no hazard event (Wisner B. ; Blaikie P. ; Cannon T. and Davis I., 2004). These three elements: risk (R), vulnerability (V), and hazard (H), can be written in a simple form:

$$R = H \times V \quad (1)$$

Risk Map

In this study an attempt has been taken to make a Risk Map. Risk index has been calculated by multiplying vulnerability and hazard index. Average depth of inundation has been assigned as hazard index. And for calculating vulnerability index, percentage of area covered with house/living place and agricultural land have been considered. The followed steps are described below:

1. The whole study area has been divided into 300m - 300m block. Total number of block is 624.
2. For calculating average inundation depth in each block, obtained 20m-20m resolution inundation map has been re-sampled to 300m resolution using Bilinear interpolation method.
3. For each block an integer value ranging from 0 to 5 has been assigned as a Hazard index according to inundation depth (shown in (Table 2).
4. For Vulnerability index, a value ranging from 0 to 10 has been calculated for each block. Weight factor 10 and 2 used for area covered by house and agricultural land respectively. Equation 2 has been used for calculating Vulnerability Index.

Table 2 *:Assigned Hazard Index (H) for varying inundation depth*

Inundation Depth	**Hazard Index (H)**
No inundation	0
Less than 1 m	1
1 to less than 2 m	2
2 to less than 3 m	3
3 to less than 4 m	4
4 m or more	A5

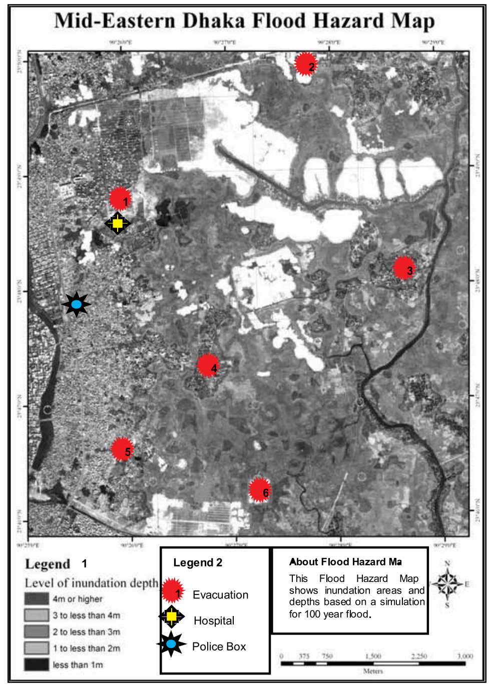

Fig 7 *:Risk Map of Mid-eastern part of Dhaka*

5. A Risk index for each block has been calculated by multiplying Hazard and Vulnerability index (Equation 3).
6. Then these Risk values have been converted to raster format and imported to ArcGIS.

$$V_{Index} = \frac{10 \times A_{House} + 2 \times A_{Agriculture} + 0 \times A_{No\ Use}}{A_{Total}} \qquad (2)$$

Where
V_{Index} = Vulnerability Index (ranging from 0 to 10)
A_{House} = Area Covered by House/Living Place
$A_{Agriculture}$ = Area Covered by Agricultural Land
$A_{No\ Use}$ = Area used for neither Living nor Agricultural
A_{Total} = Total Area of each Block

$$R_{Index} = H_{Index} \times V_{Index} \qquad (3)$$

Where
R_{Index} = Risk Index (ranging from 0 to 50)
H_{Index} = Hazard Index (ranging from 0 to 5)
V_{Index} = Vulnerability Index (ranging from 0 to10)

7. A Risk Map (Fig. 7) has been prepared by classifying into three categories: Low, Medium and High risk area according to Risk index (Table 3).

***Table 3** : Area classification according to Risk Index*

Risk Index	**Level of Risk**
1 to less than 5	Low risk area
5 to less than 10	Medium risk area
More than 10	AHigh risk area

Conclusion

It is observed in Risk Map that high risk zone covers very few areas and it is located mostly near river bank and in transitional zone between western built up area and low-lying area. In this area risk is high because, area coverage with houses is high this means population density is also high in the area. High risk area represents the area where people are more exposed to hazard than those living in other locations.

It is observed that western built up area is completely risk-free though the area is densely populated There is no inundation in this area and it means risk index is zero. Southern area where inundation depth is maximum, falls in medium risk category though no people living there. Because this area mostly covered by agricultural field.

Recommendation

The objective of Flood Hazard Map is to provide residents with the information on the range of possible damage and the disaster prevention activities. The effective use of Hazard Map can decrease the magnitude of disasters. From the resident point of view, it is an effective tool to reduce flood damage. On the other hand, Flood Risk Map represents the current scenario of that area according to degree of risk. This is very much useful for government. By using it government can prioritize some area according to degree of risk. In emergency, government can take necessary steps as soon as possible according to priority basis. As land development and urbanization is going on that area both maps should be updated regularly. The following recommendations are made for upgrading these maps:

1. Rainfall, evaporation, percolation which are ignored in current study can be included for further studies.
2. Town watching, conversation with local people and survey are very important work for making an effective Flood Hazard Map. But this work could not be performed for this study. For future studies this should be conducted.
3. For risk mapping, Hazard index has been assigned according to inundation depth. But other factors such as frequency of flood, duration of flood, etc. should be considered. For assigning Vulnerability index, two factors such as percentage of area covered with house and agricultural field have been considered. But there are lots of factors other than that responsible for degree of vulnerability which should be considered for future studies.

Acknowledgement

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Sustainable Flood Management in Changing Climate

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Abstract

The recent great floods that affected the India (1998, 2008, 2009), Pakistan (2010), Nepal (1998) and Bangladesh (1998, 2004, 2007) attracted great attention and increase in extreme weather events during last two decades created a stir. The urban floods in Mumbai (2005) and Karachi (2009) are just a few examples of exceptional floods. The analysis of worldwide loss events shows that there are distinct increases in respect of the economic losses, developments in term of the number of events represent no or only a moderate trend. Loss amounts have risen all over the world, with enormous increases in economic losses even in less developed countries.

Global environmental change is expected to increase the frequency and intensity of current extreme weather events especially greater rainfall variability (intense heavy rains and less rainy days). This unprecedented change is expected to have severe impact on the hydrological cycle, water resource (flood, drought, drinking water, forest & ecosystems, sea level/coastal area (losses of coastal wetlands and mangroves), food security, health and other related areas. The impact would be particularly disastrous for developing countries, including India and further reduce the resilience of poor, vulnerable communities, which make up between one quarter and one half of the population of most Indian cities. In the process of development, rapid development of coastal areas, urbanization, agriculture expansion, increasing population, rapid industrialization, more areas/population are becoming vulnerable to climate risk and many have no choice to migrate to safer places. On the contrary, the 'safer places' are itself getting reduced.

Today, the hydrological cycle is being modified quantitatively and/or qualitatively in most agro climatic regions and river basins of India, by human activities such as land use change, water uses, inter-basin transfers, cropping pattern, irrigation and drainage. In view of this, sustainable management of water and the supporting natural environment have gained considerable importance in recent years. An assessment of the availability of water resource in the context of future national requirements taking particular account of the multiplying demands for water and expected impacts of climate change and variability is critical for resource planning and sustainable development as a basis for economic and social development. The paper is intending to develop an integrated framework for addressing the issue of climate change, flood water, community adaptability and disaster risk reduction.

Introduction

It is well known fact that, worldwide flooding is the leading cause of losses from natural hazards and is responsible for a greater number of damaging events than any other type of natural event. At least one third of all losses due to nature's forces can be attributed to flooding. Flood damage has been extremely severe in recent decades and it is evident that both the frequency and intensity of floods are increasing. In the past ten years losses amounting to more than 250 billion dollars have had to be borne by societies all over the world to compensate for the consequences of floods. The SAARC Countries, namely Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka are being gets affected with a multitude of climate related hazards, such as cyclones, floods, drought, extreme temperature, storm surges and Glacial Lake Outburst Floods. The fourth assessment report of IPCC and first assessment report of Indian Network of Climate Change Assessment (INCCA, 2010) has confirmed that in future, Climate change is expected to increase the frequency and intensity of current climate related hazards, greater monsoon variability and also the emergence of new hazards turning into disaster i.e. sea level rise and new vulnerabilities with differential spatial and socio-economic impacts on communities. The increasing frequency and intensity of the mentioned hazards in combination with the socio economic parameters of the sub continent result in high levels of vulnerability of the population, physical and economic assets. The impact would be particularly disastrous for developing countries and further degrade the resilience of poor, vulnerable communities, which make up between half of the population of SAARC Countries. These are the most vulnerable countries to climate change and climate variability, and is identified as one of the most threatened eco- systems from the effects of the climate change (MoEF, 2010; Mall et al., 2006, 2011).

In India, almost 67% of the glaciers in the Himalayan mountain ranges have retreated in the past decades. Available records suggest that Gangotri glacier is retreating about 30 meters per year. A warming is likely to increase the melting far more rapidly than the accumulation. The past 200 years of instrumental observations indicate that the summer monsoon rainfall has undergone multi-decadal epochal variations in terms of the frequencies of droughts/ floods (i.e., alternating 20-30 year periods of more and less frequent droughts), however, on a smaller space scale, there are areas showing both increasing (e.g. west coast) and decreasing (e.g. east central India) long term trends in monsoon rainfall, sharp decrease in rainy days (Goswami et al., 2006; Rajeevan et al., 2006; Ramesh and Goswami, 2007; IPCC, 2007; INCCA, 2010). Recently Goswami et al (2006) found that the frequency of occurrence as well as intensity of heavy and very-heavy rainfall (> 150 mm) events have highly

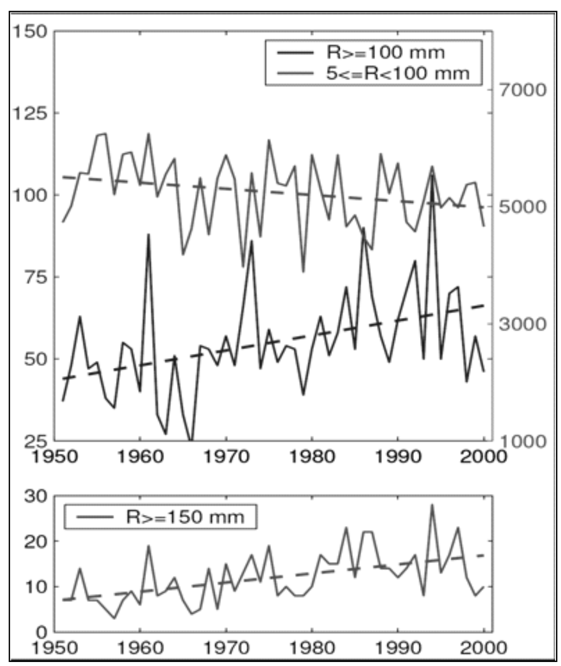

***Figure**: 1: Changes in the Frequency of Extreme Rainfall over central India (Goswami et al., 2006).*

significant increasing trends; low and moderate (<100 mm) events have significant decreasing trend over Central India (Figure. 1).

Climate change is a global problem and India will feel the heat due to its unique geophysical and hydro-climatic conditions. Presently, about 68% area liable to droughts, 8% area is prone to cyclone and 40 million hectare area (1/8 th of total area) is prone to floods. In the decade 1990-2000, an average of about 4344 people lost their lives and about 30 million people affected by disasters every year. In 2006 at global level, the most significant disasters in terms of economic damage was the flood in India i.e. US$ 3.39 billion (0.29 % of the previous year GDP) and around 40 millions were victims. The reported natural disasters and number of people killed were 21 and 1521 respectively during 2006 in India (CRED, 2007). In 2008 in India, 1063 person killed and 79 lakhs persons affected by flood (http://www.emdat.be/).

In future water resources will come under increasing pressure in Indian subcontinent due to the changing climate. The climate affects the demand for water as well as the supply and quality. Assessing the potential socioeconomic impacts of climate change involves comparing two future scenarios, one with and one without climate change. Uncertainties involved in such an assessment include: (1) the timing, magnitude and nature of climate change; (2) the ability of ecosystems to adopt either naturally or through managed intervention to the change; (3) future increase in population and economic activities and their impacts on natural resources systems; and (4) how society adapts through the normal responses of individuals and businessman and through policy changes that after the opportunities and incentives to respond. The uncertainties, the long times involved and the potential for catastrophic and irreversible impacts on natural resources systems raise questions as to how to evaluate climate impacts and investments and other policies that would affect or be affected by changes in the climate. In view of the above, an attempt has been made in this study to give a brief resume of flood management and possible impact of climate change on India's water resources and way for a sustainable management.

Floods in India

(a) Periodicity and Occurrence

Rain gauge records of the Indian monsoon are available for over a century. In 1910, Sir Gilbert Walker, the then Director General of the India Meteorological Department, used gauge records since 1840 to describe the variability of Indian monsoons. The analyses of the rainfall records of the monsoon trends have continued till this day. These analyses have yielded a 30-year cyclicity of the Indian monsoons (Mall et al., 2006).

Floods and cyclones are the natural disasters where excess of water (rains) creates the havoc in India. In floods, the swollen rivers with overflowing banks do the damage in flood plains. Of late, flooding or water logging is becoming a major problem in urban and metropolitan areas. Cyclonic storms pose a hazard mainly in coastal regions (more on the east coast as compared to the west coast) but no place in the country is free from floods (even Rajasthan suffers from floods and flooding) although flood plains of rivers and cyclone-affected coastal regions are most prone to floods. While cyclone is a natural disaster in the full sense of the term, flood problem (including flooding) has been seriously aggravated by human activities such as overgrazing, deforestation, soil erosion and siltation. On the average, the area actually affected by floods every year in India is of the order of 10 million hectares of which about half is cropland. In fact, the area prone to floods in India has been estimated to be of the order of 40 million hectares. Persistent occurrence of rainfall over an area already soaked with rain or intense rainfall often results in flood. Excess water in a river, due to heavy and/or persistent rains in the catchment area or the upper regions of the river system also create flood downstream. Absence or lack of adequate drainage in any area will aggravate the flooding. Flash floods occur due to high rate of water flow as also due to poor permeability of the soil. Areas with hardpan just below the surface of the soil are more prone to floods as water fails to seep down to the deeper layers.

As is evident, floods and drought occurring in India are closely associated with the nature and extent of the summer monsoon. The interannual fluctuations in the summer monsoon rainfall over India are sufficiently large to cause devastating floods or serious droughts (Fig. 2).

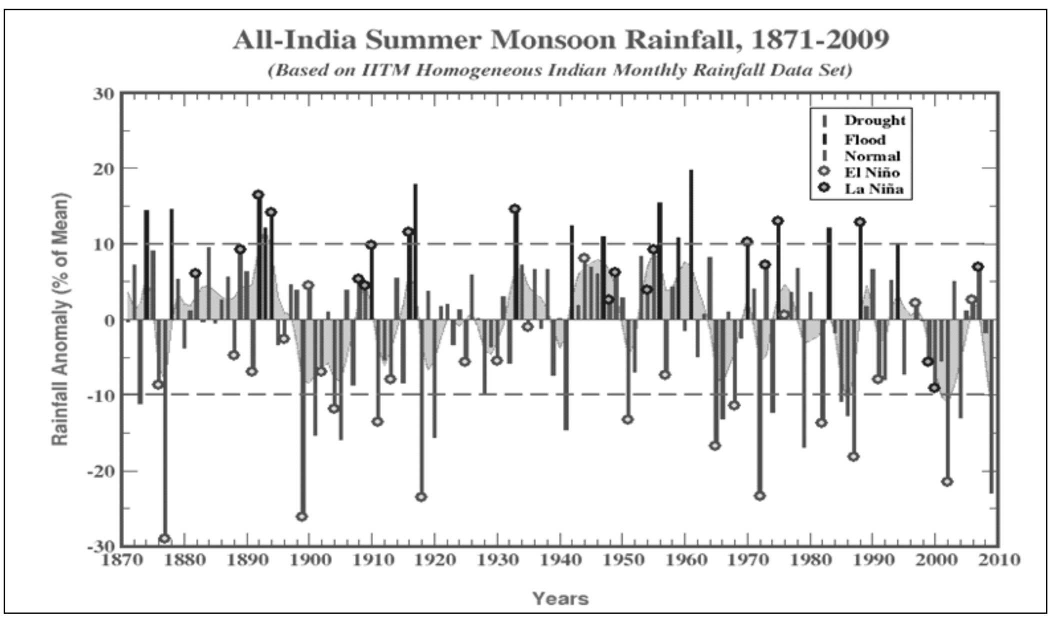

***Figure 2**: All India Summer Monsoon Rainfall, 1871-2009 (Source: IITM-Pune, India)*

(b) Impact and Trends of Floods

India is one of the most flood prone countries in the world. Twenty-three out of thirty two-states/union territories in the country are subject to floods and 40 million hectares of land, roughly one-eight of the countries geographical area, is prone to floods. The national Flood Control Program was launched in the country in 1954. Since then sizeable progress has been made in the flood protection measures. By 1976, nearly one third of the flood prone area had been afforded reasonable protection; considerable experience has been gained in planning, implementation and performance of flood warming, protection and control measures (CWC, 2007).

Fig.3: *Floods In India*

On an average (1953 to 2010), the floods resulted in an annual damage of more than Rs. 1800 crore besides the loss of precious human lives and cattle. The highlights of flood damages in India during the period of 1953-2010 are given in Table 1 (Planning Commission, 2011).

***Table**: 1: Flood affected area and damages in India (1953 to 2010).*

Sl No.	Item	Unit	Average Annual Damage	Maximum Damage (Year)
1	Area Affected	Million Hectare	7.208	17.50 (1978)
2	Population affected	Million	3.19	7.045 (1978)
3	Human Live Lost	Nos.	1612	11316 (1977)
4	Cattle Lost	Nos.	89345	618248 (1979)
5	Cropped Area Affected	Million Hectare	3.679	15.18 (2005)
6	Value of Damage Crops	Rs. Crore	693.866	4246.6 (2000)
7	Houses Damaged	Th. No.	1194.64	3508 (1978)
8	Value of Damage Houses	Rs. Crore	275.48	1307.9 (1995)
9	Value of Damage Public Utilities	Rs. Crore	814.596	5606 (2001)
10	Value of total Damage to Houses, Crops and Public Utilities	Rs. Crore	1804.419	8864 (2000)

***Source**: Planning Commission (2011)*

Floods occur in almost all rivers basins in India. Heavy rainfall, inadequate capacity of rivers to carry the high flood discharge, inadequate drainage to carry away the rainwater quickly to Streams/ Rivers are the main causes of floods. Ice jams or landslides blocking streams; typhoons and cyclones also cause floods. Excessive rainfall combined with inadequate carrying capacity of streams resulting in over spilling of banks is the cause for flooding in majority of cases. The area affected by flood in the country from 1953 to 2007 is given in Figure 4.

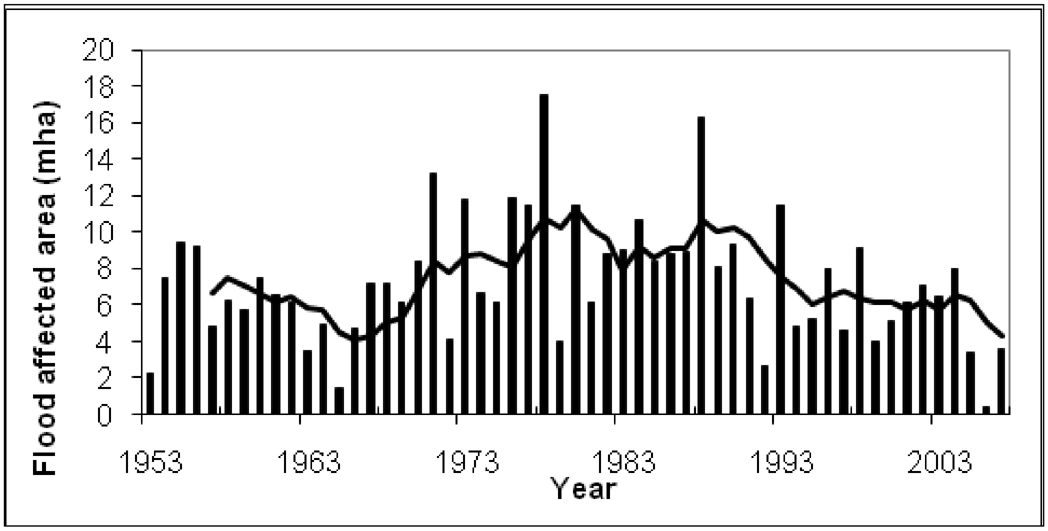

Figure 4: *Area affected by flood (1953 to 2007).*

On the average, the area actually affected by floods every year in India is of the order of 10 million hectares of which about half is cropland. Rashtriya Barh Ayog (RBA) constituted by the Government of India in 1976 carried out an extensive analysis to estimate the flood-affected area in the country. RBA in its report has assessed the area liable to floods as 40 million hectares. Persistent occurrence of rainfall over an area already soaked with rain or intense rainfall often results in flood.

Vulnerability to floods and other natural disasters is caused by the high population density, widespread poverty, unemployment, illiteracy, enormous pressure on rural land, and on economy traditionally dominated by agriculture. Children and women are particularly vulnerable. Eighty-five percent of the deaths during disasters are women and children (CRED, 2000). This can be attributed to malnourishment and ill health. Social causes can also lead to deaths of women. Women traditionally play the role of protector of house and belonging; they are usually reluctant to go to secure shelters.

Gupta et al. (2003) found that at present clearly an inadequate level of protection in the country against floods. Though non-structural measures improves the preparedness to floods and reduce losses, the necessity of structural measures would always remain to reduce the extent of physical damage caused by floods. In addition to that, there is clear evidence to suggest that exploitation of the environment can significantly impact the frequency and severity of natural disasters like floods. In future, at the national level, flood control and management planning along with climate change need to be integrated into development planning for the country.

Nath et al, (2008) discussed the outline of flood management. He has stressed the coordination by district disaster management committee before the onset of monsoon season and the very onset of the flood hazard, the highest priority is on 'search, rescue and evacuation', in addition to' organization of relief facilities'. Kale et al (1997) reviewed the flood situation in India and found that existing studies seems to concentrate in two areas viz first deals with hydro meteorological analysis of flood producing rainfall and associated synaptic conditions and second area is related to stream flow analysis and the estimation of design floods. This trend is likely to continue in future. While the quantitative approach to the problem is indispensable in predictive models, it is felt that future opportunities to improve our understanding of this recurring natural hazard should include research into the natural trends and the behavior of floods on longer time scale, and increased evaluation of the impact of anthropogenic activities on the river system (Mall et al., 2006; Gosain et al., 2006).

Observad Changes in Climate During 20th Century

In India, several studies shows that there is increasing trend in surface temperature i.e. 0.5 to 0.6o C during 1901-2005 and 0.05o C/decade year during the period 1901-2003, the recent period 1971-2003 has seen a relatively accelerated warming of 0.22oC/decade, (Singh and Sontakke, 2002; Kothawale and Rupakumar, 2005; Mall et al. 2006; Das & Hunt 2007), no significant trend in rainfall and/or decreasing/increasing trends in rainfall and sharp decrease in rainy days (Singh and Sontakke, 2002; Goswami et al., 2006; Rajeevan et al., 2006; Ramesh and Goswami, 2007). Singh and Sontakke (2002) found that the summer monsoon rainfall over western Indo Gangetic Plain Region (IGPR) shows increasing trend (170 mm/100 yrs, significant at 1% level) from 1900, while over central IGPR it shows decreasing trend (5 mm/100 yrs, not significant) from 1939, and over eastern IGPR decreasing trend (50 mm/100 yrs, not significant) during 1900-1984, and insignificant increasing trend (480 mm/100 yrs, not significant) during 1984-1999. Broadly it is inferred that there has been a westward shift in rainfall activities over the IGPR. Recently Goswami et al (2006) found that the frequency of occurrence as well as intensity of heavy and very-heavy rainfall events have highly significant increasing trends; low and moderate events have significant decreasing trend over Central India.

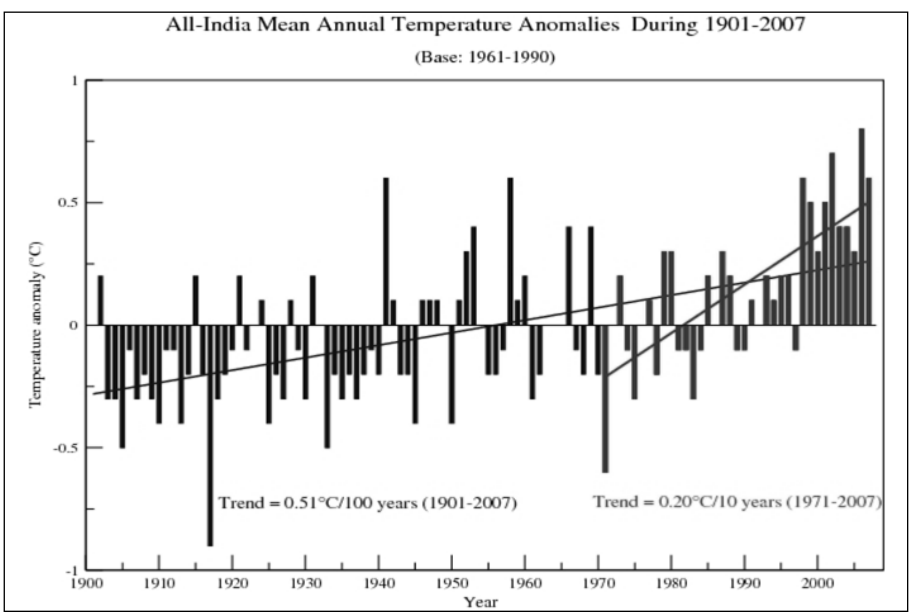

***Figure 5**: All India Mean annual temperature anomalies during 1901-2007 (Source: IITM, Pune).*

Course Change by Rivers

Reddy et al (2008) reported that during 1990 to 2004 Kosi River shows a significant shift of 3.5 km in northwestern part, followed by central and north eastern parts of river with 2.5 km shift. Course change by the rivers is an environmental problem of serious concern in the Indo Gangetic Plain Region (IGPR). At different times in the past different rivers changed their course a number of times. During the period 1731-1963 the course of the Kosi river (the sorrow of Bihar) has shifted westward by about 125 km, the courses of Ganga, Ghaghara and son at their confluence have shifted by 35 to 50 km since epic period ~ 1000 BC and that of Indus and its tributaries by 10-30 km in the 1200 years in the same. Between 2500 BC and 500 the course of the Yamuna river shifted westward to join Indus and then east to join Ganga thrice (Mall et al., 2006).

Several studies in India projected an increase in all India mean surface temperature and change in mean precipitation (increases/ decreases, change in intensity, less rainy days) with significant regional variations (Rupa Kumar et al 2006 and Krisha Kumar 2010, INCCA, 2010).

Projected Climate Change over india

Recently, according to report published by Ministry of Environment and Forest (MoEF, 2010); the projection of precipitation indicates 3% to 7% overall increase in all India summer monsoon rainfall in 2030s with respect to the 1970s; the annual mean surface air temperature rise by 2030s range from 1.7o c to 2o C and the variability of seasonal mean temperature may be more in winter months. This report also indicates that the frequency of rainy days is set to decrease in most part of the country and intensity of rain is going to increase, accept in the Himalayas, north western region and southern plateau. The daily extremes in surface temperature may intensify in the 2030s. The spatial pattern of the change in the lowest daily minimum and highest maximum temperature suggests a warming of 1 to 4 C towards 2030s. The warming in night temperatures is more over south peninsula, central and northern India, whereas day time warming is more in central and northern India.

Hydrologic Implication of Climate Change:

Different General Climate Models (GCMs) linking atmospheric chemistry to complex atmospheric and oceanic processes are used to project climate variables such as temperatures and precipitation. Climate model projection vary widely depending upon assumptions as to future scenarios and the sensitivity of the climate to change in atmospheric chemistry and how the models incorporate factors such as cloud cover, ocean currents and land surface characteristics. While the wide range of projection from the different models, methodologies and assumptions make it difficult to draw conclusions at river basin and watershed levels, some pattern as to the likely impacts of a global warming on water resources do emerge. Some of the projected principal hydrologic impact noted in the IPCC (2007) and INCCA (2010) assessment are:

1. An increase in global mean temperature of 1.5 - 4.5o C would increase global mean precipitation about 3-15%.
2. Higher Evapotranspiration rates may lead to decrease runoff even in areas with increased precipitation.

3. More intense precipitation days are likely in some regions, which could contribute to an increase in food frequencies.
4. The frequency and severity of droughts could increase in some areas as a results of a decrease in rainfall more frequent dry spells and greater ET.
5. Higher temperatures would shift the relative amounts of snow and rain and the timing of runoff in mountainous areas. This shift could increase the likelihood of flooding early in the year and reduce the availability of water during period of high demands.

A case study of Orissa and West Bengal estimates that in the absence of protection, one-meter sea levels rise would inundate 1700 km2 of predominantly prime agricultural land (IPCC, 1992). The regional effects of climate change on various components of the hydrological cycle, namely surface run-off, soil moisture, and evapotranspiration (ET) for three-drainage basis of central India is analyzed and results indicated that the basin located in a comparatively drier region is more sensitive to climatic changes. The high probability of a significant effect of climate change on reservoir storage, especially for drier scenarios, necessitates the need of a further, more critical analysis of these effects.

The hydrologic sensitivity of the Kosi Basin to projected land-use, and potential climate change scenarios has been analyzed. It was found that runoff increase was higher than precipitation increase in all the potential climate change scenarios applying cotemporary temperature. The scenario of contemporary precipitation and a rise in temperature of 4o C caused a decrease in runoff by 2-8% depending upon the areas considered and model used (Sharma et al., 2000a, b).

Gosain et al. (2003, 2006) projected that the quantity of surface runoff due to climate change would vary across the river basins as well as sub basins in India. However, there is general reduction in the quantity of the available runoff. An increase in precipitation in the Mahanadi, Brahimini, Ganga, Godavari and Cauvery is projected under climate change scenario; however, the corresponding total runoff for all these basins does not increase. This may be due to increase in ET because of increased temperature or variation in the distribution of the rainfall. In the remaining basin, a decrease in precipitation noticed. Sabarmati and Luni basin shows drastic decrease in precipitation and consequent decrease of total runoff to the tune of 2/3rd of the prevailing runoff. This may lead to severe drought conditions in future. The analysis has revealed that climate change scenario may deteriorate the condition in terms of severity of droughts and intensity of floods in various parts of the country. There have been few more studies on climate change impacts on Indian water resources (Roy et al., 2003; Tangri, 2003).

Singh et al. (2009) highlighted the assessment of the water resources in changing climate for relevant national and regional long-term development strategies. Goyal (2004) studied the sensitivity of ET to global warming for arid regions of Rajasthan and projected an increase of 14.8% of total ET demand with increase in temperature, however ET is less sensitive to increase in solar radiation, followed by wind speed in comparison to temperature. Increase in water vapor has a negative impact on ET (-4.3%).

He concluded that a marginal increase in ET demand due to global warming would have a larger impact on resource poor, fragile arid zone ecosystem of Rajasthan.

Climate Change Policy in India

The Government in India is actively involved with climate change activities since long. India is a Party to the United Nations Framework Convention on Climate Change (UNFCC). The Eight session of the Conference of Parties (COP-8) to the UN convention on Climate Change in 2002, New Delhi ended here with a Delhi Declaration has successfully resolved the technical parameters necessary for the implementation of the Kyoto Protocol (1997). The Delhi declaration gave primacy for the implementation of the Clean Development Mechanism (CDM) in the climate change process. The National Clean Development Mechanism Authority is operational since December 2003 to support implementation of CDM projects. The Bali conference on climate change (December 2009) showed all the countries the way forward to the next phase of the campaign to control the planet's changing climate, the specific objective being to put a multilateral arrangement in place that will succeed the 1997, Kyoto Protocol of the UN convention on Climate Change, which will terminate in 2012.

To address the future challenges, in June 2007, the Government announced the constitution of a high-level advisory group on climate change and prepared a **'National Action Plan on Climate Change'** and that was released by the Hon'ble Prime minister of India on June 30, 2008 (http:/pmindia.nic.in/Climate%20Change_16.03.09.pdf); which is in line with the international commitments and contains eight missions on climate mitigation and adaptation (NAPCC, 2008). Now relevant ministries are preparing and submitting their respective plans to the Prime Ministers Climate Change Council. One of the missions **"National Water Mission"** will be mounted to ensure integrated water resources management helping to conserve water, minimize wastage and ensure more equitable distribution both across and within states. The mission will take into account the the provisions of National Water Policy and develop a framework to optimize water uses and by increasing water use efficiency by 20% through regulatory mechanism and differential entitlements and pricing. It will seek to ensure that considerable share of water needs or urban areas are met through recycling of waste water, and ensuring that the water requirements of coastal cities with inadequate alternative sources of water are met through adoption of new and appropriate technologies such as low temperature desalination technologies that allow for the use of ocean water (Singh et al., 2009).

Based on the this current study it may be mentioned that for long term adaptation from Climate Variability and Climate Change several policy instruments are available at different levels and these instruments are functioning in real sense even at the remote village levels but needs improved governance, productivity and accountability of the government machinery. Conversely, over the last two decades there has been a sharp decline in the quality of services provided by the government to its citizens, especially poor.

Disaster Management Policy in India

The emergence of a permanent and institutionalised setup began in the decade of 1990s. The disaster management cell was established under the Ministry of Agriculture, following the declaration of the decade of 1990 as the 'International Decade for Natural Disaster Reduction' (IDNDR) by the UN General Assembly. Further, India witnessed series of disasters such as Latur Earthquake (1993), Malpa Landslide (1994), Orissa Super Cyclone (1999) and Bhuj Earthquake (2002) which reoriented the policy action and led to the shift from financing relief to a holistic approach for addressing disaster management. Consequently, the disaster management division was shifted under the Ministry of Home Affairs in 2003 and a hierarchical structure for disaster management evolved in India. Shifting from relief and response, disaster management in India started to address the issues of early warning systems and forecasting and monitoring setup for various weather related hazards. Consequently, a structure for flow of information, in the form of warnings, alerts and updates about the oncoming hazard, also emerged within this framework.

In 2002, a High Powered Committee Report on Disaster Management recommended establishment of a separate institutional structure for addressing disasters and enactment of a suitable law institutionalising disaster management. Further, the 10th Five Year Plan of India (2002-2007) identified the need for disaster management interventions beyond merely financing relief. The plan stressed on the need for integrating disaster management with development process. The Status Report on Disaster Management (2004) also identified that development, to be sustainable, has to take into account the disaster mitigation needs. These developments necessitated institutionalization of disaster management framework in India and consequently, <u>the Disaster Management Bill was presented in the Parliament in 2004.</u> The Bill was adopted in August 2005. Following the implementation of the Bill, the National Disaster Management Authority was set up in 2005. Disaster management came to be identified as "continuous and integrated process of planning, organising, coordinating and implementing measures required for preventing disasters, mitigating the risk, capacity building, increasing the preparedness levels, response actions, disaster assessments, evacuation, rescue and relief and rehabilitation". The Disaster Management Bill facilitated mainstreaming disaster management in many ways; firstly, by mandating the involvement of various development-related sectors in the disaster management framework, and secondly, by directing them to prepare and execute disaster management plans in their respective sectors of functioning, thirdly, by making provisions for separate resource allocation for managing disasters, in form of the Disaster Mitigation Funds, and fourthly by facilitating training of persons for disaster management through the National Institute for Disaster Management.

In this structure, National Disaster Management Authority is the nodal authority for all disaster management actions in the country. It is the policy making body that frames broad guidelines for the other ministries at the centre and authorities at the state level. The state authorities further lay down the guidelines for ministries and departments at the state level and the districts falling in their respective jurisdictions. Similarly, district authorities direct the civil administration, departments and local authorities such as the municipalities, police department and civil administration. The Executive Committees at each level are responsible for execution of the tasks envisaged by the Authorities.

Flood Management

Floods have been a recurrent phenomenon in India and cause huge losses to lives, properties, livelihood systems, infrastructure and public utilities. Considering the flood problems in the country the flood management activities had been initiated long before independence (ie 1947). In the post independence era, various Expert Committees/Working Groups headed by eminent dignitaries have made several useful recommendations, policy statements and Acts. The policy team has identified several policies however for inventory purpose selected the following policies which are in practice:

1. National Water Policy 2002;
2. State Water Policy of Assam 2007 (draft);
3. Brahmaputra Board 1980;
4. Assam Irrigation Act, 1983;
5. National Forest Policy 1988;
6. Assam Forest Policy 2004;
7. Bihar Irrigation, Flood Management and Drainage Rules 2003;
8. National Disaster Management Act 2005;
9. Bihar State Disaster Management Act 2004;
10. Bihar State Disaster Management Policy 2007;
11. Kosi Rehabilitation and Reconstruction Policy 2008;

Towards Flood Management, the National Water Policy[1] provides support for flood management and drainage measures. The National Disaster Management Act 2005[2] , provide a legal, institutional and financial framework in managing disasters. The Central Water Commission (CWC)[3] is supporting in providing Early Warnings. The Embankment Construction is taken care by the Water Resources Department. Relief and Rehabilitation is managed by the Disaster Management Department /State Disaster Management Authority (SDMA) and it is operationalised through the district administration. Regarding the rural housing in flood prone areas, specification for house construction (high plinth) is provided in the Flood Management guidelines [4].

Planning commission (2011) report provided various strategies and recommendations for XII plan which aim at reforms for short as well as long term measures of flood management. The emphasis has been made on:

- Modernization of flood forecasting network and its extension to other areas and reservoirs
- Automatic reservoir release information system
- Construction of reservoirs and diversion of flood water to water scarce areas
- Basin-wise integrated flood management approach
- Adoption of remote sensing based state of the art technologies in all spheres of flood management
- Use of new construction materials

Adaptation Options (Case Studies)

The International Centre for Integrated Mountain Development (ICIMOD) is working with national partners in China, India, Nepal and Pakistan to strengthen drought and flood adaptation strategies for mountain catchments. Case studies are being conducted in each country to understand local adaptation strategies in different climate regimes.

Assessing adaptation strategies is not enough to influence change at the policy level. ICIMOD has therefore commissioned policy studies in each project country to assess the policy environment that affects the ability of local people in mountain communities to adapt to the water-related impacts of climate change. It has also entered into a partnership with the International Institute for Environment and Development (IIED) to support the work of the policy study teams in each country.

The findings of the first round of field research are summarised in the publication "Local Responses to Too Much and Too Little Water in the Greater Himalayan Region" (ICIMOD 2009). They reveal evolving responses to complex and dynamic situations along with long-standing 'traditional' practices to deal with increasing climate variability. The responses demonstrate that state policy will always play a role in people's ability to respond to too much or too little water, even when policy signals have been unclear, or implementation weak or non-existent.

The final findings, published in report "Role of Policy and Institutions in Local Adaptation to Climate Change; Case studies on responses to too much and too little water in the Hindu Kush Himalayas" (ICIMOD 2012) echo much of the 2009 research and learning from other studies, with regional comparisons providing a bigger picture and indicating some areas where regional programmes of support can be developed. This research resulted in seven key findings:

- Climate change and variability increase uncertainty and risks, as well as promoting opportunities in livelihood systems, particularly for people dependent on agriculture for their livelihood.
- Markets and government policy have a greater impact on enhancing the adaptive capacity of communities than climate change awareness.
- Policy environments and institutions need to consider short-term responses and long-term strategies to match the pace of climate change and changes caused by other drivers, and to meet new needs for highly adaptive and resilient systems.
- A proper strategy to translate sectoral policies into local-level planning will facilitate development initiatives to address local adaptation needs.
- Structural disaster mitigation measures supported by non-structural measures, with the support and participation of local communities, enhance quick response and improve people's adaptive capacity.
- Local-level institutions and indigenous systems, with the support of non-governmental organisations, can enhance local adaptive capacity.
- Diversifying agricultural production and livelihood systems, including labour migration, is one of the ways that communities can build resilience and adapt to economic and climatic shocks and shifts.

Mitigation Options

Structural Measures

If it has become quite clear at a certain stage of time that climate change will have its predicted negative impacts in future on flooding, drought and water quality conditions, then mitigation options must be carefully planned, developed and managed. This shall then be implemented according to pre-determined priority based on results of climate change analysis and impact assessment. These measures include, but not limiting:

- To mitigate increased flooding, implement structural measures such as flood control dams, river improvements, levees, diversions, detention storages and pumping installations.
- Complement structural flood measures with various non-structural measures such as flood zoning and flood risk mapping flood forecasting and warning, flood proofing and resettlement of affected population.
- If climate change does reduce rainfall in certain parts or throughout country, catastrophic situations are certain to arise. To respond to this threat, we need to upgrade our existing infrastructure for water storage. In particular, more facilities are needed for storing water during the rainy season to help alleviate drought problems.
- Develop rules and guidelines to account for climate change impact in the design and construction or modification of the nation's infrastructure. This can of course be introduced only when simulations results from GCM's become more relaible and accurate.

Non-structural measures

- Adoption of improved water management practices in hydropower generation, irrigation and water supply.
- In order to sustain economic growth and human well being, the water resources plan of affected basins must be reviewed to improve the effective use of water resources. A survey of the vulnerability and resiliency of water basins is needed to support water-use planning in the event that climate change has its predicted adverse impacts.
- Improved water management is needed to minimize the impact of climate change including the use of decision support system tool based on say a hydrologic/stochastic simulation model coupling with an expert system. This can optimise the utilisation of available water resources. Such tools are particularly pertinent for use in agricultural and hydropower generation sectors who consume the bulk of the available water resource.
- Revise existing water law to deal with water issues (e.g., allocation, quality, etc.) in times of scarcity and under conditions of climate change.
- Establish a state water entity to deal with water shortage emergencies through authority to adopt substantive and procedural rules governing allocation of supplies.
- Sentitize the public to the problems of water wastage and to introduce policies or taxes that would cut waste and constrain demand, i.e public awareness and educational programs. Education and awareness program to promote the idea of conservation and protection of environment and water resources among the decision makers and the general public, especially the younger population is an effective long term strategy to mitigate the climate change impact.

Discussion and Conclusion

These studies are still in infancy and a lot more data both in terms of field information is to be generated. This will also facilitate the appropriate validation of the simulation for the present scenarios. However, by above studies it is clear that the global warming threat is real and the consequences of the climate change phenomena are many, and alarming. The current results from GCM's and RCMs are still considered uncertain. Present GCM's / RCMs ability in predicting the rainfall and specially extreme rainfall are still not promising. In addition, the uncertainty involved in predicting extreme flood events by the models is large. Therefore, it is difficult, at this juncture, to convince the water planning and development agencies to incorporate the impact of climate change into their projects and water resources systems. However, given the potential adverse impacts on water resources that could bring about by climate change, it is worthwhile for the authority to conduct more indepth studies and analyses to gauge the extent of problems that the country may face. Efforts must be put in to continuously update and/or upgrade our knowledge, capacity and expertise in this field to better prepare ourselves to deal with whatever likely climatic scenarios may become in future. One of the priority areas will be to perform sensitivity analysis of the existing and future water resources systems to the impact of climate change on a basin-by-basin basis. Adel (2002) studied man-made climate changes in the Ganges basin and found a reduction in the Ganges discharge by 60% over 25 years has led to about a 50% drop in water availability in surface water resources, drop in groundwater table, and generation of new surface features having different thermal properties.

To obtain a better quantitative assessment of the climate change impact, it is imperative that more accurate 'damage cost-flood' and 'damage cost-drought' relationship shall be established and updated periodically. This is especially critical in areas where rapid socio-economic development has taken placed. During dry spells, supplementing instream water supply from storages alone solves only part of the problem, maintainining the water quality is of equal importance to ensure adequate safe water supply not only for anthropogenic consumption but also for the healthy survival of its habitat and aquatic lives. Therefore, serious effort and commitment must be invested to protect the watersheds and their resources, so that water quality deterioration would not become the limiting factor in determining the availability of the water supply, thus jeopardizing the progress in social-economic development programs in future. It is recognized that prudent and integrated water resources development and management for optimum and sustainability of water utilisation is an important and urgent issue to be taken up seriously whether with or without the occurrence of climate change impact.

The following research question is arises which is still unanswered:

- What are the element at risk to flood in the present and in the future climate change scenario?
- What are the possible options to deal with the vulnerabilities associated to Climate change and variability?

It is urgently required to intensify research work with following objectives:

- Analyze recent experience in climate variability and extreme events, and their impacts on regional water resources.

- Assess the impacts of projected climate change and variability and associated extreme hydrological events in India.
- Determine vulnerability of regional water resources to climate change and identifying key risks and prioritizing adaptation responses.
- Evaluate the efficacy of various adaptation strategies or coping mechanisms that may reduce vulnerability of the regional water resources and make way of sustainable water management.
- Provide inputs to relevant national and regional long-term development strategies.

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Relating Hydrological Extremes with Area – A Case onExtreme Floods in South Central Nepal

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Abstract

Flash floods, debris flows and landslide disaster on the steep sloping terraces of hilly region are so challenging that even a real time hydro-meteorological forecasting system would not be applicable for all cases in Nepal. Flash floods are localized in short ranges with respect to time and distance; and it is very difficult to measure these flash floods in time. On the other hand, such phenomena need to be assessed for sustainable design of hydro- structures and for relocating the settlements from risk areas. A study was carried out to find the suitable relationship between area and extreme flood as well as area and extreme rainfall depth. Analysis is mainly based on the case of torrential rains in July 1993 over south central Nepal, which caused floods and debris torrents those were probably the worst in the disaster history of Nepal damaging lives and properties in Nepal during the 20th century. A relation for rainfall depth and other relation for specific flood are presented in this paper.

Keywords: *South-central Nepal, specific discharge, rainfall intensity, depth area duration.*

Background

Rainfall intensities of about 40-50 mm h-1 are common in the region between 300 m to 3000 m elevation above mean sea level of Nepal. The 24- hour rainfall depths of more than 400 mm are occasional events in the country. Some of the recorded events (DHM, 2000) are 431 mm rainfall at Bajura in the far-western region on August 12, 1980; 446 mm at Beluwa, in the western region on September 29; 1981, 500 mm at Ghumtang in the central region on August 25, 1968 and 473 mm at Anarmani in the eastern region on October 10, 1959. The maximum rainfall intensity of 88 mm h-1 was recorded in 1989 at Pokhara in western region. The 24-hour rainfall of 540 mm in 1993 broke all the previous records in Nepal; hourly peaks of the event were 70 mm and 67 mm.

Catastrophic floods have been occurring in Nepal. There was a severe flooding in 1902/03 in Bagmati River in the central region (DPTC, 1993). Floods of 1964, 1981 and 1984 in the Sunkosi River are some events in the eastern region. Doming Xu (1985) had estimated a peak flood of 15,920 m3 s-1 near the breached site of moraine dammed glacial lake, and 2316 m3s-1 at about 50 km downstream in Sunkosi. Debris flow disaster in Nakhu Khola on September 30, 1981, and flood in Tinau River in 1981 had washed away several lives and hectares of fertile lands. A 1993-flood peak of 12,000 m3 s-1

*(This artical has been adapted from Journal of Hydrology and Meteorology (2009) 6(1): 44-48)

(MOWR, 1993) was the highest flood assessed in Bagmati River at Nunthar having drainage area of 2720 km2. Temporary damming at Nunthar resulted in a flood surge of 16,000 m3 s-1. This flood broke the past flood records in the Bagmati River basin.

Hydrological and meteorological data collection at the organizational level had started during the sixties in Nepal. Since then attempts are being made to observe and analyze some of the extreme events. This paper focuses in establishing suitable relationships of peak discharge with catchment area for the south central Nepal.

Study Area

Bagmati, East-Rapti and Kamala were the three major river basins severely affected by floods. The areal coverage of the physiographical feature of Bagmati River that had favored severe flooding is only about 1845 km2. This area (Figure 1) consists of (a) 5% area as active and recent alluvial plains and sandy with cobble texture with slope less than 1 degree, (b) 4% area as river fans, ancient river terraces, and loamy texture with slope of 1 to 5 degree, (c) 11% area as moderately to steeply sloping hilly and mountainous terrain with slope 5 to 20 degree, (d) 45% area as steeply varying hilly and mountainous terrain with slope 20 to 30 degree, and (e) 35% area as steeply varying hilly and mountainous terrain with slopes greater than 30 degree.

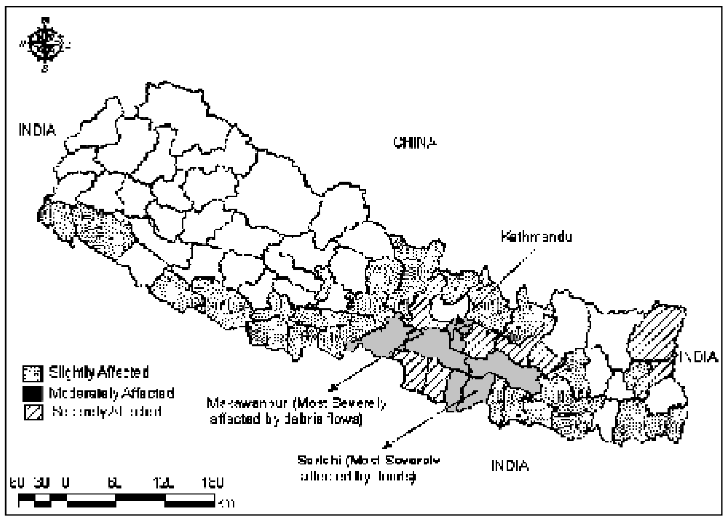

Figure 1: *Location of Study Area*

Rainfall Data

In 1993, monsoon entered in the eastern Nepal on June 6, four days earlier than usual, and covered the whole region by June 14. Monsoon trough that normally lies over the northern India shifted to Nepal in July 1993. These phenomena produced a torrential rain during the period from 19 to 21 July 1993. The hourly rainfall intensities (Figure 2 and 3) during that period were 70 mm per hour in Tistung, 67 mm per hour in Simlang, and 64 mm per hour at Nibuwatar in Bhainse.

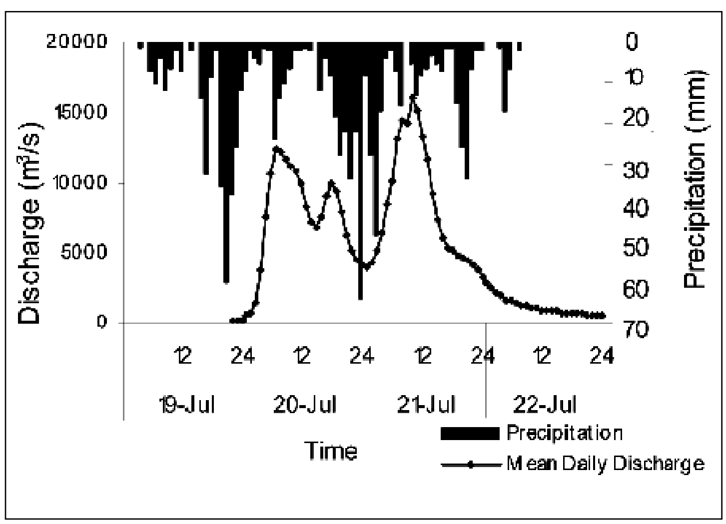

Figure 2: *Observed rainfall hyetograph at Nibuwatar and flood hydrograph of Bagmati river at Nunthar*

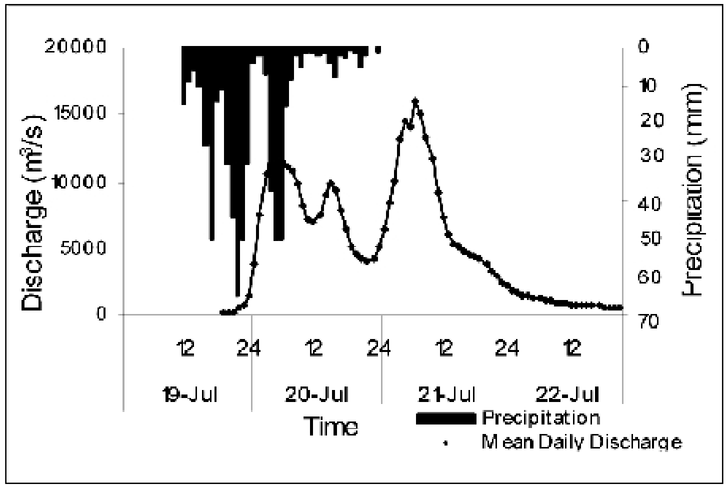

Figure 3: Observed rainfall hyetograph at Tistung and flood hydrograph of Bagmati river at Nunthar

The 24-hour rainfall depth of 540 mm at Tistung and 482 mm at Ghantemadi were recorded in morning hours of 20th July. The 48-hour rainfall depth at Ghantemadi was 600 mm. The time lag between two rainfall peaks at Nibuwatar is 26 hours. The time lag between rainfall peaks at Tistung/Simlang and the second peak at Nubuwatar is 18 hours.

Floods were generated due to continuous and prolonged rains before and during the peak rainfalls. Very gentle slope and wide flood plains of Bagmati River had contributed in retarding the first flood volume while fulfilling infiltration and other requirements such as depression and bank storages. The light and moderate rains prior to the extreme event favored landslides by saturating the soil. Floods accompanied with eroded and displaced earth mass turned into debris torrents.

Different agencies (ICIMOD, 1993; JICA, 1993; Scoot Wilson Kirpatrick, 1994; SMEC/WB, 1994) got involved in assessing floods of 1993. All discharges were estimated by slope area method with appropriate roughness coefficients. The coefficient values (DHM/DPTC, 1994) varied from 0.033 for Rapti River at Bhandara, 0.06 for Bagmati, 0.07 for Kyankhola, and 0.07 for Agrakhola. The peak floods in Bagmati and in East- Rapti River were found to be 12,000 m^3 s^{-1} and 6800 $m^3 s^{-1}$ respectively. In various cases, temporary damming was caused by landslides and bank erosions in most gullies and in headwaters locations. But there were no reports of floods damming in cases of larger rivers like Koshi, Narayani and Karnali.

Analysis and Results

a) Extreme rainfall: depth area duration Isohyet contours for 24-hour and 48-hour rainfall depths were drawn; and an equation (1) for depth area duration curves of the storm was determined:

$$P = 1.5 P_0 * \exp\left\{\frac{-\ln(A)}{6}\right\} \quad (1)$$

where, A is catchment area (km^2) with *P* rainfall depth (mm) in 24 or 48 hours duration, and P_0 is the maximum rainfall (mm) of desired duration at the centre of the storm. In the study area, P_0 is 540 mm and 600 mm observed in 1993 in 24-h and 48-h durations respectively.

b) Extreme discharge: specific discharge and area. The results of flood assessments were summarized and correlated with corresponding drainage areas. Equation (2) is a single relationship between specific peaks (m^3 s^{-1} km^{-2}) versus catchment areas (km^2) for all ranges (Figure 4) of study areas. The correlation is satisfactory. The correlation coefficient is found to be 0.78

$$q = 25\sqrt{\frac{1}{\sqrt{\left(\frac{A}{\pi}+1\right)}}} \qquad (2)$$

Where, q is the specific peak flood ($m^3\ s^{-1}\ km^{-2}$), A is the area (km^2) and π is 3.141

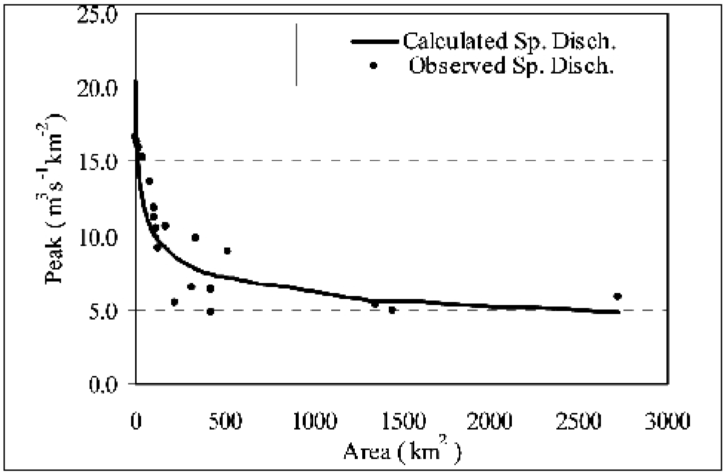

Figure 4: *Specific Flood Peaks versus Area (up to 2700 km²)*

Data were then selected and divided into two groups. One relationship for each group is established. Equation (3) and Equation (4) are derived from observed peaks from areas between 90 km^2 to 700 km^2 (Figure 5), and between 90 km^2 to 2700 km^2 (Figure 6) respectively. The value of correlation coefficients in both equations is more than 0.91.

$$q = 650\left[\frac{1}{(A+1)}\right]^{0.87} \qquad (3)$$

$$q = 47.5\left[\frac{1}{(A+1)}\right]^{0.285} \qquad \textbf{(4)}$$

Where, q is the specific peak flood ($m^3s^{-1}\ km^{-2}$) and A is the area (km^2)

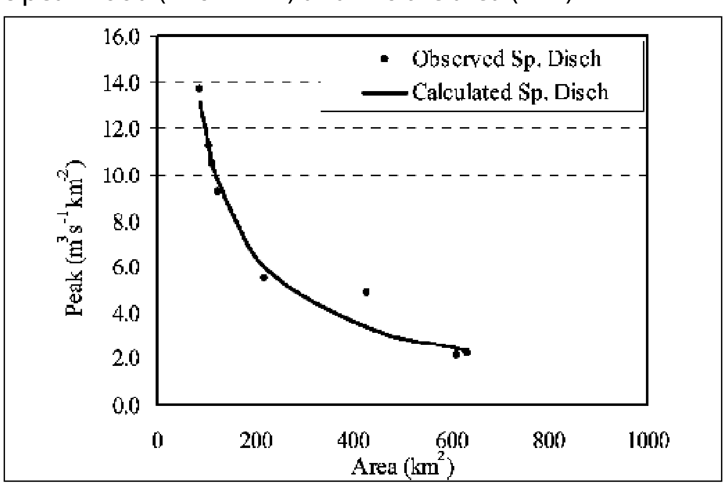

Figure 5: *Specific Flood Peaks versus Area (90 to 700 km²)*

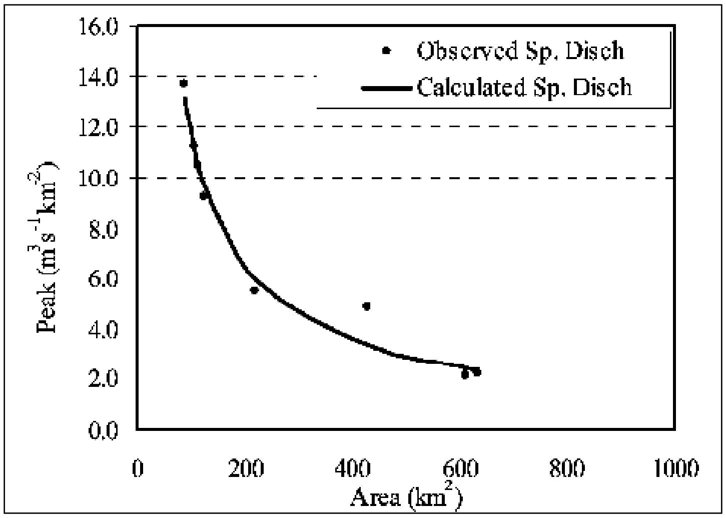

Figure 6: *Specific Flood Peaks versus Area (selected data: 90 to 2700 km²)*

Conclusion

The rainfall intensities of around 60 to 80 mm per hour and 400-550 mm in 24 hours are to be expected during unusual storms elsewhere in the country in the lower Mahabharat and in the Siwalik region (areas lying in altitude between 300 meter to 3000 meter) of Nepal.

The physiographic feature of a basin in combination with the rainfall duration and intensity is directly related to the scale of flooding. The specific flows range from 4 to 15 m3s-1 km-2 in streams having drainage areas of different sizes (100 to 3000 km^2). The streams having smaller drainage areas with less than about 100 km2 are prone to severe flooding with debris torrents. Specific discharges have been found relatively high for smaller catchments.

Floods occurred in 1993 are of approximately 100 year recurring period. The equation (3) and the equation (4) can be recommended to apply only for areas between 90 to 700 Km2 and 90 to 2700 km^2 respectively. However the equation (1) and equation (2) are recommended to assess extreme rainfall depths and extreme floods respectively for unguaged catchments in the south central region and similar basins of Nepal.

Acknowledgement

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Flood 2010: The Event, Issues and Way Forward

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Abstract

Torrential rains in the catchment areas of Swat, Kabul and Indus Rivers during the last week of July and first fortnight of August generated unprecedented floods in the River Indus. The floods during July-August 2010 caused large scale damages to the Irrigation, flood protection and drainage Infrastructure in the provinces of Khyber Pakhtun Khwa, Punjab and Sindh and a part of Balochistan. The flood damages in Punjab occurred mainly in the Districts of Mianwali, Bhakkar, Layyah, Muzaffargarh, D.G. Khan, Rajanpur and Rahim Yar Khan.

The flood 2010 was unprecedented and extraordinary in the known history of the Indus river system and the flood peaks were far in excess of the recorded historical floods. Further, the duration of flood peaks is generally short, ranging from 12 to 24 hours. In case of super flood 2010, however, the duration of peaks was extraordinarily long, as the Exceptionally High and Very High flood persisted for 115 hours at Jinnah Barrage and for 124 hours at Taunsa Barrage. Damages at Jinnah barrage were averted by operating the breaching section. The barrage was vulnerable and earmarked for rehabilitation during 2010 through World Bank assistance. Flood peak reached Taunsa barrage on 2nd August 2010. The barrage complex worked perfectly well but the Left Marginal Bund (LMB) could not sustain the pressure of flood waters and breached at RD 32-33 and became the main cause of damages.

The main issues confronted during the course of Flood 2010 were that infrequent floods caused extreme drying of embankments, cracking and rodent holes weakening the structures. In addition, this also induced lowering of guard to the level of complacency in terms of institutional preparedness. During this large scale emergency, lack of leadership and coordination was observed due to dysfunctional District and Tehsil Administration system.

Emergent repair works have been almost completed. All canals were made operational by September 15, 2010. Medium Term works including Damages to the distribution system would be repaired by end March 2011. However non perennial channels would be opened during Kharif 2011 i.e. in April. Longer term works related to protection and drainage works will be taken up after establishment of new bench marks and comprehensive evaluation.

Drawing upon the lessons of Flood 2010, the strategies for improving flood management include; establishment of new benchmarks including highest flood levels, Freeboard, etc design of embankments is to be made and the standard operating procedures have to be revised to ensure

their utility/adequacy under the present conditions. SOPs (Standard Operating Procedures) for flood management have to be prepared for individual structures keeping in view the identified weak areas / hotspots. Contingency plan is to be prepared which shall indicate the infrastructures located in the flood route with special focus to low lying areas and villages / towns to be affected. Flood protection works should be given due importance/preference/priority in resource allocation irrespective of the low frequency of floods.

Introduction

1.1 Meteorological Setting 2010

Meteorologists all over the world indicated that the meteorological setup in Pakistan during the period of July and August of 2010 was unique in terms of spatial coverage, duration and intensity comparing with the historical events. Atmospheric regimes stretching from Western Europe to South-east Asia caused unusual weather throughout the region – including the extreme heat and wildfires in Russia, the on-going catastrophic flooding and landslides in China and severe weather and flood events in central and northern Europe. (Pakmet, 2010)

Meteorologists also noticed that in early July 2010, a strong ridge of high pressure began to develop near the Ural Mountains in Russia. This ridge became stationary and established a blocking pattern, named as an "Omega Blocko by the meteorologists of the world due to its shape across almost all of the western Russia. As the ridge remained stationary for nearly two consecutive months, persistent rains fell in most of the areas of Pakistan and in parts of Afghanistan and Indian held Jammu and Kashmir beginning at the end of July 2010. With an abnormally active jet stream running around the periphery of the Omega Block into western Pakistan, profuse amounts of hot and moist air produced what some of the meteorologists called a "Super-charged Monsoon", as this unstable atmosphere led to a highly unusual pattern of long duration and high intensity rainfall. Meteorologists are of the opinion that the rapid development of a La Niña cycle in the Pacific Ocean, typically resulting in a heavier-than-normal monsoon season in South Asia, also played a role in helping create a rarely-seen atmospheric setup that led to disastrous floods in Pakistan. (PARC, 2010; Pakmet, 2010)

Torrential rains in the catchment areas of Swat, Kabul and Indus River during the last week of July and fist fortnight of August generated unprecedented flood in the River Indus. The floods during July-August 2010 inflicted large scale damages to the Irrigation, flood protection and drainage Infrastructure in the provinces of Khyber Pakhtun Khwa, Punjab, Sindh and some parts of Balochistan. In Punjab, the worst hit areas were in the Districts Mianwali, Bhakkar, Layyah, Muzaffargarh, DG Khan, Rajanpur and Rahim Yar Khan. (NDMA, 2010)

1.2 Institutional Structure for Flood Management and Relief

The agencies responsible for flood management and relief are the following:

i) Flood Forecasting and Warning: National Flood Forecasting Bureau / Meteorological Department is responsible agency.

ii) Flood Management / Fighting: Punjab Irrigation Department is the responsible agency.
iii) Flood Relief: Relief Commissioner / Punjab Disaster Management Authority are the responsible agencies.

1.3 Flood Management by IPD

Punjab Irrigation Department is responsible for the operation and maintenance of one of the largest Irrigation networks in the world. Irrigation & Power Department is responsible for rivers and riverain surveys, barrages construction work and all matters connected therewith, flood control and flood protection schemes. (IPD, 2010) The various functions performed by IPD for flood management are to:

- Prepare and update Flood Fighting Plans
- Carry out inspection of flood works and also joint inspections with concerned agencies
- Repair flood bunds and maintain and upkeep the related facilities
- Maintain headworks reports and flood related data on the barrages
- Replenish reserve stock of stone and procurement of flood fighting material
- Obtain information for flood forecasting/warnings
- Communicate timely flood forecast / warnings within the Department and to other related agencies
- Arrange for flood watching and setting / shifting of camps for flood management
- Closely monitor and regulate flood flows at barrages
- Make special arrangements for safety of vulnerable points
- Prepare for operation of breaching sections in case of emergency
- Carry out flood management of hill torrents
- Carry out upkeep and maintenance of flood related infrastructure
- Rehabilitate and modernize the existing barrages and optimize options for safe passage of flood discharges

1.4 Flood Protection Infrastructure

Flood protection infrastructure generally comprises river banks protections (direct and indirect protections), river containing structures (flood embankments, retired bunds, marginal bunds), river training structures (spurs or groynes, studs, guide banks, pitched islands, gabions retaining walls, submerged sills and diversion bunds etc).

River training works cover various types of structures constructed across or along a river to guide and confine the flow in the river channel and to control and regulate the river for effective and safe movement of floods and river sediment. It aims at controlling and stabilizing a river along a desired course with a suitable water way mainly for flood and bank protection, sediment control and land reclamation

***Table 1**: Saline Features of Flood Protection Infrastructure in Punjab*

River	Length of Rivers (miles)	Length of Bunds (miles)	No. of Spurs / Studs
Indus	342	507	131
Jhelum	227	97	43
Chenab	457	831	309
Ravi	434	394	127
Sutlej	322	254	30
Total:	1782	2,083	640

2. FLOOD 2010 – FACTS AND EVENTS

2.1 Key Feature of Flood 2010

The following key features of the flood 2010 reflect that this flood was unprecedented and extraordinary in the known history of the Indus river.

2.1.1 Very Long Dry Spell

The exceptionally high floods in Indus river were experienced after a very prolonged low discharge spell with the result that the embankments and the flood infrastructure had not been tested and the overall state of readiness had declined. Due to this long low discharge spell, the settlements within the river Khadir had also increased and the river channels started experiencing a siltation trend. As a consequence, very high flood levels were recorded along the embankments, which were beyond their design parameters and endangered the safety of the embankments and also caused breaches.

2.1.2 Quantity and Return Period

The super flood 2010 was unprecedented in the context that the flood peaks were far in excess of the recorded historical floods. This is indicated from the figures given below. It has been estimated that the flood 2010 was a 600 years extraordinary event. (IPD, 2011)

***Figure 1**: Historic and Current Flood Peaks on River Indus*

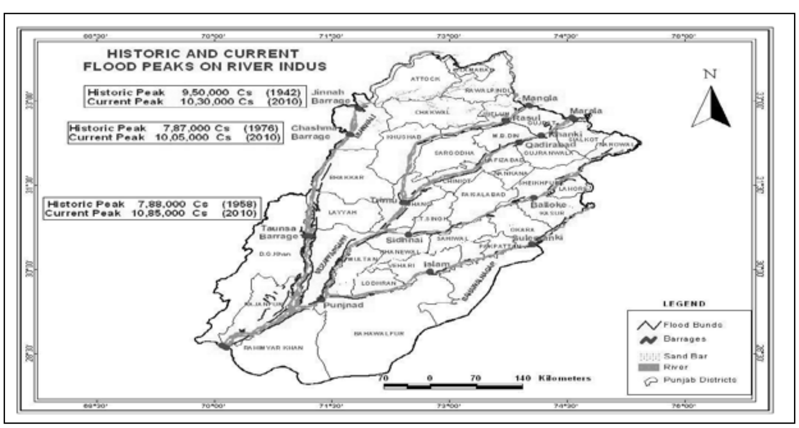


Figure 2: Peak Discharges at Jinnah Barrage 1947-2010

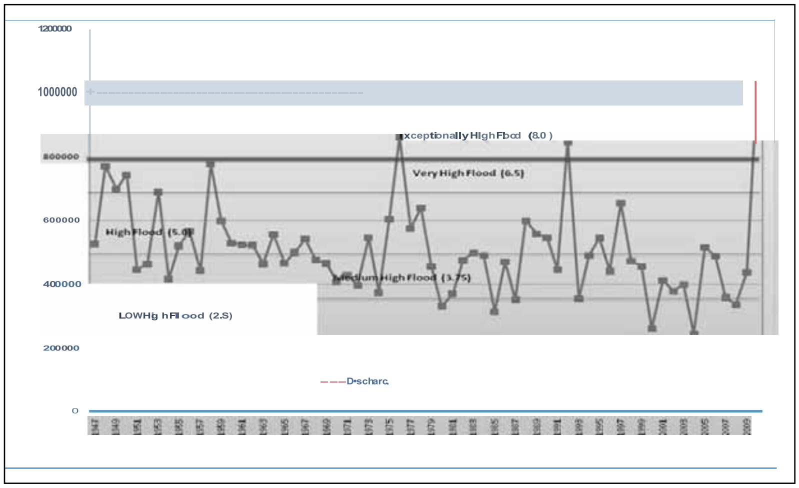
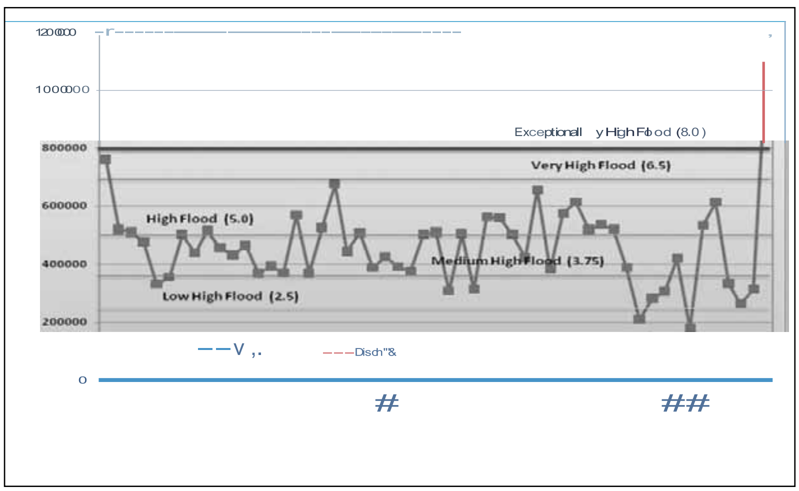


Figure 3: Peak Discharges at Taunsa Barrage 1958-2010



2.1.3 Duration

Normally the duration of flood peaks is short, ranging from 12 to 24 hours. But in case of super flood 2010, the duration of peaks was extraordinarily long, as the Exceptionally High and Very High flood persisted for 115 hours at Jinnah Barrage and for 124 hours at Taunsa Barrage. The long duration of flood 2010 is presented in the Table below:

Table 2: Duration of Flood Stage (Hours)

Barrage	Duration of Flood Stage (Hours)		
	High	Very High	Exceptional High
Kalabagh	131	85	30
Taunsa	116	97	27

2.1.4 Recurring Peaks

Another important feature of the 2010 flood was that two peaks were received in river Indus over two weeks period, which exerted extreme pressure on the infrastructure, supervisory staff and the watching establishment.

2.1.5 Continuous Rainfall and Hill Torrent Flooding

The flood situation was further exacerbated due to continuous rainfall in the river flood plane, which hampered the flood fighting activities through slippery embankments crests. The repeated and extreme hill torrent flooding in Mianwali, DG Khan and Rajanpur districts added to the complexity of the situation.

2.2 Sequence of Events

The sequence of main events of flood 2010 is presented in Box-1. (IPD, 2011)

BOX-1: Sequence of Events

- Torrential rains in the catchment areas of Swat, Kabul and Indus River during last week of July and First fortnight of August.
- Exceptionally High Flood hit Kalabagh/Jinnah Barrage on 30-7-2010. LGB breached on 29-7-2010 and breaching section activated on 30-7-2010 to save the barrage.
- With concerted efforts and intense flood fighting, major damages at Kalabagh/Jinnah barrage averted.
- Flood Peak reached Taunsa barrage on 02-08-2010. The barrage was saved by hectic efforts spread over five continuous days.
- LMB, however, could not sustain the pressure of flood waters and breached at RD 32-33 on 2-8-2010.
- The breach in LMB was the main cause of the extensive damages and inundations in Muzaffargarh District via TP link / Muzaffargarh canal.
- The super flood, after crossing Taunsa, attacked the protection bunds in DG Khan, Rajanpur and Rahimyar Khan Districts with a discharge of 1.20 Million cusecs.
- The situation became more critical due to continuous heavy rainfall and high flows in hill torrents.
- Strenuous efforts were made to save the bunds through day and night watching.
- Jampur flood bund and Mithankot flood bund could not withstand the thrust of flood water and breached, inundating the towns. The protection bund at Mithan Kot was overtopped.
- The left marginal bund of Guddu barrage, maintained by Sindh, also breached near Bhong town. This inundated vast areas and National highway connecting Punjab with Sindh.
- A second wave of very high flood generated in river Indus in the second week of August 2010 also aggravated the flood situation.

2.3 Breaches / Cuts in the Irrigation and Flood Infrastructure

2.3.1 Overall Status

The summary of various types of Breaches / Cuts in Punjab during the flood 2010 is depicted below:

***Table 3**: Flood 2010 – Summary of Breaches / Cuts*

Sr. No.	Name of Zone	Breaching Section	Breaches	Cuts made by Department	Cuts made by Public
1	Sargodha	1	1	-	-
2	DG Khan	1	45	12	20
3	PMO Barrages (Taunsa Barrage)	-	10	-	1
4	Bahawalpur	-	11	-	-
Grand Total:	**2**	**67**	**12**	**21**	

2.3.2 Jinnah Barrage

The upstream Left Guide Bund of Jinnah Barrage breached at RD 3000 on 29.7.2010. The breach developed rapidly to 900 ft. It was apprehended that in case the LGB collapsed, left flank, head regulator of Thal Canal and Jinnah Barrage may be severely damage in addition to colossal damage to the Irrigation network and other public and private infrastructure. Management of the Maple Leaf cement factory was approached and requested to provide necessary assistance. The management of the factory rendered tremendous help and stopped further erosion by dumping big sized boulder stones with help of their machinery. Further erosion was checked and system was saved from devastation. In addition the breaching section situated at RD 6700 - 8700 was operated with the help of Army Authorities which reduced pressure on the LGB. Both these breaches did not result in any damage to protected property or loss of life.

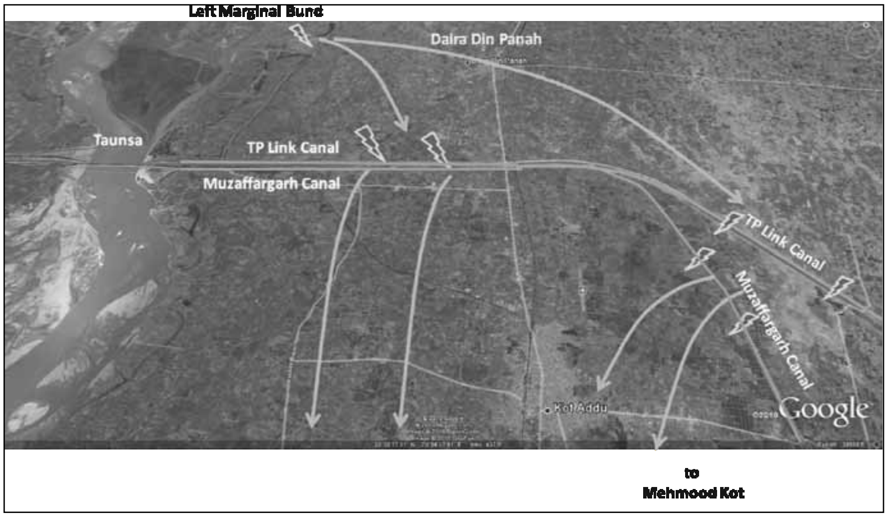
2.3.3 Taunsa Barrage

The Left Marginal Bund of Taunsa Barrage breached in RD 32-33 on 02-08-10, when the discharge in the River Indus was approaching 1.1 million cusecs i.e. at the breach point which is a 1 in 600 years flood by some estimates. Despite intense watching of the bund along with staff and earth moving machinery, the breach speedily developed to 1000 ft and 125,000 cusecs discharge was diverted, which after breaching banks of Taunsa Panjnad Link Canal and Muzaffargarh Canal, flooded a vast area in District Muzaffargarh.

***Figure 4**: Taunsa Barrage – Flood Protection Infrastructure*

***Source:** PDMA, 2010*

***Figure 5**: Breaches on Left Side of Taunsa Barrage*



***Source**: PDMA, 2010*

2.3.4 Canal Infrastructure

Extensive damages occurred to irrigation canal infrastructure including branches, distributaries and minors. TP Link suffered breaches at 4 different locations. Muzaffargarh Canal breached at 6 locations and 4 breaches occurred to Rangpur Canal. Due to some uncontrolled and controlled breaches (for effective drainage of flood water), a large scale area was inundated in Rajanpur and Muzaffargarh Districts.

***Figure 6**: Breaches in Muzaffargarh Canal*

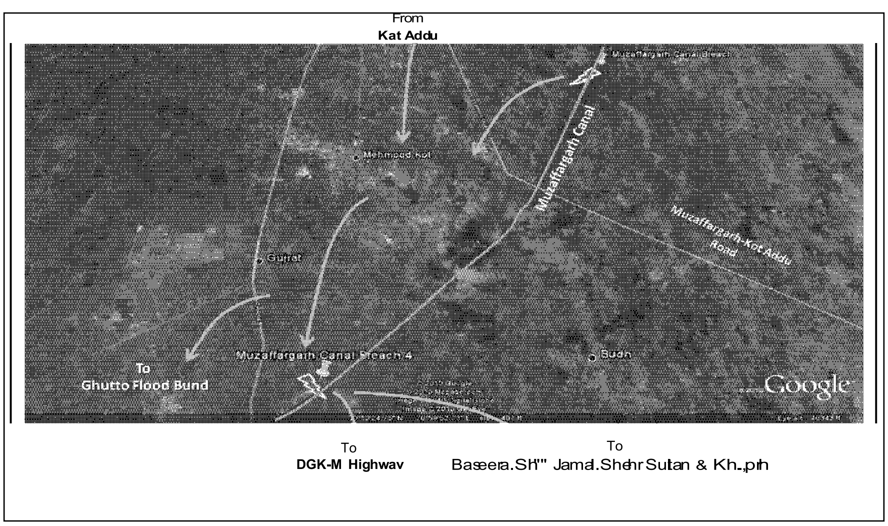
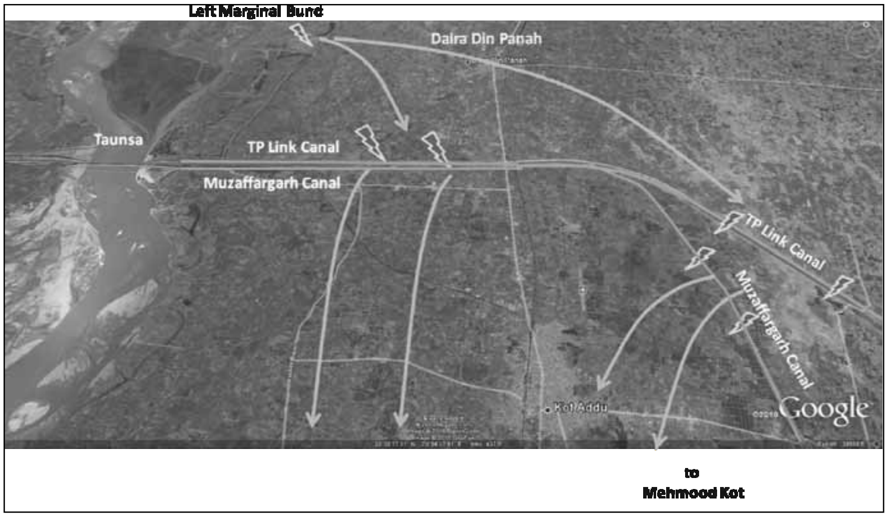


***Figure 7**: Inundation of Muzaffargarh Canal Command Area*



***Source**: PDMA*

2.4 Flood Damages

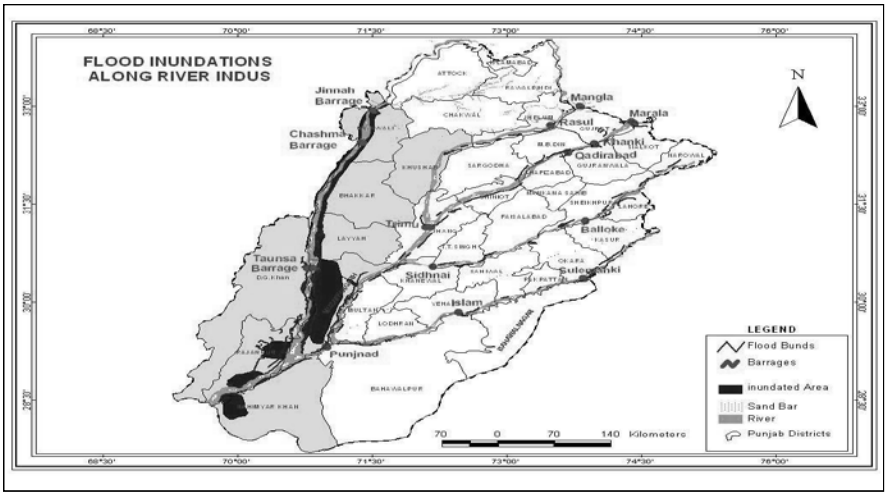
The damage need assessment for the flood 2010 was made by World Bank and Asian Development Bank. The overall assessment was to the tune of US$ 10.0 billion, and sectoral damage assessment for irrigation was US$ 278 million. The purpose of this exercise was to assess the extent of damages and losses caused. The damage assessment was conducted through data verifications while needs assessment was based on analysis and policy decisions.

Sector-wise summary of damages prepared in the Pakistan Development Forum by Asian Development Bank and World Bank is depicted in the following table: (ADB _ World Bank, 2010)

***Table 4**: Sector-wise Damage Need Assessment*

Sr. No.	Sector	US$ Million
1	Irrigation	278
2	Housing	1,588
3	Agriculture	5,045
4	Transport and Communication	1,328
5	Energy	309
6	Private Sector	282
7	Education	311
8	Health	50
9	Water and Sanitation	109
10	Governance	70
11	Financial	674
12	Environment	12
	Total:	**10,056**

***Figure 8**: Flood 2010 – Inundations along River Indus*



The flood damage assessment for irrigation and flood was carried out by World Bank and Asian Development Bank in order to determine the extent of reconstruction and remodeling of damaged infrastructure. Based on the damage need assessment, the following two options shown in Table 5 were presented:

***Table 5**: Irrigation and Flood Sector Damage and Reconstruction Costs*

Province/ Region/ Agency	Damage US$ millions	Needs: Option 1* US$ millions	Needs: Option 2** US$ millions
AJK	0.2	0.2	11.4
Baluchistan	29.6	45.6	45.6
FATA	3.0	4.6	17.6
Gilgit Baltistan	1.6	2.5	27.2
Khyber Pakhtunkhwa	68.4	105.0	600.3
Punjab	33.1	50.9	50.9
Sindh	136.9	210.6	210.6
WAPDA	4.9	7.5	7.5
Pakistan Met. Department			9.2
Federal Flood Commission			2.0
Sector Total	277.6	427	982.3

* Option-1: Reconstruction with remodeling of selected damaged infrastructure

** Option 2: Preferred Compensation Scenario - Reconstruction as for Option 1 PLUS measures for improved flood protection & management:

• "building-back-safer" for critical settlements and urban areas prone to flash floods and river bank erosion in AJK, GB and KP,
• Expansion of the Flood Early Warning System to Swat, Peshawar and DG Khan areas
• Revisit the country's overall flood management strategy

3. Flood planning and Management – a Critical Analysis

3.1 Flood Preparedness

As a pre requisite of flood planning, various flood preparedness activities are carried out every year by the respective field offices in irrigation zones and by the Drainage & Flood Zone before start of flood season. The activities of flood preparedness includes preparation of flood fighting plans, maintenance and restoration of flood infrastructure, inspection of flood protection works, removal of encroachments from bunds and spurs, replenishment / procurement of reserve stocks of stone, other flood fighting materials and equipment.

3.1.1 Major Weaknesses in the Existing System

The existing system for flood preparedness prescribes operating procedures (SOP) and departmental guidelines, which if observed in letter and spirit, could give a reasonable level of preparedness against impending flood eventualities. These procedures and guidelines were, however, not-fully followed due to lack of financing and urgency because of the long and sustained dry spells. As a result serious difficulties were encountered in the management of the super floods in the Indus River during August 2010. (IPD, 2011)

The deficiencies observed with regard to flood preparedness during the flood season
2010 are described as under:

- Weakened flood bunds due to infrequency of floods resulting in extreme damage caused due to drying of embankments, cracking and rodent holes.
- This infrequency also induced lowering of guard in terms of institutional preparedness.
- Outdated flood management plans and SOPs and lack of any 'Plan B' in the event of a breach.
- A hyperactive and, often, erroneous electronic media, spreading rumours and undermining public's trust in state machinery leading to active resistance everywhere to diversion of water to safer passage.
- Timely relief cuts could have considerably reduced the damage but could not be made due to active resistance by locals.
- Three departmental machines were burnt / damaged by mobs and staff was beaten / manhandled at number of places. Most flood management actions could be implemented only with assistance from Army.
- Lack of leadership and coordination at District and Tehsil level.

3.1.2 Gap Analysis

The following gaps / shortcomings have been indicated in management of floods:

- Flood Fighting Plans issued just in routine and not updated to incorporate changing field conditions. These also do not contain the contingency plans in case of breaches / other flood emergencies.
- Flood works not maintained to design parameters.
- The second defence lines not maintained properly, lack of financial resources and local discipline.
- Wetting channels cover the embankments in limited reaches and are not being maintained properly / use for soaking and testing of embankments.

- Aprons of spurs not constructed at lowest winter water levels remain prone to damages.
- Unauthorized zamindara bunds and watercourses crossing exist on the embankments.
- Priority for repair and restoration of flood infrastructure is accorded to spurs and most of the funds are allocated for restoration of aprons and pitching on spurs, while lesser importance is given to the restoration of earthen embankments.
- Requisite corrective action not taken on the inspection reports/ recommendations of the inspection committees before the advents of the floods.
- Bunds not inspected comprehensively by the concerned field formations before the flood season to locate rain cuts, gharas, runnels and porcupine holes etc. so as to take necessary corrective action.
- Inadequate logistics and watching arrangements for the flood embankments at critical sites.
- Inadequate flood fighting material and machinery arrangements at critical/vulnerable sites.
- Growth of vegetation on embankments.
- Updated river survey maps not available at the Barrages.
- The weak spots of the embankments created by unauthorized ramps formed on the embankments due to trespassing generally not timely attended and repaired.
- Encroachments along the embankments not checked and removed.
- Lack of proper mobility along the bunds during rains.

3.1.3 Key Areas to be Addressed

Standard operating procedures are required to be devised to address the gaps and deficiencies highlighted above so that a sound level of flood preparedness is achieved before the advent of floods. Most of the areas / omissions highlighted above can be tackled by preparing and implementing comprehensive flood fighting plans and by strictly following other SOPs (Standard Operating Procedures). Monitoring and evaluation, which uptill now has almost been absent needs to be enforced forthwith. Monitoring is a continuous process whereas the evaluation of flood control structures must be done periodically at regular intervals at-least annually and more often if needed due to special circumstances. This can be done by the staff incharge or specially constituted evaluation teams. In addition, the interagency coordination among Pakistan Meteorological Department, Irrigation and Power Department, WAPDA, District Administration, Army, Police, Communication Media and Public Representatives needs to be improved.

3.2 Breaching Sections Locations and Efficacy

The concept of breaching sections in flood bunds especially marginal bunds of barrages took shape after the floods of 1973. The idea was to save the barrages in case the flood discharge goes beyond the capacity of the barrage or the safety of Left Marginal Bund (LMB) is threatened. For this purpose a critical gauge was established in the LMB above which the bund was not considered to sustain. The breaching sections were established in Right Marginal Bunds (RMB) because on account of the general topography and land relief, any escapage through the LMB of barrages on any of the rivers in Pakistan does not return to the same river and flows on across the whole Doab destroying crops, dwellings, livestock, infrastructure and even human lives before it joins the next river. These breaching sections served satisfactorily till recently but as the areas prone to be in-undated have undergone massive development and in addition to agriculture and habitation even industry has been established, thus making the operation of some of these breaching sections exceedingly difficult while others may follow suit. It is therefore expedient to revisit the provision and consider other options such as regular by- pass system for escaping surplus flood waters in the events of exceedance areas of the capacity of barrage or the LMB. The case of Taunsa Barrage requires particular attention, as it does not have an approved breach section and two canals exist on each side. Contingent plans therefore need to be developed in order to identify optimal arrangements for by-passing the discharges in case of super floods when the barrage capacity / safety is threatened.

3.3 Regulation of Khadir Area

At many places in the river Khadir (active flood plain) tendency to take benefit of the dry periods through cropping and on some rivers even regular villages/towns has increased and become a reality. The classic example in this regard are the settlements in the bed of river Ravi around Lahore. During floods such encroachments in the active flood plain of the river become a sources of additional stress and need to be stopped. The following restrictions need to be imposed in letter and spirit.
3.4 Pond Area : Technical, Operational Implications

Pond areas are the areas acquired for construction activities at the time of original construction of barrages and were retained to avoid objections from the relevant quarters against variation in pond levels required for feeding of canals and flood control and use as borrow areas. In some cases, the pond areas were leased out for agricultural purposes but with clear restrictions against heavy plantation or construction of any infrastructure. Later these areas were also declared as Game Sanctuaries. The pond area has been transferred to wildlife department and in some cases the pond areas having been auctioned to private parties, as in case of Islam Headworks. These measures limit the flood management and regulation operations at barrages and could only impose threat by the barrage safety. To put an end to all this, the following steps need to be taken:

i) All pond areas should remain with the barrage divisions.
ii) Agricultural use should be allowed only in accordance with established rules and restrictions.
iii) No infrastructures be allowed to be raised in the pond areas.
iv) Heavy plantation may not be allowed in pond area because it restricts the movement of river channel which is most of the time required for the effective operation of the barrage.
v) RAMSAR sites can be retained but with provisions that the barrage requirements are not compromised.

3.5 Role of FFC

Federal Flood Commission (FFC) was established in January 1977 for integrated flood management on country wide basis. Functions of FFC are:

i) Preparation of National Flood Protection Plan.
ii) Approval of flood control schemes prepared by provincial Governments and concerned federal agencies.

iii) Review of flood damages to public sector infrastructure and plans for restoration and reconstruction works.
iv) Measures for improvement in flood forecasting and warning system.
v) Standardization of design and specification for flood protection works.
vi) Evaluation and monitoring relating to progress of implementation of the National Flood Protection Plan (NFPP).
vii) Preparation of a research programme for flood control and protection.
viii) Recommendation regarding principles of Regulation of reservoirs for flood control.

The Commission is headed by a Chairman, who is also the Chief Engineering Advisor to the Federal Government. Members are, Chief (Water) P&D Division, Joint Secretary (Roads), Member Water (WAPDA), Director General PMD, Member Civil Engineering (Pakistan Railways) and four provincial Irrigation Secretaries. FATA, AJK, Northern Area and NOMA are co-opted members.

Federal Flood Commission at present is providing a coordination role between the federal and provincial governments regarding funds allocation standardization of flood protection works parameters. It needs to play a more pragmatic role regarding forecasting of floods and flood management. Towards this end, it needs to conduct studies for scenario analysis for evolving holistic and more effective flood management at the national level. This has become urgent in view of the breaches on river Indus which impacted Sindh / Baluchistan provinces. New benchmarks and criteria for design and construction of flood infrastructure alongwith overall long-term plans for improving flood protection also needs to be evolved keeping in view the experience of flood 2010. (WAPDA, 2010)

3.6 Identification of Weak Areas / Hot spots

Identification of weak area / hot spots can be made through Manual Inspections – This methods required extensive vigil and inspection of the embankment body foot by foot and is a time consuming effort. The detailed survey may be carried out well before commencement of flood season along all flood bunds, spurs & river training works and weak area may be identified. Efforts may be made to strengthen the weak area to avoid the mishap. The weak area may be ascertained on the following grounds:

- Health of infrastructure
- Structural sustainability of the flood bund/ river training work.
- Hydraulic gradient line may not be exposed in any case.
- Flow behavior of river and distance of main course / creek of river.
- Villages, towns and big cities which may be affected due to any mishap.

The inspections can be facilitated through the use of modern equipment like Ground Penetrating Radar (GPR) which is a simple trolley mounted equipment and uses electro- magnetic waves to determine cavities, hollows, runnels and even buried pipes etc. It is easy to use and is provided with necessary computer and software for interpretations of observations. This equipment provides a lot of promise for ensuring safety of existing embankments. Its use however has cost implications and requires trained operators and data interpreters.

3.7 Revised SOPs (Standard Operating Procedures)

The SOPs (Standard Operating Procedures) require to be revised to ensure their utility/adequacy under the present conditions. SOPs to combat the flood may be prepared for individual structure / embankment keeping in view the weak area / hot spots identified earlier. Contingency plan may be prepared which should indicate the infrastructures coming in flood route with special focus to low lying area and villages / towns to be affected.

3.8 O&M Requirements

The O&M yardstick need to be revised and updated to ensure proper maintenance of the flood infrastructure. Exclusive provisions need to be made for restoration of aprons of the spurs and to cover emergencies caused by river erosion. This is considered essential because substantial budget is spent for addressing emergencies and much less amount is available for normal maintenance of embankments. In addition, funds need to be earmarked for converting embankment tops into all weather roads.

A review of the funding for the maintenance of embankments indicates that the budget allocations are short of the requirements with the result that the health of flood infrastructure has been impacted due to deferred maintenance. Year-wise demand and expenditure on flood infrastructure given below reflects this aspect:

Table 6: *Year-wise Expenditure on Flood Infrastructure (IPD, 2010)*

(Rs. in Million)

Year	Demand	Allocated	Expenditure
2004-05	272	199	197
2005-06	360	333	330
2006-07	473	423	418
2007-08	526	392	389
2008-09	527	456	455
2009-10	537	442	441

Substantial part of the maintenance budget is spent on spurs and on fighting emergencies during floods. This leaves much less budget for normal maintenance of embankments. The maintenance of embankments is further impacted due to long dry spells when the embankments develop cracks and rodent holes, etc.

4. Strategic Framework for Restoration of Flood Damages 2010

4.1 Description of Damages

- **Physical**
- Irrigation Network (Muzaffargarh, Rajanpur, DG Khan) including breaches in the main canals namely T.P Link Canal, Muzaffargarh Canal, D.G Khan Canal, Rangpur / Taliri Canal.
- Breaches in the Left Guide Bank of Jinnah Barrage and breaches in the Left Marginal Bund of Taunsa Barrage

- Flood Protection and drainage Structures (Bahawalpur (Guddu Barrage,), DG Khan (Jampur, Kot Mithan), Multan, Sargodha, Faisalabad and Lahore)
- **Financial**

Zone wise abstract of damages caused by flood 2010 is as under:

***Table 7**: Zone-wise Abstract of Damages*

(Rs. in million)

S. No	Name of Irrigation Zone	No. of works	Type of work	Estimated Cost
1	Sargodha	161	Flood Protection Bunds and Irrigation Infrastructure	1269.190
2	D.G Khan	140		1100.000
3	PMO Barrages	20		637.000
4	Bahawalpur	29		176.240
5	Multan	11		12.353
6	Lahore	1		2.490
7	Faisalabad	3		2.172
	G. Total:	**365**		**3199.445**

***Source**: IPD, 2010*

4.2 Flood Damages Restoration Strategy

- Works divided in three categories:
- Immediate – critical canal and embankment breaches, repair of which was necessary to contain inundation and restoration of canal supplies.
- Medium term – strengthening of weak canal banks, repair of barrage support structures, buildings and repair of distributaries and minors network.
- Long-term – strengthening and improvement of flood protection works on new bench marks

***Table 8**: Estimated Cost of Works*

Category	Description	Cost (Rs. MIL.)
Immediate Works	Canal and embankment breaches	1,000
Medium Term	Strengthening of weak canal banks, repair of barrage support structures and buildings	2,200
Long Term	Strengthening and improvement of flood protection works on new bench marks. i) Strengthening and raising of existing bunds ii) Proving wetting channels along the bunds. iii) Provision of Second Defence Bunds. iv) Improving the drainage capacity to provide relief in case of breaches	7,000

4.3 Progress

- LMB breach of Taunsa was closed on war footing basis on August 25, 2010
- Breaches of Muzaffargarh Canal, T.P Link Canal, D.G Khan Canal and Rangpur Canal were plugged and channels were made operational by September 15, 2010

- Work on damages to the distribution system is going on and would be repaired by end March 2011 and channels being non perennial in nature would be opened in April for Kharif 2011
- Repair works to the distributaries and minors being done through Departmental machinery while repair works to smaller minors and On Farm systems being done through farmer participation.
- PC-Is for the longer term works on strengthening and up-gradation of embankments have been prepared and undergoing approval process at various fora.

4.4 Financing Arrangements

i) Through Intra-sectoral ADP re appropriation (Rs.1440 million)
ii) Through Inter-sectoral ADP re-appropriation (Rs.746milion)
iii) Through intra adjustments in the O&M budget of I&P Department (Rs. 1002 million)

4.5 Implementation and oversight mechanism

- Immediate works were carried out under emergency provisions
- Wherever feasible, Departmental Machinery was used for breach closing
- All emergency works were Supervised by Third Party Monitoring Consultants

5. Recommendations

5.1 Flood Planning and Management

Flood fighting plans to be prepared and updated to incorporate changing techniques and field conditions. Flood works to be maintained to design parameters. The damaged aprons of spurs are to be repaired and maintained at lowest winter water level. Flood fighting materials to be arranged as per approved flood fighting plans and to be kept at pre-identified strategic site. Appropriate machinery for flood fighting is to be mobilized on barrages during flood seasons.

Flood protection works should be given due importance in resource allocation irrespective of the infrequency of floods. There is a need for establishment of new bench-marks in terms of protection works heights and strengths and a fresh drainage plan for quick draining of flood waters from affected areas. The regulation at the Head works / Barrages needs to be done strictly according to the Regulation Rules. New river training works, whenever required, are to be planned by model studies. There is a need for identification and demarcation of river water route escaping from the breaching section and relief cuts. Efficient communication arrangements are to be made and effective coordination is required with the District Administration, Army and Police.

Capacity building of the staff responsible for flood management on barrages needs to be enhanced by giving them appropriate training for flood fighting and management. Case study approach and special short training courses may be arranged for officers and officials of I&P Department on the subjects of flood preparedness / management, design, construction and maintenance of flood infrastructure and responding to flood emergencies.

5.1.1 Evaluating Health of Existing Flood Protection Infrastructure and Identifying Critical Needs for Rehabilitation / Improvements of Infrastructure

The evaluation of health and safety of flood works at suitable and regular intervals bears paramount importance. The current situation is that the embankments remain dry for most of the time and may develop cracks, fissures and rodent holes, etc. These bunds therefore need effective surveillance through proper maintenance during dry period, and detailed in depth inspection and requisite repairs before the onset of the flood season. As already mentioned, the procedure currently in vogue leaves much to be desired, and the SOPs (Standard Operating Procedures) needs to be updated and improved, backed by effective and efficient monitoring systems.

5.1.2 Provision and / or Strengthening of Second Defence Line and Provision of Wetting Channels

The planning of flood bund network and bund design need to be reviewed holistically and suitable plans and designs have to be prepared and implemented, as below:

- All the flood bunds were to be redesign and improved accordingly.
- The wetting channels may be provided along such embankments which are protecting big cities, major towns or major infrastructure / barrages.
- The second defence embankments may be provided in the critical / important reaches or where the river main course is approaching to the 1st defence embankments.
- Where second defence embankments are already existing, then these embankment should be strengthened and properly maintained.

5.1.3 Adequate Funding for Maintenance of Flood Infrastructure

Yardstick may be updated to cover the routine and emergency needs of flood embankments, spurs and river erosion. The funds may be provided as per Yardstick to each division well in time, but in case of emergency, special funds may be arranged for restoration without any cut in normal O&M funds.

5.2.1 Establishment of New Benchmark and Investments

Resources and investments are to be identified not only to fulfill the current needs of the recent flood event but also to cater for the future needs arising from future extreme events through establishment of new benchmarks regarding HFL, freeboard, design of embankments, and safety measures for flood protection infrastructure. Regular updating of SOPs (Standard Operating Procedures), regular drills for disaster management, regular capacity building / training of managers for flood protection, barrage management and public handling during crisis is required.

5.2.2 Holistic Drainage Improvements

Identification of flood release channels / escape channels may provide relief / reduction in flood peak discharge in the main rivers. There is a need to identify high and medium flood risk areas for permanent settlements and to devise appropriate solutions for speedy evacuation of flood waters through appropriately designed drainage infrastructure. An analysis needs to be made for Breaching options/relief cuts. The existing breaching arrangements need to be revisited and appropriate locations are to be fixed. Post breach options should also be analyzed for safe passage of spill water.

Adequate drainage facilities may be provided on roads, highways and other related infrastructures. There is a need for upgrading to a higher level than usual the drainage facilities to provide protection to the cities and town and important installations such as power stations, oil refineries, industries etc.

5.2.3 Mitigation of Flood Peaks / Damages

- Improving and extending the Flood Forecasting System to include the Upper Indus above Tarbela and Kabul river system above Nowshera.
- Construction of on channel and off channel storages that would provide major reduction in flood peak discharges in the main rivers.
- Flood Plain Mapping/Zoning along all the Indus river and its tributaries for identifying high and medium flood risk areas for permanent settlements.
- Legislation for restricting the development of permanent settlements in river flood plain and in high flood risk areas.

5.2.4 Simulation and Scenario Analysis

There is a need to build on the existing strength of Meteorological Department on weather and forecasting to provide more effective support to decision making in disaster risk management at the national, sectoral and local level. Flood forecasting and warning services needs to be fully integrated and enhanced institutional coordination and communication from central to local level is crucial for timely implementation of flood related activities and their field effectiveness. Critical observations infrastructure and its telecommunication facilities need to be reconstructed and calibrated. Forecasting models including software need to be updated and applied.

To update the system following improvements are required to:

- Operate the system for 2010 event in a manner to simulate the real time situation for different points in time in the Indus River System.
- Extend the model to include rainfall-runoff models of Kabul river of which Swat river is a tributary and Indus river upstream of Tarbela.
- Review and revise the flood regulation guidelines for Tarbela reservoir with the objective of reducing flood peaks in the Indus river downstream.
- Study the possible breach locations upstream of the structures. The path of flows through these breaches up to the point where it joins the river downstream should also be studied so that inundation patterns could be forecasted and the settlements in the flood passage may be restricted by law.

5.2.5 River Surveys / Model Studies

River survey methodology needs to be improved by utilization of new technologies that have now become available for speedy and accurate surveys e.g. imageries, digitization, bathymetries and total stations. Model study for river training works be done from control point to control point and flood protection schemes should be planned in the light of recommendations of the model studies.

5.3.1 Improving Inter-Agency Coordination

There is a need for a fresh look at the district and tehsil administration system to bring back the ability for effective leadership and coordination during emergencies. Efficient Communication links need to be established among Pakistan Meteorological Department, Irrigation and Power Department, WAPDA, District Administration, Army, Police, Press and Public Representatives. The widespread damages could have been contained in case there had been effective and improved coordination. At local level the District Coordination Officer should perform the main coordination role among various Departments including Irrigation, Agriculture, Police, District Administration, and others during the flood.

5.3.3 Role of D&F Zone

Drainage and Flood Zone was established in 1974 and its role is to coordinate activities related to flood management and flood protection infrastructure with the field engineers and the Departments of Federal Flood Commission, Pak Meteorological Department, Pakistan Army and other related agencies. Monitoring and evaluation functions need to be entrusted to the D&F Zone for effective flood management.

5.3.5 Effective Security Arrangements

Effective and efficient security arrangements should be ensured on all barrages with the help of district administration, police, Pakistan army and other related agencies. Effective security arrangements are also to be ensured by the law enforcing agencies not only for the safety of the public infrastructure but also for the personnel and Government officers working on barrages for flood fighting. Appropriate lighting arrangements should be made during the night time for effective surveillance on barrages.

5.5 Way Forward

The following strategic interventions need to be planned and implemented for improving flood management and mitigating the impacts of flood disasters:

- Build water storages to mitigate the impact of super floods
- Build back better and safer structures keeping in view the new benchmarks
- Invest in disaster preparedness and effective management of relief and early recovery when it happens
- Better regulation of riverine / khadir areas and a proper regulatory and enforcement mechanism
- Build positive synergies between an active media and positive spreading of message among masses during crisis
- Flood protection works should be given due importance in resource allocation irrespective of the infrequency of floods
- Regular updating of SOPs (Standard Operating Procedures), drills for disaster management, capacity building / training of managers for flood protection, barrage management and public handling during crisis
- Promotion of spirit of Self Reliance in emergency relief and post disaster rehabilitation

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Management of High Floods

National Disater Management Authourity, Pakistan

General

It is an irony that the nation, which was complaining about years-long shortage of water, till the month of June 2010, fell prey to unprecedented floods that damaged towns, villages and vast agricultural lands. Pakistan faced drought from 1996 till 2002 which was considered worst in last 50 years. In the past Pakistan experienced severe floods in 1973, 1992, 2006 and 2010. But 2010 floods broke all past records. This rotation of two extremes has plagued the nation with heavy economic losses and human sufferings.

The 2010 Floods began in late July 2010 following heavy monsoon rains in the Khyber Pakhtunkhwa, Sindh, Punjab and Balochistan regions of Pakistan and affected the Indus River Basin. Approximately, one-fifth of Pakistan's total land area was underwater. According to Pakistani Government data, the floods directly affected about 20 million people, mostly by destruction of property, livelihood and infrastructure, with a death toll of close to 2,000.

The Pakistani economy suffered an extensive damage to infrastructure and crops. Structural damages have been estimated to exceed USD 4 billion, and wheat crops damages are estimated to be over USD 500 million. Officials have estimated the total economic impact to be as much as USD 43 billion.

The agricultural damages are more than 2.9 billion dollars, according to an estimate, over 700,000 acres of cotton crops, 200,000 acres of sugar cane and 200,000 acres of rice crops are lost.

The power infrastructure of Pakistan also took a severe blow from the floods, which damaged 10,000 KM transmission lines and transformers, feeders and power houses in different flood-hit areas. Flood water inundated Jinnah Hydro Power Project and 150 small power plants in Gilgit. The damage caused a power shortfall of 3.135 Gigawatt.

India received comparatively less rains, managed much of the water with the help of its newly constructed dams and reservoirs and caused minor flood in Satluj River, along with borders of Kasur district of Pakistan. The disastrous natural calamity could have been further destructive; had India released the surplus water in case of heavy rains there.

In early August, the heaviest flooding moved southward along the Indus River from severely affected northern regions toward western Punjab, where at least 1,400,000 acres of cropland were destroyed, and then towards Sind and Baluchistan. By mid-September the floods had begun to recede.

Flood Hazards

In Pakistan, the Floods are caused by Monsoon rains and melting of snow and glaciers in the north. The country is commonly exposed and vulnerable to Monsoon rains which come every year during the months of June, July and August. With modern satellite weather forecast, we can take affective measures to minimize the damages. The early warning system can inform the vulnerable community about hazard.The Hazard assessment comprising of amount of precipitation, river capacity and the water spread area, announcements can help to minimize the damages.

Melting of glaciers in northern Pakistan due to global warming is also potential hazard, which can generate floods. We can reduce its affect by constructing Dams. Hydro meteorological hazards include: floods, debris and mud flows; tropical cyclones, storm surges, thunder/hailstorms, rain and wind storms, blizzards and other tsunamis.

Depletion of Existing Storages Capacity

Reservoir Sedimentation is one of the major problem, as the available capacity of existing reservoirs continues to diminish with accumulation of sediment in the storage space. Tarbela Dam stores about 1/9 of the average flows of river Indus at that site while most of the sediment is retained due to 95% trap efficiency. The storage lost is about 0.11 MAF per year. Tarbela has lost 30% of its gross storage. Similarly the per year storage loss in Mangla Dam is 0.019% MAF and it has lost 15 % of its gross storage. Table –I gives the loss of storage in reservoirs.

Present Water Availability

Pakistan is a water scarce country. According to Falcen Mark, Global Water Scarcity Indicators, if a country has less than 1700 m3 / capita water availability, it faces seasonal or regular water-stressed conditions. Pakistan per capita water availability is 1038 m3 which would reduced to 800 m3 / capita in the year 2025. (Fig-1).

In Pakistan the available storage per capita is about 100 m3 which is very low as compared to other semi-arid countries (Fig-2). The water storage capacity of Pakistan is very small and can store only 30 days of average flows (Fig-3).

Need for new Storage Dams and their role in Flood Mitigation

The existing storage capacity is reducing while more water is required to meet the growing demand due to increase in population.

During flood 2010 about 55 MAF of water passed through Kotri Barrage and went to sea. About 17.87 MAF flood water did not reach the sea, submerging areas in Sindh and Balochistan for several months. Fig-4 shows that on the average 31.25 MAF of water/year goes to sea unutilized.

In an agricultural country like Pakistan, the storage dams are life line to the nation. These reservoirs store water and regulate releases for irrigation supplies after saving precious river water from going into Sea and play an important role in mitigating floods. Low cost hydro electric power is secondary benefit of such multi purpose projects. While Pakistan has hydro- electric potential more than 50,000 MW, but we are not equally fortunate to have many large storage sites. Egypt has Aswan high dam with storage capacity of 90 MAF which saved the country not only from floods but also from 7 year drought. Three Gorges dam in China has storage of 30 MAF which produces 22000 MW of electricity in addition to flood mitigation and navigation. Pakistan does not have large yearly carry over sites. We have sites only for seasonal carry over i.e from Kharif to Rabi season. It is also necessary because of climate; rains during June, July & August and snow melt also during this period. We have 70% river flows during the three months of June, July & August while during the remaining nine months the flows are only 30%. There is no storage site on river Chenab and Jhelum. On river Indus the d/s most site is Kalabagh before the river debouches into plains. About 320 KM U/S of Tarbela, the site is Diamer Basha Dam with a gross storage of 8.4 MAF. Upstream of this, there is a site near Skardu. Any sizeable storage at the site would drown the entire valley of Skardu and Shiger with great environmental consequences. There is a site on Shiger river with about 6 MAF of storage. Except these on line storages, we have limited off-channel storages such as Akhori Dam off-taking water from river Indus and Rohtasfort dam off-taking water from river Jhelum. These off-channel storages have considerable environmental problems.

After raising Mangla Dam, its storage capacity increased by 2.9 MAF, there would be little surplus water and less flood hazard. On river Indus, we have Bungi, Dasu, Pattan and Thakot run of river projects, which can also store water about 1.15 MAF. We have to explore run of river sites with some storages on rivers Hunza, Gilgit and their tributaries.

Nowshera and Peshawar valley are flooded by river Kabul and Swat. We have Warsak hydropower project or river Kabul which is silted upto spillway crest and now run off the river project. There is no storage site on river Kabul d/s of Warsak. Munda dam is being designed on river Swat which would store about 1 MAF of water and produce 760 MW of electricity. This has 50 ft of free board to absorb the flood peaks and stagger it with the Kabul river peaks thereby mitigating floods in Nowshera.

On Gomal Zam river, we have built Gomal Dam project which would store about 0.9 MAF water, produce 17 MW and mitigate floods in addition to irrigation of 163 thousands of
Acres of agriculture land.

We have to harness the hill torrents for irrigation and flood mitigation. Govt. of Pakistan plans to build 36 small dams in the four provinces of Pakistan which would help to mitigate floods in addition to Irrigation.

We have constructed three flood canals; Greater Thal Canal, Kachi Canal and Rainee Canal which helped to mitigate floods.

Construction of dams, channels, levees and diversion of water to side channel storage or other watersheds, provide tools to reduce flood damages.

Fig-5 shown the hydrograph during 2010 floods. Tarbela Dam project absorbed a peak of 2 lac cusecs of river Indus on 30th July without which the intensity of flood would have been very server. Had Kalabagh been there, it would have also stored more than 2 MAF of water as shown in (Fig-6), and there would have been no floods.

No Mega storage dam was constructed after Tarbela and Mangla. The need for new water storage reservoirs must be realized to fulfill the water requirement and mitigate the floods.

The consequences we are facing for not building large Dams:

- Progressive loss of existing storage capacity with resultant shortfall in committed irrigation supplies and flood mitigation.
- Sustained colossal losses due to uncontrolled super floods.
- Recurring inter-provincial disputes on water sharing, particularly during early Kharif.
- Serious undermining of national food security.
- Stinted growth of domestic, industrial and agricultural sectors.
- Enhanced dependence on thermal power generation through imported fuel causing prohibitive rise in the power tariff.

Proposed Flood Mitigation Plan

Following plans are suggested / being implemented for mitigation of future floods:

1. By constructing Mega Reservoirs:
   (i) Mangla Dam Raising Project Additional flood storage capacity of 2.9 MAF.
   (ii) Constructing Munda Dam on the Swat River will be helpful in mitigating the flood in Swat River by absorbing 1.29 MAF.
   (iii) Constructing Kurram Tangi Dam to mitigate the flood to the volume of 1.20 MAF.
   (iv) Diamer Basha Dam, which can absorb a huge volume of 6.4 MAF will save downstream area upto Tarbela from any type of flood in Indus.
   (v) 32 Medium Dams will be constructed in four provinces of Pakistan in two phases. In Phase-I, 12 dams and in Phase-II, 20 dams will be constructed from 2010 to 2013 & 2011 to 2016 respectively. These 32 dams will control and absorb the flows coming from the rivers/streams in their respective areas.
   (vi) Construction of off-channel Akhori Storage Project.
2. Feasibility of re-routing floods in desert areas.
3. By constructing fuse plugs and by pass channels upstream of barrages allowing the flow to return back to the rivers.
4. By strengthening and maintaining Flood Protection Bunds with at least 100 years return period.
5. Conversion of MNVD (Main Nara Valley Drain) into flood carrying drain.
6. Feasibility for rehabilitation of Hamal and Manchar Lakes to absorb more flood volume.

7. Creation and development of lakes and wet lands wherever possible to control the flood.
8. Management of Hill Torrents by constructing checks and delay action dams.
9. Updating the existing flood plain maps and preparation of flood maps in other affected areas like Kabul and Swat Rivers. No construction below maximum flood level in Malakand, D.G. Khan, Hazara should be allowed.

Conclusions:

The overall water scarcity, escalating future demand and stagnating water availability, large annual and seasonal fluctuations in river flows, inadequate storage capacity and progressive reduction in the capacity of the existing reservoirs due to sedimentations, over exploitation of fresh aquifers and degradation of water quality are the emerging threats.

The 2010 flood was attributed to heavy rainfall, climate changes and monsoon pattern. There is great need for better management of Indus River System, emergency warning and evacuation systems and flood management.

We need to develop our limited number of storage sites to obtain maximum benefit of water, power and flood mitigation.

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Table-1: *Loss of Storage in Reservoirs in Pakistan*

Reservoir	Original	Present	Loss due to sedimentation
Tarbela	9.69 (1976)	6.77	2.92 30%
Mangla	5.34 (1968)	4.54	0.80 15%
Chashma	0.72 (1971)	0.26	0.466 3%
TOTAL	**15.75**	**11.57**	**4.18** **27%**

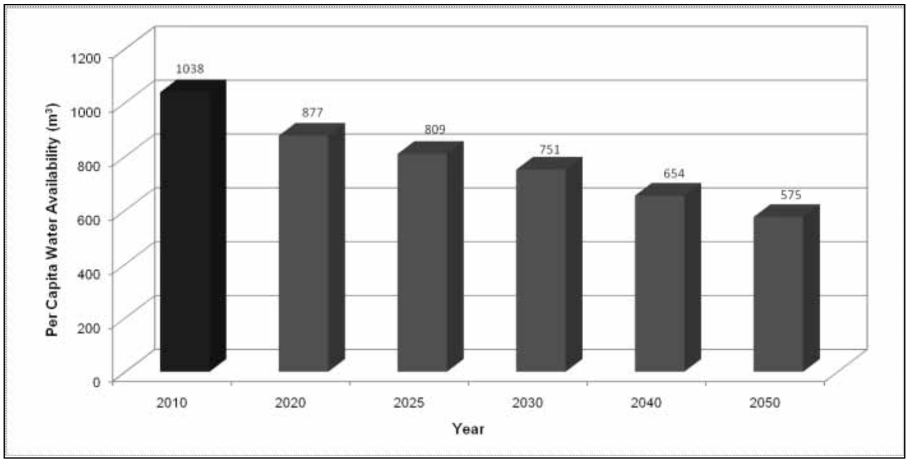

Figure 1: *Water Availability - Pakistan Projected Scenario*

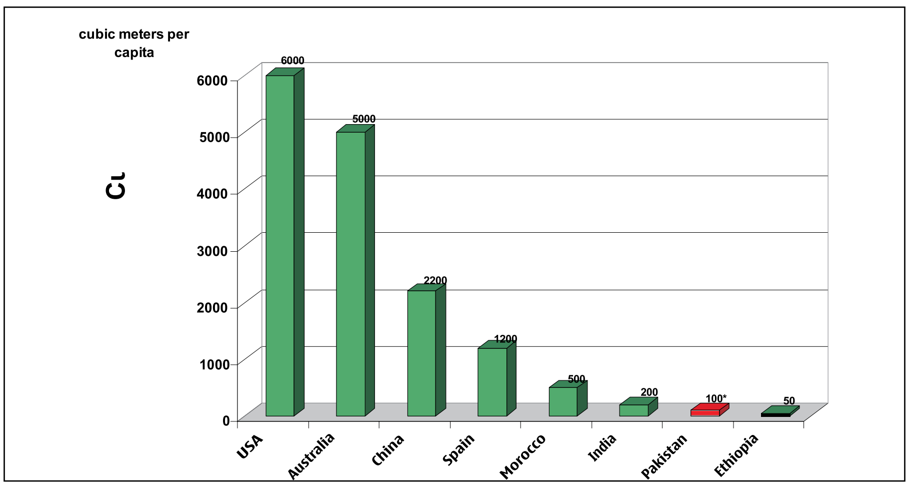

Figure 2: *Storage Per Capita in Different Semi Arid Countries*

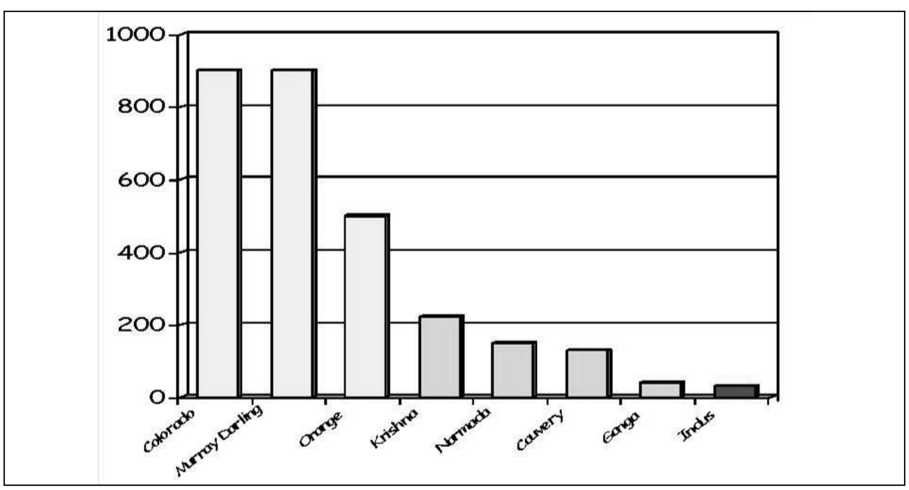

Figure 3: *Days of Average Flow which Reservoirs in Semi-Arid Countries can Store in Different Basins*
(Source: *World Bank analysis of ICOLD and GDRC data)*

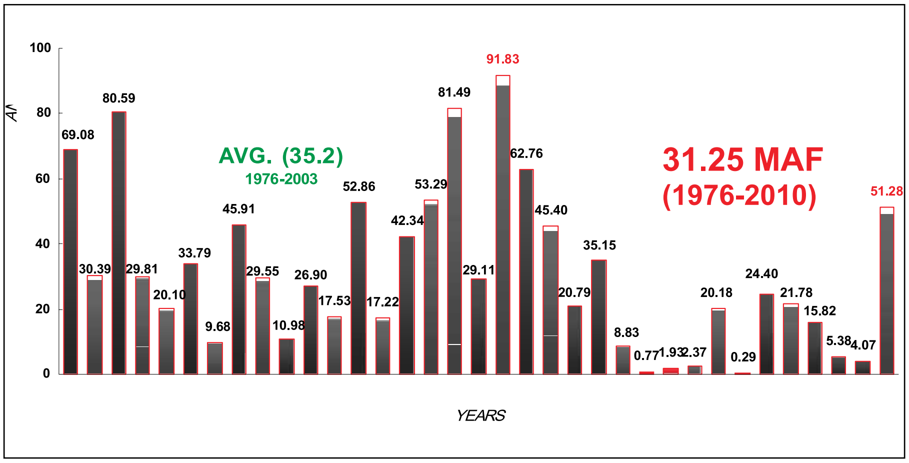

Figure 4: *Escape Below Kotri*

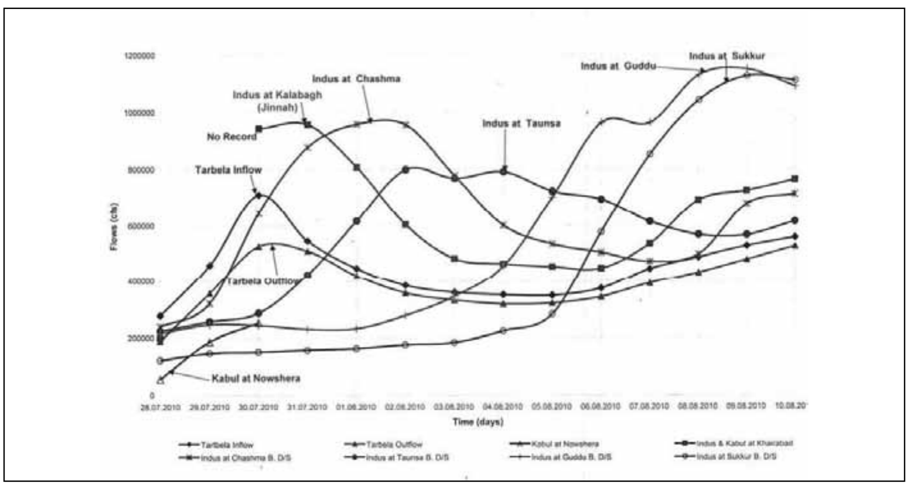

Figure 5*: Indus & Kabul River Flood Hydrographs During 2010*

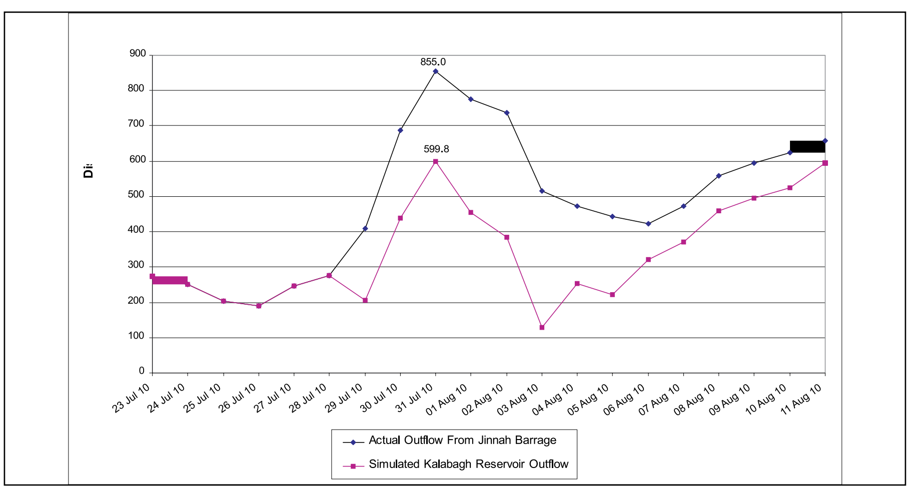

Figure 6*: Flood Mitigation with and without Kalabagh Dam During July And August 2010 Catastrophic Floods*

Pakistan Flood 2010: an Opportunity to Build Back Better

National Disater Management Authourity, Pakistan

Introduction

In Pakistan floods have been causing large scale devastation in the past. However the historic flood of 2010 caused large scale destruction of property, agricultural area , livestock and human life. The cause of this large scale devastation has mostly been the inadequate arrangements for dealing with the floods. The developed countries have established adequate systems for managing the flood disaster. These systems involve the stages of preparedness, rescue and relief and post-disaster rehabilitation and reconstruction in a planned manner. Consequently, the flood disaster is restricted to the minimal loss of life and property in those countries. Learning from the experience of the developed nations, we need to employ the principles of Town Planning in our flood disaster management system. Thus proper Town Planning intervention in flood disaster management helps in building back better. In fact, the disaster risk reduction (DRR) is a part of any plan whether it is prepared at regional level or local level. It means that if the concept of total planning i.e. planning of all areas of the country is adopted, the nation will be prepared to face all types of disasters including flood disaster. Today the new technology can help us avert the flash flood disasters also. For example, a watch and ward system can be established through a continuous study of satellite imageries of the northern and north western mountainous areas to note down the development of natural lakes which burst out to cause flash floods. Similarly, the river plains and areas liable to flooding would be strictly avoided for development of any settlement through a national planning law and local development control regulations. At regional planning level dykes and flood water channels may be built and maintained along all rivers to avoid flooding of human settlements. In countries like Pakistan, most of the settlements that are destroyed due to heavy floods are the unauthorized and unplanned settlements. In normal circumstances, it is almost impossible to demolish these houses or settlements and evict the dwellers for the purpose of redevelopment according to the principles of DRR. However, the flood disaster provides an opportunity to relocate settlements developed on dangerous sites or areas liable to flooding. Later holistic planning can be followed at the stage of rehabilitation and reconstruction of these settlements. In case the settlement is located on safe site, onsite redevelopment may be carried out with flood proof material and provision of infrastructure in a planned manner. The redevelopment works may be carried out on the basis of aided self-help so that financial burden of the government may be reduced. New land acquisition law may be promulgated to procure land for housing the flood affected poor people. Moreover, the local planning and land sub-division bye- laws may be suitably modified to allow for construction of affordable houses for the flood affected people on the basis of aided self-help.

Floods in Pakistan

There were more or less 15 flood disasters in Pakistan since its independence. However, the recent flood of 2010 was the worst of all in the history. It affected more than 20 million people and took more than 1781 lives. The following table gives the record of various floods in Pakistan[1].

Historical floods in Pakistan From 1950 till 2010		
Year	**Fatalities**	**Villages affected**
1950	2,190	10,000
1956	160	11,609
1957	83	4,498
1973	474	9,719
1976	425	18,390
1978	393	9,199
1988	508	1,000
1992	1,008	13,208
1995	591	6,85
2001	219	50
2003	484	4,376
2004	85	47
2005	59	1,931
2007	918	2 million+[2]
2010	1,781+	20 million[3]

***Source**: http://en.wikipedia.org/wiki/List_of_floods_in_Pakistan*

Types and Causes of Floods in Pakistan

There are many types of flood that occur in the country almost every year.[4]

- **Monsoon floods** are common in Pakistan. Monsoon rain can fill river basins with much water coupled with melting snows. Torrential rains from decaying monsoon low pressure area can also produce river flooding.
- **Flash floods** also occur in Pakistan, they are common in the northern areas of the country and cause great loss of life there.
- **Floods due to the breaches** of river embankments and canal breaches are a frequent occurrence in all the districts of Pakistan.
- **Urban floods** occur in the major cities of Pakistan, they are also common in the monsoon season.
- **Coastal floods** occur when a tropical storm makes landfall in the coastal areas of the country. The south eastern Sindh and the Makran coast bear the burnt of such floods.

In Pakistan, heavy concentrated rainfall in the catchments during the Monsoon season, which is sometimes augmented by snow melt flows – primarily outside the Indus Plain, generally cause floods

[5]. Monsoon currents originating in the Bay of Bengal and resultant depressions often cause heavy downpour in the Himalayan foothills. These are additionally affected by weather systems from the Arabian Sea (by seasonal lows) and from the Mediterranean Sea (through Western Disturbance) which occasionally produce destructive floods in one or more of the main rivers of the Indus system if they interact with the monsoon currents. However, exceptionally high floods have occasionally been caused by the formation of temporary natural dams by landslides or glacier movement and their subsequent collapse. These are large seasonal variations in almost all the river discharges, which further aggravates the river course and morphology. The major rivers cause losses by inundating areas along their banks, by damaging irrigation and communication facilities across or adjacent to their banks, and by erosion of land along the riverbanks. In the upper part of the Indus Basin System, flood water spilling over the riverbanks generally returns to the river. However, in the lower Indus Basin, where the Indus primarily flows at a higher elevation than adjoining lands, spills do not return to the river. This phenomenon extends the period of inundation, resulting in even greater damages. Although embankments built along almost the entire length of the river in Sindh and at many locations in the upper Indus Basin have provided some protection against floods, poor maintenance of the bunds causes breaches. Such breaches often cause great damage because of their unexpected nature and intensification of land use following the provision of flood protection. Floods are a potential threat to land, property, lives, and the ecosystem. Floods cause revenue loss and damage irrigation and drainage channels.[6]

2010 Flood in Pakistan

In 2010, almost all of Pakistan was affected when massive flooding caused by record breaking rains hit Khyber Pakhtunkhwa (KPK) and Punjab. The 2010 Pakistan floods began in late July 2010 following heavy monsoon rains in the Khyber Pakhtunkhwa, Sindh, Punjab and Balochistan regions of Pakistan and affected the Indus River basin. At one point, approximately one-fifth of Pakistan's total land area was underwater. The number of individuals affected by the flooding exceeds the combined total of individuals affected by the 2004 Indian Ocean tsunami, the 2005 Kashmir earthquake and the 2010 Haiti earthquake. At least 2,000 people died in this flood and almost 20 million people were affected by it [7].

The National Disaster Management Authority (NDMA) of Pakistan has reported the following damages of the 2010 Flood of Pakistan:

Summary of Damages	Balochistan	KPK @	Punjab	Sindh	AJ&K	GB	G.Total
Deaths	48	1156	110	234	71	183	1802
Injured	98	1198	350	1201	87	60	2994
Houses Damaged	75,261	200,799	509,814	1,114,629	7,106	2,830	1,910,439

***Source**: National Disaster Management Authority, Islamabad, 22 September, 2010 Update.*

KPK @ = Khyber Pakhtoon Khwa province + Federally Administered Tribal Area (FATA), AJ &K = Azad Jammun and Kashmir, GB = Gilgit Baltistan Province .

The infrastructure damages in Flood 2010 have been reported on the website of Urban Unit, Government of Punjab, as follows:

FLOOD 2010 (Infrastructure Damages) (26-09-2010)			
Data received & evaluated for PDMA Notified Districts			
Sector	Completely Damaged	Partially Damaged	Details Received to date
C&W			
(i) Flood affected	-	3489 kms	Details of 835 kms have been received to date
(ii) Rain affected	-	261 kms	
Irrigation & Power			
(i) Irrigation Channels	-	461	Details of Irrigation works was provided. No data on prescribed proformas has been received to date
(ii) Flood Bunds	-	67	
HUD&PHED			
(i) R.W.S Schemes		218	Most of the PHED schemes have been rehabilitated and 80 are reported as damage as of 23rd September 2010.
(ii) R.D. Schemes		20	
School Education			
(i) School Buildings	603	2317	Data for 1264 schools has been received as of 26th September 2010
(ii) Equipment	603	2317	
Higher Education			
(i) College Buildings	3	1	Data for all 4 has been received as of 26th September 2010
(ii) Equipments	3	1	

Literacy & Non-Formal Education			
(i) School Buildings	215	189	Data from 396 Non Formal Schools has been received as of 26th September 2010.
(ii) Equipments	215	189	
Health			
(i) BHUs	3	36	Data for all 44 BHUs has been received 5 of 44 BHUs were still underwater as of 9 September 2010
(ii) RHCs	-	7	Data for 6 RHCs has been received as of 9 September 2010
(iii) Dispensaries	-	3	Data for 3 Dispensaries has been received and all partially damaged as of 9 September 2010
(iv) THQ	1	3	Data for all 4 THQs has been received as of 9 September 2010
(v) Residences	1	26	Data as reported at District level till 9 September 2010
LG&CD			
(i) No. of Ucs affected			
Agriculture			

(i) Area			Total inundated area = 2.04 Million acres, Crop area irreversably loss = 1.74 Million acres. Information on Godowns was not under the Agriculture Department but had under the Agriculture Department but had to be provided by Food Department.
(ii) Crop loss			
(iii) Buildings			
Livestock			
(i) Loss of Animals (Private)	4193	-	Information of 90 buildings at District level has been received. Tehsil level information is still awaited.
(ii) Buildings	-	99	
Forestry, Wildlife, Fisheries			
(i) Area in acres			Received summary shows 723 acres damage including areas not notified by the PDMA but not in line with District level data.
(ii) Buildings			
(iii) Equipments			
Industries			
(i) Private Industries Unit			Summary showing 800 baseline industrial units in flood affected areas was provided by concerned DCO/EDO IP, however, no damage reports have been received to date.
(ii) Public Buildings			
Others			
(i) Buildings			No buildings and equipment data has been received under other sectors namely Energy, SWM, WSS, Housing etc. Data on Auqaf Department's Buildings are under its heading below.
(ii) Equipment			
Police	21	34	Received data for shows different numbers than earlier estimated.
Population Welfare			
(i) Buildings	30	3	Summary data has been received from Population Welfare Department as of September 09, 2010
(ii) Equipment	19	15	
Lahore High Court	-	2	Data for both buildings has been received as of September 22, 2010
TEVTA			
(i) Buildings	-	5	Data of 4 buildings has been received as of September 22, 2010 .
(ii) Equipment	-	5	
Auqaf (Shrines)	-	9	Data of 9 shrines and 15 buildings has been received as of September 22, 2010
(i) Buildings	5	10	

Source: *The Urban Unit, Government of Punjab.*

Rescue and Relief

According to Pakistani government data, the floods directly affected about 20 million people, mostly by destruction of property, livelihood and infrastructure, with a death toll of close to 2,000. UN Secretary-General Ban Ki-moon had initially asked for $460 million for emergency relief, noting that the flood was the worst disaster he had ever seen. Only 20% of the relief funds requested had been received as of 15 August 2010.[8] The U.N. had been concerned that aid was not arriving fast enough, and the World Health Organization reported that ten million people were forced to drink unsafe water. [9] The Pakistani economy has been harmed by extensive damage to infrastructure and crops.[10] Structural damages have been estimated to exceed 4 billion USD, and wheat crop damages have been estimated to be over 500 million USD.[11] Officials have estimated the total economic impact to be as much as 43 billion USD.[12] [13]

In response to previous floods of the Indus River in 1973 and 1976, Pakistan created the Federal Flood Commission (FFC) in 1977. The FFC operates under Pakistan's Ministry of Water and Power. It is charged with executing flood control projects and protecting lives and property of Pakistanis from the impact of floods. Since its inception the FFC has received Rs 87.8 billion (about 900 million USD). FFC documents show that numerous projects were initiated, funded and completed, but reports indicate that little work has actually been done due to ineffective leadership and corruption.[14]. Now after the earthquake of October, 2005, the National Disaster Management Authority (NDMA) is in charge of the flood relief and reconstruction efforts.

Flood Disaster Management

Flood disaster management involves various stages of preparedness, early warning system, rescue and relief, and rehabilitation and resettlement of flood affected people. The developed countries have established adequate systems for managing the flood disasters. These systems involve the science of Town Planning at appropriate levels. Consequently, the flood disaster is contained to the minimal loss of life and property in those countries. No doubt, the proper management of disasters requires a huge expenditure which developing countries cannot afford to spend. However, disaster management efforts can be made affordable by involving local people and with the help of international donor agencies. For example, by creating awareness among people, deforestation in northern mountainous areas can be avoided which may reduce the occurrence of floods in the plain areas. Similarly, by controlling the carrying out of developments in the areas liable to flooding, a great loss of human lives, crops, property and livestock can be avoided. Sincere and planned efforts can not only save a huge loss of capital, infrastructure and precious lives, but they can also result in building safe and disaster resilient settlements. Thus disaster can be converted into an opportunity for building back better through proper Town Planning [15].

Town Planning Intervention at the Stage of Preparedness

Disaster preparedness refers to measures taken to prepare for and reduce the effects of disasters. That is to predict, and where possible, prevent disasters, mitigate their impact on vulnerable populations, and respond to and effectively cope with their consequences. Preparedness for disaster management includes:

1. Early warning systems based on meteorological forecasts and satellite imageries.
2. Construction of Dams to store excess water during flood season.
3. Construction of Dykes and Flood Water Channels/ Canals and water reservoirs.
4. Preparation and implementation of Regional Plans to control development of human settlements in all urban and rural areas.
5. Restricting developments on areas liable to flooding through development control regulations at local level.
6. Arrangement of camps equipped with food supply and health services to serve the displaced persons during floods.

John Ratcliffe [16] says that town planning is 'concerned with providing the right site, at the right time, in the right place, for the right people'. It means that if the town planning principles are properly followed, there will be no unauthorized development anywhere in the country. One of the basic principles of town planning is that 'areas liable to flooding should be avoided for development' [17]. The past experience of floods in Pakistan clearly demonstrates that most of

the settlements that suffered heavy loss of lives and property were located in the flood prone areas due to lack of any planning at the regional level. Moreover, the building material used in the construction of buildings, particularly in our rural areas is usually not flood proof. As a result all such buildings collapse during floods. Therefore, it is imperative to prepare regional plans covering all urban and rural areas of Pakistan so that the human settlements may be located on safe sites away from the low-lying, flood prone areas. The flash floods are usually caused by the bursting of natural lakes which are formed by landslides in the high mountainous areas. Today the remote sensing and Geographical Information System (GIS) technology is available to monitor and keep a continuous watch on such situations. Thus catastrophic damage to human life and property can be avoided through timely measures taken to avoid collapse of natural lakes developing in the high mountainous areas. Preparedness also includes creation of awareness among people and development of early warning systems to avoid flood damage. There is a need to develop building codes for all areas of Pakistan, including the flood prone rural areas [18]. Proper implementation of these building codes will help to avoid major disasters caused by floods. In this connection, it is worth mentioning the Hugo Framework of Action (HFA) developed in Japan. The five principles adopted in HFA are:

1. Make Disaster Risk Reduction (DRR) a priority
2. Know the Risks and Take Action
3. Build Understanding and Awareness
4. Reduce Risks
6. Be Prepared and Ready to Act

A DRR consultant of UNDP in collaboration with the Ministry of Housing and Works, Pakistan has proposed to prepare a set of guidelines for preparing the following five types of DRR Guided Development Plans to be implemented at different levels [19]:

i) DRR Guided National Development Plan (DRR-GNDP) at National level
ii) DRR Guided Regional Development Plan (DRR-GRDP) at Regional level
iii) DRR Guided Structure Development Plan (DRR-GSDP) at District level
iv) DRR Guided Master Development Plan (DRR-GMDP) at City level
v) DRR Guided Local Development Plan (DRR-GLDP) at Local Neighbourhood level

If all of the above plans are prepared by incorporating DRR factor, there is every possibility of achieving proper preparedness for the disasters in the country.

Post Disaster Recovery and Resettlement: an Opportunity to Build Back Better

In the normal circumstances, it is almost impossible to demolish the unauthorized and unplanned settlements built in the areas liable to flooding since the residents pose a great resistance to eviction and resettlement. However, in the post disaster scenario, when most of the houses and settlements have been wiped out from the face of the earth in the flood affected areas, there is a great opportunity to build model villages and model neighbourhoods in the cities at suitable sites using modern planning principles. In order to reduce the cost of redevelopment, the concepts of incremental development and aided self-help should be used as in the case of Khuda-Ki-Basti in Hyderabad. The post disaster recovery may include the following type of projects [20]:

1. Projects for preventive measures, such as construction of dams, dykes, flood water channels and water reservoirs should be developed alongside reconstruction work in the flood damaged settlements. These projects should be financed by government or NGOs.
2. Flood Damage Mapping and estimation of flood damages in various settlements should be quickly done as a first step to post disaster recovery using satellite imageries and GIS technology. This job must be done by the National Disaster Management Authority (NDMA).

3. On-site improvement projects for various settlements/ villages partially damaged should be given priority provided the settlement is located at a safe site. This type of projects may be implemented by people (or their local organizations) themselves. Fixed amounts of assistance or grants decided on case to case basis may be decided and be paid to the individual persons affected by flood. However, these amounts should be given to the flood affected persons after proper scrutiny and estimations on case to case basis and with the condition that they will rebuild their houses according to flood proof technology and building materials.
4. The settlements located in the areas liable to flooding or other high risk areas should be relocated on the safer sites. Such settlements should be developed in the form of fully planned model villages. The location and layout plans of these villages should be decided by the qualified Town Planners working in the local planning agency or in the consultancy firms.

5. Enforcement of standards and codes should be ensured in all flood damaged areas. If no building codes exist in the flood affected areas, new codes should be developed by the local Tehsil Municipal Administrations (TMAs).
6. No plan or project can be implemented without the provision of a proper institutional framework. Suitably qualified staff should be appointed for handling the technical and administrative work. The principle of right man for the right job should be adopted every where. Thus capacity building of the local planning agencies such as TMAs should be done on priority basis.
7. Flood Disaster Management is a complex task and it requires coordination among various line departments and various levels of government. For example, redevelopment of a village or an urban settlement cannot be carried out with out coordination and help from the departments which provide water, electricity, gas and telephone etc. Therefore, in order to implement the provisions of a Disaster Management Plan effectively, the coordination among the line departments such as Water and Sanitation Agency (WASA), National Highway Authority, WAPDA, SUI GAS, PTCL etc. must be achieved.
8. The reconstruction of buildings should be done using disaster resilient designs and flood proof material. Qualified engineers, architects and planners should be consulted for this purpose.

Conclusion

Flood disaster management in Pakistan has been suffering from the lack of Town Planning. It is high time to give priority to holistic Planning in the whole country so that all the human settlements in Pakistan are developed in a planned manner by incorporating Disaster Risk Reduction (DRR) concepts. Necessary steps should be taken for capacity building of the local planning authorities so that DRR guided development plans may be prepared and implemented at all levels. Monitoring and evaluation of these plans should also be carried out regularly to ensure proper implementation of these plans.

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Provision of Safe Drinking Water for Flood Affected Areas

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Abstract

Floods can have disastrous impacts on people and property, including loss of life, destruction of houses and other buildings, and displacement of those whose homes are flooded.

Floods can also have dire effects on public health and the environment, particularly water quality. Containers with hazardous materials may be displaced and their contents spill into streams and spread over nearby area. Wastewater and septic systems may be overloaded and compromised. Contaminated flood waters may seep into ground water, which mostly supply drinking water for a community.

The recent floods of Pakistan which began in July 2010, following heavy monsoon rains, affected most of the Indus basin. At one point, approximately one-fifth of Pakistan's total land area was underwater. According to Pakistani government data the floods directly affected about

20 million people, mostly by destruction of property, livelihood and infrastructure, with a death toll of close to 2,000. Floods have submerged 17 million acres (69,000 km2) of Pakistan's most fertile crop land, have killed 200,000 herds of livestock and have washed away massive amounts of food grain. All this made both the surface and groundwater polluted and unfit for drinking, washing and other potable usage.

During rehabilitation of the flood affected community, an effort was made by the authors to provide enough quantity of potable water with as per national water quality standards. For this purpose a portable and economically viable water purifying system was designed and installed in the flood affected area of Nowshera KPK area where quite encouraging results were obtained. This paper will highlight the results obtained from this effort.

Key words: *Water quality, floods, water purification, potable water, economically viable system*

Introduction

Safe drinking water is a human birthright – as much a birthright for clean air. However, much of the world's population does not have access to safe drinking water. Of the 6 billion people on earth, more than one billion (one in six) lack access to safe drinking water. Moreover, about 2.5 billion (more than one in three) do not have access to adequate sanitation services. Together, these shortcomings spawn waterborne diseases that kill on average more than 6 million children each year (about 20,000 children a day).

The long duration of the 2010 flood caused immense sufferings of the people in the affected areas. Disruptions of drinking water supply, sanitation, waste disposal, and disease transmission were among the major adverse impacts of this flood. This flood heavily affected the most parts of the country almost all the four provinces. About thirty million people in the affected areas got marooned.

The most serious problem encountered by the affected people was the quality of water, which deteriorated as a result of many factors. The floodwater, already fouled by the wash- aways from the upstream areas was further deteriorated by the complete submergence of the sewerage system, septic tanks and other sanitary facilities and by the direct disposal of human waste, kitchen waste and household refuse in the absence of sanitation and municipal facilities. The affected people were directly exposed to the polluted floodwater, which resulted in the outbreak of various skin diseases, in addition to serious diarrhoea and other waterborne diseases as a result of drinking contaminated water. This study was undertaken in order to assess the extent of deterioration of both the stagnant floodwater and the supplied drinking water quality.

Below is the table given for the important organisms and their recommended microbiological levels in the treated drinking water for Pakistan.

S.No	Organism	Recommended Maximum Value
01.	E coli	0/100 ml sample
02.	Shigella	0/100 ml sample
03.	Vibrio cholerae	0/100 ml sample
04.	Giardia lamblia	0/100 ml sample
05.	Cryptosporidium	0/100 ml sample
06.	Viruses*	Nil
07.	Psuedomonas aurginosa	0/100 ml sample

** Not for routine, only for surveillance purposes*

Below is explained the methods for determination of most important microbial contaminants

E coli	Generally measured in 100 ml sample. A variety of procedures based on the production of acid and gas from lactose or the production of enzyme β - glucuronidase. The procedure includes membrane filtration followed by incubation of membranes on selective media at 44-45°C and counting of the colonies after 24 hrs.
Total coliform	Total coliform bacteria include a wide range of aerobic and facultatively anaerobic Gram-negative, non-spore forming bacilli capable of growing in the presence of relatively high concentrations of bile salts with the fermentation of lactose and production of acid and aldehyde within 24 hrs at 35-37°C. As part of lactose fermentation, the total coliforms produce β-glactosidase. The procedures include membrane filtration followed by incubation at 35-37°C.

Design of Water Treatment Plant for Small Community

For this study two populations of each 400 to 500 people were selected. A prefabricated water treatment plant of capacity 600 litres per hour to treat flood / river water for drinking purpose was designed to be installed in the center of the each community. The processes used in this plant are coagulation, sedimentation, pre-chlorination slow-sand filtration and adsorption.

A container of size 4ft x 8ft x 8ft was fabricated using steel pipe and fiber-glass sheets. Inside the container plastic tank of 800 litres for sedimentation, 600 litres plastic overhead tank with filter media tank of 600 liter, Galvanized steel filter media tank and electric motors were fixed as shown in Figure 1.150. Similarly, 150 packets per month of coagulant and disinfectant, (Alum + Calcium hypochlorite) were provided with each plant. Each packet is dosage for one run of 800 litres Flood / River water with 10 mg/ l dosage of Alum and 1 mg/l dosage of chlorine applied.

Filter media used was 8 inch layer of Lawrencepur Sand with effective size 0.65 over granular activated carbon layer of 6 inch of effective size 0.95. Another 6 in layer of aggregate crush is provided at the bottom. A perforated collection pipe was embedded in the aggregate crush layer. This perforated pipe was connected to the delivery pipe

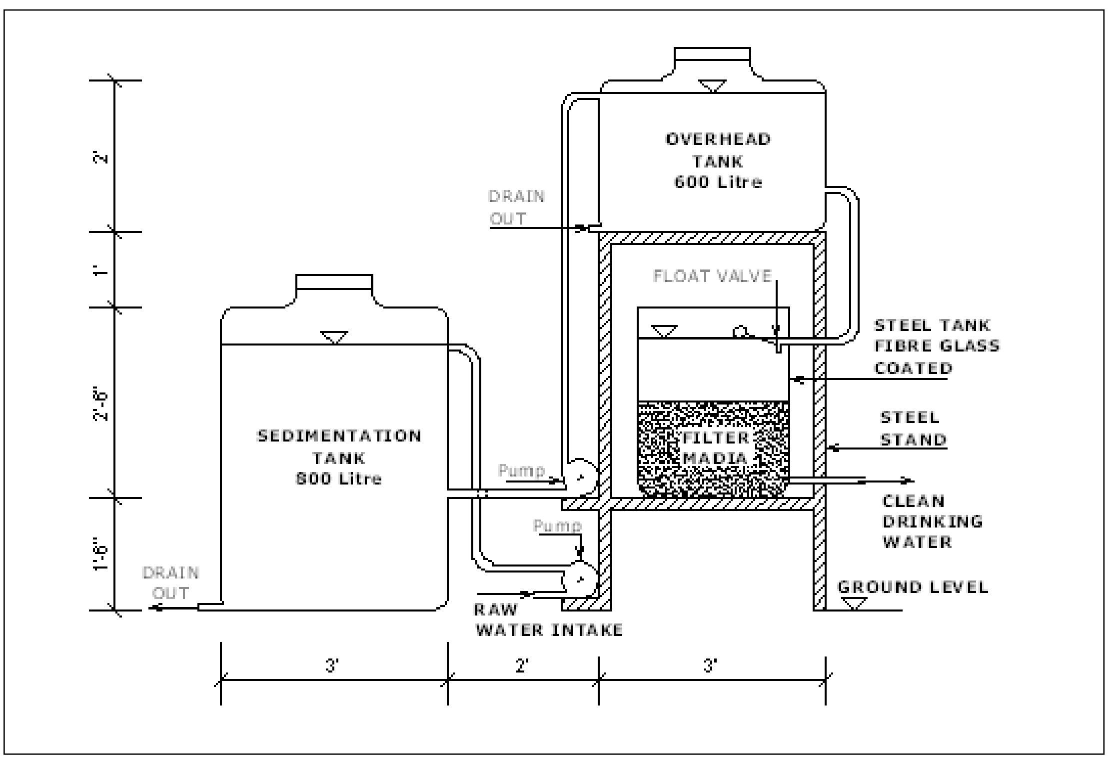

Figure1: *Treatment Plant of 600 L/Hr Capacity*

Plant runs manually with electricity. The electric motors will be operated with manual switch. One operator is required to operate it. Filling of 800 litres tank is done with electrical motor pump. It will take 15 minutes to fill this tank. Then filling of 600 litres overhead tank is also done with the electric motor. It will take 10 minutes to fill this tank. Once the 600 litres overhead tank is filled the supply of water is done through gravity flow and no electricity is required during this period. The electric water pump is 1 HP.

A float valve is provided at the top of filtration tank that controls the head of water in the filter media. Out flow is calibrated with a control valve provided at the exit of filter media before delivery valve.
A petrol generator is a good option that will be fixed with the stand. Continuous electricity to run the plant is not needed. Electricity is required for 25 minute in one hour run. The plant has to perform 2 to 3 hour run in the morning and same in the evening. So the generator is to run total 2 hours in the morning and 2 hours in the evening.

The plant is secure and the whole plant can be fitted in a cabin of 4 ft wide x 8 ft long x 8 ft high. The cabin walls are made of Fiber-glass sheet and frame will be of steel pipes. This cabin can be easily transported and will be useful to meet the security requirements at site.

Salient Features

- Compact and made of locally available material
- Treatment Plant is prefabricated
- Plant will serve the daily drinking water requirements of 500 to 600 people
- Space of 4 ft x 8ft is required for operation
- Very little / Less maintenance and operation cost
- Can be installed within one hour (pre-fabricated units)
- Easy to operate

Table 1: *Cost of 600 Litres/Hour Water Treatment Plant*

Items	**Cost (Pak Rs.)**
Cost of Steel Tank	10,000/-
PVC Tanks	15,000/-
Steel Frame Material	20,000/-
2 Motors 1 HP	10,000/-
Filter Media	20,000/-
Valves + Pipes+ Miscellaneous 1000 Packets of coagulant + Disinfectant 10,000/- (For Six month @ 5 to 6 Packets Daily)	10,000/-
Labor (Paint + Welding + Fixing + Fiber Glass Coating of steel tank)	25,000/-
Training of operation to field staff	5,000/-
Total Cost	**125,000/-**

Note:
1. Cost of 1 Kilowatt Generator not included.
2. Profit not included.
3. Transportation cost is also not included.

Methodology for Plant Operation:

1. Fill the 800 litres tank with river / flood water with the help of Electric motor pump.
2. Add one packet of Coagulant and disinfectant into the tank and stir the water with stick for five minutes.
3. Leave the tank water stationary for 30 minutes. The mud will settle down.
4. Then with the help of second motor pump the clean water to overhead tank.
5. The water will flow from overhead tank to filter media tank under gravity and when filter media will be filled the water flow will be stopped automatically because of float valve.
6. Empty the sedimentation tank and again fill with Fresh River / flood water. Add Packet, stir and let the mud settle down for 30 minutes.
7. Pump the clean water from sedimentation tank to over head tank.
8. Open the valve of filter media tank and start supply to public. The water filter is designed to discharge 600 litres per hour.
9. The over head will empty one hour. During this one hour the sedimentation tank is again filled with fresh River/ Flood water and sedimentation of water is done after adding the packet. The clean water will be ready for pumping to over head tank.
10. Pump the water to overhead tank.
11. If plant is run for four hours in the morning and four hour in the evening it can easily meet the drinking requirement of 400 to 500 people.
12. After six months filter media to be replaced.

Figure 2:*Filtration Plants Installed in the area (Nowshehra)*

***Table 2:** Water quality monitored before and after filtration unit at Lab Scale*

Turbidity (NTU)		Microbial Contamination	
Before Filtration	After Filtration	Before Filtration	After Filtration
120	2.5	Unlimited	No Contamination
105	2.3	Unlimited	No Contamination
55	2.2	High Contamination	No Contamination
53	1.2	High Contamination	No Contamination
57	2.2	High Contamination	No Contamination
50	1.4	High Contamination	No Contamination

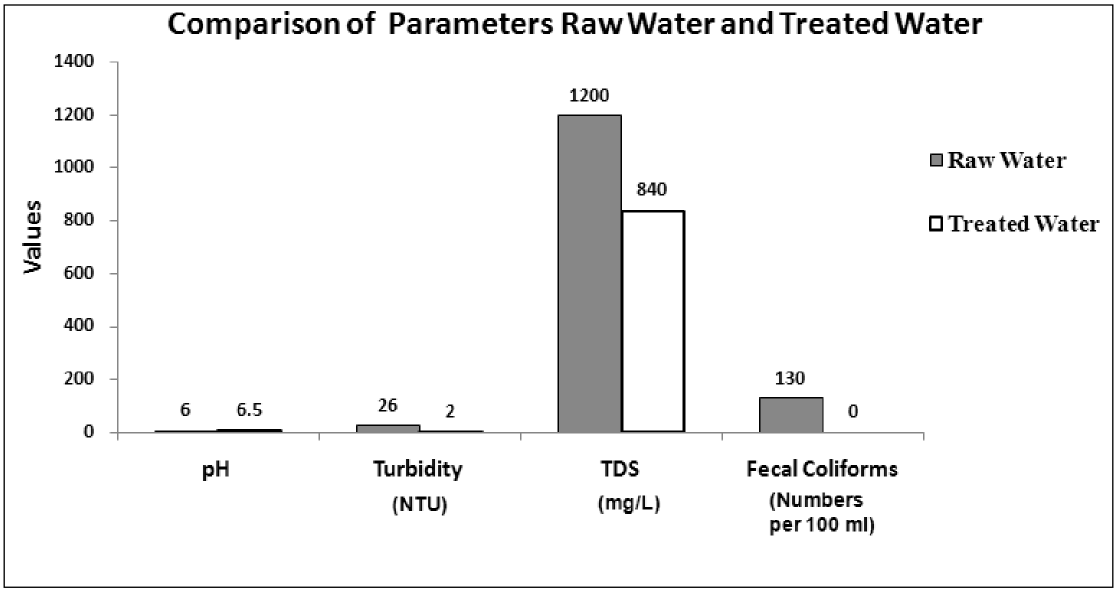

***Figure 3:**Comparison of Parameters Raw Water and Treated Water of Plant1*

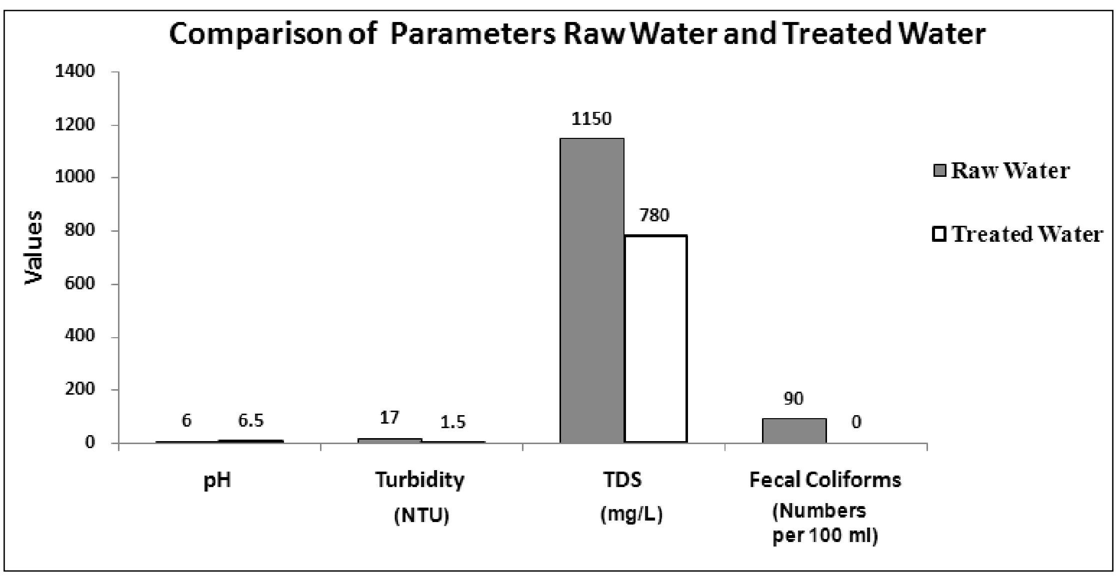

***Figure 4:** Comparison of Parameters Raw Water and Treated Water of Plant 2*

***Table 1**: WHO limits for drinking water quality*

S.No.	Water Parameter	Unit	WHO Limit
1	pH	-	6.5 – 8.5
2	Turbidity	NTU	5 NTU
3	Total Dissolved Solids	mg / L	1000 mg/L
4	Fecal Coliform Count	Numbers / 100ml	Nil

The results show that the treatment plant has efficiently treated the water. The basic parameters of the plant were tested i.e. pH, Turbidity, TDS and Fecal Coliform count. The turbidity of the raw water was 17 to 26 NTU and the treated water having a turbidity of 1.5 to 2 NTU which is in the permissible limits of safe drinking water as per WHO.

The TDS of the treated water range from 780 to 840 mg/l which is also within permissible limits. The treated water is free from Fecal coliform.

These plant are in operation for the last 7-8 months. One local person for each plant is trained. The plants are functioning efficiently by the workers and the community is happy and quite satisfied with the performance of the plants.

Conclusion

The ground water gets polluted during floods. The well water remains turbid and contaminated with disease causing organisms after a long time after the flood. The treatment plant is an economical option for emergency situations particularly in floods. It is also sustainable because local material has been used for its fabrication and media for its filling.

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Development of Flood Hazard Zonation Map for "Kalu Ganga" Basin by GIS Modeling.

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Abstract

"Kalu ganga" (river) is one of the major rivers in Sri Lanka situated in south-western part of the country. The "Kalu ganga" basin area is a highly populated area with urban centres and agricultural areas. River floods frequently occur in this area with destructive results. Local planers, decision makers and disaster relief organizations are in desperate need accurate information on the spatial distribution, magnitude and depth of flooding and the landuse classes affected by it. Only minimal effort and resources has been allocated to tackle this problem. The present research intends to provide a solution for this. The objective of this research is to develop flood hazard zone maps for the "Kalu ganga" basin area in a GIS environment. The applied methodology comprises 5 phases. Preparation phase comprises of literature survey and ancillary data collection. Fieldwork and data acquisition phase comprise spatial and hydrological data acquisition e.g. DEM, topographic, landuse , soil / geology maps etc. Modelling and flood hazard map generation phase consist of processing available data and maps using hydrological and other tools in GIS environment. Validation phase comprises the validation of the flood hazard maps using available data and records on flood phenomenon in the area of interest. On the reporting phase, the whole research process is translated in a conclusions and recommendations.

Keywords: *ArcGIS, ArcHydro tool, GIS model, SRTM DEM,*

Introduction

Flood is defined as extremely high flows or levels of rivers, lakes, ponds, reservoirs and any other water body, whereby water inundates outside of the water bodies area.

In many regions and countries floods are the most damaging phenomenon which adversely affect the socio economic establishments of a population. Each year floods cause hundreds of deaths and property damage estimated in hundreds of billions. In more recent years not only developing countries such as our own but highly developed and industrialized countries such as USA suffered heavily due to flooding.

Destruction due to floods in developing countries like Sri Lanka will continue unless the reliable coping mechanisms are well established in advance. However, due to the lack of awareness, resources and suitable approach, the problem couldn't be solved as in the pace of developed countries. This

This article has been adapted from Proceeding of ERE (2009) 1-5)

particular vulnerability of developing countries underlines the urgent need to promote relatively fast, technically tolerable, environment friendly and socially accepted cost effective structural as well as nonstructural countermeasures that should be planned and implemented by community according to their real needs and affordability.

At present the state of the art technology in the field of Geographic Information System (GIS) allows spatial analysis as well as to generate the modelling for a flood hazard phenomenon. Flood hazard zone map developed in a GIS environment, can provide information about communities and infrastructure which are at risk of flooding. It can also lead to development of plans for potential evacuation routes, evacuation places etc. to the local residents which are indispensable for emergency response and for long-term flood disaster management Since making FHM is inexpensive and quick, it would be the best way to develop social resilience and to cope with extremities in mentioned areas. The "Kalu ganga" basin situated in Western and Sabaragamuwa provinces was chosen as the focus of this research due to high population density of the area

Materials and Methods

2.1 Initial data utilized for the research

1) SRTM DEM (Shuttle Radar Topography Mission Digital Elevation Model)
2) 1:100000 Digital Soil map
3) 1:100000 Digital Geology map
4) 1:50000 Digital Landuse map
5) Flood data records in the area of interest from 1980 to 2008

2.2 Software tools utilized for the research

1) ArcGIS-ArcMap software
2) ArcHydro tool extension in ArcMap
3) MS-Excel

2.3 Processing SRTM DEM

SRTM DEM was used extensively throughout this research. This digital elevation model is readily available to download from their official website. The area covering whole Sri Lanka exists in sheets 52 & 53 as TIFF images with WGS 1984 coordinate system. These 2 sheets were marched together and clipped to extract the DEM for the area of interest.

After extracting the DEM for the study area it was further processed using the ArcHydro terrain

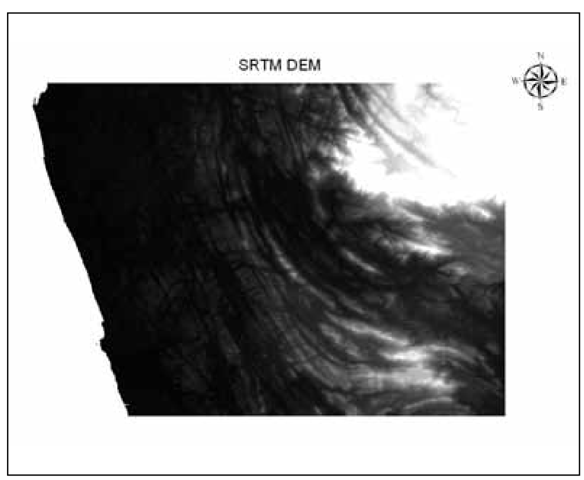

***Figure 1**:SRTM DEM of study area.*

Tool	Description
Fill Sinks	Fill sinks for an entire DEM (grid).
Flow Direction	Create flow direction grid from a DEM grid.
Flow Accumulation	Create flow accumulation grid from a flow direction grid.
Stream Definition	Create a new grid (stream grid) with cells from a flow accumulation grid that exceed used-defined threshold.
Stream Segmentation	Create a stream link grid from the stream grid (every link between two stream junction gets a unique identifier).
Catchment Grid Delineation	Create a catchment grid for segments in the stream link grid. It identifies areas draining into each stream link.
Catchment Polygon Processing	Create catchment polygons out of the catchment grid.
Drainage Line Processing	Create streamlines out of the stream link grid.

***Table 1**: ArcHydro tools & functionality*

processing tool kit. Each function was executed sequentially because each consequent function uses the output from the previous function.

Finally ArcHydro tool kit produce "Catchments Polygon" & "Stream links Polyline" shape files. For these shape files catchment area and stream link lengths was calculated using geometry calculation tool in ArcMap. Then these 2 maps were spatially joined and drainage density was calculated for each catchment. For each catchment drainage density classes were assigned according to their level of drainage density in 3 categories as: 1) High, 2) Moderate, 3) Poor.

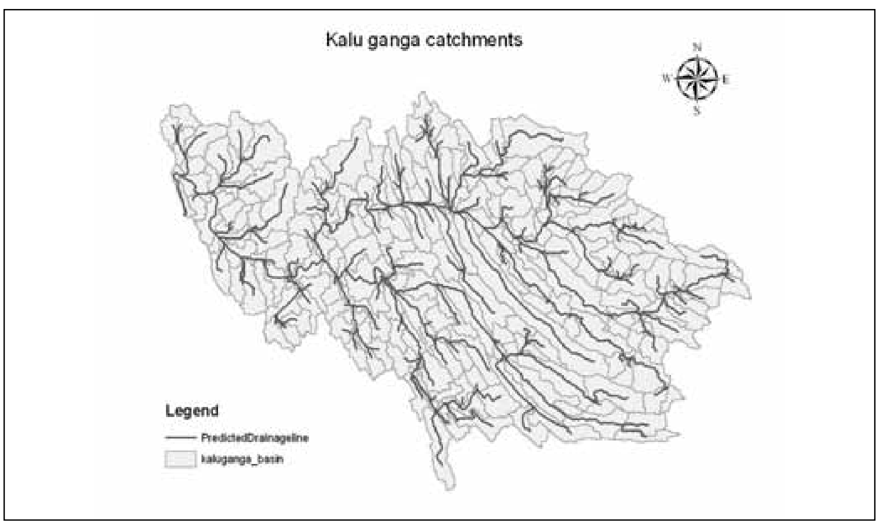

***Figure 2** : "Kalu ganga" basin Catchments & Drainage*

Further the SRTM DEM was used to develop the Slope map of the study area using 3-D analyst in ArcMap. This slope map is classified according to the slope percentage as: 1) Flat, 2) Gentle, 3) Steep.

2.3 Processing Soil Map

First the portion of the map was extracted from the entire soil map of Sri Lanka provided by DMC(Disaster management centre). According to the soil types they are classified according to their infiltration as: 1) Very high, 2) High, 3) Moderate, 4) Poor. 2.4 Processing Geology Map Geology of "Kalu ganga" basin area was covered by the 1:100000 map sheets number 16, 17, 19 and 20. we were able to acquire these maps relevant to study area from GSMB (Geological Survey & Mines Bureau) in digital DGN format. These 4 maps were exported in to shape files, merged together and the "Kalu ganga" basin area was extracted.

2.5 Processing Historical flood records

Historical flood records relevant to divisional secretariats in the area of interest were downloaded from www.desinventar.net website, which is a database of disaster invents in Sri Lanka. These records were sorted by day of occurrence & the total number of flood events was calculated for each divisional secretariat. Then the average number of flood events was calculated for timeframes of 1, 5, 10 and 25 years. Using that data flood frequency was categorized as: 1) Very, 2) Moderate, 3) Slight, 4) Sudden, 5) None flooding.

2.6 Flood Hazard map generation

by GIS modelling After all the initial maps were processed for each map a numerical weighting system was introduced for their classification. For instance, in Slope map 50 points were assigned to polygons having "Flat", 25 to "Gentle" and 5 to "Steep" classification accordingly. In assigning weightings to maps priority was given to which mostly influence flooding as follows.

Priority	property	Maximum Weighting
1	Slope	50
2	Drainage density	40
3	Soil type	30
4	Geology	20
	Total	**140**

Table 2: *Weighting system for modelling*

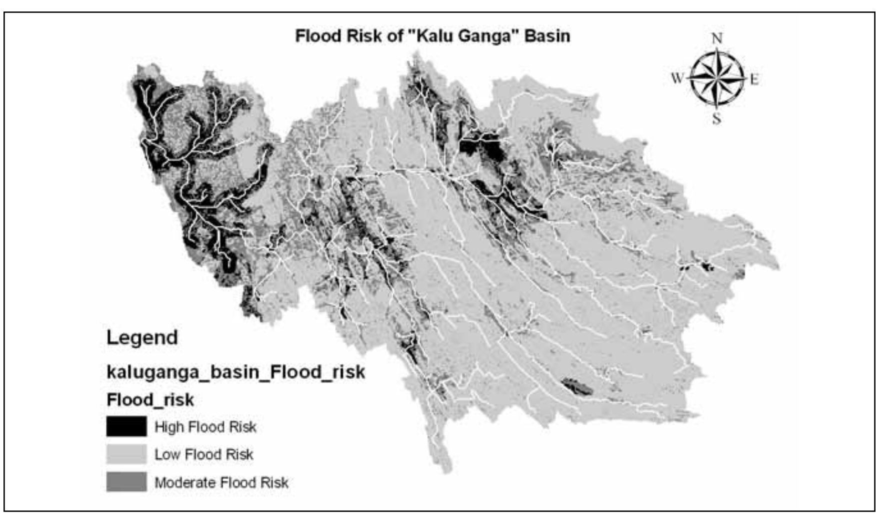

Figure 3: *Flood Hazard map of "Kalu ganga" basin*

Above stated weighting system was applied to each shape file as a new numerical value field in the attribute table. Finally the flood hazard map for the "Kalu ganga" basin was developed by combining all the maps using "Union" tool and adding up all the numerical weightings together. It is then compared with the historical flood data we already have to validate the map. Then the risk analysis is done by overlaying and comparing the Landuse map with the developed flood hazard map.

Results

Figure 3 represents the developed flood hazard zone map for "Kalu ganga" basin. The total area of the basin is approximately 319225Ha. Out of which 55124Ha are human settlements, 184337Ha are agricultural land. From the analysis of the landuse map with the flood hazard map following figures were extracted.

	Human settlement	Agricultural
High risk	7738.23Ha	15759.47Ha
Moderate	15374.42Ha	41195.65Ha

"Kalu ganga" basin spans over Sestern and Sabaragamuwa provinces In "Sabaragamuwa", Kuruvita, Elapatha and Rathnapura divisional secretariats is found to have high risk of flooding, Especially highly populated towns such as "Rathnapura", Theppanawa, Batayaya and "Kahangama". When the western province is considered "Kaluthara", "Bandaragama", "Kesbewa" "Panadura" and "Homagama" divisional secretariats are at high risk specially areas at close proximity to the "Bolgoda lake" and other tributaries. Also the "Bulathsinghala" Div-Sec is also at moderate flood risk.

Discussion

GIS modelling was preferred over numerical modelling techniques because the study area was very large and the project completion time was limited. Most difficult aspect of this project was to acquire the relevant data in a uniform format. Most of the time acquired data wasn't compatible with the software systems we utilized, so low level manipulations and processing was necessary to convert them to correct format. Although a soil classification system is available in Sri Lanka data on their mechanical properties such as hydraulic conductivity is not available. We had to rely on foreign soil data and information when determining the infiltration properties of soil. The resolution of the SRTM DEM was 100m. This resolution is acceptable for our research because the study area is comparatively large. How ever if more accurate DEM is available the accuracy of results can be improved. How ever for a subsequent flood modelling research DEM produced with LAIDAR data is recommended. For the risk analysis phase we used the digital Landuse map developed by the survey department prepared some time ago. So that some discrepancies might be there in the final results. How ever in general the analysis can be considered accurate comparing with the large study area.

Conclution

This research project was carried out to find out the areas which have high risk of flooding mainly with the emphasis on human settlements and agricultural lands. This project can be sited as the preliminary phase of a flood modelling project. Areas found to be high risk areas can be subjected to numerical flood modelling using softwares such as HECRAS, FLOAT2D to develop detailed flood models.

Acknowledgement

We would like to express our deepest gratitude to Dr O.K Dissanayake Director GSMB, for supervising and advising for the project and Mrs Anoja Weerarathne of DMC for guiding us throughout the entire project and providing necessary data and valuable advice. Also we would like to thank academic and non academic staff of Department of earth resource department especially in the RS & GIS lab. We also like to express our gratitude to staff members of GSMB and DMC for providing us necessary data.

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Flood Hazard Mapping in Lower Reach of Kelani River

I. P. Ajith Gunasekara

Abstract

After the Tsunami, disaster management strategies have undergone rapid changes. Flood hazard mapping has, particularly, been realized as one of foremost tasks to be accomplished in support of disaster management and sustainable development. As a pioneering effort, the lower reach of Kelani River which covers the islandís capital, Colombo, and two densely populated districts of the country. Colombo and Gampaha districts which are frequently and considerably affected by flood events, were chosen for flood hazard mapping together with the part of the slightly affected adjoining Kegalle district. The study covers all most all the potential flood area in Kelani river. The objective of the study were, 1) Prepare flood depth and flood extend maps for different return periods, 2) Identify flood management and flood-disaster mitigation strategies.

This exercise comprises four basic steps,1) Generation of Terrain model in the study area to work in Arc View, 2) Determination of flood discharges for different return periods, 3) Flow profile generation using Hydrodynamic model; HEC RAS and 4) Generation of flood area and depth maps by exporting the hydrodynamic model results to ArcView. The one dimensional steady flow module of HEC-RAS Software was utilized for water surface profile, flood area, and flood depth calculations. The requisite geo-spatial modeling of the flood plain was carried out conveniently by implementing HEC-GeoRAS module in the ArcView environment using a triangular irregular network (TIN) model. Peak flows associated with selected return periods were obtained from a frequency analysis and the calibration run was executed simulating the 50 year return period flood event.

Comparison of field records corresponding to the above event of 1989 indicates that the modeling of flow and terrain conditions is very successful. Accordingly, a set of flood hazard maps associated with 10 year, 20 year, and 50 year return period events. Results show that the study area would be subjected to flood encroachments of 60, 77, and 94 square kilometers for events with return periods of 10 years, 20 years, and 50 years respectively. Model results were compared and verified against the records available in the Irrigation Department in addition to the field verification.

Introduction

Sri Lanka is located in the Indian ocean between the bay of Bengal and Gulf of Mannar, between northern latitudes of 5051' to 9051' and east longitudes of 79040' to 81055'. It occupies an area of nearly 65525sq.km.

* (This article has been adapted from Engineer(2008) xxx 1:149-154

The water resources map of the country prepared in 1959 identified 103 river basins of which about 10 rivers are considered as major. Among these major rivers, Kalu, Kelani, Gin, Nilwala and Mahaweli are vulnerable to floods. Of the factors that are conducive to the creation of flood problems, one of the principal causes is encroachment by man on the flood plains of river basins.

Floods in Sri Lanka are mainly due to excessive rainfall received during monsoons and received as a result of development of low-pressure in the Bay of Bengal. Floods are directly related to rainfall and therefore a proper understanding about the distribution of rainfall becomes important. The rainfall distribution in Sri Lanka is subject to spatial and temporal variations leading to distinct patterns of seasonality, regionality and inter-annual variability in the climate. The average annual rainfall ranges from around 800 mm to over 5000 mm.

Recent past several flash floods occur, without giving much time for evacuation, and diminished within two to three days. So far, in 2008, there are three flood events one in 29th of April, 30th of May and other in 19th of July for Kelani, Kalu and Gin basins.
Floods in Kelani river are important due to its outfall being near the capital city of Colombo. When the flood levels of Kelani are in between 5.0 ft. and 7.0 ft. at the Nagalagam (Colombo) gauge, they are within the limits of minor floods. When the level exceeds 7.0 ft. the flood is defined as a major flood and when it exceeds 9.0 ft. the flood is considered to be dangerous.

Among the non-structural flood mitigation methods, Kelani is one river, where there has been a flood forecasting system. Forecasting of water levels in the river is done by means of five upstream gauges. A scheme of organization and standing orders are available to facilitate the coordination among several institutions during a flood. This scheme of organization and standing orders prepared in 1968 and updated by the Irrigation Department in 1993, can be considered as a comprehensive study to provide a detailed mitigation plan for the city of Colombo.

Flood was identified as most common and hazades natural event in Sri Lanka, proved in history and obvious as the country's topography and location.

Flood area mapping in the lower reach of the Kelani river basin became a top necessity with frequent floods in Kelani River.

Study Area

Kelani River is the second largest in the country which originates in the central hills and flows mainly to the West till it meets the sea at the northern boundary of the Colombo city. River basin is entirely located in the wet zone up to an extent of 2230sq.km. Its average annual rainfall is about 2400mm.

The river basin comprises of two distinct types of topography, mountainous upper region and flat coastal line. Approximately two-thirds of the entire catchment represents the mountainous region, where the peaks and ridges rise above 2000m MSL contour. Valley slope is very steep and the mountain streams are characterized by waterfalls and rapids.

Vegetation in this region is mainly Tea, Rubber and grass. In many places exposed bed-rock can be seen.

On the contrary, the coastal plain is extremely flat with scattered low hills. The vegetation of this region is a mixture of Rubber, Coconut, Paddy, Tea, marshy lands and grass. In the last 30km the river bed slope flattens considerably, i.e. to an extent of 1:5000, and river valleys open out revealing wide flood plains.

With the knowledge of historical flood events occurred in the basin, lower reach of Kelani river is considered for flood mapping. It covers the flood plains from Glencourse gauging station upto Nagalagam street gauging station in Colombo. Total length of the river in this section is about 55km. Study area covers three administrative districts. It occupies an area of 1200sq.km

Objective

The objectives of the study are:

3.1. Preparation of Flood hazard maps for 10yr, 20yr and 50yr return periods.
3.2. Identification of flood management & flood mitigation strategies.

Data Used

Basically three categories of data were used for this exercise.

- Data necessary for the Hydro-dynamic modeling
- Data necessary for Digital Elevation Model (DEM/TIN).
- Socio-Economic information

4.1. Data necessary for Hydro-Dynamic Modeling

To execute the hydro-dynamic model from which the water surface profiles were to be generated, several parameters and variables are necessary. Many of the parameters are given in the model itself with an option to change in the calibration phase. Other than that some important data specific to the study are used as an input to the model. Some are used as inputs but not data, instead they are outcomes of the frequency analysis or Arc View done prior to performing the model. :

- Peak annual discharges (data).
- Rating curve of the U/S & D/S gauging stations.(data).
- Cross sectional profiles of the river at regular intervals.(data)
- Cross sectional profiles of the flood plain including the river (result of Arc View)
- Flood discharges for different return periods. (result of frequency analysis).

4.2. Data necessary for TIN generation

Terrain model is very important in this exercise. Accuracy of the flood hazard map greatly depends on the data used for the Triangular Irregular Network (TIN). Data used for TIN are:

- Contours (1:10,000 as of year 2000) & Spot heights
- Stream network 4.3. Analyzing the Results This part of the study intends to make the finaloutput more informative whilst arriving at a final conclusion. They are:
- Road network
- Landuse map.
- Administrative boundaries
- Stream network.
- Cross sectional profiles of the river at regular intervals

Methodology

Methodology can be divided into four steps. i.e.

- Determination of discharges of different return periods
- Generation of Terrain model and incorporation of stream features to Terrain model
- Hydrodynamic modeling
- Flood area and flood depth mapping.
- Analyzing of results

5.1. Generation of Terrain Model

Terrain model is generated by means of the 1:10,000 topographical digital data available in the Survey department. Areal Photographs and Land surveys are the Primary source of the Digital maps. Modifications are done to it after getting the cross-sectional data of the river from the Irrigation department.

5.2. Determination of flood discharges for different return periods

Statistical methods are used to get the flood discharges of the predetermined return periods. Hydrology division of the Irrigation department has been engaging in collecting stream flow data, precipitation data and other hydro-metrological data for nearly 100 years. As such annual peak discharges at the Glencourse gauging station for last 35 years were used in statistical analysis to determine the peak discharge.

There are several statistical methods available and used by various countries as their preference. In this study, three methods are adopted and they all give more or less the same results within a margin of 10%. For the hydrodynamic modeling, the results of Gumbel Distribution were used and summary is tabulated below.

5.3. Hydrodynamic modeling and water surface profile determination

Water surface profile determination and subsequent flood-plain visualization is carried out using one-dimensional numerical model developed by Hydrological Engineering Center of US Army Corps,

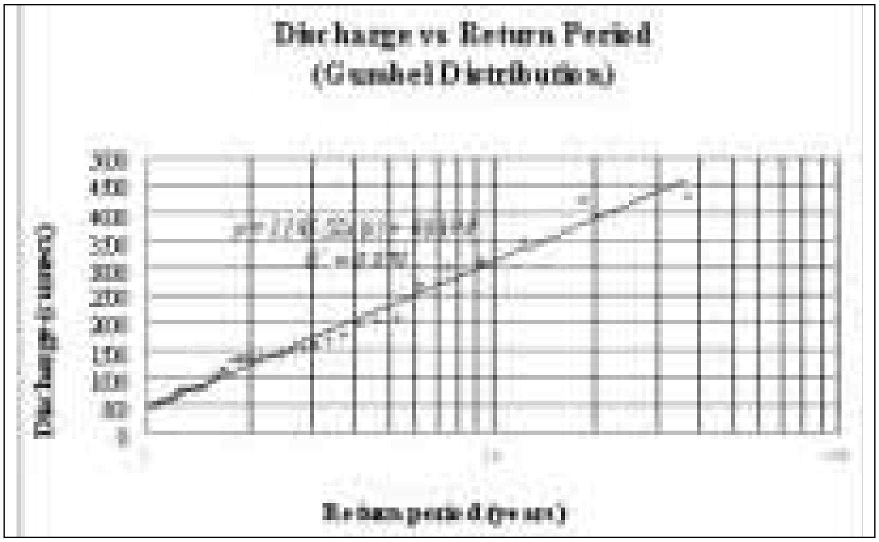

Figure 5.2.1 *:graphical presentation of frequency Analysis*

Table 5.2.1*:Summary of frequency Analysis*

Return Period Tr	Discharge (m³/sec)		
	Lognormal	Pearson	Gumbel
10	2755	2799	3128
20	3629	3839	990
50	4336	4743	4630

commonly known as HEC-RAS. HEC-GeoRAS, an extention compatible with Arc- View is used as the interface between Hydrodynamic Model and the Graphical software.

HEC-GeoRAS is capable of performing a set of step-by-step operations which allows the preparation of Geometric Data for importing into HEC-RAS and processes simulation results exported from HEC-RAS in to ArcView.

To execute the Hydrodynamic Model, Geometric data of the flood plain and stream are abstracted from the terrain elevation model. Water surface profiles, along the river reach under the study, for floods of three identified return periods are computed with sub-critical flow simulation. Finally Export file was created in HEC RAS to work with the Digital Elevation Model in Arc-View.

5.4. Flood area and flood depth mapping

Water profiles generated in HEC-RAS is exported in to the Arcview platform and the inundation areas and flood depths are visualized on the terrain model. Digital data of important features such as roads, buildings, cultivation, etc. are superimposed on to the Digital Elevation Model. Finally the flood depths are reclassified to suit preferred classification and the relevant details such as area according to Districts, No. of buildings inundated, etc. are calculated

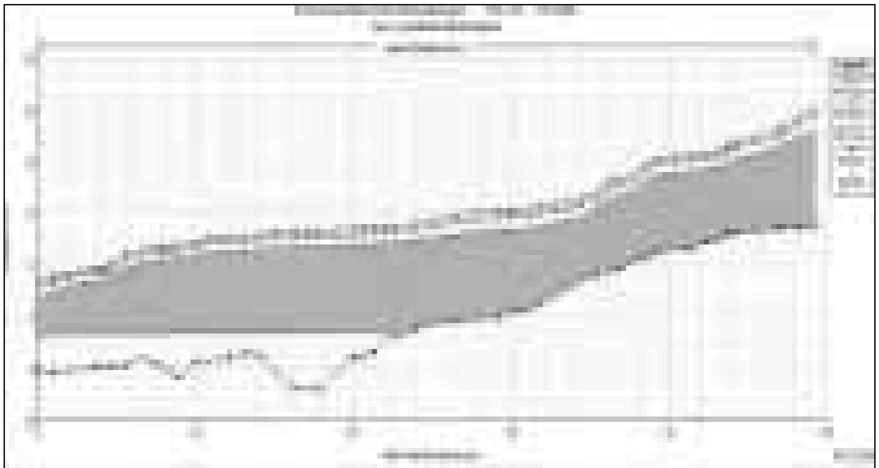

Figure 5.3.1 *:water surface profiles for 10year, 20 year and 50 year return periods*

Table 6.1 *: Total area of inundation in sq. km for different return periods*

Return Period (yrs)	Flood depth (m)				Total Area Km²
	<1	1 - 3	3 - 5	>5	
10	19	29	10	5	63
20	20	40	11	6	77
50	24	41	19	10	94

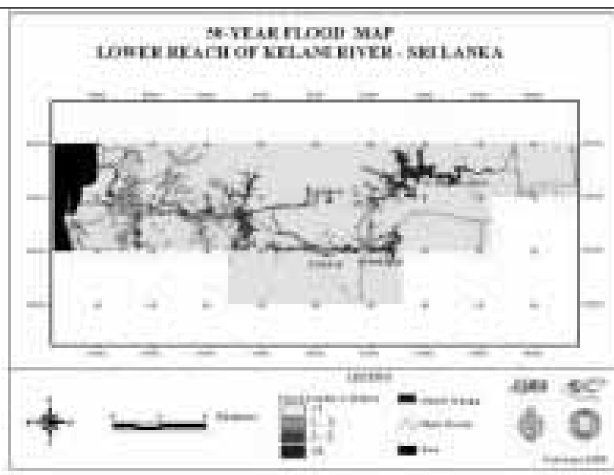

Figure 6.1 *:Flood map of 50-year return period flood*

5.5. Analyzing of results

The results obtained after the above steps are verified against the actual data. Historical records as well as the geographical data collected in field inspections and other information received from the people of the area, etc. are used in verifying the results. Until the results agree with the field records the Hydro-Dynamic Model parameters are adjusted in the calibration phase and the final flood hazard maps are prepared.

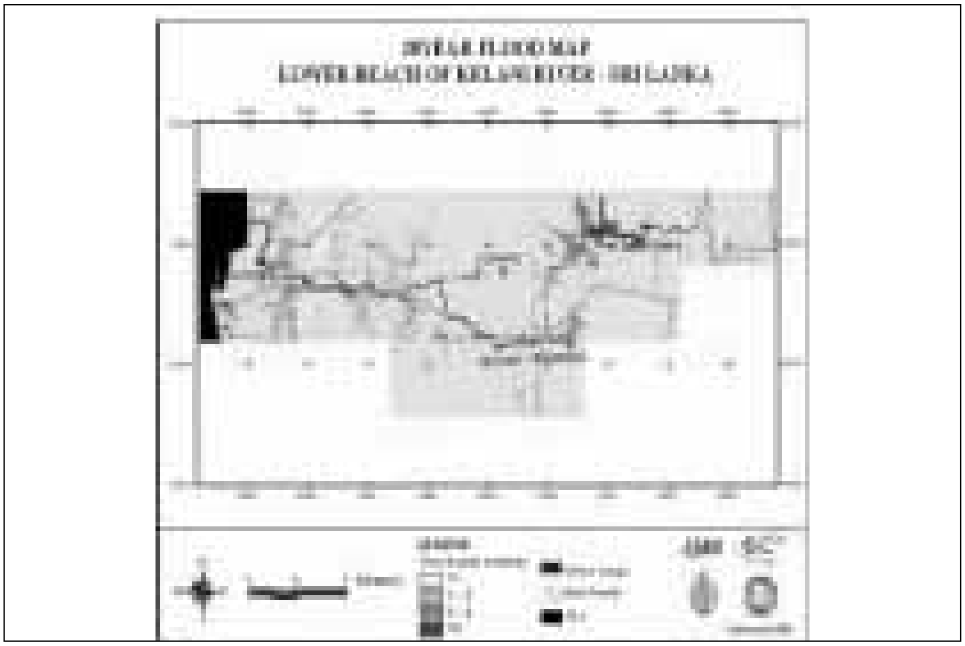

***Figure 6.2**: Flood map of 20-year return period flood.*

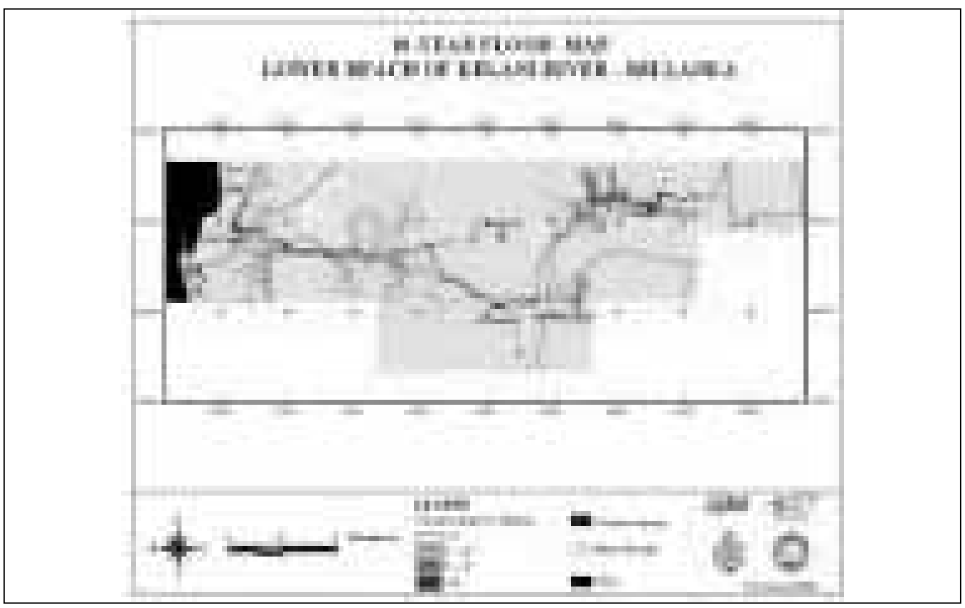

***Figure 6.3**: Flood map of 10-year return period flood.*

***Table 6.2** : Total No. of buildings affected indifferent return periods in District basis.*

Return Period (yrs)	District			Total
	Colombo	Gampaha	Kegalle	
10	5421	3589	0	9010
20	8487	5574	3	14064
50	10378	6620	7	17005

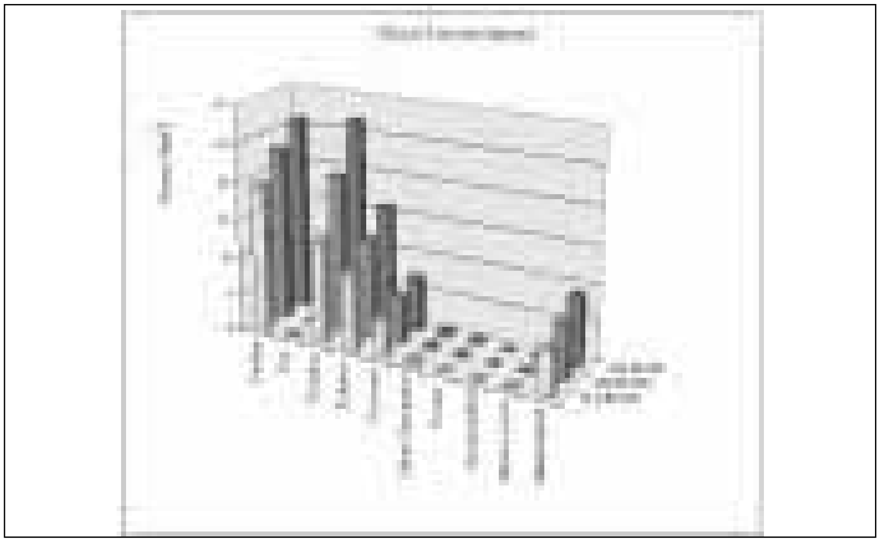

Figure 6.4 *:Flood encroachments of different return periods (Colombo, Gampaha, Kegalle Districts*

6. Results and Discussion

One objective of the study is to prepare a set of flood hazard maps for the lower Kelani River basin. This is the direct outcome of the exercise.

Flood maps for three different return periods are developed accordingly. 50-year, 20-year and 10-year return period flood maps are shown in next pages.

Identification of the flood mitigation & flood management strategies are the other objective of this study. In fact it is the most important and valuable output. According to the topo sheets, some of the possible flood management strategies in the lower part of the Kelani Basin are development of Retarding Basins and the construction of Flood bunds. There are several upstream reservoirs which have already been constructed mainly for the Hydro-power generation in a cascade. This serves greatly in flood management in the downstream part too. But construction of such reservoirs under the current socio-economic condition is far away from the reality. Topographically also there are very limited opportunities.

Using the available topographical maps and the water surface profiles generated using the Hydro-Dynamic Model, it is possible to identify the locations for Retarding basins and Flood Bunds. But field inspection is really necessary together with this as the present ground condition, most probably, would be different from the survey maps. Satellite images also can be used for this by limiting the field inspections to the finer matters.

From the maps shown below and the other details such as Land-use the information important for the planners and other stake holders are abstracted and some of them are listed in here.

7. Conclusions and Recommendations

In the study, it is considered only the lower reach of Kelani river which is good enough for flood mapping as the area affected in a flood is mostly restricted to this coverage according to the field experience of the author as well as the historical records. It is proven even by the results of the study as the number of houses going to be affected in 50-year flood in Kegalle District, located in the up stream of the study area, is negligible when compared to the other districts and hence the area selected seems matching with the requirement. But in preparing the terrain model some essential areas in Colombo and Gampha districts could not be included, due to restrictions of time as there were some clarifications to be done. However that is less than 10% of the total area, I hope to include the rest of the omitted area and produce the new set of maps for the whole study area with more information

The aerial-photographs and spot heights used in generating the Terrain model are from year 2000. Most probably there can be changes in the terrain mainly due to development activities of various parties including the Government. Only the river cross sections were adjusted to suit to the actual values as in year 2007 using the land leveling done by the Irrigation department. For accurate results updated terrain data and landuse data are essential. It is a limitation that individuals can't overcome, but only the decision makers who are supposed to use this kind of results should take prompt actions to take care of such a problem.

Further it is easy to verify the produced maps in the field in detail, more than what was done in the study, and can be adjusted if there is any drastic variation probably due to changes in land-use or terrain. Current practice of flood mapping in hydrology division, post-flood field data collection with GPS instrument, collection of information from people and leveling instruments, can be of great use for this kind of verification. It should also be noted that field data collection and preparation of a flood maps is a tedious process which consumes manpower beyond the manageable limits considering the limited resources and the assignments undertaken by the hydrology division. In contrast, verification is far easier as the area is demarcated and even the coordinates are available for easy access. . A microwave image of the study area during the flood season definitely would have been very useful in the flood extent verification, which unfortunately was not available during the study, as an option to time and human constraints. Use of modern technology for verification would be more attractive even for the users

8. Acknowledgments

First I have no hesitation in thanking Japan Aerospace Exploration Agency (JAXA) under which I had this research work conducted at Geoinformatics center, Asian Institute of Technology in Bangkok Thailand.

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Next I must thank to Ms. P.P. Liyanage of Survey Department for preparing the DEM for me, wich the study could not have been performed. She also contributed very much in preparing the Land-Use map, river network, etc.

The great encouragement given and the facilities provided by the Surveyor General Mr.B.J.P.Mendis, Director of Irrigation (Specialized services & Training) Eng. P. C. Senaratne, Deputy Surveyor General Mrs. A. L. S. C. Perera, Deputy Director (Hydrology) Eng. Miss. P.P.G. Dias, Snr. Superintendent of surveyors Mr. S. Sivanandarajah are highly coppreciated and played a keg role in achievement of this study and I am grateful to all of them.

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Managing Flood Flows for Crop Production Risk Management with Hydraulic and GIS Modeling: Case study of Agricultural Areas in Shariatpur

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Abstract

Shariatpur District, under Dhaka division with an area of 1181.53 sq km, is mainly surrounded by the two big rivers, the Padma at north and the Meghna at eastern side. Also, the Arial Khan River is located at the south western side of the district. When the Padma and the Meghna Rivers attain peak flood levels simultaneously, this district faces devastating floods. These floods have a destructive effect on agriculture especially on Aman (June- September) variety at optimum level of flood depth but also have a positive impact on next year's Boro (December- march) production due to sedimentation by the previous year's flood. So there is a scope of managing flood flows which ensures the optimum level of flood depth that promotes the crop production risk management. The present study provides a method for flood management aiming to crop production risk management. In this study, inundation maps have been produced using hydrodynamic model HEC-RAS and HEC-GeoRAS extension of ArcGIS9.2. Then calculation of optimal flood depth for crop production risk management has been done using some sophisticated statistical analysis. Finally, volume of water above the optimal flood depth has been calculated using GIS model with ArcGIS 9.2 and based on this, proposed some ways of flood flows management which ensure the crop production risk management. The study findings show that, the optimal flood depth is 1.85m (msl) in where Boro production would be safe and Aman production would face about 200 ton/yr loss, we can called this condition as crop production as farmers get more return from Boro variety. This study also find two equations that provide estimation of Mawa discharge depending on two upstream stations (Hardings Bridge and Bahadurabad Ghat) and targeted discharge of Mawa that needs to release from Mawa to the study area for ensuring the optimum flood depth.

Keywords: *Discharge; Inundation severity; Hydraulic modelling; GIS; Crop Production Risk management; Flood Depth.*

* (This Paper has been adapted from APCBEE Proceding (2012): 318-324)

Introduction

Usually four types of floods are generally recognized in Bangladesh, among them the river flood; over bank flooding caused by river discharge, is the key type that has a devastating impact on Shariatpur district. In this region the main reason of this devastating flood is the influence of the Padma and the Meghna Rivers especially during late monsoon season (first phase of September month) and due to seasonal rainfall which eventually makes the district vulnerable to flooding. During this period the Aman varieties are affected but the next year's Boro varieties become enrich as the flood leads enough sedimentation.

Boro variety is high water intensive and enough sedimentation enhances the production. Whereas, Aman variety don't face this type of problem because of having enough ground and surface water in monsoon period. But if flood occurs in high intensity (high flood depth) then Aman variety faces with huge loss but in the next year Boro varieties face bumper production due to having enough sediment. Again high depth of flooding occurs when water can't drainage easily and with huge upstream flow. So, ifwe can manage the flood flows then depth of flooding would not be as higher as it hampers the Amanvariety as well as enhances the Boro production by enough sedimentation. In this regard, we need to manage the flood flows which in turn will control the flood depth or ensure the optimum flood depth. Aiming to this philosophy, this study has found the optimal flood depth and how we can ensures the optimum flood depth in the study area. Regarding this, HEC-RAS hydraulic modeling has been developed for getting flood depths for different up-stream discharges and some statistical analysis have been carried out for finding the optimum flood depth and GIS conceptual model developed for managing flood flows towards crop production risk management.

Research Objective

This research objective is to propose some guidelines to ensure agriculture crop production risk management adapting to flood intensity. For this purpose, this study finds the optimum flood depth.

Study Area

The study area includes large part of Shariatpur district and some parts of surrounding districts such as Madaripur, Faridpur and Munshiganj District. The main focal point of this study is on Shariatpur District (Figure- 3.1). The total area of the project is about 1,700 sq.km.

3.1. River System and Hydrologic Measuring Stations

The Padma River is about 37 km in length of the river at its downstream reaches from the northern boundary of Zanjira and Naria upazila of Shariatpur district (Local Government Engineering Department 2007). Another river named Kirtinasha originated in Naria upazila and out falls to Arial Khan River in Kalkani upazila. Another distributary of Padma River named choto Padma originates in Naria Upazila of Shariatpur District. From off-take it traversed to south through Naria, Bhederganj and Damudya upazilas. There are eight water stations of BWDB in the study area (Figure 1).

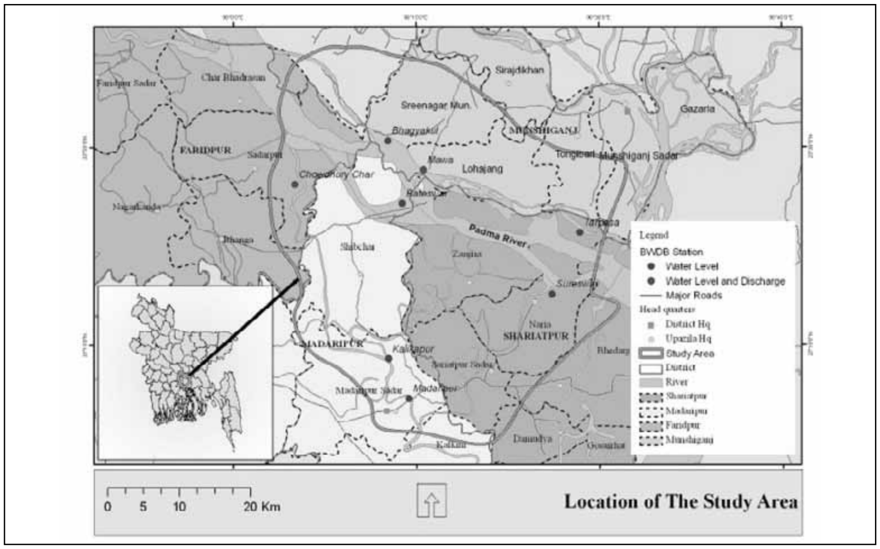

***Fig. 1**: Location of the study area*

4. Methodology

4.1. Data Collection and Processing

The sources of information used for this flood plain delineation include water level and discharge records, river cross section data, elevation data and land use map Water level and discharge data have been collected from gauge stations of Bangladesh Water Development Board (BWDB) on Padma River and Arial Khan River. River cross section and elevation data have been collected from IWM and USGS web site using ESRI products.

4.2. Selection of Model Boundary

To delineate the model boundary, it is necessary to find out the influential area of the Padma and the Meghna River. As the influence of Meghna has not been taken into consideration in this study, the areas underlying Meghna influence has been cut-off from the model boundary. Moreover according to Water Resource Planning Organization (WARPO) planning area the study area is situated under South-Central- 51 (dominated by the Padma) and South- Central- 52 (dominated by the Meghna) catchments. So, in this study the South- Central- 51 catchment area has been included only.

4.3. Hydrodynamic Model Development

Hydraulic model, HEC-RAS computes the variation of water levels along the channel and the values of water levels are overlaid on a digital elevation model (DEM) of the area to get the extent and depth of flooding using GIS (Gautam and Kharbuja 2006). In this study, HEC-RAS has been used to compute steady flow water surface profile along the channel reach for various annual maximum runoffs of Mawa station and corresponding date's runoffs of Chowdhury Char station (Figure- 2). Spatial data like crosssection, stream network, river reach, flow paths and others have been created using HEC-GeoRAS, (Arc GIS extension). These were then exported to HEC-RAS. The total number of drawn cross sections for the 4 reaches modeled was 44.

4.4. Model calibration

Manning roughness coefficient n, together with the channel geometry were considered having the most important impact on predicting inundation extent and flow characteristics. Therefore, the focus of this study is the calibration of the roughness coefficients. The 2006 water level data of Mawa point has been used as observed data for calibration of Manning's n.

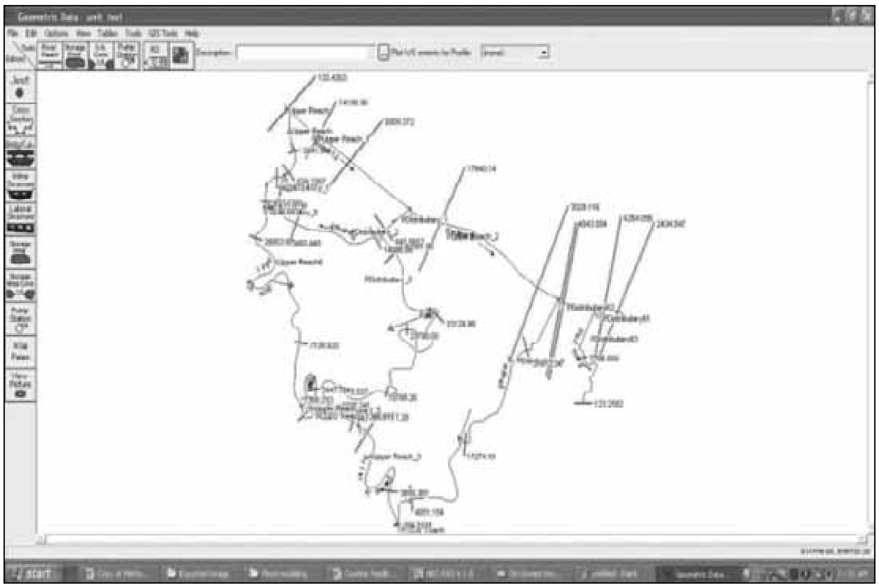

***Fig. 2.**:Schematized Model in HEC- RAS Data Editor Window*

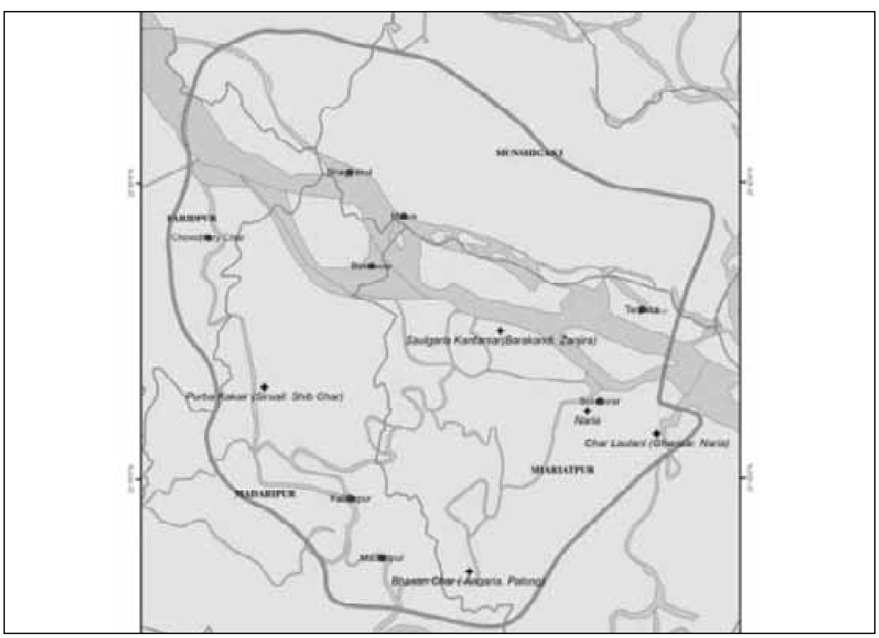

***Fig. 3**: Location of the Water Level Measuring Stations*

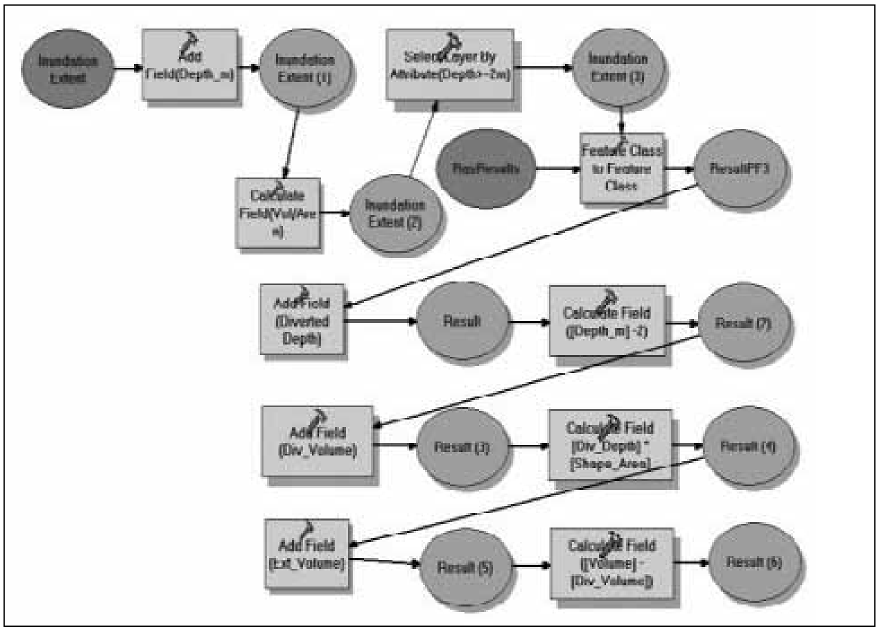

***Fig. 4**: Conceptual Model for estimating Diverted amount of water using ArcGIS Tool box.*

4.5. Floodplain delineation

The model was run and the results were imported into GIS. Then the water surface profile calculation for unsteady flow was carried out. The values of water levels obtained were overlaid on triangulated irregular network (TIN) of the area to get the extent of flooding using HEC-GeoRAS extension of ArcGIS9.2. Thus TIN-based flood inundation maps have been produced. In this way, the HEC-RAS model was used to obtain seven inundation maps.

4.6. Calculate the Optimal flood depth towards crop production risk management

Relate between Aman production and depth of flood water: Model founded average flood depths of five locations (Figure 3) and corresponding discharges (highest) have been related. Again these discharge data have been related to corresponding Aman production. Then finally relate the flood depth with Aman production.

Relate between flood depth and sediment deposition rate- without taking any practical experiment consider on literature. Islam et al (1999) studied on Ganges and Brahmaputra sedimentation. They have been estimated the suspended sediment load using a sediment rating curve, S = aQb……….(i). Here, is the sediment discharge (kg/sec), Q is the water discharge (m3/sec) and b = 1.23 and a = 0.050 for the combined Ganges- Brahmaputra rives named as Padma River. For this study, it has been assuming that 30% sedimentation has entered into this study area and from that portion 50% have been deposited.

Relate between previous year flood depth and following year's Boro production: - Here Boro production data relate with previous year sediment deposition rate. Now, another relationship (flood depth vs Boro production) has been set up considering the relationship between flood depth and sediment deposition. Now two basic relationships have been founded, one is flood depth vs Aman production and another is flood depth vs Boro production. Then from these two graphs optimal flood depth has been determined just considering no minimum Aman loss and maximum Boro loss.

4.7. Managing Flood Flows for crop production risk management

It is necessary to know how much water has to divert or cut-off from the study area. Basis on this, flood flows management technique(s) have been discussed. For this purpose ArcGIS toolbox, the conceptual model for managing flood flows towards crop production risk management has been developed (Figure- 4).

5. Results and Discussion

After several trials the best match between simulated and the observed water levels has been achieved using manning's values 0.039 for the left bank, 0.045 for the main channel and 0.054 for the right channel. With the calibrated Manning's values, the model has been run again using 1998 flood and it shows that observed value and simulated value are closely matched which indicates the calibrated value of Manning's roughness coefficients are reasonably acceptable. Finally inundation maps have been produced. By statistical analysis 1.85 meter (mean sea level) optimum flood depth has been found (Point- B) (Figure- 5). The point B is chosen then Boro production would be safe but in this case it has not any scope of more production as it starts to go down. Moreover, Aman production would face about 200 ton/yr loss at this flood depth. Prior to ensure the 1.85m flood depth, it has been calculated the volume of water that is generated by flood depth of above or equal and below 1.85m and total volume of water generated by all level of flood depth. Then finally targeted discharge has been calculated for each original discharge hit at Mawa point and an equation has been developed (y = 44.55x0.604) (Fig- 6)

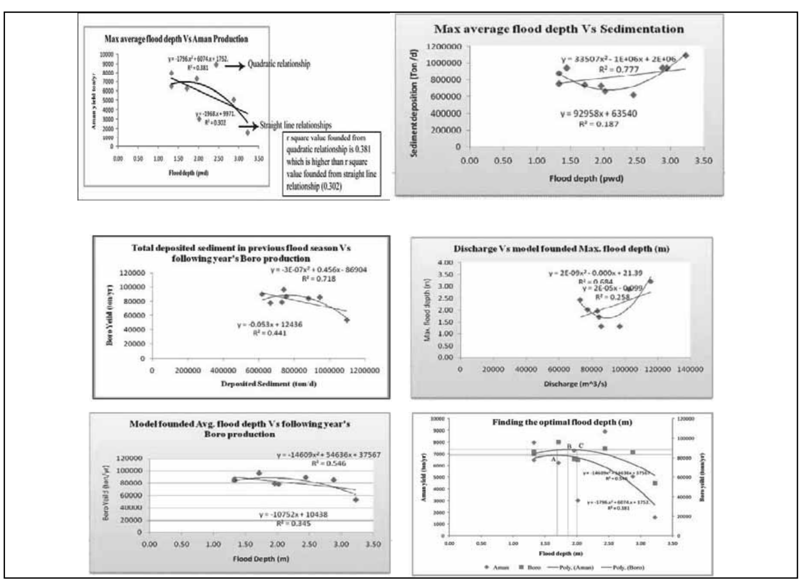

Fig. 5: Finding Optimum Flood Depth

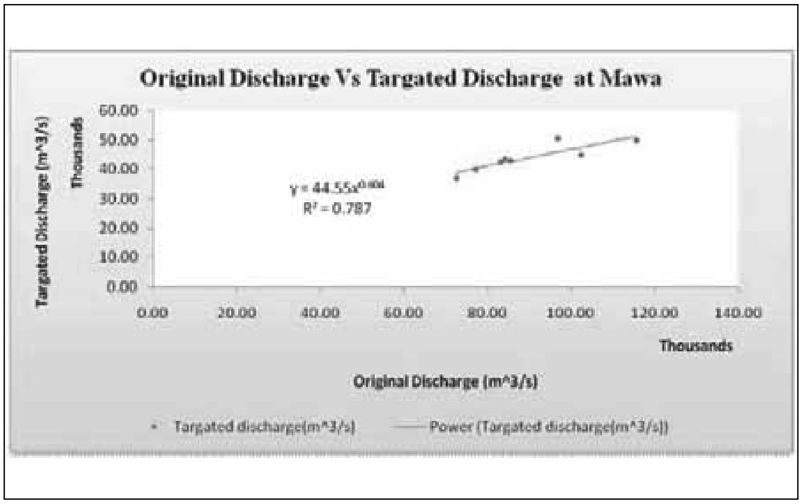

***Fig. 6**: Original Discharge Vs Targeted Discharge*

6. Conclusion

So in conclusion, we can say that if we follow the generated equation then 1.85m will be ensured towards the crop production risk management in the study area. This study has some limitations such as it didn't consider flood plain velocity, existing flood control projects' effectiveness etc which can be a future path for further research.

Acknowledgements

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Pakistan: LAI Nullah Basin Flood Problem Islamabad – Rawalpindi Cities

Ahmed Kamal

Abstract

Integrated flood management is presently being taken as a paradigm shift in the concept of flood management with a view to effectively manage and mitigate flood and related problems locally, on a national basis, regional basis and on a river basin wise. In this context, a Case Study on Flood Problem in Islamabad-Rawalpindi cities of Pakistan has been prepared. Unprecedented flood event of 2001 has been taken as an event which marked the start of paradigm shift and for development of a comprehensive Lai Nullah Flood Control Program. The paper discusses catchment and administrative jurisdiction of Lai, its topography and the present hydrological and land use patterns with specific reference to floods.

The paper discusses the country-wide river system, various structural and non-structural measures in place and those in the Case Study area. Relative importance and applicability ofthese measures have been glanced through and an account has been presented of the changed mechanism and strategies of flood management with reference to particular flood event. In this context, for Case Study area, Lai Nullah 2001 flood event has been projected and an analysis of measures being adopted/proposed for future has been made vis-à-vis for the entire river system. Paper also contains legal aspects of flood management with regard to land use, flood warning system, preparedness and response. Emerging concept of stakeholder participation has been adequately covered.

An effort has been made to concisely project the role and responsibilities of various departments engaged in IFM at country level besides role and responsibilities of federal, provincial and local authorities in the management of flood problem in the Lai Nullah Case Study area. Objectives of national water resources management policy and flood management flood policy have been discussed in the context of IFM. The paper concludes with emphasis on adopting integrated flood management approach by proposing certain recommendations both for the country as well as for the Lai Basin area for real time flood management.

Chapter –1

LAI NULLAH BASIN

Location, Physical Features, Land and Water use Patterns

1. Location

1.1 Catchment Area:

Lai Nullah Basin (Nullah in Pakistan's National Language URDU means Tributary River/Stream) has a catchment area of 239.8 Km² (161.2 Km² in Islamabad and 73.6 Km² in Rawalpindi) and a length of about 30 Km, stretching from the Margalla hills in Federal Capital City Islamabad at the Northwestern edge until Soan River at the Southy-eastern edge in District Rawalpindi of Province of the Punjab. The Basin is located between 33º 33´ and 33º 46´ North and 72º 55´ and 73º 07´ East.

1.2 Administrative Division:

The catchment area of Lai Nullah Basin is administratively divided into District Islamabad (Federal Capital) in the upper reaches of 144.4 Km² and Rawalpindi City of Punjab Province in the lower reaches of 90.5 Km².

1.3 Ground Elevation:

The ground elevation of the Lai Nullah Basin ranges from EL. 420 m at the downstream and of the Basin (i.e., the confluence with soan River in Rawalpindi City) to EL. 1,240 m at the upstream end (i.e., a mountain top in the Margalla Hill range in Islamabad City).

1.4 Physical Features:

1.4.1 Climate

The climate of the Lai Nullah Basin area is classified as "Subtropical Triple Season Moderate Climate Zone", which is characterized by single rainfall season from July to September and its moderating influence on temperature. The case Study area has hot summers and cold winters. In June the daily maximum temperature reaches to 40 ºC, while the daily minimum temperature falls near to 0 ºC in December and January. Between July and September, the temperature is slightly moderate due to humidity.

The case Study area receives rains in all seasons but monsoon rain is pronounced and constitutes a definite rain season but monsoon between July and September. The total rainfall during the rain season is about 600 mm, accounting to 60% of the annual rainfall of about 1,000 mm.

1.4.2 Topography:

The Basin could be broadly divided into the following four areas in view of topography:

i) Margalla Hill Range: It stands behind Islamabad City area as a wall, which forms the North boundary of the Lai Nullah Basin. The foot of the Margalla range stands at elevations of about 620 m, while top of the mountain, which is only 3 Km from the foot is at about 1,200 m. Among several, four major tributaries originate from here. They are Saidpur Kas, Tenawali Kas, Bedarawali Kas and Johd Kas and are as steep as nearly 10%.

ii) The Higher Plain: The Higher Plain expands over the built-up area of Islamabad city with a gradual slope from North to South.

iii) The Lower Plain: The Lower Plain is the upper part of Rawalpindi area upstream of Chaklala Bridge. The area forms a bowl-shaped topography.

iv) The Valley area in the North to South direction. After Chaklala Bridge, the topography changes very much a definite valley. The river/Nullah turns steeper with many cascades, fully down to Soan River, which is a tributary river of mighty river Indus- the largest river among major rivers in Pakistan.

1.4.3 Hydrology

In the jurisdiction are of Islamabad the river system is composed of three major tributaries, namely (i) Saidpur Kas, (ii) Tenawali Kas and (iii) Bedarawali Kas. They originate from the Margalla Hills and flow into the mainstream of Lai N ullah just upstream from Kattarian Bridge, at I.J. Principal Road forming the administrative boundary between Islamabad and Rawalpindi. Below Kattarian Bridge, in the jurisdiction are of Rawalpindi, the mainstream meets other three major tributaries; namely (i) Nikki Lai, (ii) Pir Wadhai Kas and (iii) Dhok Ratta Nullah one after another, then flows down through the center of Rawalpindi City and finally pours into Soan River. In addition to these major tributaries, there are other six (6) tributaries or drainage channels/sewage channels, which joint the mainstream between the confluences of Dhok Ratta Nullah and Soan River.

1.4.4 Geology:

In the upper raches, Lai Nullah cuts through the surficial deposits, which generally consists of Potwar loessic silt. In deposits forming a thick mantle over. In lower reaches of Lai Nullah, the surficial deposits are found to be present directly over loder formation, where the Lai Conglomerate has been removed by degradation.

1.4.5 Land and Water Use Patterns:

The land use is defined as the way how the limited land can be used in the most effectivemanner for different purposes such as residential area, industrial one or public one etc. Hence the land use is usually named and divided with different categories by urban planners.According to Master Plan, a large area of Islamabad was divided into five zone-1 (Urban), Zone- 2 (Urban), Zone-3 (forest, residential), Zone-4 & Zone-5 (sparsely populated, rural areas). Urban areas have been developed into various sectors as C, D, E, F, G, H, I etc.

In Rawalpindi City a mixed land use in pre-dominant in the control areas,. There is no clear segregation of compatible land uses, which have not been related to overall transportation system, thereby creating congestion, chaotic traffic conditions, and hazardous environmentalproblems. Fig-1 indicates land-use pattern of 2002 in case Study area. The trend of land use in the Lai Nullah Case Study area is as given in table 1.1 below.

***Table 1.1** :Lai Nullah Land use Trend*

Land Use	Present (2002)		2012		2030	
	(Km²)	(%)	(Km²)	(%)	(Km²)	(%)
Agricultural Area	33.4	14.2	29.1	12.40	11.4	4.9
Residential Area/Densely popu-lated	31.2	13.3	35.2	15.00	38.8	16.5
Residential Area/Moderately populated	53.2	22.7	68.6	29.2	95.2	40.5
Residential Area in the Suburbs	6.1	2.6	5.6	2.4	2.3	1.0
Forest	34.9	14.8	32.3	13.8	32.0	13.6
Green and Bare Land	74.9	31.6	62.4	26.6	53.5	22.8
Water Body	1.6	0.7	1.6 0.7	1.60	0.7	
Total:	**234.8**	**100.00**	**234.8**	**100**	**234.8**	**10**

The present water supply capacity in the Lai Nullah Basin area is about 785 Million Liters per day in total. Out of the total water supply, the service area of Capital Development Authority in federal Capital, Islamabad shares 507.33 Million Liters per day, while the service area of Water & Sanitation Agency (WASA) OF Rawalpindi city and can its Cantonment share 122.74 Million Liter per day and 155.48 Million Liter per day respectively. The sources of above water supply capacity is divided into surface water and ground-water. Groundwater is abstracted in the Case Study area by 450 tube-wells (182 in CDA Area, 194 in WASA area and 74 in Cantonment area).

The surface water supply capacity of the study area is 528.70 Million Liters per day, which actually is the capacity of seven treatment plants. They abstract raw water from dam reservoirs,or directly from the natural flow discharge of small distributaries. Principal surface water sources in Lai Nullah basin come from Simly Dam on Soan River, Khanpur Dam on Haro River andRawal Dam on Kurang River. Presently the flood water, as it originates from the upper four major tributaries, is not being utilized for any of the urban or irrigation purposes. Rather whatever flood water is generated it goes as waste water to Soan River besides inundating low lying areas.

1.5 Gender activities, Tasks etc:

In Islamabad, high paying professionals predominate including professionals (man & women) in fields of science, education, banking, etc. There are poor people in Islamabad too with subsistence level of income. They live in low-lying flood prone areas of Lai Nullah, generally referred to as "Katchi Abadi". Their men usually engage in work of daily wages like white washing, gardening etc. with women being engaged in private home cleaning and the like.

In Rawalpindi urban area mostly people are engaged in business relating to small and medium scale enterprises. Domestic works are the major form of employment for poor female in the area. Middle class women is mostly engaged in teaching and cloth stitching jobs besides assisting their man in their home run business.

Chapter –2

LAI NULLAH FLOOD PROBLEM

2.1 Lai Nullah Flood

Lai Nullah flood flows actually contribute to River Soan which is the tributary river of River Indus – the largest river among major rivers in Pakistan.

Available past record indicates that floods in Lai Nullah Basin occur in the Monsoon Season (July-September every year) when the overall country receives down pour from three weather systems: namely I) Monsoon depressions from the Bay of Bengal India (the most dominate system), ii) Westerly waves from the Mediterranean Sea, and iii) Seasonal Low from the Arabian Sea. This is superimposed by snow melt for the Indus River.

2.2 Extreme Flood Events:

Scraps of descriptions about post floods, as collected from several study reports indicate that, in the Lai Nullah Basin area, flood has occurred with the frequency of 19 years, at least in 59years from 1944 to 2002 as may be noted from table 2.1 below. In other words, flood damage broke out almost once in every three years in the two cities of Islamabad-Rawalpindi of Pakistan Among the above extreme flood years, 1981, 1988, 1997 and 2001 had been the worst with 2001 being of highly unprecedented nature.

***Table 2.1**: Lai Nullah – Extreme Flood Years*

Year	Date	Year	Date
1944	August 13	1985	No data
1957	No date	1988	No data
1966	July 31	1990	No data
1970	No data 1	994	July 3
1972	No data 1	995	July 24
1976	No data	1996	July 29
1977	No data	1997	August 27
1978	No data	2001	July 23
1981	No data	200a2	August 13
1982	August		

In Rawalpindi City, being on the lower elevation, low-lying areas along Lai Nullah and tributariessuffer from even small floods. Serious flood events to occur along in particular: the main stream between Gunj Mandi Bridge and Railway bridge, and the tributaries of Arya Nullha, Dhok RataNullah Dhok Charaghdin. Flood inundation starts in these areas once the water level of Lai Nullah reaches 18 feet (491.5 m) at Gawal Mandi Bridge.

2.4 2001 Flood Disaster:

The flood in 2001 has been the largest and heaviest among the recorded floods, and thus can be taken as a national disaster. On July 23, 2001, a total of 620 mm rainfall was recorded in a spar of only 10 hours (0600 hours to 16 hours PST) AT Islamabad Met station. The water level of Lai Nullah and its tributaries remarkably rose and all houses and some road bridges along the way were swept away. According to Pakistan Meteorological department (PMD), instead of monsoon depression, this rainfall was caused by a freak combination of disastrous weather events including: (a) intense heating on the surface, (b) presence of mid latitude westerly trough and (c) moisture feeding through monsoon flow along Himalayas. According to PMD reports, the intensity as well as amount of rainfall was more in Islamabad than in Rawalpindi. The swollen flow invaded Rawalpindi causing several times damages than Islamabad. A total of 74 human lives were lost, about 400,000 people were affected, 742 cattle head were totally perished, 1,087 houses were completely damaged in Rawalpindi besides some 2,448 partially damaged. Estimates indicate a damage/loss of more than 15 billion rupees (US $ 0.25 billion) to infrastructure, Government property and to Small and Medium scale Business Enterprises.

2.4.1 Flood Event Categorization:

At the country wide level the flood related disasters are categorized in terms of Flood Classification for the main river system (five rivers namely: Indus, Chenab, Ravi, Jhleum and Sutley). In this context there are two flood categories: i) Mild and ii) Danger.

Mild Flood Category:

This flood category is further sub-classified into three types based on flood intensity in main river(s) as under:

a) Low Flood:	River flowing within deep (winter) channel(s) but about to spill threatening only river islands/belas(small dry land within rivers)
b) Medium Flood:	River partly inundating river islands/belas
c) High Flood:	River almost fully submerging islands/belas and flowing upto high banks/bunds but without encroachment on the freeboard (margin over and above the High Flood Design Level ofbank/bund/embankment to cater for any above high flood level situation)

Danger Flood Category:

This flood category is further sub-classified into two types based on flood intensity in main river(s) as under:

a) Very High Flood:	River flowing between high banks/bunds with encroachment on free board.
b) Exceptionally High Flood:	Imminent danger of overtopping/breaching or the high bank areas have become inundated

2.5 Differential Impact of 2001 Flood Disaster on Women and Men:

An interview survey was conducted to assess differential impact of 2001 flood disaster onwomen and men some of the common replies obtained are:

- 2001 flood had badly damaged our houses, assets and it would take 15-20 years to fully recover;
- Flood affecters were unable to buy books for their school going kids and resultantly had discontinued their kids from going to schools
- Most of the buildings were badly damaged and residents feel that if they are again hit by floods of even lesser magnitude, their buildings are going to collapse.
- The male members of the families, who were doing private jobs, spent 1-2 months at home to clean and rehabilitate their homes and assets, became jobless. This economic disaster further increased their vulnerability.
- Due to floods, large number of dowries of young girls were perished, resulting in economic as well as social damage to individually affected families.
- Continuous fear of flooding again when ever there is rain.
- Female members of families, living at the edge of Nullah feel insecure that government will demolish their houses, most of which come under the definition of encroachment.
- If flood comes again we will be shelter less/home less.

Chapter –3

FLOOD MANAGEMENT MEASURES

3.1 Flood Management Measures – Countrywide:

3.1.1 Floods, Losses & River System:

Five main rivers, namely, the Indus, Jhelum, Chenab, Ravi and Sutlej flow through the Pakistan's plains. Supplemented by a number of smaller tributary rivers and streams, these rivers supply water to the entire Indus Basin Irrigation System. The rivers have their origin in the higher altitudes and derive their flows mainly from snowmelt and monsoon rains.

The floods in above major rivers are generally caused by heavy concentrated rainfall in the catchments, during the monsoon season, which is sometimes augmented by snowmelt flows.Monsoon currents originating in the Bay of Bengal and resultant depressions often result in heavy downpour in the Himalayan foothills which occasionally produce destructive floods in one or more of the main rivers of the Indus System. However, in some cases exceptionally high floods have occasionally been caused by the formation of temporary natural dams by landslide or glacier movement and their subsequent collapse.

3.1.2 Flood Management Strategies in Place:

Flood management planning in Pakistan is being carried out to essentially achieve: i) Reduction of flood losses in an economically sound manner; ii) Prioritizing of areas of greater economic hazards; iii) Protecting the cities and vital infrastructural installations; iv) Exploring the possible use of existing flood control facilities; v) Promoting appropriate land use in flood hazard areas; vi) Minimizing adverse effects on national ecosystem and environment and vii) Creating flood awareness and adaptability in the Riverian areas.

In order to achieve above planning, structural as well as non-structural flood management measures are in place. The structural measures include embankments, dykes, spurs, bunds, water diversion structures and water dispersion structures etc. on the main as well as on the tributary rivers and on various hill torrents while non structural measures include flood forecasting and warning system including three weather radar system, High frequency Radio Communication system at 19 barrages & major reservoirs for effective river inflow/outflow data receipt and dissemination besides inter-provincial and inter-agency coordination at the federal and provincial level. Contrary to the past practices, efforts are now on to achieve integrated flood management through implementation of structural flood protection measures on river reach-wise basis.

3.2 Flood Management Measures – Lai Nullah Basin:

As stated earlier Lai Nullah basin lies in the twin cities of Islamabad & Rawalpindi and most of its active part passes through the urban areas of Islamabad & Rawalpindi besides a part of it through rural communities in Islamabad. At present no active and integrated flood management approach is seen in Islamabad in managing the flood waters of Lai Nullah Basin. On the other hand some realization is seen in Rawalpindi to manage Lai floods in the back drop of unprecedented floods of 100 years return period occurred in July 2001.

As a part of strategy to manage flood following measures have been taken: i) Straightening and widening of some of the reaches of Lai Nullah passing through congested Rawalpindi City area; ii) Stone pitching of some of the existing portions of Lai Nullah in Rawalpindi City in order to prevent erosion and danger of collapse of building standing close to the Nullah catchment; iii) Removal of garbage disposal, by the people living in the vicinity, into the flowing water of Lai Nullah, which actually plays a major role in creating artificial floods in some of the reaches, due to heading up of flood waters at the bridge piers; iv) Raising of heights of some of the road bridges built long time age on Lai Nullah; v) Removal of encroachments.

3.3 Mechanisms in Place for Effective use of Floodwater and Floodplains and their efficacy:

The Irrigation System of Pakistan is the largest integrated irrigation network in the world, serving 13.96 million hectares (34.5 million acres) of contiguous cultivated land. The system is fed by the waters of the Indus River and its tributaries. The salient features of the system are three major storage reservoirs, namely, Tarbela and Chashma on River Indus, and Mangla on River Jhelum; 19 Barrages; 12 inter-river link canals and 43 independent irrigation canal commands. The total length of main canals alone is 58,500 Km. Water courses comprise another 1,621,000 KMs.

Diversion of river waters into off taking canals is made through barrages, which are gated diversion weirs. The main canals in turn deliver water to branch canals, distributors and minors. The watercourses get their share of water through outlets in the irrigation channels. Distribution of water from a watercourse is effected through a time-schedule or "warabandi" under which each farm gets water for a specified period once a week. The time-share or "wari" is proportionate to the farm area owned by a farmer under the command of the watercourse.

The system draws an average of 13.08 million hectares meters (106 MAF) of surface water each year for irrigation. Supplemented by an annual groundwater pumpage of some 5.31 million hectares meters (43 MAF), the average depth of water available at the farm gate is 2.31 meters per hectare. Approximately 3 million individual farms with an average size of about 4.856 hectares benefit from this system.

It may be pointed out here that for the Lai Nullah Case Study Area presently no mechanism is available for effective use of flood water and floodplain.

3.4 Flood Mitigation Measures:

3.4.1 Country-wide Structural Measures in Four Provinces including those for Lai Nullah Basin:

In Punjab, the flood protection bunds/embankments have been generally constructed either to protect head-works and other irrigation structures, or to safeguard certain towns and villages. Due to general topography of the area sloping towards the south west, the embankments along head-works and irrigation structures have been constructed in such a way that breaching sections are provided on the right marginal bunds to give relief to water heading up against the left marginal bunds during floods and keep the flow through the Barrages within safe limits for the Hydraulic structures. This is done to avoid breaches in the left marginal bunds, which can cause widespread devastation, as most of the development is on the left side of the river. In order to protect areas from erosion, spurs have been constructed. These spurs have protected the areas and in some cases even the eroded lands have been recovered.

The Indus River flows on a ridge in Sindh Province, and surrounding areas are generally lower than the river bed; hence, water once leaving the Indus River does not return back. Escaped water thus causes greater damage to widespread areas, and it persists for a longer period even after the flood peaks are over. Moreover, Sindh is situated on a receiving end of drainage of all the rivers and if flood protection measures adopted in the upper reaches are not properly planned, severe damages are likely to occur in the Province. In order to minimize such eventualities, double line of flood embankments has been constructed on almost both the banks. These embankments have been further compartmentalized to contain widespread inundation. These embankments are often threatened by active erosion by the river flows and leakages in the embankments due to poor soils in some reaches.

In **NWFP,** the floods are mainly due to flashy hill torrents having steep bed slopes, which greatly increase flood velocity and severely erode the banks. In NWF Province, mostly spurs, dykes and gabion walls have been constructed to save the areas from erosion. However, due to very steep gradient in some of the river reaches, serious damages to the existing spurs system also sometimes occurs involving fair amount of Operation & Maintenance cost.

Due to peculiar physiographic and climatic characteristics in **Balochistan,** mostly embankments and flood walls have been constructed to protect orchards or abadies from flood damages. Some bunds have also been constructed to serve as flood diversion/abatement measures. Due to heavy torrential rains damages to these structures take place for which there is a dire need of developing local techniques to use flood waters like: i) Delay action dams, ii) water dispersion structures, iii) Water diversion structures, iv) Provision of small water storages for local usage.

For the Lai **Nullah Case Study Area** some of the structural flood measures have been briefly stated in item 3.2 above.

In order to implement greater integrated water and flood management approach, new structural measures are required to be placed in view of provincial priorities besides ensuring proper Operation & Maintenance of the existing infrastructure. For Lai Nullah issue, to avoid incidence of 2001 like situation there is an urgent need of implementation of some immediate, short, medium and long term priority interventions (which are to be discussed later).

3.4.2 Country-wide Non-structural Measures including those for Lai Nullah Basin:

A weakness in flood management had always been the lack of early flood warning system on our rivers. The comprehensive program for strengthening of Pakistan's flood forecasting and warning capability was conceived by the Government after super floods in 1992. The existing measures include: i) 69 High Frequency Radio sets for main federal and provincial agencies involved in the task of flood management including major barrages; ii) 10 cm Quantitative Precipitation Measurement (QPM) Weather Radar at Pakistan Meteorological Department at Lahore (Punjab), 5.36 cm weather radar at Sialkot (Punjab) besides weather surveillance radars at Karachi (Sindh), Rahim Yar Khan (Punjab), D.G Khan (Punjab) and Islamabad (Federal Capital); iii) Mapping of flood prone areas along the Indus River and its major tributaries using the Global Position System (GPS) techniques and the related development of a Digital Terrain Model (DTM); iv) Computer based Indus Basin Flood Forecasting System(FFS), and v) Meteoro-burst Telecommunication System for real time hydromet data receipt and transmission. This system, however, needs to be further extended besides urgent requirement of weather radars to monitor monsoon weather system from Bay of Bengal and to address torrential rain problems in remote areas of Balochistan.

For the case of Lai Nullah, presently PMD monitors storm rainfall through existing four rainfall gauging stations and one weather surveillance radar at PMD Office, Islamabad. The existing rainfall gauging stations are, however, not equipped with automatic data transmittal system, which caue difficulties in the collection of accurate gauged data on real time basis. Rawalpindi Municipal Corporation (now Tehsil Municipal Administration-TMA) also operates two manual (off-line) water level gauging stations at Gawal Mandi Bridge and Ratta Amral Bridge to monitor flood water level of Lai Nullah. These stations were, however, abandoned due to reconstruction of the above bridges after 2001 floods.

3.4.3 Relative Importance of Structural & Non-structural Measures:

Structural Measures:

Pakistan has one of the world's largest irrigation and canal network. Also the Indus River System is among the world's largest systems. The importance of structural measures always exists there for: i) Safety of major irrigation infrastructure, ii) safety of local community living close to the riverian areas, iii) more land reclamation for enhanced agricultural practices, iv) effective utilization of available water resources & v) to keep the river system within the main river meandering belt. In the context of Lai Nullah Case Study Area existing structural measures as stated in item 3.2 above, and their further strengthening is of paramount importance in order to ensure safety of the surrounding communities in situations similar to that of 2001.

Non-structural Measures:

On the other hand non-structural measures have their own merits in: i) the provision of real time weather system, especially, the monsoon system, for careful forecasting for river flows and urban area inundation, ii) effective and real time data receipt and dissemination, iii) management of outflows from country's two major reservoirs, especially, for Mangla Dam in the event of super floods, in such a way that downstream hydraulic structures which are the back bone of Pakistan's irrigation system are protected. In the context of Lai Nullah Case Study Area there is an urgent requirement of effective flood forecasting and warning system at Islamabad- Rawalpindi level which presently is almost non-existent.

3.4.4 Women's and Men's Participation in Flood Mitigation Measures:

Flood management at country-wide basis is being managed through Federal as well as Provincial entities and as such the inter relationship between women's and men's participation in above two types of flood mitigation measures in terms of responsibilities and tasks is nonexistent. However, there are Non-Governmental Organizations which work at the provincial and federal level at their own and have shared responsibilities and tasks among women and men. In the context of Lai Nullah Case Study Area, 2001 flood incident proved a good example of joint relief work by local as well as international NGOs with equal gender participation.

3.5 Modifications to Flood Mitigation Measures Following Extreme Events:

3.5.1 Flood Management Activities:

At the country-wide basis, after the super floods of 1992, National Flood Forecasting Bureau (now Flood Forecasting Division-FFD) was established for more effective liaison and interagency coordination during flood season every year. Flood Warning Centres have been made operative at district level to collect and pass on the related information to respective Provincial Flood Warning Centres who in turn pass the same to FFD for nation-wide dissemination of real time information. In the context of Lai Nullah Case Study Area, some changes in the flood management strategies are in the proposal stage, as explained in later section in the Case Study relating to two urgent projects.

3.5.2 Changes to Existing Structural and Non-Structural Measures:

At the country-wide level, after the super floods of 1992, serious efforts have been made to follow integrated flood management approach by undertaking implementation of over 250 flood protection schemes on five major rivers on river reach basis after detailed feasibility study. However, important areas of community participation and ensuring reasonable Operation & Maintenance after construction had not been given desired attention which are now being considered for upcoming new flood management projects. In the context of Lai Nullah Case Study Area, after the unprecedented rains and consequent floods in 2001 some reasonable structural improvements have been placed in order to: i) minimize over spillage of flood water and resultant inundation of some of the low lying areas in Rawalpindi City, ii) somewhat improved garbage collection and disposal system, iii) removal of encroachments & iv) local level involvement of NGOs and community based organizations. However, these improvements are only at Rawalpindi level and thus need to be integrated with Islamabad City which is the main source of flood generation in Lai Nullah due to its four major tributaries being originated from the foot hills of Islamabad.

3.5.3 Adoption of New Structural and Non-Structural Measures:

Side by side with the existing flood management measures, regular occurrences of rain/flood related disasters in Pakistan, has prompted the Government agencies in devising & adopting new and improved strategies to combat the flood menace. Prominent among these include: i) adopting integrated river and flood management approach through planning and implementation of flood works on river reach to reach basis, assigning due consideration to their effects/impacts downstream, ii) experimenting provision of battery of spurs in an attempt to shift river meander and to control erosion & reclaim more land, iii) further improvement in the shapes of spurs through model testing, iv) adopting river reach wise model testing as a pre-requisite to suggest any on-ground intervention, v) master planning of hill torrents has been done with a view to exploit their water potential for local irrigation of drinking water supply etc. On non-structural side: i) new and advanced weather radar systems get priority, ii) Data collection system which had proved successful in the past is being extended to further remote areas, iii) for flood control projects community participation concept is being introduced in various schemes to ensure placement of any intervention with the participation of beneficiaries in siting, planning & implementation of schemes.

In the context of Lai Nullah Case Study Area, implementation of two urgent projects has been suggested including: i) Provision of flood retardation basin in Islamabad through Capital Development Authority (CDA) with Federal Flood Commission (FFC) as the central coordinating body, as a structural measure, in order to cater for super flood and to shave off flood peaks at initial stages with a view to ensure safe and secure flow in Lai Nullah downstream in urban Rawalpindi, ii) Placement of an effective flood forecasting & flood warning system with Islamabad-Rawalpindi under PMD with Federal Flood Commission as the central coordinating body. Some medium term and long term measures are also being proposed which includes provision of a long diversion channel (in two stages) to divert flow of Lai Nullah upstream in Islamabad and just close to downstream located Rawalpindi City to a tributary river (Kuran River) so that Lai Nullah high flood is diverted through this channel thus protecting downstream areas on permanent basis. This channel will take flood flows of a number of small streams which flow into main Lai Nullah in Islamabad area.

3.5.4 Changes in the Relative Importance of Structural & Non-structural Measures:

Over the last decade or so the overall development in the above areas have been considerable and as such change in their relative importance is not so evident or desirable. As a matter of fact there is an increased demand, from the federating units, for more structural interventions on secondary and tertiary rivers in addition to the main rivers on account of water and flood water becoming precious commodity. In the non-structural sector, emphasis is now being given to development of Flood Warning Manual. The idea behind is to depict details of villages, infrastructure, cattle-head, crops etc. parallel to flood of a certain category (e.g. 500,000 Cfs, 600,000 Cfs etc. i.e. 14,160 to 16,1992 cubic meters per second) in order to ensure real time evacuation and migration of communities who are likely to be affected at the occurrence of flood of a certain category. Another shift in the non-structural flood control measure is involvement of beneficiaries in various processes of project implementation so that post implementation O & M problems are handled through sense of ownership by the beneficiaries. This also applies to the Lai Nullah Case Study Area.

3.5.5 Information/Data Collection Mechanisms:

As described in the preceding items, data collection and dissemination related to rainfall, river flood etc. is managed through a network of flood warning centres connected with the FFD at the national level. Automatic as well as manual gauge systems are available with the main river system on country-wide level for this purpose. Meteorobusrt Telecommunication System is a recent addition to this data collection and transmission field, besides High Frequency Radio System, which has greatly improved the efficiency of concerned federal and provincial agencies on one hand and has also resulted in improved river flow/routing and forecasting practices due to real time data.

In the context of Lai Nullah Case Study Area, lack of reasonable information collection and data dissemination system is noticeable.

3.5.6 Inter-agency Coordination:

An important area that was requiring most urgent attention is improvement in the coordination between different departments of Islamabad & Rawalpindi in order to ensure integrated flood management of Lai Nullah floods. These include Capital Development Authority (CDA), Rawalpindi Development Authority (RDA), Tehsil Municipal Administration (TMA), Rawalpindi, Small dams Organization of Punjab Province in Rawalpindi and Rawalpindi cantonment Board (RCB). A visible improvement has very recently been witnessed in the recent past, as FFC has now been entrusted with the task of ensuring inter-agency coordination for the Lai Nullah Case Study Area. At the national level a more responsible approach is being seen in coordination of flood management and relief measures activities.

Chapter – 4

FLOOD AND WATER MANAGEMENT INSTRUMENTS

4. Disaster Management Laws:

4.1 Present Position:

According to World Disaster Report 2002, two percent of Pakistan's population were killed or adversely affected by disasters during 1999 to 2001 period. Disaster management is Pakistan is basically revolves around flood disasters with a primary focus on rescue and relief. The existing institutional structures responsible for disaster management lend themselves to reactive shortterm responses.

A serious weakness exists between the documented responsibilities of stakeholder agencies and their aptitude to and comply with their tasks. At present there is no comprehensive and strategic national disaster management policy that reflects an all risk approach to disaster management. However, there exists legislation and a variety of governmental and nongovernmental organizations that are addressing some critical aspects of preparedness, mitigation, early warning and response to natural and human induced disasters.

4.2 Legal Aspects of Flood Management:

(a) Land use:

The four provinces are the managers of respective catchments and flood plains of Indus river system and the present land use policy in operation is that river catchments and flood plains are exclusively to be kept as no go area for the riverian community. Also legislations are there that prohibit from developing any ill legal dwellings/encroachments in the river Khadir (i.e., floodplain/river catchment). Contrary to this lot of encroachers are there and in the context of Lai Nullah flood problem, the devastation that had been caused to human life was largely on account these encroachers. Situation has improved after 2001 disaster. RDA/TMA has also enforced certain land use regulations to discourage ill legal developments alongside the Lai Nullah especially to stop ill legal construction of residences, Small & Medium Scale Enterprises, massive dumping of garbage in the mainstream of the Nullah besides measures for construction of single span new bridges in place of multiplier old bridges in an effort to cater for the downstream artificial heading up and ultimate flooding of residential area and small industrial units in the close vicinity.

(b) Flood Warning:

In line with NFPP, PMD is currently entrusted with the task of flood warning in order to ensure effective flood management. In this context PMD FFD is responsible for the dissemination of the flood forecasts/ warnings to considerably large number of recipients directly or indirectly concerned with the flood mitigation process. Press briefings are arranged by FFD as a regular feature to ensure correct and authentic flood and weather information to the public. Such briefings are arranged through the representative of the Information Department. Considerable improvement has since been made in the flood warning & their dissemination system since the time that it was initially started. Most of the discrepancies sated above have been removed. A much better coordination new exists with WAPDA.

To forewarn the frontline flood mitigation authorities regarding the possibility of floods due to the arrival of monsoon low/depression in the vicinity of the Pakistan, Colour Coded Qualitative Forecasts are issued. To facilitate the understanding of the flood situation for those recipients who are highly placed Government functionaries (mostly at the federal level) and thus need to know the Weather/ Flood situation in general (easily understandable) terms and are not concerned with detailed river forecast, weather/flood forecast are issued. To give the quantitative information of the magnitude of prevailing and the forecast flood flows at maximum number of directly or indirectly concerned recipients routine daily flood forecasts are given. Significant flood forecast is issued at the occurrence of a flood of 'High' or higher level at a specific site/sites over a river and/or nallah within the Indus basin river system. Areal inundation flood forecast is issued only when the exceptionally high flood occurs and the areal inundation is forecast on the basis of the hydrodynamic model.

(c) Flood Preparedness & Response:

Presently both at the federal as well as at provincial level very effective planning and practical arrangements are ensured every year and in this context all resources are mobilized to create a sense of response among the affected people towards government efforts. However, affected communities are sometimes vocal about mis-management and lack of effective preparedness by the state owned concerned agencies. The reason being that sometimes required relief measures are not reached to every affected person due to state/provincial constraints and limited real time resource availability.

4.3 Allocation VS Use of Resources for IFM:

Since 1977 up-till now an approximate sum of Rs 34 billion (US$ 0.65 billion-including foreign loans) have been spent against a provincial demand of Rs 70 billion (US $ 1.3 billion) on construction of some 750 flood protection works, restoration of some 4,045 rain/flood affected irrigation & flood control schemes besides reasonable improvements in the flood forecasting capability. In this context it is worth mentioning that amount spend on integrated flood management had been less than fifty percent of the actual demand on ground. In the context of Lai Nullah integrated flood management, only recently a serious investment of Rs over 0.40 billion (US $ 7 million) have been made against a constant requirement of funds more that 2.00 billion (US $ 35 million).

4.4 Access and Control on Resources of Women & Men:

In the context of integrated flood management in Pakistan, state owned agencies (concerned federal and provincial departments) have an over access and control over resources meant for ensuring IFM. Role of women and men is just confined to sharing of benefits, but, as far as planning, siting, designing and implementation of a certain flood management intervention is concerned, only state owned agencies have their say. In the past there have been instances of allocating and spending meager flood management resources on politically motivated schemes thus completing ignoring IFM approach. Nevertheless, this trend has now changed and funds are being spent on implementation of disaster/

flood control strategies based on integrated river reach basis. Very recently, women & men have got an access and control on resources through the induction of social mobilization and community participation approach in overall flood management strategy of the country.

4.5 Efficacy of Law Enforcement Mechanisms:

In its true sense although the federal and the provincial governments have certain laws in place and certain policies devised to stop occupation of river bed/river catachment (in the four provines)/space between first line of defence and second line of defence (in Sindh province) by the local community, however, local people are habitual in cultivating crops on small scale to earn their living besides resorting to development of permanent dwellings, in the shape of stone/bush made house, in the river belt. At the advent of flood of a certain magnitude provincial, local and district administration issue regular flood alerts for shifting to safer places, however, such flood alerts and warnings always prove meaningless and people become shelterless and homeless. In the context of Lai Nullah Case Study area, over the last 25 years, people had been following course of ill development of businesses and residential units without being noticed. The prevailing laws are required to be modified as there are flaws which allow the encroacher to get long repeated stays on one pretext or the other once the municipality issues certain instruction for removal etc.

Government is allocating lands to farmers in areas other than river bed to discourage the trend besides local NGOs engaged in awakening the female gender in cheap home based bread earning kills including stitching etc. In Lai Nullah TMA has introduced strict laws and penalties for i) the land encroachers, ii) garbage dumping in line with 2001 flood incident. TMA & RDA has removed more than 2000 encroachments from the vicinity of the Lai Nullah by paying market prices for the encroachments. At the same time RDA has prepared a comprehensive resettlement plan to avoid any civic and social problem.

Chapter – 5

INSTITUTIONS RESPONSIBLE FOR FLOOD MANAGEMENT

5.1 Agencies Involved In Flood Management & the Extent of their Mutual Cooperation:

5.1.2 Country-wide:

Flood management is a multifunctional process involving different organizations. The Government Organizations which play major role in the flood management are Provincial Irrigation & Power Departments (PIDs), Water & Power Development Authority (WAPDA), Provincial Relief Organizations/ Departments, Pakistan Army, Pakistan Commissioner for Indus Waters (PCIW), Emergency Relief Cell (ERC), FFC and FFD. Proper understanding of role of these organizations is a necessary pre-requisite for close coordination between them. Role of these organizations are briefly described below:

i) Provincial Irrigation & Power Departments (PIDs):

PIDs plays a front line role in the process of flood forecasting as well as flood mitigation. Major flood related functions include: i) Flow measurement at the specific sites at rivers, canals and nallahs; ii)

Planning, design, construction and maintenance of flood protection works; iii) Maintenance of data communication network, iv) Supervision of the Flood Warning Centre; v) Close coordination with FFD for the issuance & dissemination of the flood forecasts/warnings; vi) Updating & execution (if required) of the divisional flood fighting plans.

ii) WAPDA:

WAPDA is actively involved in the Flood Forecasting process by providing river and rain data from its telemetric gauge sites within the upper catchments of Indus and Jhelum Rivers. Besides WAPDA's involvement in providing the hydrometric flood data, it is also involved in providing the data from such hydraulic structures as Mangla and Tarbela dams and the Chashma barrage. Coordination between FFD and WAPDA sharply improved after the 1992 flood disaster. Its major role is regulating the flows of Mangla and Tarbela reservoirs during flood season every year.

iii) Provincial Relief Organization/Departments:

Provincial Relief Organizations are charged with the responsibility pertaining of disaster preparedness, emergency response, and post disaster activities pertaining to all disasters including floods. Relief functions at the district and Tehsil (sub-district) level are performed through the District Coordination Officers (DCOs) who coordinate with the other departments to execute the flood mitigation functions at the district level under the new Devolution Plan of Government which is meant for transferring powers to the communities at the grass root level through Community Based Organizations, Village Councils and Community Citizen Boards.Flood preparatory actions required to be taken by the Relief Commissioner include: i) Arranging inspection of the flood protection works by the Irrigation Departments and Pakistan Army to ensure that all vital flood protection bunds etc are in a satisfactory state of maintenance; ii) To establish flood warning centre and the flood centres at the district and tehsil levels; iii) To ensure that all flood related agencies/departments involved in the process of flood mitigation are fully geared to perform the functions pertaining to their respective areas; iv) To ensure that flood forecasts/warnings are disseminated without loss of time to all concerned and that they are fully aware of the actions to be taken under each situation.

iv) Pakistan Army:

Pakistan Army's flood related functions encompass all the three phases of flood operations from the pre-flood to post flood phases including the all important flood phase. Pre-flood phase is the flood preparatory phase during which the adequacy and the serviceability of the flood fighting equipment is ensured. Since Punjab is the most flood prone province, it is the Relief Commissioner Punjab, who provides the bulk of the flood fighting equipment to the Army. Preflood inspections of the flood protection structures are also carried out by the respective commander corps of engineers for their respective areas to ensure that the structures (bunds, barrages, spurs etc.) are in satisfactory state of maintenance. Availability of sufficient stock of explosives to activate the breaches, if required, is ensured. Pakistan Army's major flood related function starts after the flood occurs. In the event of any flood situation, units of the Army move out to their respective areas of responsibility and carry out the relief and rescue operations in coordination with the civil administration.

v) Commissioner for Indus Waters (C.I.W):

Pakistan has a unique flood forecasting problem in the sense that greater part of the flood producing upper catchments of the Sutlej, Ravi, Jhelum and Chenab rivers lie across the border in India/held Kashmir. Furthermore a number of control structures like dams and barrages etc exist over the rivers across the border with the result that the free flow conditions are destroyed making the operation of the rainfall/runoff model extremely difficult. The situation underlines the need for the river flow data from across the border in respect of the important sites over the rivers in India/held Kashmir. Consequently, an agreement has been signed between the two countries through their respective Commissioners for Indus Waters, which includes a provision to receive from India such river flow and rain data as is considered important for flood forecasting in Pakistan. A number of river flow stations are specified for this purpose. The data is then passed on to FFD.

vi) Emergency Relief Cell (ERC):

Emergency Relief Cell has been established under the Cabinet Division and is controlled by the Cabinet Secretary. The Cell is headed by the Director General Relief. Main role of the Emergency Relief Cell include: i) Planning and assessment of relief requirements of major disasters; ii) Stock piling of basic necessities needed during emergency such as dry ration, blankets etc.; iii) Establishing emergency fund upon declaration of any part of the country as calamity affected; iv) Maintaining contact with UNDP and other international aid giving agencies; v) Making arrangements of disaster relief assistance from other countries; vi) Located at Islamabad, ERC maintains contact with the Federal Flood Commission(FFC).

vii) Federal Flood Commission (FFC):

Main responsibilities of FFC include: i) Preparation of National Flood Protection Plan (so far three 10 yaer each National Plans have been implemented and the third is being implemented); ii) Approval of Flood Control Schemes prepared by Provincial Governments and concerned federal agencies; ii) Review of flood Damages to public sector infrastructure and review of plans for restoration and reconstruction works; iii) Measures for improvements in Flood Forecasting and Warning System on country-wide basis; iv) Standardization of designs and specifications for Flood Protection Works; v) Evaluation and monitoring relating to progress of implementation of the National Flood Protection Plan(NFPP); vi) Preparation of a research program for Flood Control and Protection; vii) Recommendations regarding principles of regulation of reservoirs for flood control; viii) Overall coordination for effective flood management on country-wide basis with all concerned federal and provincial departments (for structural, non-structural measures, policy matters relating to floods, water, irrigation, drainage etc.); ix) Liaison with international organizations like ICOLD, ICID, ICIMOD, UNDP, ADRC, ADPC, World Bank, ADB, IDB, JICa, JBIC etc.

In the context of flood warning dissemination, Chairman FFC (being also the Chief Engineering Advisor to the Federal Government) renders suitable reports to the President and the Prime Minister as and when the situation so demands. A Flood Monitoring Situation Report on Weather & River Discharges is prepared and issued to important Government officials on daily basis during the flood season every year. Since its establishment in 1977, FFC has been involved in the implementation of flood works over Rs 10 billion.

viii) Flood Forecasting Division (FFD):

FFD of the Pakistan Meteorological Department plays a pivotal role in the entire flood warning and management process. Hydrometeorological data from the various national and international sources is received in this Bureau which is then processed to produce flood forecasts and warnings to be disseminated outwards to various national organizations.

5.1.3 Lai Nullah Case Study Area:

The management and/or administration of Lai Nullah is presently undertaken by: i) FFC, ii) CDA, iii) RDA, vi) Small Dams Organization (SDO), v) TMA and RCB. Their role/responsibilities in the context of Lai Nullah are given as under:

Federal Flood Commission:

In view of lack of coordination between the administrations of Islamabad & Rawalpindi cities, Laui Nullah problem had been aggravating since 1980. In order to manage Lai Nullah problem in the context of integrated river and flood management approach, Government of Pakistan, in 2001 decided that this important & joint flood management problem in the federal capital and in the important city of Province of Punjab should be tackled by FFC through medium and long term planning and implementation of measures.

FFC is ensuring necessary steps in this regard. Two urgent nature projects (one structural and one non-structural) are being finalized for implementation with the cooperation of CDA, PMD, RDA & TMA.

Capital Development Authority (CDA):

Responsible for master planning of Islamabad. After the 2001 super floods, CDA was forced to realize the importance of operational plan to fight against the expected rainwater storm in future.

Small Dams Organization (SDO):

It is a sub-ordinate office of Punjab Irrigation Department and is presently responsible for maintenance of Rawal Dam which is one of the main sources for water supply in Islamabad-Rawalpindi. This Office has vast experience in flood management of small rivers and hill torrents and construction of small dams in Potohar Platuo around Islamabad. It has so far constructed 31 small dams and is also looking after their maintenance.

Rawalpindi Development Authority (RDA):

The major responsibilities of RDA are, to plan, guide, control and implement major and long term development works in Rawalpindi City. It deals with surface drainage or flood mitigation projects relating to Lai Nullah in the context of water supply, sewerage, land development and management. Tehsil Municipal Administration (TMA), Rawalpindi: Responsible for: i) Execution & management of development plans, ii) Enforcement of all municipal laws, rules etc., iii) Prevention of encroachments,

iv) Collection of approved taxes, user fees, rates, rents, tolls, charges, levies, fines, and penalties after approval of Tehsil Council & v) coordinating & supporting municipal functions amongst unions and villages. Rawalpindi Cantonment Board (RCB): Responsible for: i) Provision of civic amenities, ii) maintaining of public markets, slaughter houses, public toilets, iii) regulating trade and professions, iv) Enforcing Muslim Family Laws. RCB dose not have any precautionary measures arrangements against the flood water flowing through Lai Nullah in the jurisdiction of RCB.

5.2 Central Authority for Flood Mana gement & Coordination:

5.2.1 Country-wide:

Up to the end of 1976, the relevant authorities in the Provincial Governments were responsible for the planning and execution of flood protection works. Disastrous floods of 1973 and 1976 resulted in heavy losses indicating that existing flood protection facilities and planning were inadequate to provide effective protective measures for the country. Heavy losses sustained to the economy were discussed at an Inter-Provincial Conference in 1977 and subsequently in January 1977 it was decided to establish Federal Flood Commission with a prime objective to coordinate resources at a focal point for their effective utilization among the federating units and to deal with flood management problem at the national level to introduce integrated approach.

Establishment of Federal Flood Commission greatly helped in integrating the planning measures at the national level and furnishing financial resources for the flood projects. Federal funding through Federal Flood Commission proved a vehicle for quick execution of flood management projects. Though, the Federal funding has provided impetus for flood management planning in Pakistan, the available financial resources have been gradually declining in terms of actual funding as well as in the real terms due to inflation.

5.2.3 Lai Nullah Case Study Area:

Until 1984 no concrete flood management & coordination for Lai Nullah Case Study Area in Islamabad-Rawalpindi was in place. In 1984, the Executive Committee of National Economic Council (ECNEC), decided to setup a Technical Committee in M/O water & Power to deal with the Lai Nullah flood problem through coordination among the concerned stakeholders. However, due to varied priorities of CDA in Islamabad and RDA in Rawalpindi, the two departments were not able to arrive at one opinion on managing the Lai flood problem till 1997 when a major flood event hit the twin cities. FFC was assigned the task to act as a coordinating agency between Federal capital and Rawalpindi Administrations. A number of steps were taken in this context as confidence building measures and ultimately FFC has been able to built a consensus among the stake holders on implementing structural and non-structural measures as stated above.

5.3 Interest Group Involvement in Flood Management Activities:

In dealing with the flood management issues at Federal and Provincial levels, mainly Federal and Provincial departments have main involvement in different activities. Irrigation Departments of

Provinces are mainly responsible for preparation of Project Cost Estimates for their respective flood control schemes, but these should be in line with the priorities set in the National Flood Protection Plan which is the jurisdiction of FFC. For that matter FFC has certain bench marks devised for Provincial schemes. Once the schemes are submitted to FFC these are scrutinized with reference to these bench marks. Hence FFC technically clears a certain flood control scheme with assurance of federal financing. Province on the other hand are responsible for execution.

As regards involvement of NGOs, women and men from communities, in decision making process, this culture is at its beginning. In one of on-going flood projects, Federal Government is experimenting involvement of NGO Group in mobilizing the community so that they have a sense of ownership after its completion and thus feels responsibility towards its maintenance.

Chapter – 6

POLICY

6.1 Policy:

6.1.1 Water Resources Management Policy:

Draft of the National Water Policy has been issued in January 2002. The Policy is due to be finalized soon through its approval by the Government for adoption.

The specific objectives of National Water Policy are to:

i) Make more effective use of the surface and ground waters that have been developed to realize greater productivity per unit of water; ii) Achieve equitable and assured distribution of water; iii) Bridge deficit between O&M and cost recoveries; iv) Increase the availability of surface and groundwater resources to the optimal level; v) Store and use river water flood surpluses through multipurpose storage projects for increased surface irrigation water availability, flood control and hydropower generation; vi) Conserve the quality of the water resources both surface and groundwater; vii) Reduce the extent of waterlogging land from 14 percent to 9 percent of the canal command area; viii) Minimize drainable surplus by improving management and lining of distributaries, minors and watercourses; ix) Facilitate eventual evacuation of the saline drainable surplus from the Indus Basin to the Arabian Sea where feasible; x) Increase the role of private sector in the development and maintenance of water sector infrastructure and pilot-test the concept of farmers organizations for O&M; xi) Introduce biological drainage with the involvement of farmers; xii) Slowly introduce the concept of water property rights and water pricing for surface and groundwater; xiii) Bring 1.4 million acres of additional land under cultivation; xiv) Strengthen farmers organizations and their capability to manage irrigation systems, drainage and O&M operations; xv) Strengthen and restructure water sector institutions to meet future challenges; xvi) Assist in the studies required for formulation of National Water Policy through the application of Computer Technology in the field of Water Resources Planning and Management; xvii) Bring more agricultural land into production; xviii) Utilize flood flows to augment water availability; xix) Improve flood warning and forecasting systems; xx) Establish a centralized Management Information System (MIS) and computer database of river discharge data, canal diversion, cropped areas, canal maintenance etc. for improving monitoring and management of irrigation systems; xxi) Ensure participation of the public in each phase of planning, design, implementation and management; encourage public awareness of water resources development and improve transparency of decision-making process; xxii) Improve research and development in the water sector and conduct studies in response to national priority setting and xxiii) Optimally develop the water resources in the barani areas.

Water resources management in Pakistan falls under the following legislations: i) Indus water Treaty-1960; ii) Water Apportionment Accord-1991; iii) Canal and Drainage Act-1873; iv) Provincial Irrigation and Drainage Act-1997 and v) Punjab Minors Act-1905.

6.1.2 Flood Management Policy:

Flood management planning & policy in Pakistan is being carried out to essentially achieve the policy objectives including: i) Reduction of flood losses in an economically sound manner; ii) Prioritizing of areas of greater economic hazards; iii) Protecting the cities and vital infrastructural installations; iv) Exploring the possible use of existing flood control facilities; v) Promoting appropriate land use in flood hazard areas; vi) Minimizing adverse effects on national ecosystem and environment; and vii) Creating flood awareness and adaptability in the Riverian areas. National Flood Protection Plan contains implementation strategy for these policies.

6.1.3 Land Use and Management:

Pakistan is one of the more than 100 countries of the world affected by desertification, which is resulting in environmental degradation, loss of soil fertility, biodiversity and reduction in land productivity. For Pakistan, currently the real issue is not the amount of land demarcated as a protected area but the poor management of the areas already protected. Some acts/ordinance that are concerned with land use and management in terms of environment are: i) Punjab Development of Damaged Areas Act-1952; ii) The Punjab Soil Reclamation Act-1952 and iii) The Islamabad (Preservation of Landscape) Ordinance-1966.

6.1.4 Development Planning and Disaster Prevention:

The updated national development strategies in Pakistan are formulated through i) Three Years Rolling Plan (2001-2004) and ii) Ten Year Perspective Plan (2001-2011) prepared by the Planning & Development Division of Planning Commission of Government of Pakistan taking into account recommendations and suggestions from relevant federal and provincial agencies. The two national development plans include various sectors including water (with sub-sectors as flood, irrigation, drainage, ground-water, small dams etc.). Water Vision-2025 of WAPDA is presently being used for the above two plans in the area of water resources management whereas NFPP of FFC is used for development planning in the flood sector which now also accommodates Lai Nullah Study Area future requirements of development. Presently all the development in the flood control, improvement in Garbage disposal system, water supply & sanitation is being done by RDA through ADB funded project. Also the above two plans contain priorities for future water supply and irrigation requirements in Lai Nullah Case Study Area and this is coordinated by FFC as a policy matter for more integrated water resources management in the study area.

6.2 National/Provincial Policies Vs Stakeholders Participation:

The Draft National Water Policy clearly states the involvement of all the public as well as private stakeholders in all water sector issues besides decentralizing water service delivery, involving users in planning and management of water projects and encouraging stakeholders to contribute towards policy formulation. In the flood sector under Third National Flood Protection Plan (1998-2012), the concept of community participation for social mobilization, disaster preparedness and participation of related communities in project planning, siting, designing, implementation and post construction O & M is being implemented through the services of a local NGO at federal level and its interaction with provincial local government representatives through the coordinated role of FFC. By virtue of this a sense of ownership towards a particular flood control project will be promoted and the beneficiaries are expected to contribute in terms of labor, manpower & material etc.

6.3 Policy Changes in Response to Extreme Flood Events:

Upto the end of 1976, the relevant authorities in the Provincial Governments were responsible for the planning and execution of flood protection works. Disastrous floods of 1973 and 1976 resulted in heavy losses indicating that existing flood protection facilities and planning were inadequate to provide effective protective measures for the country. Heavy losses sustained to the economy resulted in the establishment of Federal Flood Commission which greatly helped in integrating the planning measures and their implementation at the national level and furnishing financial resources for the flood projects. A shift in the policy for federal funding, as a result of extreme flood events of 1973 & 1976, through Federal Flood Commission proved a vehicle for quick execution of flood management projects. Though, the Federal funding has provided impetus for flood management planning in Pakistan, the available financial resources have been gradually declining in terms of actual funding as well as in the real terms due to inflation. In the Lai Nullah Study Area, flood management planning problem is prevailing for the last atleast 25 years. Unprecedented rains & consequent floods of July 2001 had resulted in colossal damages to property and human life. The main reason behind this catastrophe has been lack of coordination and confidence among various provincial and federal departments agency. FFC in a very short time has been able to: i) Prepare master plan for flood management of Lai Nullah, ii) identified two urgent projects (structural and non-structural) for immediate execution, iii) requested foreign donors through formal Concept Clearance documents for grants, iv) prepared Project Cost Estimates for the two urgent projects with the consensus of all the stakeholders of Islamabad, v) included Lai Nullah problem area in its National Plan.

6.4 IWRM is the Practical Approach:

The discussion under Serial No. 6.3 above very clearly manifests the applicability of Integrated Water Resource Management approach both at the national level as well as provincial and city level.

Establishment of FFC had resulted in planning and implementation of NFPP based on IWRM while assigning the role of coordinating agency to FFC in the Lai Nullah area has resulted in pooling of all the resources/strategies for attaining IWRM at sub-national/city level.

Chapter – 7

LESSONS LEARNED

7. Implementation of Integrated Flood Management:

7.1 Main Lessons Derived and Can Be Applied:

This shall be given one by one:

(a) Formulation of National Flood Protection Plan:

As has also been briefly stated in preceding chapters, that prior to 1977, flood management and planning had been the responsibility of four provinces who use to plan structural and nonstructural flood control measures based on their own provincial requirements. Floods of 1973 and 1976 had resulted in colossal damage to national economy and to provincial irrigation & flood control infrastructure. As a new strategy at par with other developed countries, Federal Government decided on nation-wide flood control planning & management though FFC. This strategy has proved extremely successful as so far two ten year each NFPPs have been implemented and further improved and integrated third NFPP is being implemented accordingly.

(b) River Reach-wise Planning & Implementation:

Prior to the present arrangements, flood management planning and implementation was being done on an hap-hazard way by the provinces based on their on priorities and without taking into account the impact(s) of certain structural flood management intervention upstream/downstream. A comprehensive improvement has been brought in by i) undertaking river-reach wise study of the entire river system of Pakistan fully catering for integrated relationship of proposed structural measures with upstream and downstream river areas. For example for Indus River feasibility studies for the entire reach has been carried out in phases (i.e., Chashma-Taunsa River Reach, Taunsa-Guddu River Reach, Guddu-Sukkur River Reach and Sukkur-Kotri River Reach). Based on the schemes identified in the feasibility study (of course which are feasible and having sound Economic Internal Rate of Return & Cost-Benefit Ratio) physical implementation is carried out. The present strategy has resulted in increased stability of structures based on sound engineering design and specifications.

(c) Model Testing of each Individual Flood Protection Scheme:

Past practice in implementation of flood works rarely involved prior confirmation of efficacy of a certain structure through model testing which had often resulted in repeated failures even at low flows and increased O&M costs. A mandatory requirement is now to undertake physical model testing of river structure in order to base its effectiveness in conditions of super flows. This approach is proving excellent in all the new flood works and has resulted in reduction of restoration costs.

(d) Battery of Spurs to Control Erosion:
As a measure to achieve IFM, instead of promoting riverside erosion through single spur provision, consideration is being given to the implementation of a series/battery of spurs to shift river meander and to reclaim additional cultural land besides saving valuable irrigation infrastructure and installations etc. This strategy is proving very effective in NWF Province and in Punjab.

(e) Control on Encroachments:
The experience of controlling encroachments in the Case study area and resettlement of encroachers can be adopted for the main river system as well as this will ultimately result in reducing loss of crops, human life as well as property. Concept of flood cess needs to be implemented as outlined in third NFPP.

f) Inter-agency & Inter-provincial Coordination:
With FFC at the national level coordinating the overall flood control planning, implementation of structural & non-structural strategies, management etc. through various federal and provincial agencies, issue of lack of inter-agency coordination has been resolved to certain extent. However, this requires enhanced and strengthened role of FFC through its institutional and logistical up bringing.

(g) Improved Flood Forecasting & data Dissemination System:
After the super floods in nineties, which proved the inadequacy of flood forecasting and warning capability, some good non-structural interventions had been inducted into the system. These measures like: i) quantitative precipitation measurement weather radar system, ii) real time data collection & dissemination system, iii) river rainfall-runoff modeling for improved downstream forecasting, Zero Flood warning Manual, iv) updating of river discharge rating curves/weir formulae for some of the rivers, v) establishment of FFD, vi) overall coordination role of FFC has greatly resulted in implementing the concept of IFM. This concept is further promoted through extensions of above system, assigning country-wide monitoring role to FFC etc.

In the context of Lai Nullah, devastating flood episodes in the past had further stressed the need of a central coordinating body in order to control rural and urban flooding in the twin cities. Additionally earlier lack of coordination among RDA/TMA and CDA had kept the problem pending till 2001 without any concrete solution. Also PMD's deficient coverage of the area and confined rain recording capability has so far kept concerned apart. Change is now imminent due to assigning of overall coordination role to FFC.

7.2 Institutional and Legal Changes Required for IFM:

Lai Nullah Case Study Area:

<u>(a) Capacity Building:</u> Judging form the technical capacity of the staffs of relevant agencies, the capacity building through i) development of key management capability, ii) financial and legal management capability, iii) planning & design management capability including environmental

knowledge, iv) O&M and contract management capability and v) logistic support including public relation and coordination capability etc. is required.

(b) Land Use Control: Through Zoning Ordinance for specifying type and functions of structures that can be built around the study area with a view to minimize flood risk. Sanitary Ordinance to reduce the risk of health problems as a result of sewage disposal, groundwater infiltration into pipes etc. Building Ordinance to specify structural requirements of new building to reduce their vulnerability to flooding, reduce health and safety hazards to occupants and minimize the extent that the building could impede the flow of floodwaters.

(c) Legislation for Encroachment Removal: The existing Land Acquisition Act (LLA) needs to be improved for latest environmental guidelines, regulation of policy guidelines governing "resettlement" and "rehabilitation". Restoration of community and household productive assets, or standard or quality of life, is not covered by LLA besides no legal framework is available to pay compensation to informal settlers, encroachers or ill occupants. LLA needs to be revised to cover all above aspects.

(d) Strengthening of Organizational Set-up: For the river management/administration of Lai Nullah, there is a dire need of reactivation of Management Committee under Federal Water & Power Ministry with FFC, CDA, RDA, TMA, RCB & SDO as members with the following function:

(i) Providing support to manage financial arrangements for implementation of master plan;
(ii) General monitoring of progress of implementation of flood mitigation plan for Lai Nullah;
(iii) Coordination on issues beyond control of FFC's Task Force between Federal and Provincial agencies.

(e) Establishment of a Task Force: In order to cope with the implementation of Lai Nullah Urgent, Short-Term, Medium Term and Long-Term improvement measures, it is recommended to set up a Task Force with the following basic functions:
(i) Review and modifications in the master plan;
(ii) Financial arrangements for implementation of measures proposed in the master plan;
(iii) Land acquisition and house evacuation of the project components to each agency responsible;
(iv) Supervision and coordination for works; and
(v) Overall management and instruction for O&M works

Country-wide Basis:
(a) National Disaster Management Agency: In order to handle all the national disasters on country-wide basis, there is a requirement of National Disaster Management Agency which should work under the auspices of Federal Government National Disaster Management Committee having members from all related departments/agencies. This agency should have its provincial branches as Provincial Disaster Management Agencies to work under Provincial Disaster Management Committee with

further bifurcation at the district levels as District Disaster Management Committees. This will ideally help in the implementation of disaster management approaches on an integrated basis.

(b) Land Use Control: Through Zoning Ordinance for specifying type and functions of structures that can be built around certain city/village with a view to minimize flood risk.

(c) Legislation for Encroachment Removal: In the context of overall IFM the existing Land Acquisition Act (LLA) needs to be improved for latest environmental guidelines, regulation of policy guidelines governing "resettlement" and "rehabilitation". Internationally prevailing regulations specifying removal of encroachers and their timely settlement must not be ignored as in the past, especially for River Indus in Lower Punjab Province, Sindh Province on certain nullahs in Punjab etc.

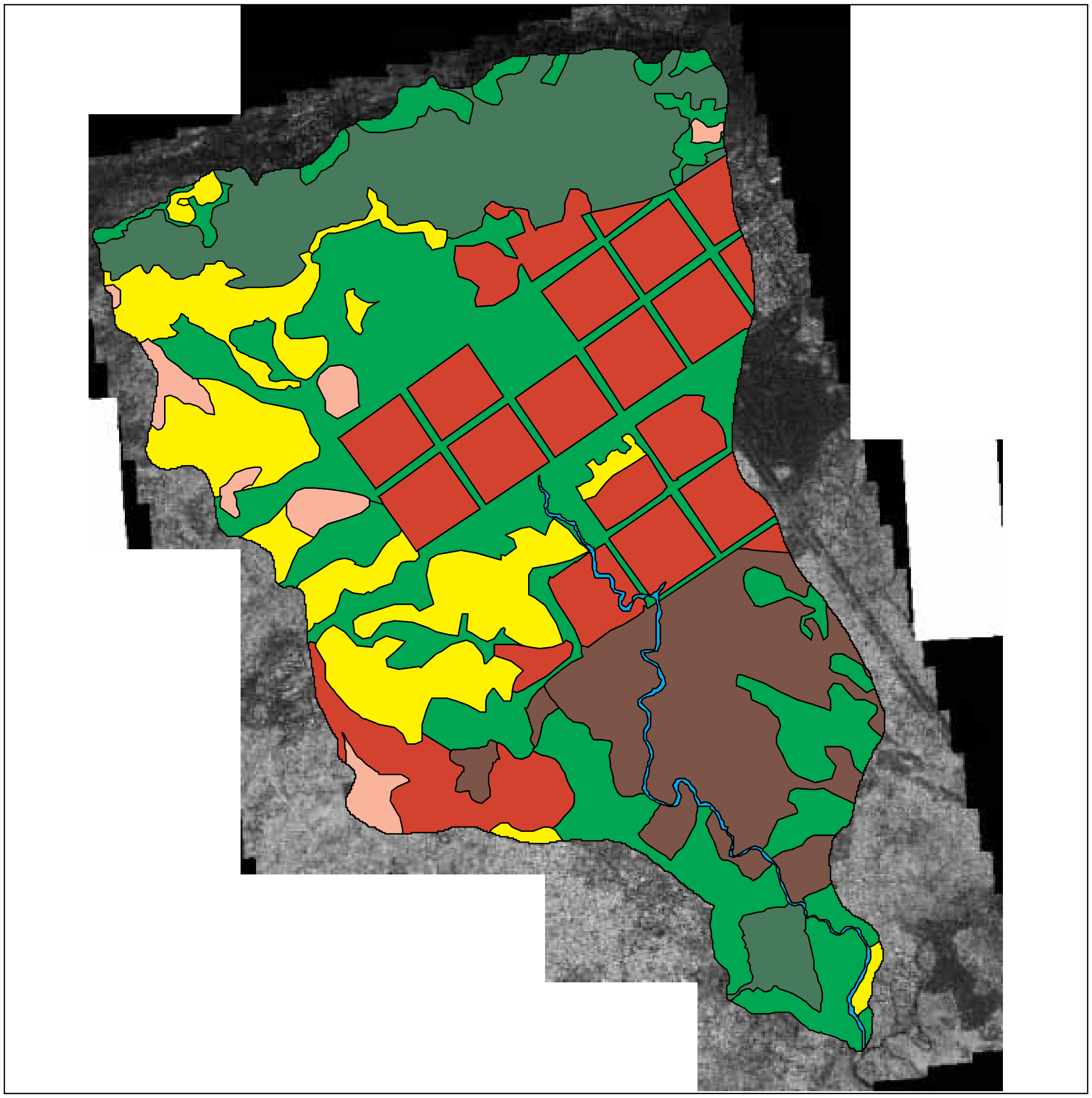
(d) River Management Law OR Water Law: There are many laws, acts and ordinances for land administration but less for the river management in Pakistan. As such when river system extends over two different jurisdiction areas, the river is administered by different land administrators, and thus consistent river basin administration is hardly achieved. In order to improve such unfavorable conditions, it is indispensable to enact the "River Management Law OR Water Law".

(e) Role of FFC: In view of active role of FFC being the central coordinating organization at the national level, it is important to enhance its in house capability through induction of staff in specialized fields besides converting it from Commission to Authority. There is a requirement of regular technical as well as financial monitoring to be carried out by FFC to ensure that limited available resources are spent of technically sound and economically viable integrated flood management measures.

(f) Community Participation in Flood Management Works: Flood works implemented in the past had been entirely without any involvement of the beneficiaries. In order to ensure effective O&M of an individual flood protection scheme after its construction, it is important to make it conditional that every flood works is undertaken through active participation of concerned community representative(s) and local government representatives.

(g) In built O & M Mechanism: Flood works implemented in the past were not being maintained in the past as well as presently due to lack of O&M funds by the provinces. In all new flood works, each Project Cost Estimate (PC-I) must include advance provision of O&M funds, atleast for initial three years, in the overall capital cost so that important flood works are maintained well in times of any flood emergency.

***Fig-1** : Land Use Pattern - 2002*



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